UC DAVIS CIVIL AND ENVIRONMENTAL ENGINEERING

PEER

Caltrans

UC DAVIS UNIVERSITY OF CALIFORNIA

Development of Performance-Based Multi-hazard Engineering (PBME) Framework with Inclusion of Climate Change and Bridge Vulnerability

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Outline

❖ Introduction

- Objectives and relevance
- Existing frameworks

❖ Current Work

- Proposed framework
- Implementation of general framework for single hazards

❖ Planned Work

- Scour experiment plan
- Deliverables and timeline

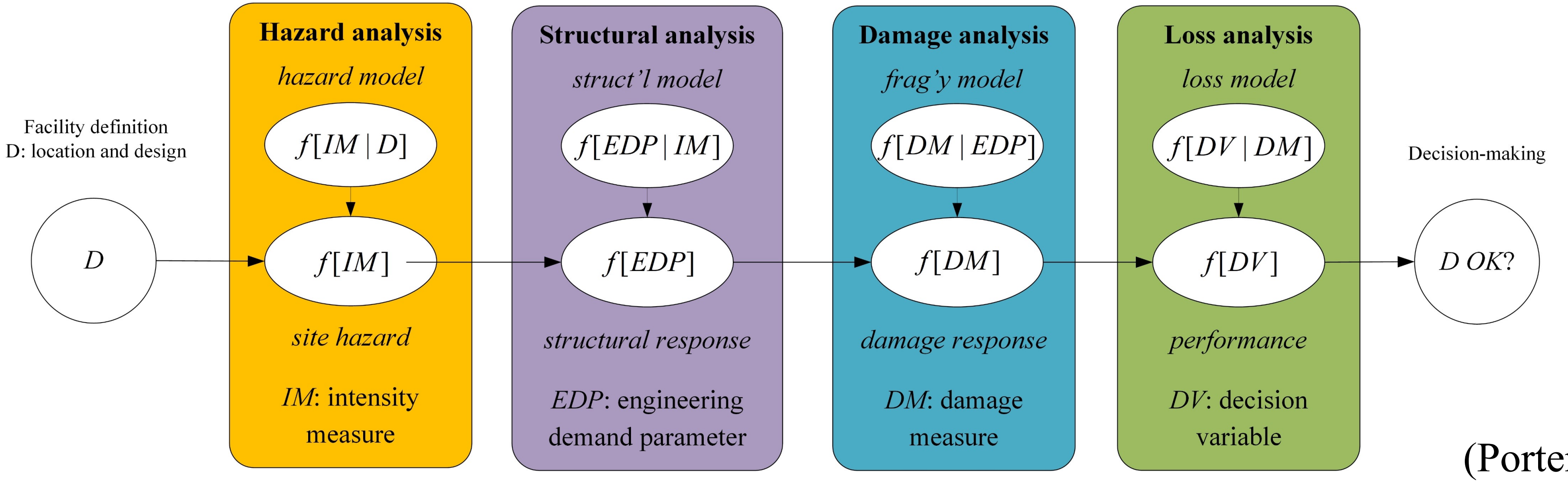
Objectives

- Formulating new theoretical framework for Performance-Based Multihazard Engineering (PBME) accounting for both hazard and vulnerability non-stationarity
- Implementing this framework for seismic and scour risk analysis of bridges
- Adapting the proposed framework to include interaction between seismic and scour hazards
- Documenting project's results and developing a possible plan for implementation

Relevance

- Addressing significant effects of climate change and structural aging
- Assessing and reducing risk for bridges subject to seismic and scour hazards
- Developing recommendations for (Caltrans/AASHTO) design standards

