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Quantitative Risk Assessment in CCUS Projects: An Overview

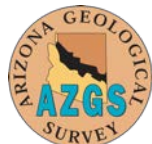
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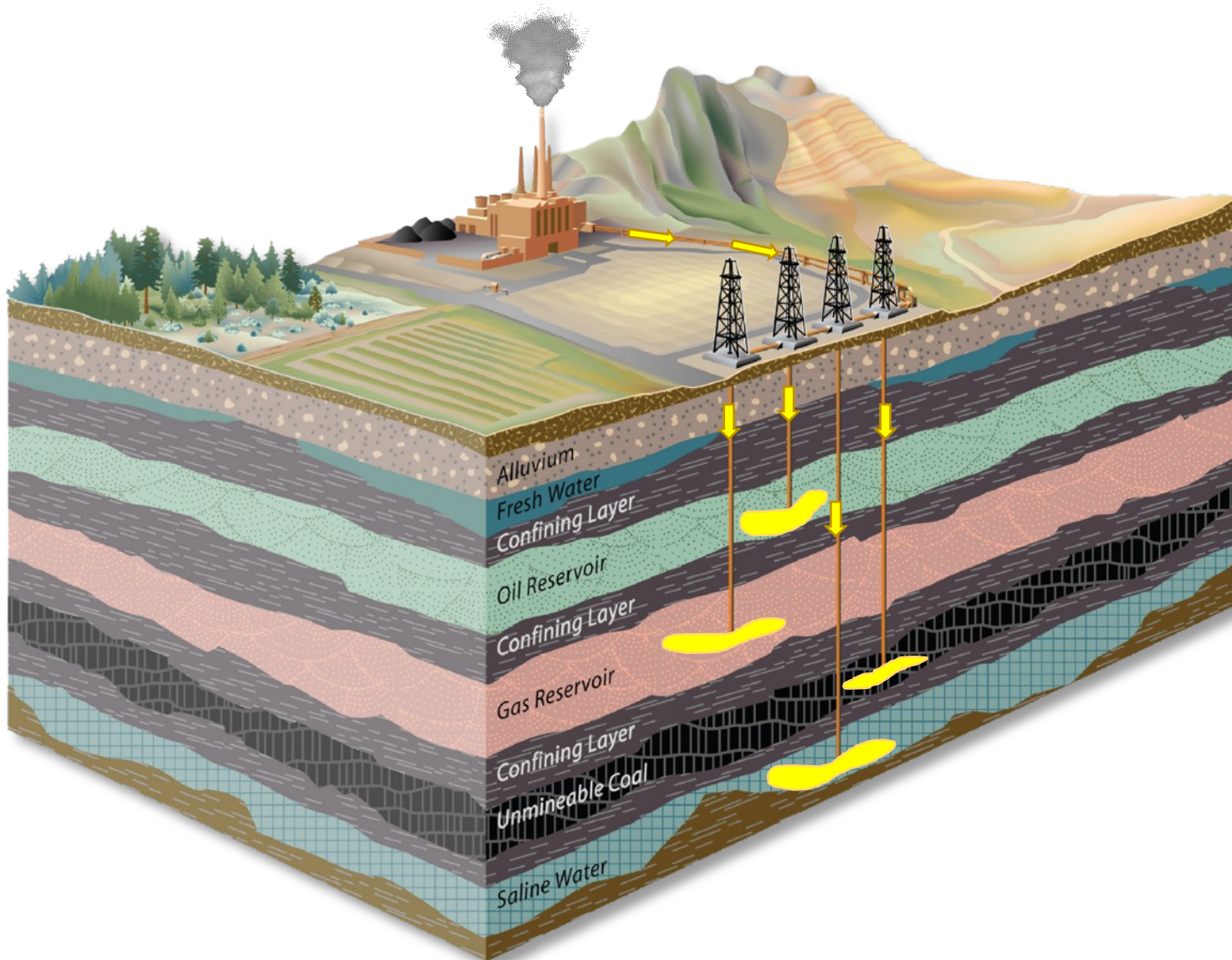
University of Utah

09/19/2023

Acknowledgement



CO₂ Capture, Utilization, and Storage



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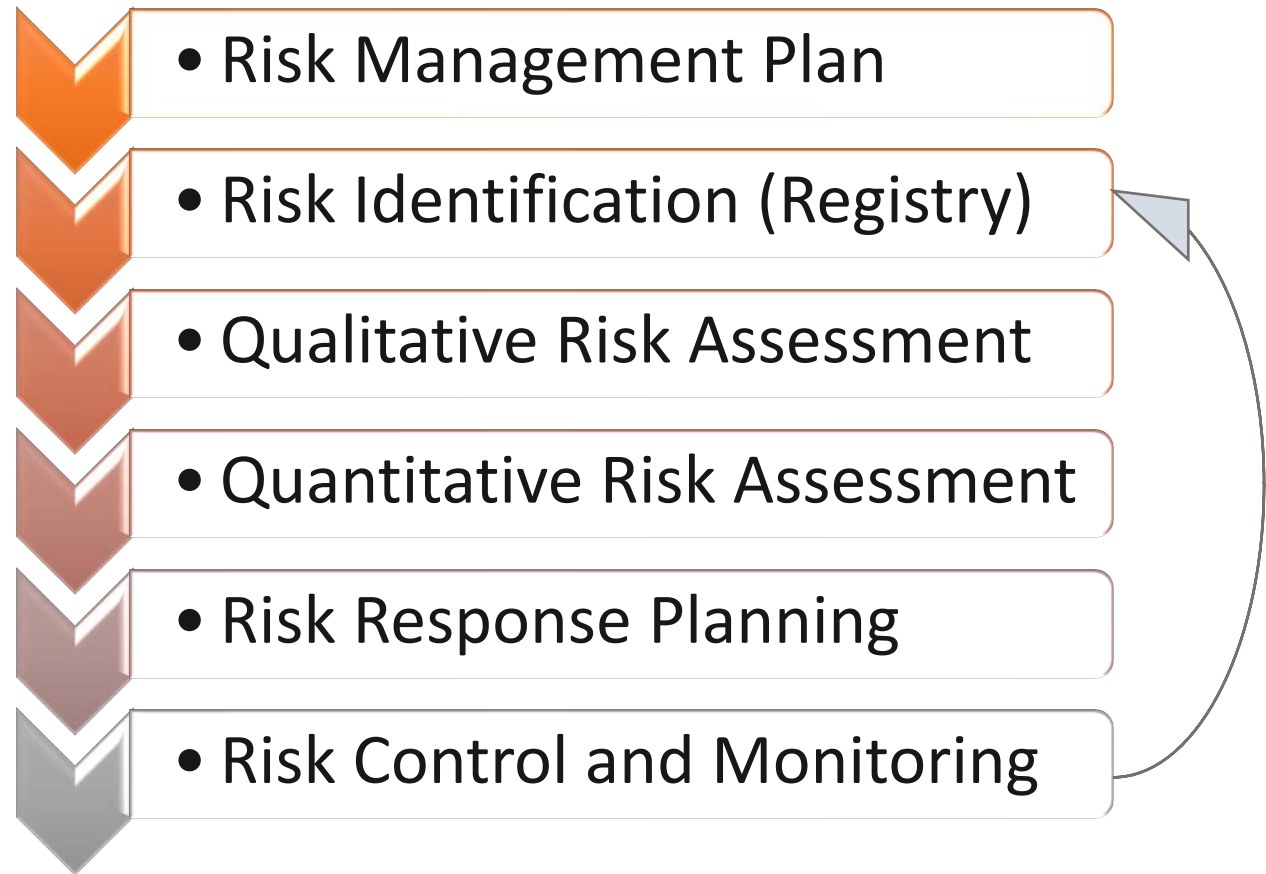
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Risk Assessment for CCUS

