UCLA Samueli Civil & Environmental Engineering

Next Generation Liquefaction Supported Modeling Team Approach

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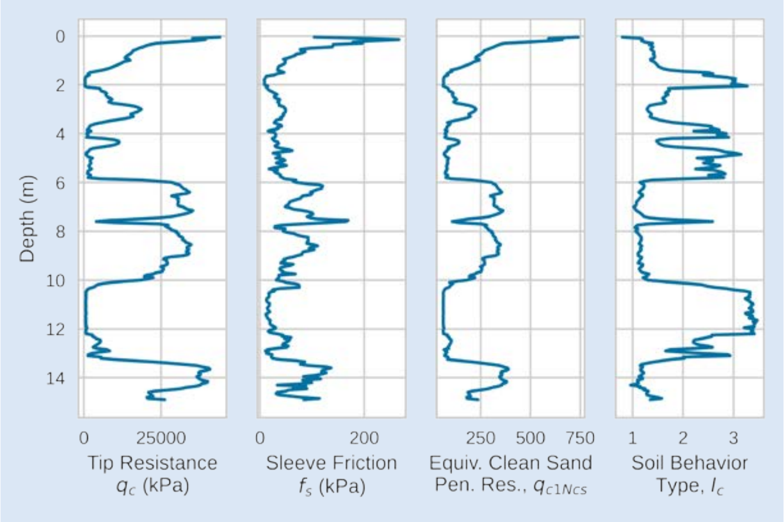
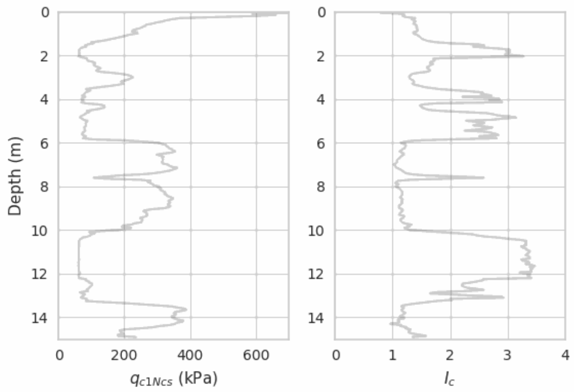
The Supported Modeling Team (SMT) of the Next Generation Liquefaction (NGL) project is charged with developing a liquefaction triggering model. The SMT is pursuing a three-phase approach to development of a triggering model with the goal of producing a consistent, objective, transparent, and well-documented framework for case history data processing, interpretation, uncertainty quantification, and regression.

