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Extreme Events: Designing Earthquake Shake Tables to Demonstrate Structural Integrity and Soil Liquefaction

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Background and Research Goals

The goal of this research project was to develop two shaker tables in order to experiment with and demonstrate the effect of soil liquefaction and to build structures in the classroom. Soil liquefaction is a phenomenon where saturated soil loses its structural integrity during earthquake shaking and behaves like liquid.

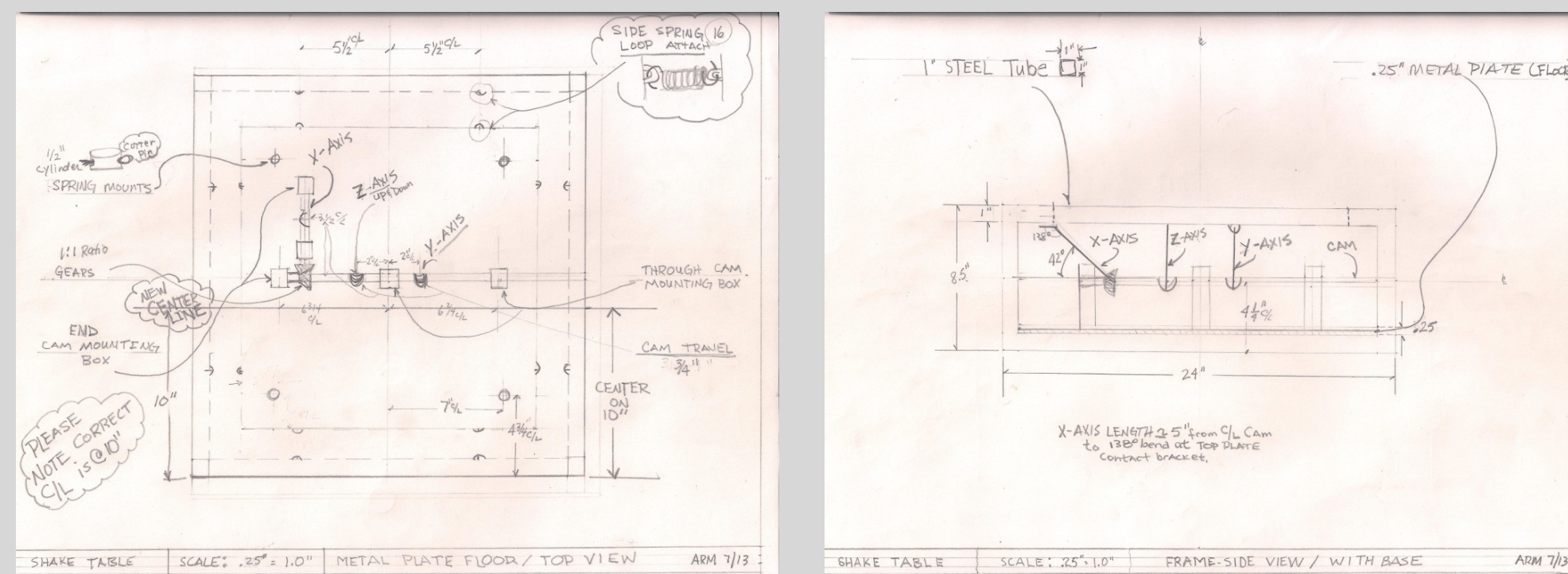
Structural earthquake engineering is an iterative process that strives to improve structural response to earthquake-induced forces. Earthquakes can cause walls to crack, foundations to move or settle, utility lines to rupture, and even entire buildings to collapse. In an effort to protect the public and avoid structural damage, engineers incorporate into their structural designs techniques that withstand these incredible forces. Some examples include cross bracing, tapered profiles, base isolation and tuned mass damping. In all cases, engineers develop an idea, test it, and then, based on its performance, re-engineer the structure until the desired outcome is reached.

Through this project students should be able to :

