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CEC Project – Seismic Risk Assessment Tool for Natural Gas Storage and Transportation Systems

PEER Researchers' Workshop
September 19, 2022

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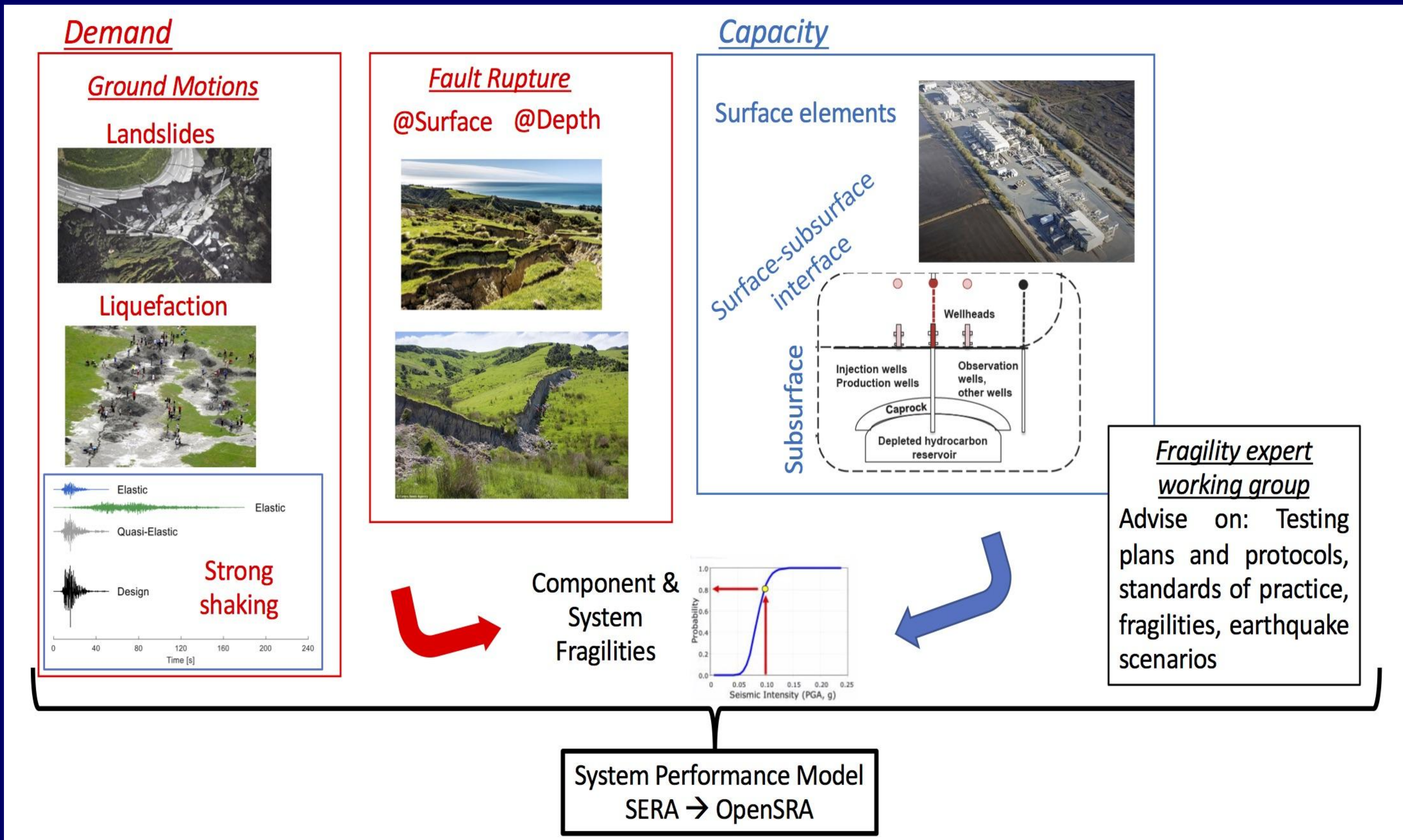
Proposed Seismic Risk Methodology



