Development of Next Generation Liquefaction (NGL) Database for Liquefaction-Induced Lateral Spread – Phase I Interim Report – Tasks 2 - 6

Prepared for the Utah Department of Transportation
Research Division

In cooperation with the Pacific Earthquake Engineering Research Center
Next Generation Liquefaction (NGL) Project

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University of Utah

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Contents

Background

This research will be conducted in conjunction with the Pacific Earthquake Engineering Research (PEER) Center and various state DOTs via a pool-fund study managed by the Utah Department of Transportation (UDOT). The research topic addresses the need to improve empirical, semi-empirical, analytical and numerical methods to estimate the amount of permanent ground displacement associated with liquefaction-induced lateral spread resulting from major earthquakes. The project will be executed in two phases: (1) database development and collection, and (2) predictive model development.

Liquefaction-induced lateral spread is a type of permanent ground deformation resulting from the horizontal movement of surficial soil resulting from liquefaction that has occurred at depth. It generally is the most pervasive and damaging type of liquefaction-induced ground failure occurring during major earthquakes. Lateral spread displacement has caused significant damage to transportation infrastructure and other facilities during major earthquakes. Examples of such damage can be found in the engineering literature from the following earthquakes: 1964 Alaska; 1964 Niigata, Japan; 1983 Nihonkai-Chu, Japan; 1989 Loma Prieta, California; 1999 Kocaeli, Turkey; 1999 Chi-Chi, Taiwan; 2004 Northridge, California; 2005 Kobe, Japan; 2010 Chile; 2011 Tohoku, Japan; 2011 Christchurch New Zealand. During these and other earthquakes, lateral spread horizontal ground displacement ranging from a few tenths of a meter to several meters was common in liquefaction prone areas. These displacements resulted in millions of dollars of damage to transportation facilities such as bridges, embankments, culverts and pavements.

Recent liquefaction-induced ground failures from earthquakes in Japan and New Zealand have raised questions about the profession's ability to assess, delineate and quantify the lateral spread hazard in vulnerable locations. The best defense against such damage is to first, identify areas prone to lateral spread ground failure, estimate the expected amount of ground displacement, and establish planning or other engineering countermeasures to mitigate the hazard and ensure more earthquake resilient infrastructure. Nonetheless, many regions in the U.S. (e.g., California, Pacific Northwest, Intermountain West, mid-America and Northeastern and Central Atlantic seaboard) remain vulnerable to liquefaction damage associated with future, major earthquakes.

To address the need for improvement in liquefaction research and practice, the National Research Council (NRC) has formed an ad hoc committee to critically examine the technical issues regarding liquefaction hazard evaluation and consequence assessment. Amongst other items, the NRC committee is assessing the adequacy and accuracy of empirical and mechanistic methods to evaluate liquefaction triggering and post-liquefaction deformations of earth structures and structures founded on or in the earth, such as large embankment dams, levees, dikes, pipelines, highway embankments, bridges, pile-supported decks, and other structural foundations. The NRC study included a workshop in on data gathering, vetting of field and laboratory data, and new developments in the assessment of earthquake induced soil liquefaction which was held in March 10th and 11th, 2014 in Tempe, Arizona at Arizona State University. It is expected that the NRC final report, which is not yet released, will comment on the state-of-the-art and practice for liquefaction analyses. It will also address the recommended directions for future research and practice related to: (i) collecting, reporting, and assessing the sufficiency and quality of field case history observations as well as in situ field, laboratory, and model test data; (ii) addressing the spatial variability and uncertainty of these data; and (iii) and developing more accurate tools for assessing liquefaction triggering and its consequences. Important to this project, it is expected that the NRC final report will endorse the efforts of PEER in establishing a community database for evaluating liquefaction effects, including lateral spread.

Recently, PEER has initiated the next generation liquefaction (NGL) database project, which began work with a workshop at the University of California Berkeley in April 2014 followed by an additional workshop in February 2016:(http://www.uclageo.com/NGL/Document/02052016workshop/NGL%20Meeting%20PEER%20Feb%205%202016_Notes.pdf).

These workshops consisted of presentations and discussions regarding additions to and improvement of the liquefaction triggering and lateral spread databases, primarily focusing on data gathering and documentation of recent earthquakes conditions and effects in Japan and New Zealand.

Our efforts in this proposal will focus on gathering, documenting and archiving information regarding liquefaction-induced lateral spread.

The data collected for this project herein will include: soil properties, site characteristics (soil layering, topography, etc.), earthquake strong ground motion, and observations and measurements of soil response (e.g., post liquefaction ground deformations) for important, well-documented historical earthquakes. Included in this data gathering will be an assessment of the inherent characteristics associated with the data (e.g., quality, uneven distribution, scarcity, uncertainty, etc.). In addition, the data will be warehoused in a spatial database, and archival and dissemination tools will be developed for future assessment and model development by interested researchers.

Research Objectives

The primary outcome of this research is a vetted and community database of seismic, topographical, geotechnical and horizontal displacement measurements pertaining to case histories of liquefaction-induced lateral spread for further research and model development by other researchers and investigators under the auspices of the Pacific Earthquake Engineering Research (PEER) Center (http://peer.berkeley.edu/). Secondary outcomes will be the software development and support required to host and disseminate this database and supporting information.

This project has the following research objectives: (1) develop peer-reviewed and consistent methodology for data documentation and archiving of lateral spread case histories, (2) develop quality assurance protocols for assessing and documenting data quality, (3) develop methods and/or protocols to quantify uncertainties associated with the collected data, (4) populate the case history database with well-documented examples of liquefaction-induced lateral spread, (5) explore methods of integrating SPT and CPT data into analyses and evaluations, (6) disseminate this database for general use using web-based software tools.

1 Task 1 Procurement of Software and Kickoff Meetings

1.1 Software Procurement

Software - The project planning and execution have included data collection, GIS database compilation, and the development of ArcGIS™ custom user interfaces, as needed, that will facilitate the querying and use of the database. The database has been developed in Microsoft Access™ which can be important into many different formats. The structure of the database is presented ins Section 4.

1.2 Next-Generation Liquefaction Project Workshop - 9/12/2014

Next-Generation Liquefaction Project

Jonathan P. Stewart

Professor and Chair

UCLA Civil & Environmental Eng. Dept.

Liquefaction Workshop
September 12, 2014

Project Co-Director: Steven L. Kramer

Students and Post-Doctoral Scholars: Allan Ng, Michael W. Greenfield, Christine Beyzaei, Tadahiro Kishida, Dong Youp Kwak

Principal Collaborators (to date):

US: Steven Bartlett, Ross W. Boulanger, Yousef Bozorgnia, Jonathan D. Bray, Brady Cox, Russell Green, Robert E. Kayen, Tom Shantz, T. Leslie Youd

Japan: Kohji Tokimatsu, Toru Sekiguchi, Shoichi Nakai **NZ:**

Misko Cubrinovski

Funding provided by PEER center (Lifelines and TSRP)

1.2.1 Outline

OUTLINE

- Project introduction and motivation
- Research philosophy and approach
- Opportunities and priorities for site characterization
- Example preliminary results
- Next steps

1.2.2 Introduction and Motivation

Introduction and Motivation

Analysis techniques for ground failure are empirical or semi-empirical

Small data sets – a few sites are especially consequential

Existing data sets are necessarily incomplete

Introduction and Motivation

Alternate liquefaction models can provide different outcomes. Why?:

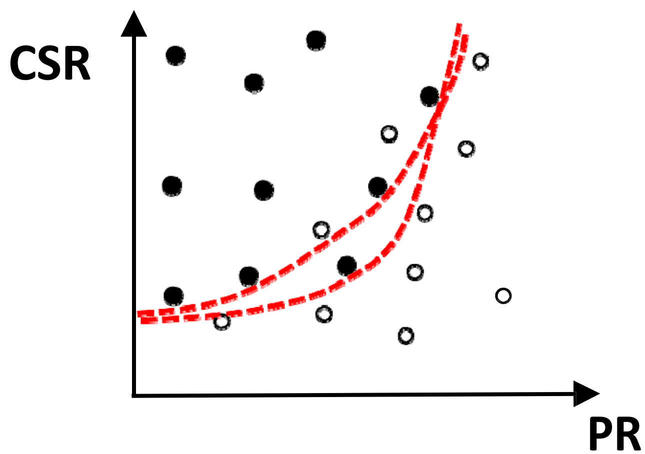
1. Different philosophies on some key points
2. Data sets not always consistent
3. Minimal between-developer interaction

Introduction and Motivation

Outcomes:

1. Model-to-model uncertainty large.
2. May reflect more than the epistemic uncertainty inherent to model building.
3. ‘Right’ and ‘wrong’ arguments between developers.
4. Substantial confusion regarding best practices

Introduction and Motivation



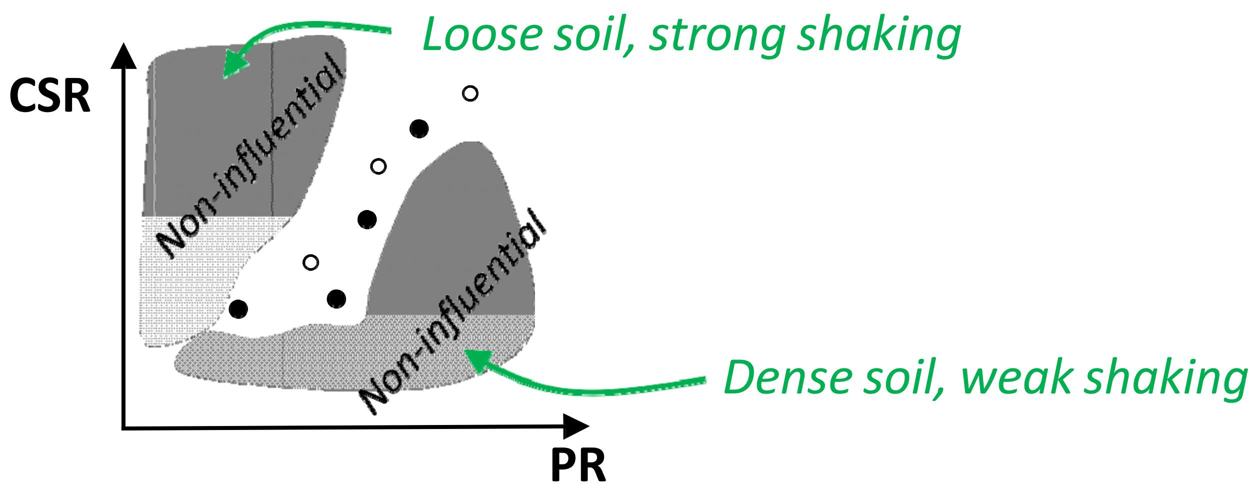
- Liquefaction
- No Ground Failure

Model deviations result in part from differences in data interpretation

Some may be due to errors in interpretation

Graphic: Kramer

Introduction and Motivation



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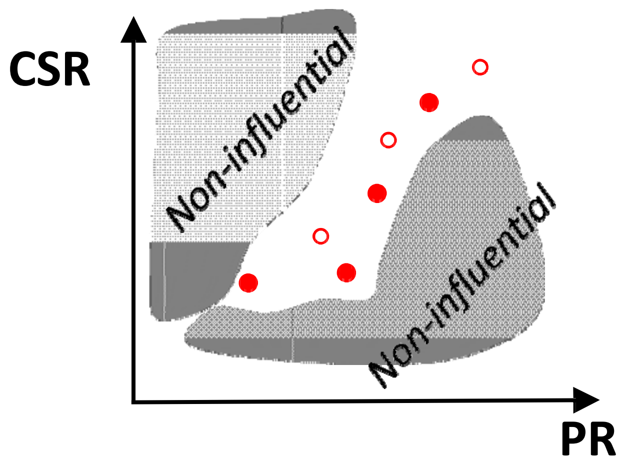
Introduction and Motivation



Attention should be focused on potentially influential, high-value case histories

Graphic: Kramer

Introduction and Motivation

NRC committee: summarizing problem but not providing recommendations on use of current analysis procedures

NGL conceived as a research approach to:

- Improve the resources available for model development
- Improve transparency in model building process
- Provide 'vetted' models having rapid impact.

1.2.3 Research Philosophy and Approach

Research Philosophy and Approach

- NGA as prototype
- Expand database
- Project organization/plan
- Anticipated products

1.2.3.1 NGA as prototype

NGA as prototype

Community database – many contributors

Supporting studies of critical effects poorly constrained by empirical data

Model development teams drawing upon common database.

Coordination between modeling teams.

Data not used in model development requires justification.

NGA as prototype

Addresses root causes of the current predicament:

1. Non-uniform data access and interpretation
2. Lack of transparency in data inclusion/exclusion
3. Lack of interaction during model development potentially leading to bugs in models and misunderstandings between modelers.

1.2.3.2 Expand database

Expand Database

Recent earthquakes enable database expansion, including:

1. High-consequence sites. Near threshold
2. Non-liquefaction sites poorly explained by current methods
3. Sites with measured deformations
4. Sites near ground motion stations.
5. Ground improvement sites

Relevant events include:

1. 2011 NZ and Japan
2. 2010 El Mayor-Cucapah
3. 2010 Chile
4. 2004 and 2007 Japan
5. 1999 Turkey, Taiwan

1.2.3.3 Project Organization / Plan

- Establish institutional partnerships: PEER, CUEE, UCQC, NCREE
- Project Management Committee at PEER
- Post docs at PEER to develop database under direction of PMC.
- Funded researchers to develop case histories Model development teams (later)
- Community workshops (results dissemination, input)

1.2.3.4 AnticipatedProducts

Community database for use by practitioners and non-affiliated researchers

Models for ground failure phenomena:

1. Multiple models by distinct developer teams, or
2. Consensus median models with defined aleatory variability and epistemic uncertainty

1.2.4 Opportunities and Priorities for Site Characterization

Opportunities/Priorities

- Numerous workshops held with Japan and NZ researchers to establish initial priorities
- Work began April 2014
- Initial emphasis is on site characterization for high-value sites

Opportunities/Priorities

1.2.4.1 New Zealand

Extensive CPT soundings already available   Virtually no

SPT blow counts or laboratory test data

9 sites selected based on field performance not matching expectation. Not near accelerometers.

Additional sites (from R. Green) to be included

1.2.4.2 Japan

Sites with measured ground deformations Chiba sites (details below)

Various sites near ground motion stations:

1. Some site have vertical arrays (e.g., PARI)
2. Liquefaction and no ground failure
3. Borehole data often already available
4. Adding V_S and CPT soundings. Checking N-values

Sites with measured ground deformations

Chiba sites (details below)

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1. Some site have vertical arrays (e.g., PARI)
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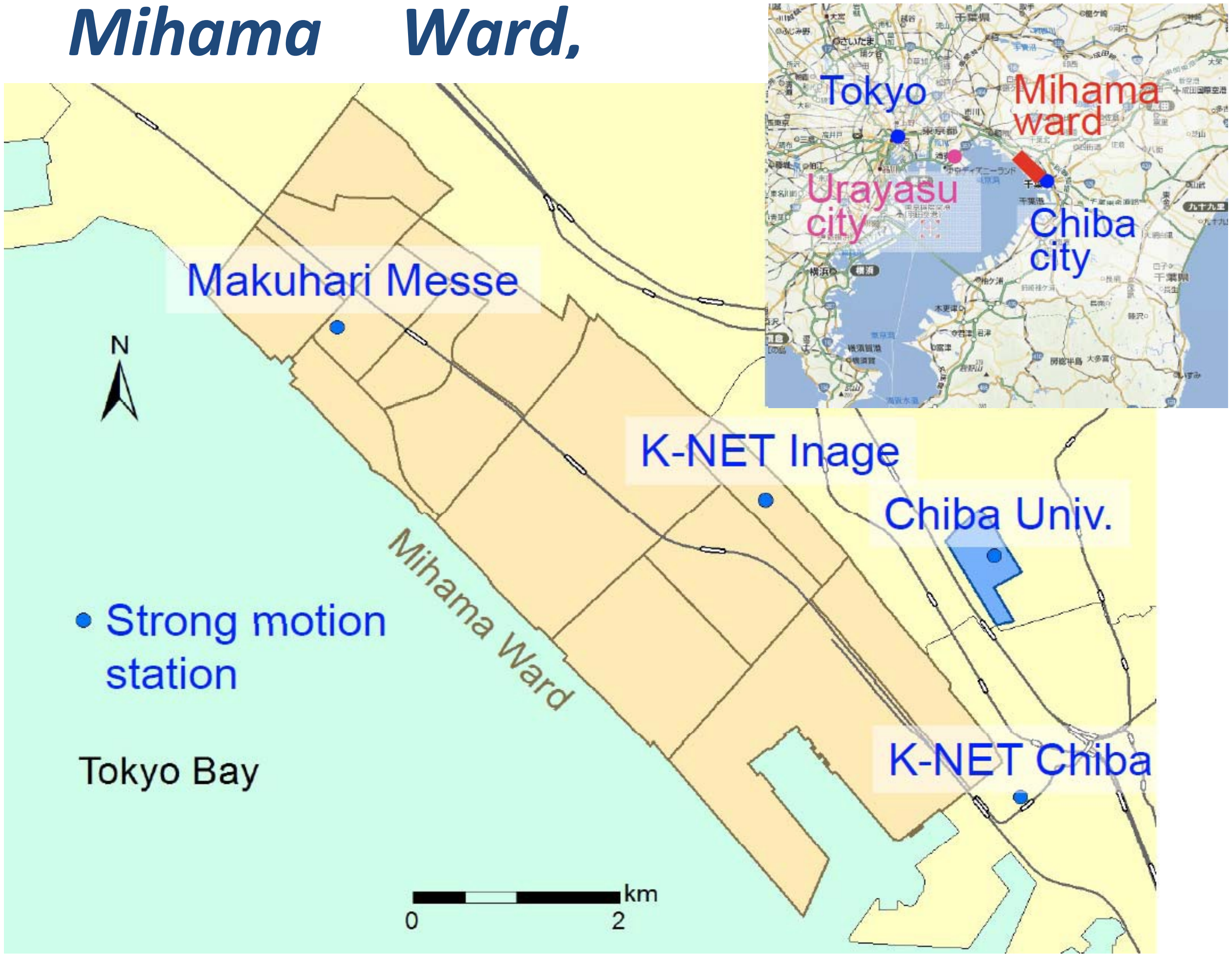
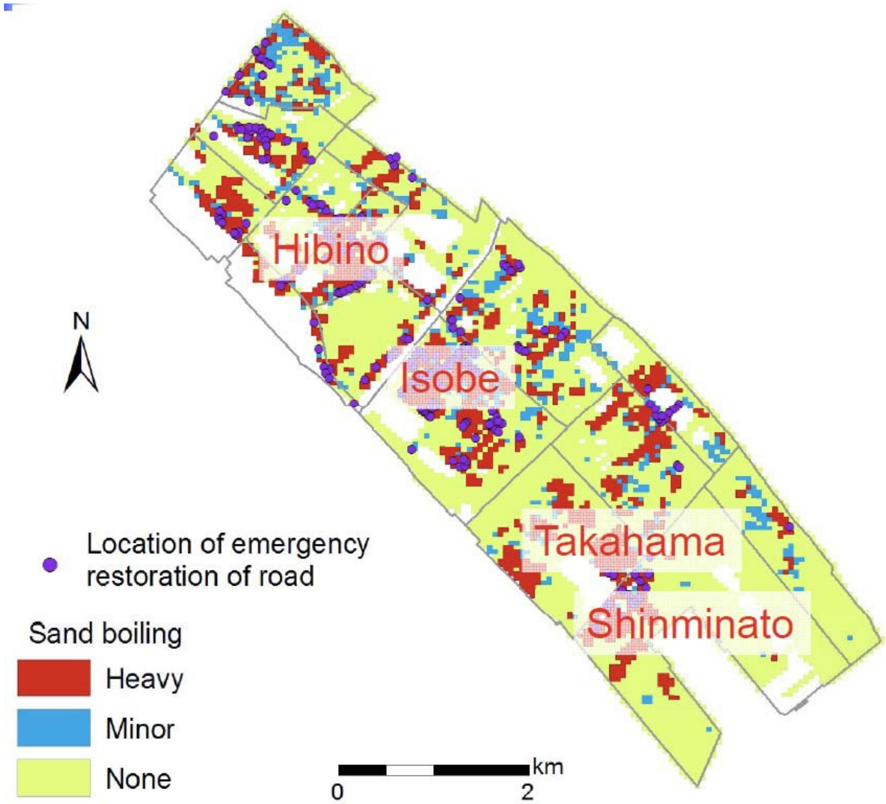
Mihama Ward,



Images: Sekiguchi and Nakai

1.2.4.2.1 Mihama Ward, Chiba

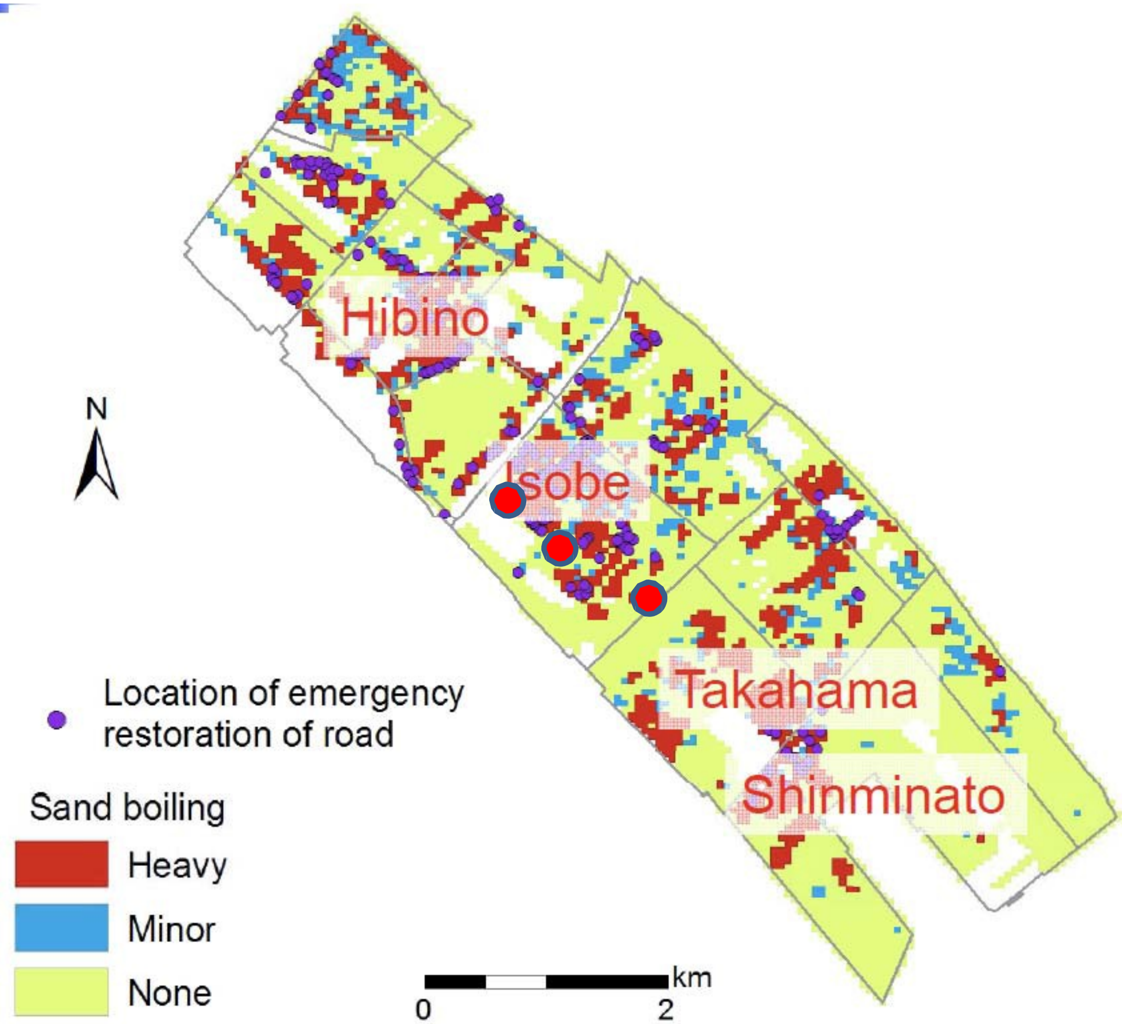
Field performance characterized



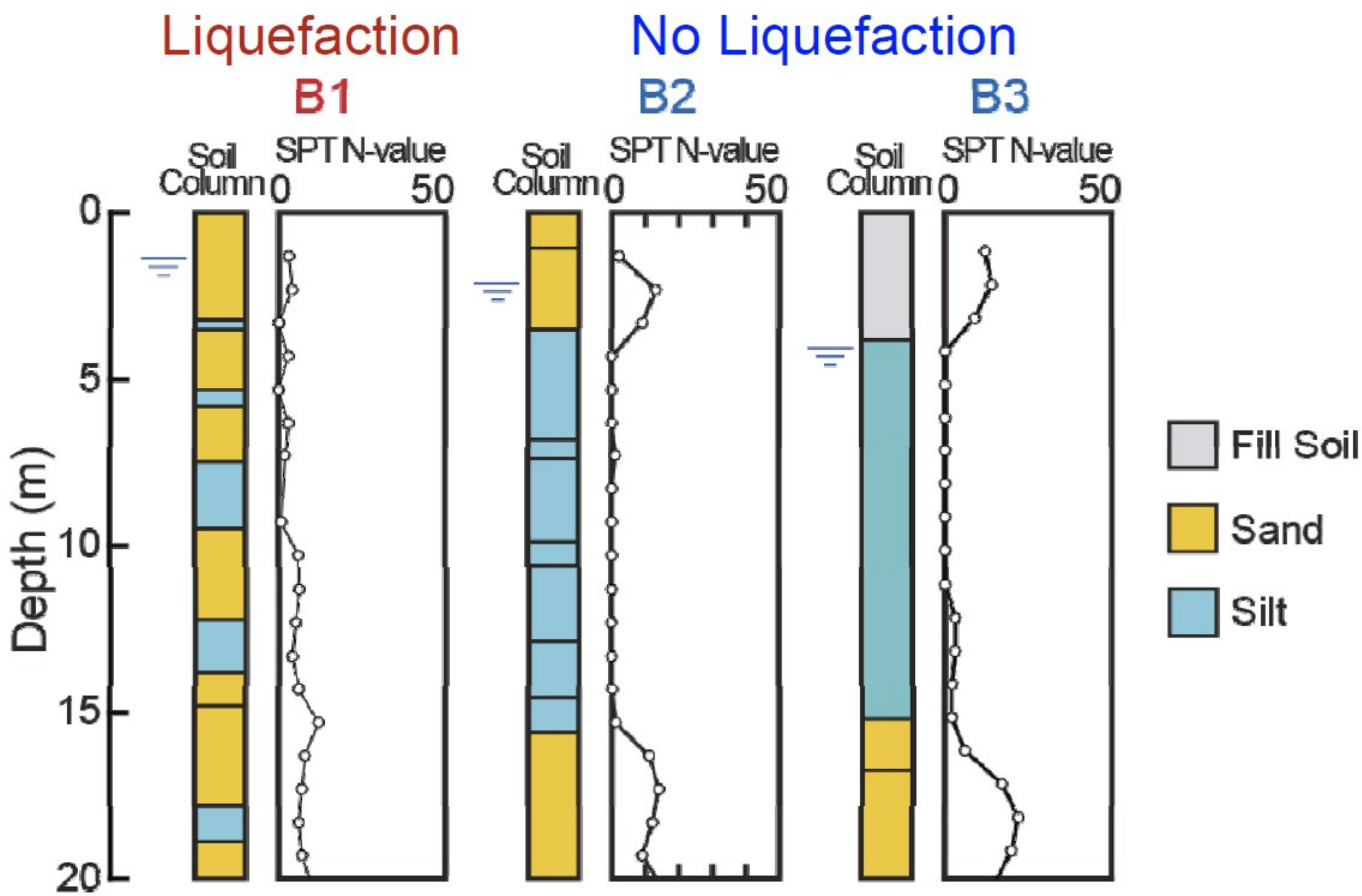
Images: Sekiguchi and Nakai

Field performanc
characterized

Few boreholes in L an
non-ground failur
areas



Images: Sekiguchi and Nakai



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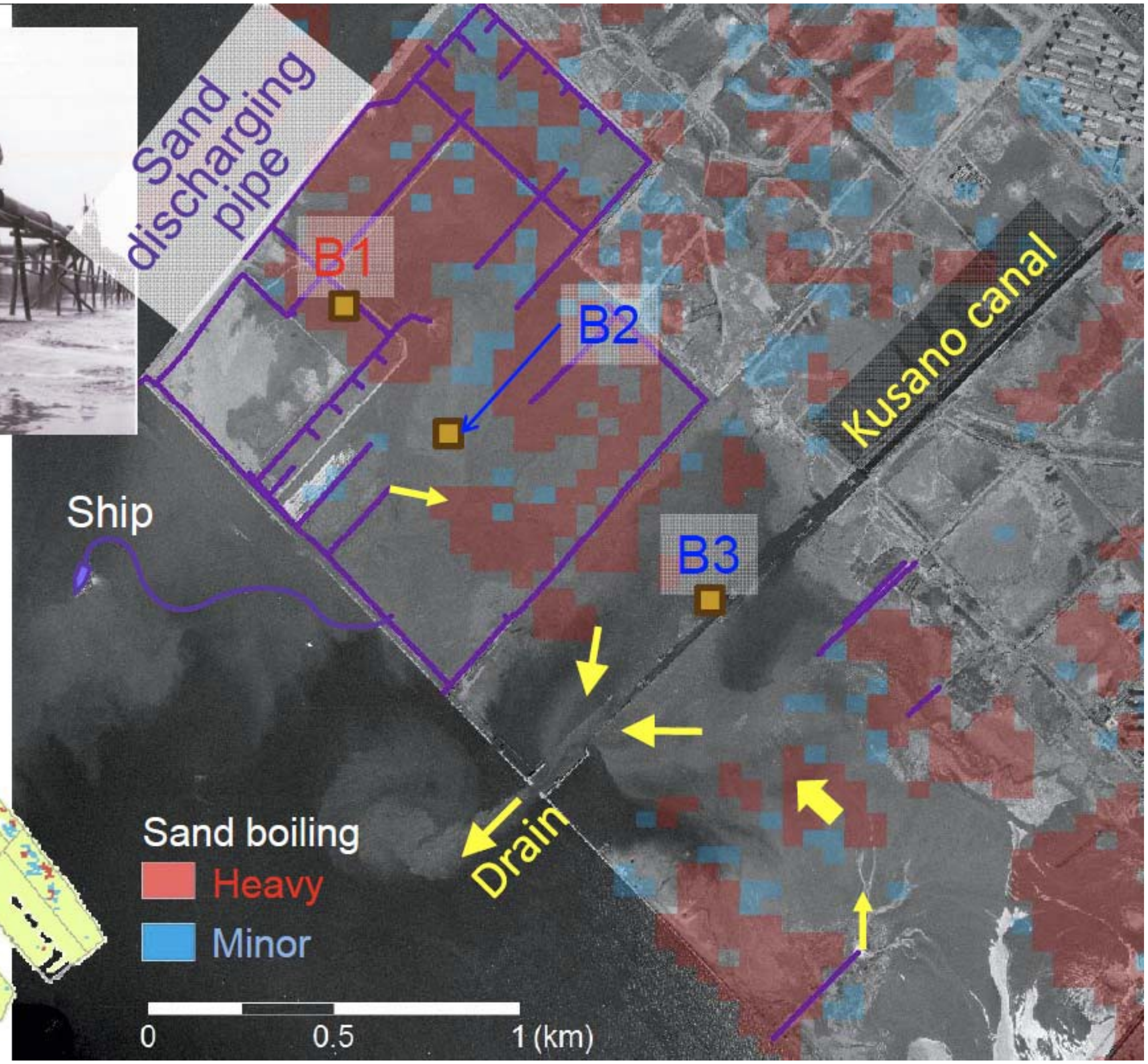
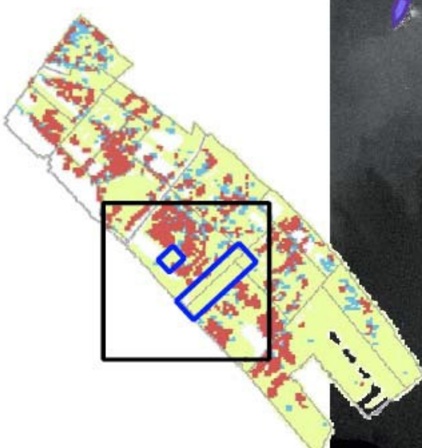


Liquefaction areas related to HF pipe locations



Images: Sekiguchi and Nakai

Mihama Ward, Chiba Summary:

Available now:

1. Field performance data
2. Historical knowledge of hydraulic fill placement
3. Boring and CPT logs in liquefaction and no-ground failure areas

Pending:

1. Laboratory testing (index, more advanced) of materials in different performance areas.
2. Limited additional CPTs and borings

1.2.4.2.2 SMA Sites

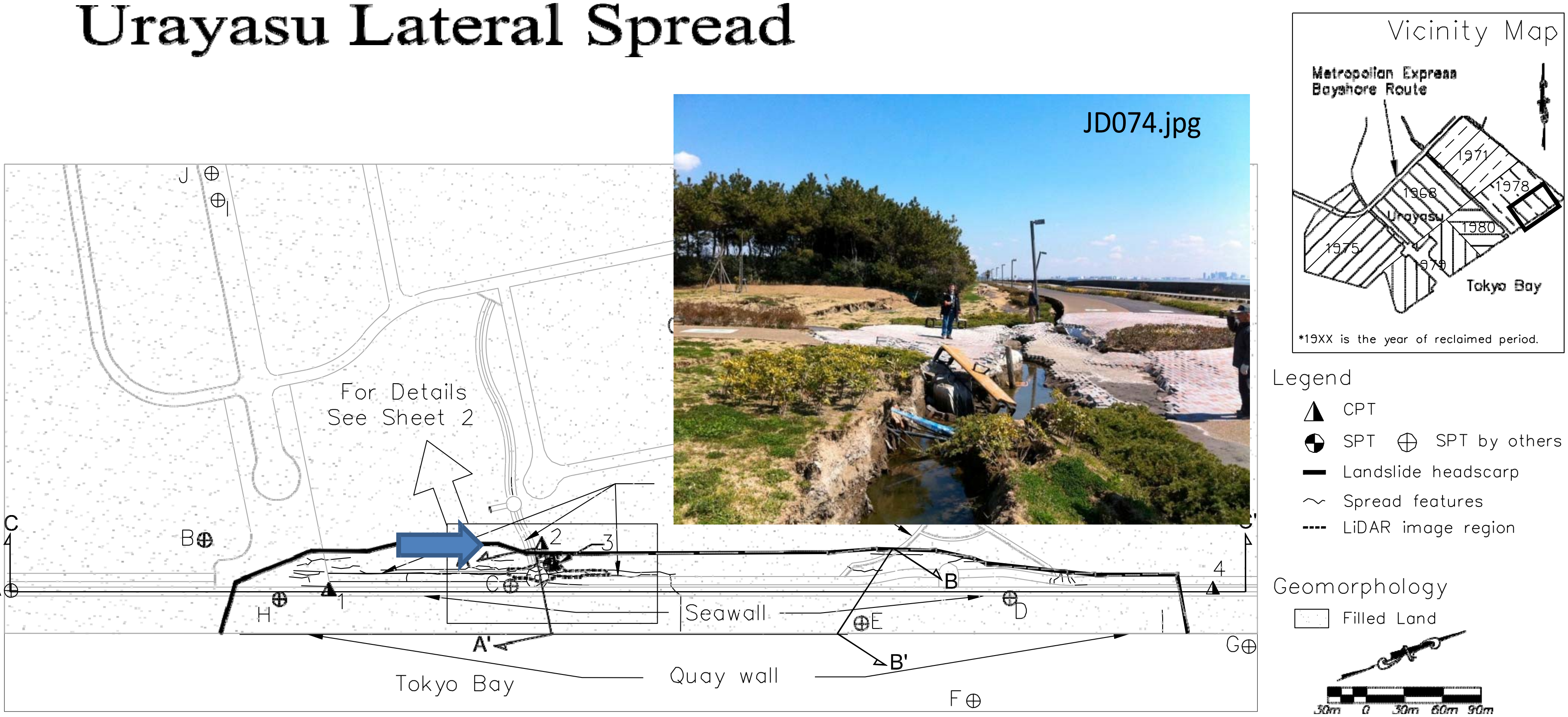
- Project introduction and motivation
- Research philosophy and approach
- Opportunities and priorities for site characterization
- **Example preliminary results**
- Next steps

Example Results

- Lateral spread site in Urayasu
- Accelerograph sites with liquefaction and without ground failure

Urayasu Lateral Spread

Urayasu Lateral Spread



NGL Point	Type	Lat. (N)	Long. (E)	TSN
1	CPT	35.636922	139.932152	120007
2	CPT	35.638020	139.933517	120008
3	CPT/SPT	35.637925	139.933560	120009/110003
4	CPT	35.640294	139.938279	120010

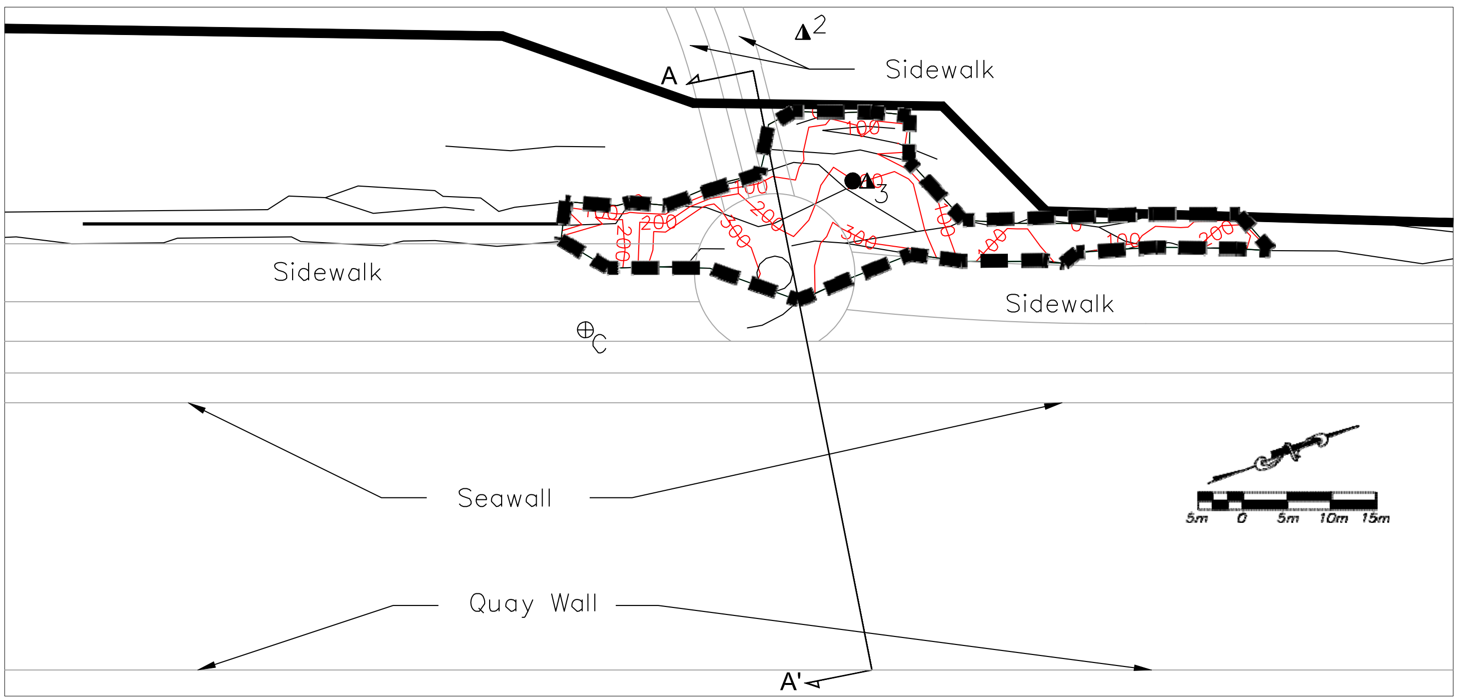
Existing Point	Type	Lat. (N)	Long. (E)	Source	Name
A	SPT	35.635416	139.929354	Chiba	cjz05237
B	SPT	35.636436	139.930544	Chiba	cjz05290
C	SPT	35.637666	139.933504	Chiba	cjz05328
D	SPT	35.639646	139.937164	Chiba	cjz05329
E	SPT	35.638726	139.936054	Chiba	cjz09853
F	SPT	35.637686	139.936694	Chiba	cjz09854
G	SPT	[illegible]	[illegible]	Chiba	[illegible]
H	SPT	35.636696	139.931914	Chiba	cjz25561
I	SPT	35.638736	139.929494	Chiba	cjz25656
J	SPT	35.638946	139.929234	Chiba	cjz25658

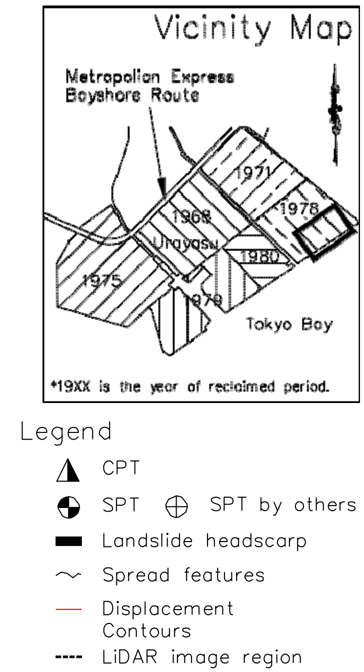
Priliminary Site Characterization

NGL 1.4; GEER JS27
Ground Motion Station: CHB008

PREPARED BY	DATE	SCALE	REVIEWED BY	PRJ. NO. xxxxxxx
AYN	3/8/14	1cm= 30m	JPS, RK	SHEET 01 OF XX

Urayasu Lateral Spread





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G	SPT	[illegible]	[illegible]	Chiba	[illegible]
H	SPT	35.636696	139.931914	Chiba	cjz25561
I	SPT	35.638736	139.929494	Chiba	cjz25656
J	SPT	35.638846	139.929234	Chiba	cjz25658

NGL Project
Priliminary Site Characterization

NGL 1.4; GEER JS27
Ground Motion Station: CHB008

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AYN	3/8/14	1cm= 5m	JPS, RK	SHEET 02 OF XX

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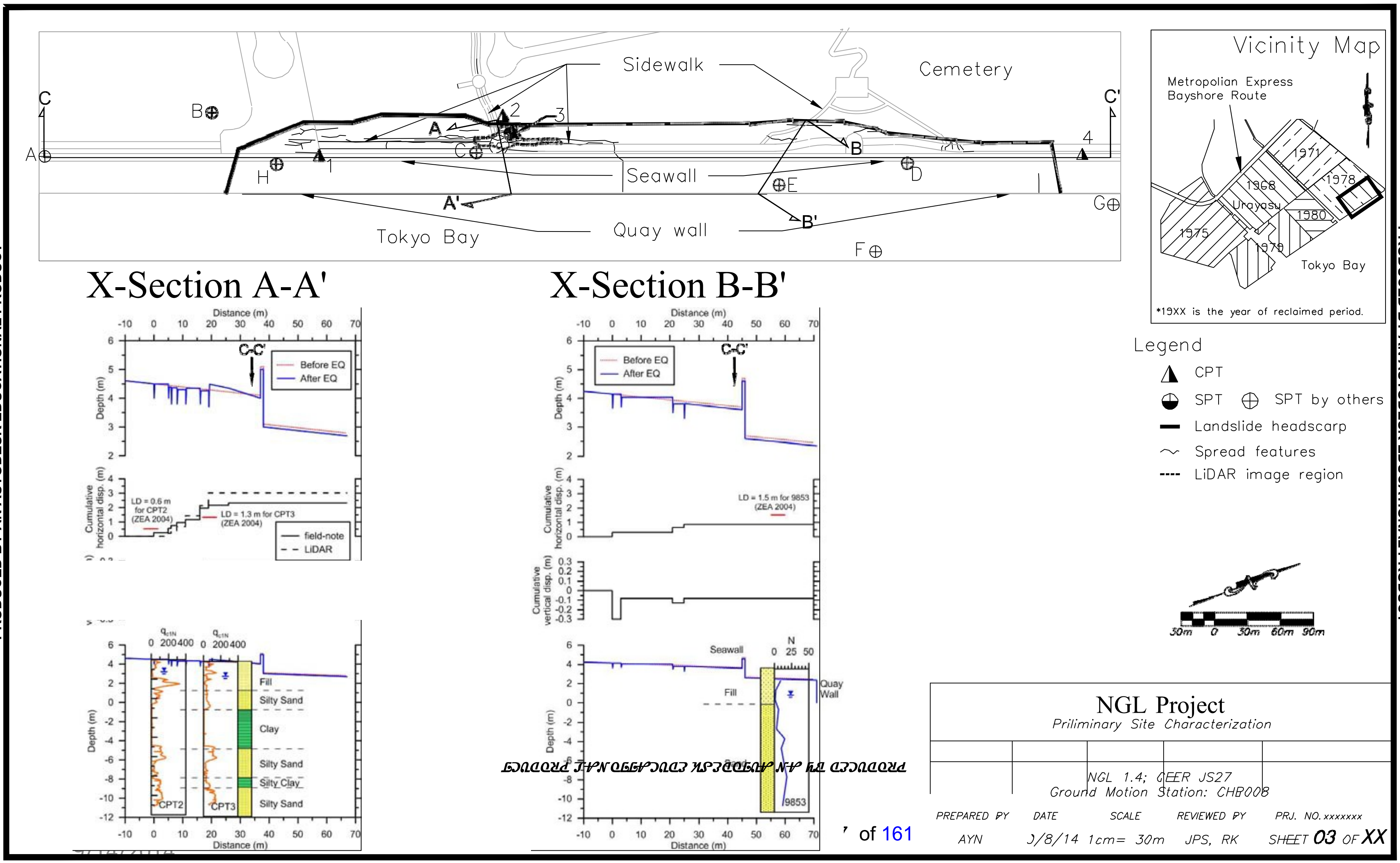

Sidewalk
Cemetery
Seawall
Tokyo Bay
Quay wall
Vicinity Map
Metropolian Express Bayshore Route
Urayasu
*19XX is the year of reclaimed period.
X-Section A-A'
X-Section B-B'
Distance (m)
Depth (m)
Before EQ
After EQ
C-C'
Cumulative horizontal disp. (m)
LD = 0.6 m for CPT2 (ZEA 2004)
LD = 1.3 m for CPT3 (ZEA 2004)
field-note
LiDAR
LD = 1.5 m for 9853 (ZEA 2004)
Cumulative vertical disp. (m)
Fill
Silty Sand
Clay
Silty Clay
CPT2
CPT3
Seawall
Quay Wall
9853
Legend
CPT
SPT
SPT by others
Landslide headscarp
Spread features
LiDAR image region
30m 0 30m 60m 90m
NGL Project
Priliminary Site Characterization
NGL 1.4; GEER JS27
Ground Motion Station: CHB008
PREPARED BY
DATE
SCALE
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PRJ. NO. xxxxxxx
AYN
3/8/14
1cm= 30m
JPS, RK
SHEET 03 OF XX

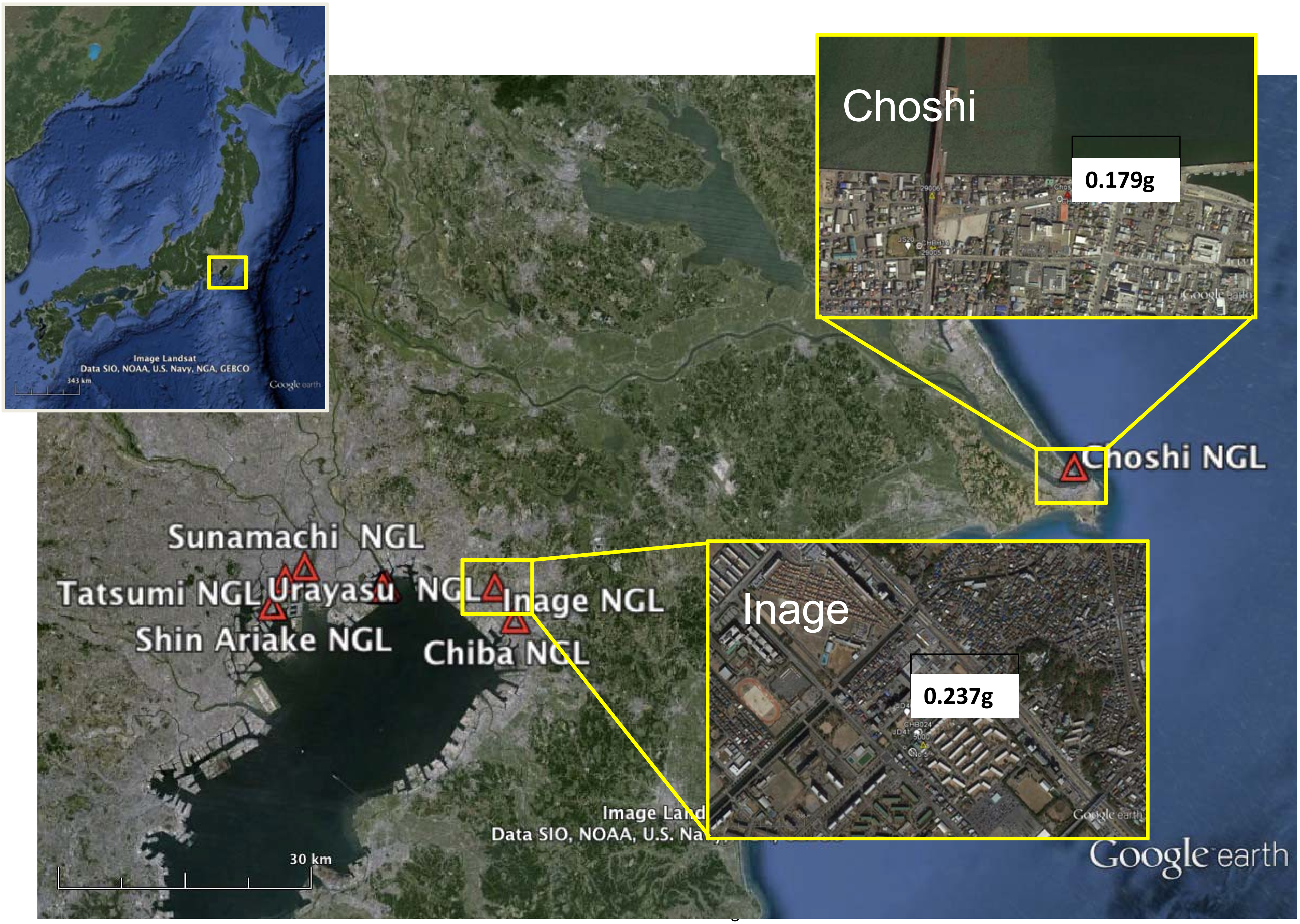
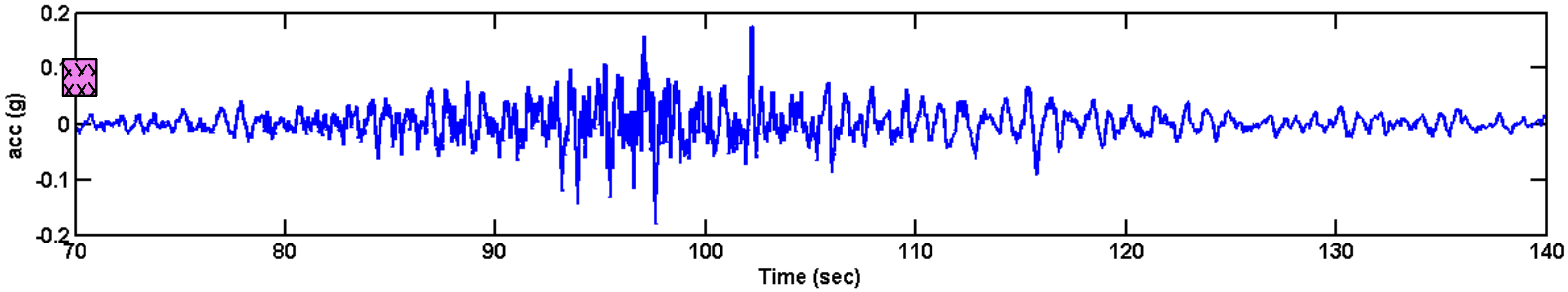
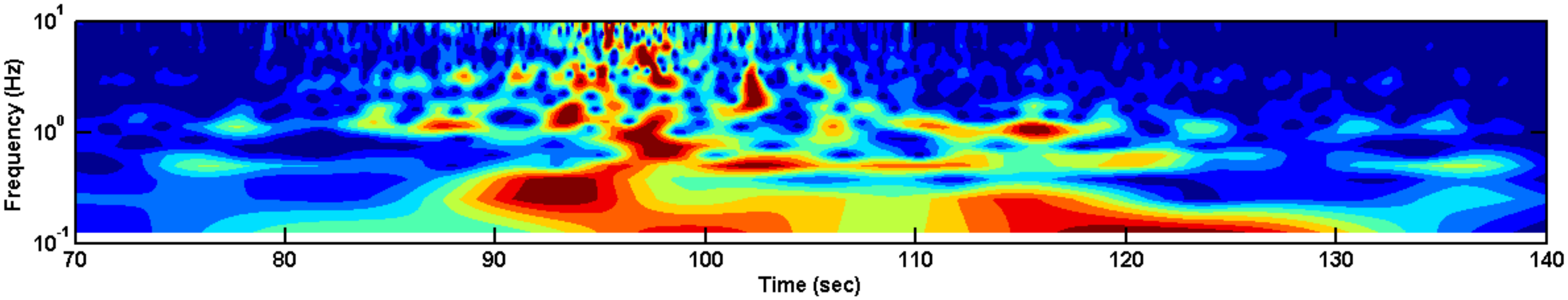


Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
343 km
Google earth
Choshi
0.179g
Choshi NGL
Sunamachi NGL
Tatsumi NGL
Urayasu NGL
Inage NGL
Shin Ariake NGL
Chiba NGL
Inage
0.237g
30 km
Google earth

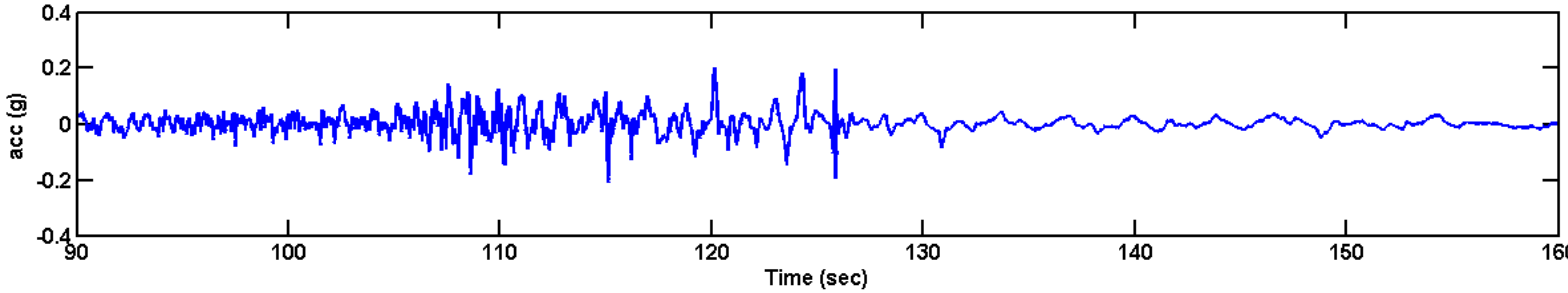
Choshi Site (Knet CHB005): No ground failure

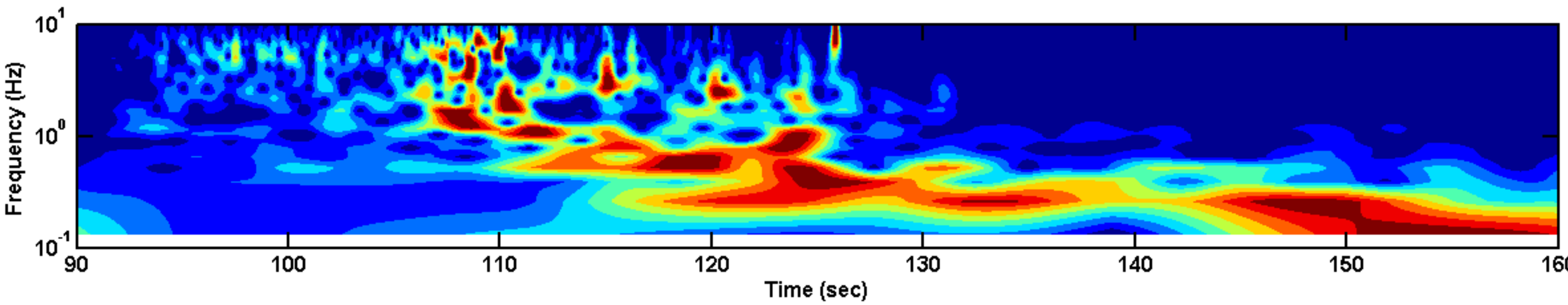




Reconnaissance

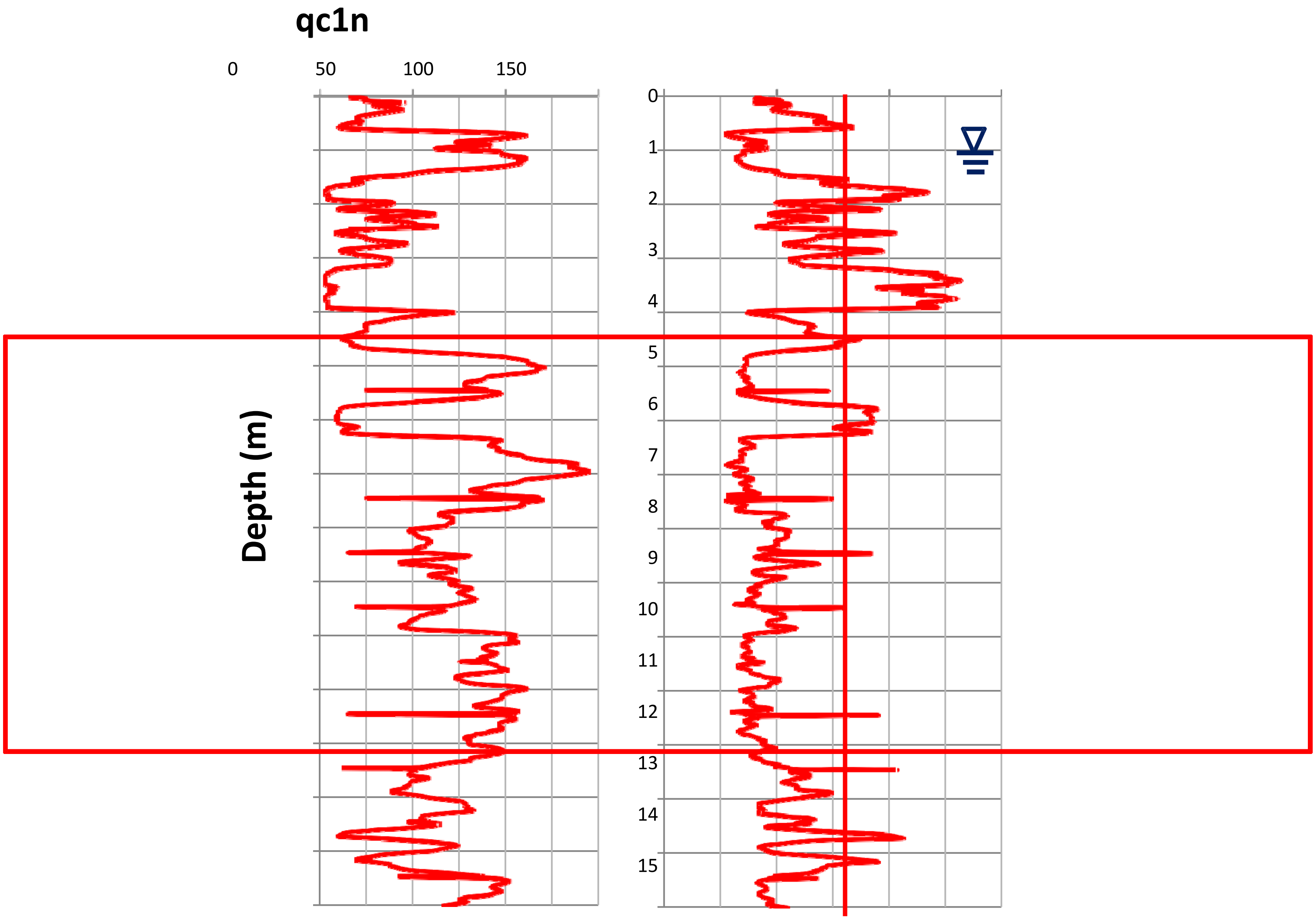
Inage Site (CHB024):



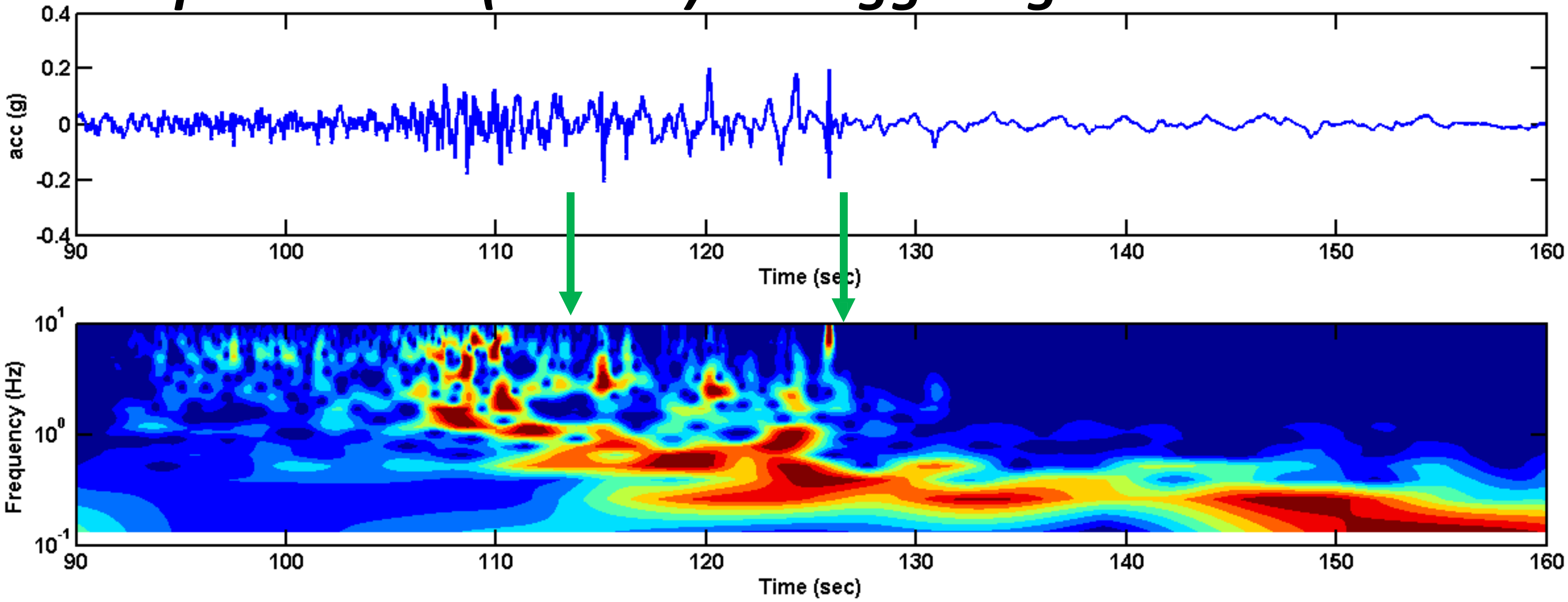


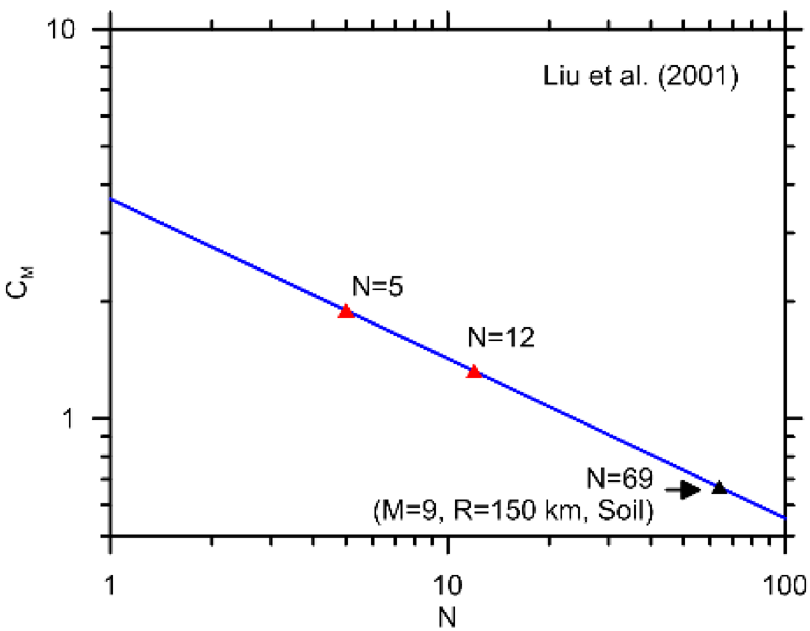

GEER,

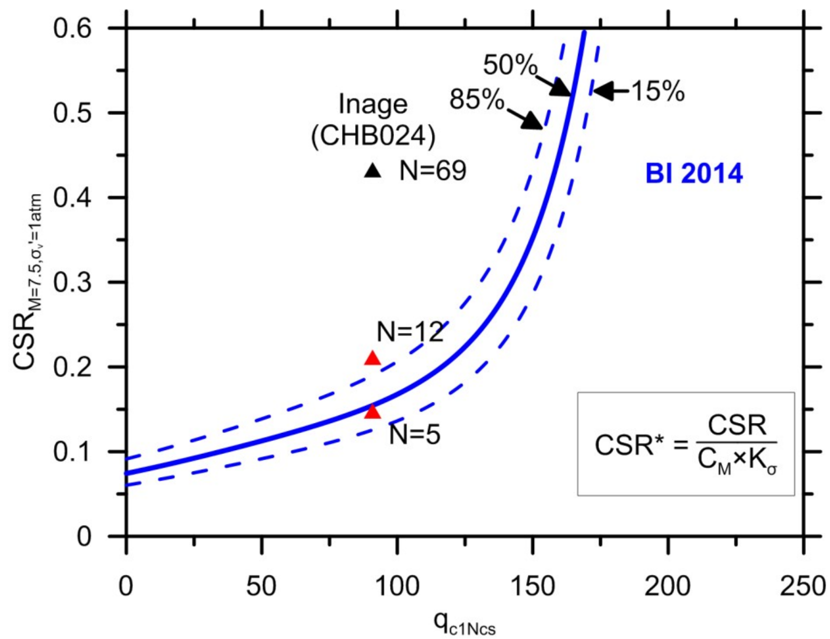

JD142.J


qc1n
0
50
100
150
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Depth (m)

Attempt to locate (CSR-PR) on triggering curve







1.2.5 Next Steps

Next Steps for NGL

- NRC report will endorse NGL
- Continue to gather information for impactful sites (Japan, NZ earthquakes). Planned for 2014-2015
- Need to secure long-term funding
- Establish data archival tools
- Longer term: supporting studies, modeling teams, dissemination, etc.

