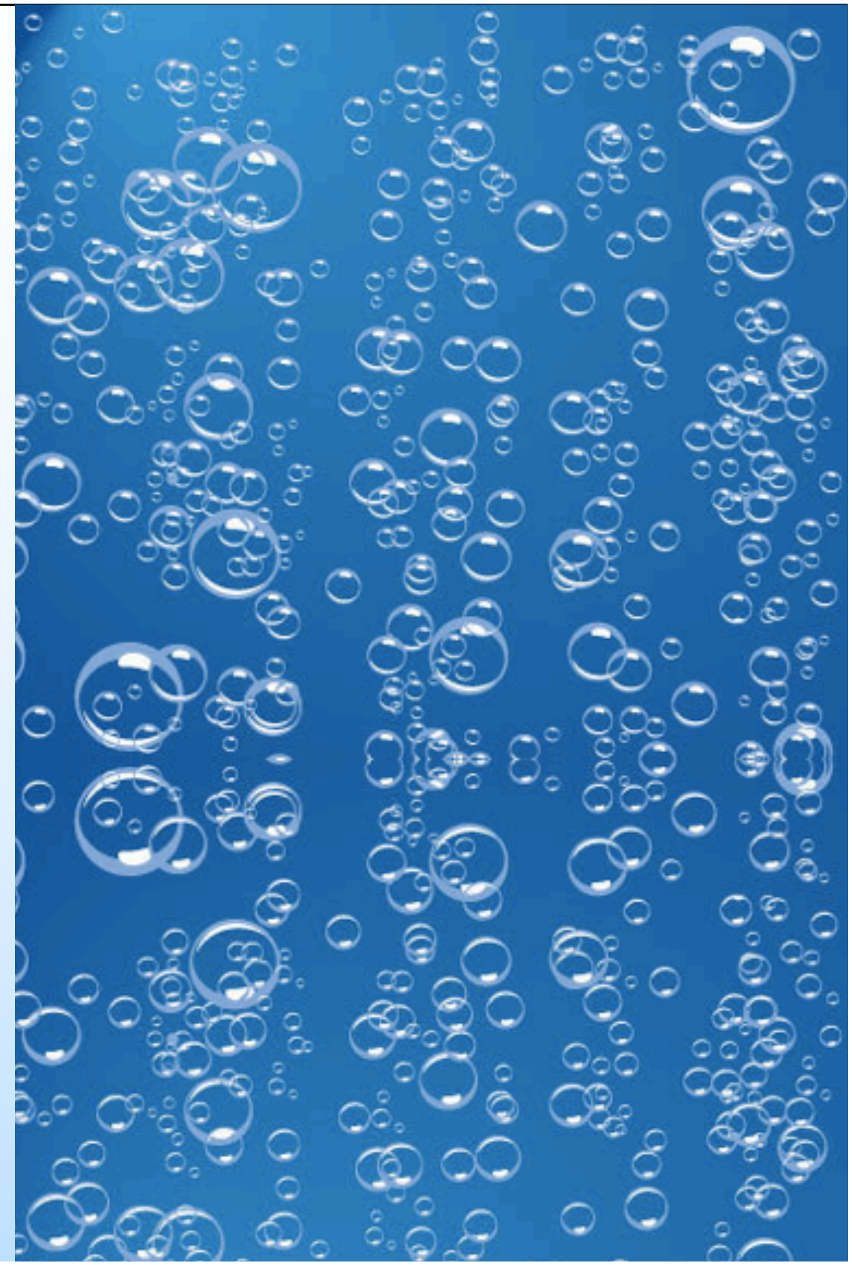
National Risk Assessment Partnership
Containment Assurance

Elizabeth Keating
Los Alamos National Laboratory

U.S. Department of Energy
National Energy Technology Laboratory
Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting
August 1-3, 2017

Presentation Outline

- Project goals
- Technical Status
- Accomplishments to Date
- Lessons Learned
- Synergy Opportunities



National Risk Assessment Partnership

Managing environmental risk and reducing uncertainties for CO_2 storage sites

Phase II tasks

- Containment assurance
- Induced seismicity risk
- Strategic monitoring for uncertainty reduction
- Demonstration of Risk Assessment Tools and Methodologies using Synthetic and Field data
- Addressing critical questions related to Assessment and Management of Environmental Risk at CO_2 Storage Sites

Containment Assurance task goals

1. Address key scientific questions related to leakage risk and mitigation

- How does CO_2 and brine flow through damaged cement in wellbores?
- How do caprocks response to stress?
- What are viable strategies for finding leaking wells and killing blow-out wells?
- What are appropriate risk-based frameworks for pressure management?

Containment Assurance task goals

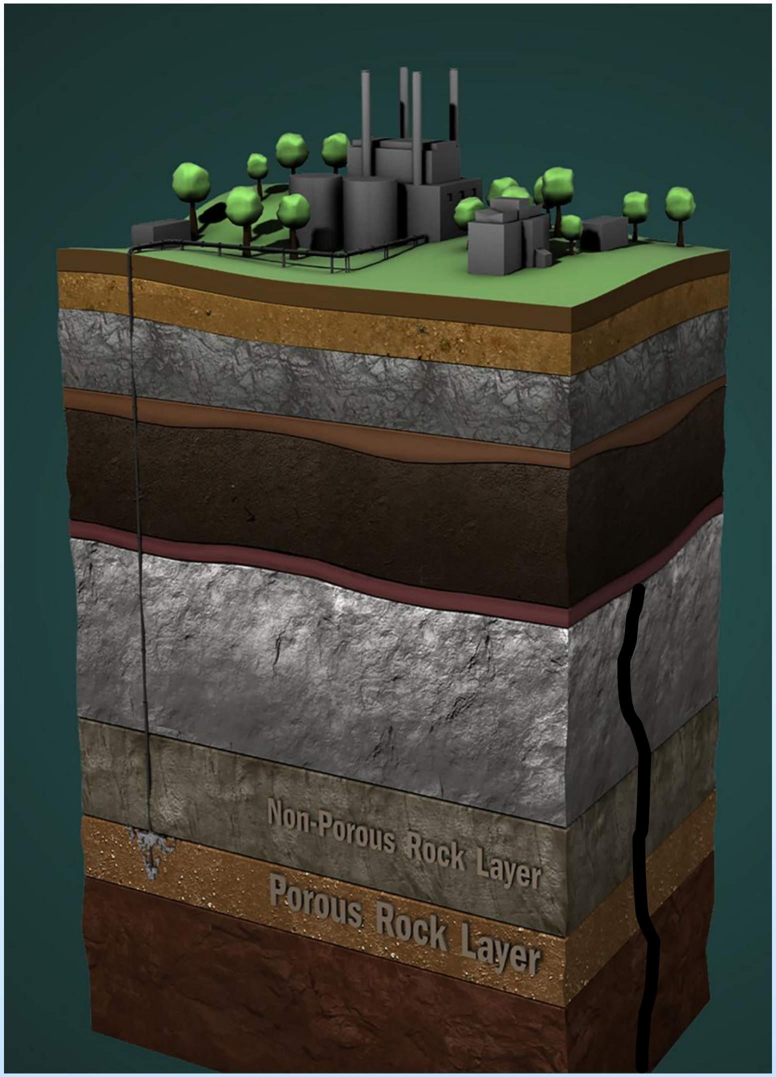
2. Develop software tools to support decision making at CCS sites, with capability to

- Quantify the risks associated with CO_2/brine leakage
- Update risk assessments with monitoring data
- Evaluate options for risk mitigation
- Assist in risk-based design of monitoring networks