Performance-Based Earthquake Engineering (PBEE) Framework

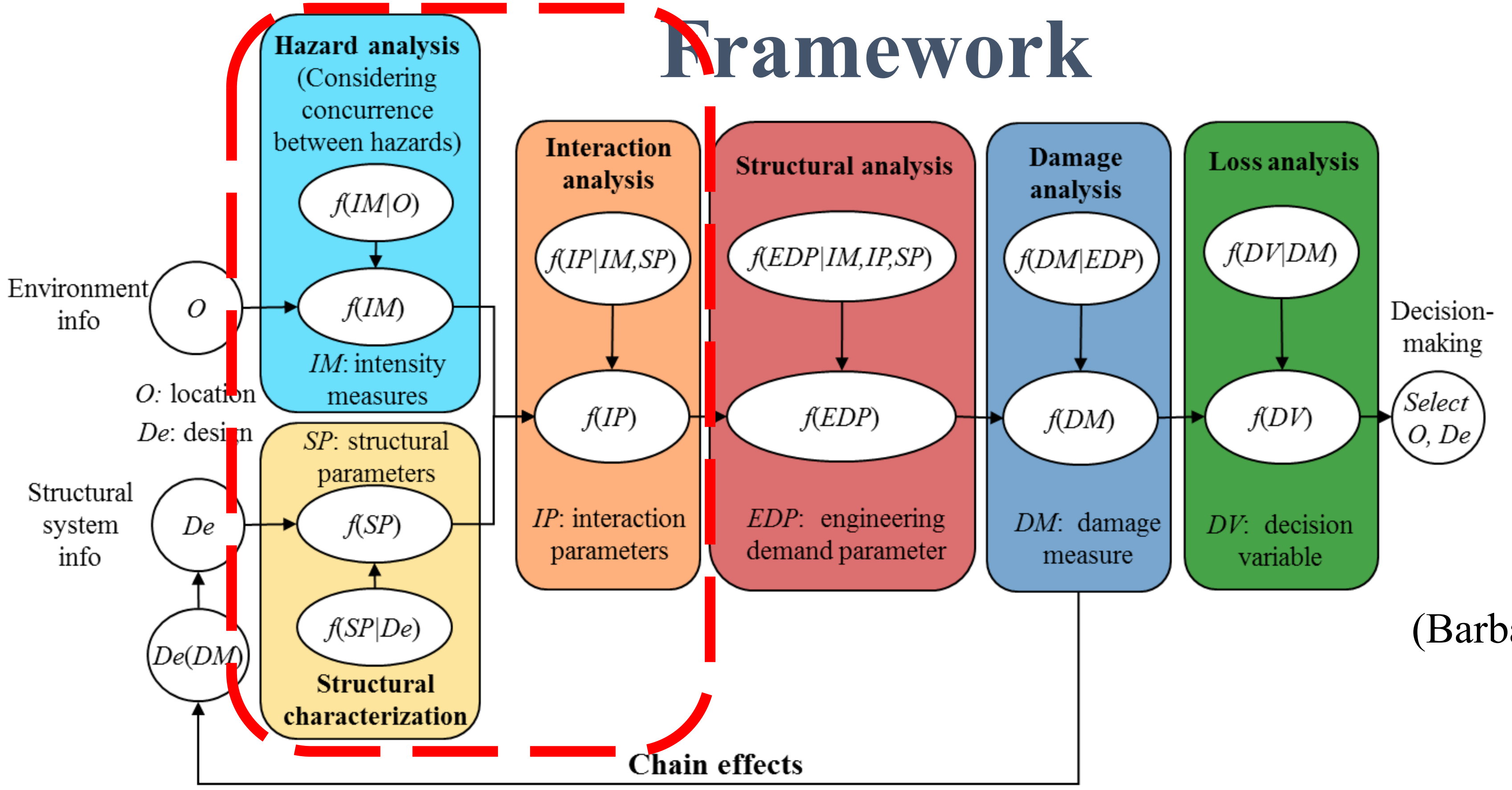


(Porter, 2003)

$$G(DV) = \iiint G(DV \mid DM) \cdot f(DM \mid EDP) \cdot f(EDP \mid IM) \cdot dDM \cdot dEDP \cdot dIM$$

$G(\cdot)$ = complementary cumulative distribution functions, and $G(\cdot \mid \cdot)$ = conditional complementary cumulative distribution function; $f(\cdot)$ = probability density function, and $f(\cdot \mid \cdot)$ = conditional probability density function; DV = decision variable, DM = vector of damage measures; EDP = vector of engineering demand parameters; IM = vector of intensity measures;