1.3 UDOT Kickoff Meeting Notes – 8/15/2015

Summary of Pre-Contract Research Meeting
TPF-5(350) Development of Next Generation Liquefaction (NGL) Database for Liquefaction-Induced Lateral Spread
http://www.pooledfund.org/Details/Study/601
Meeting Date: August 15, 2016
Meeting Location: UDOT Central Office and Web Conference

Attended in person:
- Dr. Steven Bartlett, Univ. of Utah
- Grant Gummow, UDOT Geotechnical Division
- David Stevens, UDOT Research Project Manager
- Vincent Liu, UDOT Research Implementation Engineer

Attended via web conference:
- Steven Kramer, Univ. of Washington
- Kevin Franke, Brigham Young University
- Dan Gillins, Oregon State University
- Les Youd, BYU Emeritus
- Justice Maswoswe, FHWA Technical Liaison
- Tom Shantz, Caltrans
- Susan Ortiz, Oregon DOT
- Jim Cuthbertson, Washington State DOT (for Tony Allen)
- David Hemstreet, Alaska DOT&PF
- Rick Saeed, Questar Gas
- Devin Baird, Questar Gas

Main agenda items included:
- Introductions
- Presentation by Steve Bartlett – Background and scope of work for the proposed study (the draft UDOT-UofU contract scope was distributed to the group for review before the meeting)
- Group discussion on scope and approach
- Contracts and funding
- Next steps

Major discussion items included:
- Steve Bartlett gave a brief presentation on the proposed study background, objectives, and tasks, including the type of data and maps needed from available lateral spread case studies for the new database. Study and database development/population would take about two years, starting this summer. (See the draft scope of work.)
- Dissemination of the new database could be via ArcGIS Server.
  CALTRANS wants team to investigate the work currently done by UCLA (Jonathan Stewart) before finalizing any software platform. The scope of work has been changed to remove any reference to ESRI Arc GIS products.
- Phase II screening criteria task is proposed but not currently funded.
  The task remains unfunded and un-finalized in the present SOW. There were differences in opinion about the scope and timing of this task, so it will remain un-finalized until after the kickoff meeting.
- Data quality is important; process would give objective decision.
- Rick Saeed asked what the practical aspect of the research is. Steve Bartlett responded that the applied aspect from this phase of the study is screening criteria. Model development would come after that, to better predict the amount of lateral spread. The models could help industry too.
  Model development will be done under future projects pending the completion of the community database.

- Tom Shantz expressed concern about the GIS database approach. He suggested the researchers look at Jonathan Stewart's (UCLA) database version for liquefaction triggering and try to make the lateral spread database compatible.
  (See response above)
- Tom also asked about how other researchers would contribute data. Steve Bartlett suggested they could provide the data to the PI's on this study and then the PI's would process the new data into the database. Kevin Franke said that the study would create the framework and database, and then perhaps PEER could vet and screen new data. He suggested unvetted data might also be available to researchers in the database, until the data is vetted and screened and added to the main dataset.
  It appears that PEER, who is the keeper of the physical database, should take the lead in screening "future" data. The project described in this scope of work will focus on the data associated with Table 2 of the present scope. The outputs of tasks 2 and 3 can be used in the future to define the required screening for "future" data.
- Steve Kramer and Jonathan Stewart have already laid the groundwork for the database. Steve Kramer said his students have a working database. His intent is to work closely with the lateral spread database project to provide coordination and consistency.
  (See response above)
- Lateral spread database study will look at the liquefaction triggering database setup, as well as various appropriate software. Dan Gillins had recommended the use of ArcGIS Server due to widespread use.
  (See response above)
- Scanned and digitized data logs would also be incorporated in the database.
- Limitations of the dataset would be quantified.
- Regarding the software and framework, it was suggested in the meeting that Jonathan Stewart be included in the lateral spread database kickoff meeting with researchers. We can learn what's used and what's best, and then marry the two datasets (triggering and lateral spread). Steve Bartlett said the kickoff meeting would be held in the next couple months.
  (Initial discussion on this topic to be held the week of Aug. 28th, 2016.
- Justice Maswoswe asked who would take care of the long-term vetting and maintenance of the database. Steve Bartlett suggested PEER.
  (see response above)
- Susan Ortiz asked if PEER is involved. Yes, Jonathan Stewart, Steve Kramer, and Tom Shantz are closely connected with PEER. Steve Bartlett and others have also attended recent PEER NGL coordination meetings.
  (Yes PEER is involved)
- Justice Maswoswe asked whether there would be set criteria for adding data or if we would take all data. Steve Bartlett mentioned some data is more crucial. Kevin Franke suggested ranking is needed for the minimum data that is needed, which the study would define. Steve Bartlett added that the model development that comes later will benefit from screening criteria, helping with the applicability of the models.
  (Tasks 2 and 3 address these issues)
- Les Youd expressed concern about the timing or long duration of the study. He emphasized we need to have some short-term progress to benefit practitioners with urgent needs. Two empirical methods for lateral spread analysis exist: SPT-based by Bartlett and Youd, and CPT-based by Peter Robertson. Layer thickness is a big issue, since some big lateral spread mitigation is being designed.
  (A 2-year duration is not considered to be long time. Because this is a community database open for all to use, the developers of the database will be discouraged from doing model development. However, some progress can be made towards developing screen criteria that is applicable to practice.
- Kevin Franke described a separate USGS proposal that he, Les Youd, and Peter Robertson submitted on CPT and lateral spread. This is outside the NGL scope and could help address the layer thickness issue. The proposal decision is pending.
  (see above comment)

- Les Youd and others emphasized that we need to understand the zero-displacement cases. Steve Bartlett said it is unfair to interpret the data entirely while populating the database. Layer thickness could be addressed partially in the Phase II screening criteria task, currently unfunded. Kevin Franke suggested that Japan and other recent events could help with understanding this too.
  (see above comment)
- Steve Bartlett said the screening criteria development is important. This would be in Tasks 10 and 11 of the study, currently unfunded. Could these be funded too by the study sponsors? It would be another $50,000.
- We briefly checked in with Questar Gas and Alaska DOT&PF about their ability to contribute to the overall study. Rick Saeed said they'll discuss further offline with Steve Bartlett and Kevin Franke. Dave Hemstreet said he'll check with his research office and let David Stevens know.
- The study as planned would involve two contracts at the Univ. of Utah: one with UDOT (leading the pooled fund study), and one with the Mountain-Plains Consortium. Steve Bartlett will coordinate with the other three universities involved for subcontracts.
  (MPC contribution shown in present contract)

The meeting was adjourned a little early due to a fire alarm and evacuation at the UDOT offices.

1.4 NGL Workshop – 2/5/2016

1.4.1 NGL Meeting – PEER Feb 5 2016

Participants: Donald Anderson, Richard Armstrong, Ariya Balakrishnan, Sjoerd van Ballegooy, Steven Bartlett, Christine Beyzaei, Yousef Bozorgnia, Scott Brandenberg, Jonathan Bray, Brian Carlton, K. Onder Cetin, Ahmed Elgamal, Kevin Franke, Russell Green, Mike Greenfield, Tadahiro Kishida, Steven Kramer, Dong Youp Kwak, Jorge Meneses, Shoichi Nakai, Thomas Shantz, Jonathan Stewart, T. Leslie Youd, Thomas Weaver, Zia Zafir, Paolo Zimmaro

1. J Stewart – Introduction: objective database vs subjective Flatfile (synthesis of parameters used for model development)
    - Z Zafir: Visit old datasets? Ans: Yes – specifics are given in the 6ICEGE NGL paper (accessible from web site)
    - R Moss: how to avoid between-developers issues? Ans: No magic bullet. But aside from the notable recent example, we have proven over time to be a community that can cooperate. Good leadership and a clear mandate from the outset should provide the basis for cooperation.
    - Y Bozorgnia: We don't exclude any specific team for modeler.
    - J Bray: key is that we are focusing on the data. The objective data cannot be disputed. Start there and move forward.
2. S Kramer - NRC Study:
    - NRC study examines state-of-the-art and practice in earthquake induced soil liquefaction
    - Y Bozorgnia: NRC study is complementary to NGL. These efforts are not in competition.
3. S Nakai (Chiba Univ., Japan) – Liquefaction effects in Mihama ward (Japan)
    - A Elgamal: expresses some concerns about higher order site effects (2D, 3D) that are not considered because the site response is assumed as 1D. Ans: the complexity of the layering is exaggerated in Nakai's slides because of vertical exaggeration in cross sections. The actual layering is quite flat and 1D likely ok.
    - S Nakai: Difference of PGA or PGV across the area was not large based on ground motion recordings.
    - L Youd: Were settlements measured in the study area? Ans: yes, but they are relative settlements (i.e., structure relative to surrounding ground). They do not have absolute settlements. In subsequent discussion it was discussed that there are remote sensing data sources that can likely be used to extract this information (information of this type is available in Urayasu, for example). We will pursue this.
4. D Kwak – case history development for the Tokyo-Chiba area
    - Few comments.
    - R Moss: They measured V_S (MASW and SASW) for the Urayasu lateral spread site
5. M Greenfield – Presented rationale and methodology for examining ground motion recordings at liquefaction sites to locate the CSR-PR value on the triggering curve. Finding the time of liquefaction from accelerogram can be done several ways (STFT: time is smeared, Wavelet: not effective, Stockwell: good compromise – drops of high frequency content for evaluating initiation of liquefaction). With that time, PR value, PGA, and rd, can identify point in CSR-PR space. Requires corrections for pore pressure, penetration resistance, and timing of softening

relative to the surficial evidence. A wide ranging discussion followed that got into issues of how ground motions are affected by liquefaction and how they should be estimated for NGL project.

- R Moss: We would ideally like to have vertical array data with downhole record below liquefiable layer and surface record. Would allow for more reliable estimate of CSR for hypothetical no-pore pressure condition.

There was discussion of how reliable are the SPT values at Knet and Kiknet sites. J Stewart reported on meeting with NIED staff where they indicated that Knet logs are by low bidders, Kiknet was one large national company managing whole network.

- S Nakai – Japanese experience is that KNet data are usually not reliable.
- A Elgamal: In site documentation, it is important to include maps and cross sections that show the site configuration, so that geologic heterogeneity and possible static shear stress effects can be evaluated.

6. C Beyzaei – New Zealand
    - They have focused on 53 sites from a series of projects. They have performed testing and compiled documentation so that they can be added to NGL database. Actually entering the data remains to be completed in most cases.
    - An especially valuable aspect of these data set is that most locations are 5 case histories, due to being shaken in multiple events.
    - J Stewart and group discussion: T&T have been working with various researchers on additional sites with excellent documentation – field performance, ground motions from Brendon Bradley, borings with samples and lab tests, CPT, Vs from multiple sources. There are 55 such sites. To what degree do these overlap with the UCB sites? These should be added in next phase of work – who will do this (Christine or Dong Youp)?
7. S Bartlett – NGL-lateral spreading:
    - He is leading a NGL-themed lateral spreading project with funding from various state DOTs.
    - Intent is that this data will be part of NGL case history database.
    - S Brandenberg: consider Lidar-based lateral displacements for recent case histories
    - K Franke: How to define lateral spread vs. slope displacement
8. L Youd: Presented lateral spread case history data that fit Bartlett and Youd model poorly, it was judged deficient because it may not have satisfied certain conditions that went into the development of that model.
    - J Stewart: We cannot decide on the suitability of a data set based on how it fits a model.
    - L Youd: Agree. We need to be careful about only using high quality data. Data screening is important, especially for lateral spreading prediction). Lateral continuity is necessary for using Youd et al. (2002) equation. This procedure is now abused also when you do not meet main assumptions of the method
9. D Kwak – NGL Database
    - J Stewart: Add source of the photographs
    - J Bray: Need to clearly state what is objective and what may be somewhat subjective data (there is some modest subjectivity in the ground motions).
    - Y Bozorgnia: Ground motion data might not even be objective because it's sensitive to how it's processed

- R Moss: geotech would want to do a ground response analysis rather than use a nonlinear site response regression equation. Can get ground response analysis results to interpret cyclic stress in critical layer rather than using rd.
- J Stewart: site-specific analysis can be incorporated into the proposed ground motion estimation procedure, but we need to provide suitable documentation.
- Y Bozorgnia: capture the epistemic by using more than 1 GMPE
- Y Bozorgnia and T Shantz: Interpretation of ground motion at a specific site could be supporting study.

How to contribute to the database?

- Group favors "Anyone can upload, and filter afterward", but may need to start with "Database manager(s) receive data, filter, and upload".
- J Bray: As soon as the database is ready you have to publish it right away before developing models
- Y Bozorgnia: avoid the publication of unreliable data (the model developers will be performing a double check on the data)
- R Moss: Need to get away from level ground and start studying sites with buildings and other sources of driving shear stress. Information about initial driving shear stress must be included in the database (site plan, google maps, cross sections, etc., these items will be useful for K_α and modeling)
- J Bray: Adapazari dataset (downloadable from PEER web site) should be incorporated into the NGL database
- J Stewart: Taiwan too, also on PEER web site.
- S Bartlett: Can you link lidar (or point clouds) to the database, if so, which software? Ans: not sure.

10. T Shantz (Caltrans) – Perspective of funding agency.
    - Caltrans has an important design guidelines document on the effects of lateral spreading on bridges, formal approval is pending. This follows a 2011 PEER report by Ashford, Boulanger, Brandenberg.
    - Caltrans screened about 6000 bridges down to 450 that need further analysis. Based largely on susceptibility and horizontal continuity of crucial layers.
    - Caltrans MTD (memo to designers) 20-15 is currently in progress. Makes lateral spread guidelines official.
        - Dropping inertial load (or displacement demand) contribution
        - Analysis through global bridge model instead of single bent
        - More lenient performance criteria. Column ductility demands <= 8, Footing settlement < 24 inches, Allow plastic hinging of piles with max drift <= 20%.
    - Caltrans has committed $210K to NGL + $60K to UDOT project + numerical modeling (Martin and Elgamal). Previously funded $100K for field work in Japan. NGL needs to deliver a practical research product ... soon. A research product means a deployable product, such as an update to a triggering relation, not a deliverable such as part of a database. Need to find low-hanging fruit to facilitate future funding. Stewart, Kramer, and Bozorgnia to follow up with Tom on this point (these deliverables will relate to triggering and lateral spreading).

11. T Weaver (US NRC) – Perspective of potential funding agency (NRC)
    - Performance-based target goal. Frequency of liq = 10^{-5} year, or also to target displacement values.
    - Principles of good regulation
        - Clarity
        - Reliability
    - RG 1.198 is the key document. Weaver is responsible for updating.
    - Code of Federal Regulations requires evaluation for liquefaction potential for spent fuel storage and reactor citing.
    - Target 10^{-5}/year probability of exceeding the onset of inelastic deformation.
    - NRC Interests
        - Reliable database and predictive models
        - Evaluation at high confining stress (structures embedded down to 40ft)
        - Evaluating settlement (free field and beneath structure)
    - NGL Contributions
        - Openness of process
        - Reliable database, models and methods
        - Increased clarity
        - Lead to improved regulatory guidance and geotechnical engineering practice
    - S Brandenberg: is NRC interested in the study of levees that protect structures?
    - T Weaver: it will be desirable to include details on these systems.
12. Kramer-led discussion starting 3:38 pm
    - R Armstrong: Gravel correction for SPT blow counts (important for dams)
    - Shantz spoke with Elgamal at PEER annual meeting about numerical modeling (permeability in numerical models is the most important parameter)
    - S Bartlett: Can measure horizontal permeability using CPT.
    - S Kramer: System permeability (i.e., permeability gradients or layering) might be more important than permeability at a point.
    - R Green: Fines content is a very important parameter. Correlation between fines content and Ic based on New Zealand specific model was actually worse than generic fines correction by Idriss and Boulanger.
    - R Moss: driving shear stress is fundamental (we need improvement on this issue)
    - S Kramer: cyclic simple shear tests are important for improving understanding on driving static shear stress
    - R Moss: cyclic simple shear test is important to better understand the effect of static shear stress.
    - S Kramer: When we are assessing effects, rather than triggering, we need to integrate the effect (strains, etc.), which avoids the need to identify a single critical layer.
        - R Moss: there are many studies on identifying the critical layer – end result is that the selection is extremely subjective. Geology and geomorphology should dictate the choice.

- Fines content and depth effect are most important. Seemed to be a group consensus on this. (Others are effects of initial shear stress, selection of critical layer, void redistribution, aging effects, and ground motion estimation).
- New IM's may be explored, and new alternatives to PR (i.e., vector including PR plus Vs).
- R Moss and S Kramer: only a few procedures have been developed for picking the critical layer (useful for developers)
- S Bartlett: pattern of observed deformations/damages is important. For probability analysis neural network could be a good solution (pattern is more important than 1D integration). There is a way to make the critical layer less subjective
- J Bray: Depth, fines, GM, void redistribution are the 4 most important issues
- S Brandenberg: Combination of penetration resistance with VS for resistance measure
- K Franke: How deep should we go?
- Z Zafir: Geologic age may be different from aging. Aging is a function of number of past earthquakes, which correlates with geologic age but in a region-specific manner depending on seismic hazard (focus on Holocene series)
- S Brandenberg: SSI effects on consequences and triggering (by means of shear stress)

1.4.2 Comments and Concerns from February 5, 2016 NGL Workshop Les Youd

1. The NGL team are to be commended for getting this project underway and finding and accumulating funding to press onward.
2. NGL is modeled after the NGA Ground-Motion Prediction Project, which has successfully produced improved consensus ground motion prediction equations. The improved equations, however, are not new equations, but improvements and enhancements of past pioneering modeling efforts. I expect that the products generated by NGL will be similar. For example, the final models and procedures with respect to lateral spread prediction most likely will be enhancements of the pioneering work by Bartlett and Youd and by Zhang and Robertson. Thus new case histories added to the data base should collected to include the information necessary to apply, verify and improve previous models.
3. Similarly, next generation for prediction of free field ground settlements will likely be enhancements and improvements to the pioneering models developed by Tokimatsu and Seed and Ishihara and Yoshimine. Case history data needs to be collected with information necessary to apply, verify or improve the previous procedures.
4. On this note, I encourage Professor Nakai and those collecting data from areas that did and did not liquefy in Chiba, Japan to collect quantitative data on free-field ground settlements. Supplementing the case histories with this data will increase their value.
5. This Chiba data collection issue brings up a major concern. It appears that the NGL data collection efforts are being separated from the NGL modeling and analysis efforts. My past experience is that such a division of effort is a recipe for disaster. Modelers should be sufficiently involved in collection effort to review on the fly the data and information being collected from each uniquely different case history site. It is unlikely that adequate specifications can be developed that will assure that the all of the available and pertinent data and information will be collected in each gathering effort. Asking one group to collect data for another group to analyze will likely lead to frustration and inferior final products. In all of the data collecting and modeling efforts in which I have been involved, have incorporated close cooperation between field investigators and modelers. For example, I believe that modelers of ground settlement will be frustrated and hindered by the lack of measured ground settlements at Chiba case history sites.
6. I suggest that the NGL steering committee formulate important modeling needs from case history sites. For example, for lateral spreads, future needs include: a. Assessment ofsusceptibility or lack of susceptibility of fine grained sediment to lateral spread. Field case histories to data indicate that fine-grained sediment such as those beneath Adapazari, Turkey, although susceptible to liquefiable, were not susceptible to lateral spread. Also clay-like soils appear to be immune to lateral spread. According to the findings of Bartlett and Youd, lateral displacement decreases markedly with increasing fines content. All of these apparent findings need confirmation and further definition. My review as a consultant of predicted lateral spread displacements based on the Zhang and Robertson procedure do not similarly demonstrate the impeding effects of fine-grained soils. Thus more confirmative case histories from fine grained soils need to be collected.
7. Another need for more well documented case histories from lateral spreads is influence of thinness of the liquefiable layer ion lateral spread displacement. The thinnest layer in the

Bartlett and Youd dataset in which lateral spread occurred is about 1.0 meter. In a review as a consultant of a recent lateral spread analysis at a proposed major development, displacements I noted that up to several feet of displacement was predicted, but most of that displacement originated from layers a few to several inches thick rather thinly layered sediments. I believe those displacements are greatly over predicted. The proposed cost developed by the consultant for ground modification to stabilize these layers against lateral spread exceeds $60 million (likely several times the amount of hoped for NGL funding). Thus, we (NGL) need to better define the influence of layer thickness on lateral spread displacement.

8. Similarly, the profession needs more carefully documented field case histories to demonstrate the influence of fines content and thickness of liquefiable layers on ground settlement.
9. A more minor concern to me is to develop more accurate terminology, as mentioned by others at the workshop. I was concerned about the apparent confusion between occurrence of liquefaction and surface evidences of liquefaction, such as sand boil deposits. There are several sites where liquefaction is known to have occurred at depth without generation of sand boils, such as instrumented sites where a shift of natural frequency, as discussed at the workshop, but without the eruption of sand boils.
10. Although not mentioned at the workshop, many of most useful case histories have come from instrumented sites. For example, the Wildlife Site, near Brawley, California, for which I was a principal investigator in instrumenting the site in 1982, produced invaluable records of ground motions above and below a liquefying layer and pore pressures within the layer as liquefaction developed during the 1987 Superstition Hills earthquake. Instrumentation at that site was replaced and greatly expanded in 2003 as a NEES field instrumentation site. A few other sites have subsequently been instrumented,but have not yet produced significant records. Important additional earthquake records have been collected from the Wildlife Site since that re-instrumentation, but, another large liquefaction-producing earthquake has not occurred. However, the site is in a highly seismic area with high probability for liquefaction generating earthquakes. NEES has pulled the plug on funding for the Wildlife. Jamie Steidl, the present principal investigator, has scraped together enough funding, including some from the Nuclear Regulatory Commission, to temporarily keep the site in operation, but long-term funding has not been secured. I believe that the Wildlife Site, now called the Wildlife Liquefaction Array (WLA), is an important asset to NGL and, if not already considered, should be considered and supported as an important liquefaction case history site. NGL may wish to invite Jamie to make a presentation on the site at a future NGL meeting.

1.4.3 Comments from February 5, 2016 NGL Workshop Sjoerd van Ballegooy

1. In terms of lateral spreading – if known it would be important to record in the NGL database the observed eye witness accounts of the timing of the lateral spreading relative to the strong shaking motions. In the case of the Christchurch earthquakes, lateral spreading was not observed to occur during the strong motions, but was observed to start approximately 5 mins after the strong motions had occurred. Unsure when the lateral spreading ceased, because 10mins after the ground motions the land was covered with ejected sand and water
2. Free field liquefaction observations should not be connected with a single CPT, because as in the case of Christchurch, liquefaction ground failure has been demonstrated to be also dependent on spatial variability and spatial continuity of the soil layers. Therefore, similar to lateral spreading, I recommend that multiple surrounding investigation records should be able to be included in the database for each case history.
3. Also, the severity of ground failure observations at "free field" case histories are dependent on topography and land use and should be included in the NGL database for each case history.

    For example in Christchurch properties typically subsided more than roads (by 100 to 200mm) because properties were approximately 500mm higher than the adjacent roads for storm water management purposes. Therefore, topographic maps for each case history site are important to include in the NGL database.

    Similarly, there are cases in Christchurch were the ground failure severity was significantly exacerbated by infrastructure such as buried pipes and manholes that uplifted puncturing the non-liquefying crust, creating preferential paths for ejecta.

    Also power poles and streetlight poles that rocked backwards and forwards duringthe shaking created an annulus and hence a preferential path for ejecta in the non- liquefying crust.

    Conversely, liquefaction manifestations in adjacent parks and farmland that was flat and not developed were not as severe. Therefore, land use descriptions, maps and photos for each case history site are important to include in the NGL database.
4. I didn't hear whether other investigation types (in addition to CPT and boreholes with SPT and lab tests) could also be included in the database. Test pit logs which are available for some case history sites in Christchurch are extremely valuable to show the spatial variability and continuity of the soil layers at case history sites as well as capturing the paleo-liquefaction history at the sites. Also, many case history sites have good geophysical investigation data (Vs to measure the in situ small strain stiffness and Vp to measure the in-situ partial saturation).
5. Finally, there 55 case history sites throughout Church with very detailed observations across all the 2010-2011 events that were not mentioned that we are currently working compiling that have a large quantity of investigations in close proximity including CPT, boreholes with SPT, lab tests, cross hole and downhole Vs and Vp profiles and piezometer ground water records. Many of these 55 case history sites are cases where the B&I 2014 CPT-based liquefaction procedures either over predict or under predict liquefaction relative to the observations for one or more of the Church events. I think that these case histories would be very important to include in the NGL database and would be happy to provide them.

1.5 NGL Workshop – 7/12/2007

Outline

- Overview of NGL database vision and mission.
- Why a relational database instead of traditional data repository?
- Database current status and future directions.
- Vision for how developers will interact with NGL database.

NGL Database Objective

- Develop a database of liquefaction case histories, and provide a geo-spatial web interface to the data.
- Permit users to upload data to, and download data from the database.
- Permit users to view with data in the web application, and eventually perform calculations using the data (will require DesignSafe integration).

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What is a Database?

- Common definition used by engineers:
  - A collection of data.
  - Examples include experimental data archived in DesignSafe, or the ground motion records made available through the various NGA projects.
- However, this is a data repository, not a database, according to the computer science community
- The word "database" refers to a relational database (e.g., MySQL, MS Access).

What is a Relational Database?

- A structured body of related information.
- Data are organized as a set of tables formally described by a “schema”.
- Tables are related to each other by shared fields called “keys”.
  - Primary Key: A unique identifier for each record
  - Foreign Key: A field in one table that identifies a record in another table. Used to relate two tables.
- Databases are typically accessed using the *structured query language* (SQL).

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Example Database

Table: users

name	company	company_address	url1	url2
Joe	ABC	1 Work Lane	abc.com	xyz.com
Jill	XYZ	1 Job Street	abc.com	xyz.com

- Problems:
  - What if a future user wants to list three URL's? Would need to add columns, and many users would have null fields.
  - Multiple users might work for the same company. No need to duplicate company info for every user.

Example Database

- Solve problems by dividing into multiple related tables:
  - Assign primary key to every field.
  - Eliminate fields that do not depend on the key, and create new table for those fields.
  - Relate fields in separate tables using foreign key.

Third Normal Form

Table: users

userId	name	companyID
1	Joe	1
2	Jill	2

Table: companies

companyID	company	company_address
1	ABC	1 Work Lane
2	XYZ	1 Job Street

Table: urls

urlId	relUserId	url
1	1	abc.com
2	1	xyz.com
3	2	abc.com
4	2	xyz.com

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Why is NGL a Relational Database?

- One option would be to store case history data in a file repository. This is problematic for a few reasons:
  - To extract data (e.g., latitude and longitude) to populate the web app, a large number of files would need to be opened and read, which is inefficient and slow.
  - Data repositories often require repeated information, increasing the possibility of inconsistencies in repeated fields (e.g., NGA Flatfiles) or lost relationships among data quantities.

NGL Database Progress

- Database structure has been created, and is continuously being revised.
- Web interface has been developed.
- Database has been populated with 63 case histories by several different researcher groups.
- We have learned quite a bit about data structure and user experience, and are nearing the release of the second version of the database and web app.

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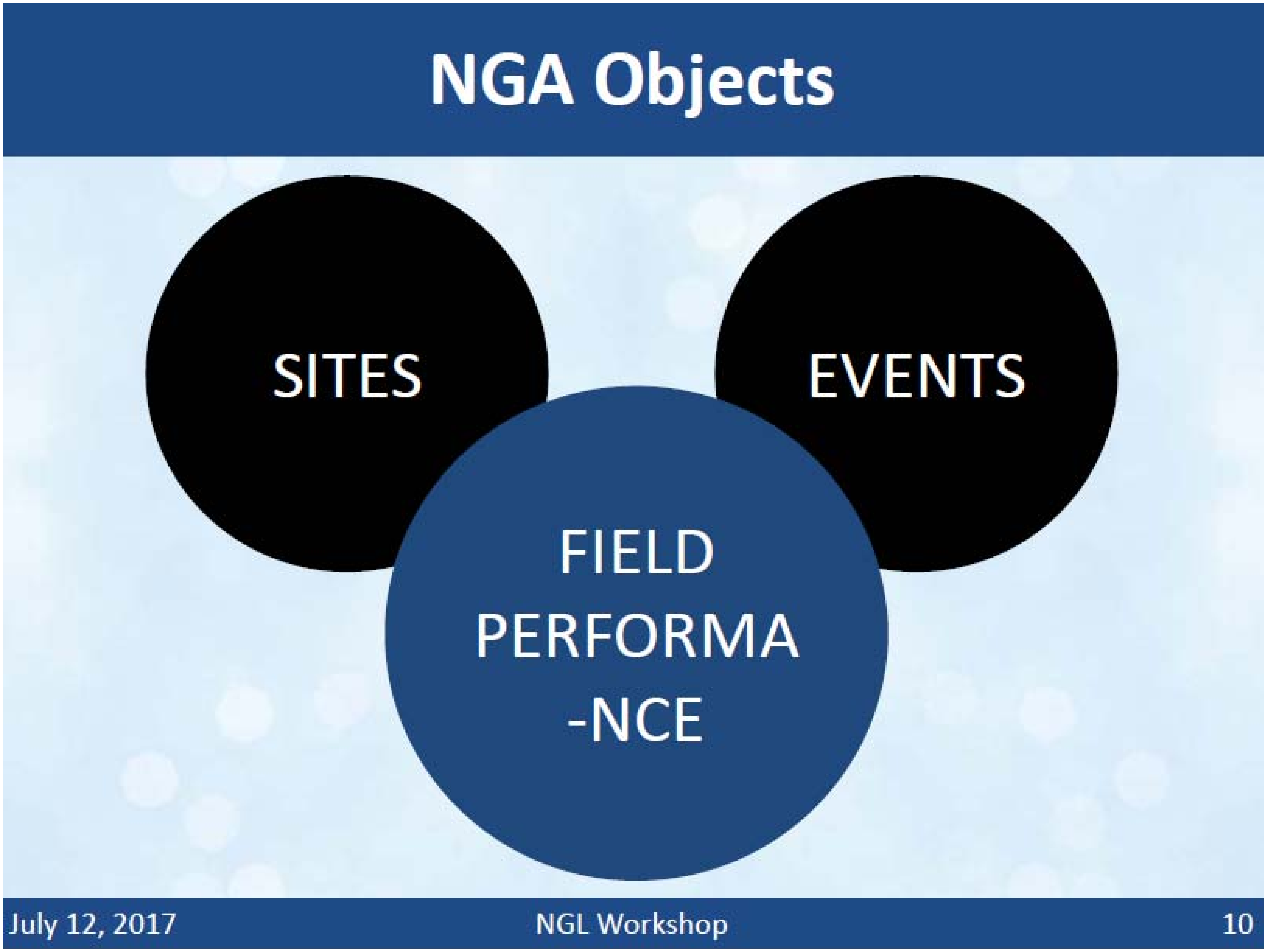
NGA Objects
SITES
EVENTS
FIELD
PERFORMA
-NCE
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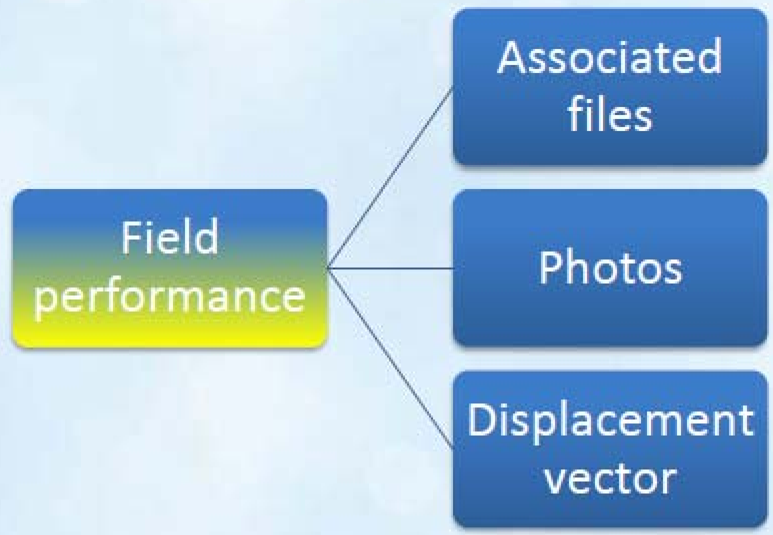
- A site is a collection of data selected by a user.
- Consists of specific locations where boreholes, CPT soundings, test pits, or geophysical measurements are performed.
- Includes laboratory tests performed on samples.

