NRAP Task 6 - Assessing Risks of Rapid Commercial-Scale Deployment of Geologic Carbon Storage

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FECM/NETL Carbon Management Research Project Review Meeting
Thursday, August 31, 2023

NRAP
National Risk Assessment Partnership

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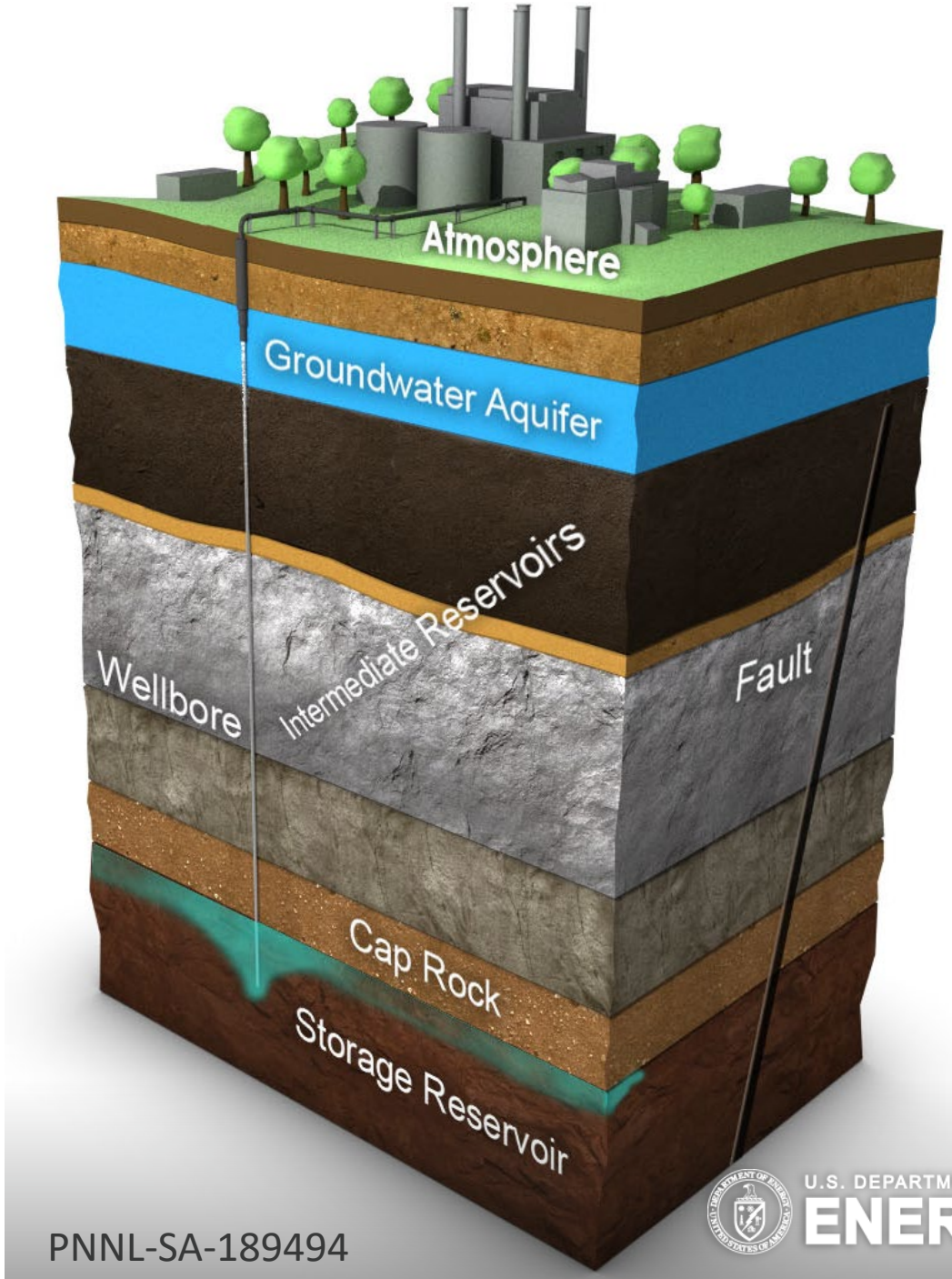