- Whether CO₂ can be successfully stored in subsurface.
- Whether CO₂ can be safely stored for long term.



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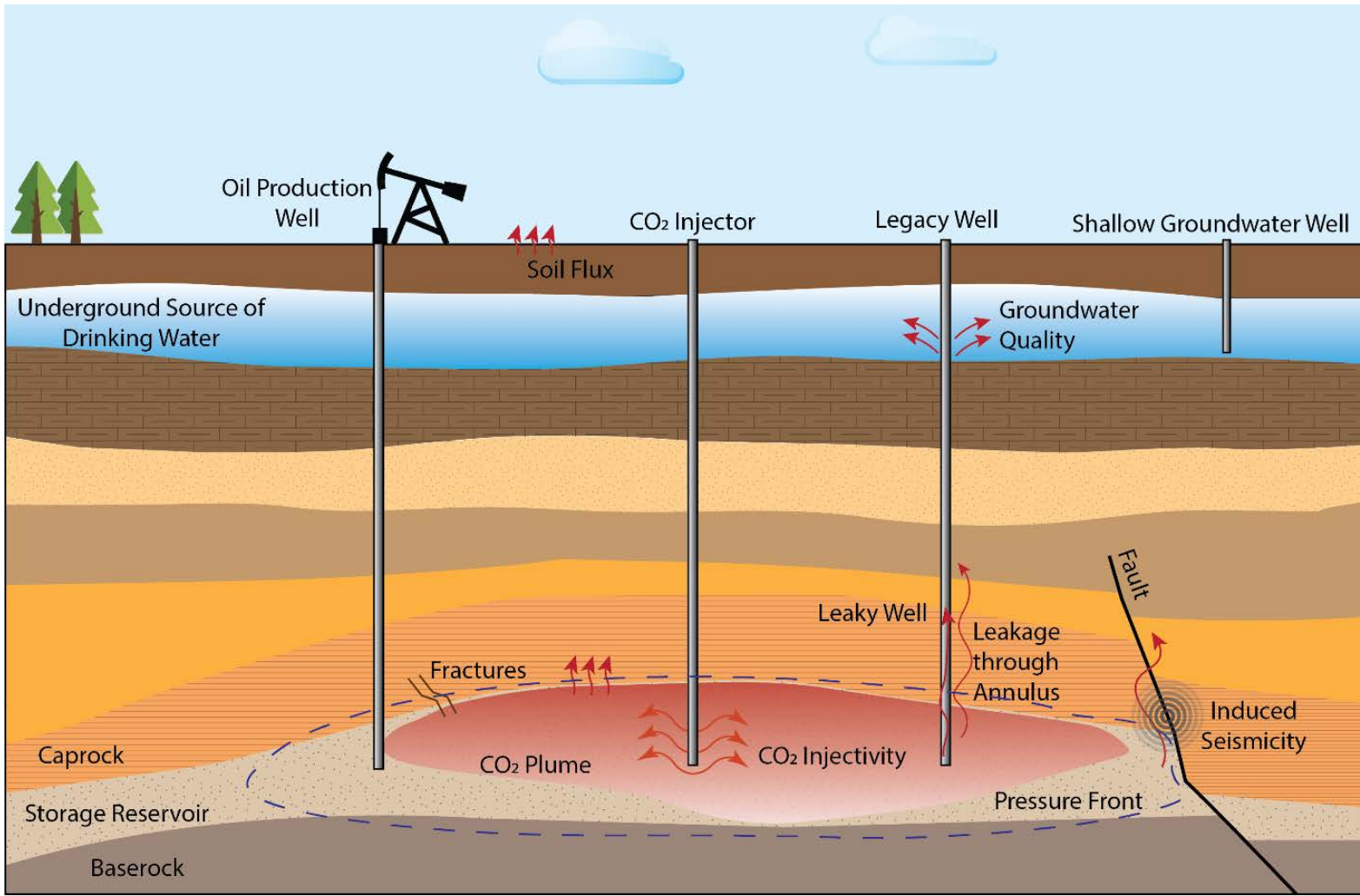
Risk Identification



		LIKELIHOOD				
		Improbable 1	Unlikely 2	Possible 3	Likely 4	Probable 5
MITIGATION Control Measures						
PREVENTION						
SEVERITY	Light (L) -1	-1 1L	-2 2L	-3 3L	-4 4L	-5 5L
	Serious (S) -2	-2 1S	-4 2S	-6 3S	-8 4S	-10 5S
	Major (M) -3	-3 1M	-6 2M	-9 3M	-12 4M	-15 5M
	Catastrophic (C) -4	-4 1C	-8 2C	-12 3C	-16 4C	-20 5C
	Multi-Catastrophic (MC) -5	-5 1MC	-10 2MC	-15 3MC	-20 4MC	-25 5MC

- 25 to -20: Non-operable**
- 16 to -10: Intolerable**
- 9 to -5: Undesirable**
- 4 to -2: Acceptable**
- 1: Negligible**
- Categories/Groups:**
- Air/Atmosphere
 - Surface-Near Surface
 - Subsurface
 - CO₂ Transportation
 - Ownership & Environment
 - Community