Performance-Based Hurricane Engineering (PBHE) Framework

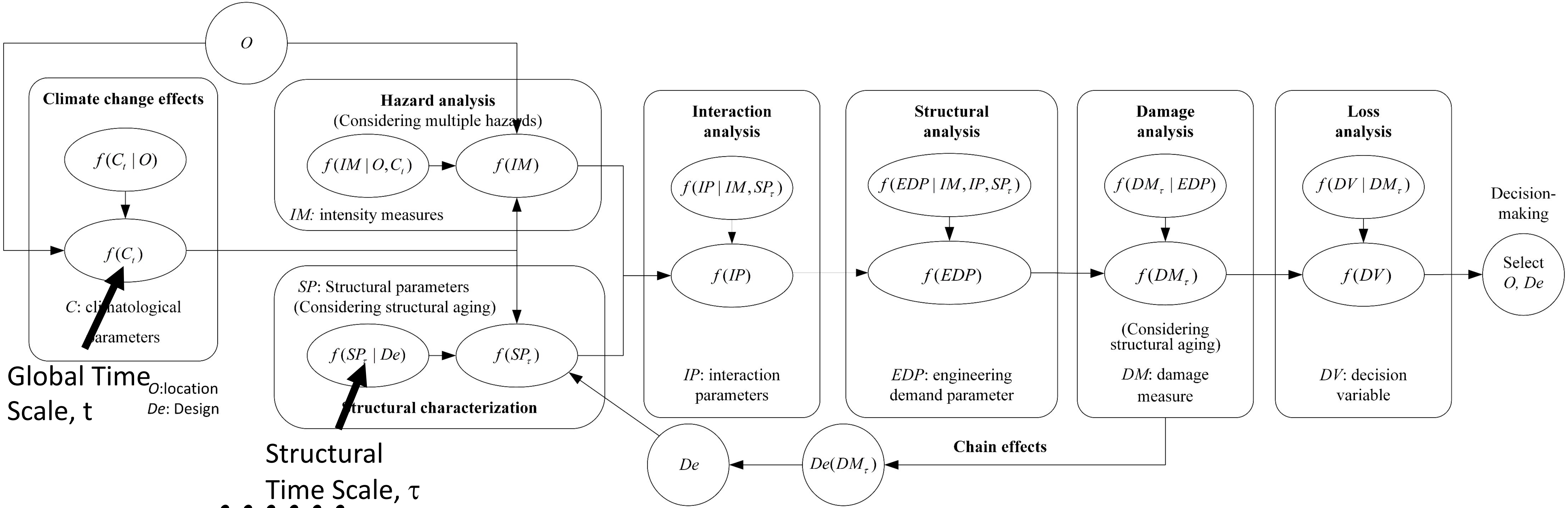


(Barbato et al., 2013)

$$G(DV) = \int\int\int\int\int G(DV \mid DM) \cdot f(DM \mid EDP) \cdot f(EDP \mid IM, IP, SP) \cdot f(IP \mid IM, SP)$$
$$\cdot f(IM) \cdot f(SP) \cdot \mathrm{d}\,DM \cdot \mathrm{d}\,EDP \cdot \mathrm{d}\,IP \cdot \mathrm{d}\,IM \cdot \mathrm{d}\,SP$$

IP = vector of interaction parameters; SP = vector of structure parameters;

Proposed PBME Framework



$$G(DV) = \iiiiiint G(DV_{t,\tau} \mid DM_\tau) \cdot f(DM_\tau \mid EDP, C_t) \cdot f(EDP \mid IM, IP, SP_\tau) \cdot f(IP \mid IM, SP_\tau)$$
$$\cdot f(IM \mid C_t) \cdot f(SP_\tau \mid C_t) \cdot f(C_t) \cdot dDM_\tau \cdot dEDP \cdot dIM \cdot dIP \cdot dSP_\tau \cdot dC_t$$

C_t = climatological parameters;
τ = structural time scale; t = global time scale