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U.S. DEPARTMENT OF ENERGY

Project Overview

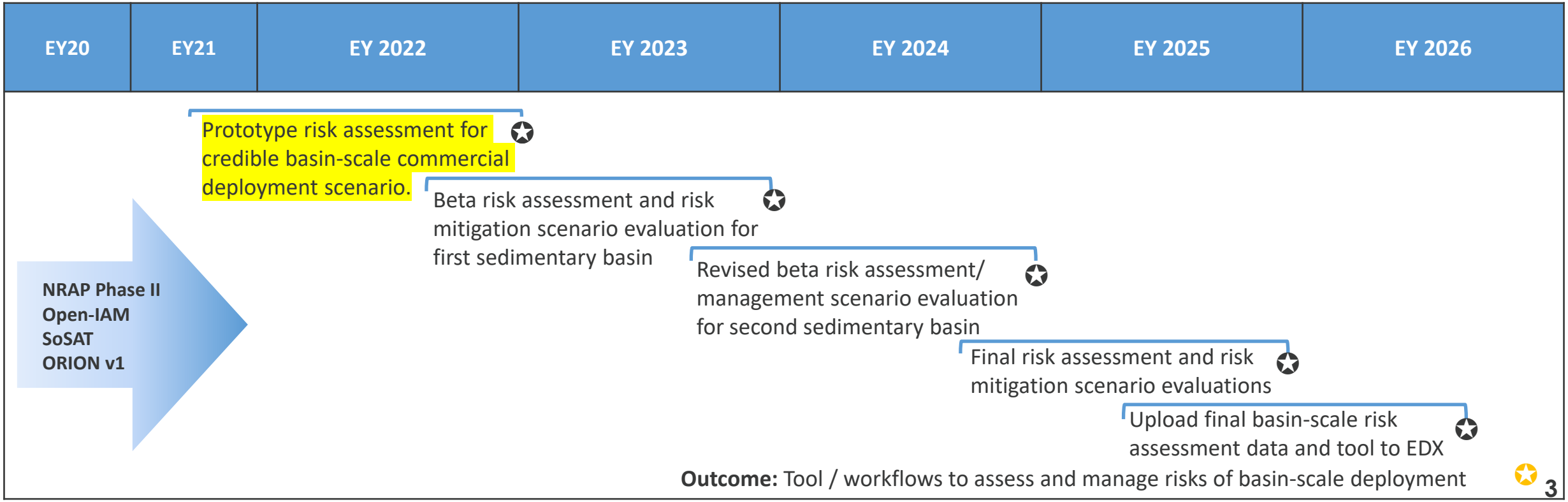
Key Project participants

PNNL	NETL	LBNL	LLNL
• Diana Bacon • Julia de Toledo Camargo • Ashton Kirol • Ryan Haagenson	• Gabe Creason • Greg Lackey • Paige Morkner	• Quanlin Zhou • Abdullah Cihan	• Jaisree Eier • Briana Schmidt

Task 6 Assessing and Managing Risks of Rapid, Basin-Scale GCS Deployment

Objective

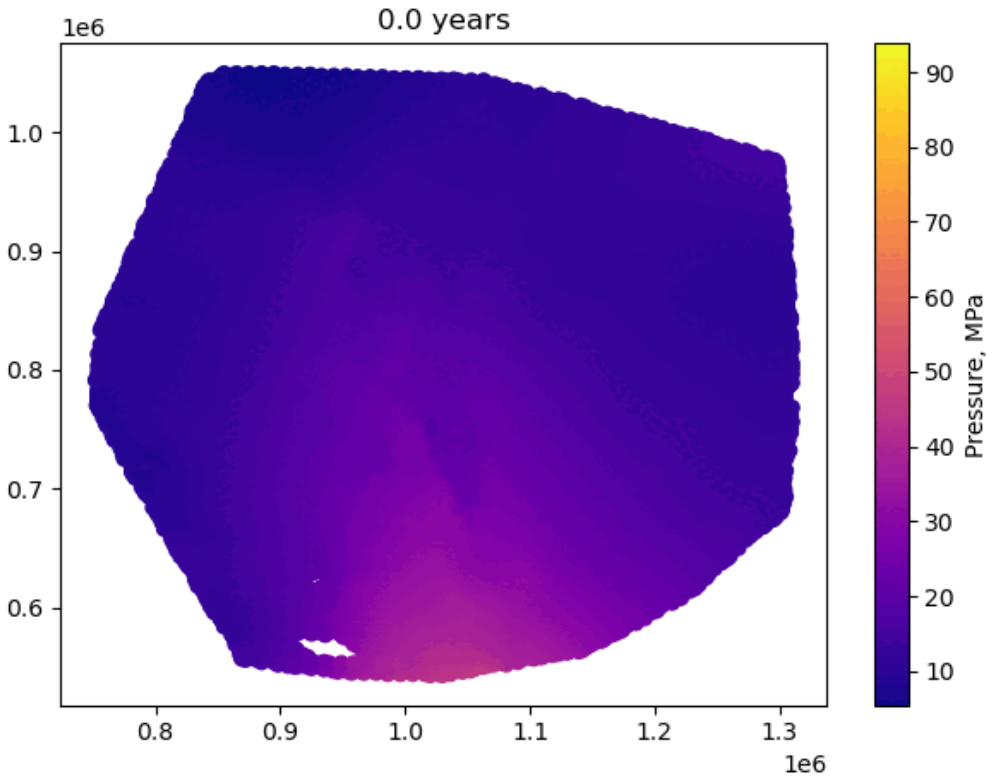
To develop and demonstrate a first-of-kind tool to assess and mange subsurface environmental basin-scale risks associated with rapid commercial-scale deployment of GCS.