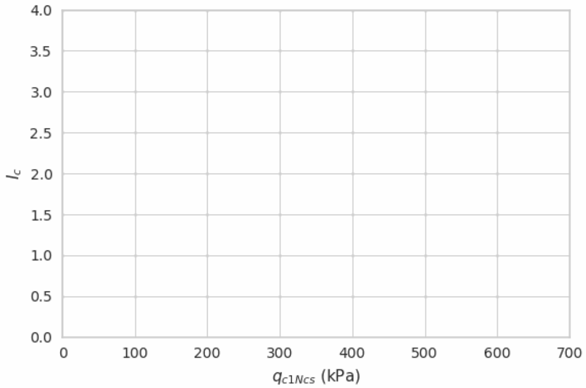
Phase 1

DATA-DRIVEN INITIAL INTERPRETATION OF RAW CASE HISTORY DATA

Phase 1A: Layer Detection Algorithm for CPT

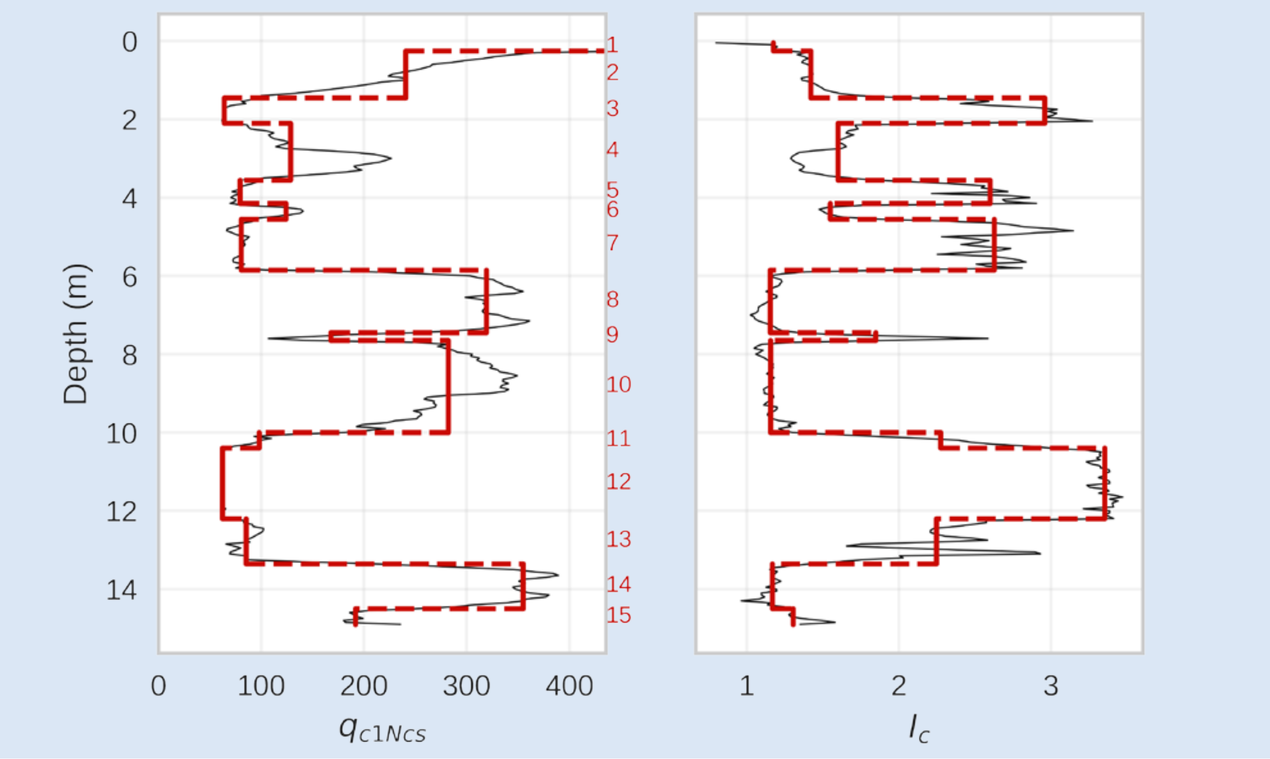






We developed a layer detection algorithm for creating simplified profiles for critical layer selection using Agglomerative Clustering

Phase 1A: Layer Detection Algorithm for CPT



Phase 1C: Preliminary Critical Layer Selection

NOTATION

We are implementing variables that account for probability of susceptibility in critical layer selection