Implementation of General Framework for Single Hazards

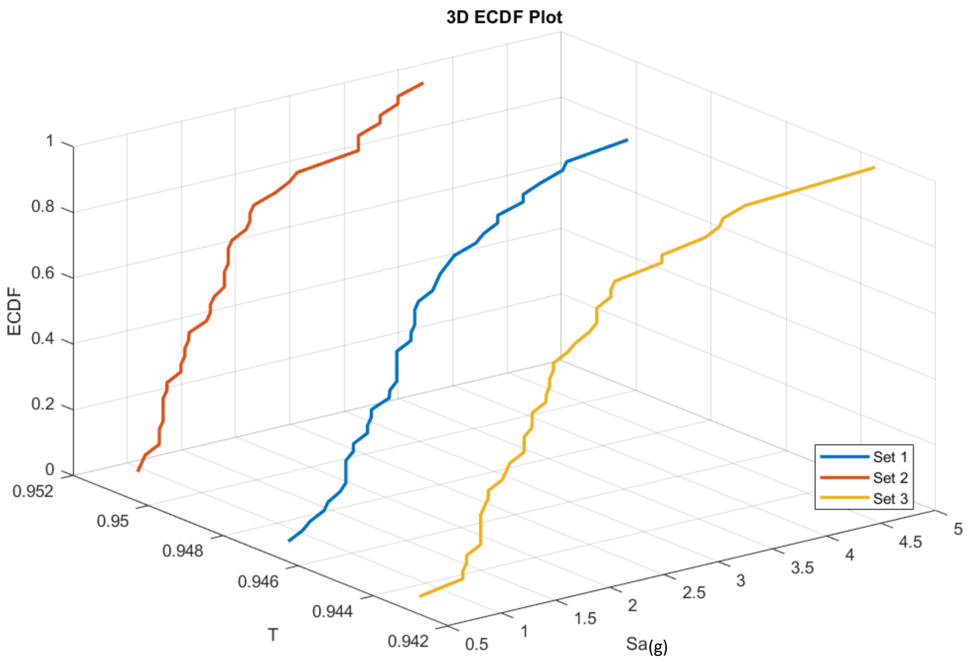


Fig 1. ECDF of Probability of Failure vs Sa. & T of a 4-Story Building

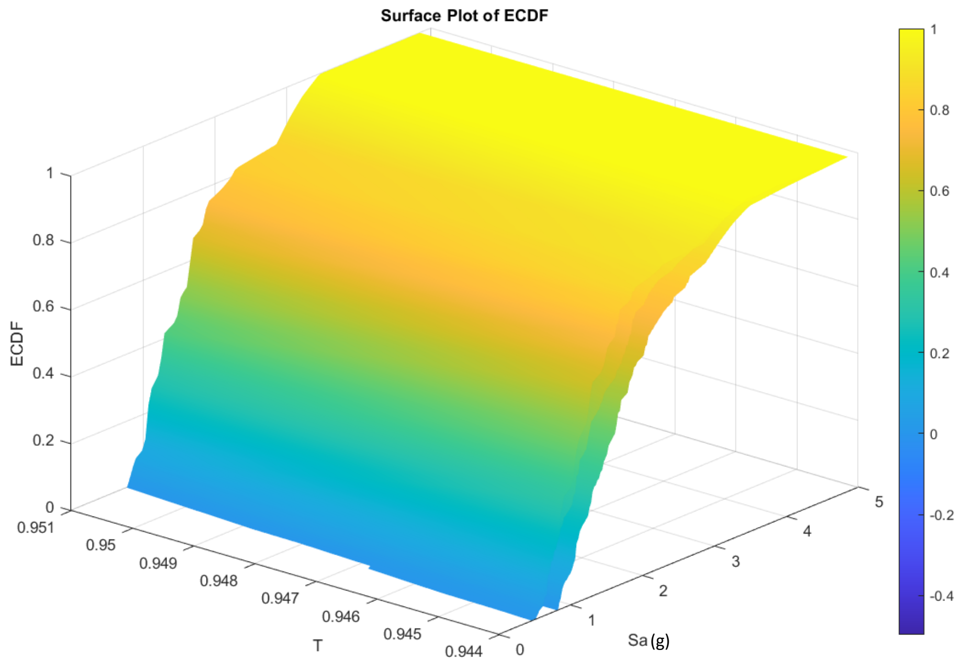
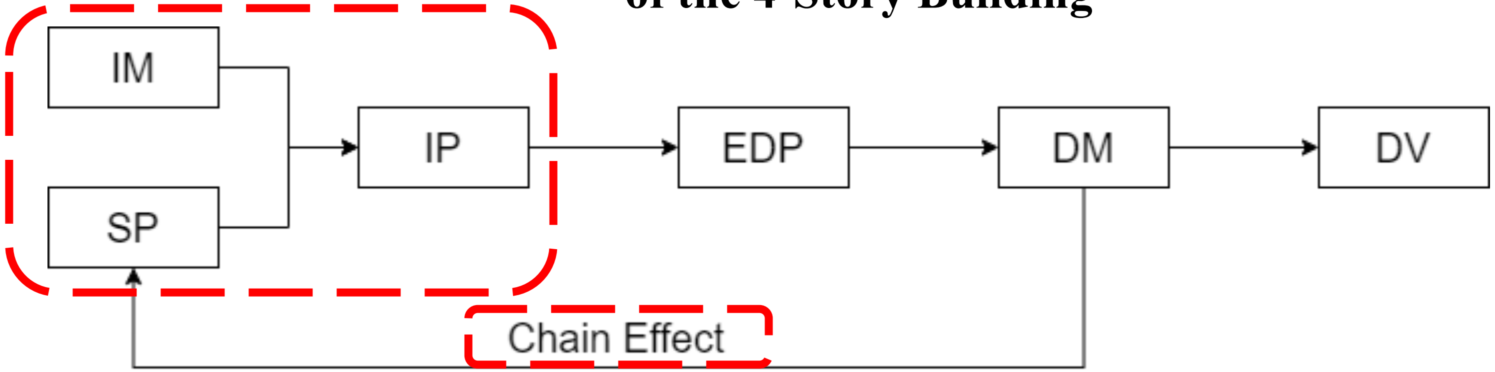