Basin Scale Risk Assessment

Problem Definition

- **Pressure increases from adjacent geologic carbon storage (GCS) sites are likely to overlap**
- **Pressure build up from industrial-scale injection of CO_2 into saline formations in sedimentary basins could increase risks associated with CO_2 storage, including potential:**
  - Wellbore leakage
  - Fault leakage
  - Induced seismicity
- **Pressure buildup could also increase the cost of GCS by**
  - limiting CO_2 injection rates, requiring more injection wells
  - constraining dynamic storage capacities to be far below estimates based on accessible pore volume
  - requiring adaptive pressure management measures (e.g., brine extraction)

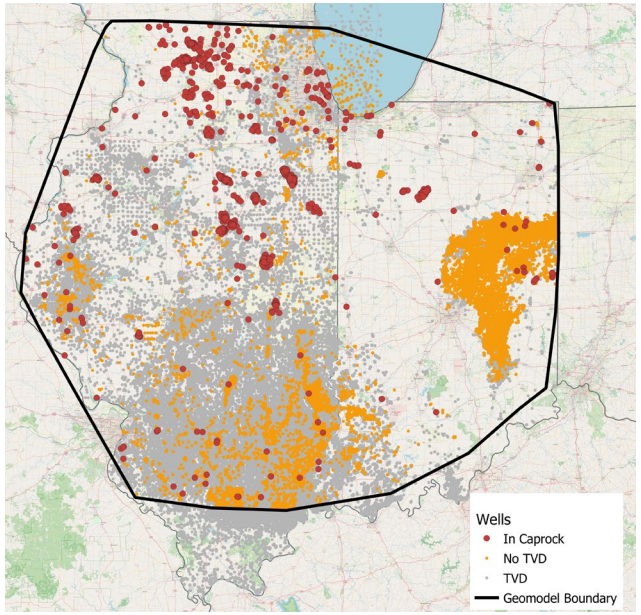


Pressure
(20 injectors)

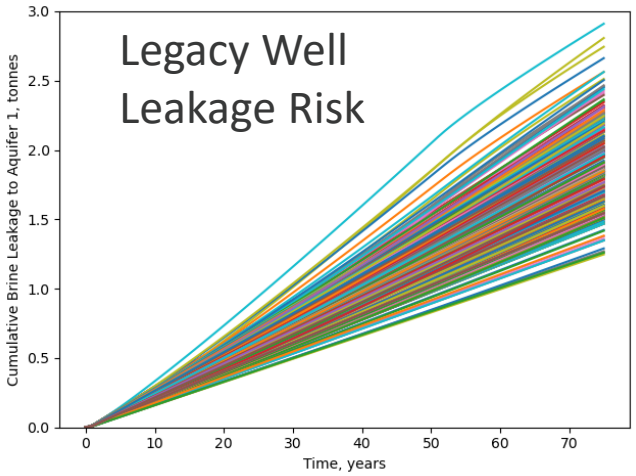
Basin Scale Risk Assessment

Challenges

- Challenges using conventional methods
  - Simulations of GCS for multiple emitters in a large basin are computationally expensive
  - Collecting the characterization data for an entire basin is time consuming
  - Previous studies have calculated pressure increases but not estimated risk
- Role of NRAP computational tools and methods to address those challenges
  - Computationally efficient reduced order models
    - to calculate pressure increases
    - to estimate risks associated with lack of containment, geomechanical failure, induced seismicity
    - with reduced input data requirements