$$q_{cp} = \frac{q_{c1Ncs}}{P_{susc.}}$$

$$FS_{Lp} = \frac{FS_L}{P_{susc.}}$$

$$\varepsilon_{vp} = \varepsilon_v \cdot P_{susc.}$$

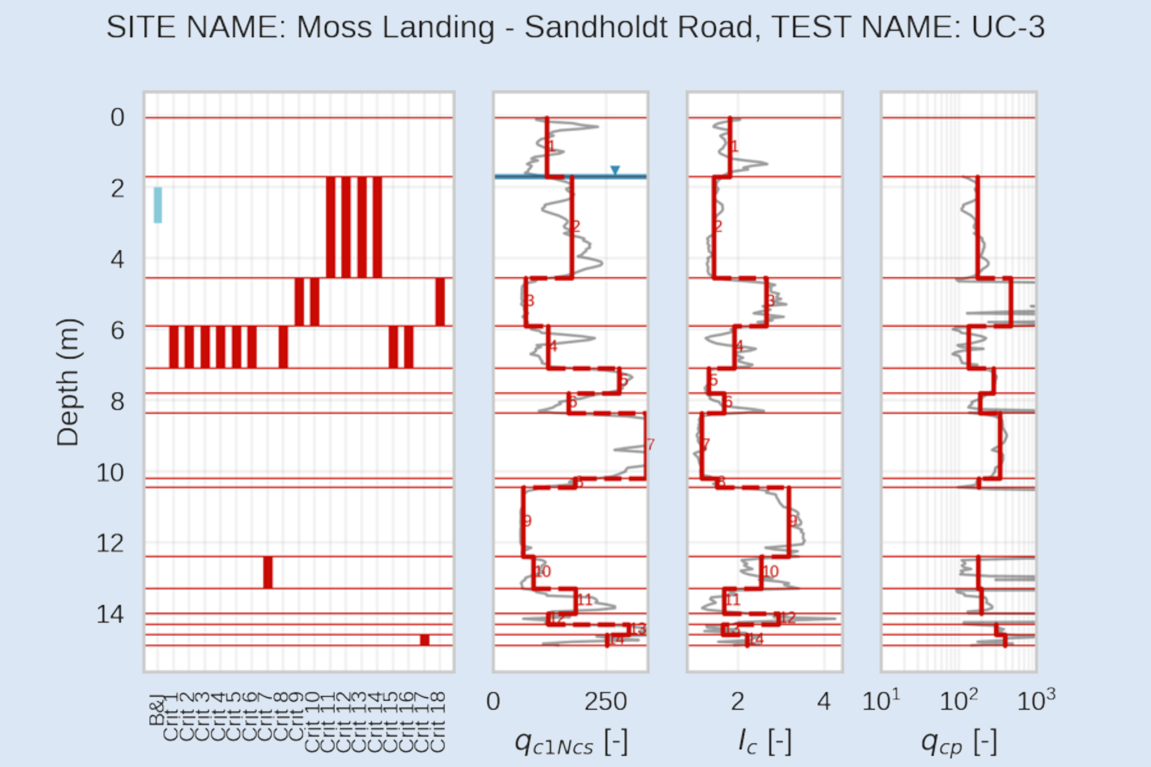
Where q_{cp} is the tip resistance adjusted for probability of susceptibility,
$P_{susc.}$ Is the probability of susceptibility, such as a function based on I_c (Maurer et al., 2017),
q_{c1Ncs} is the equivalent clean sand penetration resistance,
FS_L is the factor of safety against liquefaction (the ratio of cyclic stress to cyclic resistance),
FS_{Lp} is the factor of safety against liquefaction adjusted for susceptibility,
ε_v is the volumetric strain,
and ε_{vp} is the volumetric strain adjusted for susceptibility

Phase 1C: Preliminary Critical Layer Selection

We developed 18 different criteria for critical layer selection. Each criterion selects a layer, and the critical layer is chosen as the layer with the most criteria selecting it. The first two criteria are listed below as examples.

No.	Critical Layer	Comments
1	Layer with lowest value of q_{cp} within it	Simple, easy
2	Layer with lowest value of $\overline{q_{cp}}$ based on average of q_{cp} values	Straight average of all values within layer.

Phase 1C: Preliminary Critical Layer Selection



Phase 2

REVIEW AND REVISION OF LAYER DETECTION AND SELECTION

Phase 2: Review

REVIEWING AND EDITING SELECTION ALGORITHMS

We are looking carefully at the layering algorithm and critical layers selections compared with prior published critical layer selections and adjusting calculations to reflect better judgement

CONFIRMING OR MODIFYING RESULTS

Reviewing many “problematic” CPTs and selecting layers that are better based on the SMT’s judgement

