IUSS
Scuola Universitaria Superiore Pavia

Theoretical framework for environmental risk assessment due to NaTech event

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Introduction

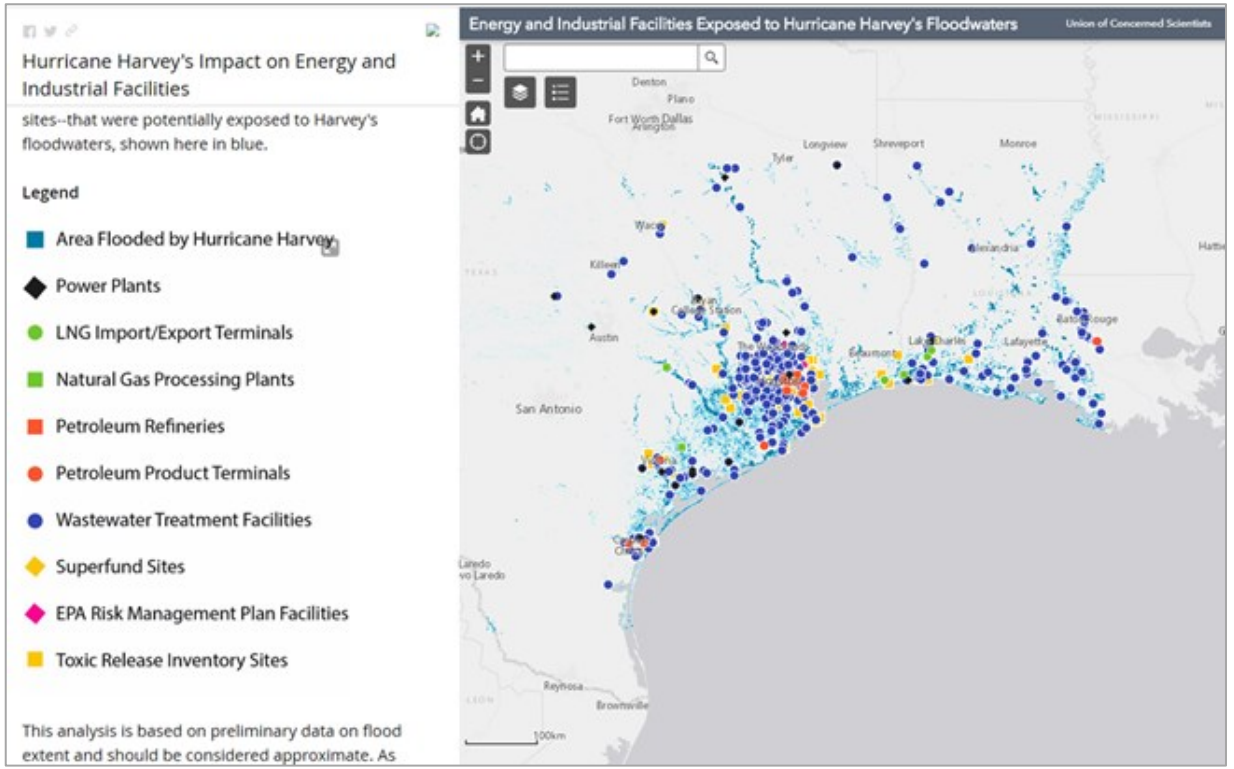
"Technological accidents triggered by a natural hazard or disaster"

Natural hazard triggered technological accidents involving the releases of hazardous materials (hazmat) are known as Natechs.

(Cruz et al., 2019)

Charatheristics:

- Large area impacts;
- Simultaneous releases from single or multiple sources;
- Emergency of concurrent disasters;
- Safety and protection barrier are usually not designed for Natech accidents;



Proposed framework: conceptual model and Risk chain

Natural hazard:
- ❑ Flood (Hf, Vf)
- ❑ Earthquake (Mw,…)
- ❑ Lightning (….)
- ❑ Landslide (displacement, rate)
- ❑ Tsunami
- ❑ Storm surge
- ❑ Cold wave

Flood

NaTech Event:
- NH Probability x Probability of Filling Level
- Magnitude: Spilled Volume
- Interested area

"Tech" structure:
- Tank/Vessel (atmospheric, pressure)
- Pipelines
- Equipment

Vessel buckling (Landucci et al., 2012; Yang et al., 2020)
Vessel displacement (Yang et al., 2020)
Vessel flotation (Yang et al., 2020)
Pipe disconnection