Field Performance Database Structure

- Field performance database consists of associated files (e.g., LiDAR point clouds), photos, and displacement vectors.



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Event Database Structure

- Event database consists of event info (M_w, style of faulting, etc.), station info, fault geometry info, and ground motion IM's.
- NGAWest2 and NGASub datasets will be included in addition to other necessary events.
- Events uploaded by super-users

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Site Table

SITE_ID	INT(6)	UNSIGNED AUTO_INCREMENT	Unique ID for the table SITE
USER_ID	INT(6)	UNSIGNED	Unique ID for the table USER
SITE_NAME	VARCHAR(30)		Site name may be defined based on the name of the location.
SITE_LAT	VARCHAR(30)		Latitude of the site (e.g., center of the site) in decimal degree following WGS84 system
SITE_LON	TIMESTAMP		Longitude of the site (e.g., center of the site) in decimal degree following WGS84 system
SITE_ELEV	VARCHAR(30)		Surface elevation with respect to mean sea level
SITE_GEOL	VARCHAR(30)		Description of surface geology. If available, indicate geoloty unit in parentheses [e.g., Alluvial plain (Qa)].
SITE_REM	VARCHAR(30)		Remark
SITE_STAT	BOOL		For upload status (1 = submitted / 0 = temporal)
SITE_REVW	BOOL		For review status (1 = reviewed / 0 = not reviewed)

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Location Table

LOCA_ID	INT(6)	UNSIGNED AUTO_INCREMENT	Unique ID for the table LOCA
SITE_ID	INT(6)	UNSIGNED	Unique ID for the table SITE
LOCA_LAT	FLOAT(10)		Latitude of activity in decimal degree following WGS84 system
LOCA_LON	FLOAT(10)		Longitude of activity in decimal degree following WGS84 system
LOCA_TYPE	VARCHAR(10)		Type of activity. Four options: - Borehole - Cone penetration test (CPT) - Test pit - Geophysical investigation
LOCA_GL	VARCHAR(10)		Surface elevation with respect to mean sea level.
LOCA_STAR	VARCHAR(20)		Start date of activity.
LOCA_ENDD	VARCHAR(20)		End date of activity.
LOCA_REM	VARCHAR(1000)		Remark

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SPT Table

ISPT_ID	INT(6)	UNSIGNED AUTO_INCREMENT	Unique ID for the table ISPT
LOCA_ID	INT(6)	UNSIGNED	Unique ID for the table LOCA
ISPT_TOP	VARCHAR(10)		Depth of the top of main blows
ISPT_TPEN	VARCHAR(10)		Penetration depth from depth top (main drive only; e.g., 30 cm)
ISPT_NVAL	VARCHAR(5)		Number of blow counts for main drive
ISPT_ERAT	VARCHAR(10)		Hammer drop energy ratio
ISPT_MECH	VARCHAR(100)		Hammer drop system. Example: - Rope-cathead Trip - Semi-automatic - Automatic Another system can be described.
ISPT_METH	VARCHAR(100)		Method (i.e., standard) followed if different from ASTM D1586-11.
ISPT_REM	VARCHAR(1000)		Remark

NGL Schema

- Some tables have structured data fields (e.g., ISPT has depth, blow count, energy ratio, etc.).
- The database also accepts files of any type that users wish to upload (e.g., geology maps, LiDAR point clouds, etc.) using the BLOB database format.

Example Table for Files

Field	LOCF_ID	INT(6)	UNSIGNED AUTO_INCREMENT	Unique ID for the table LOCF
Field	LOCA_ID	INT(6)	UNSIGNED	Unique ID for the table LOCA
Field	LOCF_DESC	VARCHAR(1000)		Detailed description of the associated file (e.g., original data, profile image).
Field	BLOB_ID	INT(6)	UNSIGNED	Unique ID for the table BLOB

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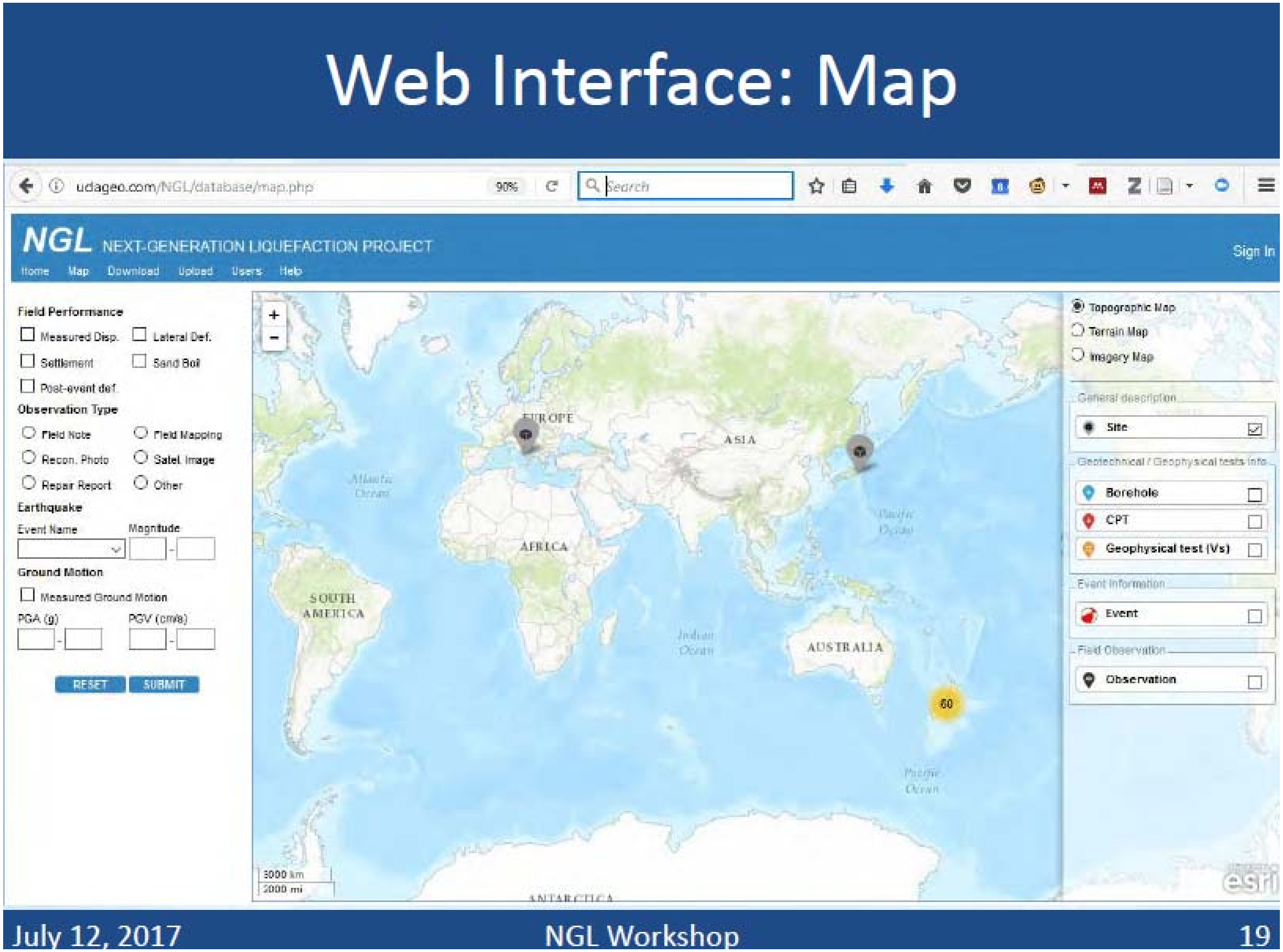
Web Interface: Map
udageo.com/NGL/database/map.php
NGL NEXT-GENERATION LIQUEFACTION PROJECT
Home Map Download Upload Users Help
Sign In
Field Performance
Measured Disp.
Lateral Def.
Settlement
Sand Boil
Post-event def.
Observation Type
Field Note
Field Mapping
Recon. Photo
Satel. Image
Repair Report
Other
Earthquake
Event Name
Magnitude
Ground Motion
Measured Ground Motion
PGA (g)
PGV (cm/s)
RESET
SUBMIT
EUROPE
ASIA
AFRICA
SOUTH AMERICA
AUSTRALIA
ANTARCTICA
60
Topographic Map
Terrain Map
Imagery Map
General description
Site
Geotechnical / Geophysical tests info
Borehole
CPT
Geophysical test (Vs)
Event Information
Event
Field Observation
Observation
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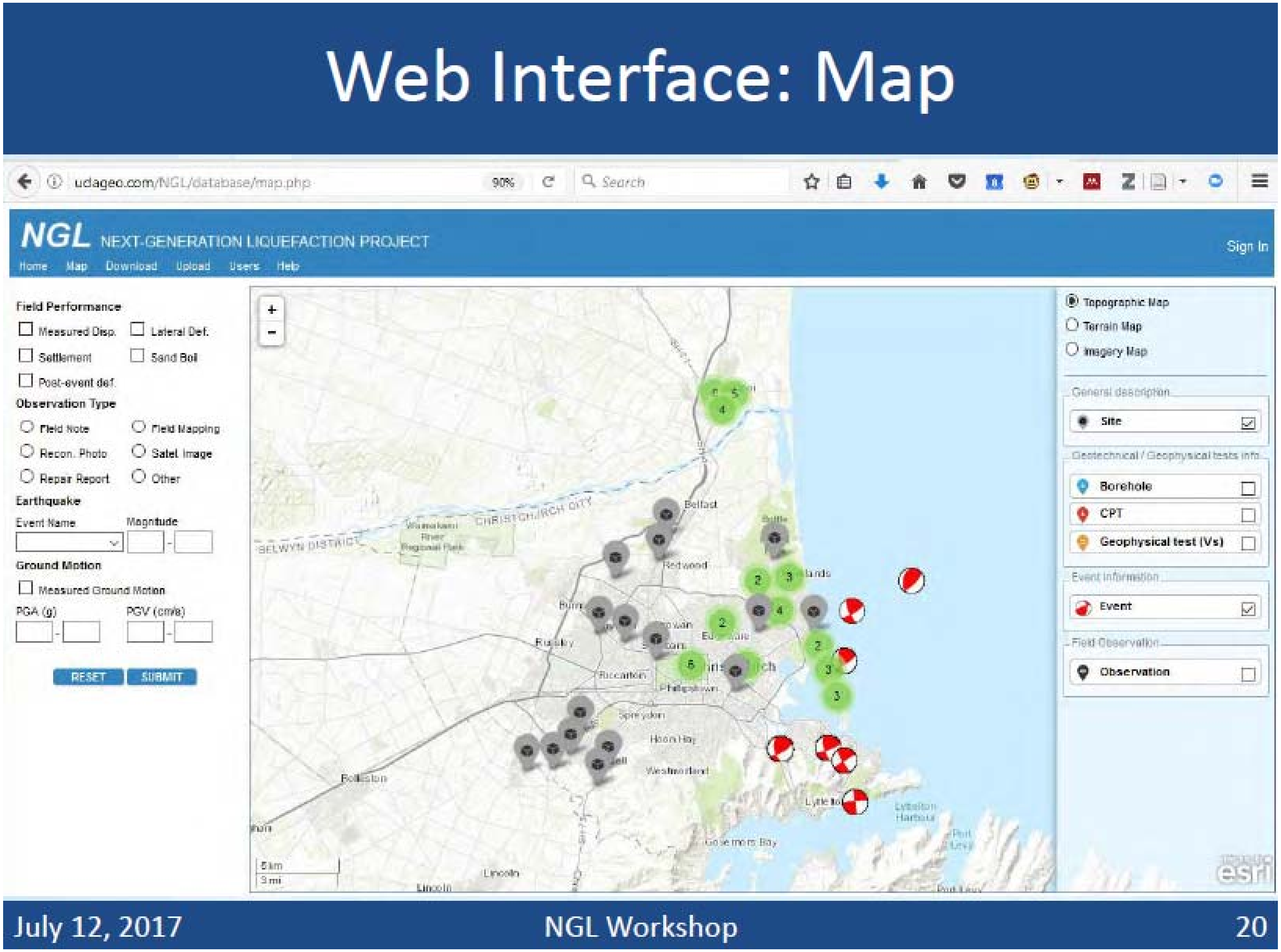
Web Interface: Map
udageo.com/NGL/database/map.php
NGL NEXT-GENERATION LIQUEFACTION PROJECT
Home Map Download Upload Users Help
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Field Performance
Measured Disp.
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Other
Earthquake
Event Name
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PGA (g)
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Imagery Map
General description
Site
Geotechnical / Geophysical tests info
Borehole
CPT
Geophysical test (Vs)
Event information
Event
Field Observation
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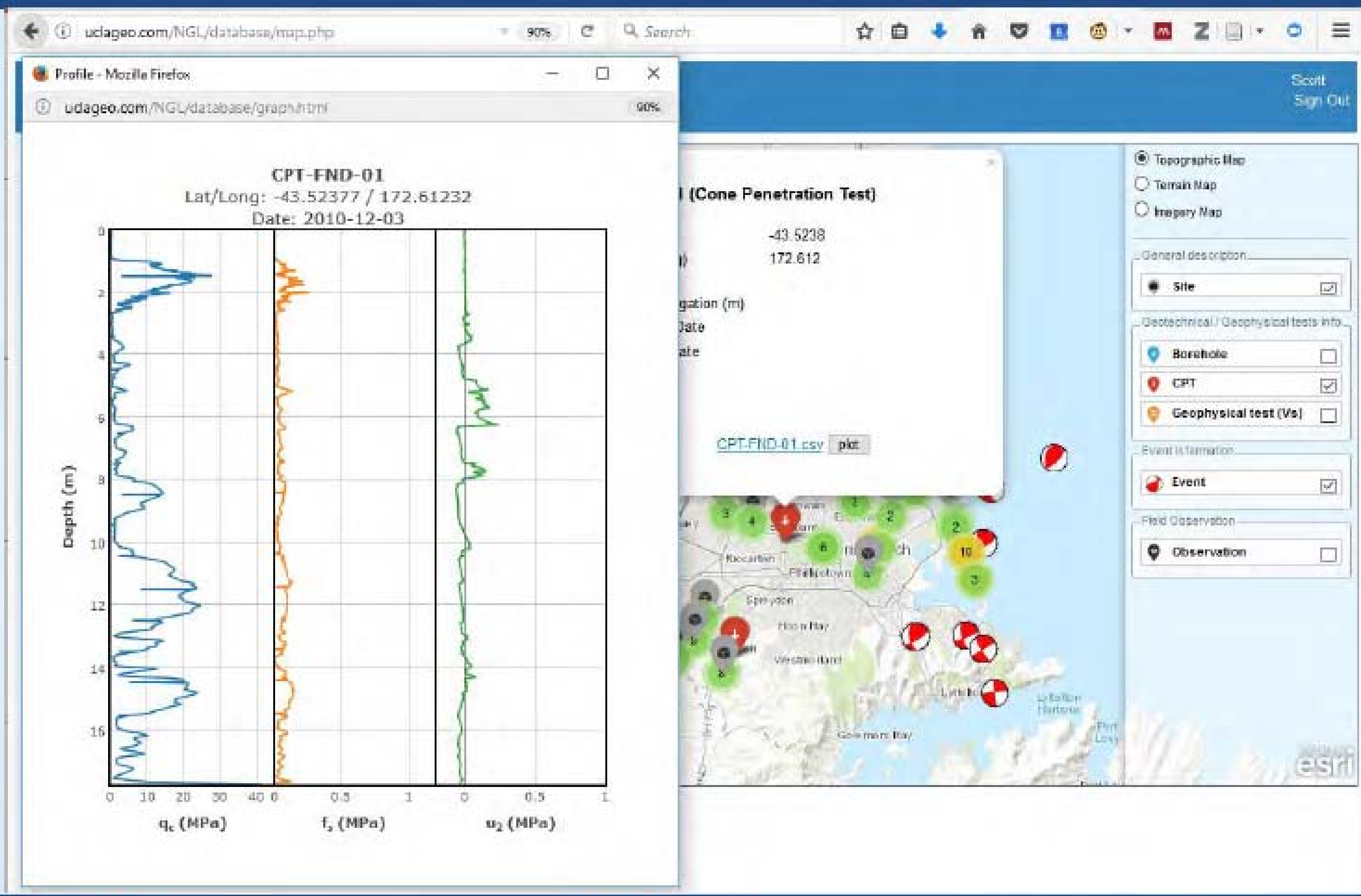
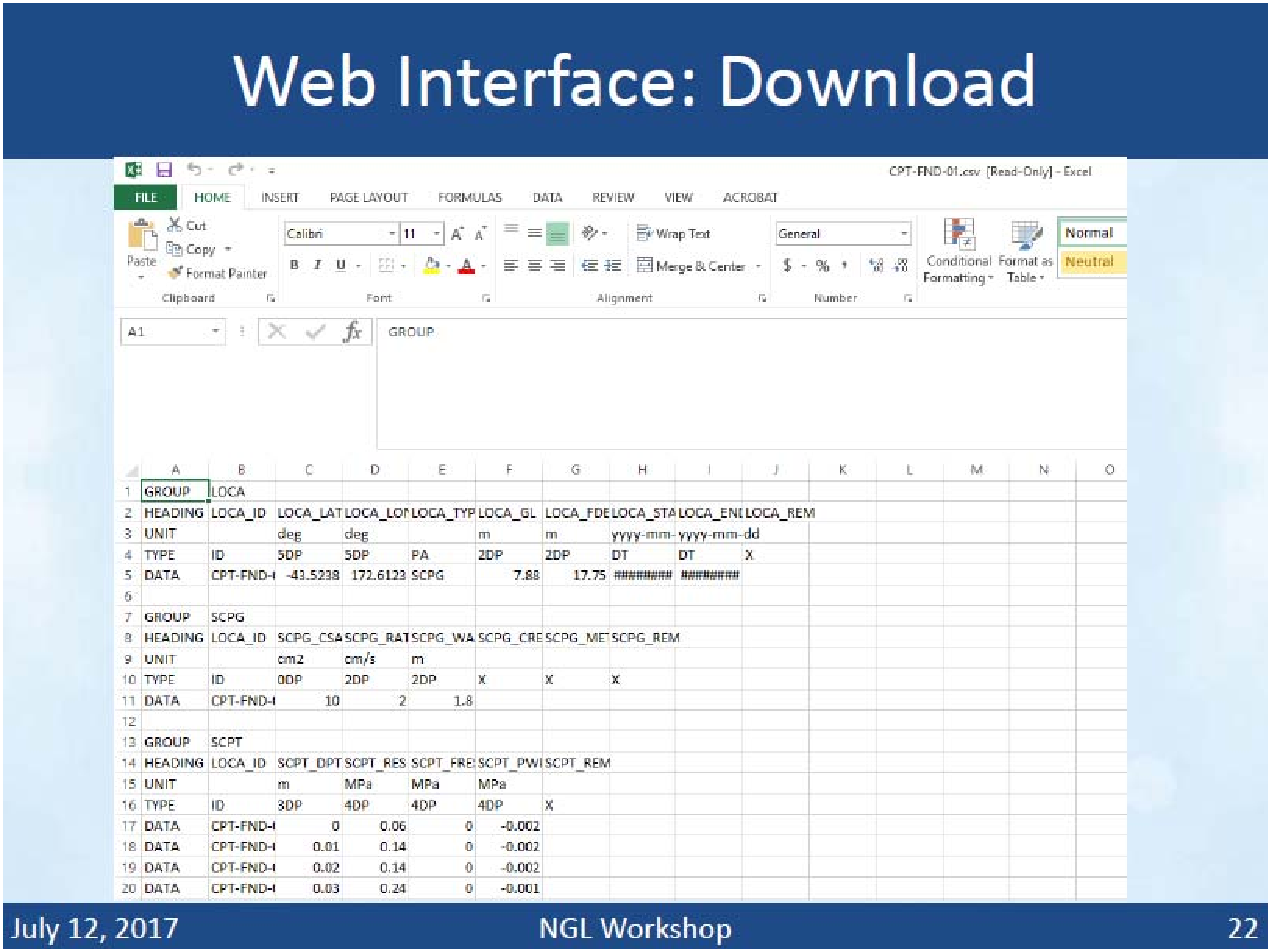
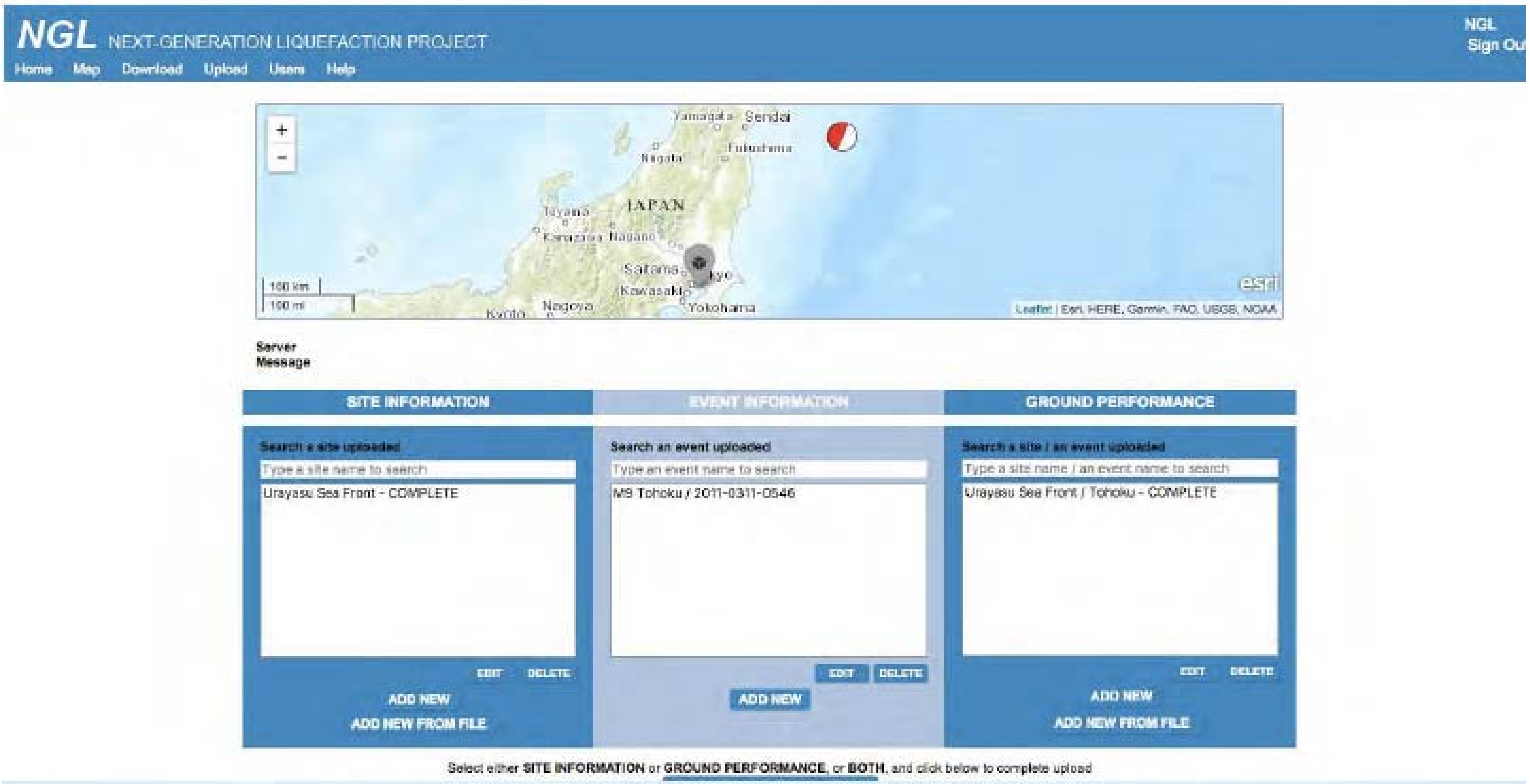
Web Interface: Map





	A	B	C	D	E	F	G	H	I	J
1	GROUP	LOCA								
2	HEADING	LOCA_ID	LOCA_LAT	LOCA_LON	LOCA_TYP	LOCA_GL	LOCA_FDE	LOCA_STA	LOCA_ENI	LOCA_REM
3	UNIT		deg	deg		m	m	yyyy-mm-	yyyy-mm-dd	
4	TYPE	ID	5DP	5DP	PA	2DP	2DP	DT	DT	X
5	DATA	CPT-FND-(	-43.5238	172.6123	SCPG	7.88	17.75	########	########	
6										
7	GROUP	SCPG								
8	HEADING	LOCA_ID	SCPG_CSA	SCPG_RAT	SCPG_WA	SCPG_CRE	SCPG_MET	SCPG_REM		
9	UNIT		cm2	cm/s	m					
10	TYPE	ID	0DP	2DP	2DP	X	X	X		
11	DATA	CPT-FND-(	10	2	1.8					
12										
13	GROUP	SCPT								
14	HEADING	LOCA_ID	SCPT_DPT	SCPT_RES	SCPT_FRE	SCPT_PWI	SCPT_REM			
15	UNIT		m	MPa	MPa	MPa				
16	TYPE	ID	3DP	4DP	4DP	4DP	X			
17	DATA	CPT-FND-(	0	0.06	0	-0.002				
18	DATA	CPT-FND-(	0.01	0.14	0	-0.002				
19	DATA	CPT-FND-(	0.02	0.14	0	-0.002				
20	DATA	CPT-FND-(	0.03	0.24	0	-0.001				

Web Interface: Upload



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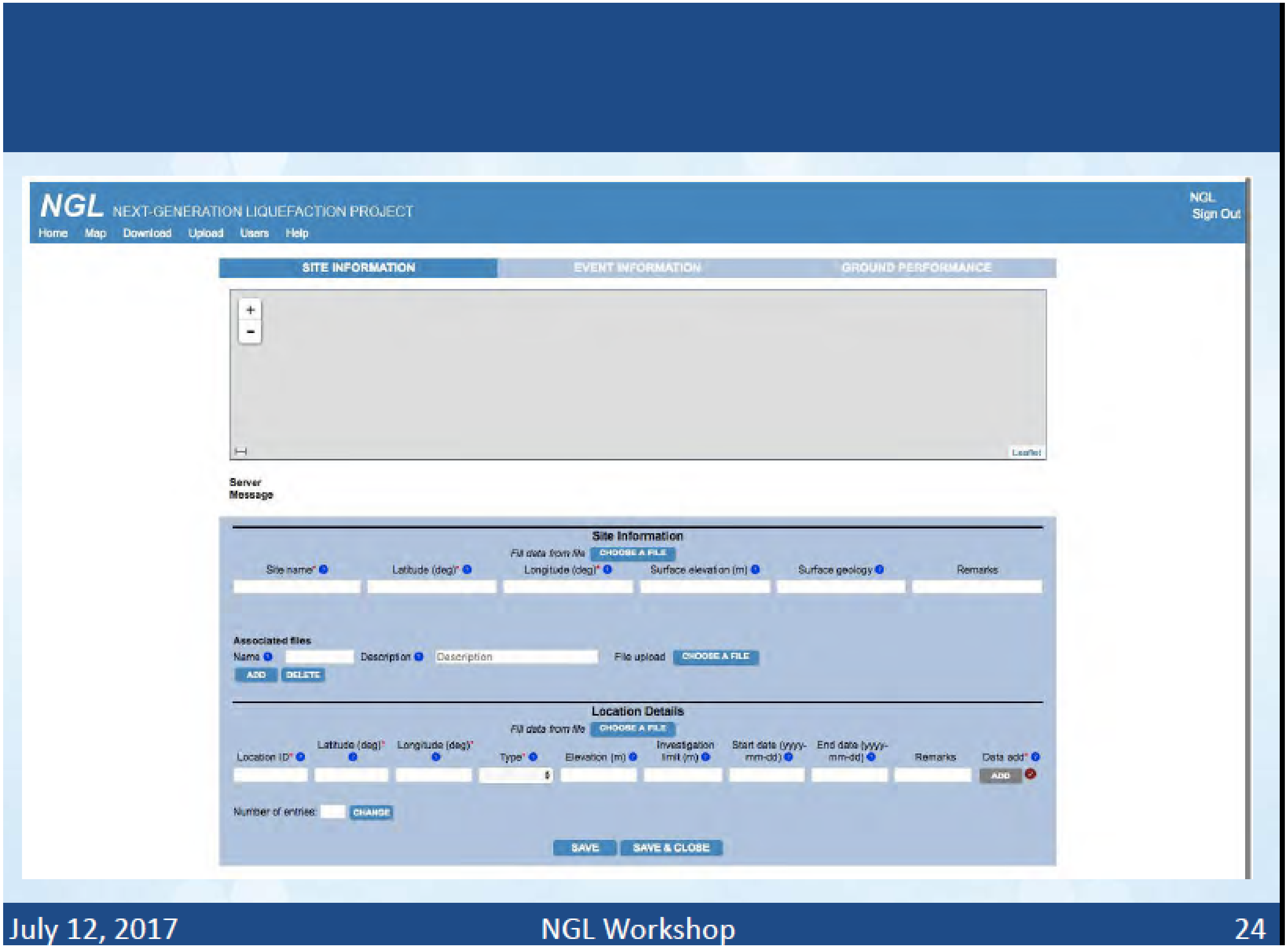
NGL NEXT-GENERATION LIQUEFACTION PROJECT
Home Map Download Upload Users Help
NGL
Sign Out
SITE INFORMATION
EVENT INFORMATION
GROUND PERFORMANCE
Server Message
Site Information
Fill data from file CHOOSE A FILE
Site name*
Latitude (deg)*
Longitude (deg)*
Surface elevation (m)
Surface geology
Remarks
Associated files
Name
Description
File upload CHOOSE A FILE
ADD
DELETE
Location Details
Fill data from file CHOOSE A FILE
Location ID*
Latitude (deg)*
Longitude (deg)*
Type*
Elevation (m)
Investigation limit (m)
Start date (yyyy-mm-dd)
End date (yyyy-mm-dd)
Remarks
Data add*
ADD
Number of entries: CHANGE
SAVE
SAVE & CLOSE
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Integration with DesignSafe

- NGL is currently hosted at uclageo.com, which is a domain I own and maintain.
- We are integrating with DesignSafe to leverage data security, staff support, and the ability for developers to interface with the data in the cloud.
- The amount of data is going to be too large to operate effectively using old-fashioned methods (i.e., download all data and process on a local computer).