Risks Associated with GCS



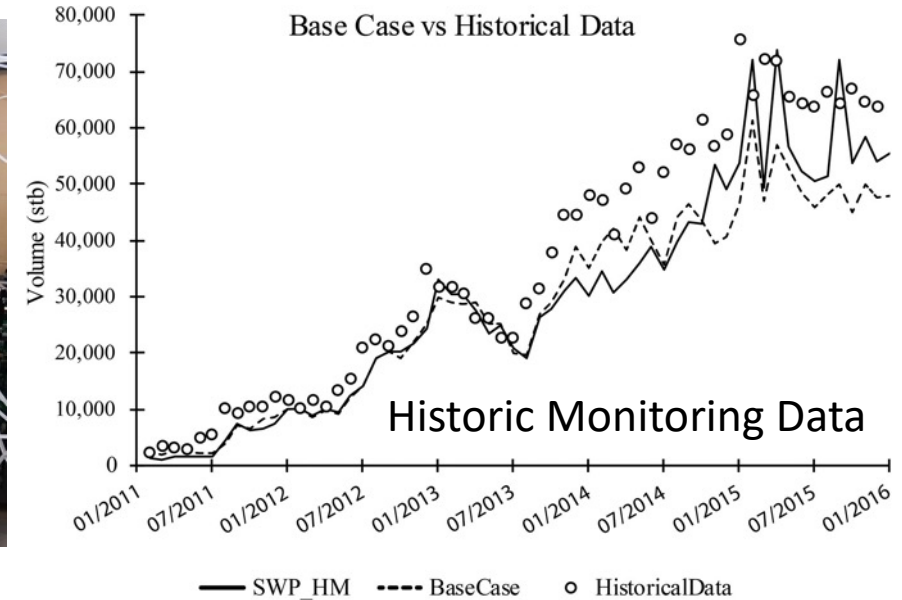
-  CO₂ Flow & Storage Capacity
-  Leakage
-  Induced Seismicity
-  Underground Sources of Drinking Water (USDW)
-  Atmosphere
-  Non-Technical Risks

Quantitative Risk Assessment Methods

Uncertain Components

Numerical Simulations

Forecast of Risks and Uncertainties



Simulation results are validated by available characterization, monitoring, and laboratory data.