Fig 2. ECDF surface of Probability of Failure vs Sa. & T of the 4-Story Building



Scour Experiment Plan (1)

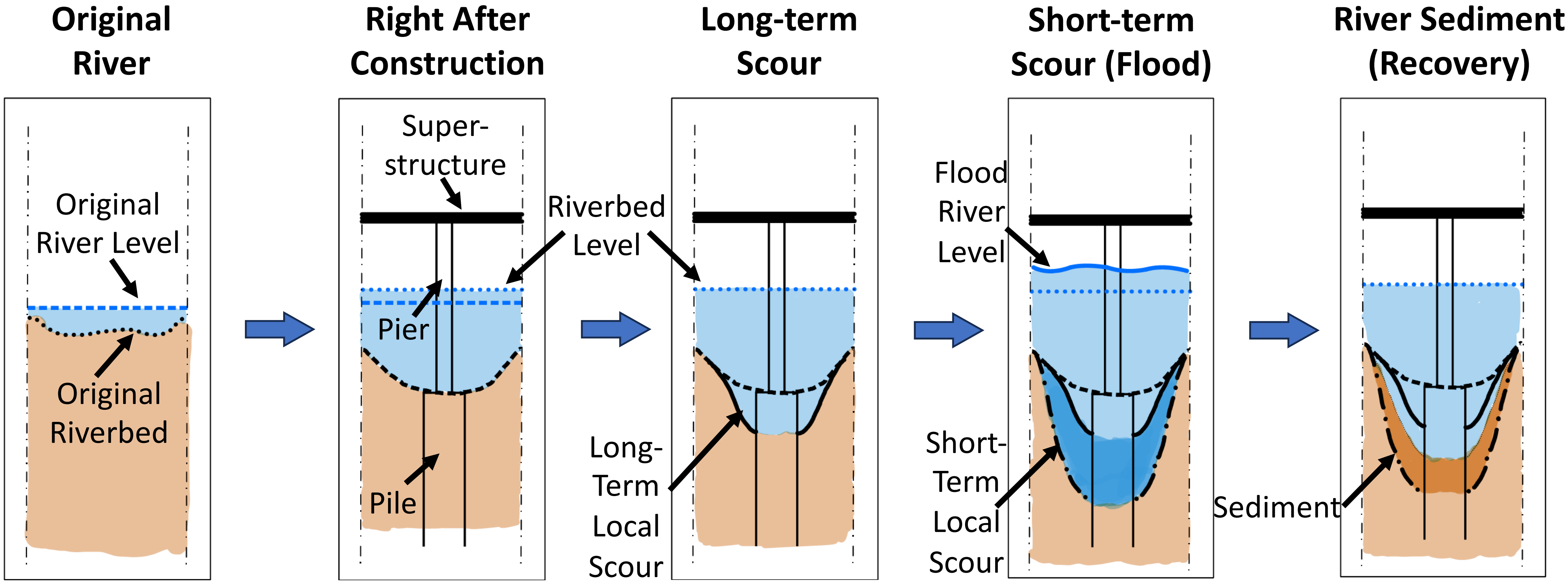


Fig 3. Bridge Scour Information

*Direction: Perpendicular to the traffic

Scour Experiment Plan (2)