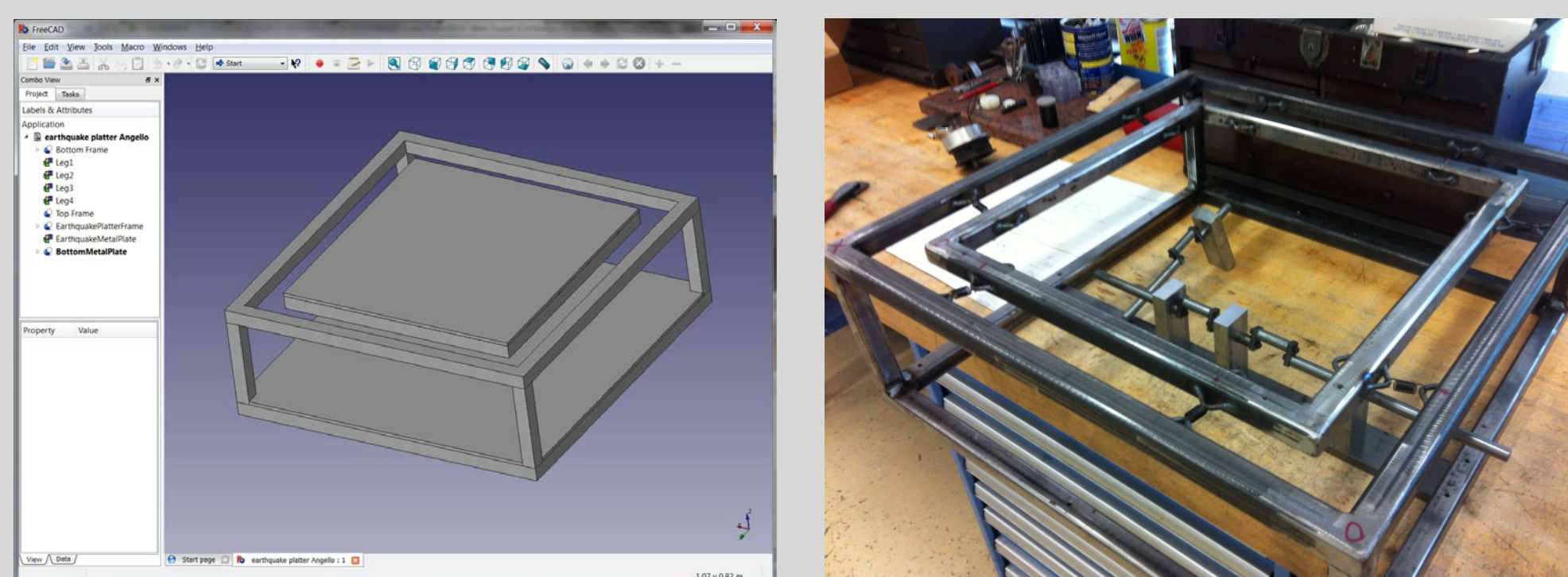
- Observe soil liquefaction and its potential destructive impact
- Identify the factors that make soils susceptible to liquefaction
- Identify the factors that make structures in liquefied soil susceptible to damage
- Explain why engineers need to study earthquakes
- Predict methods to improve and re-engineer the structure or soil profile to better resist damage
- Identify cause-effect relationships between earthquakes, liquefaction, and structures
- Describe how to apply what has been learned to new buildings and old buildings
- Summarize in a journal a record of observations and conclusions

Designs of Shaker Tables

Two shaker tables were designed for this project. One is powered manually using a crankshaft, while the other is powered using two DC motors. In both designs the shake platters are designed to be free floating and supported with springs to the main frame. The platters are also designed for motion along three axes, X, Y, and Z in order to simulate both P and S waves during earthquakes.

