PEER

PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Modeling of lifelines – recent advances in re fire following earthquake including reference to the Japan earthquake

Realistic Performance Assessment of Water Supply Systems Under Extreme Events

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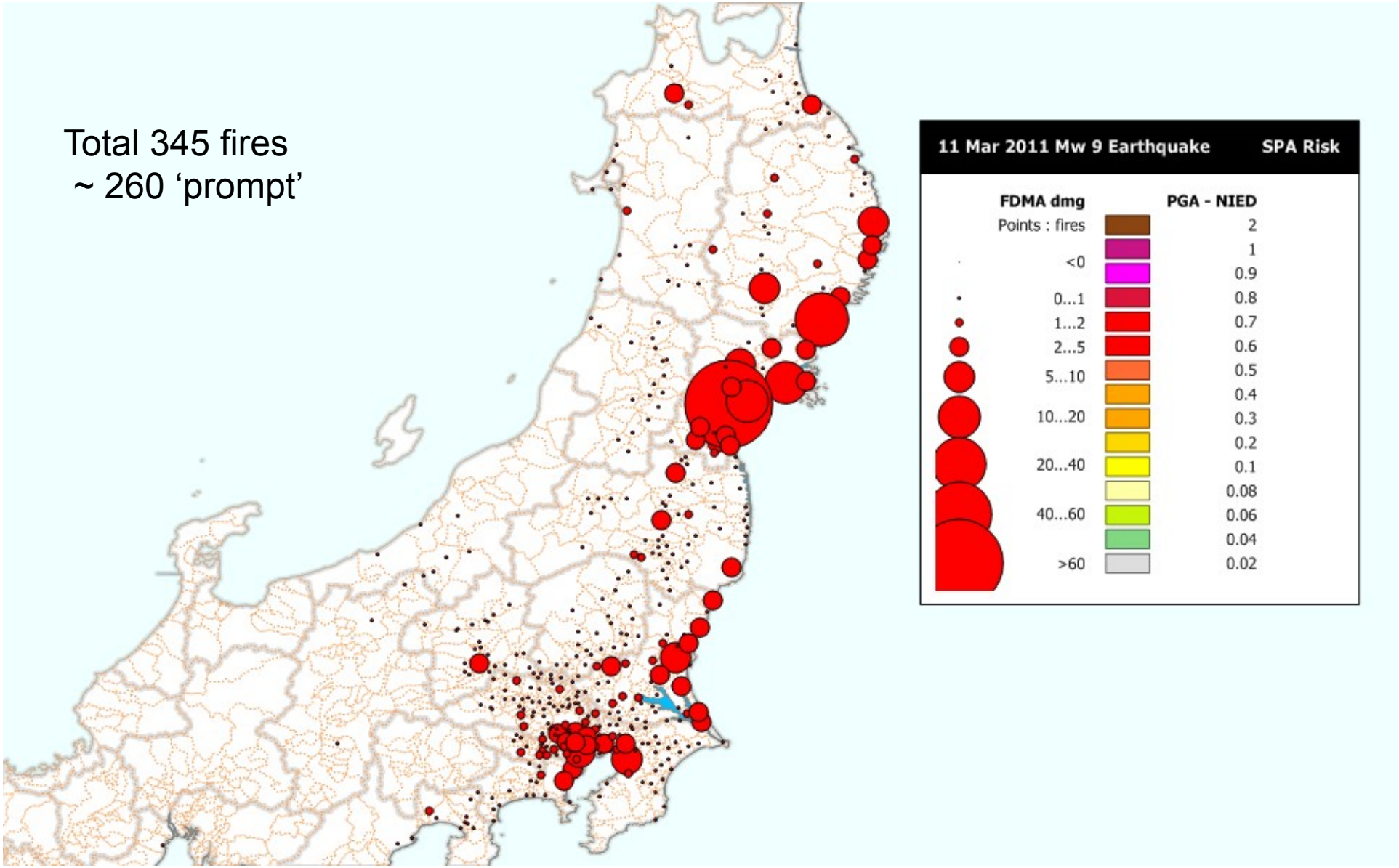
Overview

- Fire following earthquake due to Japan EQ.
- Motivations
- Seismic reliability model
- Seismic damage simulation
- Hydraulic damage simulation
- Case study

11 March 2011 Eastern Japan Earthquake – fire following earthquake

Total 345 fires
~ 260 'prompt'



11 March 2011 Eastern Japan Earthquake – fire following earthquake

Observations

- ~345 fires following earthquake, due to both shaking and tsunami
- several urban conflagrations
- two major oil refinery fires (1 shaking, 1 tsunami)
- LPG Tank cars scattered by tsunami
- 30+ ignitions in Tokyo

Implications

- Japan, US very vulnerable to fire following earthquake
- refineries in LA / LB and SFBA

Research Opportunities

- Tohoku ignitions >> all previous ignitions
- Get the data! Digest / understand it! Applicable to US
- impacts of loss of water supply
- fire department response?

Fire following earthquake - shakOut

- 1,600 ignitions
- 1,200 large fires
- Super-conflagrations in LA & Orange County