NRAP tools open meeting: Today 3:30 – 6:30 Grand Station III-V

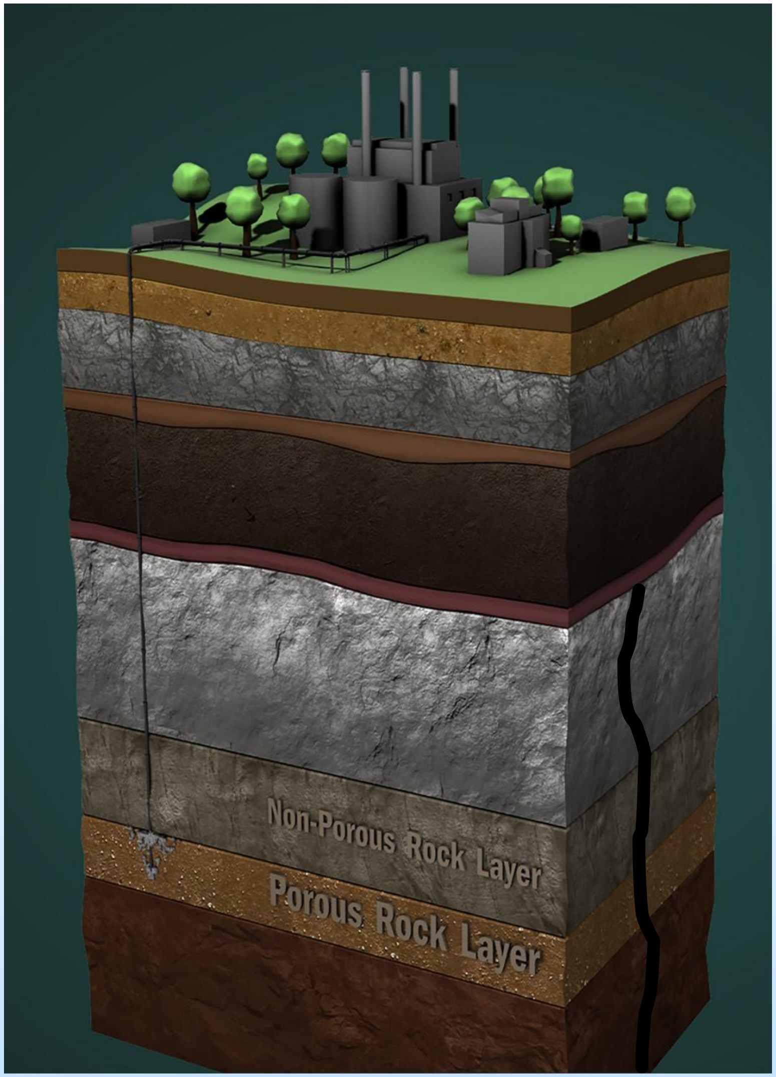
Technical Status

- Seal integrity
- Wellbore integrity
- Leak mitigation
- Integrated risk assessment



Technical Status

Seal integrity



Bill Carey, Dustin Crandall, Preston Jordan, Ernest Lindner, Nataliia Makedonska, Rajesh Pawar

NATIONAL ENERGY TECHNOLOGY LABORATORY
BERKELEY LAB
Los Alamos NATIONAL LABORATORY EST. 1943

Shearly, you must be joking ….

NATIONAL ENERGY TECHNOLOGY LABORATORY
Dustin Crandall, Jonathon Moore
Los Alamos NATIONAL LABORATORY EST. 1943
Bill Carey, Luke Frash
BERKELEY LAB
Tim Kneafsey, Seiji Nakagawa

March 14th, 2017

Distinctly different behavior of fractures undergoing shear, dependent on the rock type. More clay -> more smearing -> lower permeability after shear

Characterization of CO_2 leakage through fractured caprocks

Rajesh Pawar
Nataliia Makedonska

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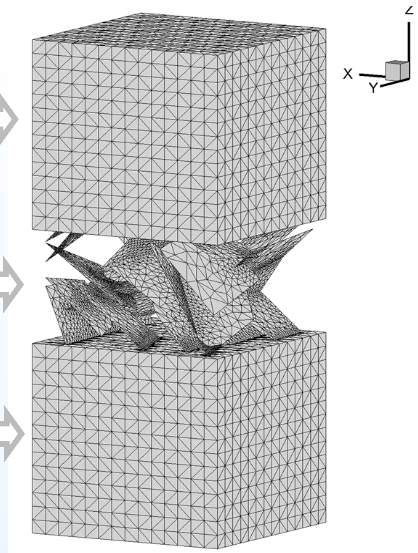
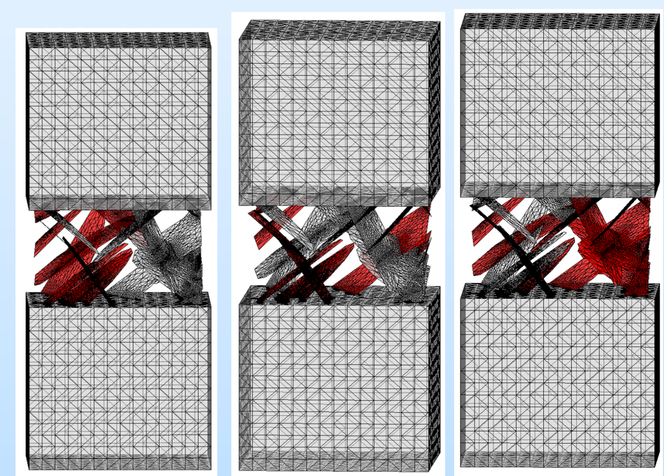


Not all fractures contribute to flow

Operational scenarios affect CO_2 movement

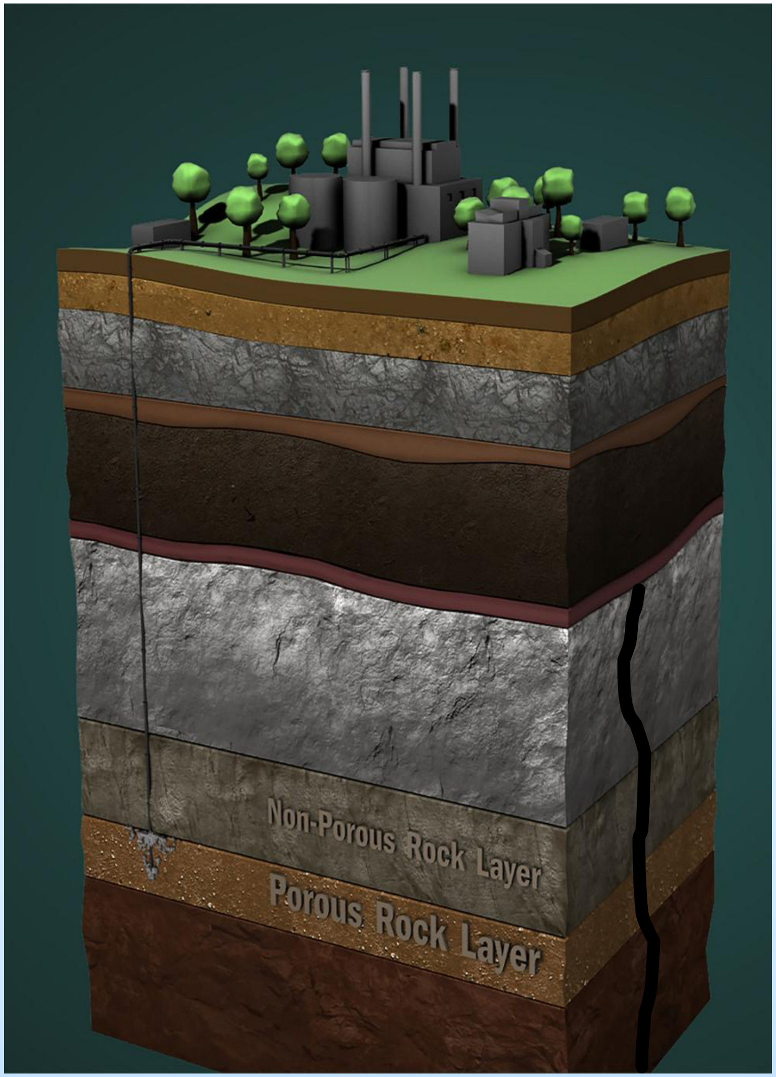


Fractures primarily contributing to flow are represented with red color

Technical Status

Wellbore integrity

Susan Carroll, Shaoping Chu, Dylan Harp, Jaisree Iyer, Preston Jordan, Kenton Rod, Pratanu Roy, Nik Huerta



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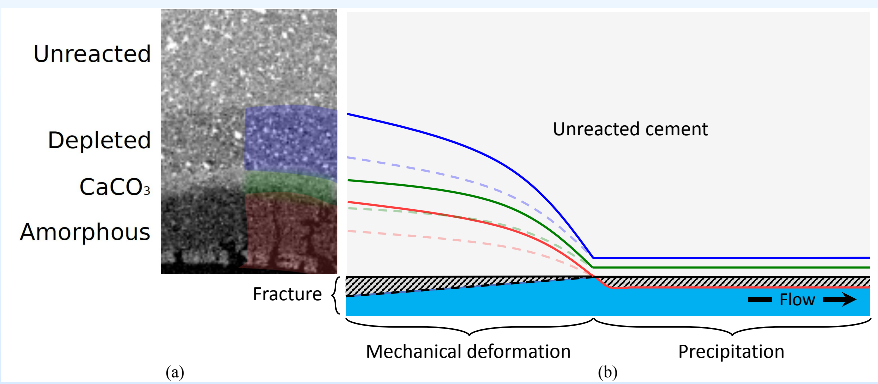
Pacific Northwest NATIONAL LABORATORY