Open Seismic Risk Assessment (OpenSRA) Tool

Project Teams

DR. THOMAS O'ROURKE

Hazards

Liquefaction and Landsliding

- University of California, Berkeley (UCB)
- Dr. Thomas O'Rourke
- Lettis Consultants International, Inc. (LCI)

Fault Displacement Hazard

- Lettis Consultants International, Inc. (LCI)

System Fragility

Fragility of Buried Pipelines

- University of California, Berkeley (UCB)

Fragility of Wells and Caprocks

- Lawrence Berkeley National Laboratory (LBNL)

Fragility of Above Ground Systems and Components

- University of California, San Diego (UCSD)
- University of Nevada, Reno (UNR)

Other Objectives

Monitoring Technology

- University of California, Berkeley (UCB)

OpenSRA Development

- Slate Geotechnical Consultants, Inc. (Slate)
- NHERI SimCenter

Efficient Risk Calculation

- University of California, Berkeley (UCB)

General

Project Management

- Slate Geotechnical Consultants, Inc. (Slate)

Outreach and Upkeep

- Pacific Earthquake Engineering Research Center (PEER)

Project Tasks

Task	Task Description	Status
2	Sensitivity Analysis	Complete
3	OpenSRA Development	Complete
4a	Fault Displacement Hazard	Complete
4b	Regional Liquefaction and Ground Deformation	Complete
4c	Seismic Response of Wells and Caprocks	Complete
4d	Seismic Response of Pipelines and Gas Storage	Complete
4e	Sensor and Monitoring Technologies	Complete
4f	System Wide Response and Fragility Model	Draft
5	Validation	Draft
6	User Workshop	January 11, 2023

Project reports can be found at:
Peer.Berkeley.edu/OpenSRA

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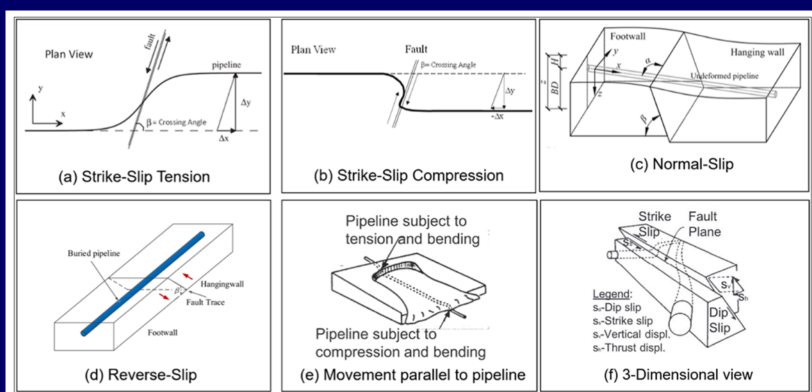
Task 4b: Pipeline Fragility Curves – Ground Shaking

Modeling



Damage Model

$$\ln(\varepsilon_{comp}) = \frac{\tanh^{-1}\left(\frac{\ln \Delta_f - b_0}{b_1}\right)}{b_2} - 4 \pm \sigma_{\ln \varepsilon}$$

where:

ε_{comp} is the pipe longitudinal compressive strain (%);
Δ_f is the input ground deformation (m);
$\sigma_{\ln \varepsilon} = 0.571$ is the standard deviation of the model (natural log units);
β_u=0.3 is the estimated model epistemic uncertainty;
$b_0 = -6.50785 + 0.98692\, D + 0.01601\, L_a + (-0.04575\, F_\beta)$;

$b_1 = 4.54097 - 0.01093\, L_a$;

$b_2 = 0.34262 + (-0.10918\, D) + 0.00197\, L_a + 0.0027\, F_\beta$;

$$F_\beta = \begin{cases} 0, & for\ 120 < \beta < 175 \\ \beta - 120, & for\ 95 < \beta \le 120' \end{cases};$$

where:

D is the outside pipe diameter (m);
L_a is the pipeline anchorage length (m);