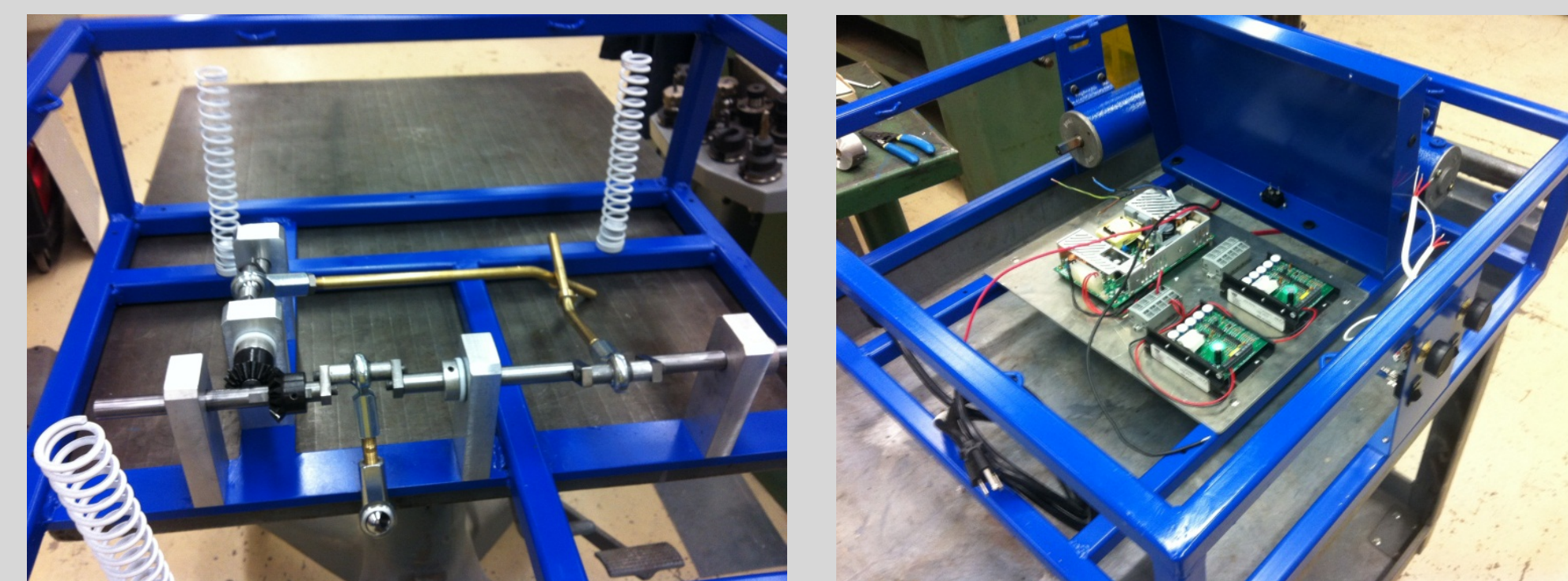


Initial design sketch



Computer drawing and early construction

Shaker Table Construction

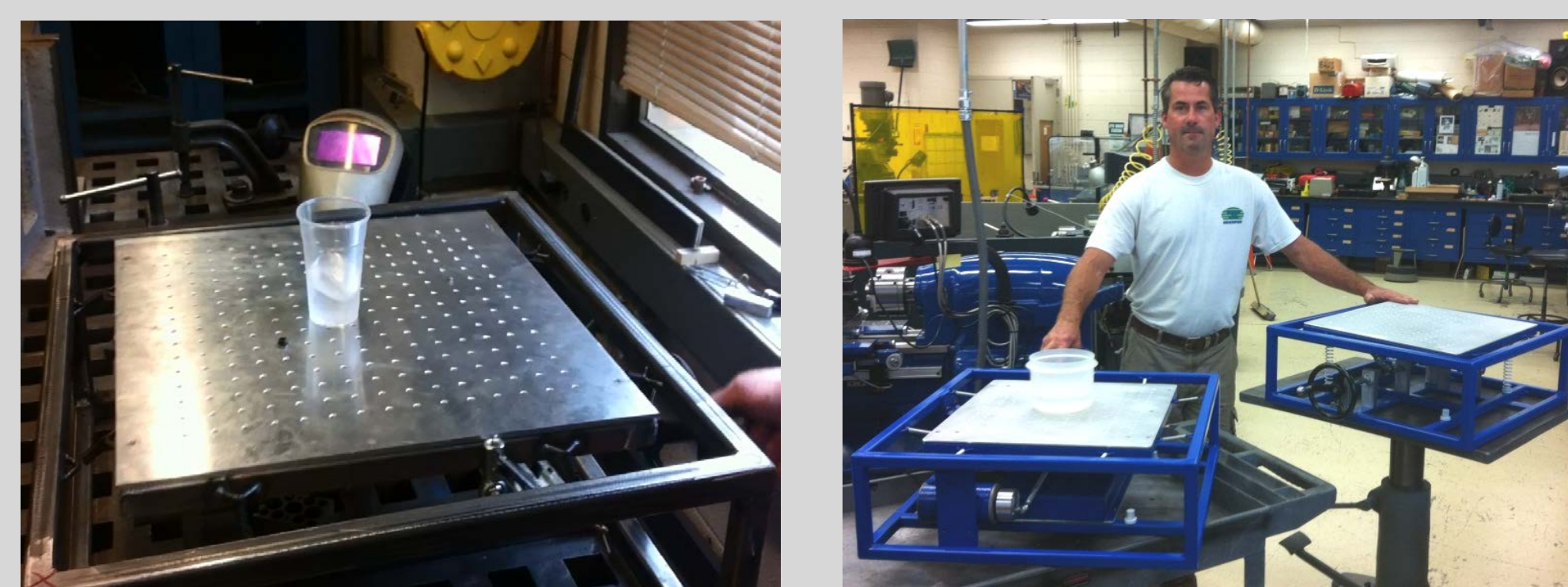


Crankshaft design

Motorized design



Completed shaker tables: crankshaft and motorized designs



Shaker table preliminary trial

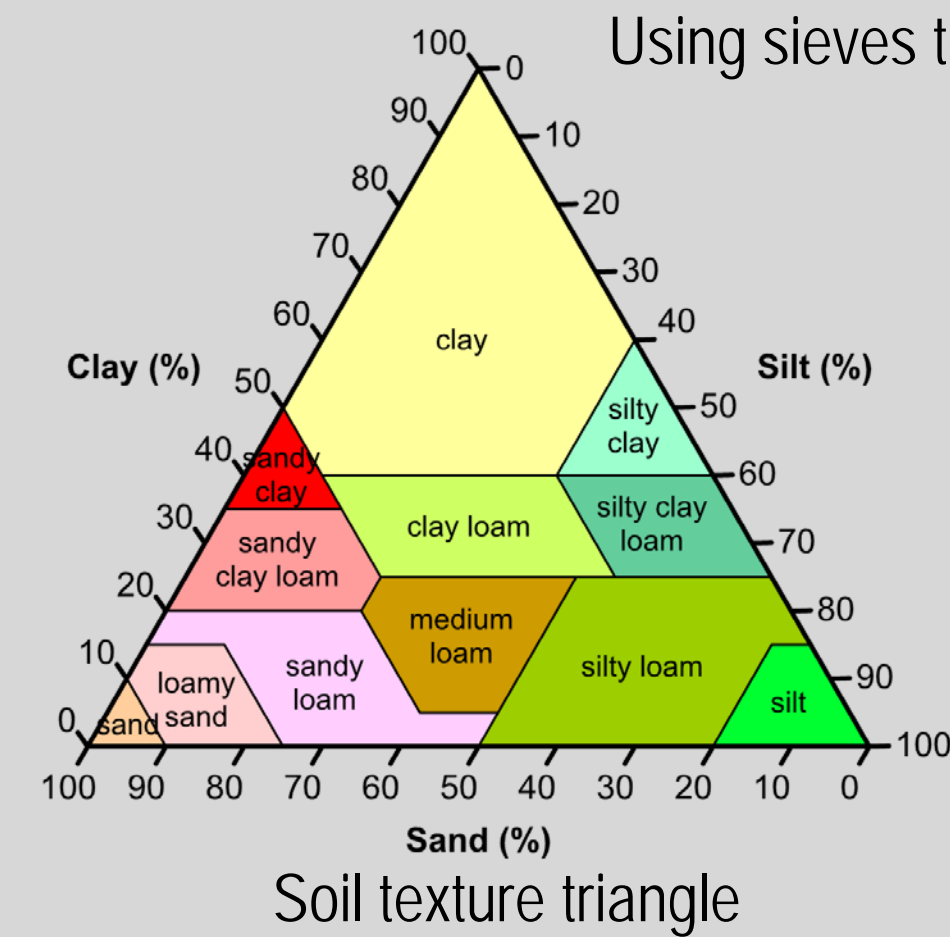
Shaker table fabricator, Kevin Cullinan of the UB CAS Machine Shop

Soil Box Construction

Two of the soil boxes constructed were uniform, one completely of sand and one of sorted gravel. The third soil box is of Western New York (WNY) soil that was collected from Tift Nature Preserve, sifted to remove debris, and mixed. The soil boxes are then saturated with water. At this time the structure is placed in the soil profile boxes and then placed on the shaker table. Simulation of an earthquake is then implemented to determine if soil liquefaction occurs and what happens to the structure that is built on that type of soil.