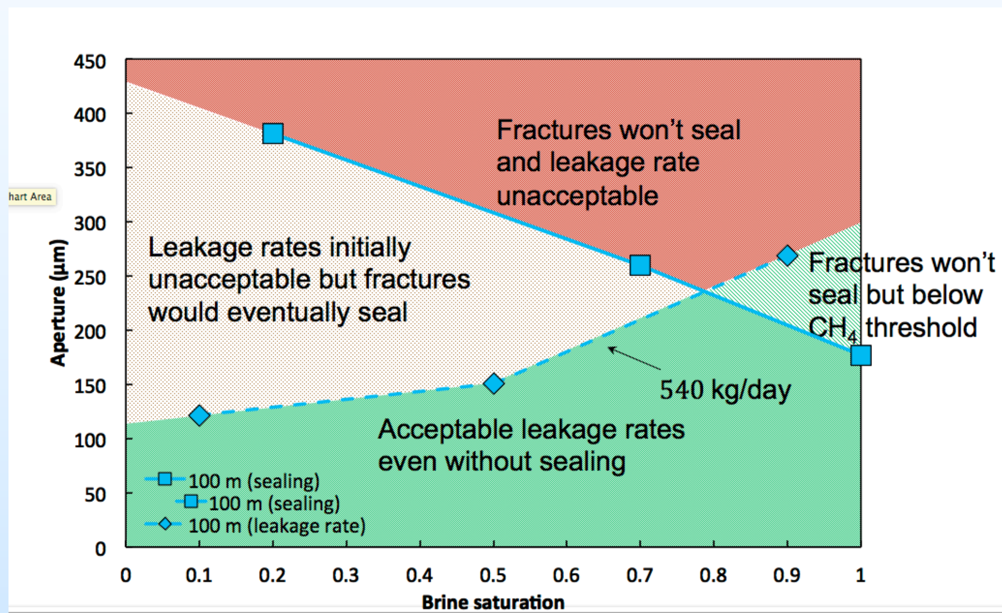
Developed first-in-kind model that forecasts changes in well integrity by including chemistry, mechanics, and flow

Susan Carroll, Jaisree Iyer, Stuart Walsh

Multi-physics simulations of CO_2 and brine flow along a fracture



Damage zones of concern for a 10 MPa overpressure

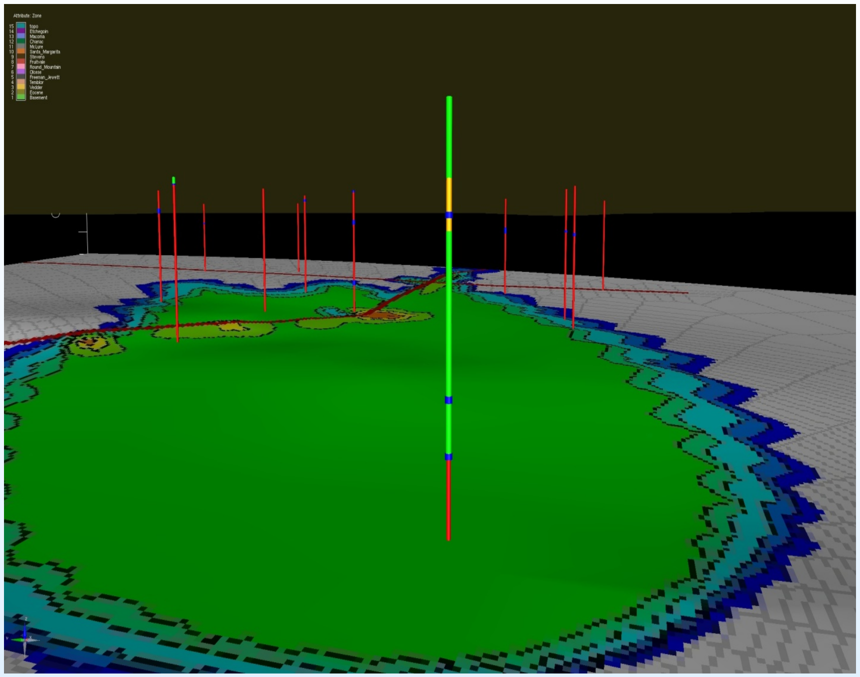


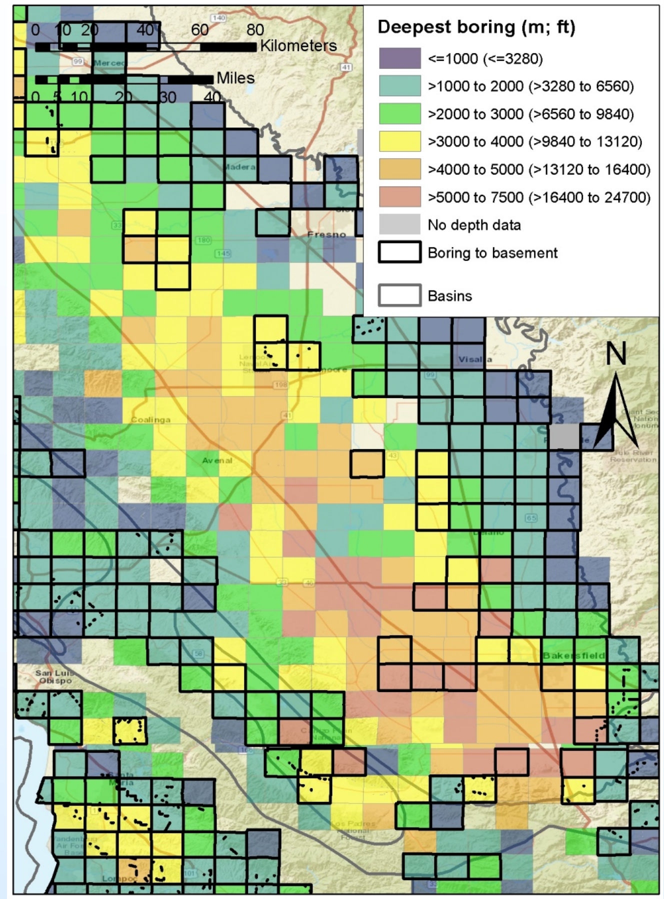
Developing a New ROM that incorporates impact of chemistry and mechanical alteration

Mining datasets on uncased borings

Preston Jordan

Energy Geosciences
EARTH & ENVIRONMENTAL SCIENCES AREA



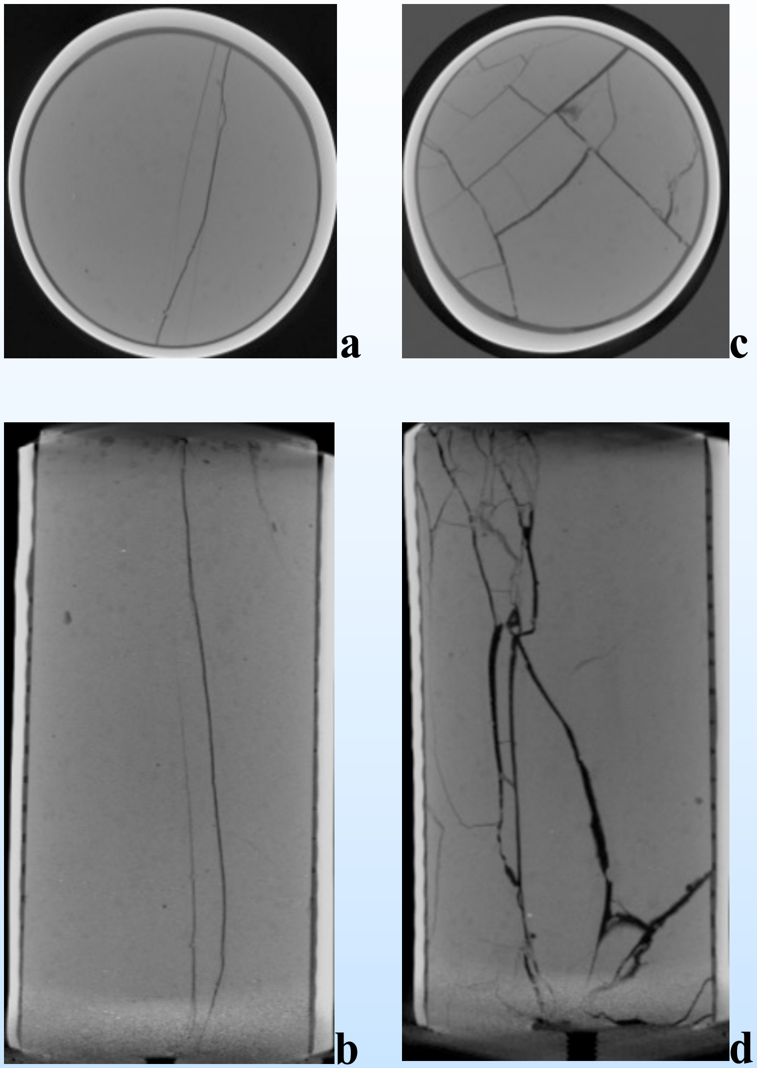


- Ubiquitous, at least in oil and gas basins
- A large proportion are plugged above the base of USDW, particularly prior to ~1981 when the Safe Drinking Water Act was implemented
- Transmissivity unknown - could be open, gelled, or sealed due to squeezing or collapse
- Research needed to constrain this substantial unknown (epistemic risk)