Regional Economics - ShakeOut

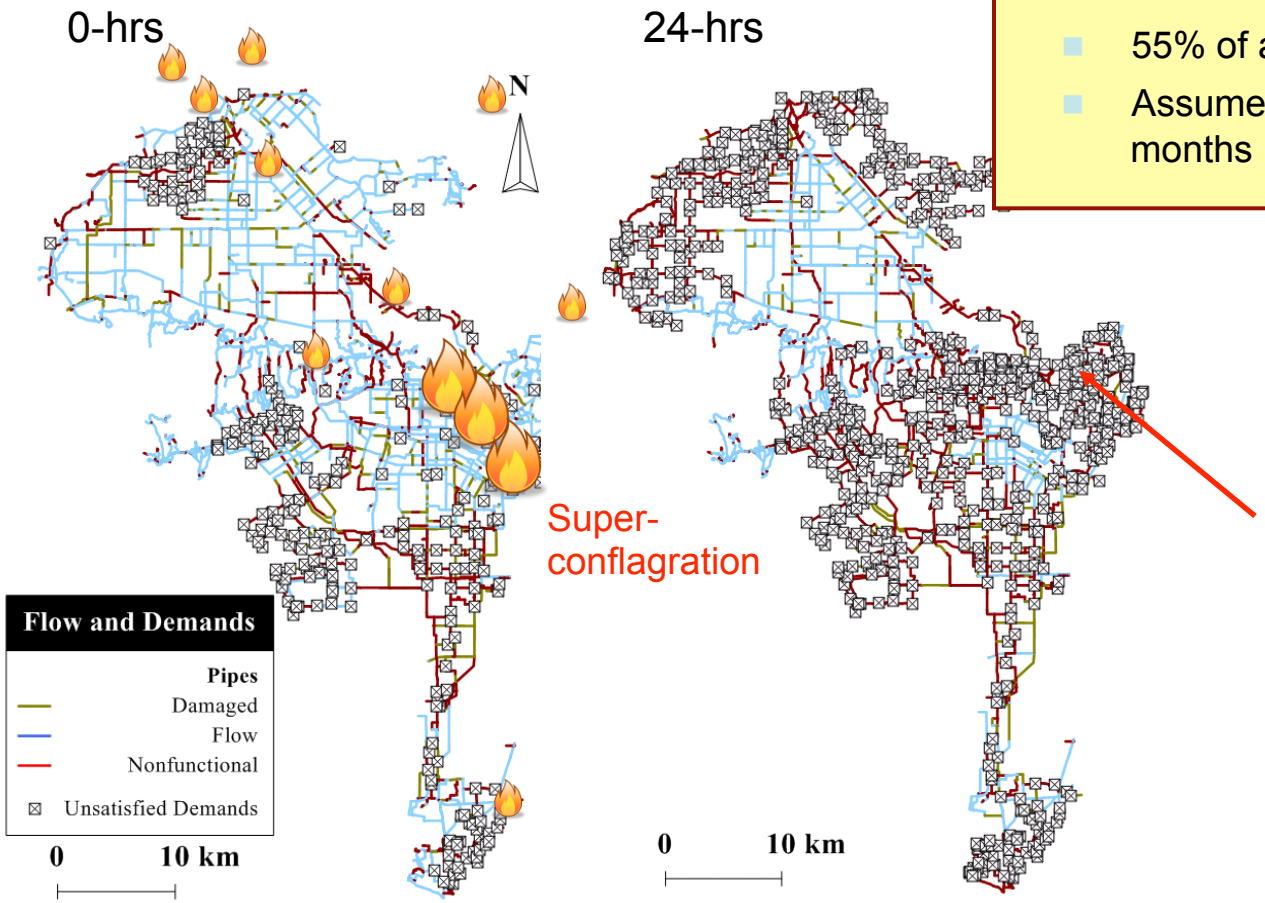
$213.3 Billion total losses

$87 Billion loss from fire

- 40% of total

$53 Billion business interruption loss from water

- 25% of total
- 55% of all business interruption
- Assumes all aqueducts restored in 6 months



- Damaged pipes inhibit suppression
- 31% serviceability Central City is insufficient
- Fire fighting drops serviceability to zero

Davis (2009)

Introduction - lit. rev.

- Shinozuka et al. (1981): Monte Carlo simulation + flow analysis
- Isoyama and Katayama (1981): Monte Carlo simulation + maximum possible flow
- Moghtaderizadeh (1981): heuristic
- Markov et al. (1994): negative pressure treatment
- Shi (2006) & Wang (2006): leakage modeling (GIRAFEE)

Motivations

- Pressure driven model vs demand driven

$$q^{req}\left(\frac{H^{avl} - H^{min}}{H^{des} - H^{min}}\right)^{\frac{1}{\alpha}}$$

- Include pipe failure mechanism due to 1995 Kobe EQ. data
- Heavy leakage simulation
- Verification with measured demand and pressure due to 1995 Kobe EQ. data

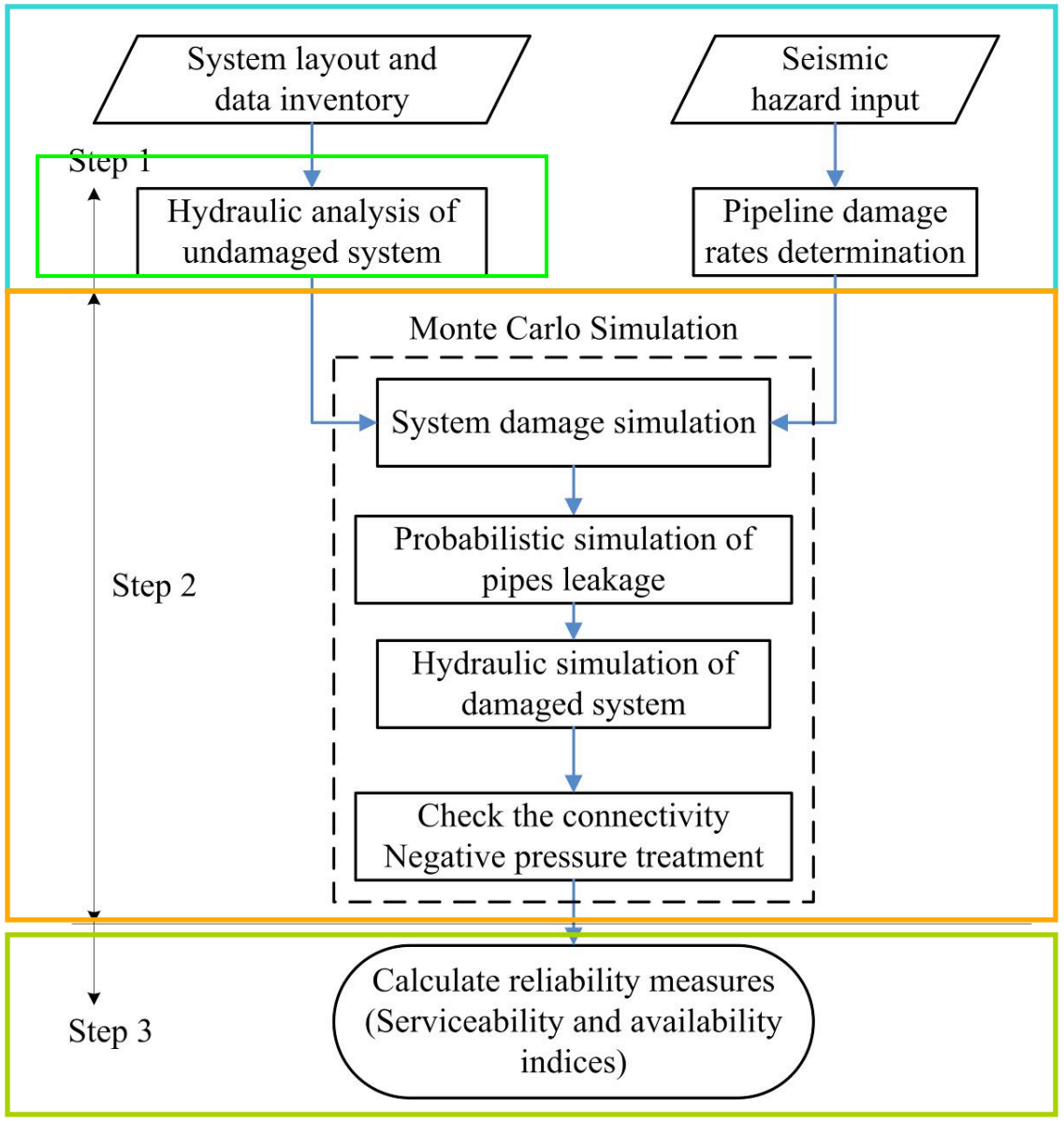
Seismic reliability model

ArcGIS

➢EPANET

Matlab + EPANET (PDA)