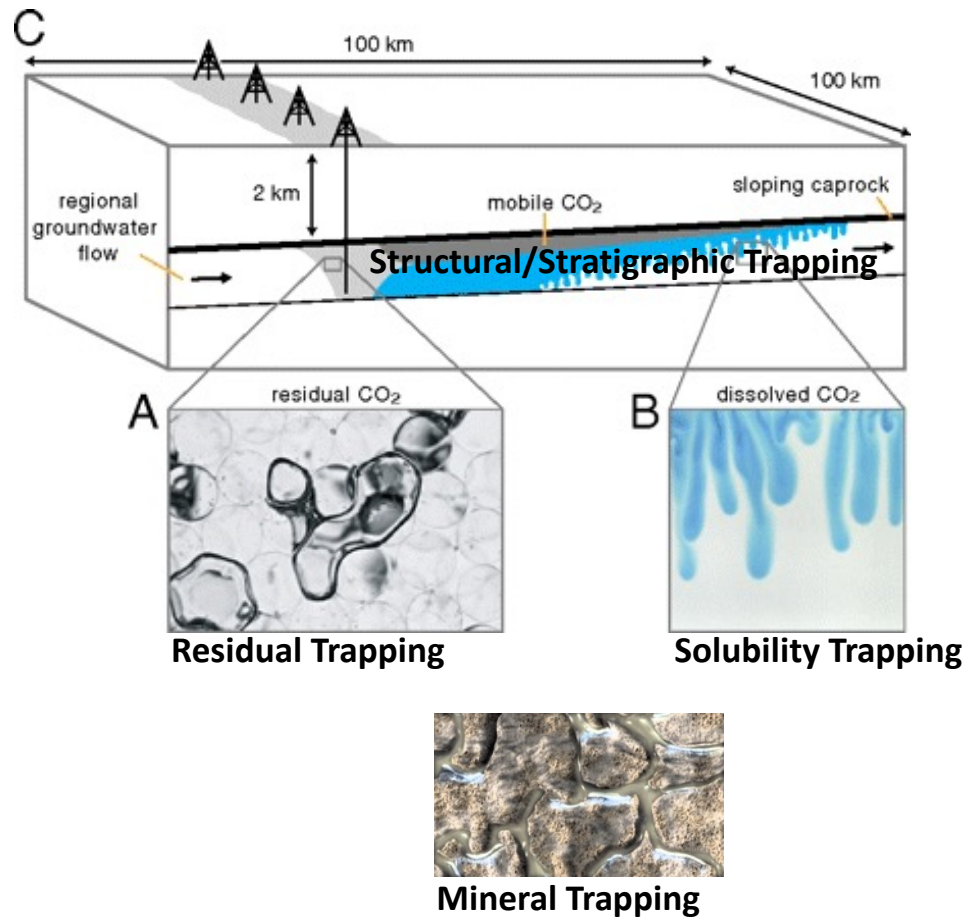
Monte Carlo Simulation

Reduced Order Models

Uncertainty Quantification

Machine Learning

CO₂ Flow & Storage Capacity



Geological Storage Capacity

Long-Term Injectivity

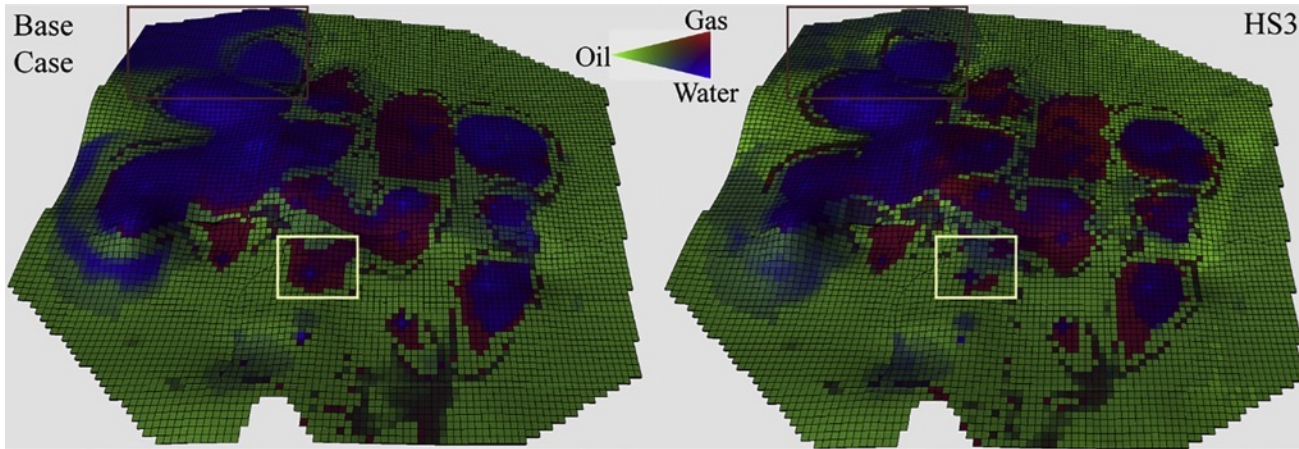
CO₂ Plume Migration

Storage Mechanisms

Storage Capacity Loss

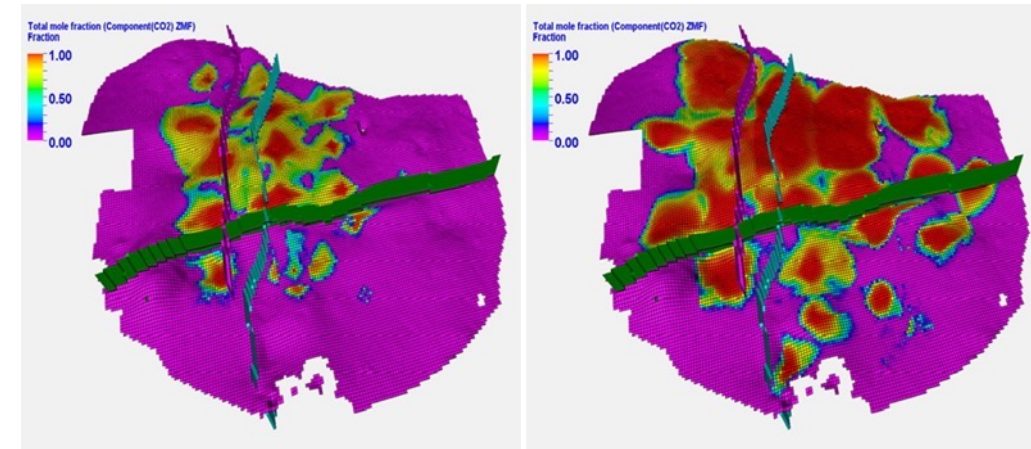
CO₂ Flow & Storage Capacity

- CO₂ Plume Forecast



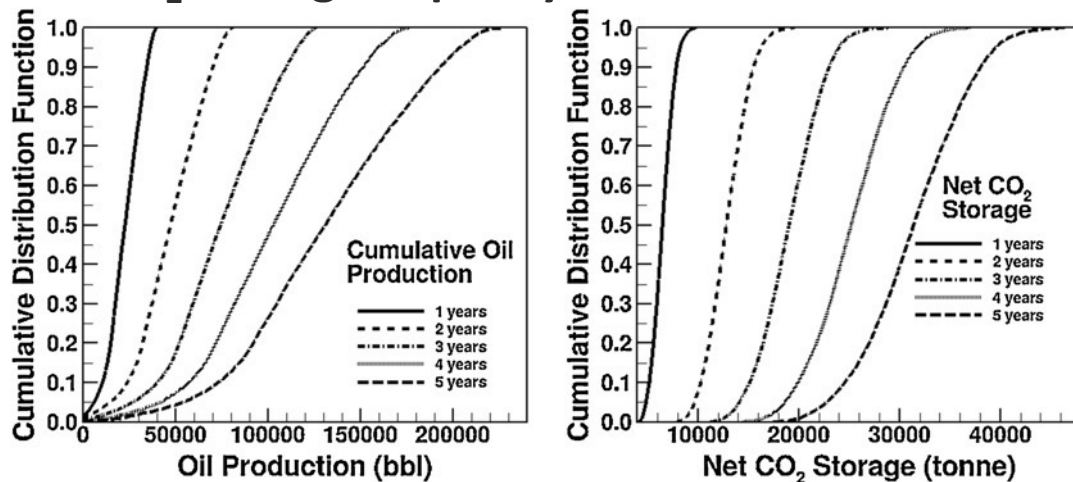
Three-phase saturation map with different relative permeability settings