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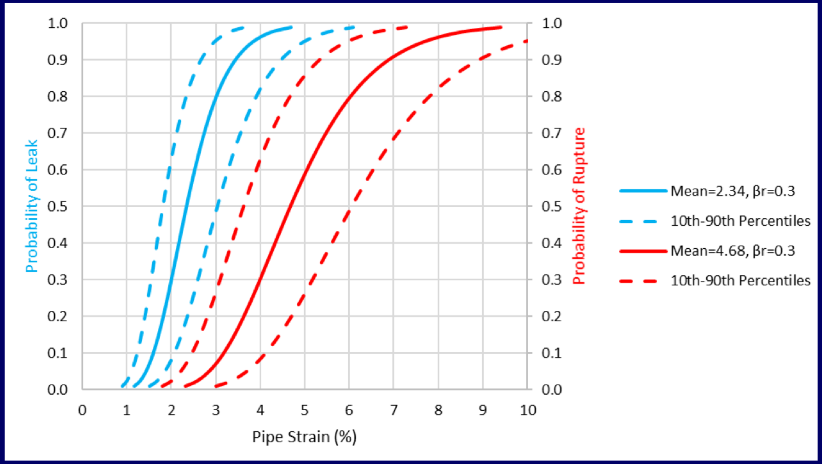
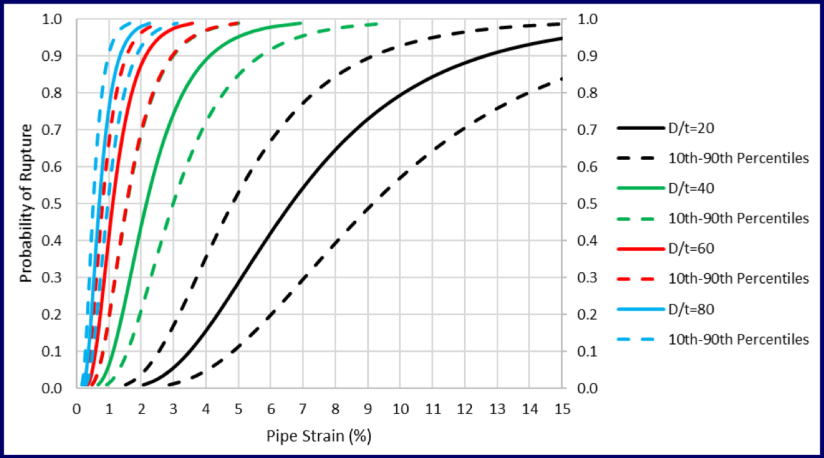
Task 4b: Pipeline Fragility Curves – Ground Shaking

Tensile State



Compressive State



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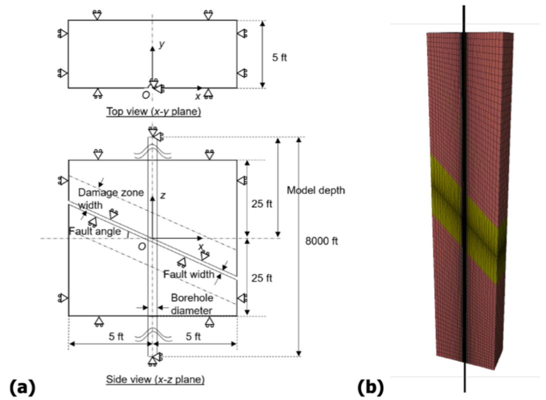
Task 4c: Well Fragility Curves – Fault Displacement

Modeling



(a) The geometry and boundary conditions of the well shear model; (b) an overview of the model in FLAC3D (brown is intact rock, dark yellow fault zone).

Damage Measure Model

First Well Mode with Cement – Tubing

$$\gamma_{tubing} = b_0 + b_1\theta + b_2\theta^2 + b_3W_{fc} + b_4W_{dz} + b_5E_{rock} + b_6{E_{rock}}^2 + b_7(FD - Inflection)$$

Where:

$$Inflection = 0.1605 - 0.004\theta + 7 * 10^{-5}\theta^2$$

γ_{tubing} is the mean shear strain on the tubing (fractional strains);
θ is the fault intersection angle with the well (degree);
W_{fc} is the fault core width (m);
W_{dz} is the damage zone width (m);
E_{rock} is the Young's modulus of the rock (GPa);
FD is the fault displacement (m);
$b_0, b_1, b_2, b_3, b_4, b_5, b_6, b_7$ are the model coefficients given in Table 20;
σ for the model is also provided in Table 20;