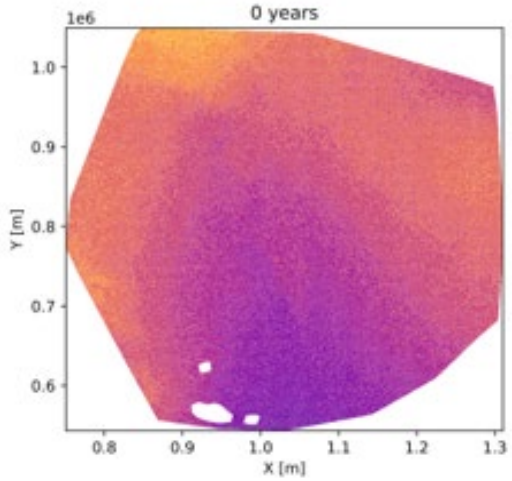
Legacy Well Locations



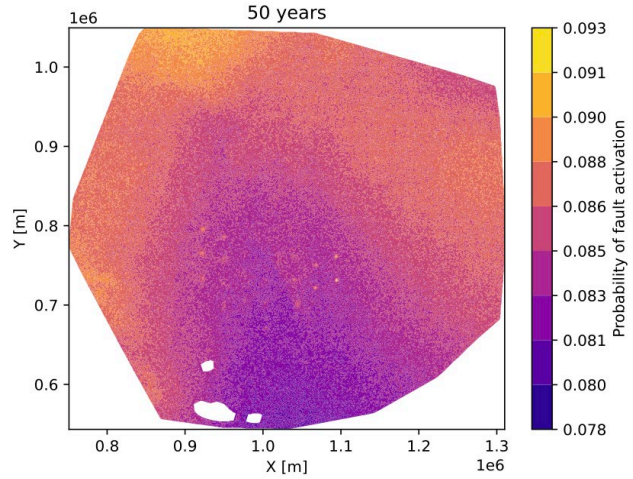
Basin Scale Risk Assessment

Contribution to commercial-scale CCS deployment

- **Plan a new storage site**
  - Estimate impact of preexisting storage sites on risk
  - Evaluate pressure management strategies
- **Existing site can update risk assessment as new projects come online**
- **Evaluate potential to store CO_2 from all existing emitters**
- **Compare dynamic estimates of basin storage potential with static capacity estimates**
- **Look at benefits of unitization (sharing risk across sites)**
- **Allow regulators to optimize storage across multiple permits**



Geomechanical Risk (SOSAT)



Illinois Basin Geomodel

Subtask 6.2: Developing a Geomodel to Support Basin-Scale Leakage Risk Modeling

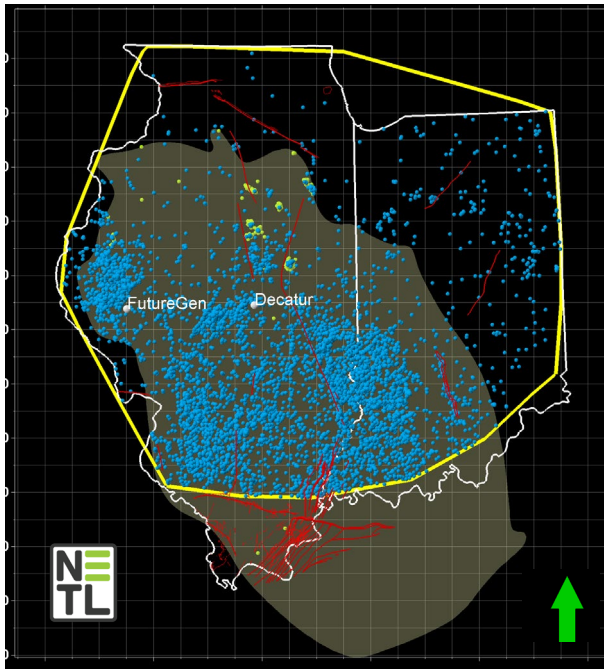
Gabe Creason, NETL

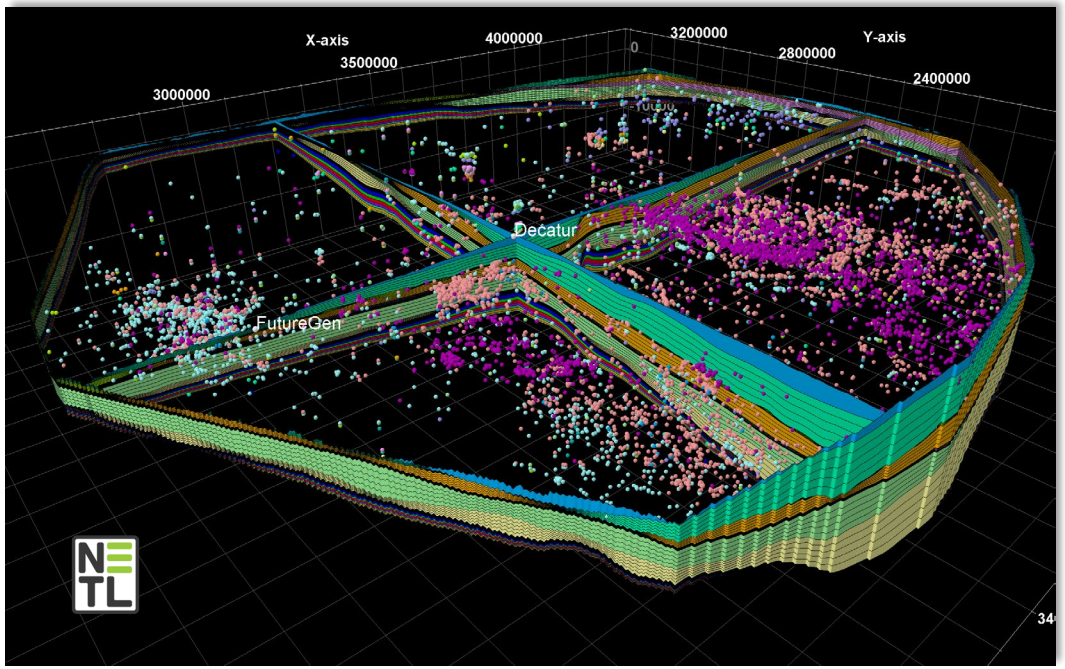
Data resources include:

- ISGS public well data, IHS proprietary well data
  - Processed 800,000+ formation tops
- IBDP static geomodel
- Surface faults
- Petrophysical rock properties:
  - Porosity, permeability, salinity, temperature