- CO₂ Injection Optimization

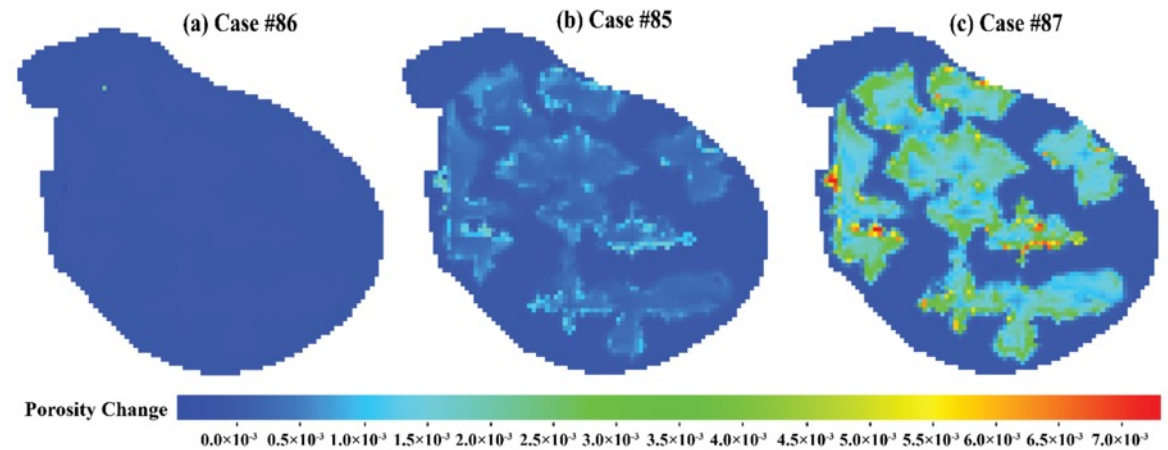


Max injection with optimized water alternating gas

- CO₂ Storage Capacity Forecast

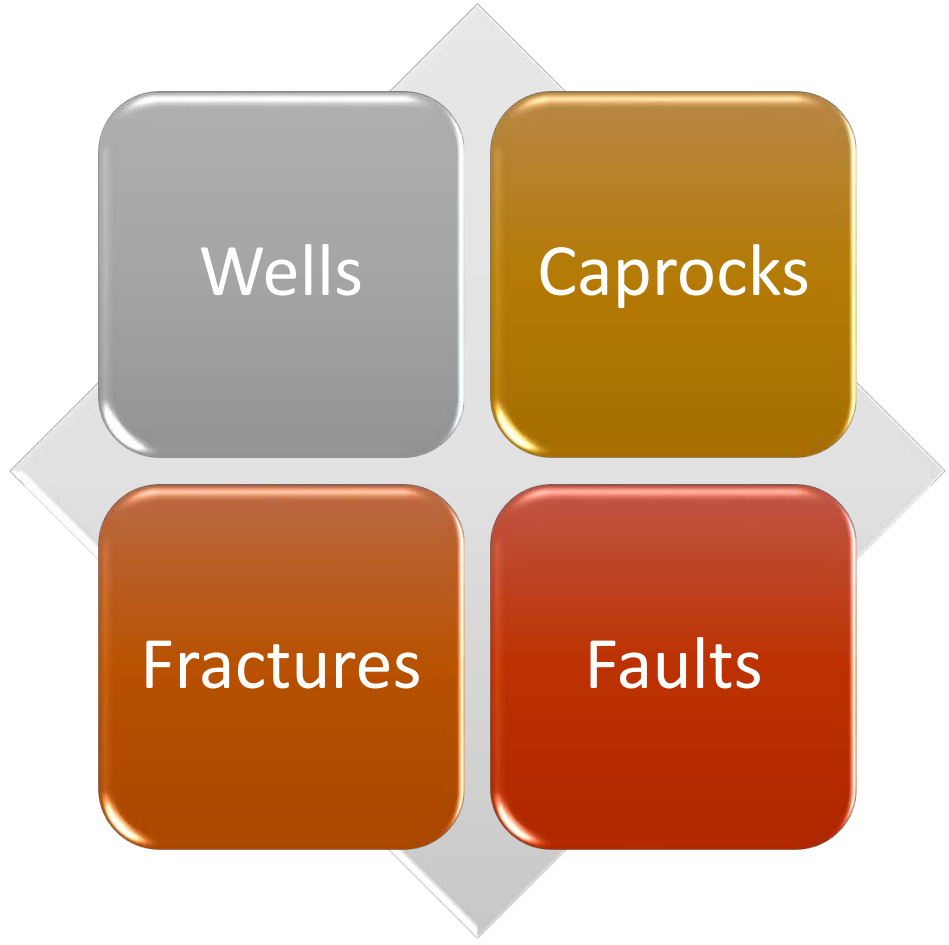
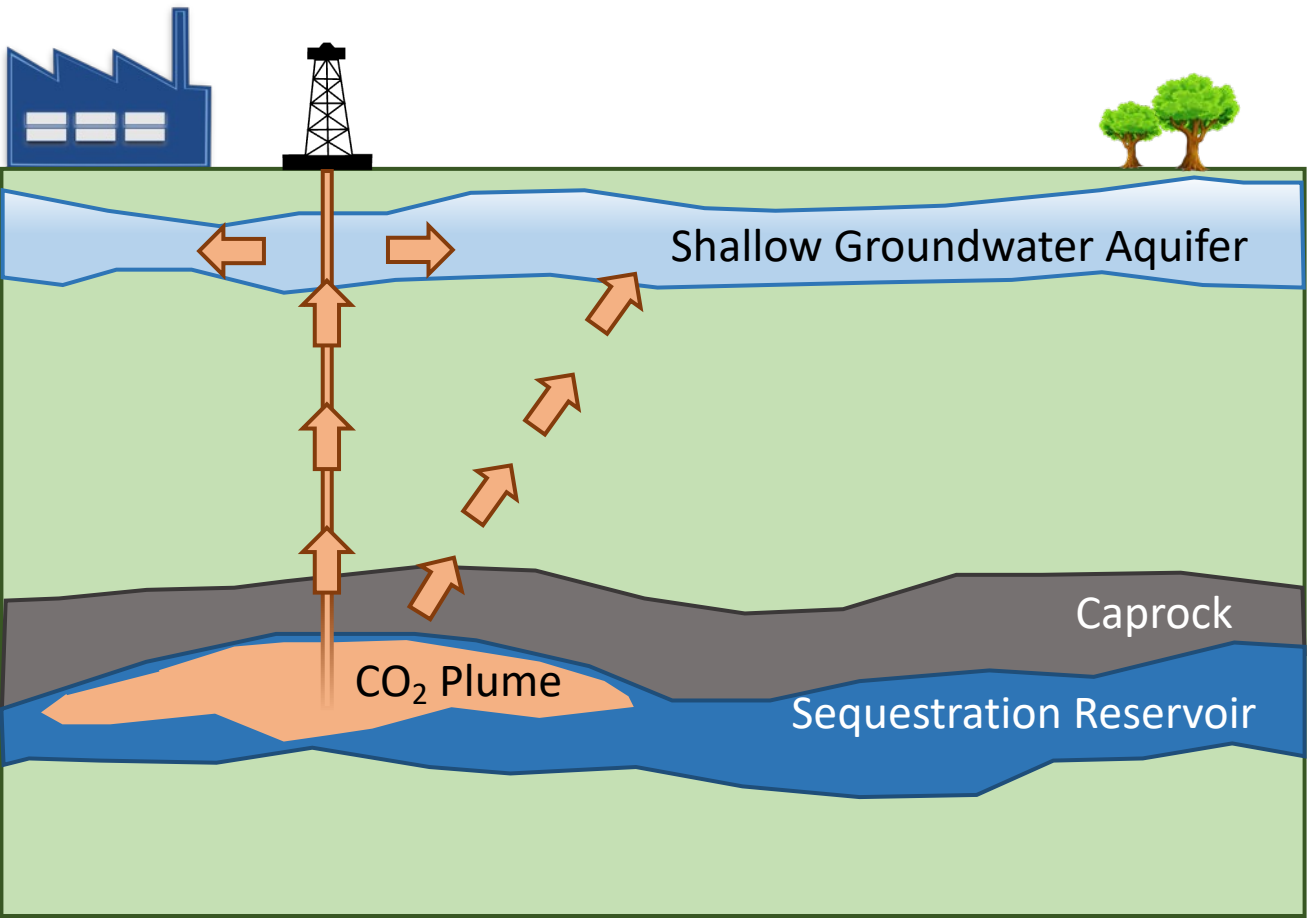