ArcGIS



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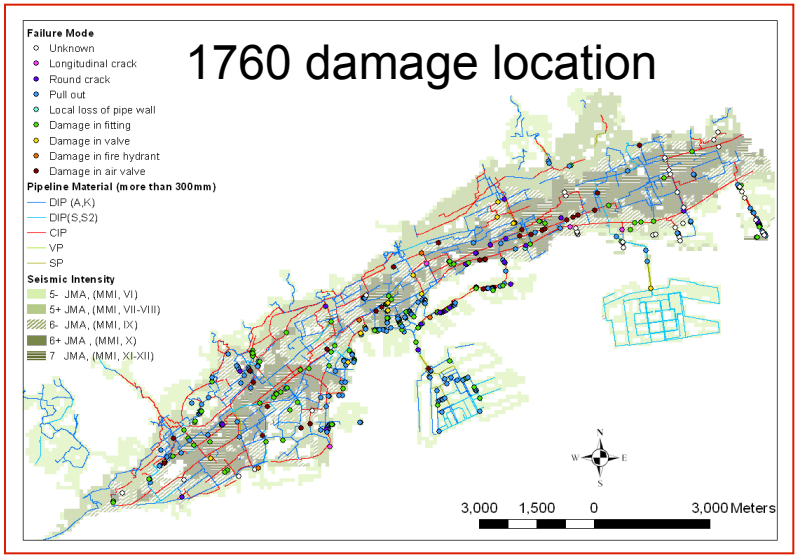
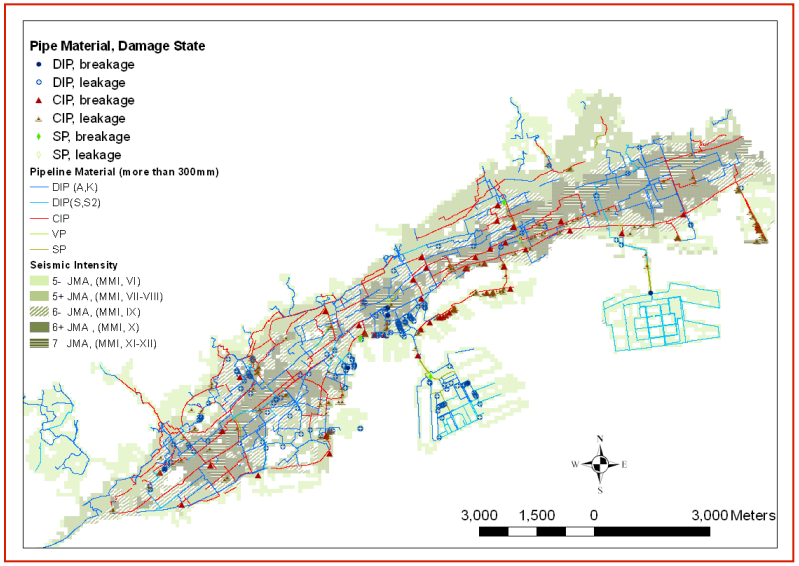
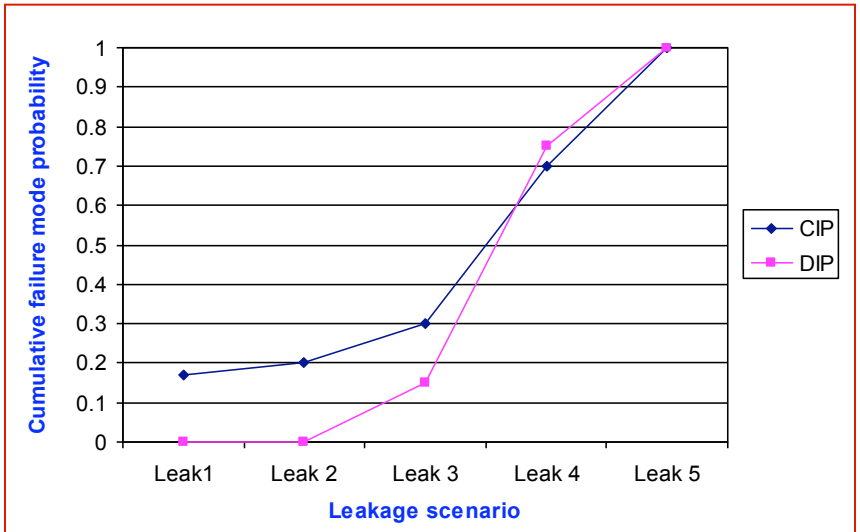
Failure mechanisms and damage states



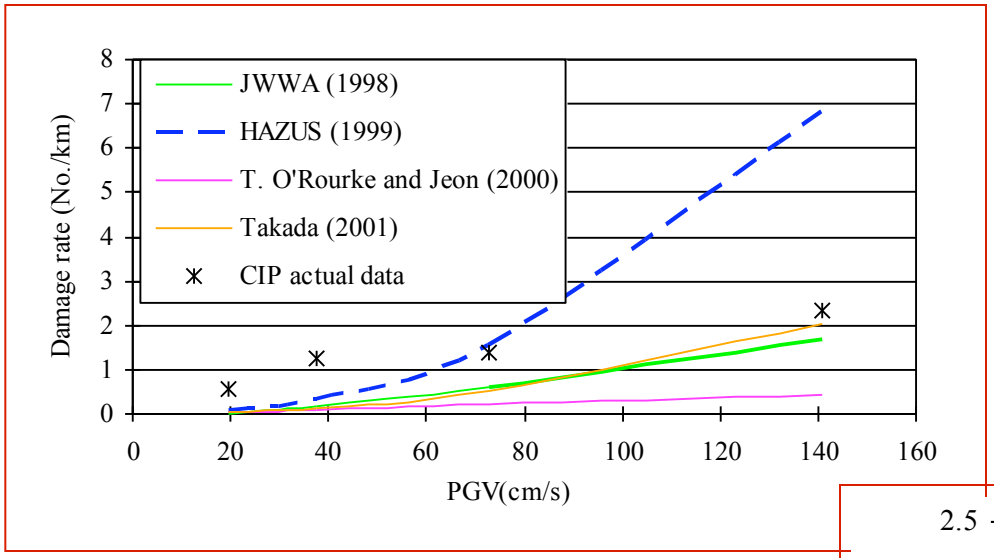
➢ Failure mode occurrence probability

Pipe material / *Failure mode*	CIP	DIP
Round crack	0.17	0.00
Longitudinal crack	0.03	0.00
Damage in fitting and tear of pipe wall at welded joint	0.10	0.15
Pull-out	0.40	0.60
Local loss of pipe wall	0.30	0.25