Phase 3

DEVELOPMENT OF PROBABILISTIC TRIGGERING MODEL

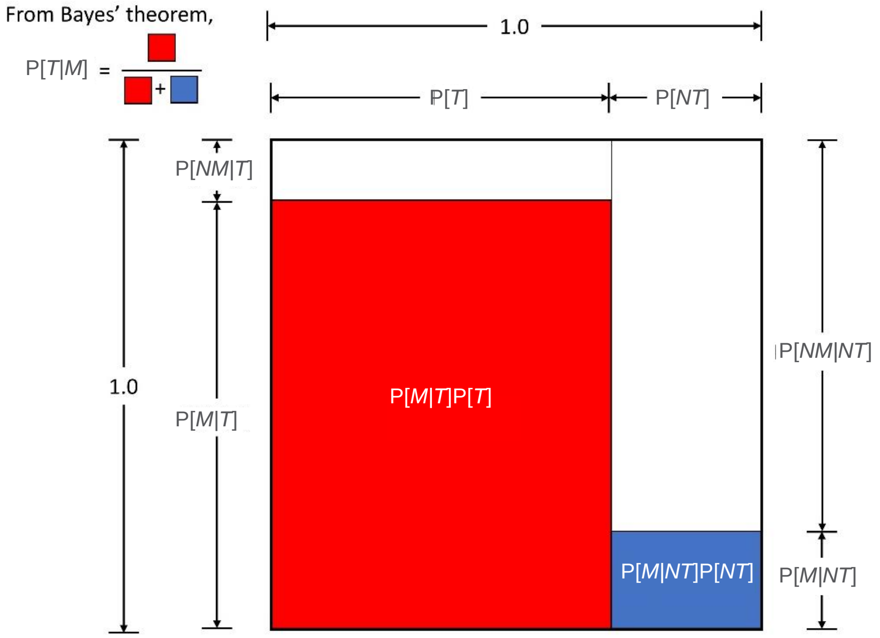
Phase 3: Probabilistic Triggering Model Development

BAYES' THEOREM

$$\mathrm{P}[T|M] = \frac{\mathrm{P}[M|T]\mathrm{P}[T]}{\mathrm{P}[M]} = \frac{\mathrm{P}[M|T]\mathrm{P}[T]}{\mathrm{P}[M|T]\mathrm{P}[T] + \mathrm{P}[M|NT]\mathrm{P}[NT]}$$

Probability	Description
P[*T*]	Probability that the critical layer triggers. For now, assume we know this (more later).
P[*NT*]	Probability that critical layer doesn't trigger = 1 – P[*T*]
P[*M*|*T*]	Probability of manifestation given that critical layer triggers. A probabilistic version of Hutabarat model would provide this.
P[*NM*|*T*]	Probability that no manifestation occurs even when the susceptible soil layer triggers.
P[*M*|*NT*]	Probability that high pore pressures (but not high enough to trigger liquefaction) cause sand boils or other observations we usually interpret as manifestation of liquefaction. Can potentially occur with thick liquefiable layer under thin crust.
P[*NM*|*NT*]	Probability that no manifestation is observed when liquefaction is not triggered.