- Potential Storage Capacity Loss

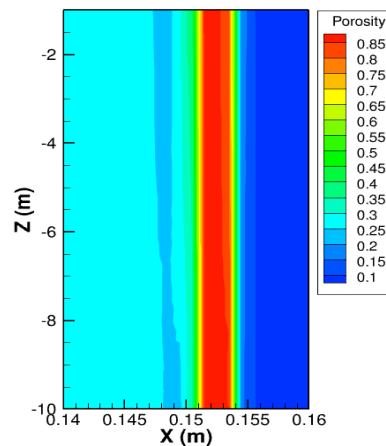
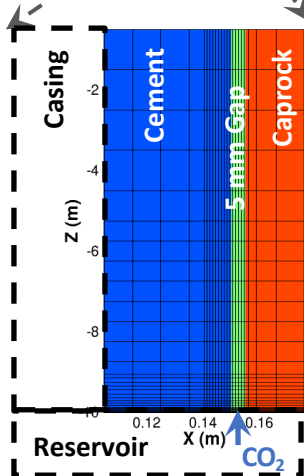
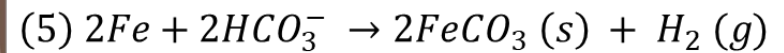
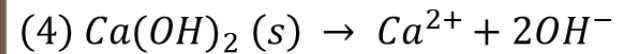
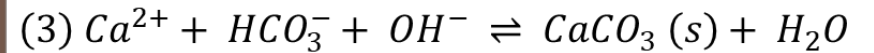
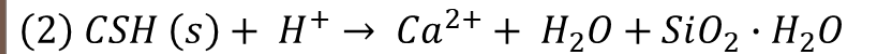
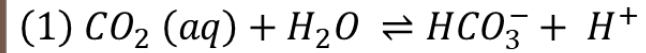
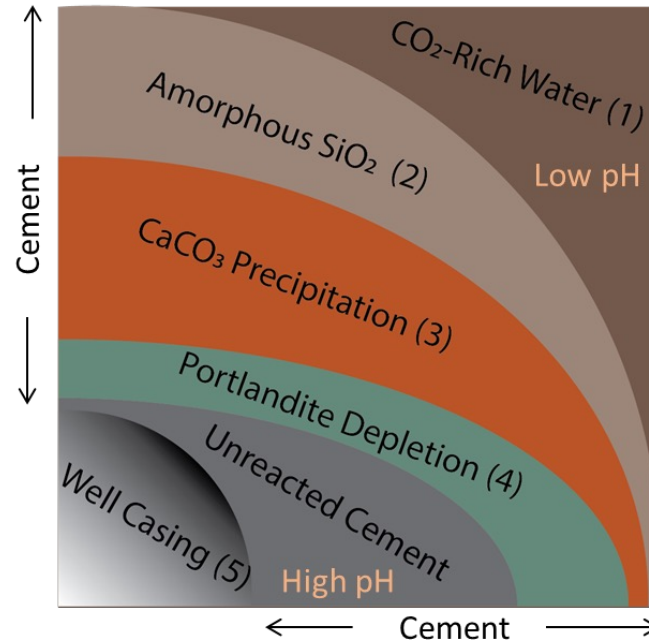
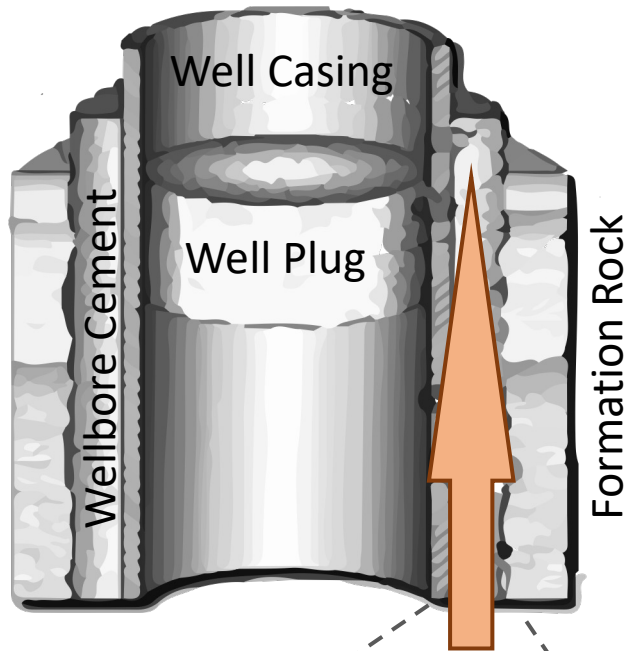