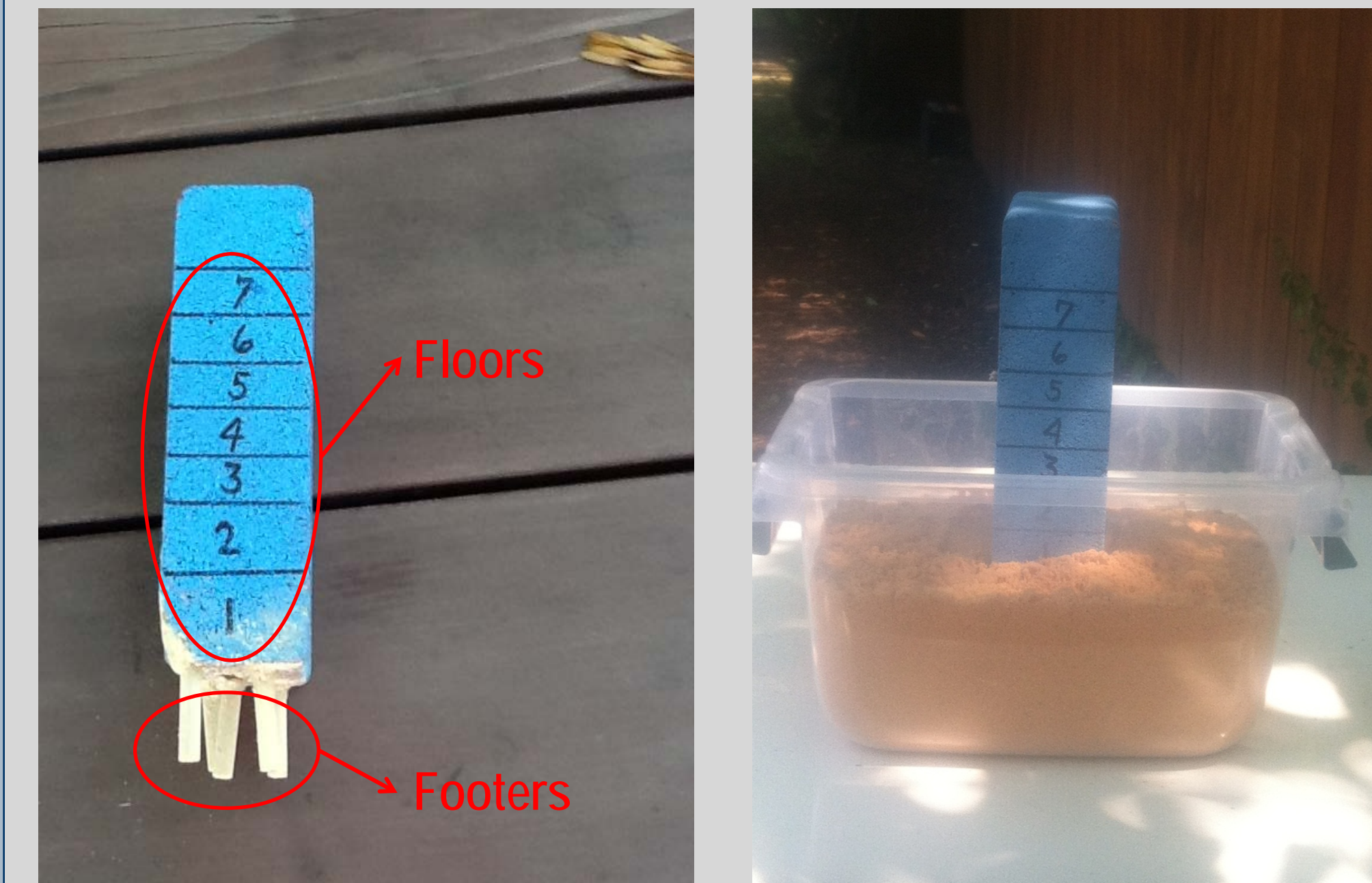


Using sieves to determine grain size of various soil profiles



Shaker table trial with saturated sand

Earthquake Experiment



Model structure made out of a brick

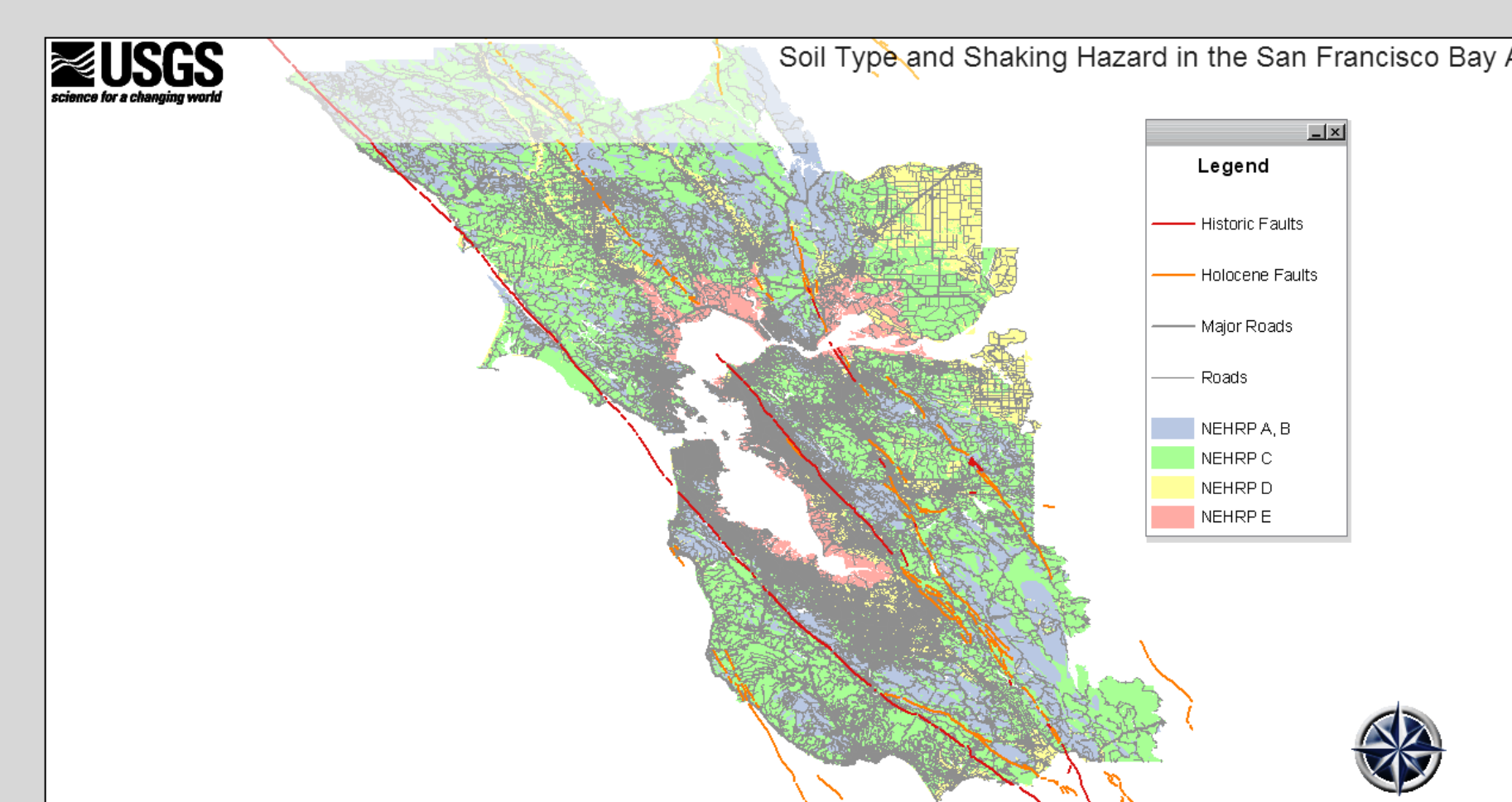
Model structure on soil box

Preliminary results of shaker table testing with three soil profiles:

	Composition	Result	
Sand	100% Sand (0.75 to 1.00 mm)	<ul style="list-style-type: none"> • Structure fails and sinks • Liquefaction occurs 	
Gravel	100% Sorted Gravel (>4 mm)	<ul style="list-style-type: none"> • Structure fails • No Liquefaction 	
Control (WNY Soil)	22% Clay, 43% Silt, 35% Sand	<ul style="list-style-type: none"> • Structure fails • Limited liquefaction 	

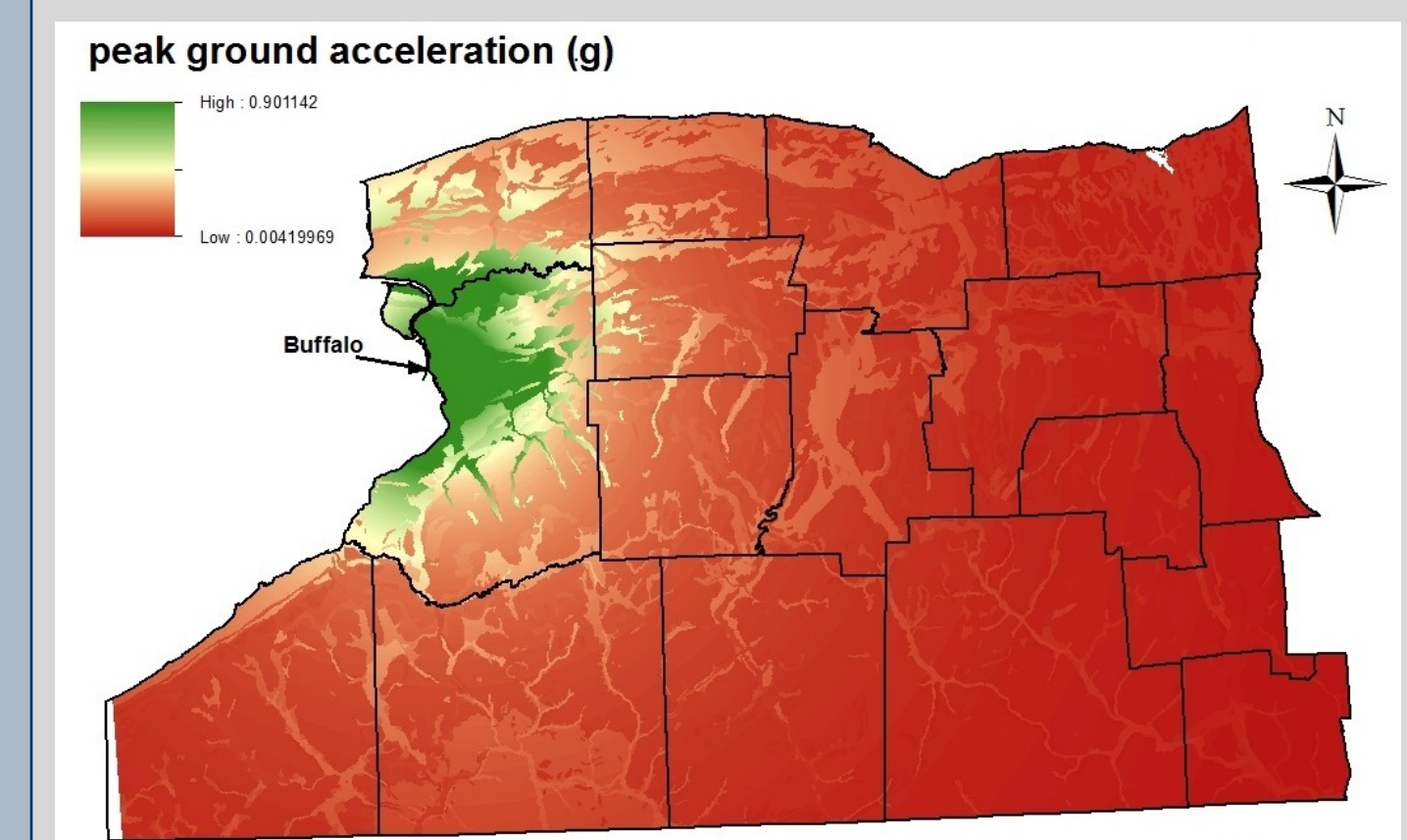
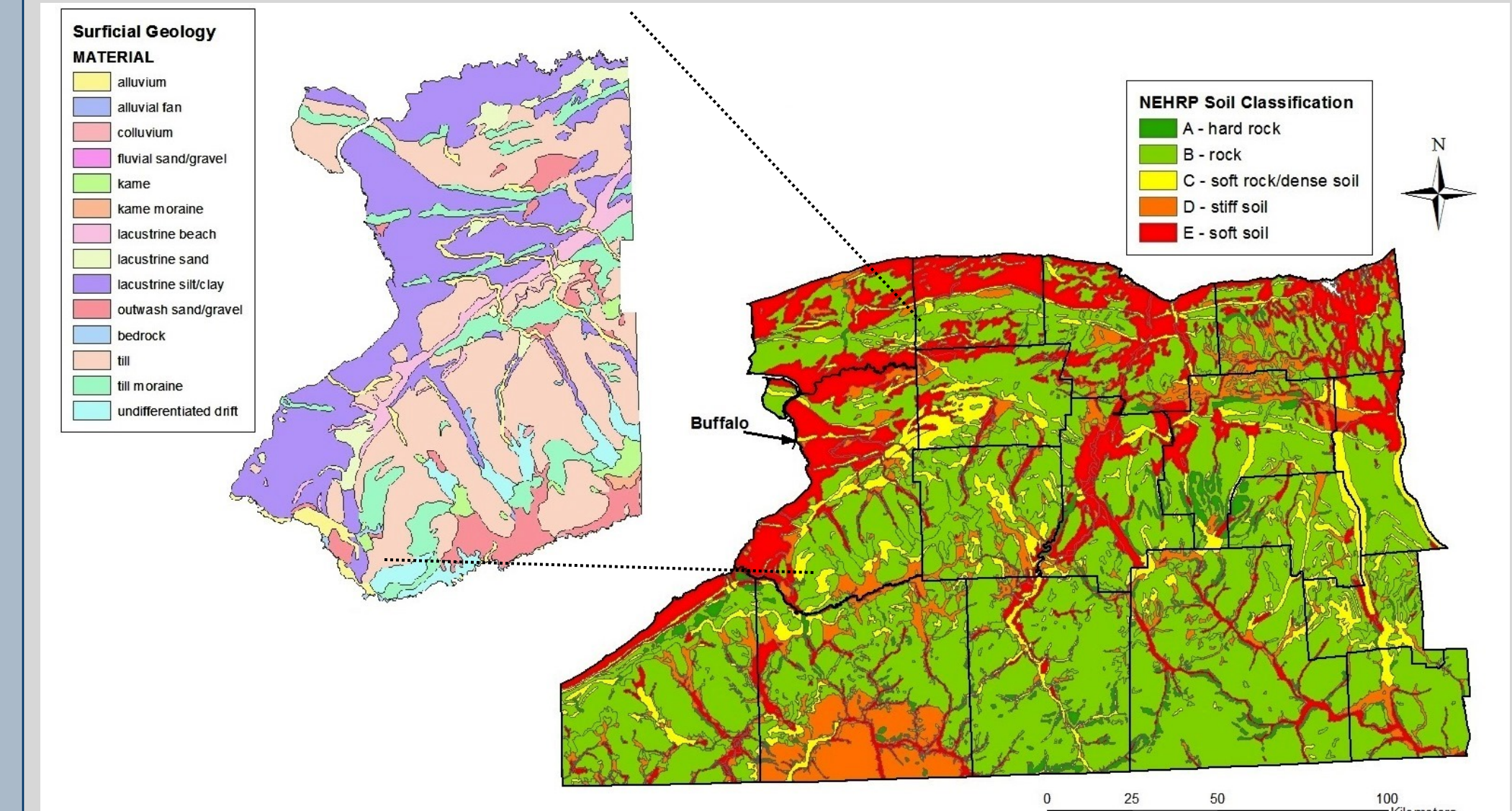
The experiments conclude that both shake tables are able to not only simulate an earthquake, but also recreate the soil liquefaction where water would rise to the soil surface. Students in the classroom will be able to replicate these results. They will also be able to identify the factors that would improve hazard safety in relation to where they live.

Spatial data for WNY soil composition was acquired from the U.S. Department of Agriculture and the National Earthquake Hazard Reduction Program and processed using GIS methodologies. This information makes it possible to recreate soil compositions reflecting any regions in the United States. For example students will be able to make a comparative study between WNY regions and regions with high earthquake risk, such as areas along the San Andreas fault in California.