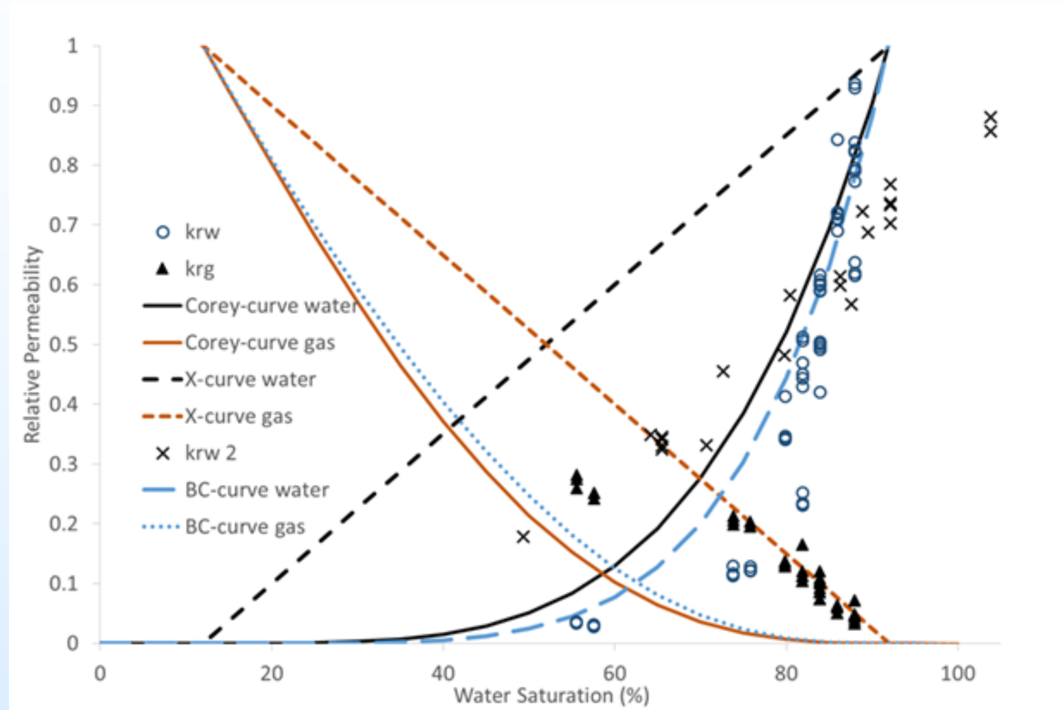
Relative Permeability for Water and Gas through Fractured Cement

Kenton Rod

Pacific Northwest NATIONAL LABORATORY



X-ray Computed Tomography (XCT)



Cement fracture aperture size and complexity influences which relative permeability model is most valid

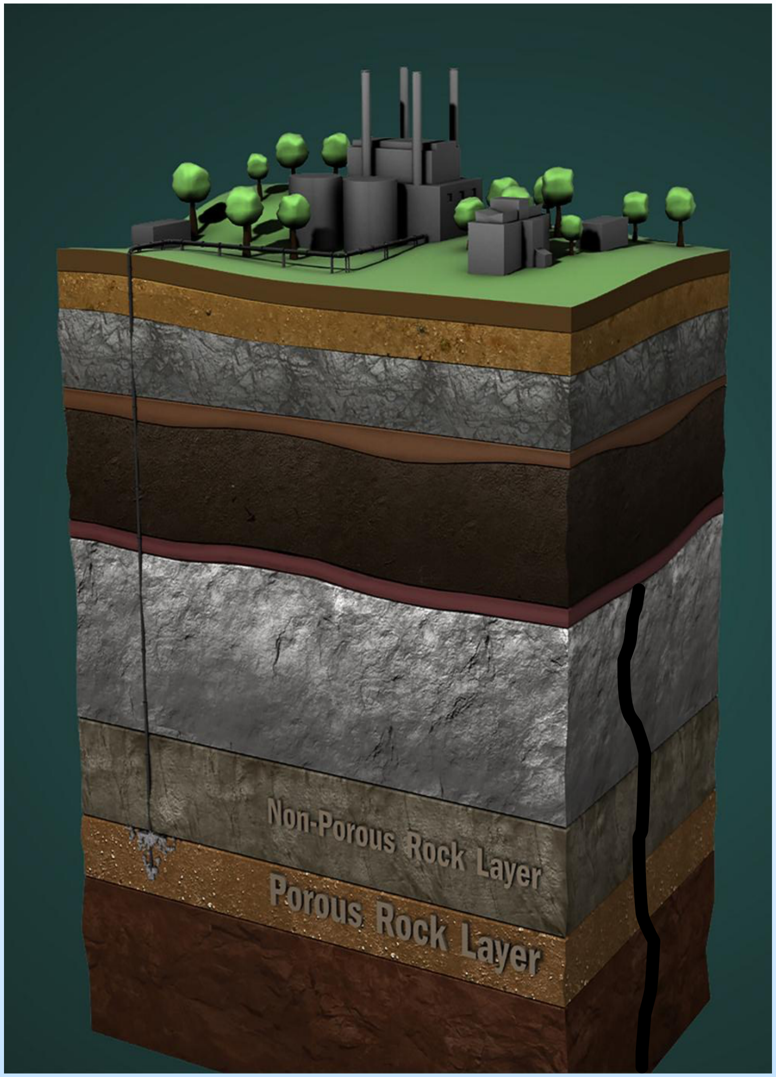
Technical Status

Leak Mitigation

Curt Oldenburg

Lehua Pan

Abdullah Cihan



Development of risk assessment and mitigation approaches for leakage

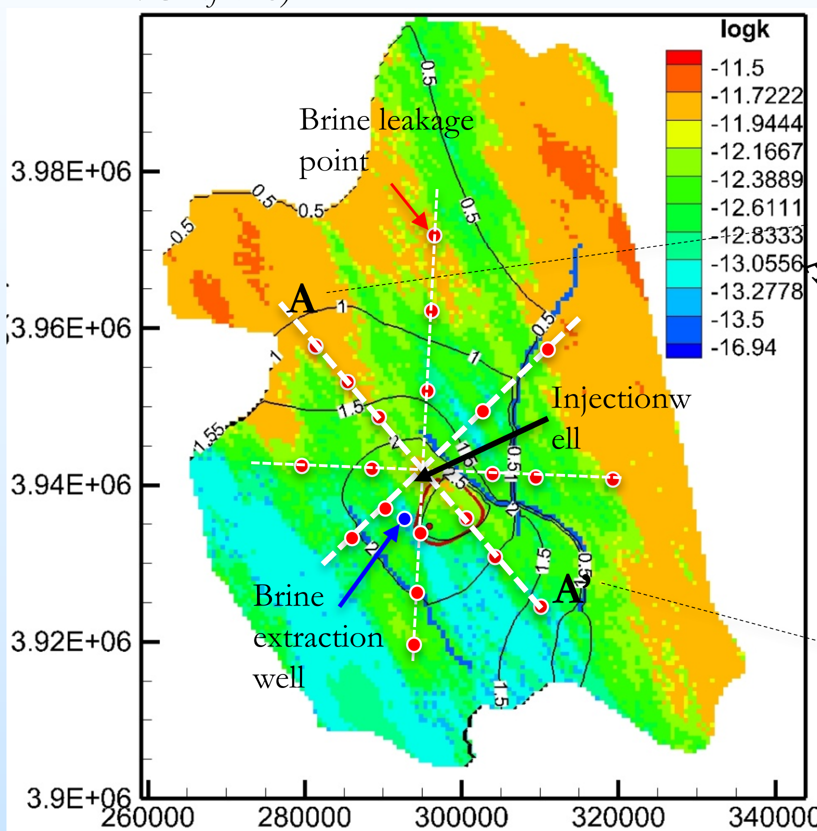
Objective: Using the risk map-based risk assessment approach (*Siirila-Woodburn et al.*, 2017), assess how the risks for leakage evolve with time by applying mitigation options:

1) **Stop injection**
2) **Stop leakage**
3) **Pressure control**

via brine extraction

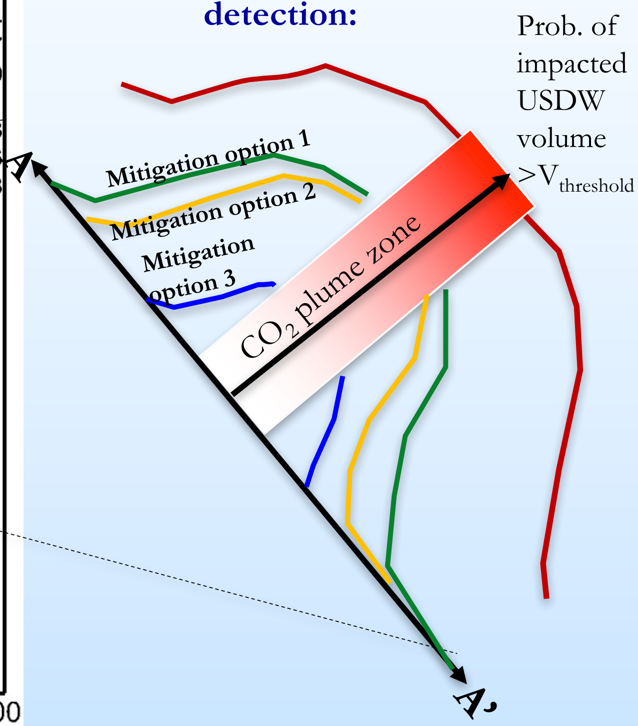
- Focus on understanding and quantifying brine leakage *risks* from abandoned wells
- Can be used to inform site selection and monitoring during and post-injection