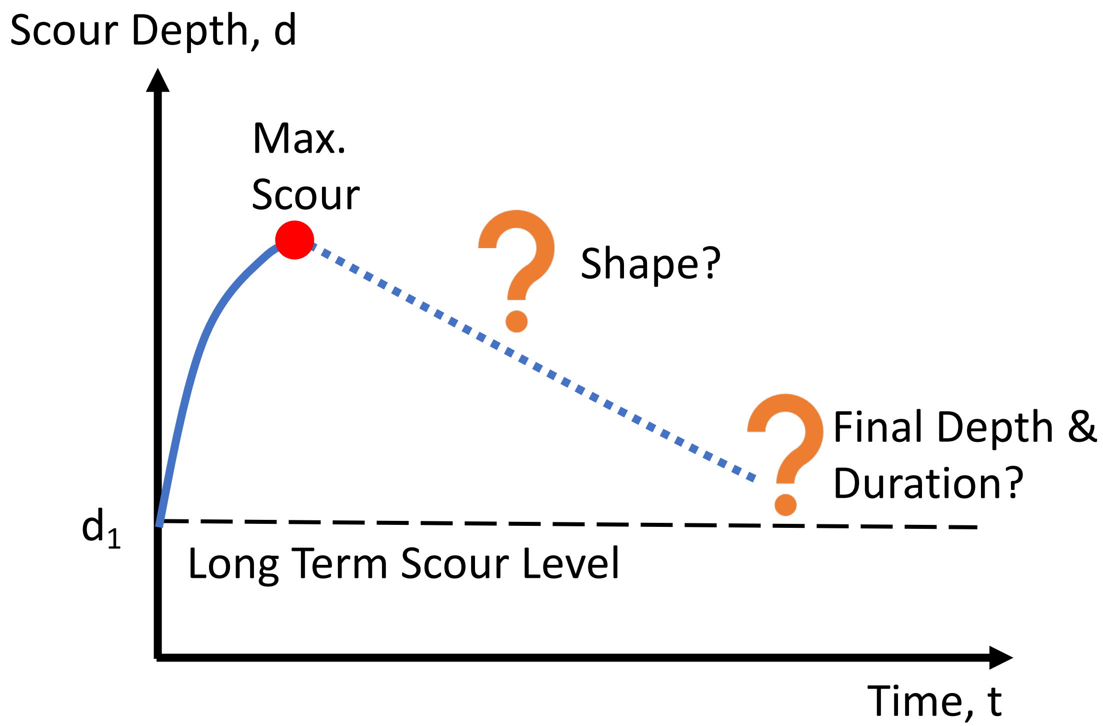
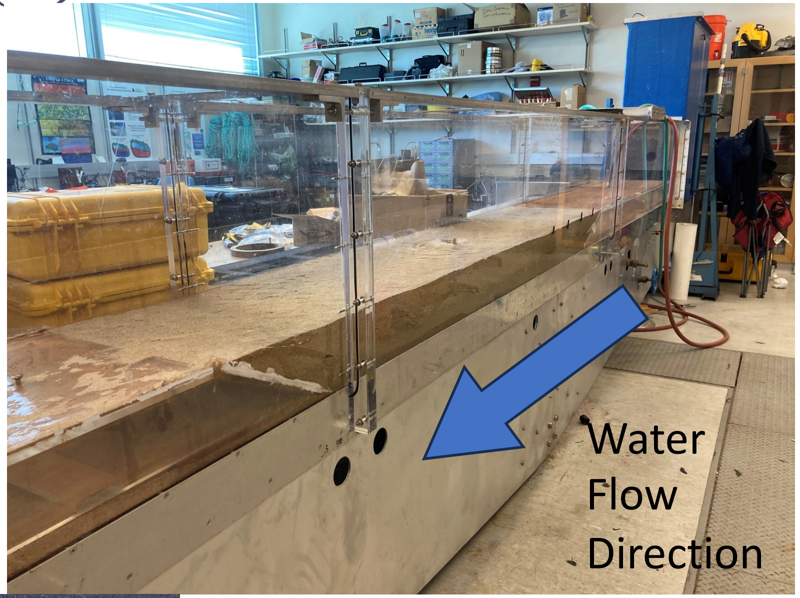