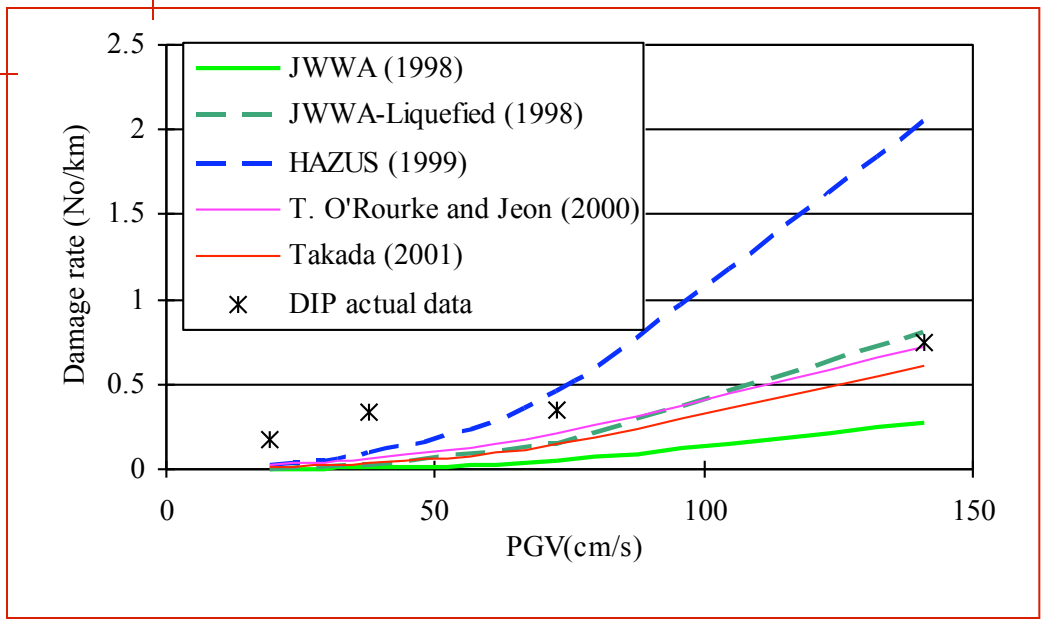




Variability of the pipe fragility functions

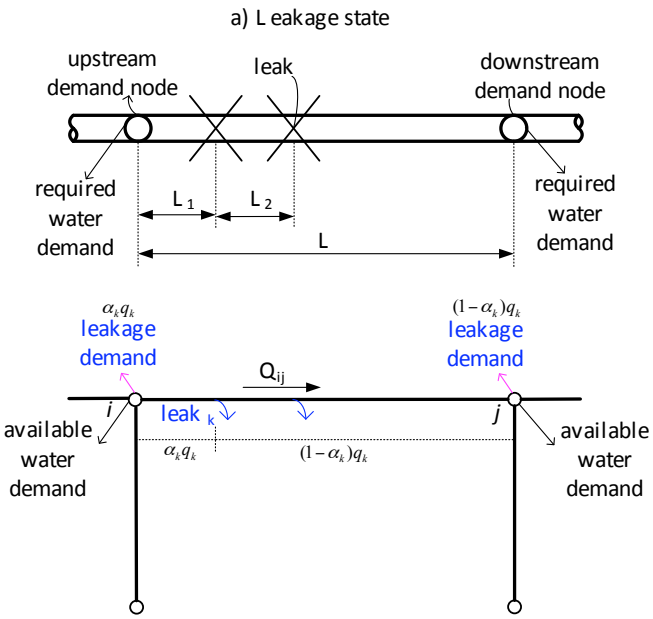


Damage rate for CIP

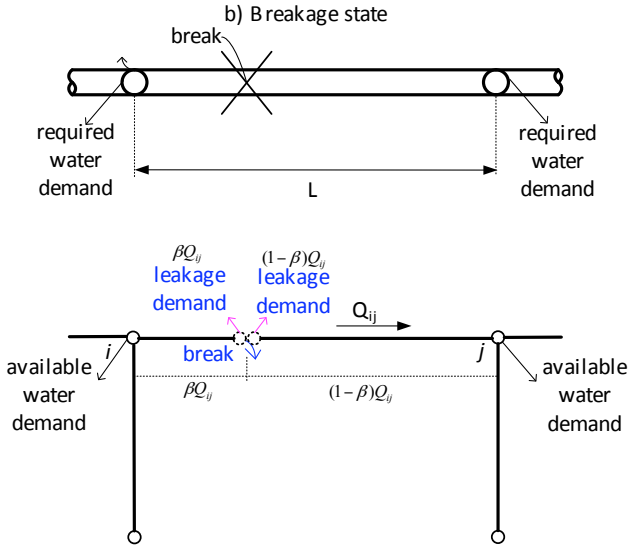


Damage rate for DIP

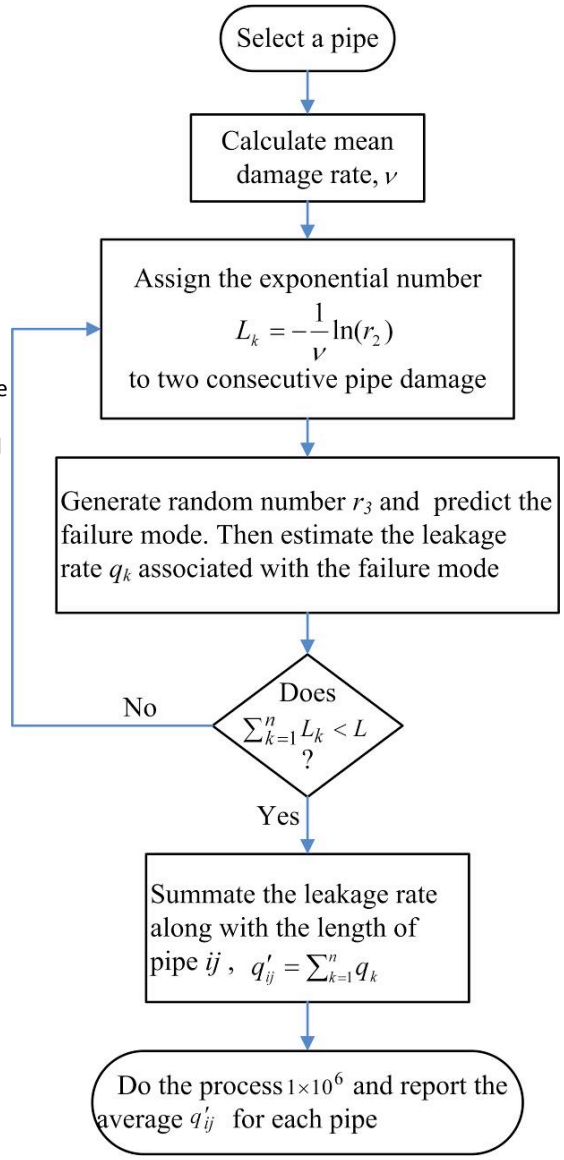
Seismic damage simulation



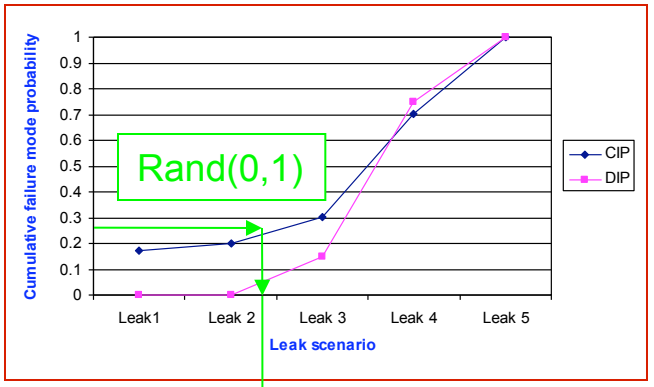