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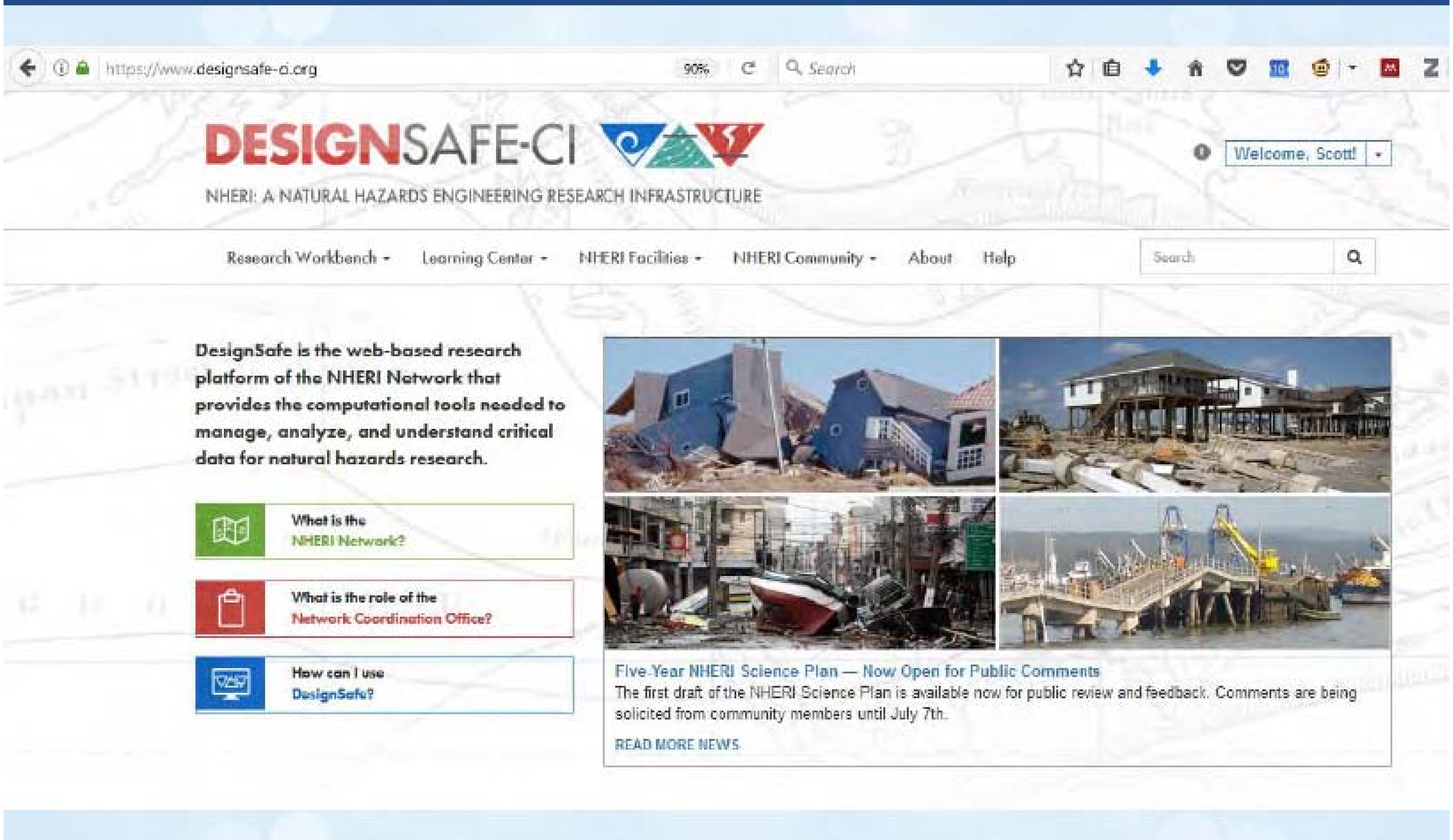
Integration with DesignSafe



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Integration with DesignSafe

- Likely to keep website hosted at UCLA, and mirror database at DesignSafe.
- Could transition web app to DesignSafe too. URL would be ngl.designsafe-ci.org.
- Users will be able to interact with database using MySQL queries in Matlab, or Jupyter notebooks running Python and/or R kernels.

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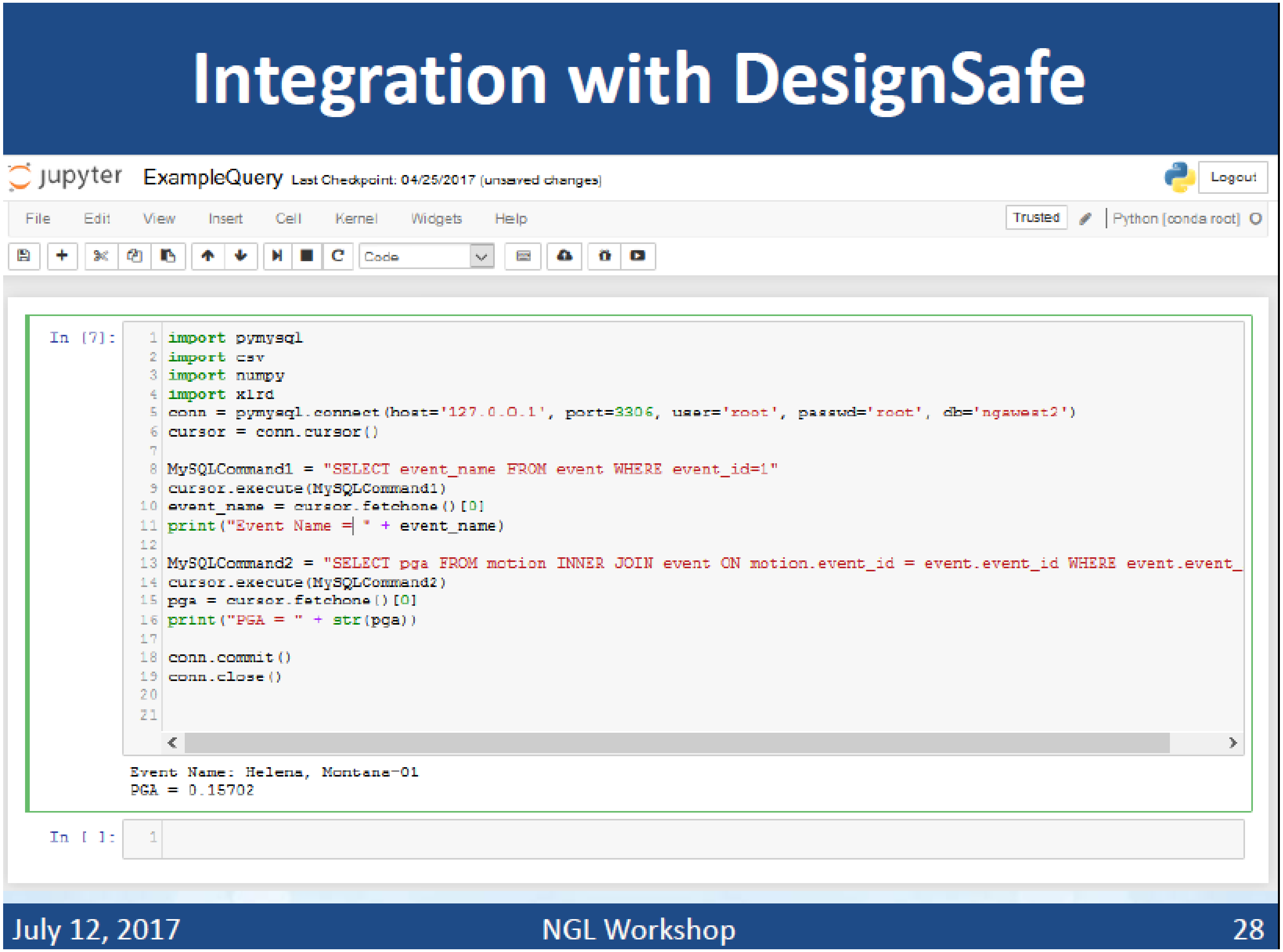
Integration with DesignSafe
jupyter ExampleQuery Last Checkpoint: 04/25/2017 (unsaved changes)
Logout
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python [conda root]
Code
In [7]:
import pymysql
import csv
import numpy
import xlrd
conn = pymysql.connect(host='127.0.0.1', port=3306, user='root', passwd='root', db='ngawest2')
cursor = conn.cursor()
MySQLCommand1 = "SELECT event_name FROM event WHERE event_id=1"
cursor.execute(MySQLCommand1)
event_name = cursor.fetchone()[0]
print("Event Name = " + event_name)
MySQLCommand2 = "SELECT pga FROM motion INNER JOIN event ON motion.event_id = event.event_id WHERE event.event_
cursor.execute(MySQLCommand2)
pga = cursor.fetchone()[0]
print("PGA = " + str(pga))
conn.commit()
conn.close()
Event Name: Helena, Montana-01
PGA = 0.15702
In [ ]:
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Questions / Discussion?

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2 Task 2 Development of Data Quality Indicators / Metrics, QA and Protocols

2.1.1 Development data quality indicators/metrics, quality assurance and database population protocols.

Development of Protocols - The project team has developed protocols for collecting, populating and archiving the database information. This included the numerical measurements as well as the supporting information such geotechnical reports, maps, aerial photography, etc. This was done to ensure consistency of methods amongst the various researchers performing the work.

Development of Data quality indicators - Lateral spread evaluations available in the technical literature have been carried out with differing quality levels in terms of the seismological, geological, geotechnical, topographical and displacement measurement data. For the purposes of this project, we intend to incorporate methods or metrics to quantify the data quality (i.e., data quality indicators) and uncertainty associated with the database measurement as the project progress. As a start, we have categorized the geological and geotechnical data into 3 broad levels of data quality, as discussed below.

The data has been classified into 3 primary levels according to the data quality.

Level 1 data is the highest (best) quality of subsurface data. It consists of site-specific geotechnical data for a mapped surficial geologic unit which generally consists of subsurface data from standard penetration test (SPT) boreholes, or from cone penetration tests (CPT), or from downhole or surface geophysical measurements of shear wave velocity. Also included with this level of data are corresponding soil descriptions, estimates or measurements of fines, plasticity and clay content, mean grain size and depth to water table. The borehole locations must be identified, so that the spatial context of the data is known. Also included with Level 1 data are corresponding soil descriptions, measurements of soil properties (e.g., density, fines and clay content, mean grain size and Atterberg limits) and depth to water table.

Level 2 data consists of geotechnical data that may not meet all of the requirements of Level 1 data but can still be reasonably used to evaluate liquefaction and lateral spread analyses. Level 2 data should have sufficient information to estimate soil types and the percentage and thickness of saturated cohesionless soils (i.e., sands and non-plastic silts) in a particular geologic unit. Level 2 data should also contain sufficient information to make reasonable estimates of the approximate distribution of SPT or CPT penetration resistances and fines content and plasticity for saturated cohesionless soils within the unit

Level 3 data solely consist of surficial geological mapping where the relative liquefaction hazard can be determined using the classification developed by Youd and Perkins (1978).

Level 4 data consist of unknown, unreported, or estimated by others. The quality of such data is unknown.

For all levels of data, surface geological maps, groundwater elevation maps and topographical maps are required to complete liquefaction and lateral spread calculations. An ArcGIS™ compatible database will be structured and populated with Level 1, 2 and 3 data. The case history database will consist of a significant amount of geospatial data. Geospatial data refers to data that contains spatial elements with location characteristics (e.g., maps, photos, satellite images, LiDAR, vector displacement maps etc.

This project does not involve data creation, because only existing case history will be incorporated into the database. However, the standards or methods used in developing the data from the various sources will need to be assessed as part of defining the data quality.

2.1.2 Description of data fields for data quality/reliability indicators

The table below shows the fields for data quality/reliability indicators as well as their respective description and indicator types are discussed under Task 3.

Field Name	Description	Indicator type
BoreDiam_ES	1 = directly from log; 2= from log drilled by same rig and driller; 3= unknown borehole diameter	Completeness
Elev_ES	1 = directly from log; 2 = estimated from nearby logs; 3 = from maps; 4 = unknown	Completeness
GWT_ES	1 = directly from log at least 24 hours after drilling; 2 = from log but date not listed; 3 = from nearby log; 4 = not reported in log	Completeness
HAMMERTYPE_ES	1 = directly from report; 2 = from other reports; 3 = not reported	Completeness
latitude_ES	1 = directly from log; 2 = digitized from maps; 3 = digitized from maps of lesser quality; 4 = perceived from other data	Completeness
longitude_ES		
latitude_positional_error;	NR = not reported; measurements otherwise	Accuracy
longitude_ positional _error	NR = not reported; measurements otherwise	Accuracy
displ_vector_magnitude_ES	0 = directly from map; 1 = measured from map;	Completeness
displ_vector_type	indicates if the vector is on the ground or on a building or bridge, etc.	Completeness
topol_type	indicates if the point is on the ground or on a building or bridge, etc.	Completeness

2.1.3 Quality assurance plan

As a part of the quality assurance plan and to minimize the errors or omissions during the process of digitizing or transcribing data, each data set will be verified by another member of the research team. Every stage of data development or modification to the Microsoft Access database will be logged in three categories: 1) inputting data, 2) modifying data, and 3) verifying data. Attachment shows the corresponding checklists that will be completed for each dataset before merging with the master database as shown in the flowchart on next page. The items in these forms are in the hierarchical order. Hard copies of these forms will be archived by the PI.

2.1.3.1 Organizing and storing data

The work of populating the dataset has been divided amongst the participating universities and researchers. There will be one master database which will be updated on a case-by-case basis, meaning that after the initial required dataset for each case history is gathered and verified, the data will be merged into the master database by the PI. The master database which is not a shared database will be kept by the PI and changes to the database structure can only be made by the PI. After entering data of each case history into the master database, a copy of the newest version of the main database will be archived as backup. Initial data will be stored into draft Microsoft Access and/or Microsoft Excel databases in a shared folder in the cloud-based Box platform hosted by the University of Utah. At this stage, only the PI, co-PIs, and research assistants have permission to view or edit draft databases. Two identical copies of each revision will be stored as backups in two separate storage areas.

The main database is a Microsoft Access database compatible to PEER-NGL project and consequently AGS4 format for most fields. There are also some additional fields required to describe liquefaction-induced lateral spread phenomena. All fields of the main database are described in detail under Task 4.

2.1.3.2 Data sharing and re-use

The final version of main database will be hosted on the PEER server, or on the server of one of the participating universities. A web-based dissemination tool and instructions will be provided to allow querying and downloading from the main database.

3 Task 3 Defining Methods for Quantifying Uncertainty of Key Inputs

3.1.1 Defining methods for quantifying uncertainty of key inputs

Assessment of uncertainty - Part of the data quality assessment deals with defining the uncertainty associated with datasets or individual datum. Various sources of major uncertainty in the database will be identified and quantified as the data are gathered, interpreted and populated into the database. In general. the following types of uncertainties exist in obtaining and evaluating the geotechnical and field data and the subsequent evaluation or modeling of the data: (1) uncertainty due to natural variation of the geotechnical properties within a geological unit or layer. (Even well-characterized geologic units have this type of inherent variability due to natural variations in the soil formation, depositional, post-depositional processes.) (2) Uncertainty arising from the in situ or field measurement method itself (e.g., unknown or unmeasured SPT hammer energy ratio, errors in measuring displacement vectors, uncertainty in elevations or terrain for topographical surveys, etc.) (3) Uncertainty resulting from an unknown processes or mechanisms that affect lateral spread displacement which are not fully described or addressed in current field evaluations, or the development of empirical, analytical and models (i.e., model uncertainty).

Uncertainty related to item (1) above is referred to as **aleatory or statistical uncertainty**. Uncertainty associated with items (2) and (3) is referred to **as epistemic or systematic uncertainties**. Uncertainty from items (1) and (2) will be quantified or estimated during the development of the database. Uncertainty from item (3) will be discussed and summarized by this study for future reference and for potential predictive model development and or improvement.

3.1.1 Sources of error

The first step in quantifying data quality is to determine sources of error and the approaches to minimize it if possible. Below is a discussion of potential sources of error related to the datasets used in this project:

If the original data is not electronically recorded, it needs to be digitized and it consequently increases the uncertainty with the data. Since most common methods of digitizing involve the interpretation of geographic features via the human hand, there are several types of errors that can occur during capturing the data. The type of error that occurs when the feature is not captured properly is called positional error, as opposed to attribute errors where information about the feature capture is inaccurate or false. Different types of digitizing are listed below:

- Manual digitizing which involves tracing geographic features from an external digitizing tablet using a puck (a type of mouse specialized for tracing and capturing geographic features from the tablet)
- Heads up digitizing (also referred to as on-screen digitizing) that is the method of tracing geographic features from another dataset (usually an aerial, satellite image, or scanned image of a map) directly on the computer screen\
- Automated digitizing which involves using image processing software that contains pattern recognition technology to generated vectors.

The data sets of our database are mostly of the non-electronic type and have been digitized by operators. As a part of the quality assurance plan, in order to minimize the error during the process of digitizing, each digitized data set was verified by another member of the group.

3.1.2 Data quality/reliability indicator types

Quality of the data is assessed using four types of indicators listed below:

- Authority: source of geospatial data to some extent indicates reliability as described by Xia

(2012). For instance, the SPT data obtained by a well-known company/department for a high importance structure such as a hospital is less likely to be inaccurate than the SPT data obtained by a typical engineering firm for a residential building,

- Accuracy: referring to the level that data is accurately represented such as the minimum and maximum positional errors in extracting displacement vectors from aerial photographs,
- Consistency and validity (Xia 2012): the question needs to be asked in this context is that is this the only dataset available for this site or are there analogous datasets from other sources that could validate it? Although not having a validation dataset does not invalidate existing dataset, consistency and validity with other datasets could be used as a data reliability indicator. As a subtopic of consistency and validity, spatial distribution quality using triangulation technique could be assessed. Data points with higher number of adjacent supports could be more reliable since they can be validated to some extent by the adjacent data. For instance, at a small zone where there are 12 adjacent displacement vectors, most of them pointing toward south-west and only one of them has the opposite direction; it is likely that, that one vector with opposite direction is false
- Completeness: referring to missing key information such as hammer energy ratio or ground water level in SPT borehole logs.

4 Task 4 Development and Structuring of Database

4.1.1 Development and structuring of database

Development and Database structure – Table 1 below lists the types of information that will be collected and archived. However, this table is preliminary in nature and its contents will be added to or modified pending initial project deliberations.

Table 1 – Case History Information

Seismological Factors	Earthquake Name and Year
	Earthquake Magnitude, Mw
	Location
	Source Distance Measures, Rrup, Rjb, etc.
	Peak Ground Acceleration
	Other measures of intensity (MMI, spectral accelerations, etc.
	Duration
	Nearby accelerogram (if available)
Geological Factors	Geological unit and type of sediments
	Age of sediments
	Depth to groundwater
	Geological map (if available)
Topographical Factors	Topographical survey or Topographical map or Digital Elevation model
Geotechnical / Soil Factors	SPT borehole logs
	Sampler type, dimensions, liner
	Interpreted soil profiles
	Hammer type
	Hammer Energy Ratio
	Type of drill rig
	Method of drilling
	Location of borehole
	Depth of borehole
	Date of drilling
	Driller
	SPT blow counts
	Soil Description by interval or layer
	Fines content by interval or layer
	Plastic Limit by interval or layer
	Liquid Limit by interval or layer
	Mean grain size by interval or layer
	CPT logs (as available)
	Vs logs (as available)
Damage / Displacement measurements	Surface damage photos
	Aerial photography of lateral spread area
	Horizontal displacement vector maps or point estimates (required)
	Vertical settlement vector maps or point estimates, if available
	Source of displacement estimates (e.g., ground survey, crack width integration, aerial photography interpretation, LIDAR, SAR, INSAR, etc.

4.1.2 Structure of database

Following terms are used in the explanation:

- *Table*: A table is a database object that will be used to store data about a particular subject, such as CPT data logs or displacement vectors. A table consists of records and fields.
- *Record*: each record contains data about one instance of the table subject, such as a particular CPT outputs at a certain depth. A record is also commonly called a row or an instance.
- *Field*: Each field contains data about one aspect of the table subject, such as N_{60} or depth. A field is also commonly called a column or an attribute.

PART I: Lateral spread tables		
Table LSDV: Lateral Spread Displacement Vectors		
Field identifier	Field name	Description
LSDV_ID	Unique record identifier	
LOCA_ID	LOCA_ID associated with first point of its site	There are two points for each lateral displacement site
LSDV_X1	Local x coordinate of starting point of displacement vector	
LSDV_Y1	Local y coordinate of starting point of displacement vector	
LSDV_X2	Local x coordinate of ending point of displacement vector	
LSDV_Y2	Local y coordinate of ending point of displacement vector	
LSDV_original_unit	Original units of local coordinates	
LSDV_S	Amount of settlement	
LSDV_S_original_unit	Original units of settlement	
LSDV_REM	Remarks	
Table LSTP: Lateral Spread ToPography		
Field identifier	Field name	Description
LSTP_ID	Unique record identifier	
LOCA_ID	LOCA_ID associated with first point of its site	There are two points for each lateral displacement site

LSTP_LX	Local X coordinate	
LSTP_LY	Local Y coordinate	
LSTP_LZ	Local Z coordinate	
Table LSCC: Lateral Spread Coordinates Conversion		
Field identifier	Field name	Description
LSCC_ID	Unique record identifier	
LOCA_ID	Associated LOCA_ID that needs conversion	
LSCC_LAT	Latitude of location	In degrees
LSCC_LON	Longitude of location	In degrees
LSCC_LX	Equivalent local x coordinate	
LSCC_LY	Equivalent local y coordinate	
LSCC_unit	Local units	
Table ISPT: Standard Penetration Test Results		
Field identifier	Field name	Description
ISPT_RECORD_ID	Unique record identifier	
LOCA_ID	Location identifier	NGL database compatible
ISPT_LX	Local x coordinate	
ISPT_LY	Local y coordinate	
ISPT_GCA	Is the global coordinate available?	yes / no
ISPT_TOP	Depth to top of test	NGL database compatible
ISPT_TOP_original_unit	Original units of depth to top of test	
ISPT_NVAL	SPT 'N' value	NGL database compatible
ISPT_Rod_Length	Rod length	

ISPT_Rod_Length_original_unit	Rod length original units	
ISPT_Hammer_energy	Hammer energy	In percentage
ISPT_Borehole_diameter	Borehole diameter	
ISPT_Borehole_diameter_original_unit	Borehole diameter original units	
ISPT_Liner	Liner	Yes | No | Unknown
ISPT_REM	Remarks	NGL database compatible
ISPT_SOILTYPE	Soil type	
ISPT_DRYUNIT	Dry unit	
ISPT_WETUNIT	Wet unit	
ISPT_RELDENSITY	Relative density	
ISPT_SPGRAVITY	Relative density	
ISPT_FINES	Fines content	
ISPT_CLAY	Clay content	
Table SCPT: Static Cone Penetration Tests		
Field identifier	Field name	Description
SCPT_RECORD_ID	Unique record identifier	
LOCA_ID	Location identifier	NGL database compatible
SCPT_LX	Local x coordinate	
SCPT_LY	Local y coordinate	
SCPT_GCA	Is the global coordinate available?	yes / no
SCPT_DPTH	Depth of result	NGL database compatible
SCPT_DPTH_original_unit	Original units of depth of result	
SCPT_RES	Cone resistance	NGL database compatible
SCPT_RES_original_unit	Original units of cone resistance	
SCPT_FRES	Local unit side friction resistance	NGL database compatible
SCPT_FRES_original_unit	Original units of friction resistance	
SCPT_PWP2	Shoulder porewater pressure	NGL database compatible

SCPT_PWP2_original_unit	Original units of porewater pressure	
SCPT_REM	Remarks	NGL database compatible
Table FlatFiles: Flat Files Details		
Field identifier	Field name	Description
ff_id	Unique record identifier	
ff_name	Flat file name	Maximum 255 characters
ff_type	File extension	
ff_description	Additional description	
PART II: NGL compatible tables		
Table DETL: Stratum Detail Descriptions		
Field identifier	Field name	Description
DETL_RECORD_ID	Unique record identifier	Added to NGL database
LOCA_ID	Location Identifier	
DETL_DESC	Detail description	
Table GEOL: Field Geological Descriptions		
Field identifier	Field name	Description
LOCA_ID	Location identifier	
GEOL_TOP	Depth to the top of stratum	
GEOL_BASE	Depth to the base of description	
GEOL_GEOL	Geology code	
GEOL_COL		Not defined in AGS4 format.
GEOL_DESC	General description of stratum	
Table GRAT: Particle Size Distribution Analysis - Data		
Field identifier	Field name	Description
GRAT_RECORD_ID	Unique record identifier	Added to NGL database
LOCA_ID	Location identifier	
SAMP_ID	Sample unique global identifier	
SPEC_REF	Specimen reference	

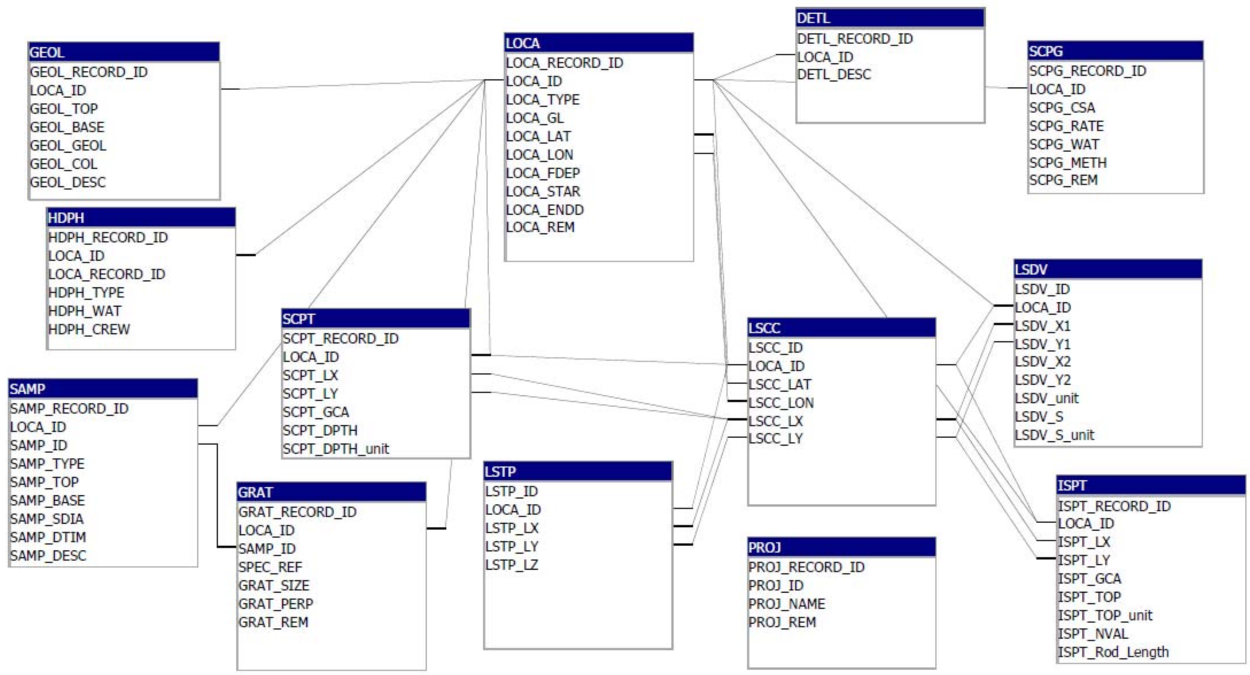
GRAT_SIZE	Sieve or particle size	
GRAT_PERP	Percentage passing/finer than GRAT_SIZE	
GRAT_REM	Remarks	
Table HDPH: Depth Related Exploratory Hole Information		
Field identifier	Field name	Description
HDPH_RECORD_ID	Unique record identifier	Added to NGL database
LOCA_ID	Location identifier	
LOCA_RECORD_ID	Location unique record identifier	
HDPH_TYPE	Type of depth related information	
HDPH_WAT	Water table level	Not defined in AGS4 format.
HDPH_CREW	Name of rig/drill crew	
HDPH_REM	Remarks	
Table LOCA: Location Details		
Field identifier	Field name	Description
LOCA_RECORD_ID	Unique record identifier	Added to NGL database
LOCA_ID	Location identifier	
LOCA_TYPE	Type of activity	
LOCA_GL	Ground level relative to datum of location or start of traverse	
LOCA_LAT	Latitude of location or start of traverse	
LOCA_LON	Longitude of location or start of traverse	
LOCA_FDEP	Final depth	
LOCA_STAR	Date of start of activity	
LOCA_ENDD	End date of activity	
LOCA_REM	Remarks	
Table PROJ: Project information		
Field identifier	Field name	Description
PROJ_RECORD_ID	Unique record identifier	Added to NGL database
PROJ_ID	Project identifier	
PROJ_NAME	Project title	
PROJ_REM	Remarks	

Table SAMP: Sample information		
Field identifier	Field name	Description
SAMP_RECORD_ID	Unique record identifier	Added to NGL database
LOCA_ID	Location identifier	
SAMP_ID	Sample identifier	
SAMP_TYPE	Sample type	
SAMP_TOP	Depth to top of sample	
SAMP_BASE	Depth to base of sample	
SAMP_SDIA	Sample diameter	
SAMP_DTIM	Date and time sample taken	
SAMP_DESC	Sample/specimen description	
SAMP_REM	Remarks	

Table SCPG: Static cone penetration test		
Field identifier	Field name	Description
SCPG_RECORD_ID	Unique record identifier	Added to NGL database
LOCA_ID	Location identifier	
SCPG_CSA	Surface area of cone tip	
SCPG_RATE	Nominal rate of penetration of the cone	
SCPG_WAT	Groundwater level at time of test	
SCPG_METH	Standard followed for testing	
SCPG_REM	Remarks	

4.1.3 Relationship between fields and tables

The related fields and tables in the database are shown graphically below.



5 Task 5 Selection of Case Histories

5.1.1 Selection of case histories

Selection of case histories - The initial list of earthquakes that will be reviewed is found in Table 2. The potential number of case histories may increase or decrease as the project progresses pending data availability and data quality assessment.