Environmental Risk for soil and groundwater:
- Type of contaminant
- Area hit by Loss of Containment (Grimaz et al., 2008)
- Shallow or depth Groundwater?
- **Evaluation contaminant magnitude: concentration contaminant scenario major than threshold?**

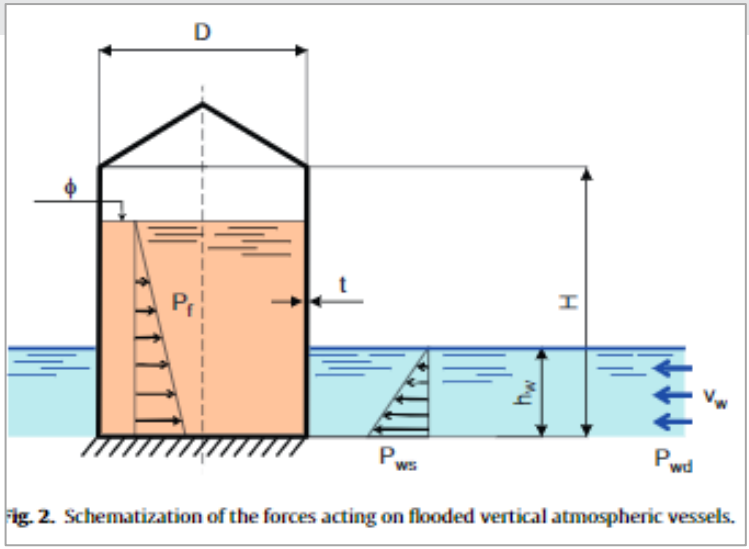
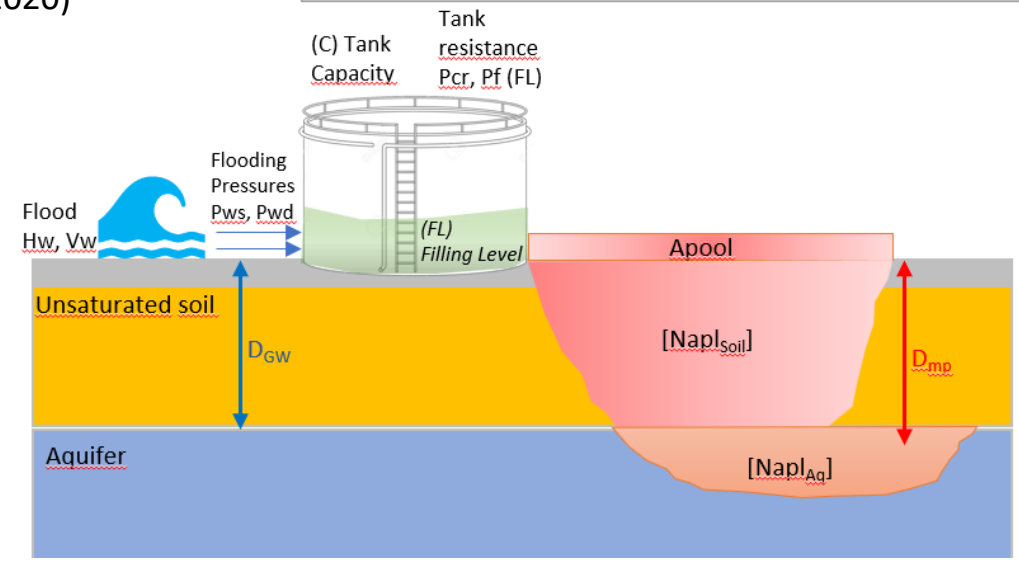


Fig. 2. Schematization of the forces acting on flooded vertical atmospheric vessels.



Case Study

Gasoline Tank					
ID	Volume m^3	Diameter (m)	Height (m)	Area (m^2)	Height max (m)
1	4,300	21.34	12.9	354.3	12.1
2	4,300	21.34	12.9	354.3	12.1
3	1,400	12.19	12.9	114.8	12.2
4	1,400	12.19	12.9	114.8	12.2
5	8,600	27.43	14.72	586.6	14.7
6	8,600	27.43	14.72	586.6	14.7
7	13,000	30.48	18.38	724.9	17.9
8	8,600	27.43	14.72	586.6	14.7
	41,600	Max Stored Volume m^3			

Case study assumptions:

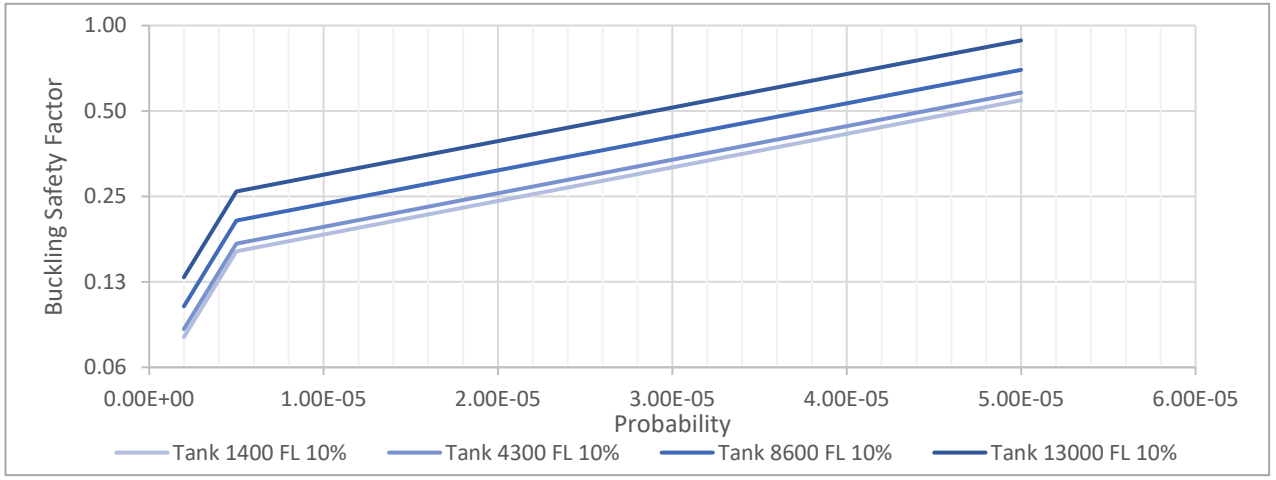
- Three flood scenarios: Flood depth and velocity
- Three filling levels scenarios

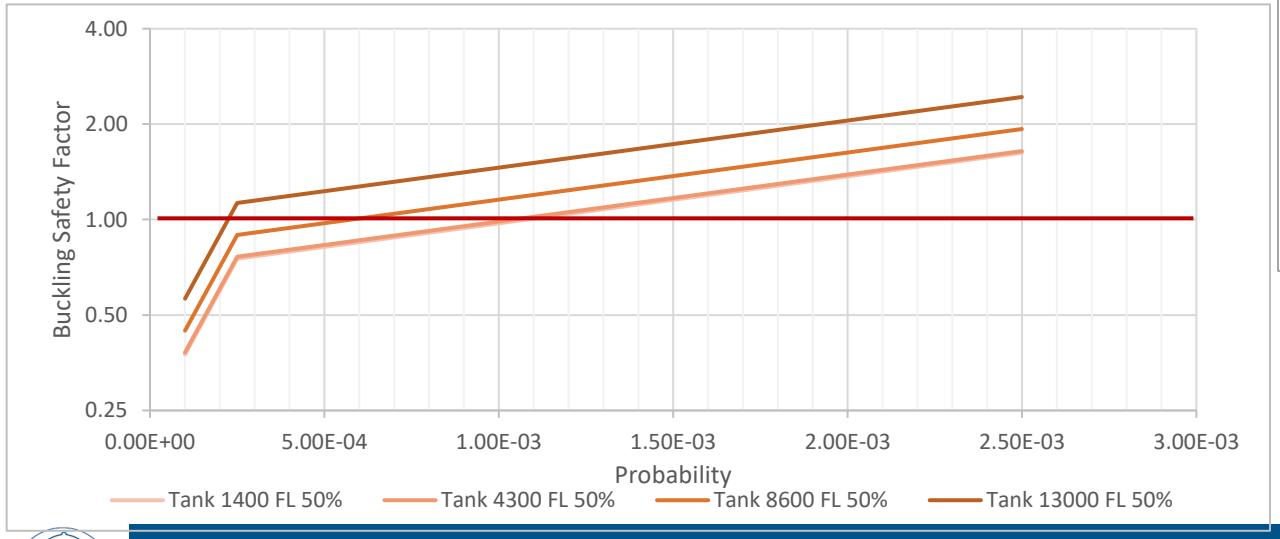
Retrun period	Prob	Hw [m]	Vw[m/s]
20	0.05	1	1.2
200	0.005	2	2
500	0.002	4.3	2.5