❑ Leakage model



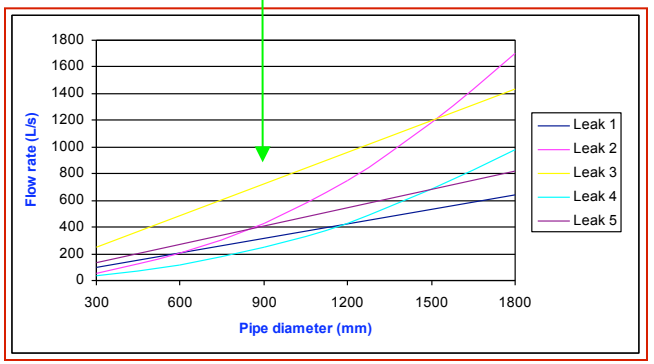
❑ Breakage model



❑ Probabilistic model for leakage simulation

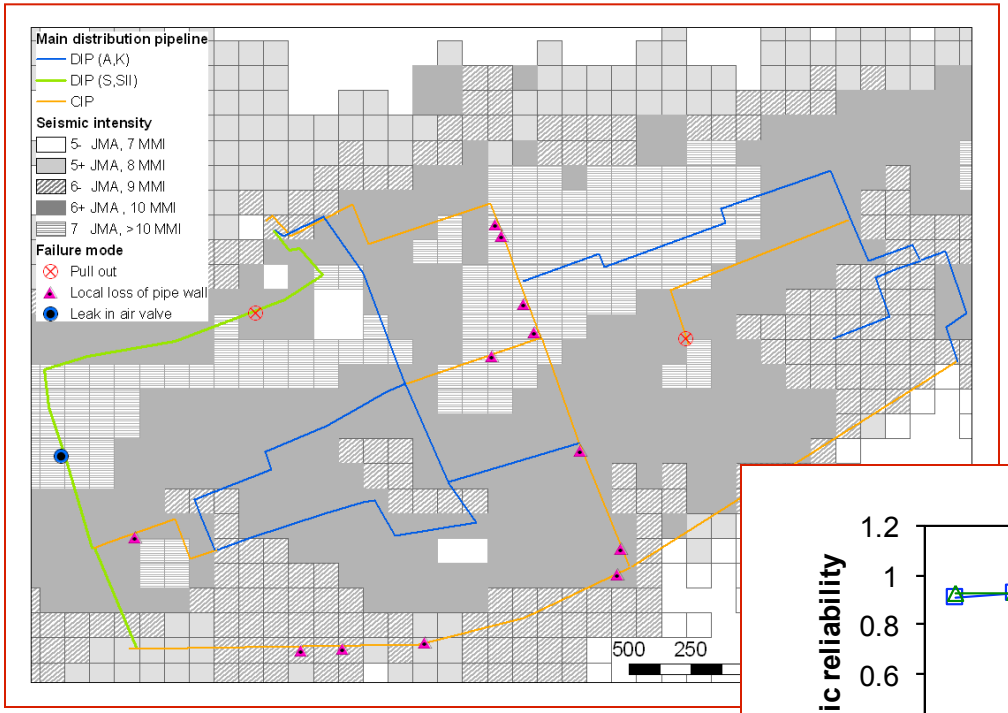


❑ PDF of failure modes



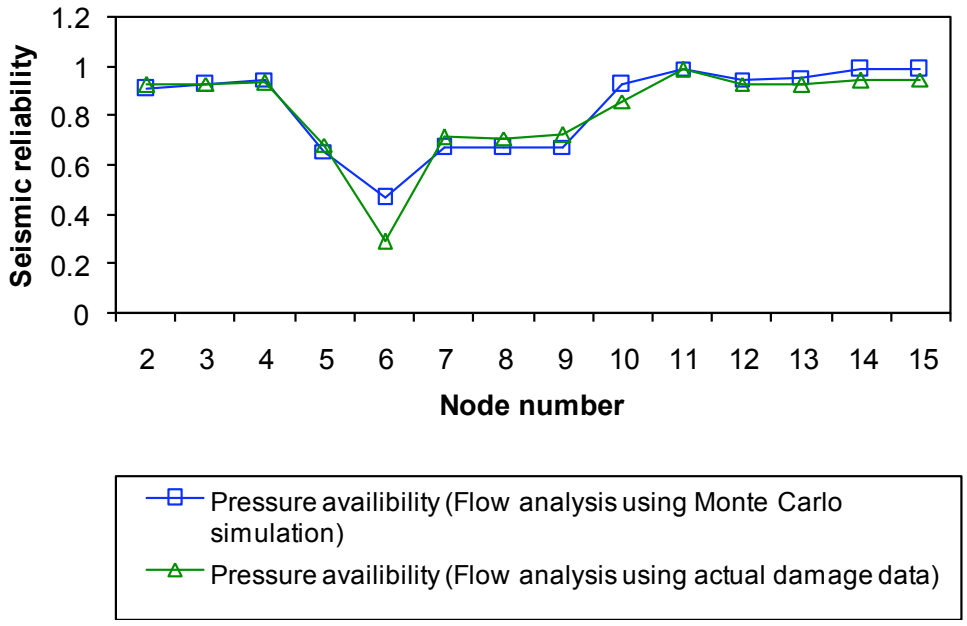
❑ Leakage scenarios

Hydraulic damage simulation & verification

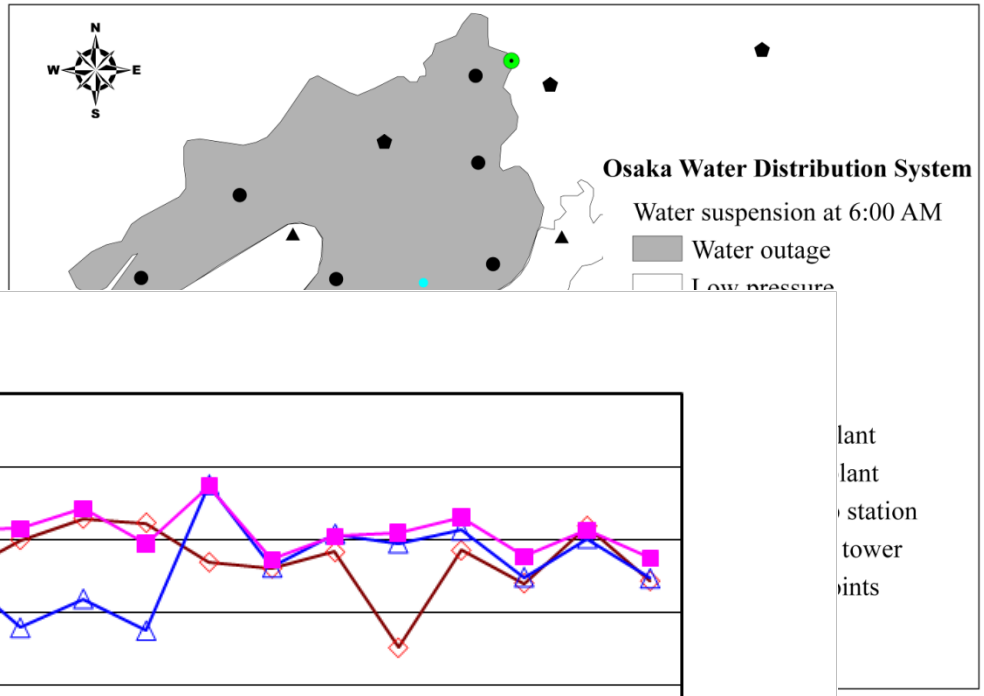