At each ***point (red dot)****, simulate brine leakage deterministically for a range of well permeability values* ∈ *[k_{min}, k_{max}] and then calculate plume sizes in USDW with salinity higher than some threshold (e.g. secondary MCL of TDS)*



Pressure-buildup contour lines (black) in MPa and CO_2 plume extent (red) in the first Vedder Sand, Kimberlina

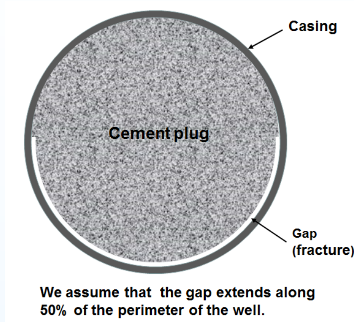
Schematic risk profiles at a time t after leakage detection:



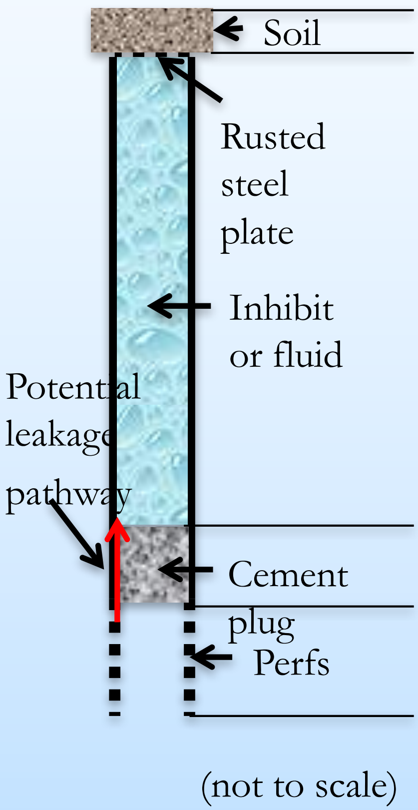
Mitigation of Well Leakage

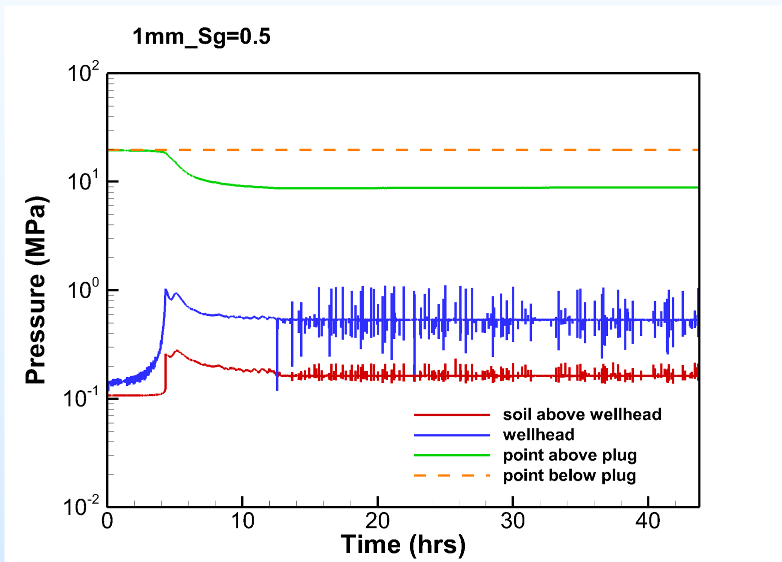
Curt Oldenburg, Lehua Pan

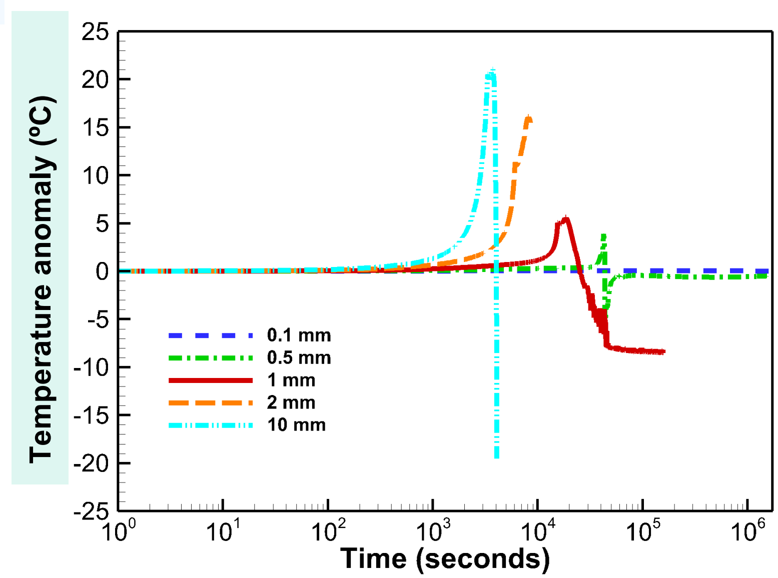
Conceptual model of leakage pathway in gap due to cement plug failure



The first temperature signal is from upward flow of warm water. Then gas breaks through leading to a big drop in temperature because of expansion cooling.







Temporal patterns of P, T, and gas saturation may provide detectable signatures of low-flow-rate leakage in shallow subsurface around abandoned well

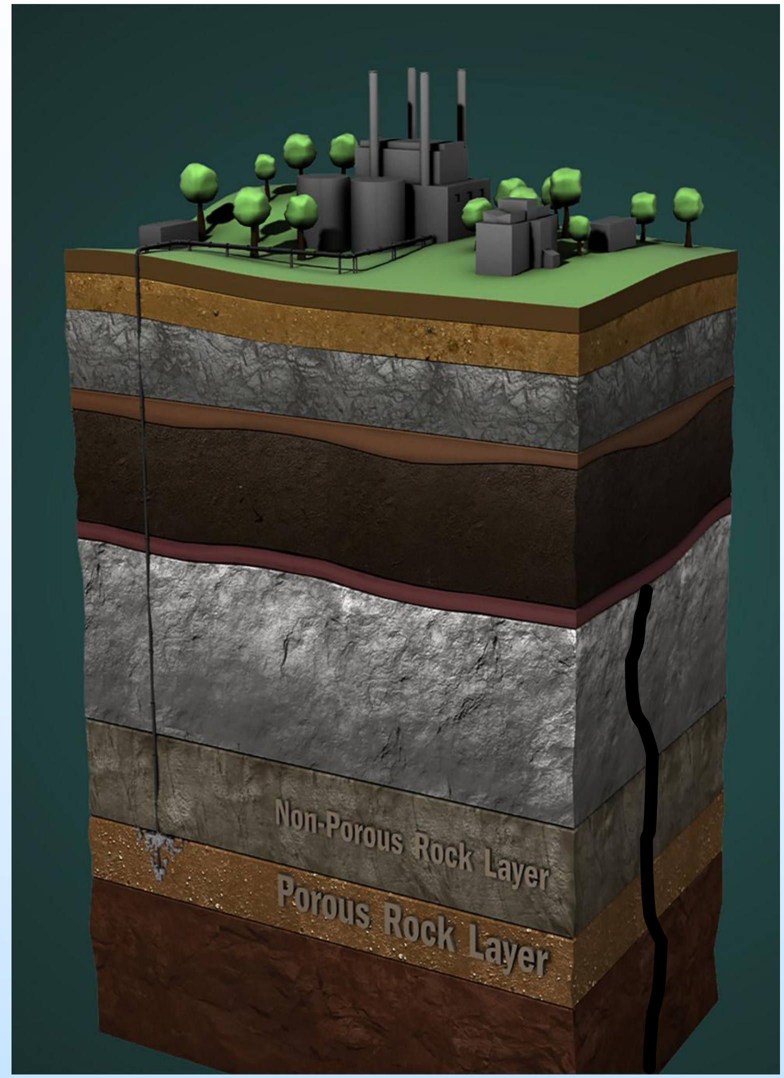
The temperature signal is very weak when the aperture is below 1 mm (< 1 °C) due to very small leakage rate.