Table 2 – List of Case Histories for Database

1906 San Francisco, California Earthquake	Coyote Creek Bridge near Milpitas California
	Mission Creek Zone in San Francisco
	Salinas River Bridge, Salinas California
	South of Market Street Zone in San Francisco
1964 Alaska Earthquake	Bridges 141.1, 147.4, 147.5, 148.3 on Matanuska River, Alaska
	Bridges 63.0, 63.5 on Portage Creek Alaska
	Highway Bridge 629 Placer River, Alaska
	Bridge 605A, Snow River, Alaska
	Bridges, 3.0, 3.2, 3.3, Resurrection River, Alaska
1964 Niigata, Japan Earthquake	Numerous lateral spreads within Niigata City
1971 San Fernando Earthquake	Jensen Filtration Plant, San Fernando, California
	Juvenile Hall, San Fernando, California
1979 Imperial Valley Earthquake	Heber Road near El Centro, California
	River Park near Brawley, California
1983 Borah Peak, Idaho Earthquake	Whiskey Springs near Mackay, Idaho
	Pence Ranch near Mackay, Idaho
1983 Nihonkai-Chubu, Japan Earthquake	Numerous lateral spreads within Noshiro City
1987 Superstition Hills, California Earthquake	Wildlife Instrumentation Array near Brawley, California
1989 Loma Prieta, California Earthquake	Pajaro River
	Moss Landing, Monterey
	Marina District, San Francisco
1990 Luzon Philippines Earthquake	Dagupan City
1991 Costa Rica Earthquake	Railroad and Highway Bridge sites
1994 Northridge, California Earthquake	King Harbor, Redondo Beach
	Balboa Blvd., San Fernando Valley
	Malden Street, San Fernando Valley
	Wynne Avenue, San Fernando Valley
	Potrero Canyon, San Fernando Valley
1995 Kobe, Japan Earthquake	Lateral Spreads on Port Island
	Lateral Spreads on Roko Island
1999 Kocaeli, Turkey Earthquake	Cark Canal Site
	Yakin Street Site

	Cumhuriyet Avenue Site
	Sapanca Hotel Site
	Police Station Site, East Izmit Bay
	Soccer Field Site. East Izmit Bay
	Degirmendere Nose Site
	Yalova Harbor Site
1999 Chi-Chi, Taiwan Earthquake	Wufeng Site C
	Wufeng Site C1
	Wufeng Site B
	Wufeng Site M
	Nantou Site N
	Leuw Mei Bridge
2010 Maule, Chile Earthquake	Port Coronel
	Valparaiso
	Llacolen Bridge
	Juan Pablo II Bridge, Concepcion
	La Mochita Bridge, Concepcion
	Tubul Bridge, Tubul
	Mataquito Bridge, Iloca
2011 Tohoku, Japan Earthquake	Several lateral spreads
2010 Darfield, New Zealand Earthquake	Several lateral spreads in and around Christchurch
2011 Christchurch, New Zealand Earthquake	Several lateral spreads in and around Christchurch

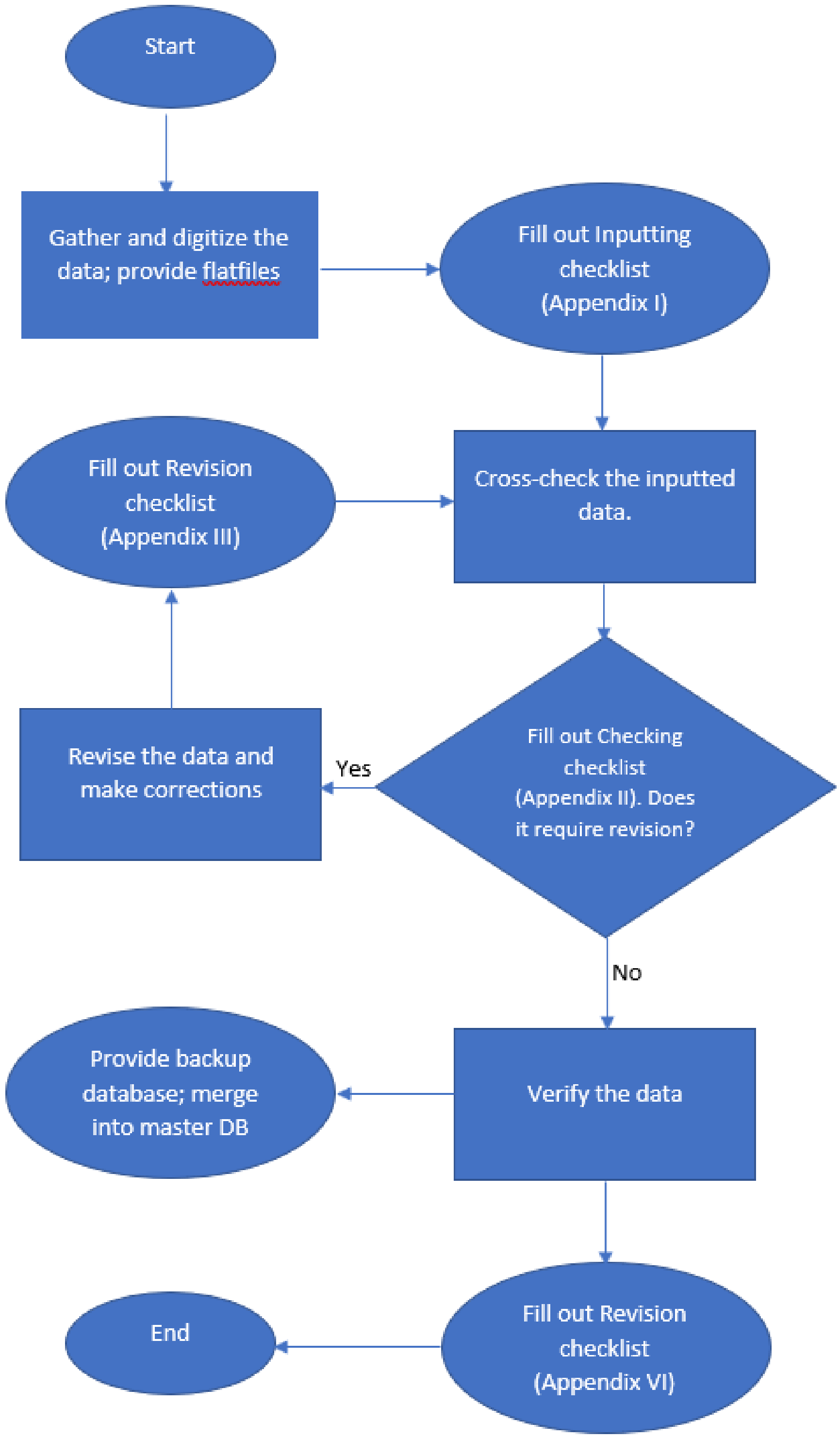
6 Task 6 Obtaining and Screening of Case History Information

6.1.1 Obtaining and screening of case history information

Obtaining and Screening of Case Histories - The information listed in Table 1 with gathered for the potential case histories listed in Table 2. The case history information will be screened and prioritize for entry into the dataset using the data quality metrics developed in Task 2.

The data in this project will be captured from various sources including, but not limited to, hard copies of horizontal displacement vector, surficial geological and topographical maps, borehole logs, and corresponding laboratory and other data available in published journal papers, workshop reports and conference proceedings. Hard copies have to be digitized and stored in digital formats. Displacement vectors, CPT and SPT borehole logs, topographical data will be stored in Microsoft Access database as numerical measurements. On the other hand, pdf files of the raw data from which the digital data are captured as well as other supporting information such as geotechnical reports, maps, aerial photography, and etc. will be provided to the end-user as flatfiles. File names will use a standardized format that includes the case name, type of the data, and data unique code. Flatfiles will also be listed in the designated table in database.

6.1.2 Data collection flowchart



6.1.3 Data obtained to date

Table below shows the amount of data gathered so far:

Case history	Site	Displacement vectors	Boreholes	Subsurface data (row)	Topology (points)
1964 Niigata	F10	179	24	359	429
	G10	585	68	1574	256
	H9	112	4	92	235
	J9	442	45	192	297
	K8	285	4	62	302
	Total	1603	145	2279	1519
1983 Noshiro	South	266	128	462	176
	North	147	59	848	348
	Total	413	187	1310	524
1971 San Fernando	Jensen water plant	69	33	494	flatfile
	Juvenile hall	79	6	121	flatfile
	Total	148	39	615	-
1964 Alaska	Total	14	20	411	flatfile
1979 Imperial valley	Heber road	in progress	3 (in progress)	54 (in progress)	in progress
	River park site	in progress	4	62	in progress
1983 Borah peak, Idaho	documents gathered, ready to digitize, in progress				
1906 San Francisco	documents gathered, ready to digitize, in progress				

7 References

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Zhang, G., Robertson, P.K., Brachman, R.W.I. (2004). “Estimating Liquefaction-Induced Lateral Spread Displacements Using the Standard Penetration Test or Cone Penetration Test,” Journal of Geotechnical and Geoenvironmental Engineering, Vol. 130, No. 8, August 2004.

Attachment 1 - Progress Reports

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency: Utah Department of Transportation

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project #	Transportation Pooled Fund Program - Report Period
TPF-5(350)	_ Quarter 1 (January 1 – March 31, 2016) _ Quarter 2 (April 1 – June 30, 2016) **X Quarter 3 (July 1 – September 30, 2016)** _ Quarter 4 (October 1 – December 31, 2016)

Project Title: Development of Next Generation Liquefaction (NGL) Database for Liquefaction-Induced Lateral Spread		
Name of Project Manager(s): David Stevens	**Phone Number:** 801-589-8340	**E-Mail** davidstevens@utah.gov
Lead Agency Project ID: FINET 42080, ePM PIN 15017 UDOT PIC No. PL05.350	**Other Project ID (i.e., contract** UDOT Contract No. 17-8236	**Project Start Date:** September 8, 2016
Original Project End Date: March 31, 2019	**Current Project End Date:** March 31, 2019	**Number of Extensions:**

Project schedule status:

X On schedule   _ On revised schedule   _ Ahead of schedule   _ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$110,354.93 (current contract) $120,000.00 (total TPF commitments)	$4100	4%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
This Quarter = 0% Total Project = 0%	$4100	3%

Project Description:

This research will be conducted in conjunction with the Pacific Earthquake Engineering Research (PEER) Center and various state DOTs via a pool-fund study managed by the Utah Department of Transportation (UDOT). The Mountain Plains Consortium (MPC) is also providing funding for certain aspects of this study, under separate contract with the University of Utah. The research topic addresses the need to improve empirical, semi-empirical, analytical and numerical methods to estimate the amount of permanent ground displacement associated with liquefaction-induced lateral spread resulting from several major earthquakes. This scope of work addresses the development of a lateral spread community database as part of the PEER Next Generation Liquefaction Project (http://peer.berkeley.edu/lifelines/projects/ngl/). It does not address predictive model development for lateral spread evaluations, which is future effort planned by PEER, but not included in this work plan.

The primary outcome of this research is a vetted and community database of seismic, topographical, geotechnical and horizontal displacement measurements pertaining to case histories of liquefaction-induced lateral spread for further research and model development by other researchers and investigators under the auspices of the PEER Center (http://peer.berkeley.edu/). Secondary outcomes will be web host and publishing required to house and disseminate this database and its supporting information.

Phase I Tasks include (funded):

(1) Kickoff meeting and procurement of software
(2) Development of data quality indicators/metrics, quality assurance and database population protocols
(3) Defining methods for quantifying uncertainty of key inputs
(4) Development and structuring of database
(5) Selection of case histories
(6) Obtaining and screening of case history information
(7) Population of case history database
(8) Phase I Reporting
(9) Database dissemination

Phase II Tasks include (not yet funded):

(10) Review and Development of Screening Criteria for Lateral Spread Potential
(11) Phase II Reporting

The principal investigators for this study will be Drs. Steven Bartlett (U. of Utah), Steven Kramer (U. of Washington and PEER Research Executive Committee Member), Kevin Franke (Brigham Young University) and Daniel Gillins (Oregon State University). The technical advisory committee (TAC) for the study currently includes representatives from Utah, California, Oregon, and Washington State DOTs. The MPC is providing additional funding for the study.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Contract – UDOT and the rest of the TAC reviewed the draft contract scope. The scope was finalized, and the research prime contract with UDOT and the University of Utah was executed. (subcontracts set up as well??)

TAC meetings – A pre-contract web conference was held on August 15 for the TAC and the research team to discuss the project scope together.

Task 1 – Dr. Bartlett and the research team began working on the initial tasks of the project. They contacted Jonathan Stewart (UCLA) to learn more about the online platform that UCLA has been working on to house earthquake ground failure databases.

Task 1 – U of U, BYU and Oregon State have meet to coordinate the work and discuss the subcontracts required amongst the various institutions.

Task 4 – U. of Utah has received the UCLA liquefaction triggering database structure and is structuring an M.S. Access database with this structure.

Anticipated work next quarter:

(revise as needed)

Task 1 – The principal investigators of the study will meet for planning purposes for Tasks 2 and 3. Prior to the kickoff meeting, the PIs will also test drive the UCLA platform/database and then make recommendations about implementation at the kickoff meeting.
Task 2 – Database quality indicator system will be established during this quarter.
Task 4 – Database development will continue by adding additional information and the supporting fields to the database structure required for lateral spread evaluations.

TAC meetings – None planned this quarter.

Contract – UDOT will work with the TAC members to transfer their remaining funding commitments to Utah. UDOT will also coordinate with representatives of Questar Gas Company regarding their potential funding contribution to the study.

Significant Results:

Database structure has started.
Initial coordination meetings held.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency: Utah Department of Transportation

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Transportation Pooled Fund Program Project #	**Transportation Pooled Fund Program - Report Period**
TPF-5(350)	_ Quarter 1 (January 1 – March 31, 2016) _ Quarter 2 (April 1 – June 30, 2016) _ Quarter 3 (July 1 – September 30, 2016) **X Quarter 4 (October 1 – December 31, 2016)**

Project Title:
Development of Next Generation Liquefaction (NGL) Database for Liquefaction-Induced Lateral Spread

Name of Project Manager(s): David Stevens	**Phone Number:** 801-589-8340	**E-Mail** davidstevens@utah.gov
Lead Agency Project ID: FINET 42080, ePM PIN 15017 UDOT PIC No. PL05.350	**Other Project ID (i.e., contract** UDOT Contract No. 17-8236	**Project Start Date:** September 8, 2016
Original Project End Date: March 31, 2019	**Current Project End Date:** March 31, 2019	**Number of Extensions:**

Project schedule status:

X On schedule _ On revised schedule _ Ahead of schedule _ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$110,354.93 (current contract) $120,000.00 (total TPF commitments)	$10,020	5%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
This Quarter = 6% Total Project = 10%	$5,920	10%

Project Description:

This research will be conducted in conjunction with the Pacific Earthquake Engineering Research (PEER) Center and various state DOTs via a pool-fund study managed by the Utah Department of Transportation (UDOT). The Mountain Plains Consortium (MPC) is also providing funding for certain aspects of this study, under separate contract with the University of Utah. The research topic addresses the need to improve empirical, semi-empirical, analytical and numerical methods to estimate the amount of permanent ground displacement associated with liquefaction-induced lateral spread resulting from several major earthquakes. This scope of work addresses the development of a lateral spread community database as part of the PEER Next Generation Liquefaction Project (http://peer.berkeley.edu/lifelines/projects/ngl/). It does not address predictive model development for lateral spread evaluations, which is future effort planned by PEER, but not included in this work plan.

The primary outcome of this research is a vetted and community database of seismic, topographical, geotechnical and horizontal displacement measurements pertaining to case histories of liquefaction-induced lateral spread for further research and model development by other researchers and investigators under the auspices of the PEER Center (http://peer.berkeley.edu/). Secondary outcomes will be web host and publishing required to house and disseminate this database and its supporting information.

Phase I Tasks include (funded):

(1) Kickoff meeting and procurement of software
(2) Development of data quality indicators/metrics, quality assurance and database population protocols
(3) Defining methods for quantifying uncertainty of key inputs
(4) Development and structuring of database
(5) Selection of case histories
(6) Obtaining and screening of case history information
(7) Population of case history database
(8) Phase I Reporting
(9) Database dissemination

Phase II Tasks include (not yet funded):

(10) Review and Development of Screening Criteria for Lateral Spread Potential
(11) Phase II Reporting

The principal investigators for this study will be Drs. Steven Bartlett (U. of Utah), Steven Kramer (U. of Washington and PEER Research Executive Committee Member), Kevin Franke (Brigham Young University) and Daniel Gillins (Oregon State University). The technical advisory committee (TAC) for the study currently includes representatives from Utah, California, Oregon, and Washington State DOTs. The MPC is providing additional funding for the study.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Task 1 – Scope of work has been negotiated with BYU. OSU (Dan Gillins) has left the university, so OSU will not be participating in the study. Dan Gillins, now with NOAA will continue as a consultant and PI of the study. OSU student support will be shifted to BYU and U of U.
Task 2 – In progress, but not finalized.
Task 3 – In progress
Task 4 – U. of Utah has structured the database.
Task 5 – No work yet.
Task 6 – Work on the Niigata, Japan case histories in progress
Task 7 – Started

Task 8 – No work yet.
Task 9 – No work yet.

TAC meetings – None were held this quarter.

Contract – No changes were made.

Anticipated work next quarter:

Task 1 – Finalize SOW and contract with U. of Washington
Task 2 – Database quality indicator system will be established during this quarter.
Task 3 – Continue to inventory methods of quantifying uncertainty and data quality
Task 4 – Seek review from BYU and U.W. regarding developed structure
Task 5 – Prioritization of case histories for database entry
Task 6 – Involve other universities in case history screening
Task 7 – Continued population of data set
Task 8 – None.
Task 9 – None.

TAC meetings – None are planned this quarter.

Contract – UDOT will work with the TAC members to transfer their remaining funding commitments to Utah. UDOT will also coordinate with representatives of Questar Gas Company regarding their potential funding contribution to the study.

Significant Results:

Include a brief technical update for this quarter:

Database structure completed. Population of database with Niigata, Japan case history is underway. We will use this as an example to check for completeness of the database and make modification, as we progress.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

None yet.

TRANSPORTATION POOLED FUND PROGRAM QUARTERLY PROGRESS REPORT

Lead Agency: Utah Department of Transportation

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Transportation Pooled Fund Program Project # **TPF-5(350)**		**Transportation Pooled Fund Program - Report Period** **X Quarter 1 (January 1 – March 31, 2017)** _ Quarter 2 (April 1 – June 30, 2017) _ Quarter 3 (July 1 – September 30, 2017) _ Quarter 4 (October 1 – December 31, 2017)
Project Title: Development of Next Generation Liquefaction (NGL) Database for Liquefaction-Induced Lateral Spread		
Name of Project Manager(s): David Stevens	**Phone Number:** 801-589-8340	**E-Mail** davidstevens@utah.gov
Lead Agency Project ID: FINET 42080, ePM PIN 15017 UDOT PIC No. PL05.350	**Other Project ID (i.e., contract** UDOT Contract No. 17-8236	**Project Start Date:** September 8, 2016
Original Project End Date: March 31, 2019	**Current Project End Date:** March 31, 2019 (31 months)	**Number of Extensions:**

Project schedule status:

X On schedule _ On revised schedule _ Ahead of schedule _ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$110,354.93 (current contract) $120,000.00 (total TPF commitments)	$0 (paid by UDOT) $16,750 (at the U. of Utah)	15%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
This Quarter = 5% Total Project = 15%	$6730	25%

Project Description:

This research will be conducted in conjunction with the Pacific Earthquake Engineering Research (PEER) Center and various state DOTs via a pool-fund study managed by the Utah Department of Transportation (UDOT). The Mountain Plains Consortium (MPC) is also providing funding for certain aspects of this study, under separate contract with the University of Utah. The research topic addresses the need to improve empirical, semi-empirical, analytical and numerical methods to estimate the amount of permanent ground displacement associated with liquefaction-induced lateral spread resulting from several major earthquakes. This scope of work addresses the development of a lateral spread community database as part of the PEER Next Generation Liquefaction Project (http://peer.berkeley.edu/lifelines/projects/ngl/). It does not address predictive model development for lateral spread evaluations, which is future effort planned by PEER, but not included in this work plan.

The primary outcome of this research is a vetted and community database of seismic, topographical, geotechnical and horizontal displacement measurements pertaining to case histories of liquefaction-induced lateral spread for further research and model development by other researchers and investigators under the auspices of the PEER Center (http://peer.berkeley.edu/). Secondary outcomes will be web host and publishing required to house and disseminate this database and its supporting information.

Phase I Tasks include (funded):

(1) Kickoff meeting and procurement of software
(2) Development of data quality indicators/metrics, quality assurance and database population protocols
(3) Defining methods for quantifying uncertainty of key inputs
(4) Development and structuring of database
(5) Selection of case histories
(6) Obtaining and screening of case history information
(7) Population of case history database
(8) Phase I Reporting
(9) Database dissemination

Phase II Tasks include (not yet funded):

(10) Review and Development of Screening Criteria for Lateral Spread Potential
(11) Phase II Reporting

The principal investigators for this study will be Drs. Steven Bartlett (U. of Utah), Steven Kramer (U. of Washington and PEER Research Executive Committee Member), Kevin Franke (Brigham Young University) and Daniel Gillins (NOAA and consultant). The technical advisory committee (TAC) for the study currently includes representatives from Utah, California, Oregon, and Washington State DOTs. The MPC is providing additional funding for the study.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Task 1 – Working meetings held. Final contract documents submitted by BYU.
Task 2 – Completed. Will be reviewed by BYU during next quarter.
Task 3 – In progress. Spatial uncertainty for Niigata Japan case histories completed
Task 4 – In progress.
Task 5 – In progress.
Task 6 – Completed for Niigata japan
Task 7 – Continuing
Task 8 – Not started
Task 9 – Not started

TAC meetings – None were held this quarter.

Contract – No changes were made.

Anticipated work next quarter:

Task 1 – Finalize SOW and contract with U. of Washington.
Task 2 – Database quality indicator system will be reviewed by BYU.
Task 3 – Continue to inventory methods of quantifying uncertainty and data quality.
Task 4 – Finalize database structure pending BYU review.
Task 5 – Prioritization of case histories for database entry.
Task 6 – Finalize database list
Task 7 – Continue population of data set.
Task 8 – None.
Task 9 – None.

TAC meetings – None are planned this quarter.

Contract – UDOT will work with the TAC members to transfer their remaining funding commitments to Utah. UDOT will also coordinate with representatives of Questar Gas Company regarding their funding contribution to the study.

Significant Results:

Database structure completed and populated with Niigata, Japan. Data quality indictor system finalized.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.

Potential Implementation:

None yet.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency: Utah Department of Transportation

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Transportation Pooled Fund Program Project #		**Transportation Pooled Fund Program - Report Period**
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Project Title: Development of Next Generation Liquefaction (NGL) Database for Liquefaction-Induced Lateral Spread		
Name of Project Manager(s): David Stevens	**Phone Number:** 801-589-8340	**E-Mail** davidstevens@utah.gov
Lead Agency Project ID: FINET 42080, ePM PIN 15017 UDOT PIC No. PL05.350	**Other Project ID (i.e., contract** UDOT Contract No. 17-8236	**Project Start Date:** September 8, 2016
Original Project End Date: March 31, 2019	**Current Project End Date:** March 31, 2019 (31 months)	**Number of Extensions:**

Project schedule status:

X On schedule _ On revised schedule _ Ahead of schedule _ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$110,354.93 (current contract) $140,000.00 (total TPF commitments)	$20,000.00 (paid by UDOT) $16,750.00 (at the U. of Utah)	18%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
This Quarter = 18% (paid by UDOT) This Quarter = 15% (at the U. of Utah) Total Project = 18% (paid by UDOT) Total Project = 15% (at the U. of Utah)	$20,000.00 (paid by UDOT) $0 (at the U. of Utah) (Funding for U of U student from MPC funds)	33%

Project Description:

This research will be conducted in conjunction with the Pacific Earthquake Engineering Research (PEER) Center and various state DOTs via a pool-fund study managed by the Utah Department of Transportation (UDOT). The Mountain Plains Consortium (MPC) is also providing funding for certain aspects of this study, under separate contract with the University of Utah. The research topic addresses the need to improve empirical, semi-empirical, analytical and numerical methods to estimate the amount of permanent ground displacement associated with liquefaction-induced lateral spread resulting from several major earthquakes. This scope of work addresses the development of a lateral spread community database as part of the PEER Next Generation Liquefaction Project (http://peer.berkeley.edu/lifelines/projects/ngl/). It does not address predictive model development for lateral spread evaluations, which is future effort planned by PEER, but not included in this work plan.

The primary outcome of this research is a vetted and community database of seismic, topographical, geotechnical and horizontal displacement measurements pertaining to case histories of liquefaction-induced lateral spread for further research and model development by other researchers and investigators under the auspices of the PEER Center (http://peer.berkeley.edu/). Secondary outcomes will be web host and publishing required to house and disseminate this database and its supporting information.

Phase I Tasks include (funded):

(1) Kickoff meeting and procurement of software
(2) Development of data quality indicators/metrics, quality assurance and database population protocols
(3) Defining methods for quantifying uncertainty of key inputs
(4) Development and structuring of database
(5) Selection of case histories
(6) Obtaining and screening of case history information
(7) Population of case history database
(8) Phase I Reporting
(9) Database dissemination

Phase II Tasks include (not yet funded):

(10) Review and Development of Screening Criteria for Lateral Spread Potential
(11) Phase II Reporting

The principal investigators for this study will be Drs. Steven Bartlett (U. of Utah), Steven Kramer (U. of Washington and PEER Research Executive Committee Member), Kevin Franke (Brigham Young University) and Daniel Gillins (NOAA and consultant). The technical advisory committee (TAC) for the study currently includes representatives from Utah, California, Oregon, and Washington State DOTs. The MPC is providing additional funding for the study.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Task 1 – Working meetings were held. Final contract documents were submitted by BYU. Some of the researchers met on May 18 (BYU and U of U); the notes from the meeting were distributed to the TAC.
Task 2 – Completed. The work flow / Q&A/QC protocols will be further refined and implemented by BYU students for data entry.
Task 3 – In progress. Spatial uncertainty for Niigata, Japan case histories was completed. The task will continue as other data are added to the dataset.
Task 4 – In progress. Major changes to the data structure planned as a result of changes to the NGL triggering database by UCLA (Jon Stewart). Rev. 0 of this database is attached. We are reviewing these changes and making our database compatible with this effort. The triggering database is now a SQL database, and will be housed with the DESIGN SAFE

website.
Task 5 – In progress. Working on data issues associated with Christ Chruch New Zealand dataset.
Task 6 – Completed for Niigata, Japan. Working on Noshiro, Japan
Task 7 – Continuing.
Task 8 – Sections of report completed, but not ready for release
Task 9 – Not started.

TAC meetings – None were held this quarter.

Contract – Remaining funding commitments were transferred to Utah, including from Questar Gas Company, and applied to the project funds.

Anticipated work next quarter:

Task 1 – BYU students will begin populating the database with other case histories.
Task 2 – Database entry and review protocols will be developed and implemented by BYU and U of U students.
Task 3 – Continue to inventory methods of quantifying uncertainty and data quality.
Task 4 – Restructure part of our current database, so to be consistent as possible with NGL triggering database (see attachment)
Task 5 – Prioritize case histories for database entry.
Task 6 – Finalize database list.
Task 7 – Continue population of data set.
Task 8 – Release Interim Phase I Report
Task 9 – Not started. Database dissemination is planned through DESIGN SAFE. The decision to use DESIGN SAFE as a data repository affects Phase I Deliverable 1c – Instructions for use of ARCGIS for desktop tools. This will not be needed due to the new platform (https://www.designsafe-ci.org/)

TAC meetings – None are planned this quarter. Steve Bartlett and Kevin Franke will attend a NGL coordination meeting on July 12th at UC Berkeley.

Contract – Consider amending the research contract to include Phase II Tasks and the available funds.

Significant Results:

(provide new brief technical update and results)

Working meetings were held. Final contract documents were submitted by BYU. U of U and BYU researchers met on May 18 . The work flow / Q&A/QC protocols reviewed and will be further refined and implemented by BYU and U of U students for data entry.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

The restricting of the NGL triggering database by UCLA has made it necessary for us to restructure our database to be consistent with their efforts; hence the database structure is still not finalized. Rev. 0 of the NGL triggering database is shown in the attachment.

Potential Implementation:

None yet.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency: Utah Department of Transportation

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project #	**Transportation Pooled Fund Program - Report Period**
TPF-5(350)	_ Quarter 1 (January 1 – March 31, 2017) _ Quarter 2 (April 1 – June 30, 2017) **X Quarter 3 (July 1 – September 30, 2017)** _ Quarter 4 (October 1 – December 31, 2017)

Project Title: Development of Next Generation Liquefaction (NGL) Database for Liquefaction-Induced Lateral Spread		
Name of Project Manager(s): David Stevens	**Phone Number:** 801-589-8340	**E-Mail** davidstevens@utah.gov
Lead Agency Project ID: FINET 42080, ePM PIN 15017 UDOT PIC No. PL05.350	**Other Project ID (i.e., contract** UDOT Contract No. 17-8236	**Project Start Date:** September 8, 2016
Original Project End Date: March 31, 2019	**Current Project End Date:** March 31, 2019 (31 months)	**Number of Extensions:**

Project schedule status:

X On schedule _ On revised schedule _ Ahead of schedule _ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$110,354.93 (current contract) $140,000.00 (total TPF commitments)	$20,000.00 (paid by UDOT) $19,409 (at the U. of Utah)	20%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
This Quarter = 0% (paid by UDOT) This Quarter = 2.6% (at the U. of Utah) Total Project = 18% (paid by UDOT)	$0 (paid by UDOT) $2659 (at the U. of Utah) (Funding for U of U student	42%

Total Project = 17.6% (at the U. of Utah)	from MPC funds)	

Project Description:

This research will be conducted in conjunction with the Pacific Earthquake Engineering Research (PEER) Center and various state DOTs via a pool-fund study managed by the Utah Department of Transportation (UDOT). The Mountain Plains Consortium (MPC) is also providing funding for certain aspects of this study, under separate contract with the University of Utah. The research topic addresses the need to improve empirical, semi-empirical, analytical and numerical methods to estimate the amount of permanent ground displacement associated with liquefaction-induced lateral spread resulting from several major earthquakes. This scope of work addresses the development of a lateral spread community database as part of the PEER Next Generation Liquefaction Project (http://peer.berkeley.edu/lifelines/projects/ngl/). It does not address predictive model development for lateral spread evaluations, which is future effort planned by PEER, but not included in this work plan.

The primary outcome of this research is a vetted and community database of seismic, topographical, geotechnical and horizontal displacement measurements pertaining to case histories of liquefaction-induced lateral spread for further research and model development by other researchers and investigators under the auspices of the PEER Center (http://peer.berkeley.edu/). Secondary outcomes will be web host and publishing required to house and disseminate this database and its supporting information.

Phase I Tasks include (funded):

(1) Kickoff meeting and procurement of software
(2) Development of data quality indicators/metrics, quality assurance and database population protocols
(3) Defining methods for quantifying uncertainty of key inputs
(4) Development and structuring of database
(5) Selection of case histories
(6) Obtaining and screening of case history information
(7) Population of case history database
(8) Phase I Reporting
(9) Database dissemination

Phase II Tasks include (not yet funded):

(10) Review and Development of Screening Criteria for Lateral Spread Potential
(11) Phase II Reporting

The principal investigators for this study will be Drs. Steven Bartlett (U. of Utah), Steven Kramer (U. of Washington and PEER Research Executive Committee Member), Kevin Franke (Brigham Young University) and Daniel Gillins (NOAA and consultant). The technical advisory committee (TAC) for the study currently includes representatives from Utah, California, Oregon, and Washington State DOTs. The MPC is providing additional funding for the study.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Task 1 – Meetings at U. C. Berkeley were held with PIs, database structure finalized. No other activities planned for task 1. This task is completed.
Task 2 – Completed. Draft documents to be included in interim report.
Task 3 – In progress. This task will continue as other data are added to the dataset.
Task 4 – Major changes to the data structure were introduced as a result of changes to the NGL triggering database by UCLA (Jon Stewart) at the U.C. Berkeley workshop. We are reviewing these changes and making our database compatible with this effort.
Task 5 – In progress. Working on data issues associated with Christ Church New Zealand dataset.
Task 6 – Completed for Niigata, Japan and Noshiro, Japan. Started work on Alaska dataset.

Task 7 – Continuing.
Task 8 – Sections of report completed, but not ready for release.
Task 9 – Not started.

TAC meetings – None were held this quarter.

Contract – No changes.

Anticipated work next quarter:

Task 1 – BYU students to start populating the database with more recent case histories.
Task 2 – Included these items in interim report
Task 3 – Continue to inventory methods of quantifying uncertainty and data quality.
Task 4 – Minor changes to database structure as we continue populating
Task 5 – Prioritize case histories for database entry.
Task 6 – Obtaining of data in progress.
Task 7 – Continue population of data set.
Task 8 – Release Interim Phase I Report.
Task 9 – Not started. Database dissemination is planned through DESIGN SAFE. The decision to use DESIGN SAFE as a data repository affects Phase I Deliverable 1c – Instructions for use of ARCGIS for desktop tools. This will not be needed due to the new platform (https://www.designsafe-ci.org/).

TAC meetings – Consider holding a TAC web conference after the Interim Phase I Report is provided.

Contract – Consider amending the research contract to include Phase II Tasks and the available funds.

Significant Results:

Working meeting held at U. C. Berkeley to finalize database structure. BYU contract in place. Rev. 1 database structure released to us from UCLA (Jon Stewart).

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Potential Implementation:

None yet.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency: Utah Department of Transportation

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project #	**Transportation Pooled Fund Program - Report Period**
TPF-5(350)	_ Quarter 1 (January 1 – March 31, 2017) _ Quarter 2 (April 1 – June 30, 2017) _ Quarter 3 (July 1 – September 30, 2017) **X Quarter 4 (October 1 – December 31, 2017)**

Project Title:
Development of Next Generation Liquefaction (NGL) Database for Liquefaction-Induced Lateral Spread

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
David Stevens	801-589-8340	davidstevens@utah.gov
Lead Agency Project ID: FINET 42080, ePM PIN 15017 UDOT PIC No. PL05.350	**Other Project ID (i.e., contract** UDOT Contract No. 17-8236	**Project Start Date:** September 8, 2016
Original Project End Date: March 31, 2019	**Current Project End Date:** March 31, 2019 (31 months)	**Number of Extensions:**

Project schedule status:

_ On schedule _ On revised schedule _ Ahead of schedule X Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
\$110,354.93 (current contract) \$140,000.00 (total TPF commitments)	\$20,000 (paid by UDOT) \$25,346 (at the U. of Utah)	30%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
This Quarter = 0% (paid by UDOT) This Quarter = 11.5% (at the U. of Utah) Total Project = 18% (paid by UDOT) Total Project = 49% (at the U. of Utah)	\$0 (paid by UDOT) \$5098 (at the U. of Utah) (Funding for U of U student from MPC funds)	51%

Project Description:

This research will be conducted in conjunction with the Pacific Earthquake Engineering Research (PEER) Center and various state DOTs via a pool-fund study managed by the Utah Department of Transportation (UDOT). The Mountain Plains Consortium (MPC) is also providing funding for certain aspects of this study, under separate contract with the University of Utah. The research topic addresses the need to improve empirical, semi-empirical, analytical and numerical methods to estimate the amount of permanent ground displacement associated with liquefaction-induced lateral spread resulting from several major earthquakes. This scope of work addresses the development of a lateral spread community database as part of the PEER Next Generation Liquefaction Project (http://peer.berkeley.edu/lifelines/projects/ngl/). It does not address predictive model development for lateral spread evaluations, which is future effort planned by PEER, but not included in this work plan.