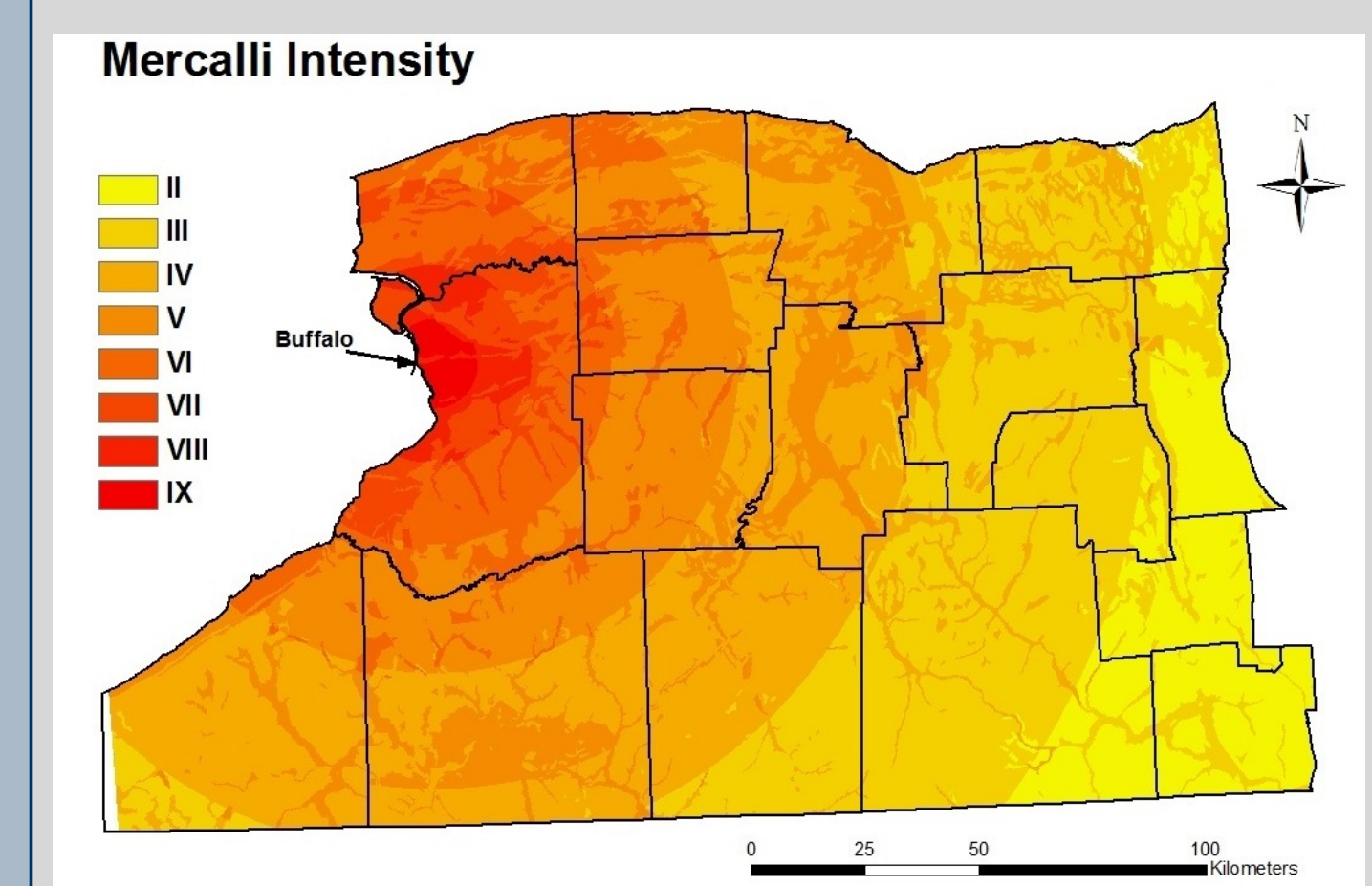


Spatial Analysis of WNY Geology and M-7 Earthquake

1) Local soils were classified into five types according to their potential to amplify ground shaking during an earthquake based on previous shear wave velocity tests.



2) Peak ground acceleration (PGA) was then calculated using a distance attenuation formula and separate amplification factors for each soil class. PGA is modeled here for a theoretical magnitude 7 earthquake with an epicenter in Buffalo, NY.



3) PGA relates directly to the Mercalli Intensity scale, which is a description of how earthquakes are experienced by humans and infrastructure.

Classroom Implementation of Research

DIRECT:

Shaker Table Experiments – The tables will be used in the classrooms to experiment with responses by different soils and structures. Students can operate the tables themselves and design their own structures for testing.

Triangulation Lab – Students will determine where three seismograph stations are located, given a know epicenter.

INDIRECT (INQUIRY-BASED):

Emergency Evacuation – Given maps of local infrastructure and a modeled earthquake scenario, students will predict what infrastructure is likely to fail. They will then design their own emergency evacuation plans, taking into account traffic patterns and knowledge of which locations are most likely to be damaged based on maps of Mercalli Intensity.

Mass Movement – Teachers will use Abaqus simulation modeling to demonstrate different mass movements that cause structural damage.