Filling level	0.1	0.25	0.5
Probability	0.001	0.005	0.01

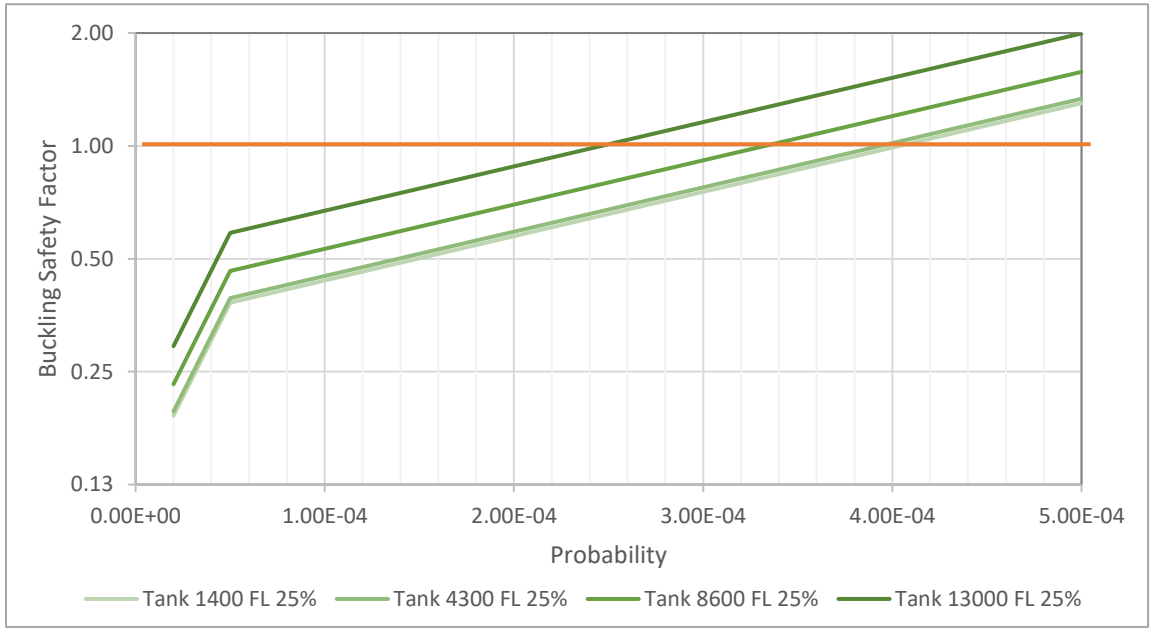
Case study: Vessel stability assessment during flood

Pnatech = $Prob_{flood}$ x $Prob._{filling\ level}$ (1.7) (From Bayes theorem)