Model development ongoing:

- Refine stratigraphic interpretations
- Assign fault geometries at depth
- More sophisticated assignment of rock properties





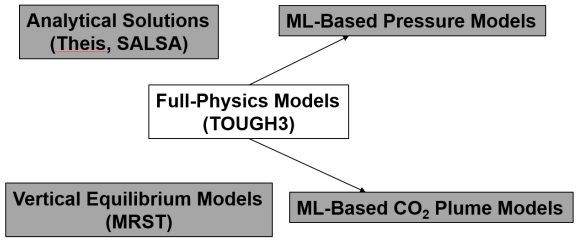
- *Model boundary is yellow line*
- *Well data locations shown as points: blue = IHS commercial; green = ISGS public*
- *Major structures shown as red polylines*
- *Illinois Basin extent is brown shaded area*

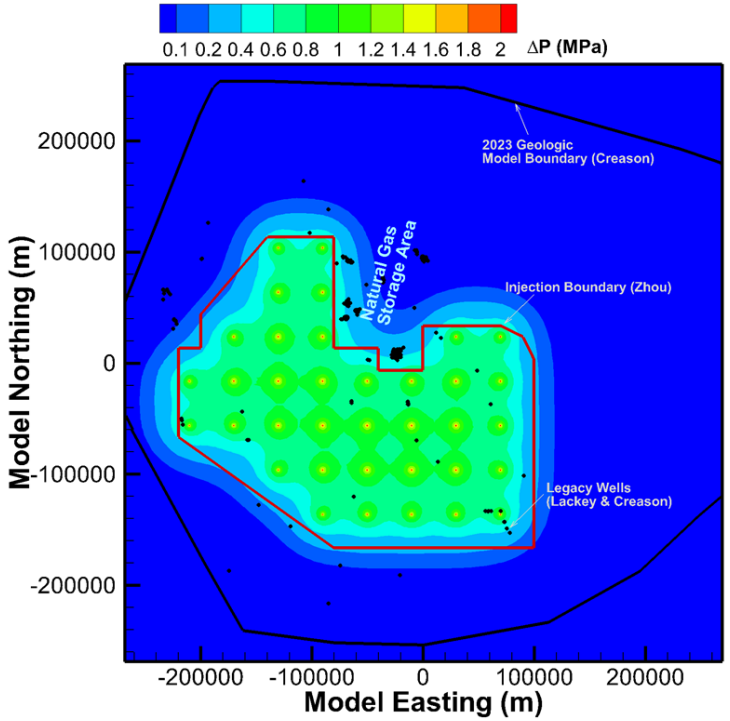
Model geometry (nI x nJ x nK):	*560 x 507 x 73*
Total number of grid cells:	*20726160*
Number of stratigraphic zones:	*12 (18)*
Number of geological layers:	*73*

Basin-Scale Reservoir Simulations

Subtask 6.2. Update NRAP-Open-IAM to Perform Basin-Scale Leakage Risk Assessment
Quanlin Zhou, LBNL (lead)

- **Modeling strategies**
  - Multiple modeling tools are developed to complement each other for efficient basin-scale reservoir simulations with sufficient accuracy;
  - Single- and multi-aquifer analytical solutions are incorporated into NRAP-Open-IAM (done/in process);
  - ML-based pressure model for the entirety of the basin and ML-based CO_2 plume model for each injection site are trained using the full-physics models (e.g., TOUGH3);
  - Vertical equilibrium model with 2-D numerical simulation and vertical restructure serve as a fast version of 3-D numerical model, with a focus on basin-scale pressure plume.
- **The basin-scale geological model of the Illinois Basin was used for developing these models**
  - Basin-scale reservoir simulations focused on the Eau Claire Shale and Mt Simon Sandstone (with eight subunits revised based on the ADM projects) and the basement rock to consider vertical heterogeneity;
  - 32 injection well clusters were identified in the core injection area with sufficient depth and salinity and away from natural gas storage fields;
  - In the first injection scenario, one million metric tonnes of CO_2 is injected into the Mt Simon A unit at each well cluster for 30 years.