Technical Status

Integrated risk assessment and risk management

OpenIAM-CS

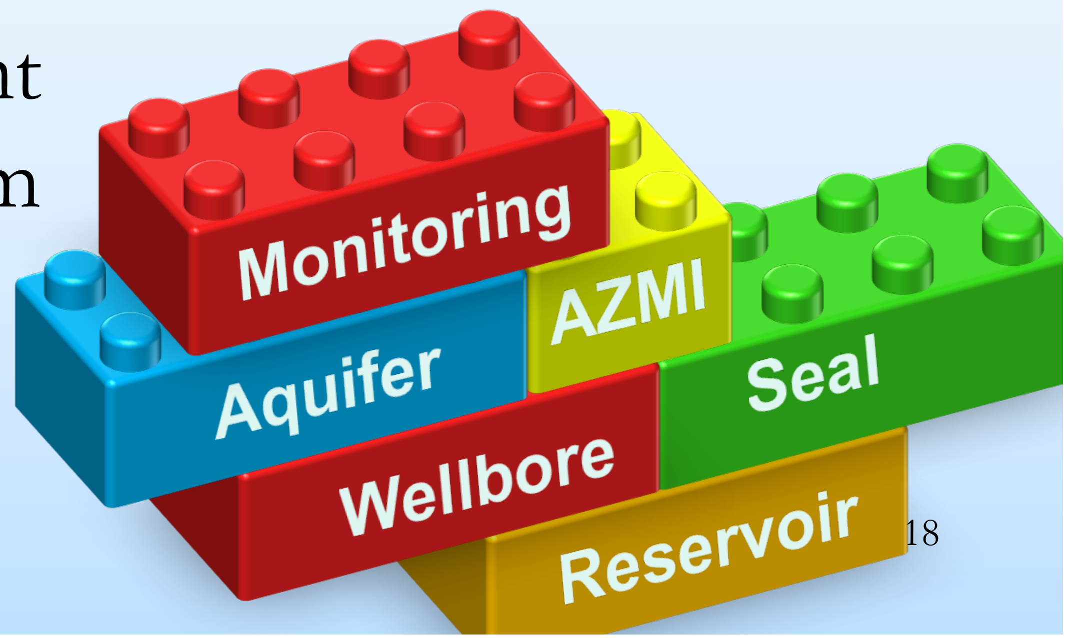
Seth King (lead), Diana Bacon, Dylan Harp, Veronika Vasylkivska, Cheryl Yang, Xiao Chen, YQ Zhang



Phase II Integrated Assessment Model

Development Goals

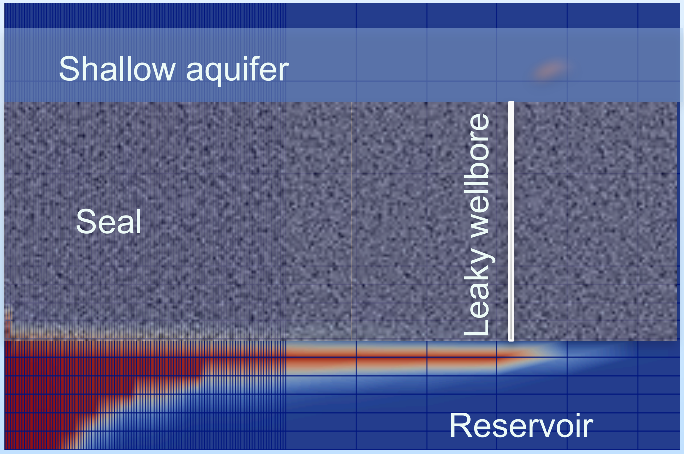
- risk assessment and risk management
- inform monitoring design
- assess concordance between models and field data
- evaluate leak mitigation performance
- update risk assessment with information from monitoring



Phase II Integrated Assessment Model

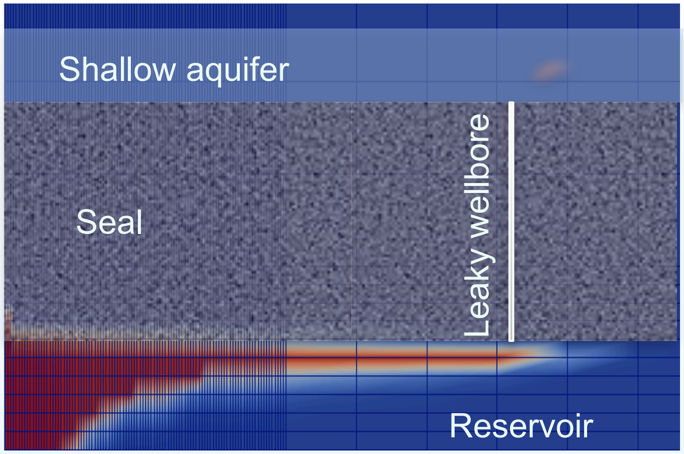
Code design

- Transparent, open-source, easily extensible
- Python-based
- Component models:
  - Built-in generic models
  - Tools for incorporating results from detailed site-specific models