39 out 48 scenarios results tanks collapsing and its consequences…

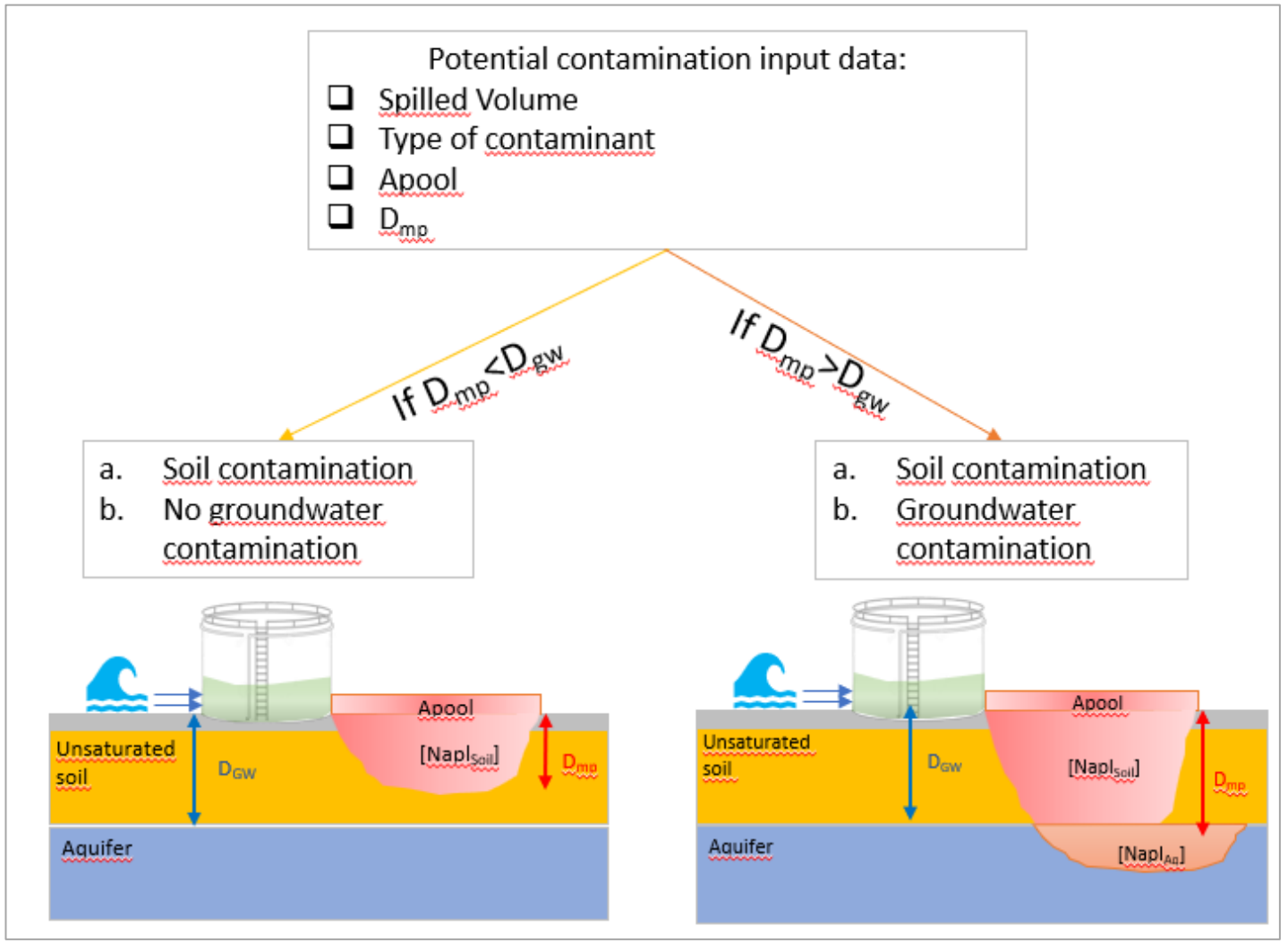


Tank buckling Factor = Pr/ Pw ≤ 1

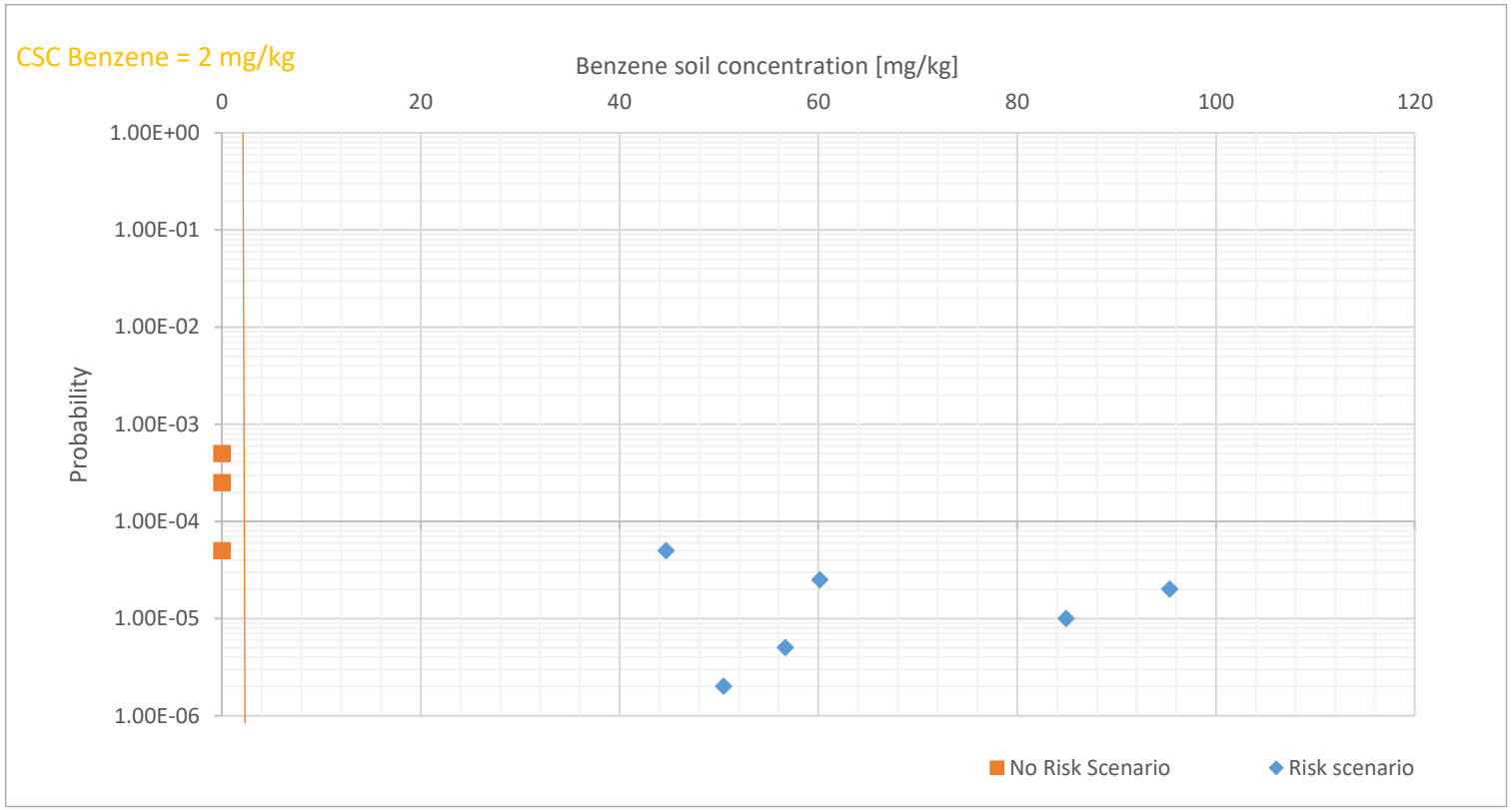
The tank collapse (1.5)

Case study: Environmental consequences?

Tank collapsing could generate environmental impact. Our goals are to figure out how much contaminants could polluting soil and groundwater.