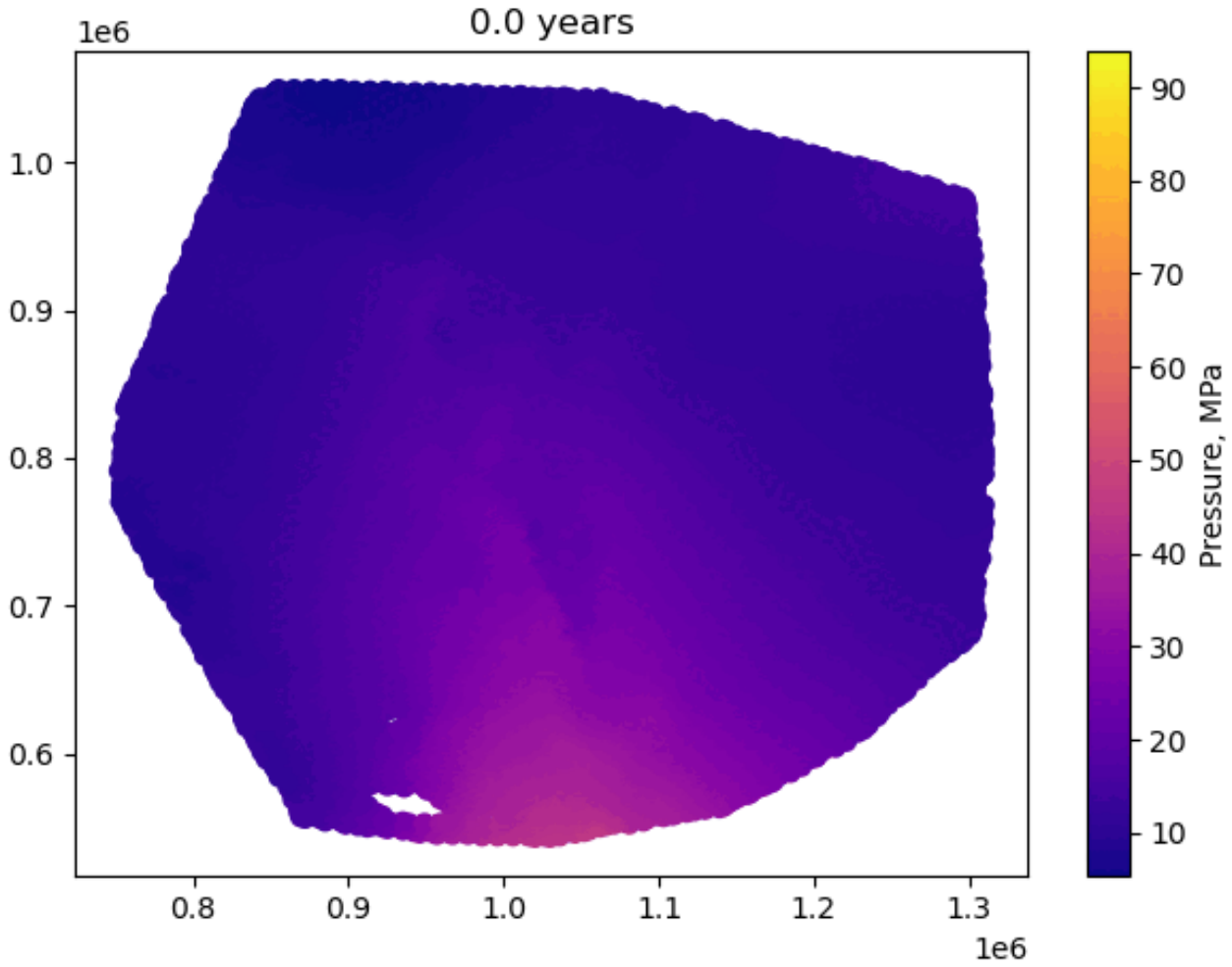




Basin Scale Reservoir Simulations

Subtask 6.2. Update NRAP-Open-IAM to Perform Basin-Scale Leakage Risk Assessment
Diana Bacon, PNNL

- **NRAP-Open-IAM Theis reservoir component with time-varying injection rates and multiple injectors/producers completed**



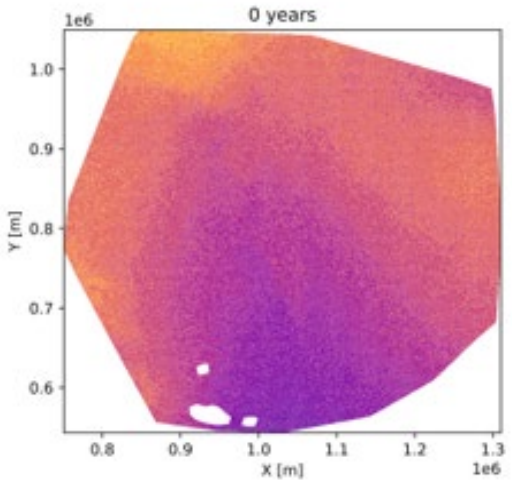
Geomechanical and Induced Seismicity Risk

Subtask 6.3 Update NRAP-Open-IAM to Perform Basin-Scale Geologic Hazard Assessment
Julia de Toledo Camargo (lead), Ryan Haagenson, PNNL