Estimated porosity loss

Leakage Risks



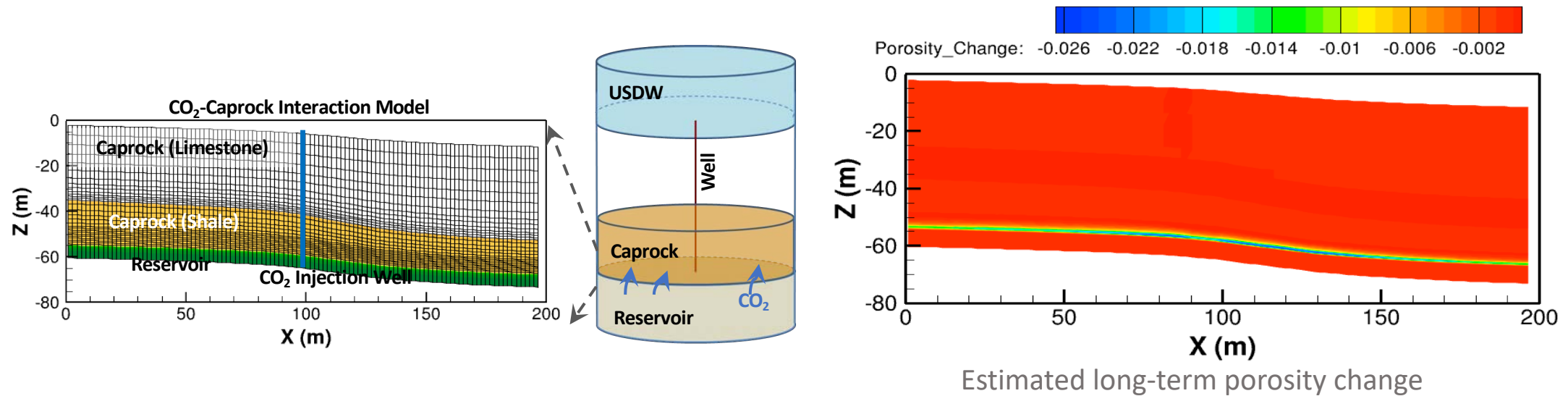
Leakage Through Wells



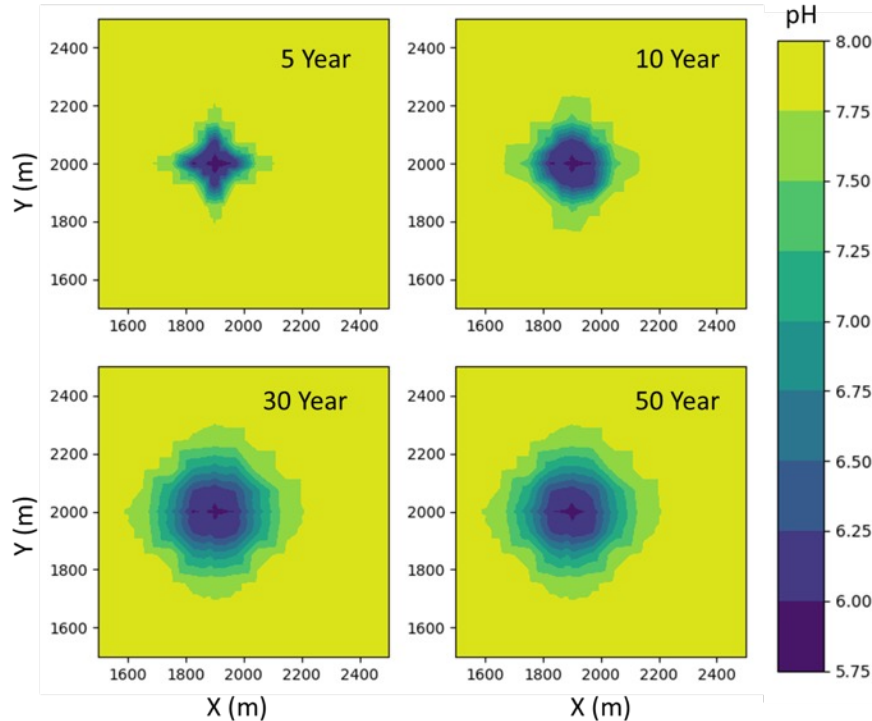
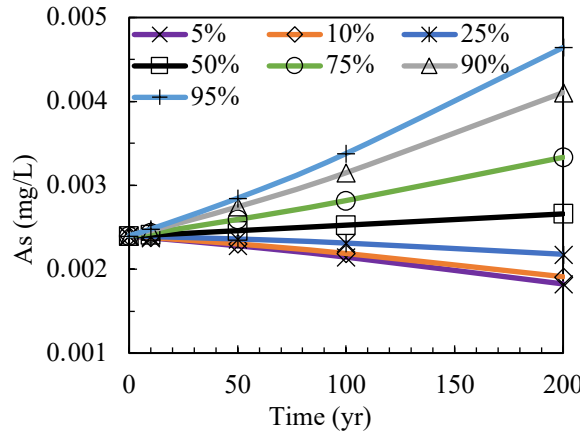
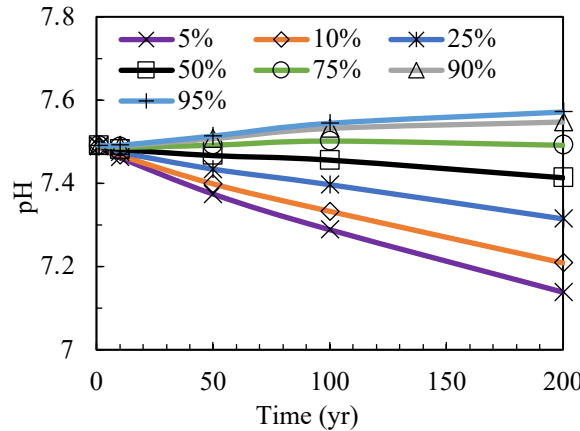
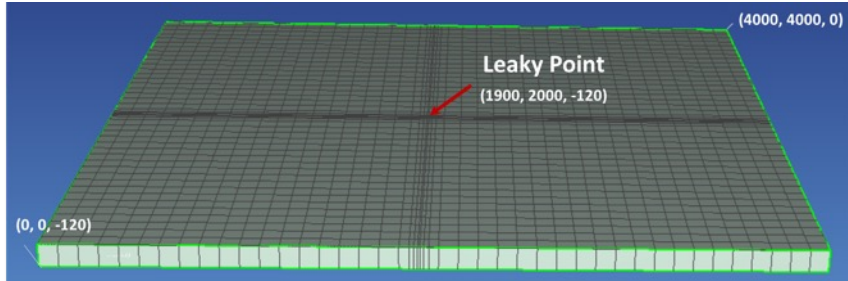
- Legacy wells are considered with more risks.
- Expected leakage is minimal (< 0.01% total injection).
- Worst-case scenarios (open holes) can lead to 0.4-1% leakage of the total injected CO₂.

Leakage Through Caprocks

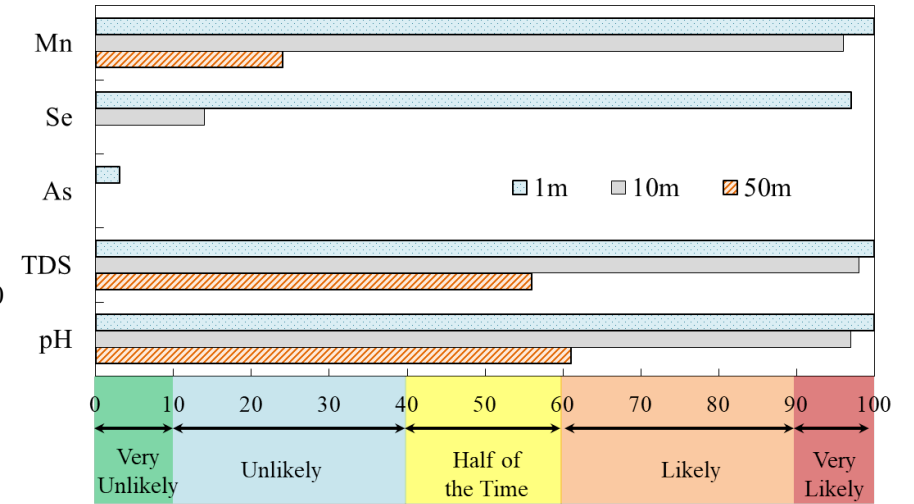
- Long-term safety relies on caprock capacity and integrity.
- Leakage mechanisms include diffusion, capillary pressure breakthrough, and fractures (pre-existing and induced).
- Caprocks may maintain their long-term integrity.