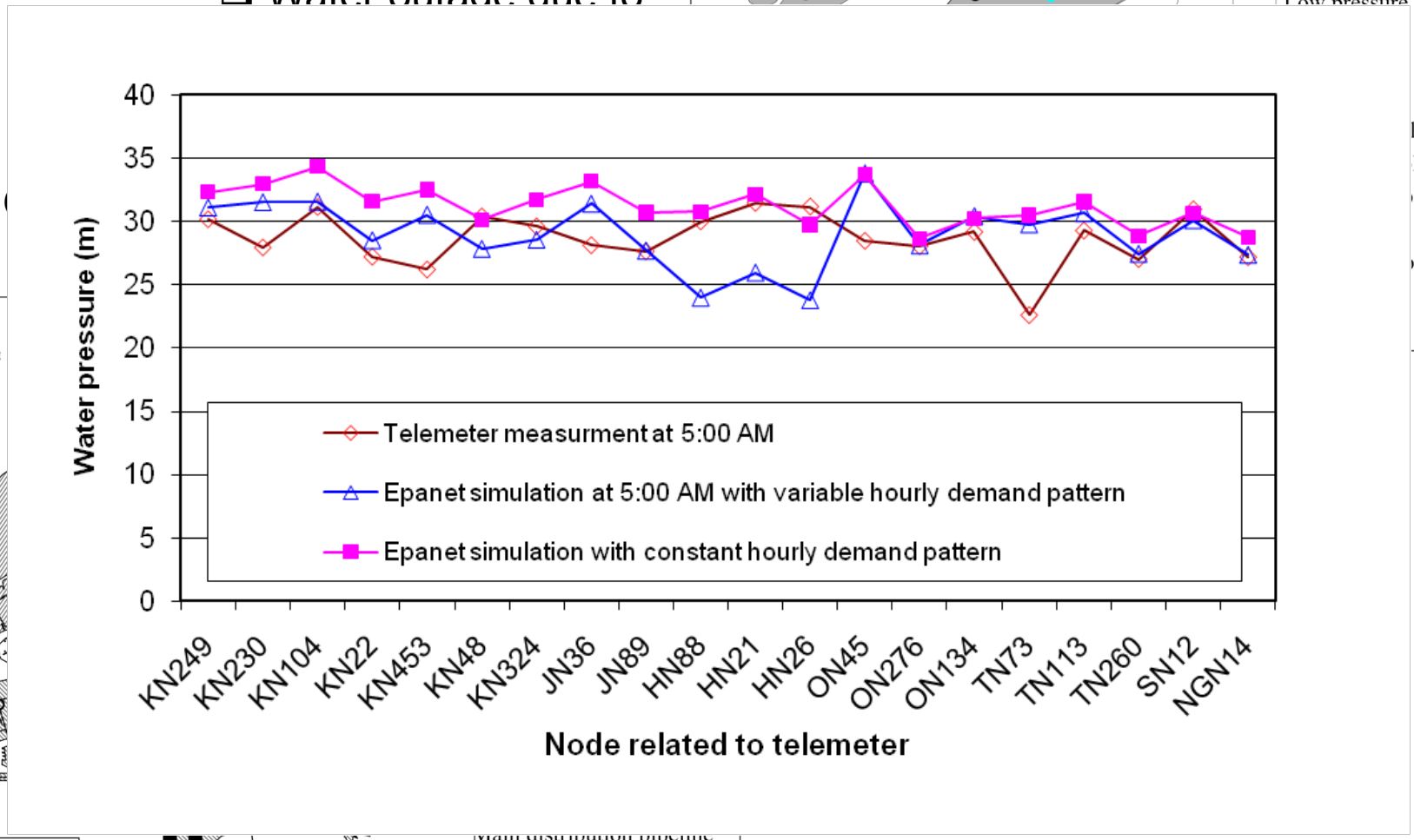
❑ Kobe WSS

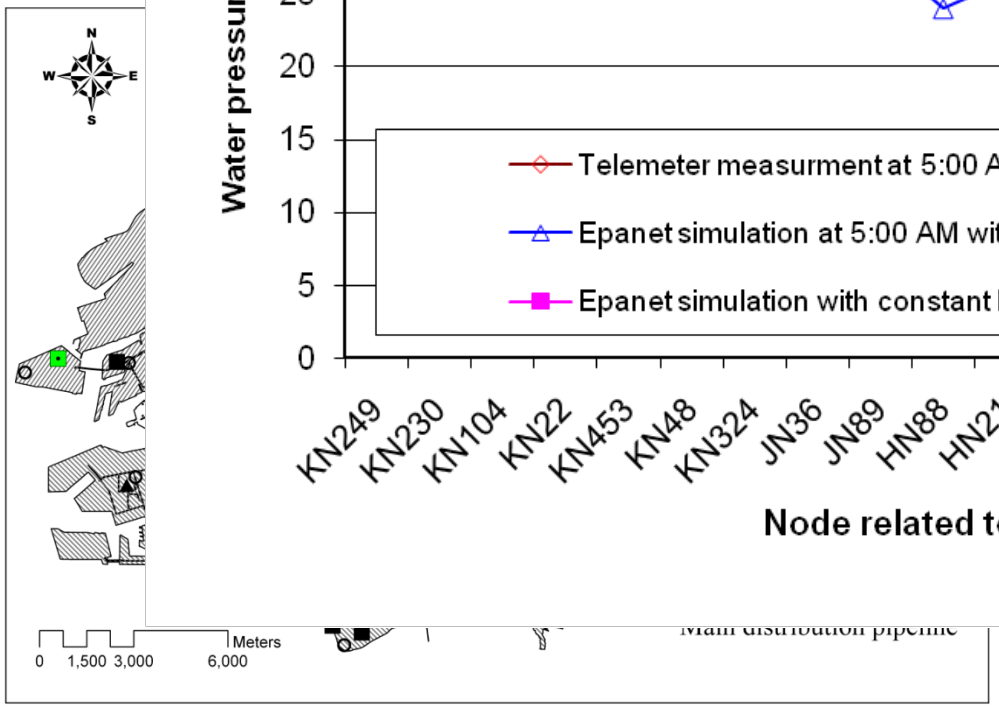
❑ Model verification



Case study – Osaka City WSS







❑ Hydraulic calibration

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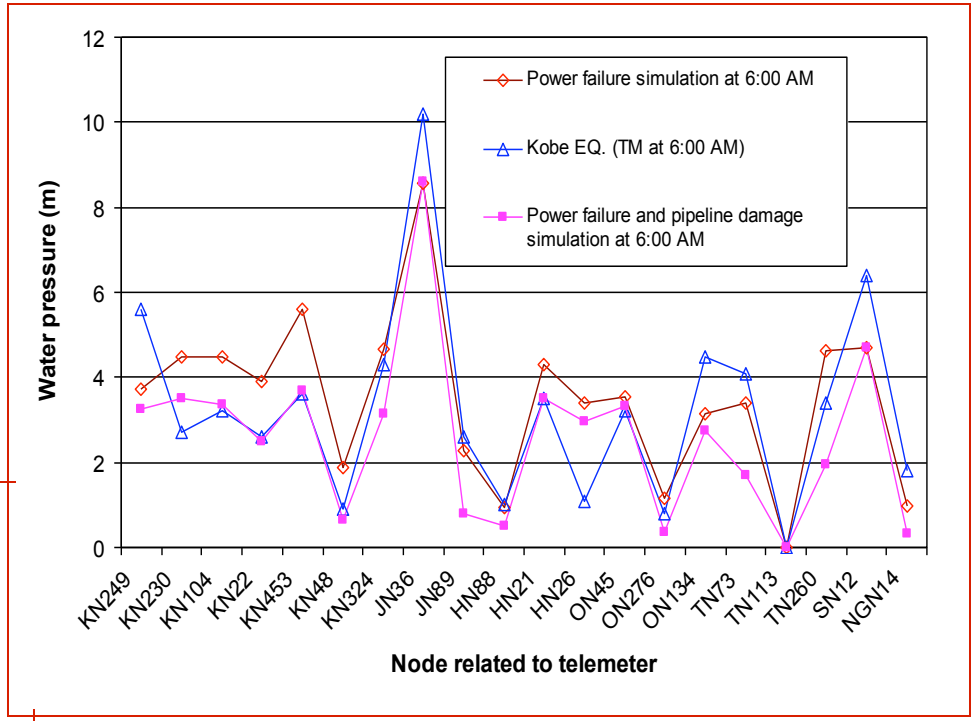
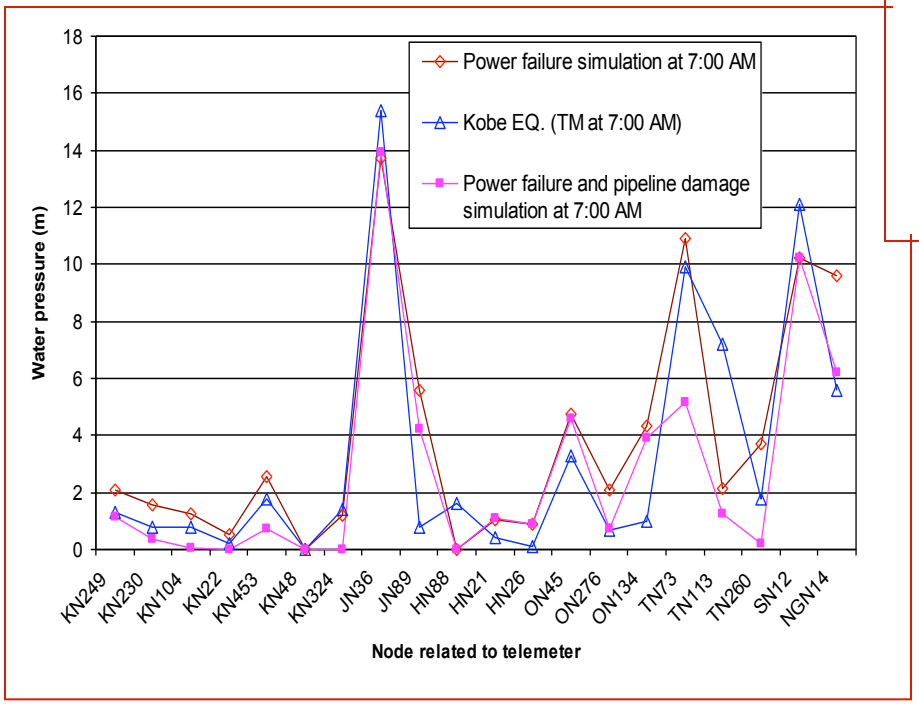
Case study – Osaka City WDS