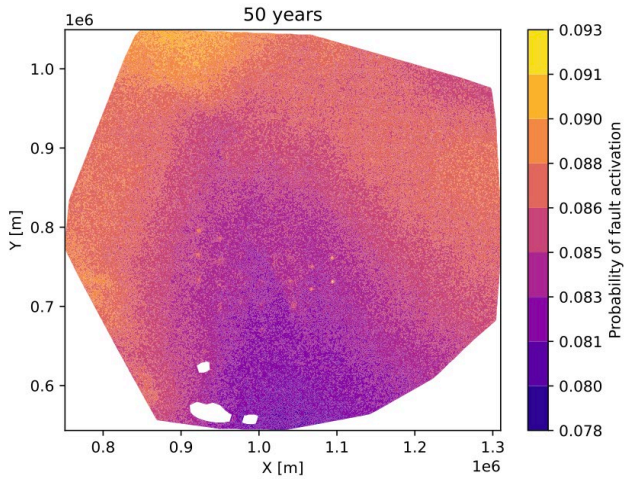
Coupling of NRAP-Open-IAM and SOSAT (in progress)

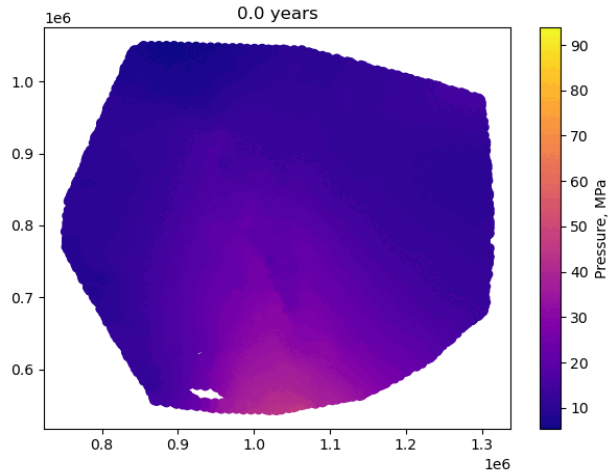
- Developed script with Lookup Table Reservoir component of NRAP-Open-IAM to create pressure data file to be transferred to SOSAT
- SOSAT needs pressure data, depths, overburden density, frictional faulting and regional faulting regime constraints to run probability of failure.
- Estimates increase in probability of failure due to CO_2 injection

Initial condition



After 50 years of 5 Mt CO_2/year Injection





Geomechanical and Induced Seismicity Risk

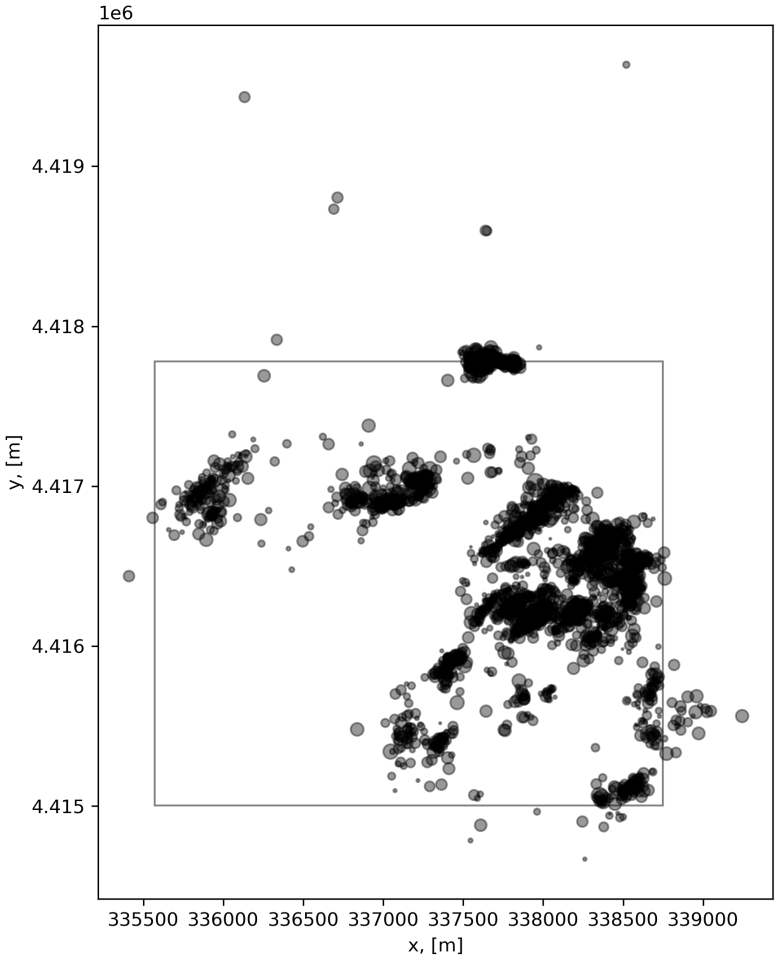
Subtask 6.3 Update NRAP-Open-IAM to Perform Basin-Scale Geologic Hazard Assessment

Veronika Vasylkivska, NETL

Coupling of NRAP-Open-IAM and ORION (in progress)

- Developed script with Lookup Table Reservoir component of NRAP-Open-IAM to create pressure data file in a format (hdf5) accepted by ORION
- Selected Decatur example distributed with ORION as test problem for coupling of the two tools: ORION needs both pressure data/pressure model and seismic catalog to run forecast prediction