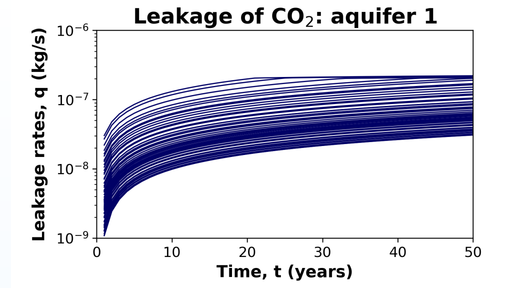


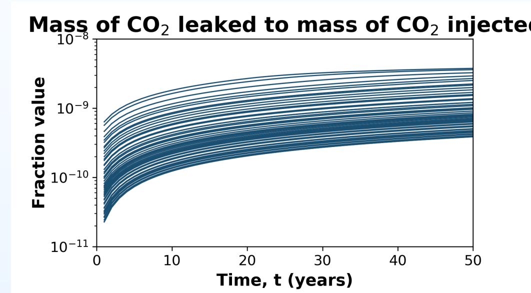
Open-IAM-CS Prototype example

Leakage scenario

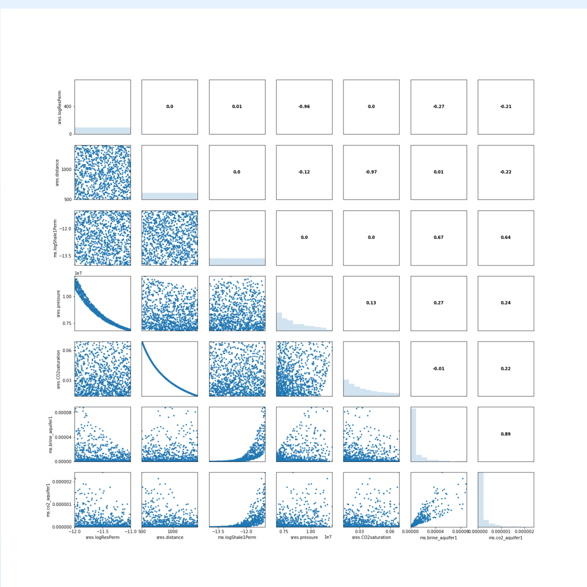


Probabilistic leakage risk calculations

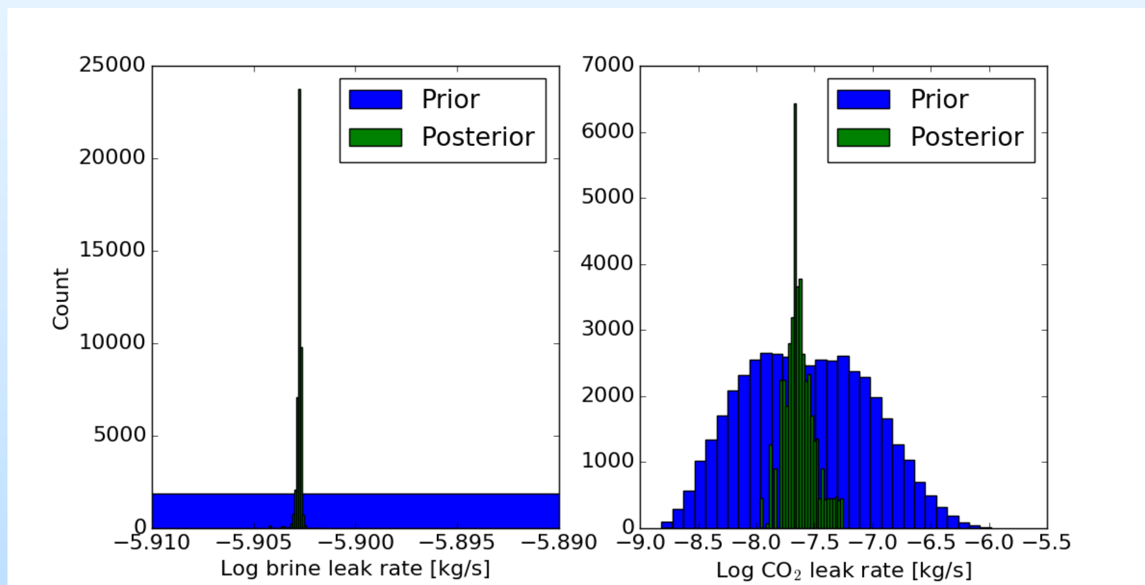




Parametric study



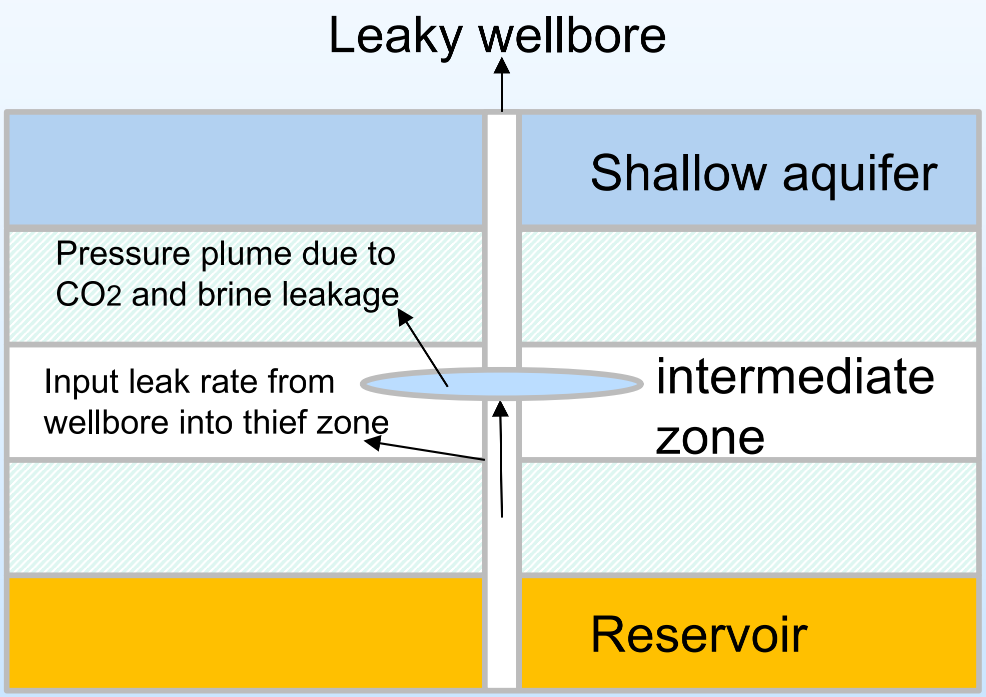
Risk assessment update using monitoring data

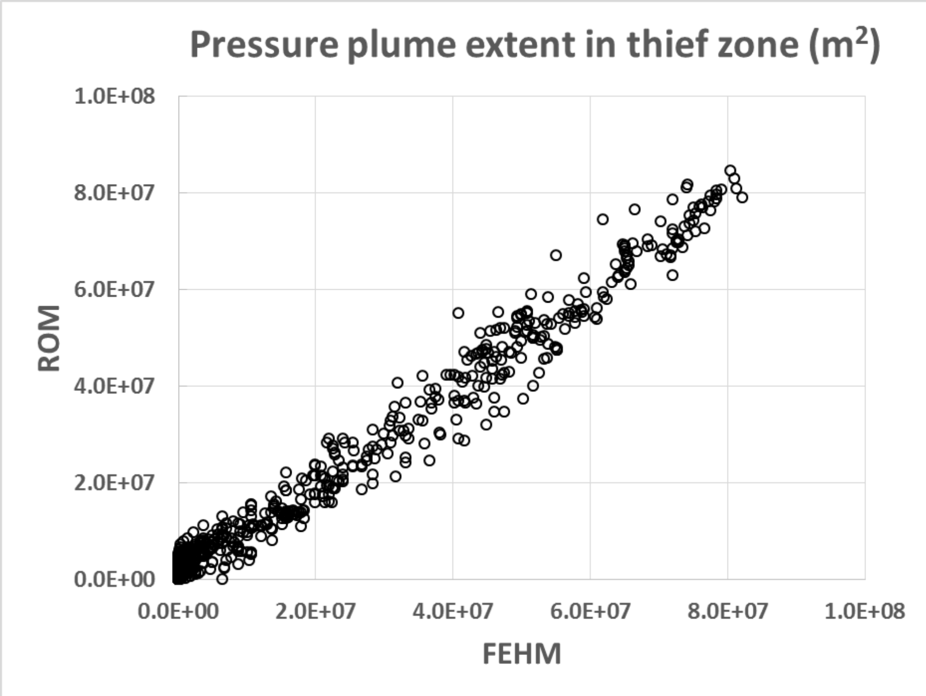


New reduced-order model development Pressure plumes in intermediate zones

Shaoping Chu, Dylan Harp, Rajesh Pawar

Los Alamos National Laboratory





Accomplishments to Date

- 14 papers have been published in the past year
- Multi-lab study on the effectiveness of various types of seals is complete; report in preparation
- New reduced-order models are in development (wellbore leakage, pressure plume in AZMI layers)
- Phase II Integrated Assessment Model Design Basis Document is complete
- Prototype OpenIAM-CS is up and running.

Remaining challenges

- Coupled processes continue to be challenging
  - Coupled steel corrosion, cement carbonation and CO_2 flow (wellbore integrity)
  - Coupled mechanical deformation and carbonation in CO_2 alteration of cement (wellbore integrity)
  - Coupled fracture mechanics, chemical alteration and CO_2 flow (caprock)
- Experiments are needed
  - to define relative permeability models for CO_2-brine mixtures flowing through fractured wellbore systems.
  - to define the relationship between CO_2-brine saturation and the extent of chemical reaction with cement.
- Knowledge gaps still exist in understanding and predicting post-injection processes, partly due to lack of long-term data

Synergy Opportunities

– Collaboration with CarbonSafe projects
– Looking for beta testers for the Phase II Integrated Assessment Model (2018)
– Collaboration with EPA, exploring ways that the IAM could be used to
  - support the well permitting process
  - to enhance operator/regulator communication

Thank you!

NRAP tools open meeting: Today 3:30 – 6:30 Grand Station III-V

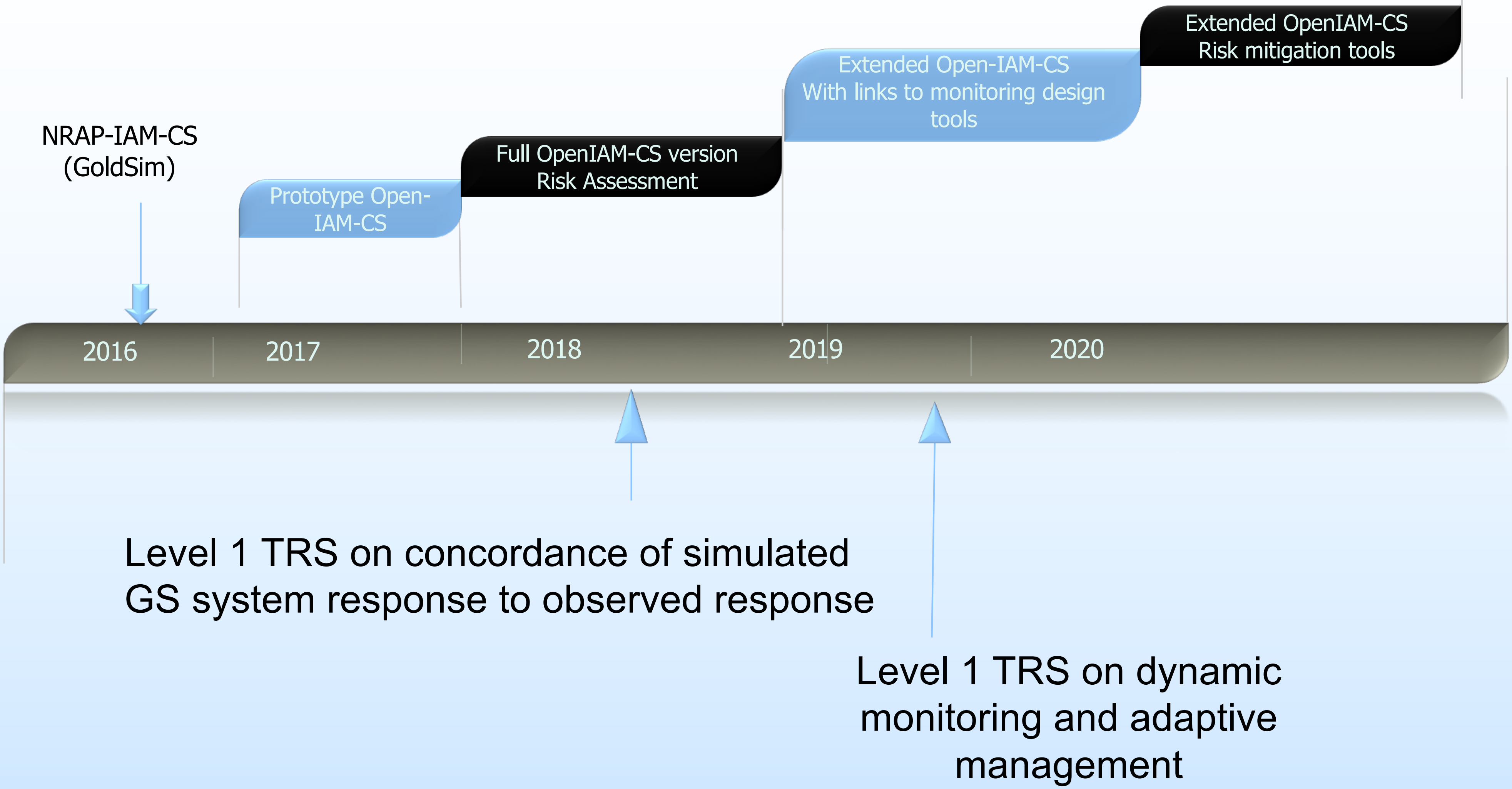
Benefit to the Program

The motivating goal of NRAP is to develop science-based methodologies and tools for calculating risks at any CO_2 storage site while providing necessary scientific and technological advances to support that methodology.