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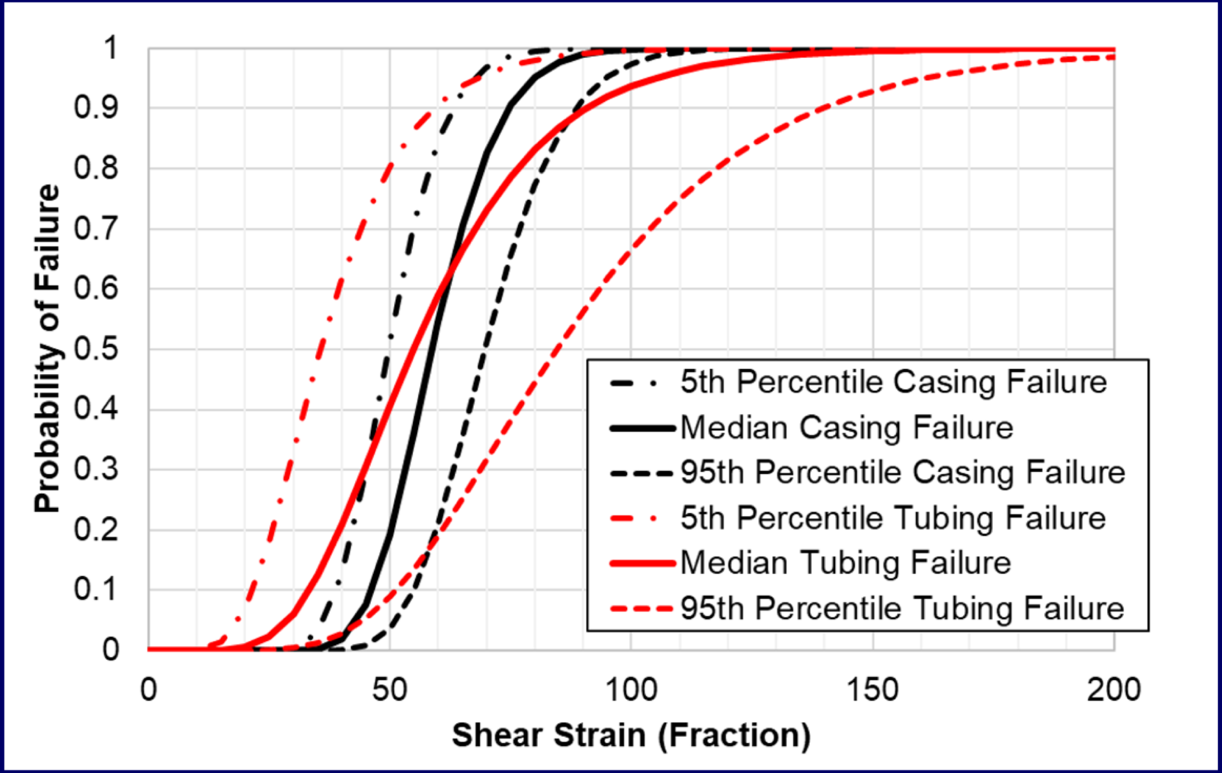
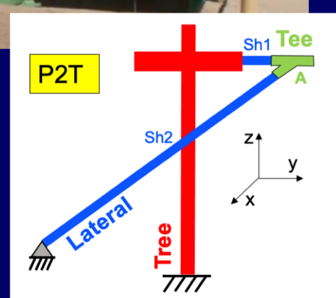
Task 4c: Well Fragility Curves – Fault Displacement

Fragility Model



Task 4d: Wellhead Fragility Curves – Ground Shaking

Modeling



Damage Model

$$\ln(Rot) = b_0 + b_1 ln(H_t) + b_2 ln(L_2) + b_3 ln(L_6) + b_4 ln(PGA) + b_5 ln(H_t)^2 + b_6 ln(L_2)^2 + b_7 ln(L_6)^2 + b_8 ln(PGA)^2$$

Where,

Rot is the median rotation (degree);
H_t is the entire height of the well tree (ft);
L_2 is the length of pipe segment 2 (ft);
L_6 is the length of pipe segment 6 (ft);
PGA is the peak ground acceleration of the ground motion (g); and
b_0 to b_8 are regression coefficients given by Table 31.