Underground Sources of Drinking Water



Forecast the impact area with simulations

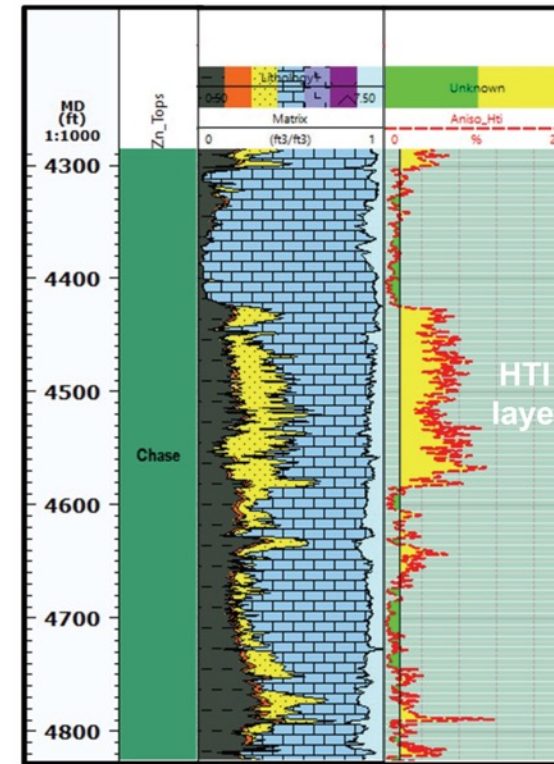
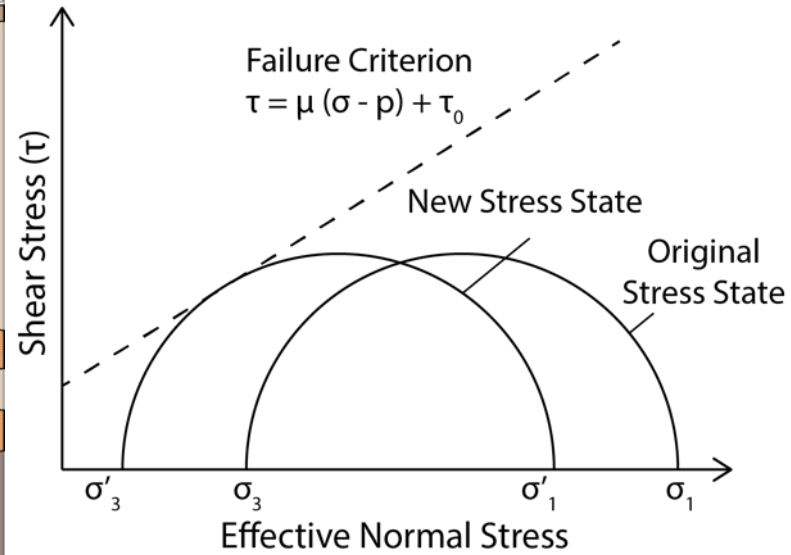
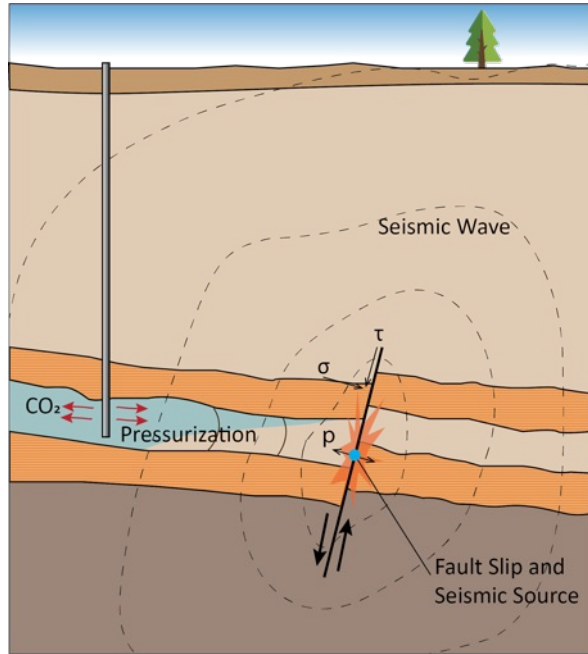


Estimate of likelihood of impacts

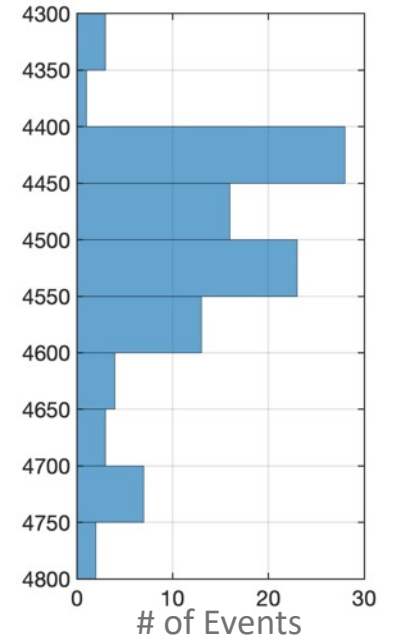
- Monitoring is important to detect any leakage and guide risk assessment.
- Risk assessment also guides and optimizes monitoring strategy.

Estimate changes of water quality

Induced Seismicity



Magnitude of most events is -1 – 0.5



Data!

Summary

- With the goal of “net-zero” greenhouse gas emissions by 2050 in the U.S. and the 45Q tax credit for CCUS, CCUS will be heavily invested.
- Risk assessment is crucial for CCUS projects (both science and commercialization).
- Risks and uncertainties of CO₂ behavior in the reservoirs, leakage, impacts to the USDW and surface, and induced seismicity are studied quantitatively with advanced techniques by the CSR team.



THANK YOU!



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