- Power failure and pipelines damage simulations

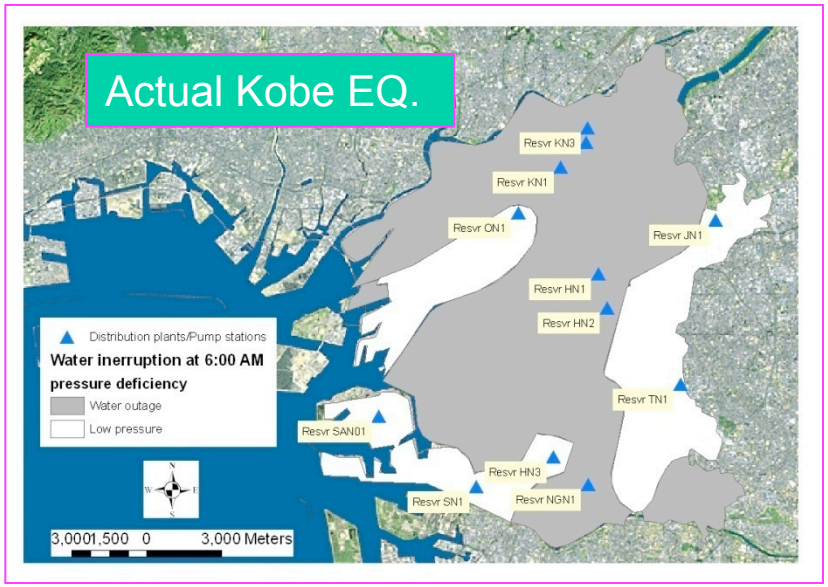


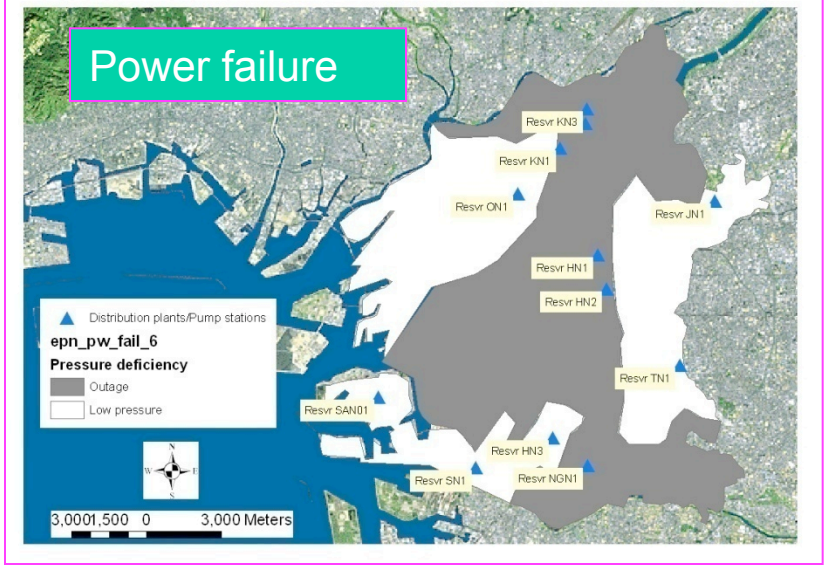
- Right after EQ. (6:00 AM)

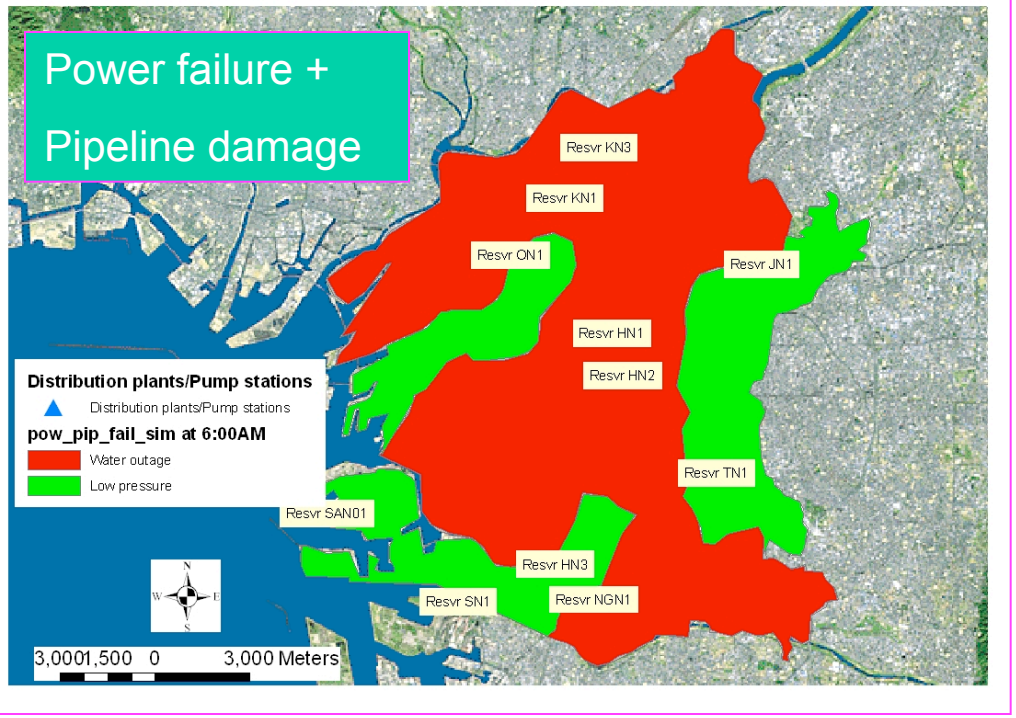


- One hour after EQ. (7:00 AM)

Water outage simulation – right after EQ.

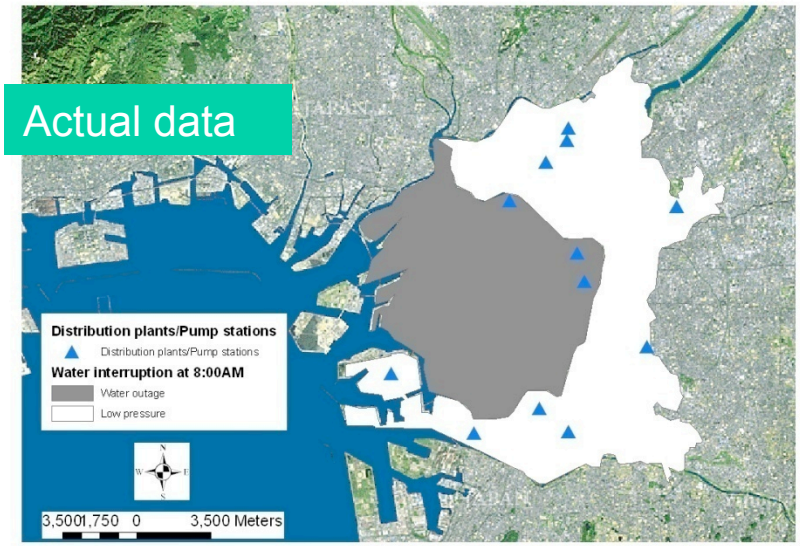




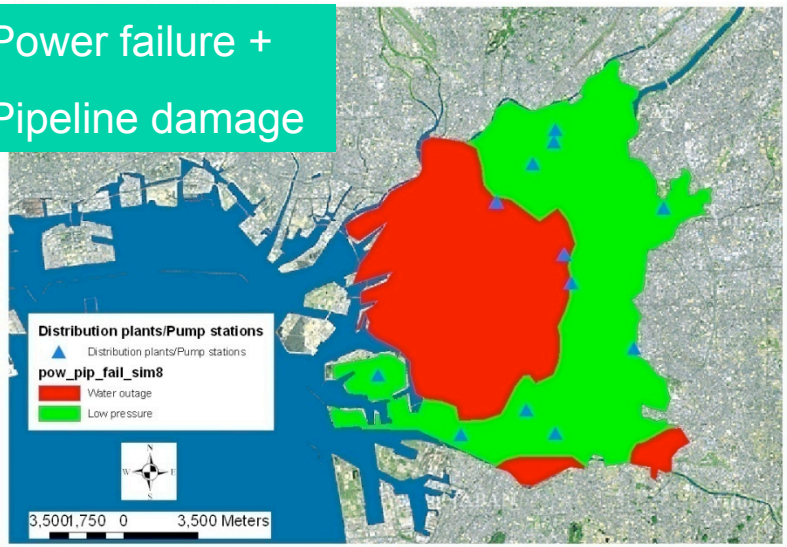


Water outage simulation – two hours after EQ.