The primary outcome of this research is a vetted and community database of seismic, topographical, geotechnical and horizontal displacement measurements pertaining to case histories of liquefaction-induced lateral spread for further research and model development by other researchers and investigators under the auspices of the PEER Center (http://peer.berkeley.edu/). Secondary outcomes will be web host and publishing required to house and disseminate this database and its supporting information.

Phase I Tasks include (funded):

(1) Kickoff meeting and procurement of software
(2) Development of data quality indicators/metrics, quality assurance and database population protocols
(3) Defining methods for quantifying uncertainty of key inputs
(4) Development and structuring of database
(5) Selection of case histories
(6) Obtaining and screening of case history information
(7) Population of case history database
(8) Phase I Reporting
(9) Database dissemination

Phase II Tasks include (not yet funded):

(10) Review and Development of Screening Criteria for Lateral Spread Potential
(11) Phase II Reporting

The principal investigators for this study will be Drs. Steven Bartlett (U. of Utah), Steven Kramer (U. of Washington and PEER Research Executive Committee Member), Kevin Franke (Brigham Young University) and Daniel Gillins (NOAA and consultant). The technical advisory committee (TAC) for the study currently includes representatives from Utah, California, Oregon, and Washington State DOTs. The MPC is providing additional funding for the study.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Task 1 – This task is completed.
Task 2 – Completed. Draft documents to be included in interim report.
Task 3 – In progress. This task will continue as other data are added to the dataset.
Task 4 – Completed
Task 5 – In progress. BYU working on 2010 Maule, Chile; 2011 Tohoku, Japan, 2010 Darfield and 2011 Christ Church Earthquakes
Task 6 – U of U Completed for Niigata, Japan; Noshiro, Japan and Alaska datasets.
Task 7 – Continuing.
Task 8 – Sections of report completed, but not ready for release.

Task 9 – Not started.

TAC meetings – None were held this quarter.

Contract – No changes.

Anticipated work next quarter:

Task 1 – completed.
Task 2 – completed
Task 3 – Continue to inventory methods of quantifying uncertainty and data quality.
Task 4 – completed
Task 5 – In progress. BYU working on 2010 Maule, Chile; 2011 Tohoku, Japan, 2010 Darfield and 2011 Christ Church Earthquakes
Task 6 – Obtaining of data in progress.
Task 7 – Continue population of data set.
Task 8 – Plan to release interim report at end of March 2018
Task 9 – Not started. Database dissemination is planned through DESIGN SAFE. The decision to use DESIGN SAFE as a data repository affects Phase I Deliverable 1c – Instructions for use of ARCGIS for desktop tools. This will not be needed due to the new platform (https://www.designsafe-ci.org/).

TAC meetings – Consider holding a TAC web conference after the Interim Phase I Report is provided.

Contract – Consider amending the research contract to include Phase II Tasks and the available funds.

Significant Results:

Finalized structuring of database; Alaska dataset entered

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Potential Implementation:

None yet.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency: Utah Department of Transportation

INSTRUCTIONS:

Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project #	**Transportation Pooled Fund Program - Report Period**
TPF-5(350)	X Quarter 1 (January 1 – March 31, 2018) _ Quarter 2 (April 1 – June 30, 2018) _ Quarter 3 (July 1 – September 30, 2018) _ Quarter 4 (October 1 – December 31, 2018)

Project Title:
Development of Next Generation Liquefaction (NGL) Database for Liquefaction-Induced Lateral Spread

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
David Stevens	801-589-8340	davidstevens@utah.gov
Lead Agency Project ID: FINET 42080, ePM PIN 15017 UDOT PIC No. PL05.350	**Other Project ID (i.e., contract** UDOT Contract No. 17-8236	**Project Start Date:** September 8, 2016
Original Project End Date: March 31, 2019	**Current Project End Date:** March 31, 2019 (31 months)	**Number of Extensions:**

Project schedule status:

_ On schedule _ On revised schedule _ Ahead of schedule X Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$110,354.93 (current contract) $140,000.00 (total TPF commitments)	$21,209.08 (paid by UDOT) $39,678.17 (at the U. of Utah)	40%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
This Quarter = 0% (paid by UDOT) This Quarter = 11.5% (at the U. of Utah) Total Project = 18% (paid by UDOT) Total Project = 49% (at the U. of Utah)	$1,209.08 (paid by UDOT) $34,580.17 (at the U. of Utah) (Funding for U of U student from MPC funds)	61%

Project Description:

This research will be conducted in conjunction with the Pacific Earthquake Engineering Research (PEER) Center and various state DOTs via a pool-fund study managed by the Utah Department of Transportation (UDOT). The Mountain Plains Consortium (MPC) is also providing funding for certain aspects of this study, under separate contract with the University of Utah. The research topic addresses the need to improve empirical, semi-empirical, analytical and numerical methods to estimate the amount of permanent ground displacement associated with liquefaction-induced lateral spread resulting from several major earthquakes. This scope of work addresses the development of a lateral spread community database as part of the PEER Next Generation Liquefaction Project (http://peer.berkeley.edu/lifelines/projects/ngl/). It does not address predictive model development for lateral spread evaluations, which is future effort planned by PEER, but not included in this work plan.

The primary outcome of this research is a vetted and community database of seismic, topographical, geotechnical and horizontal displacement measurements pertaining to case histories of liquefaction-induced lateral spread for further research and model development by other researchers and investigators under the auspices of the PEER Center (http://peer.berkeley.edu/). Secondary outcomes will be web host and publishing required to house and disseminate this database and its supporting information.

Phase I Tasks include (funded):

(1) Kickoff meeting and procurement of software
(2) Development of data quality indicators/metrics, quality assurance and database population protocols
(3) Defining methods for quantifying uncertainty of key inputs
(4) Development and structuring of database
(5) Selection of case histories
(6) Obtaining and screening of case history information
(7) Population of case history database
(8) Phase I Reporting
(9) Database dissemination

Phase II Tasks include (not yet funded):

(10) Review and Development of Screening Criteria for Lateral Spread Potential
(11) Phase II Reporting

The principal investigators for this study will be Drs. Steven Bartlett (U. of Utah), Steven Kramer (U. of Washington and PEER Research Executive Committee Member), Kevin Franke (Brigham Young University) and Daniel Gillins (NOAA and consultant). The technical advisory committee (TAC) for the study currently includes representatives from Utah, California, Oregon, and Washington State DOTs. The MPC is providing additional funding for the study.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Task 1 – This task is completed.
Task 2 – Completed. Draft documents to be included in interim report.
Task 3 – In progress. This task will continue as other data are added to the dataset.
Task 4 – Completed
Task 5 – In progress. BYU working on 2010 Maule, Chile; 2011 Tohoku, Japan, 2010 Darfield and 2011 Christ Church Earthquakes
Task 6 – U of U Completed for Niigata, Japan; Noshiro, Japan and Alaska datasets.
Task 7 – Continuing.
Task 8 – Sections of report completed, but not ready for release.

Task 9 – Not started.

TAC meetings – None were held this quarter.

Contract – No changes.

Anticipated work next quarter:

Task 1 – completed.
Task 2 – completed
Task 3 – Continue to inventory methods of quantifying uncertainty and data quality.
Task 4 – completed
Task 5 – In progress. BYU working on 2010 Maule, Chile; 2011 Tohoku, Japan, 2010 Darfield and 2011 Christ Church Earthquakes
Task 6 – Obtaining of data in progress.
Task 7 – Continue population of data set for U.S. Case histories
Task 8 – Plan to release interim report at end of 2nd Quarter 2018
Task 9 – Not started. Database dissemination is planned through DESIGN SAFE. The decision to use DESIGN SAFE as a data repository affects Phase I Deliverable 1c – Instructions for use of ARCGIS for desktop tools. This will not be needed due to the new platform (https://www.designsafe-ci.org/).

TAC meetings – Consider holding a TAC web conference after the Interim Phase I Report is provided.

Contract – Consider amending the research contract to include Phase II Tasks and the available funds.

Significant Results:

Japan and Alaska datasets finalized, started on U.S. dataset.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None

Potential Implementation:

None yet.

TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency: Utah Department of Transportation

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during

which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # **TPF-5(350)**		**Transportation Pooled Fund Program - Report Period** __Quarter 1 (January 1 – March 31, 2018) X Quarter 2 (April 1 – June 30, 2018) __ Quarter 3 (July 1 – September 30, 2018) __Quarter 4 (October 1 – December 31, 2018)
Project Title: Development of Next Generation Liquefaction (NGL) Database for Liquefaction-Induced Lateral Spread		
Name of Project Manager(s): David Stevens	**Phone Number:** 801-589-8340	**E-Mail** davidstevens@utah.gov
Lead Agency Project ID: FINET 42080, ePM PIN 15017 UDOT PIC No. PL05.350	**Other Project ID (i.e., contract** UDOT Contract No. 17-8236	**Project Start Date:** September 8, 2016
Original Project End Date: March 31, 2019	**Current Project End Date:** March 31, 2019 (31 months)	**Number of Extensions:**

Project schedule status:

_ On schedule _ On revised schedule _ Ahead of schedule **X** Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Project**	**Percentage of Work Completed to Date**
$110,354.93 (current contract) $140,000.00 (total TPF commitments)	$33,050.70 (paid by UDOT) $49,731.45 (at the U. of Utah)	55%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
This Quarter = 0% (paid by UDOT) This Quarter = 11.5% (at the U. of Utah) Total Project = 18% (paid by UDOT) Total Project = 49% (at the U. of Utah)	$11,841.62 (paid by UDOT) $10,053.28 (at the U. of Utah) (Funding for U of U student from MPC funds)	65%

Project Description:

This research will be conducted in conjunction with the Pacific Earthquake Engineering Research (PEER) Center and various state DOTs via a pool-fund study managed by the Utah Department of Transportation (UDOT). The Mountain Plains Consortium (MPC) is also providing funding for certain aspects of this study, under separate contract with the University of Utah. The research topic addresses the need to improve empirical, semi-empirical, analytical and numerical methods to estimate the amount of permanent ground displacement associated with liquefaction-induced lateral spread resulting from several major earthquakes. This scope of work addresses the development of a lateral spread community database as part of the PEER Next Generation Liquefaction Project (http://peer.berkeley.edu/lifelines/projects/ngl/). It does not address predictive model development for lateral spread evaluations, which is future effort planned by PEER, but not included in this work plan.

The primary outcome of this research is a vetted and community database of seismic, topographical, geotechnical and horizontal displacement measurements pertaining to case histories of liquefaction-induced lateral spread for further research and model development by other researchers and investigators under the auspices of the PEER Center (http://peer.berkeley.edu/). Secondary outcomes will be web host and publishing required to house and disseminate this database and its supporting information.

Phase I Tasks include (funded):

(1) Kickoff meeting and procurement of software
(2) Development of data quality indicators/metrics, quality assurance and database population protocols
(3) Defining methods for quantifying uncertainty of key inputs
(4) Development and structuring of database
(5) Selection of case histories
(6) Obtaining and screening of case history information
(7) Population of case history database
(8) Phase I Reporting
(9) Database dissemination

Phase II Tasks include (not yet funded):

(10) Review and Development of Screening Criteria for Lateral Spread Potential
(11) Phase II Reporting

The principal investigators for this study will be Drs. Steven Bartlett (U. of Utah), Steven Kramer (U. of Washington and PEER Research Executive Committee Member), Kevin Franke (Brigham Young University) and Daniel Gillins (NOAA and consultant). The technical advisory committee (TAC) for the study currently includes representatives from Utah, California, Oregon, and Washington State DOTs. The MPC is providing additional funding for the study.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Task 1 – This task is completed.
Task 2 – Completed. Draft documents to be included in interim report.
Task 3 – In progress. This task will continue as other data are added to the dataset.
Task 4 – Completed
Task 5 – In progress. BYU working on 2010 Maule, Chile; 2011 Tohoku, Japan, 2010 Darfield and 2011 Christ Church Earthquakes
Task 6 – U of U Completed for Niigata, Japan; Noshiro, Japan, Alaska and San Fernando Ca., datasets.
Task 7 – Continuing.
Task 8 – Draft interim report finalized.

Task 9 – Not started.

TAC meetings – None were held this quarter.

Contract – No changes.

Anticipated work next quarter:

Task 1 – completed.
Task 2 – completed
Task 3 – Continue to inventory methods of quantifying uncertainty and data quality.
Task 4 – completed
Task 5 – In progress. BYU working on 2010 Maule, Chile; 2011 Tohoku, Japan, 2010 Darfield and 2011 Christ Church Earthquakes
Task 6 – Obtaining of data in progress.
Task 7 – Continue population of data set for U.S. Case histories
Task 8 – completed Aug. 5, 2018
Task 9 – Not started. Database dissemination is planned through DESIGN SAFE. The decision to use DESIGN SAFE as a data repository affects Phase I Deliverable 1c – Instructions for use of ARCGIS for desktop tools. This will not be needed due to the new platform (https://www.designsafe-ci.org/).

TAC meetings – Consider holding a TAC web conference after the Interim Phase I Report is provided.

Contract – Consider amending the research contract to include Phase II Tasks and the available funds.

Significant Results:

Started on population of U.S. dataset.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None

Potential Implementation:

None yet.

Attachment 2 - PEER-NGL Project: Open Source Global Database and Model Development for the Next-Generation of Liquefaction Assessment

6th International Conference on Earthquake Geotechnical Engineering 1-4 November 2015
Christchurch, New Zealand

PEER-NGL Project: Open Source Global Database and Model Development for the Next-Generation of Liquefaction Assessment Procedures

J. P. Stewart[1], S. L. Kramer[2], D. Y. Kwak[3], M. W. Greenfield[4], R. E. Kayen[5], K. Tokimatsu[6], J. D. Bray[7], C. Z. Beyzaei[8], M. Cubrinovski[9], T. Sekiguchi[10], S. Nakai[11], and Y. Bozorgnia[12]

ABSTRACT

The Next-Generation Liquefaction (NGL) project was launched to (1) substantially improve the quality, transparency, and accessibility of case history data related to ground failure; (2) provide a coordinated framework for supporting studies to augment case history data for conditions important for applications but poorly represented in empirical databases; and (3) provide an open, collaborative process for model development in which developer teams have access to common resources and share ideas and results during model development, so as to reduce the potential for mistakes and to mutually benefit from best practices. NGL at present is a concept developed from multiple international workshops; aside from concept development, work to date has focused on compiling high-value case histories. We describe the project motivation, explain and illustrate how data resources will be compiled and organized, summarize preliminary results from ongoing data collection, describe needed supporting studies, and review project status and next steps.

Introduction

Early efforts toward the development of procedures for evaluation of liquefaction potential were based on laboratory testing. Since undisturbed sampling of the types of loose, clean, saturated sands known to have been involved in early documented cases of liquefaction is extremely difficult, tests were performed on reconstituted soil specimens. These tests provided valuable insights into the effects of factors such as soil density, effective confining pressure, and cyclic shear stress amplitude on liquefaction resistance, but it was eventually discovered that test specimens prepared to the same densities but by different procedures exhibited very different

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liquefaction resistances when tested under identical stress and loading conditions. The differences were attributed to differences in soil fabric produced by the different specimen preparation procedures. Combined with potential age effects, the direct applicability of laboratory test results to field conditions was recognized as tenuous.

At that time, the standard of practice for evaluation of liquefaction potential shifted to a basis rooted in the interpretation of *in situ* behavior as interpreted from field case histories. Case histories of sites where potentially liquefiable soils were shaken during earthquakes were investigated with both site conditions and ground motions characterized. Sites where liquefaction occurred, as indicated by surficial evidence such as sand boils and ground cracking, were noted as were sites with no observed ground failure. The characteristics of the case histories were condensed into measures of loading, most commonly a magnitude-corrected cyclic shear stress ratio, and resistance, typically expressed in terms of penetration resistance. By plotting the case histories on axes of loading and resistance, combinations corresponding to liquefaction and non-liquefaction could be identified. In the early stages of case history-based evaluation of liquefaction potential, the boundary between liquefaction cases and non- liquefaction cases was drawn by hand in a generally conservative manner. More recently, Bayesian analysis procedures have been used to evaluate probabilities of liquefaction, taking into consideration uncertainties associated with individual data points and variabilities among the central values of distinct data points.

To date, research on liquefaction triggering and effects has occurred within the traditional framework of individual or small groups of researchers assembling and interpreting case history data to support the development of predictive models. Liquefaction case history databases have been developed based upon the initiative, effort, and personal connections and data inventories that individual researchers or research teams have been able to assemble over time. Typically only the team of researchers that assembled a particular database has had access to its source data. As a result, the databases have been of different size, breadth, and quality, and their vetting by only small groups of researchers has complicated the identification of potentially problematic data.

Under the traditional framework, the groups that assemble case history databases also develop empirical predictive models. The groups work independently to interpret individual case histories, a process that often requires judgment and subjective decisions. In this framework, the models developed by individual groups have often indicated different behavior due to differences in their databases, different interpretations of the data in their databases, potential errors in data interpretation, different approaches to constraining model behavior under data-poor conditions, and different philosophies of model development. Detailed discussions of subjective and philosophical decisions related to the interpretation of case history data, which can strongly affect model behavior, have rarely been published. In the end, the developed models make their way into practice to varying degrees depending largely on the reputation of the lead investigators and the venues used for dissemination of results.

It is not surprising that the models developed by individual teams of researchers operating in this framework can have significant differences. Varying levels of database size, breadth, and quality, the potential for mistakes in data interpretation, and the general opacity of the process lead to differences that cannot be clearly understood and judged by practitioners. This is clearly inefficient and undesirable. Unfortunately this is also the present state of liquefaction models in the US and elsewhere.

The Next Generation Liquefaction (NGL) project has been conceived by researchers at the Pacific Earthquake Engineering Research (PEER) center in California and partnering organizations globally as a new paradigm for ground failure research and engineering model development. As will be described in this paper, NGL is largely a concept at the present stage, being supported by seed funding that has targeted documentation of high-value case histories from recent earthquakes in Japan and New Zealand and supported many workshops that have contributed to the conceptual development of NGL. Over the long-term, the goals of NGL are to coordinate activities of international partners in support of a community database for liquefaction and related ground failure case histories. Moreover, we envision that distinct model teams will utilize this common database, in combination with results from supporting studies of key effects poorly constrained by available data, to develop next-generation models for liquefaction susceptibility, triggering, and effects in a much more transparent and collaborative manner than has been possible previously.

Subsequent sections of this manuscript elaborate upon the plans for and status of NGL, in particular:

1. Statement of NGL project vision, scope, organization, and status;
2. NGL data products, including illustration of what constitutes a case history;
3. Review of preliminary data collection efforts;
4. Role of supporting studies;
5. Anticipated products and next steps

NGL Project Vision and Objectives

Procedures for engineering assessment of liquefaction hazards are based to a large extent on the interpretation of field performance data from sites that have or have not experienced ground failure attributable to liquefaction. In this context, *ground failure* refers to permanent displacements of the ground surface, which can be caused by liquefaction or other phenomena such as cyclic softening of clays or seismic compression of unsaturated soils. The number of case histories supporting liquefaction procedures is remarkably small. For example, while nearly 200- 400 case histories support most modern liquefaction triggering procedures, typically only a few dozen of these most tangibly affect the position of the threshold curve. Empirical procedures for analysis of undrained residual strength of liquefied soils are also controlled by only a few dozen case histories. Given the small number of most relevant case histories, it is no surprise that existing databases are *incomplete*, meaning they cannot constrain important components of engineering predictive models.

This situation can now be improved by substantial increases in the size and quality of field performance data sets. The database expansion is to a large extent associated with the devastating earthquakes during 2011 in Japan and New Zealand, which caused a great deal of damage attributable to liquefaction and its effects. However, numerous other earthquakes have produced data that has not yet been considered in most of the current liquefaction triggering and effects models, including the 1999 events in Turkey and Taiwan, 2004 and 2007 events in western Japan, and the 2010 event in Chile. We describe some of the unique opportunities afforded by recent case histories subsequently in this paper.

To fully realize the benefits of new and existing data resources, fundamental changes are needed in the manner by which data are collected and analyzed. As described in the Introduction, the traditional research approach is somewhat opaque regarding database development and case history interpretation. This complicates the task of practitioners to select the best of the available models for a particular application. Difficulties occur when the research community is unable to put forth clear standards on best practices, which is the current state of affairs for most important problems in liquefaction hazard assessment, including susceptibility, triggering, residual strength, and the analysis of displacements. The ongoing National Research Council (NRC) study was undertaken to respond to this lack of clarity, although the recommendation of specific models was not part of the committee's scope.

NGL was established to support the development of a community database for liquefaction case histories, to help identify the need for and to help facilitate studies on key effects poorly constrained by the database, and to establish a collaborative framework within which models can be developed by distinct groups of model developers drawing upon these resources. Our vision is that the entire process of database development and model development would be undertaken with regular communication among investigators via project coordination meetings and with public workshops to enable community engagement and input. A major benefit of this approach is that the resulting model predictions would reflect genuine, 'apples-to-apples', epistemic variability associated with alternate methods of interpreting a common data set, which is not the case today.

This approach is motivated in part by the success of the Next-Generation of Attenuation (NGA) projects for ground motion prediction (e.g., Power et al., 2008; Bozorgnia et al., 2014), which developed this research approach and enjoyed substantial global buy-in and broad application.

NGL Data Products

The NGL database will consist, at its core, of a GIS platform (Google Earth, ArcGIS, or similar) documenting as completely as practical individual case histories of liquefaction, ground failure or non-ground failure (where 'ground failure' indicates permanent ground displacement). Attribution of data sources will be provided, but data will be presented in a common format. A usable case history of field performance generally requires the following attributes:

- *Observations of field performance from post-event reconnaissance.* This can vary from notes and photographs to relatively detailed mapping efforts producing ground failure displacement measurements.
- *Geotechnical data.* Required information on geotechnical conditions at a site of interest includes the soil stratigraphy, ground water depth, details pertaining to soil type (typically from gradation and index tests), and penetration resistance.

- *Ground motions.* The characterization of ground motion most often involves intensity measures such as peak acceleration, pseudo-spectral acceleration, or cumulative absolute velocity, but increasingly also may include full waveforms that are used to judge the presence and timing of liquefaction triggering.

The present availability of this information has been assessed through review of prior data compilations (e.g., Cetin et al. 2000, Boulanger et al., 2012, Moss et al., 2003) as well as presentations and discussions at the aforementioned international workshops. The number of currently available case histories in recent liquefaction triggering models are 230 for borehole/standard penetration test-based site characterization (Boulanger et al., 2012), 268 for cone penetration test-based site characterization (Boulanger and Idriss, 2014), and 422 for shear- wave velocity-based site characterization (Kayen et al., 2013). As part of the NGL project, we seek to significantly expand the size and breadth of the data set using observations from relevant events that are either missing from or not adequately represented in the existing inventories. Those events include the 1999 Kocaeli Turkey, 1999 Chi Chi Taiwan, 2004 and 2007 events near Niigata Japan, 2010 Maule Chile, 2011 Christchurch New Zealand, and 2011 Tohoku Japan earthquakes.

We argue that the NGL database as archived in a GIS platform is for practical purposes *objective*, in that it reports factual information on field performance, geotechnical conditions, and seismic demands. NGL will also populate a *Flatfile*, which will contain a synthesis of parameters used for model development. The process of distilling the information from the database to the format required for a flatfile is subjective. We illustrate through example the contents of the database and flatfile in the subsections below, including discussion of the subjective decisions required to produce a flatfile data point.

NGL GIS Database

The GIS database is intended to document as completely as practical (and in a common format), case histories of liquefaction, related ground failures, and non-ground failures. Aspects of the required documentation include the field performance, geotechnical conditions, and ground motions. We illustrate these aspects of a typical case history using an example site having both ground failure (liquefaction-induced lateral spreading) and non-ground failure in adjacent areas. As shown in Figure 1, the site is located in Urayasu (Lat: 35.6380°; Long: 139.9335°), and the case history is related to performance from the 2011 Tohoku earthquake mainshock.

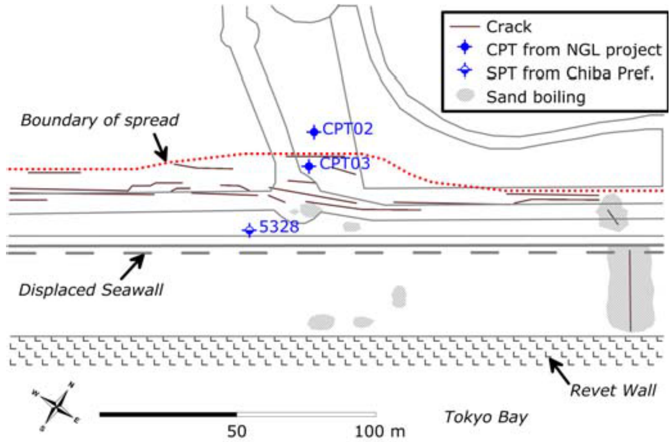

Figure 1. Sea front in Urayasu city where lateral spread occurred by the 2011 Tohoku Earthquake.

Field performance

Reliable evaluation of field performance requires post-event reconnaissance from a trusted source such as the Geotechnical Extreme Events Reconnaissance (GEER) association, the Earthquake Engineering Research Institute (EERI), local professional or governmental groups, and/or local university professors and students. The minimal required documentation is a written description of ground failure that occurred at the site and in the vicinity, a description of the lack of ground failure (as applicable), the date/time of the observation, and the precise location (with geodetic coordinates) of the observations. Additional useful information includes ground-based photographs, maps of surface features, relatively advanced imaging of surficial features through Light Detection And Ranging (LiDAR) scanning, or post-event images of the site from air photos or satellites. Evidence of ground failure from these data sources may include sediment boils, ground cracks, and deformations of above- or below-ground structures. Liquefaction can be identified as the cause of ground failure when sediment boils are observed. A lack of ground failure is an important observation, but it should be understood that such an observation does not preclude the occurrence of liquefaction or strength loss at the site.

In the case of the Urayasu site, the reconnaissance was performed by GEER (GEER, 2011) and includes information from all of the above-listed sources. Figure 1 distills the essential observations for the purpose of identifying portions of the site with and without ground failure.

Geotechnical conditions

A case history of ground failure is only useful for model development if some quantitative evaluation of site conditions is available. All sites listed in the NGL database will have such information. At this time, we anticipate that the minimum required information will include the soil stratigraphy, ground water depth, details pertaining to soil type, and penetration resistance. Information on soil type is critical and is an element of site data that is often missing or incomplete. The minimum required information on soil type is tip and sleeve resistance from cone penetration test (CPT) soundings or soil classification based on visual inspection or testing when samples are available. Additional information related to soil type that can significantly increase the value of a case study includes:

- Gradation testing and plasticity tests
- Water content
- Assessments of mechanical behavior of soil through cyclic testing or undrained monotonic testing in combination with consolidation tests (to evaluate potential undrained strength normalization).

Penetration resistance testing from CPT is desirable due to the standardization of these procedures. In the case of standard penetration testing, energy ratios associated with measurements should be reported. These energy ratios ideally are based on site- and equipment- specific energy measurements (Abou-Matar and Goble, 1997), but otherwise can be based on local experience or published values (e.g., Youd et al., 2001; Cetin et al., 2004). *In situ* seismic velocity testing will also be included with the geotechnical characterization where available.

At the example Urayasu site, Figure 2 shows results of CPT soundings both in the ground failure/liquefaction zone and the non-ground failure zone. The ground water depth at this location is 1.3 to 1.5 m. The cone data in Figure 2 has been processed and evaluated per the recommendations of Robertson (2012) as a dimensionless and overburden-normalized penetration resistance (Q_{tn}) and soil behavior type index (I_c). The site characterization in this case included CPT-based soil sampling in layers judged to be most critical for ground failure during field work; results of index tests from these samples are shown in Figure 2. The interpretation of this data for identification of the 'critical layer' is deferred to a subsequent section on the NGL flatfile.

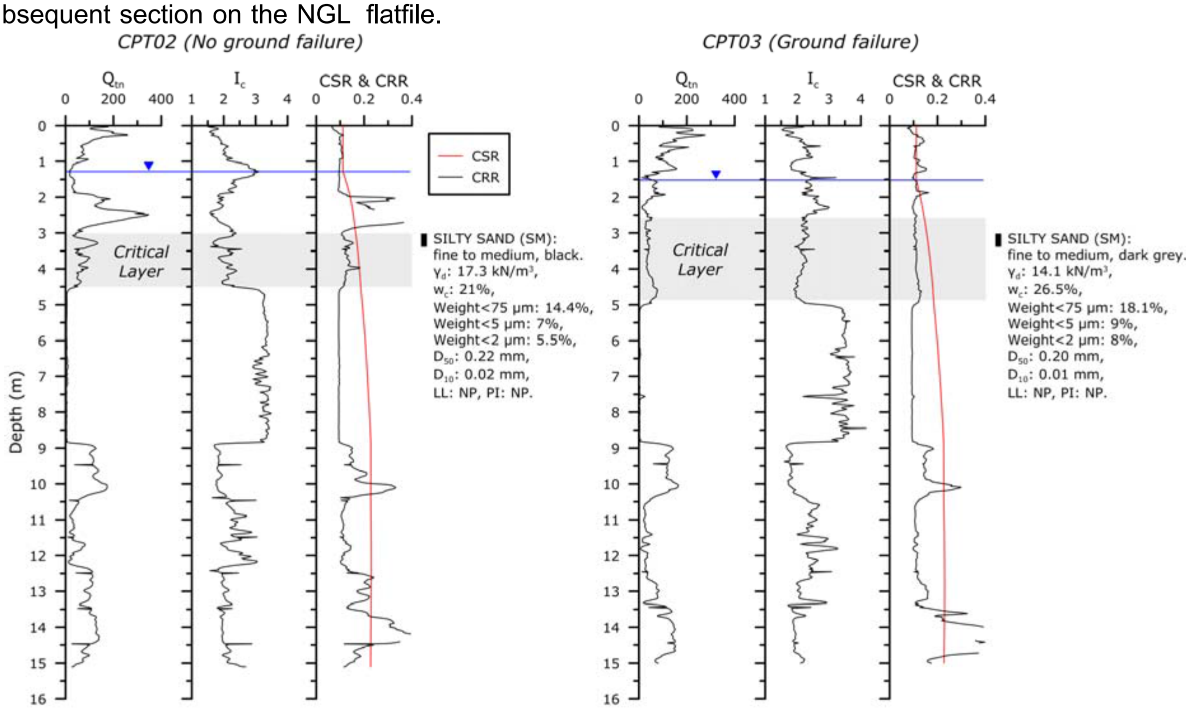

Figure 2. Normalized CPT resistance (Q_{tn}), soil behavior type index (I_c), cyclic stress ratio (CSR) and cyclic resistance ratio (CRR) profiles on the location of no ground failure and ground failure. Laboratory index test results from the samples retrieved by a CPT sampler are indicated.

Ground Motion

For the NGL database, ground motion characterization generally pertains to the intensity of shaking at the ground surface. The only exception to this is vertical arrays, where ground motions are recorded at depth (a rare circumstance at ground failure case history sites). The evaluation of cyclic stresses at depth given the shaking intensity at the surface is a modeling issue that enters the documentation at the flatfile stage, as described in the next section.

The ground motion intensity measure used for liquefaction analysis is generally the horizontal, median-component (denoted RotD50, Boore, 2010) peak ground acceleration (PGA). This parameter is widely used because the product of PGA and total vertical stress at the depth of interest is generally taken as proportional to the peak shear stress imposed by the earthquake at that depth (Seed and Idriss, 1971). Additional intensity measures used in some cases are cumulative absolute velocity beyond a 5 cm/s threshold (CAV_5), Arias intensity (I_A), and pseudo- spectral accelerations at various oscillator periods. Our remarks here are focused on PGA, but additional intensity measures are likely to be included in the database.

We propose the following procedures for estimating PGA, in order of preference:

1. When the earthquake event that produced the case history is included in ground motion databases used to derive ground motion prediction equations (GMPE), ground motions at the site should be taken as the sum (in natural log units) of the GMPE median (using appropriate site parameters including V_{S30} and basin depths), the event term associated with that earthquake and the GMPE, and a mapped within-event residual to correct for spatial correlations in path and source. This approach, which is explained further in Kwak et al. (2015a), takes into consideration recordings in the vicinity of the case history site, while accounting for differences in site conditions. This approach is similar to procedures given previously by Wald et al. (2005), Yamazaki et al. (2000), Sawada et al. (2008), and Bradley (2014), but has distinct features as described by Kwak et al. (2015a).
2. When recordings are available for the earthquake in question, but the event was not included in the GMPE database, the procedure from (1) can be applied but with the event term set to zero. In this case the mapped residuals will likely have a non-zero mean.
3. When recordings for the event are either not available or are very sparse, GMPE log mean predictions should be used. These estimates are likely to carry a larger degree of uncertainty than those from (1) or (2).