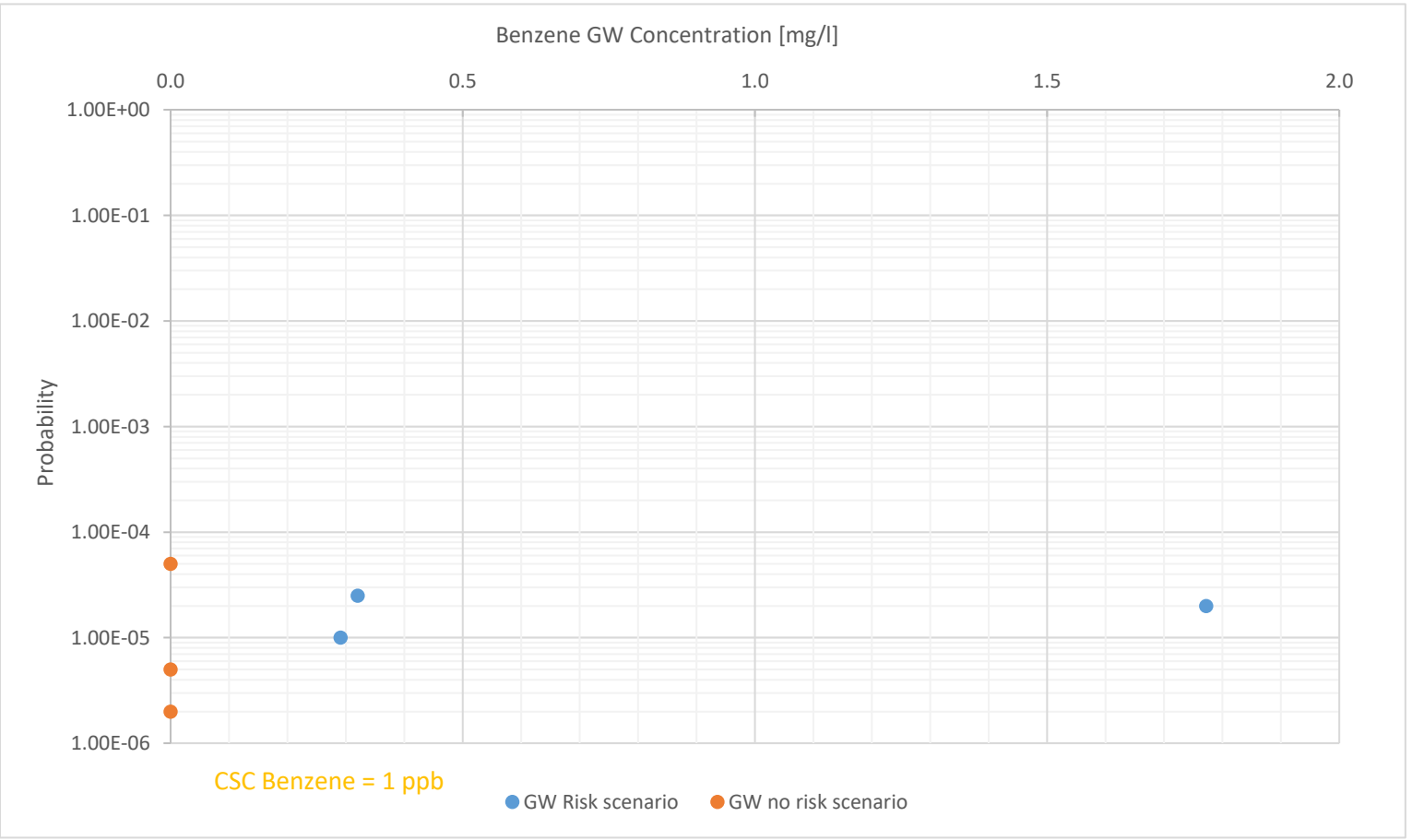


Case study: Results environmental consequences

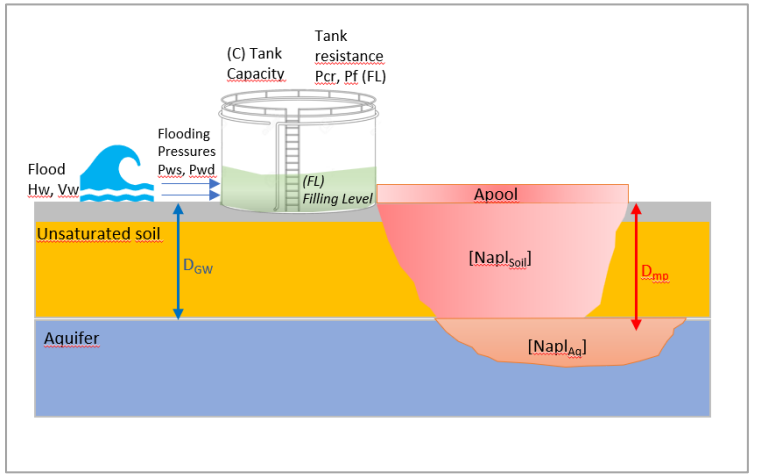


Since Gasoline is composed by many different contaminants (Toluene, Xilenes…), in this case study we consider only benzene as target contaminant.

Case study: Results environmental consequences



Reminding to conceptual model, only 2 scenarios figure out a groundwater contamination.



Case study: cost of remediation

Since the Soil volume affected by Natech is figure out, it could be easy find out the cost of remediation of each scenario:

Cost = Volume affected x Unit Cost of remediation

Unit cost for soil remediation	25	euro/Ton of treated soil
Unit cost for GW	50	Euro/m3 H_2O

Flood Return time	Filling level	Prob. Filling level	Soil concentration [mg/kg]	GW concetration [mg/l]	NatechEnv probability	Cost soil remediation	Cost GW remediation
500	0.1	0.001	50	0	2.00E-06	9,367,403 €	- €
500	0.25	0.005	85	0.29	1.00E-05	10,911,413 €	4,364,565 €
500	0.5	0.01	95	1.77	2.00E-05	26,024,285 €	10,409,714 €
200	0.1	0.001	57	0	5.00E-06	9,242,517 €	- €
200	0.25	0.005	60	0.32	2.50E-05	20,270,054 €	468,185 €
200	0.5	0.01	45	0	5.00E-05	23,580,744 €	- €
20	0.1	0.001	0	0	5.00E-05	9,242,517 €	- €
20	0.25	0.005	0	0	2.50E-04	- €	- €
20	0.5	0.01	0	0	5.00E-04	- €	- €