Phase 3: Probabilistic Triggering Model Development



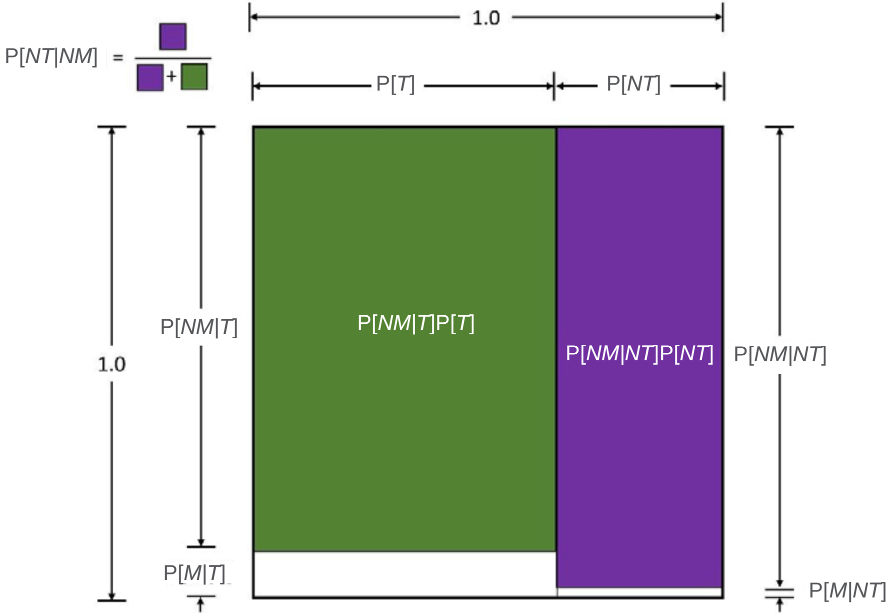
BAYES' THEOREM VISUALIZATION

The red zone is the probability of manifestation due to triggering of the liquefiable layer

The blue zone is the probability of manifestation in the absence of triggering

For P[*T*] = 0.7, P[*M*|*T*] = 0.9, and P[*M*|*NT*] = 0.2 (approximately the values in the figure), P[*T*|*M*] = 0.913 – almost, but not quite certain, triggering.

Phase 3: Probabilistic Triggering Model Development



BAYES' THEOREM VISUALIZATION

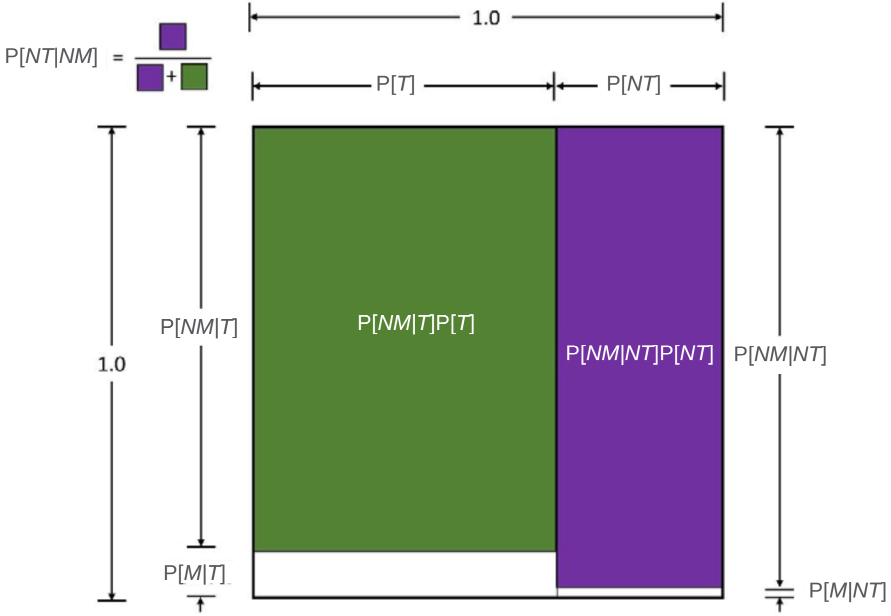
The purple zone is the probability of no manifestation when the liquefiable layer does not trigger

The green zone is the probability of no manifestation if liquefaction is triggered

For P[*T*] = 0.7, P[*M*|*T*] = 0.1, and P[*M*|*NT*] = 0.02 (approximately the values in the figure), P[*T*|*M*] = 0.921

However, P[*NT*|*NM*] would only have been 0.318, meaning that no manifestation means no triggering is a bad assumption

Phase 3: Probabilistic Triggering Model Development



BAYES' THEOREM VISUALIZATION

If this case history had a "no manifestation" observation, then we could represent it using two co-located points on penetration resistance-CSR space, one "open circle" point with a weighting factor of 0.318 and one "closed circle" point with a weighting factor of 0.682.

In the past, this would just be an "open circle" point. – almost, but not quite certain, triggering.

Thank You