For all three approaches, the GMPE should be appropriate for the tectonic regime that produced the earthquake event (Stewart et al., 2015). Ground motion estimates from approach (1) will converge to the recorded PGA as the separation distance between an accelerograph and the site approaches zero. For this reason, the procedures listed above apply both to sites with and without on-site or adjacent ground motion recordings. For sites with a strong motion station within some nominal distance (likely about 100 m), the recorded ground motion would likely be directly used. In addition to recent case histories, we expect to re-process ground motions for previous case histories in this manner so that demands for all NGL sites are estimated consistently.

For the example Urayasu site, recordings near the site produce a median estimate of $PGA \approx 1.174$ g (using procedure 2 above) with an uncertainty of 0.28 (natural log units). The uncertainty estimate is based on semi-variograms by Jarayam and Baker (2009), and takes into consideration the separation distance between the site and the nearest ground motion station, which is 0.5 km.

A subset of sites that is being developed in NGL has observations of liquefaction manifest at the surface and ground motion recordings that exhibit evidence of liquefaction effects. Special procedures have been developed to interpret ground motions for these sites, with the goal of identifying conditions at the liquefaction triggering threshold. Kramer et al. (2015) describe in more detail this important aspect of the NGL project.

NGL Flatfile

The NGL flatfile is envisioned as a synthesis of parameters used for model development. Parameters used in three recent liquefaction triggering models (Boulanger et al., 2012; Boulanger and Idriss, 2014; Kayen et al., 2013) are shown in Table 1. The NGL flatfile for triggering model development would include these parameters and likely others identified over the course of the project.

The key parameters produced from the flatfile that are used for the development of triggering models are a "reference" cyclic stress ratio (denoted CSR^*) that corresponds to reference conditions of σ'_{v0} = 1 atm, τ_{static} = 0, and $\mathbf{M}$ = 7.5, and a parameter representing soil penetration resistance or seismic velocity. Parameter CSR^* is computed as (adapted from Cetin et al., 2004, and others):

$$CSR^* = 0.65 \frac{\sigma_v}{\sigma_v'} \frac{PGA}{g} r_d \times \frac{1}{K_\sigma K_\alpha C_M} \qquad (1)$$

where σ_v and σ_v' are total and effective stresses at the depth of interest (usually the center of the critical layer), r_d is a stress reduction factor to account for the flexibility of the soil column above the depth of interest, K_σ is an overburden factor to correct the seismic resistance for decreased soil dilatancy as effective stress increases, K_α is a shear stress correction factor to account for changes in dilatancy when static, horizontal-plane shear stresses are non-zero, and C_M is a magnitude scaling factor to account for the increasing severity of seismic demands as $\mathbf{M}$ increases.

A number of parameters, such as r_d, K_σ, K_α, and C_M are not source data, but are intermediate parameters that characterize particular components of most liquefaction triggering models. As such, these parameters are somewhat subjective and will vary between modelers. Naturally, CSR^* as derived from Equation (1) is then also subjective. This subjectivity may require multiple flatfiles for multiple modeling teams, or at least separate families of parameters within a single flatfile for those teams. The fundamental differentiation of objective data in the NGL database and subjective data in the flatfile is an important element of NGL.

Table 1. List of parameters used in three recent liquefaction triggering models.

Parameters	Boulanger et al., 2012 (SPT)	Boul. & Idriss, 2014 (CPT)	Kayen et al., 2013 (V_s)
Fundamental Parameters			
Moment magnitude, **M**	•	•	•
Peak ground acceleration, *PGA*	•	•	•
Liquefaction manifestation	•	•	•
Average depth to critical layer	•	•	•
Depth to ground water table	•	•	•
Unit weight, γ			
Static shear stress on horizontal plane, τ_{hv}			
Fines content, *FC*	•	•	
CPT tip resistance, q_c		•	
CPT sleeve friction, f_s		•	
SPT blow count, *N*	•		
SPT energy ratio (if measured)	•		
Shear wave velocity, V_s			•
Intermediate or Derived Parameters			
Total vertical stress, σ_v	•	•	•
Effective vertical stress, σ_v'	•	•	•
Shear stress reduction factor, r_d	•	•	•
Earthquake-induced cyclic stress ratio, *CSR*	•	•	•
Overburden correction factor, K_σ	•	•	
Shear stress correction factor, K_α			
Magnitude scaling factor, C_M	•	•	•
CSR for **M**=7.5, σ_v'=1atm, and α=0, *CSR**	•	•	•
Exponent for overburden normalization, *n*		•	
Soil behavior type index, I_c		•	
Overburden correction factor, C_N	•	•	•
Overburden-normalized tip resistance, Q_{tn} and q_{c1N}		•	
Overburden-normalized sleeve friction, *F*		•	
Friction ratio, F_r		•	
SPT energy ratio (if inferred)	•		
Energy- and overburden stress-corrected blow count, $(N_1)_{60}$	•		
Normalized shear wave velocity, V_{s1}			•
Equivalent clean-sand tip resistance, q_{c1Ncs}		•	
Equivalent clean-sand corrected blow count, $(N_1)_{60cs}$	•		

To illustrate this process, we apply to the Urayasu case history site the r_d, K_σ, K_α, and C_M estimates from Boulanger and Idriss (2014). Figure 2 identifies the depth range for the "critical layer." This process of identifying the critical layer is itself highly subjective. In the present case our judgment is that the base of the critical layer is bound by a non-susceptible (clay) layer. The shallow limit of the critical layer is bound by a dense near-surface layer (no-ground failure location) and by relatively plastic (high I_c) material within the ground failure zone. Table 2 shows the parameters required for flatfile development for these sites both in the ground failure and non-ground failure regions (using CPT-based soil penetration resistance).

Table 2. Parameters for liquefaction triggering analysis for no-ground failure (CPT02) and ground failure (CPT03) locations at example site. Derived parameters from Boulanger and Idriss (2014).

	M	*PGA* (g)	Critical Interval (m)	Avg. Depth (m)	GWT Depth (m)	σ_v (kPa)	σ_v' (kPa)	r_d	CSR	K_σ	K_α	C_M	*CSR**
CPT02	9	0.174	3.0-4.5	3.75	1.27	67.5	43.2	1.0	0.177	1.08	1	0.916	0.178
CPT03	9	0.174	2.5-5.0	3.75	1.51	67.5	45.5	1.0	0.168	1.07	1	0.939	0.167
	FC (%)	q_c (MPa)	f_s (MPa)	f_r (%)	Q	n	F	I_c	C_N	q_{c1N}	Δq_{c1N}	q_{c1Ncs}	CRR (P_L=15%)
CPT02	14.4	4.41	0.046	1.04	65.7	0.5	1.06	2.07	1.57	68.3	18.7	87.1	0.123
CPT03	18.1	2.82	0.022	0.77	40.6	0.5	0.78	2.17	1.58	44.1	25.5	69.7	0.107

Figure 3 shows where the results for the critical layers plot relative to the Boulanger and Idriss (2014) probabilistic liquefaction triggering criteria and their data. The uncertainty around the plotted data points in the horizontal and vertical directions are related to dispersion of *PGA* (vertical direction) and penetration resistance within the critical layer (horizontal direction). The example sites plot near the liquefaction triggering threshold.

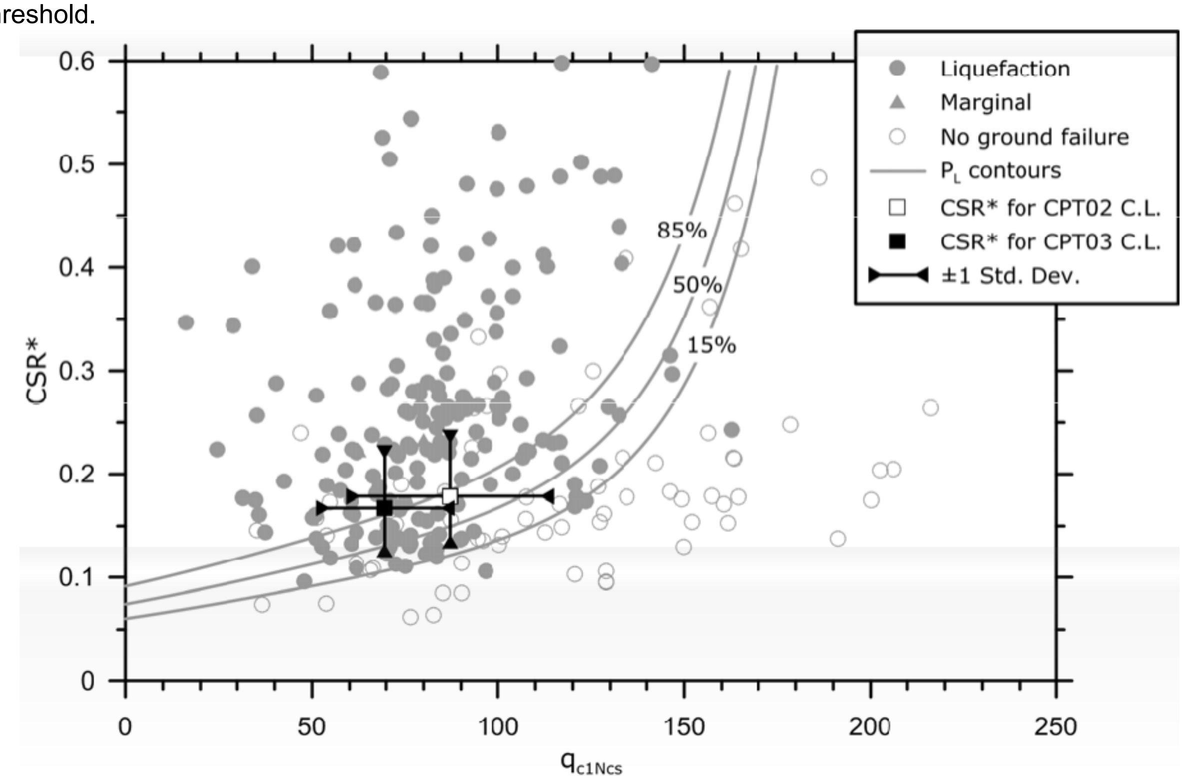

Figure 3. Liquefaction triggering database showing *CSR** vs. q_{c1Ncs} and $CRR_{M7.5,\sigma'=1atm}$ for 15, 50, and 85% probabilities of liquefaction (after Boulanger and Idriss, 2014). Data points for critical layers and ±1 standard deviations of *CSR** and q_{c1Ncs} are shown for no ground failure (CPT02) and ground failure (CPT03) locations at example site in Urayasu, Japan.

Preliminary Data Collection

As mentioned in the Introduction, work to date in the NGL project has been directed towards developing high-value case histories and formulating the project vision, organization, and scope. In this section, we provide an overview of data collection to date and additional efforts planned in the near-future relative to the time of this writing (June 2015). We describe how sites were selected for geotechnical characterization and the types of tests that were performed. In all cases, the sites selected for characterization activities had prior geotechnical data that was supplemented to fill data gaps in the present work.

Field work in Japan

The 2011 **M** 9.0 Tohoku earthquake produced a wealth of field observations of liquefaction and non-liquefaction, including sites with measured ground deformations and measured foundation performance (GEER, 2011). Following extensive discussions at several international workshops among many of the authors of this paper and others with expertise and experience in this area, priorities for site characterization were identified as follows:

1. Sites having well documented lateral ground deformation from traditional mapping and LiDAR imaging.
2. Sites having ground motion instrumentation and well-documented field performance with respect to liquefaction or lack of ground failure.
3. A series of sites on reclaimed land areas in Mihama ward, Chiba Prefecture. The fill materials in these areas were placed hydraulically.
4. Vertical ground motion array sites, many operated by the Port and Airport Research Institute, where varying levels of ground failure were observed.

Based on the above criteria, seven sites at the locations in Figure 4 were investigated in the first phase of data collection (completed in April-July 2014). One site was selected per the first criterion (lateral ground deformation) while six were selected per the second criterion (near strong ground motion stations). Table 3 lists the sites and attributes that led to their selection. Testing at the sites included CPT (including sampling) and borings with sampling include SPTs with energy measurements. Work currently in the planning stages will occur at sites selected per criteria 2-4.

Figure 4. Locations of ground failure or no-ground failure sites investigated in first phase of NGL characterization work in Japan (base map from Google Earth™).

Table 3. List of first-phase characterized sites in Japan from NGL project.

Location	Tests	Latitude	Longitude	Nearest Station	PGA (g) at N.S.	Site-to-station distance (km)	Ground failure observation
Urayasu, Chiba	CPT	35.63692	139.93215	HND /Keiyo Gas	0.174	0.61	Lateral spread
	SPT / CPT	35.63802	139.93352	HND /Keiyo Gas	0.174	0.54	
	CPT	35.63793	139.93356	HND /Keiyo Gas	0.174	0.54	
	CPT	35.64029	139.93828	HND /Keiyo Gas	0.174	0.73	
Choshi, Chiba	SPT / CPT	35.73536	140.82732	CHB005 /K-NET	0.179	0.02	No ground failure
Chuo, Chiba	SPT / CPT	35.60048	140.10209	Chiba-g /PARI	0.128	0.16	No ground failure
Mihama, Chiba	CPT	35.63469	140.07777	CHB024 /K-NET	0.237	0.07	Severe liquefaction
Sunamachi, Tokyo	CPT	35.66226	139.83430	TKY013 /K-NET	0.144	0.06	No ground failure
Tatsumi, Tokyo	CPT	35.64967	139.80849	TKY017 /K-NET	0.223	0.27	Moderate liquefaction
Shinariake, Tokyo	CPT	35.62293	139.79100	Shinariake /TMG	0.122	0.12	No ground failure

Lateral Spread at Urayasu City

The ground failure and non-ground failure example described in the previous section (Figures 1-3) is from the Urayasu lateral spread site. Figure 5 is a plan view of the spread feature, showing displacement vectors of up to 2.8 m horizontally towards the sea (1.0 m of subsidence also occurred). The width of the spread feature is about 600 m. The spreading occurred in artificial fill towards a free-face height estimated as 6 m based on the fill thickness and surface elevations of pre-fill borings from Chiba Prefecture Geology and Environment Information Bank (CP, 2015). A supporting estimate of the free-face height is computed using the lateral dimension of a revetment slope below the sea wall and its approximate slope of 2H:1V.

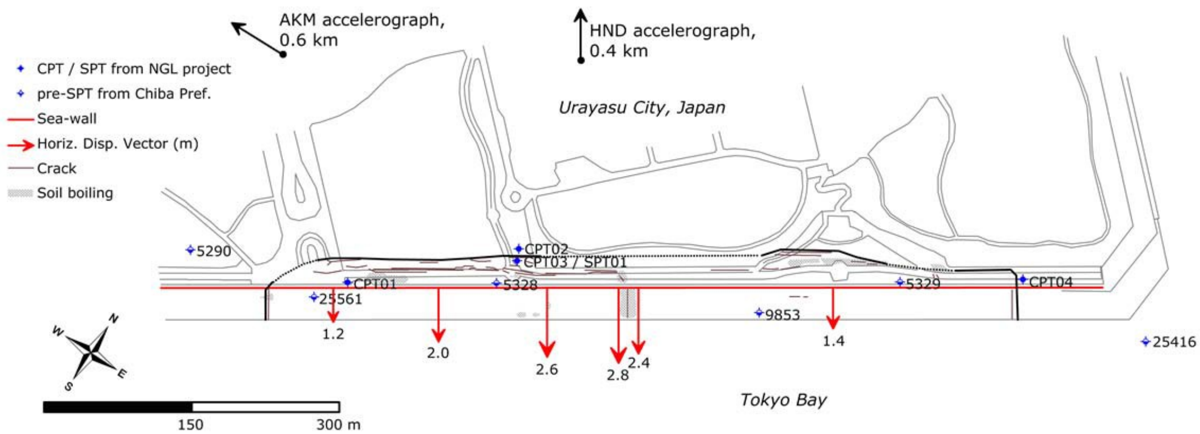

Figure 5. Plan view of Urayasu sea front where lateral spread occurred during 2011 **M** 9.0 Tohoku earthquake mainshock. All surface features based on field mapping, ground and air photos, and LiDAR imaging.

Site performance was first documented by the GEER reconnaissance team using field mapping and photography. A subsequent phase of work in the GEER reconnaissance imaged ground morphology using terrestrial LiDAR. Both the field mapping and LiDAR imaging were used to evaluate displacement vectors and to support the development of the site plan in Figure 5. We performed four CPTs and one boring with SPT to evaluate subsurface conditions inside and outside of the deformation zone. There are also four pre-existing boring logs performed in the 1970s to 1990s, which are available from Chiba Prefecture (CP, 2015).

Four other lateral spread sites have similar levels of mapping but lack geotechnical data. This data may be compiled in future work. The inventory of data from these sites is useful both for triggering and semi-empirical lateral spread models.

Strong Ground Motion Stations in Tokyo and Chiba

Observations of liquefaction and no-ground failure in the vicinity of accelerograph stations are especially valuable for model building, because the seismic demands at these sites have significantly less uncertainty than those for sites where ground motions must be estimated. For this reason, GEER reconnaissance activities emphasized locations near accelerographs (GEER, 2011). Resulting observations and preliminary analysis of these conditions are provided by Cox et al. (2013) for 22 liquefaction sites and 16 no-ground failure sites that are mostly located in the greater Tokyo Bay region of Japan.

Many of the accelerograph sites for which field performance and ground motion information are available also have some geotechnical data. For example, accelerographs within the K-NET network (Kinoshita, 1998) have boring logs, SPT N-values, and V_S profiles that typically extend to 10-20 m depth. A similar format is used for accelerographs in the PARI network (PARI, 2015), except that borehole depths are variable. Boring logs and V_S profiles are available for KiK-net vertical array sites, although these profiles extend considerably deeper. However, as described by Cox et al. (2013), there are several complications in the use of this data, including lack of quantitative soil type information (from laboratory index tests) and unknown SPT energy levels, which are particularly variable at K-NET and PARI sites (Kwak et al., 2015b). Our site characterization was motivated in large part by a need to fill these data gaps. As shown in Table 3, we investigated four K-NET sites, one PARI site, and one site maintained by the Tokyo Metropolitan Government site (Shinariake).

Among the five K-NET and PARI sites, three (CHB005, Chiba-g, TKY013) had no observable ground failure, despite low penetration resistance, shallow ground water, and the presence of silty soils. An important issue in these cases is whether those fine-grained materials are liquefaction-susceptible. Site CHB024 had severe liquefaction, and was investigated to support NGL-related activities to identify CSR^*–penetration resistance conditions at the liquefaction triggering threshold (as described by Kramer et al., 2015). Site TKY017 had moderate liquefaction and was investigated for similar reasons.

We performed CPTs for each investigated site, and SPTs for CHB005 and Chiba-g. An objective of the SPTs at K-NET and PARI stations was to investigate energy ratios for SPT N-values reported in the logs. Hammer energy ratios were recorded using equipment and analysis procedures given by Abou-Matar and Goble (1997). Laboratory index tests for specimens from SPT samplers and CPT samplers were also performed.

Three sites in Tokyo (Sunamachi, Tatsumi, and Shinariake) are located in the vicinity of ground motion stations (K-NET and Tokyo Metropolitan Government, TMG) and have instrumentation to record ground settlement and ground water table fluctuation measurements (TMG, 2011). We performed exploration at the Shinariake site, which has a downhole array with four seismographs at 2, 16, 36, and 75 m depth in addition to the ground water elevation and settlement instruments. This site experienced settlement but had no other surface manifestation of liquefaction.

As noted in Table 3, there are cases in which borings and CPTs were not co-located with accelerographs. This resulted from inabilities to secure necessary permission in some cases.

Mihama-Ward (reclaimed land by hydraulic fill)

Mihama-ward in Chiba, Japan is constructed on reclaimed land that was developed using hydraulic fill procedures in the mid-1970s (Sekiguchi and Nakai, 2012). As shown in Figure 6, locations of discharge pipes are well known, which is useful because during hydraulic filling relatively fast flow velocities are expected near discharge locations (producing relatively coarse sediments) whereas slower velocities in intermediate areas would be expected to produce relatively fine-grained sediments. The variable composition of these materials is of considerable interest from a liquefaction susceptibility perspective.

After the Tohoku event, extensive reconnaissance of reclaimed land areas in Mihama-ward was conducted by Chiba University as well as several government agencies. The Chiba University reconnaissance, documented by Sekiguchi and Nakai (2012), mapped the surface manifestation of liquefaction according to three levels: 1) Heavy liquefaction: “The overflow area of the sand boiling found in the spot is more than about 1 m”; 2) Minor liquefaction: “The overflow area is less than about 1 m”; 3) no liquefaction: “No sand boiling was found.”

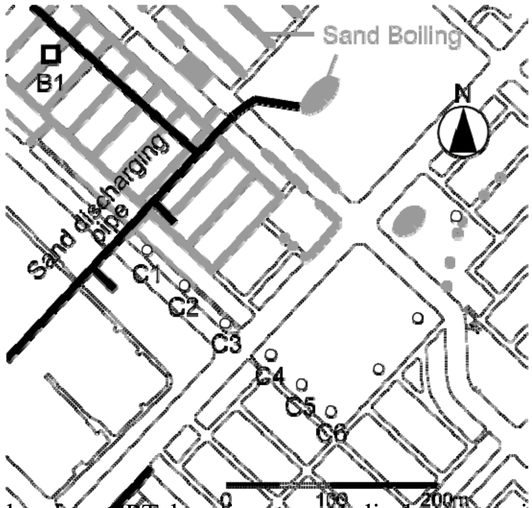

Figure 6. Mihama-ward site showing CPT locations, sand discharging pipe, and sand boiling traces (Sekiguchi and Nakai, 2012).

There is a general correlation between field performance and discharge pipe locations – with liquefaction being most concentrated near discharge pipes and intermediate areas having no- ground failure. Our work in this region has the objective of identifying soil compositional factors that contribute to varying levels of liquefaction severity. Many borings and a small number of CPTs have already been performed in the area (including the six CPTs shown in Figure 6), but laboratory test data is scarce and is not sufficient to study liquefaction susceptibility issues. Our future work will fill this data gap.

New Zealand

Following the 2010-2011 Canterbury Earthquake Sequence (CES), several engineers and researchers conducted field studies in Christchurch, New Zealand to characterize subsurface conditions at sites that either had surface manifestation of liquefaction or no observed ground failure. Over 18,000 CPT soundings and over 3,000 soil exploratory borings have been performed since the CES making this dataset incredibly valuable, especially considering that each site was shaken multiple times by major earthquake events (four of which had **M** > 5.9).

Post-earthquake reconnaissance efforts were conducted by several organizations, including government agencies, private consultancies, academic research institutions, and volunteer engineers and geologists. The Earthquake Commission, Tonkin & Taylor, and the University of Canterbury facilitated many of these efforts. Among the four events, the best reconnaissance documentation is for the 4 September 2010 Darfield (**M** 7.1) and 22 February 2011 Christchurch (**M** 6.2) earthquakes. This documentation includes reports by the National Science Foundation (NSF)-sponsored Geotechnical Extreme Events Reconnaissance (GEER) Association. The observations contained in these reports have been incorporated in the Canterbury Geotechnical

Database maps, showing available post-earthquake observations throughout the Canterbury region for each of the four major earthquake events.

The NGL New Zealand dataset focused on pulling together a select number of the most insightful case histories from four well-documented geotechnical projects, the earliest beginning in 2011 and the most recent continuing today. Combining the resources of international, governmental, and private organizations, along with researchers from a diverse range of backgrounds, these projects represent a significant contribution to the global dataset in development of the next generation liquefaction assessment procedures. While the projects are individually detailed in separate publications, their case history data are being standardized and compiled for incorporation in the NGL database.

Canterbury, New Zealand subsurface geotechnical data were gathered from four projects summarized in Table 4, which collectively investigated the site locations shown in Figure 7. All sites within the dataset contain CPT data, with sonic boring, laboratory testing data, and shear wave velocity profiles available for many of the sites. Case histories at these sites are based on ground failure observations from the 2010-2011 Canterbury Earthquake Sequence and cover a broad spectrum of liquefaction effects, ranging from no observation to severe damage.

Table 4. New Zealand sites for NGL database

Reference	No. of Sites	CPT	Sonic Boring	Undisturbed Sampling
Beyzaei et al. (2015), Stringer et al. (2015), UC Berkeley & Univ. of Canterbury (2015)	8	•	•	•
Markham et al. (2015)	8	•		•
Tonkin & Taylor (2013)	12	•	•	
Green et al. (2014)	25	•		

Figure 7. Geographic distribution of NGL New Zealand sites in the Canterbury Region

The sites to be included in the NGL database are summarized as follows:

- *Project 1: NSF-PEER-MBIE-EQC Liquefaction Triggering & Consequence for Low-Plasticity Silty Soils (8 'SM' Sites)*

Each site in the silty soils project has a CPT sounding, sonic boring with disturbed samples, and mud rotary cased boring with undisturbed sampling. Sites were selected based on the presence of silty soils in the upper few meters and comparisons of observed vs. predicted liquefaction for the September 2010 Darfield earthquake and the February 2011 Christchurch earthquake, with an emphasis on sites in which prevalent liquefaction triggering and ground settlement procedures over-predicted the observed performance.

Beyzaei et al. (2015) and Stringer et al. (2015) provide detailed information on the laboratory testing program for two of the sites investigated as part of the silty soils project. Cyclic triaxial laboratory testing data, Atterberg limits, and particle size analysis are presented in addition to the field work and pre-existing data summaries.

As the most recent of the four NGL New Zealand projects, the silty soils project includes direct support from NGL funding towards the field work and laboratory testing program. The three additional projects listed below were independently funded, but are being standardized and incorporated in the NGL database through the support of NGL funding.

- *Project 2: NSF CBD Project (8 'CBD' sites)*

Each site in the Central Business District (CBD) of Christchurch project has at least one CPT sounding and at least one mud rotary cased boring with undisturbed sampling. Sites were selected based on observed building damage, covering varying degrees of damage due to global settlement and differential settlement. Significant amounts of silty sand are present in the upper few meters at some sites.

- *Project 3: Tonkin & Taylor Liquefaction Vulnerability Study (12 'T&T' sites)*

Each site in the Liquefaction Vulnerability Study has one CPT sounding and one nearby soil boring with sampling. Sites were selected by Tonkin & Taylor to evaluate differences between CPT-based and SPT-based liquefaction triggering procedures.

- *Project 4: Virginia Tech & Univ. of Canterbury & Others Liquefaction Triggering Study (25 'VT-UC' sites)*

The VT-UC sites are described in Green et al. (2014). The authors state that they:

… selected 25 sites to analyze in detail, many of which had minor surficial liquefaction manifestations resulting from the Darfield or Christchurch earthquake. The sites were evaluated during both these events, resulting in 50 high-quality case histories. The sites selected for detailed evaluation were located relatively close to strong ground motion stations and were characterized by both CPT soundings and surface wave testing.

Role of Supporting Studies

We envision the NGL liquefaction triggering and effects models as being 'semi-empirical', meaning that both empirical data analysis and results of supporting studies will be considered (to varying degrees) in model development. Supporting studies are needed to examine specific technical issues that are essential for model development but which cannot be resolved solely on the basis of empirical data, even after the database is expanded in the manner described above.

Some of the topics to be considered by such teams are envisioned to include liquefaction at large depth, pore pressure generation and strength loss in soils having high fines content and intermediate levels of plasticity, liquefaction of gravels, age effects on liquefaction resistance, potentially increased liquefaction resistance of thin soil layers near drainage boundaries (or the upper portion of relatively thick layers near the boundary), and volume change/shear deformations of soils having variable levels of density, fines content, and overburden stress. Some of these issues can be addressed by high-quality laboratory tests; centrifuge or large shake table model testing may also be used to resolve others. Still others may be addressed with numerical modeling of problems that employ well-calibrated constitutive models. Table 5 lists several topics that have been identified in international workshops, provides a brief explanation of the technical issues, and cites examples of prior work in the subject area.

For each of these technical issues, our approach will be to evaluate work to date on the subject, identify further research needs to further develop understanding of the issue so that it can be modelled, support projects to develop this understanding, and ultimately incorporate appropriate representations of the effect in NGL models.

Table 5 only pertains to liquefaction triggering models. Supporting studies will also likely be needed for a range of issues related to liquefaction effects, including ground settlement, structure settlement, post-liquefaction shear strength, and lateral spreading.

Table 5. Example topics where supporting studies are needed for NGL liquefaction triggering model development

Topic	Issues	Example references
Liquefaction at depth	• Empirical data constrains models for depths, $z < \sim 12$ m • Large epistemic uncertainty in r_d models for $z > \sim 3$ m. Effects of profile, ground motion, and soil nonlinearity poorly understood. • Large epistemic uncertainty in K_σ models • Modest epistemic uncertainty in factors for penetration resistance normalization, C_N	r_d: Youd et al. (2001); Cetin et al. (2004), Idriss (1999), Kishida et al. (2009) K_σ: Cetin et al. (2004); Boulanger (2003a) C_N: Youd et al. (2001); Boulanger (2003a); Robertson (2012); Montgomery et al. (2014)
Effects of fines	• Compared to clean sands, soils with fines have reduced penetration resistance and different liquefaction 'strength' or resistance for a given state (or relative density, in case of non-plastic fines) • Current modeling approaches are empirical, which combines the two effects. Preferred approach is to understand each effect and its sensitivity to fines content and fines plasticity	Effects on penetration resistance: Carraro et al. (2003) Effects on liquefaction strength: Polito and Martin (2001) *Approximate combined effects*: all recent triggering models
Ageing effects	• Empirical data is mostly from artificial fills and young (Holocene) sediments • For a constant relative density, older materials have higher penetration resistance and higher liquefaction resistance • The increase of liquefaction resistance is greater than predicted by the increased penetration resistance, so additional corrections needed.	Leon et al. (2006); Hayati and Andrus (2009); Andrus et al. (2009); Maurer et al. (2014)
Effects of static shear stress	• Effects of normalized static shear stress, α, not included in most current models. • One published model for effect of α on liquefaction resistance, but lack of community consensus	Boulanger (2003b)

Anticipated Products and Next Steps

As with prior NGA projects for ground motions, the NGL project deliverables are anticipated to consist of data resources and engineering predictive models. The data resources will include the NGL database and flatfile, as described previously. The liquefaction models will consist of probabilistic models for liquefaction susceptibility, triggering, and effects. The liquefaction triggering models will consist of equations for the limit state function representing the boundary between liquefaction and non-liquefaction. The liquefaction effects models will enable computations of free-field settlements, foundation settlements, free-field displacements from lateral spreading, and post-liquefaction liquefied shear strength.

Because liquefaction and ground failure analyses are routine in engineering practice and are of great practical importance, we anticipate the development of guidelines documents for application, likely tailored to needs of various agencies (e.g., Nuclear Regulatory Commission, State Departments of Transportation, U.S. Army Corps of Engineers).

As mentioned in the introduction, as of this writing, NGL is at present a concept that enjoys broad community support, but which is not yet fully launched due to pending funding commitments. Work to date has largely consisted of compilation of high-value data as described in this paper and the holding of workshops to develop the project vision. We expect the project to expand in scope and activity in 2016.

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Attachment 3 – Quality Assurance Checklists

Inputting Checklist

Title[1]: Data type: Records count:	
Name: From[3]: Description:	Signature:

Item	Check	Date[2]
Data collection		
Scanned copies (Flatfiles)		
Listing flatfiles in draft databse		
Data digitization		
Data entry into draft database		
Initial checking		
Submission for cross-checking		

[1]Include site name
[2]Add data range if applicable
[3]Name the institute

Checking Checklist

Title[1]: Data type: Records count:		
Name: From[3]: Description:		Signature:
Item	Check	Date[2]
Data reception		
Data checking		
Submission for revision[4]		
Submission for verification[4]		

[1]Include site name
[2]Add data range if applicable
[3]Name the institute
[4]Only one of these fields has to be filled

Revision Checklist

Title[1]: Data type: Records count:	
Name: From[3]: Description:	Signature:

Item	Check	Date[2]
Data reception		
Data revision		
Initial checking		
Data re-submission for cross-checking		

[1]Include site name
[2]Add data range if applicable
[3]Name the institute

Verification Checklist

Title[1]:

Data type:

Records count:

Name: Signature:

From[3]:

Description:

Item	Check	Date[2]
Data reception		
Data verification		
Merging into the master database		

[1]Include site name
[2]Add data range if applicable
[3]Name the institute