Fig 4. Scour and Recovery Time History

Fig 5. Large Scale Hydraulic Flume at UC Davis



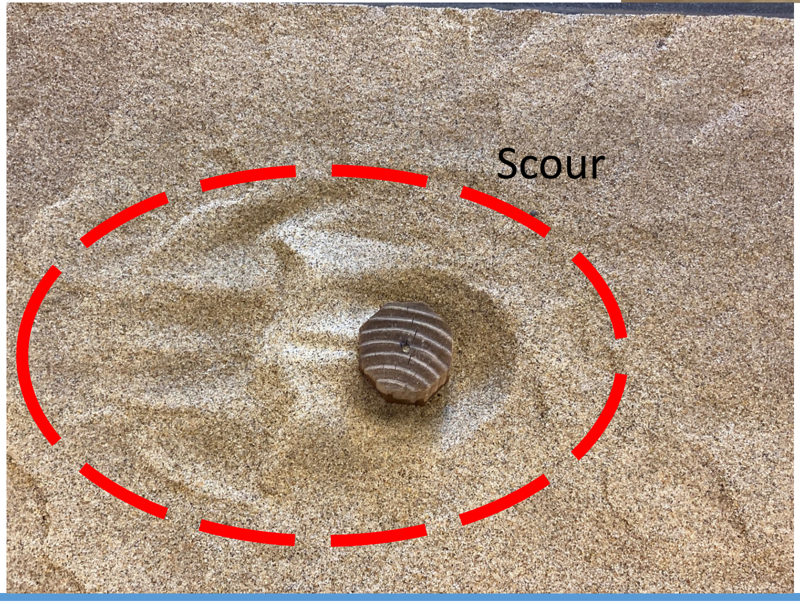
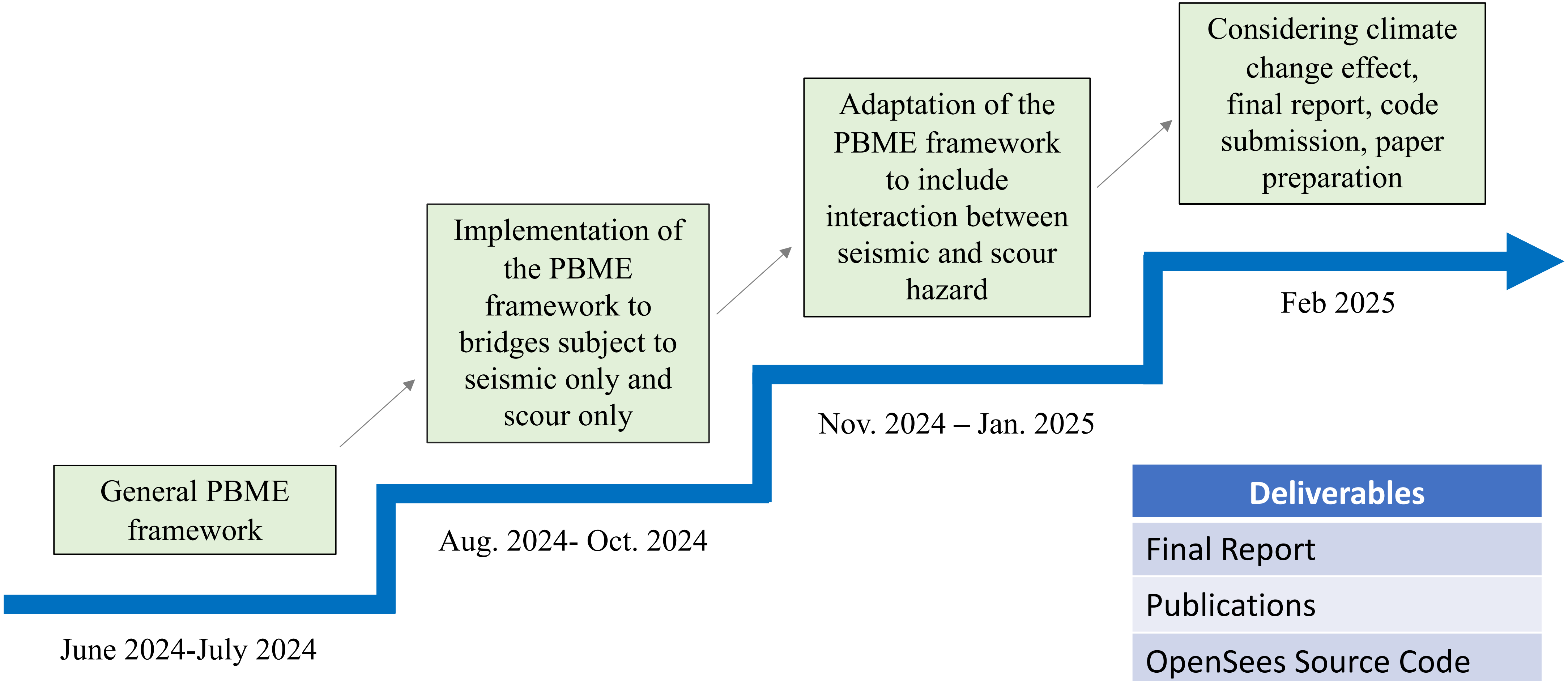