- Software tools for calculating and managing risks are being developed with expanded capabilities and improved transparecy

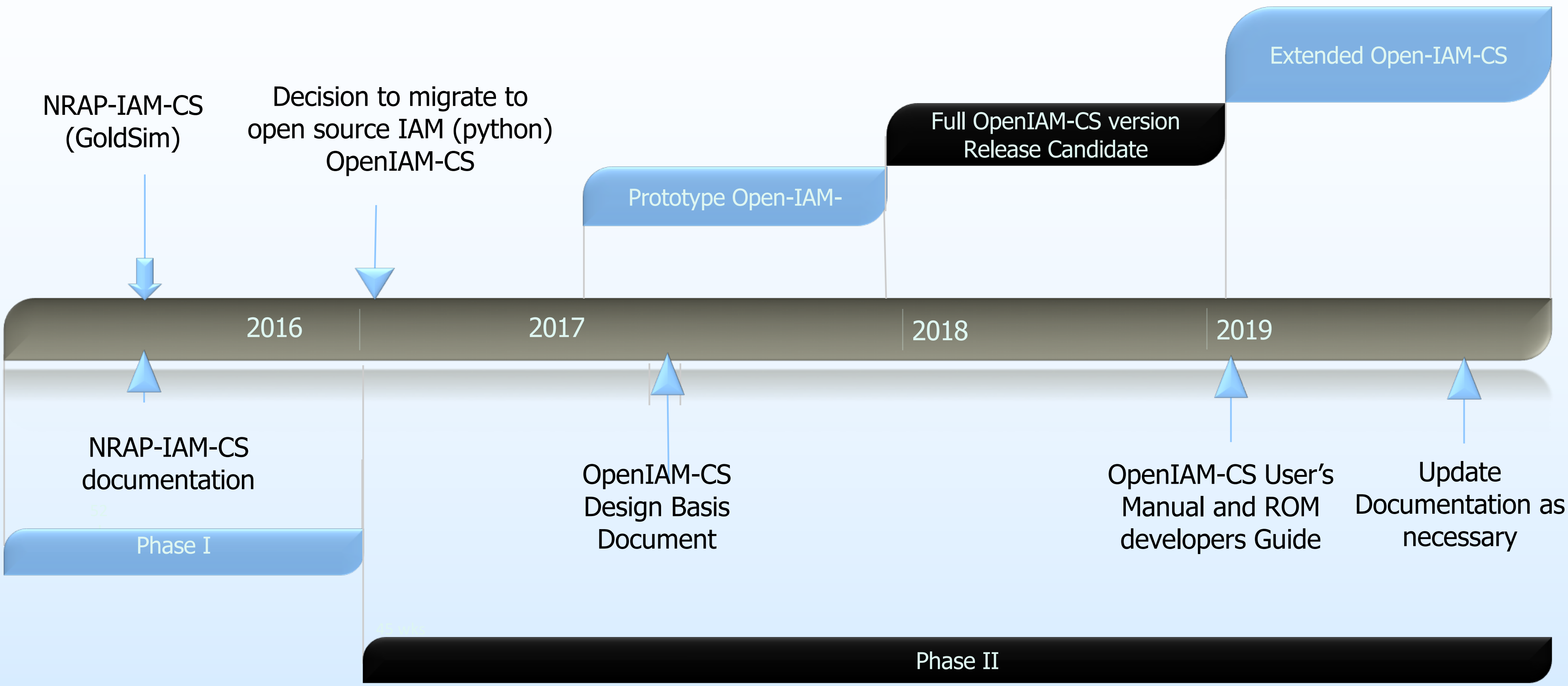
- Fundamental scientific understanding is being advanced
  - Well integrity
  - Well leakage mitigation
  - Seal integrity
  - Pressure management

Milestones



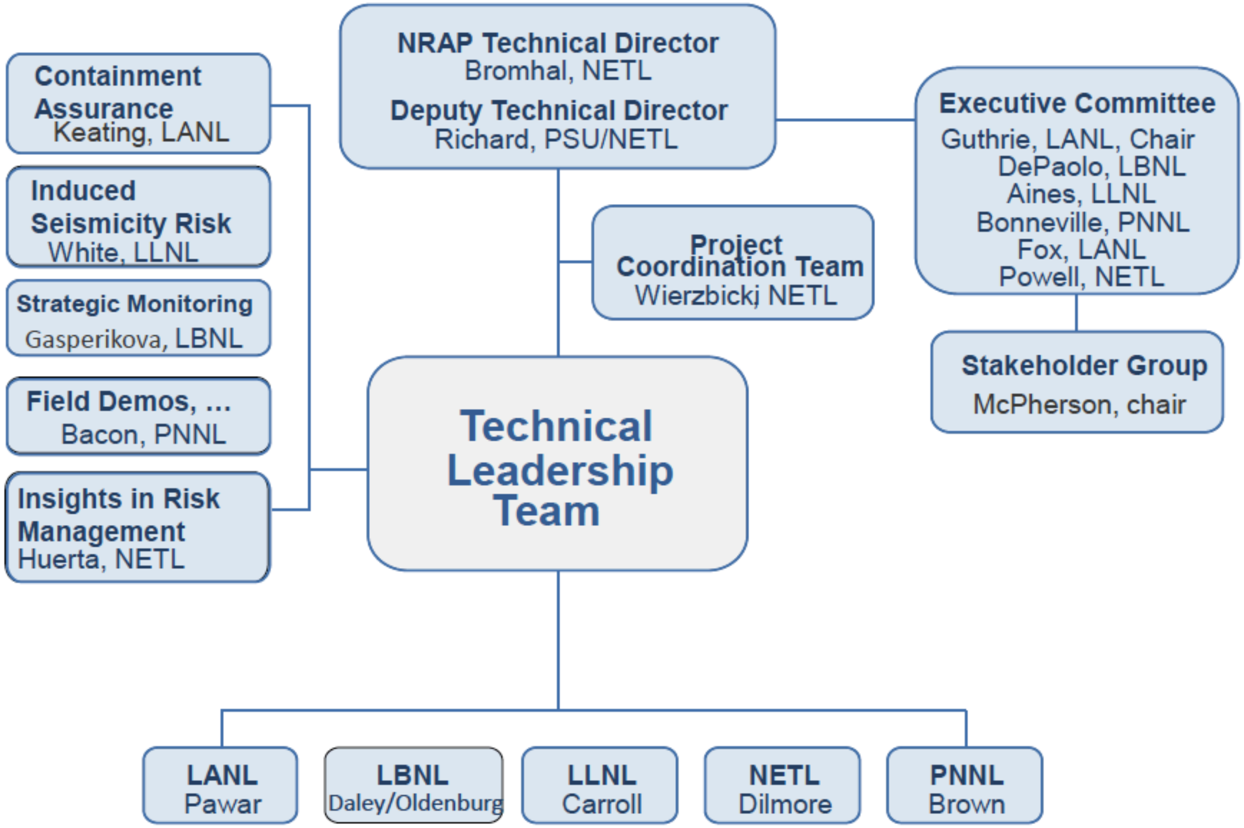
Extended OpenIAM-CS
Risk mitigation tools
Extended Open-IAM-CS
With links to monitoring design tools
NRAP-IAM-CS
(GoldSim)
Full OpenIAM-CS version
Risk Assessment
Prototype Open-IAM-CS
2016
2017
2018
2019
2020
Level 1 TRS on concordance of simulated GS system response to observed response
Level 1 TRS on dynamic monitoring and adaptive management

Python based OpenIAM-CS development Timeline



Phase II NRAP Organizational Structure

Organized by Task



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