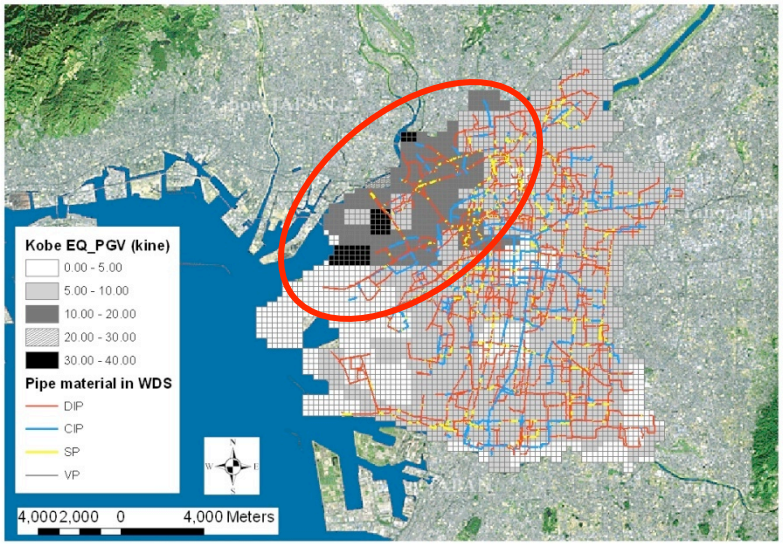
Actual data



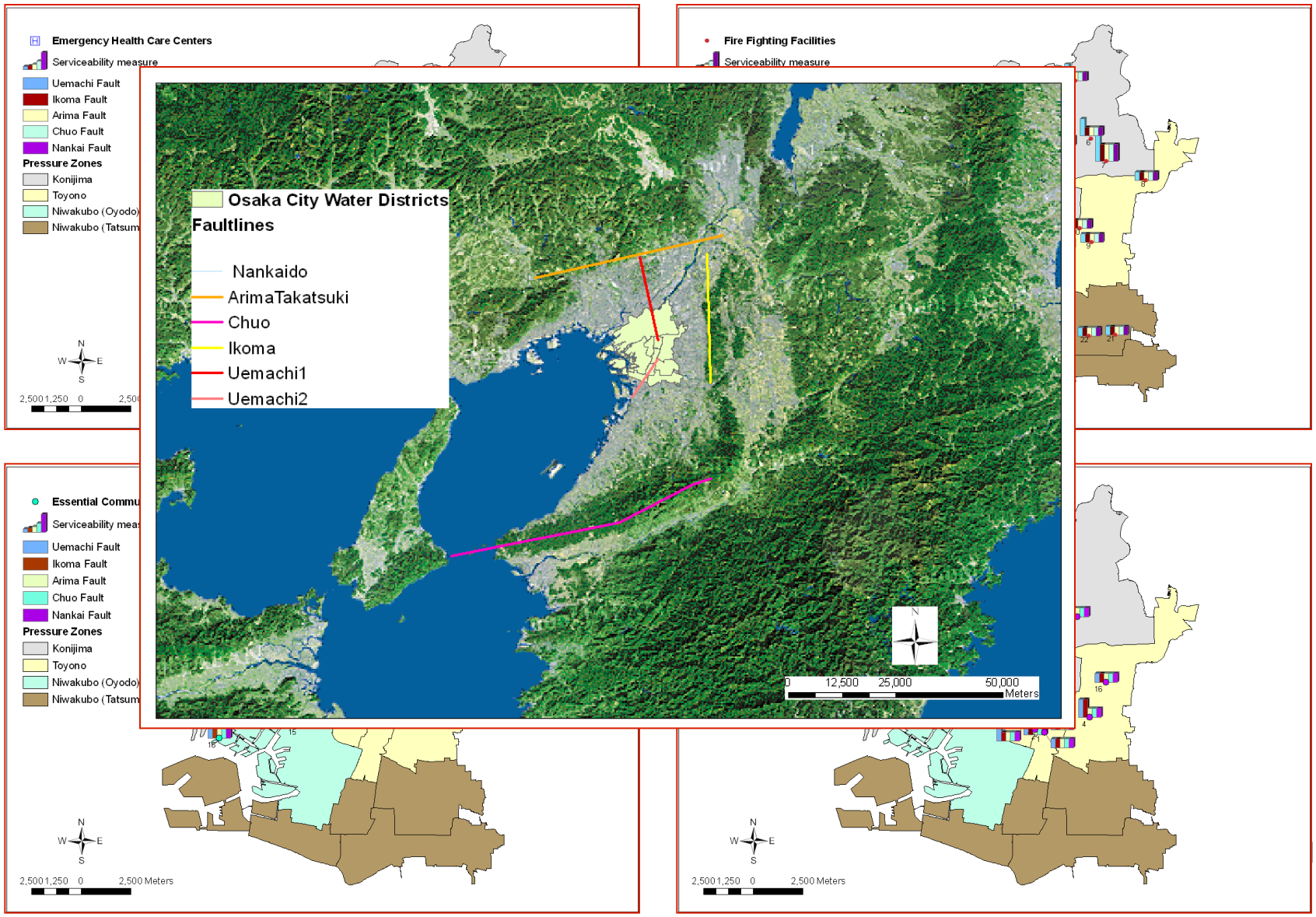
Power failure + Pipeline damage



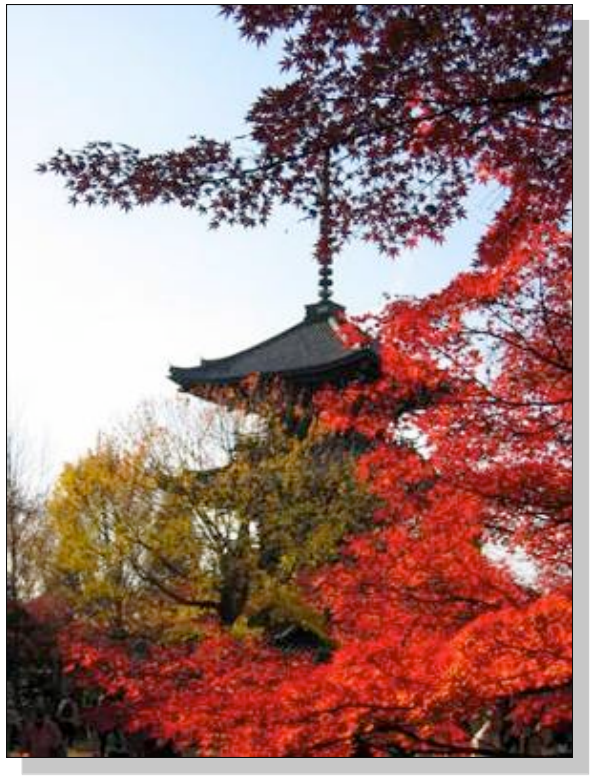
Power failure



Serviceability to Important Customers



Thank you

Questions?

Javanbarg@quake.kuciv.kyoto-u.ac.jp