Fig 6. Sample Scour Experiment

Deliverables and Timeline



Deliverables
Final Report
Publications
OpenSees Source Code
Finite-element Model

Application Example

Example: Otay River Bike Bridge

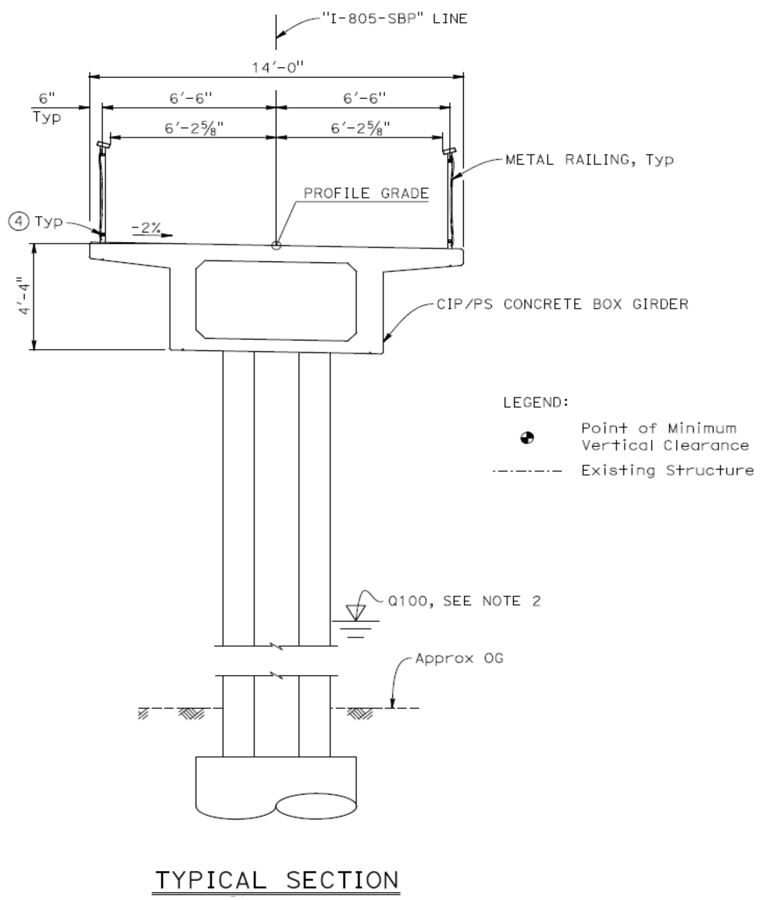


Fig 7. Bridge Typical Section

Discharge:

Flood Event	Peak Discharge (cfs)
Q-50	12,000
Q-100	22,000
Q-200	29,000

Scour Information:

Substructure Component	Short-Term Scour Depths	Long-Term Scour Depths		Total Scour Depth (ft)
	Local Scour (ft)	Degradation (ft)	Contraction Scour (ft)	
Abutment 1	0.00	0.00	0.00	0.00
Pier 2	8.60	0.00	2.31	10.91
Pier 3	6.82	0.00	2.31	9.13
Pier 4	7.59	0.00	2.31	9.90
Abutment 5	0.00	0.00	0.00	0.00

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Thank you very much!
Questions?

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