Conclusion

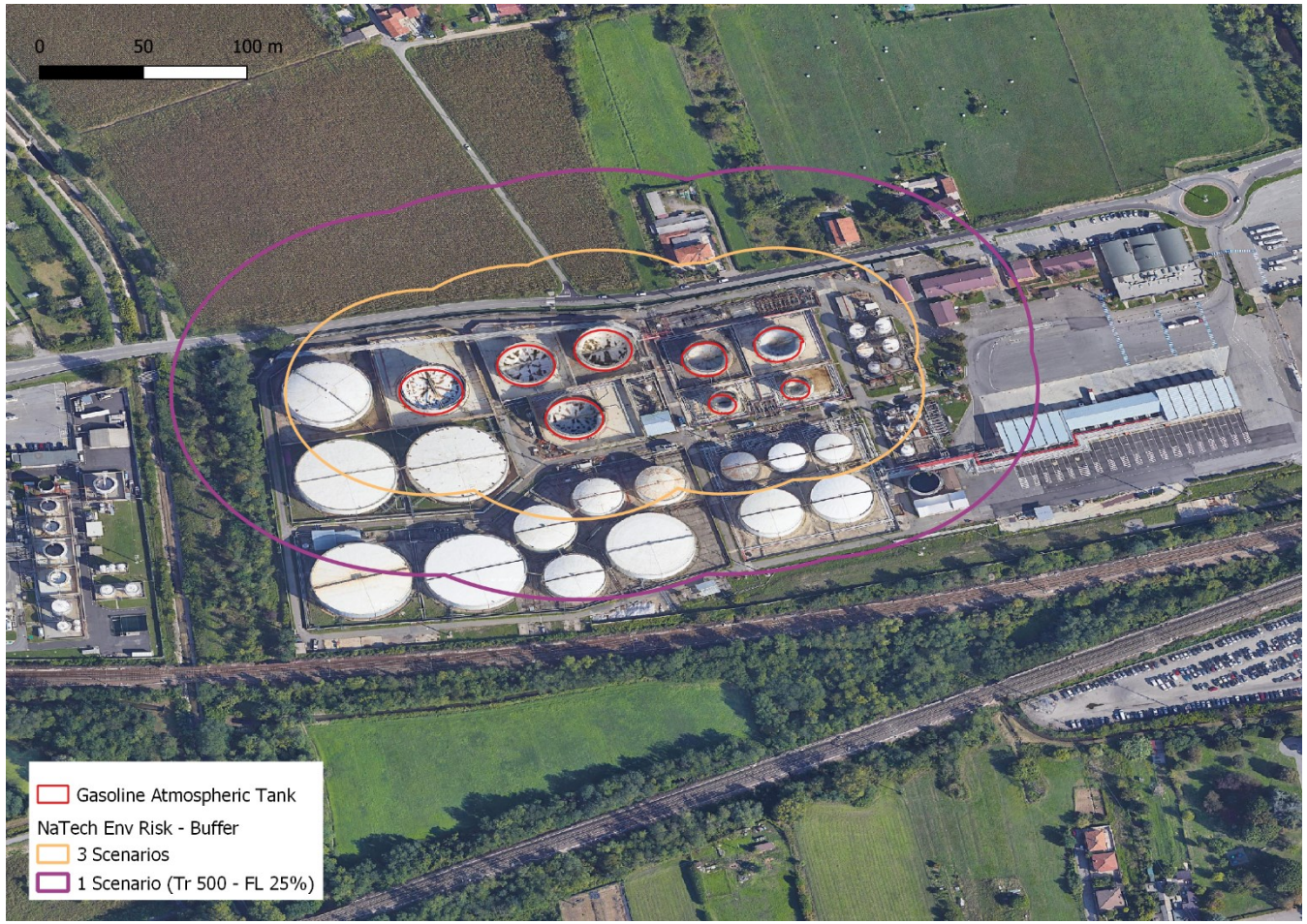
- The new framework created and applied in a realistic hypothetical case study generated different scenarios and concepibile consequences;

- We presented the vulnerability analysis regarding only buckling. Others tank collapsing dynamic will be take in consideration and evaluated (Flotation, displacement…)

- The Risk chain proposed is overconservative and it has relevant assumptions;

- The framework might be suitable also for earthquake, tsunami, cold wave…

- It is suitable to assess different structure but…we are missing vulnerability functions!



Thank you for your attention!

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