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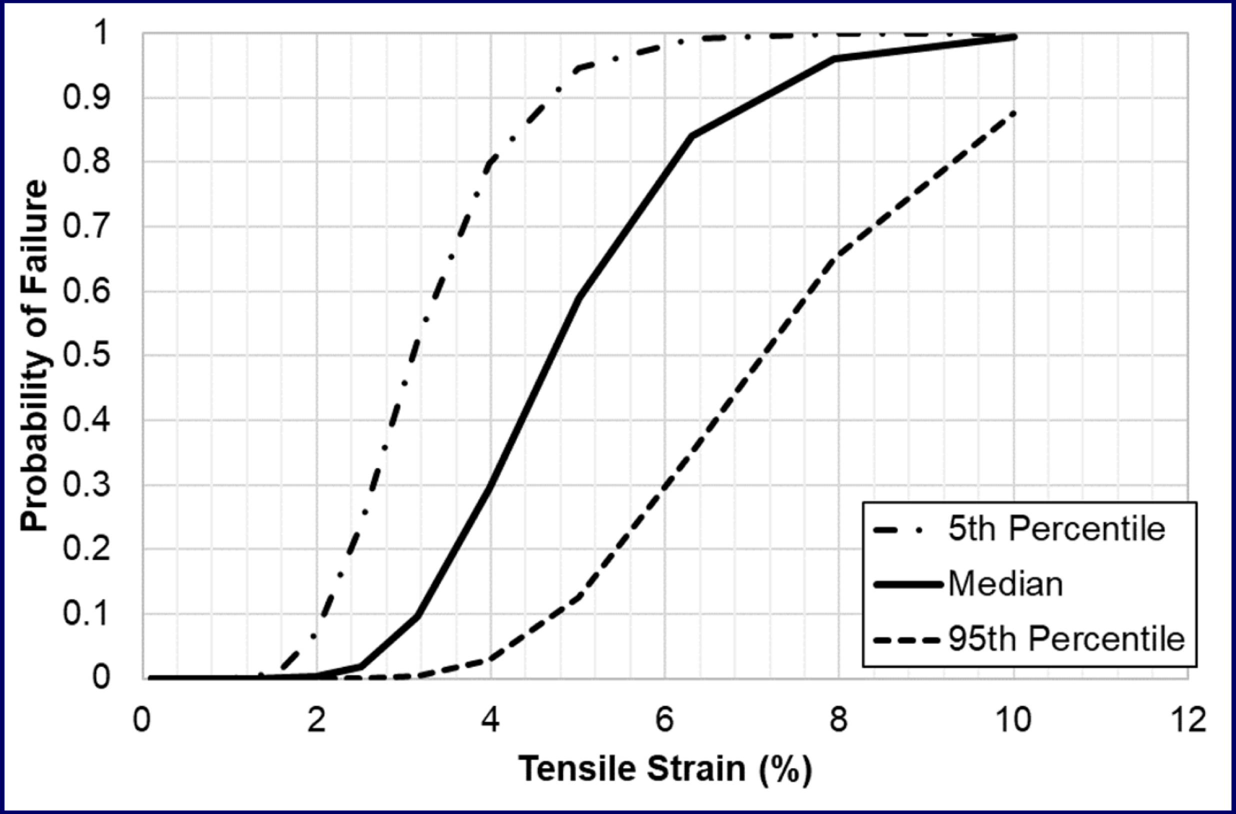
Task 4d: Wellhead Fragility Curves – Ground Shaking

Fragility Model



Main Deliverable: OpenSRA

- Capabilities:
  - Deterministic Scenarios
  - Shake map integration
  - Risk
  - Map based results
  - Individual component results
- Flexible software that can incorporate a range of input data and capabilities

Questions?

Join us January 11th for the User Workshop!

Details coming in the next few weeks.