Decatur Example Seismic Catalog



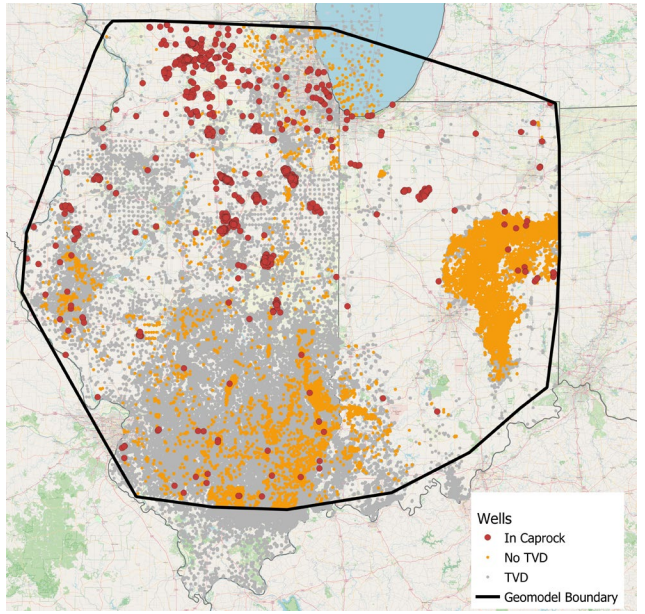
Wellbore Leakage Risk

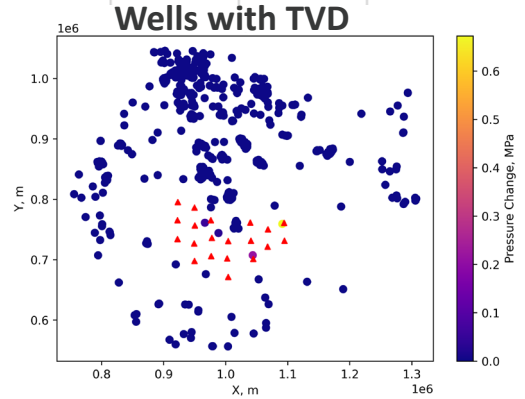
Subtask 6.4.1 Assessing and Managing Basin-Scale Risks
Greg Lackey, NETL (lead)

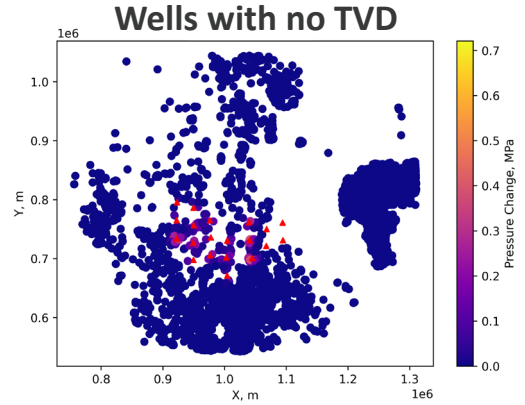
- **Status:**
  - Developed basin-scale approach for screening wells
  - Constructed NRAP-Open-IAM model for IL Basin
  - Evaluated leakage risks associated with wells that have known (1,652) and unknown (29,428) true vertical depths (TVD)
- **Next steps:**
  - Evaluate risks with stochastically assigned depths
  - Identify wells impacted by far-field effects

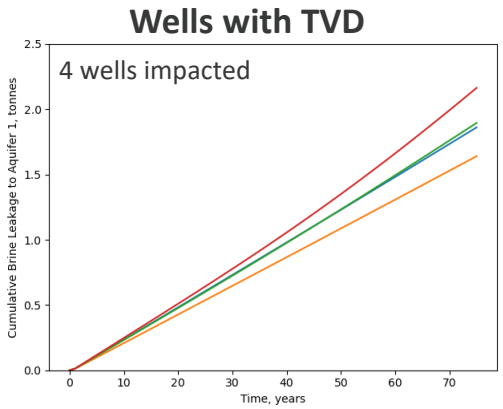
Well Counts

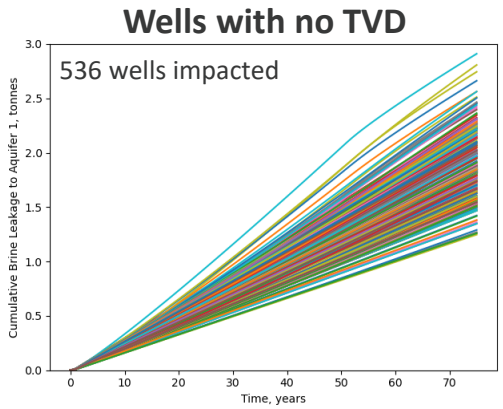
State	Total	Geomodel	No TVD	TVD	Eau Claire	Mt. Simon
IL	197,520	187,848	6,563	181,285	1,542	1,116
IN	52,562	49,293	22,865	26,428	110	86
Total	250,082	237,141	29,428	207,713	1,652	1,202







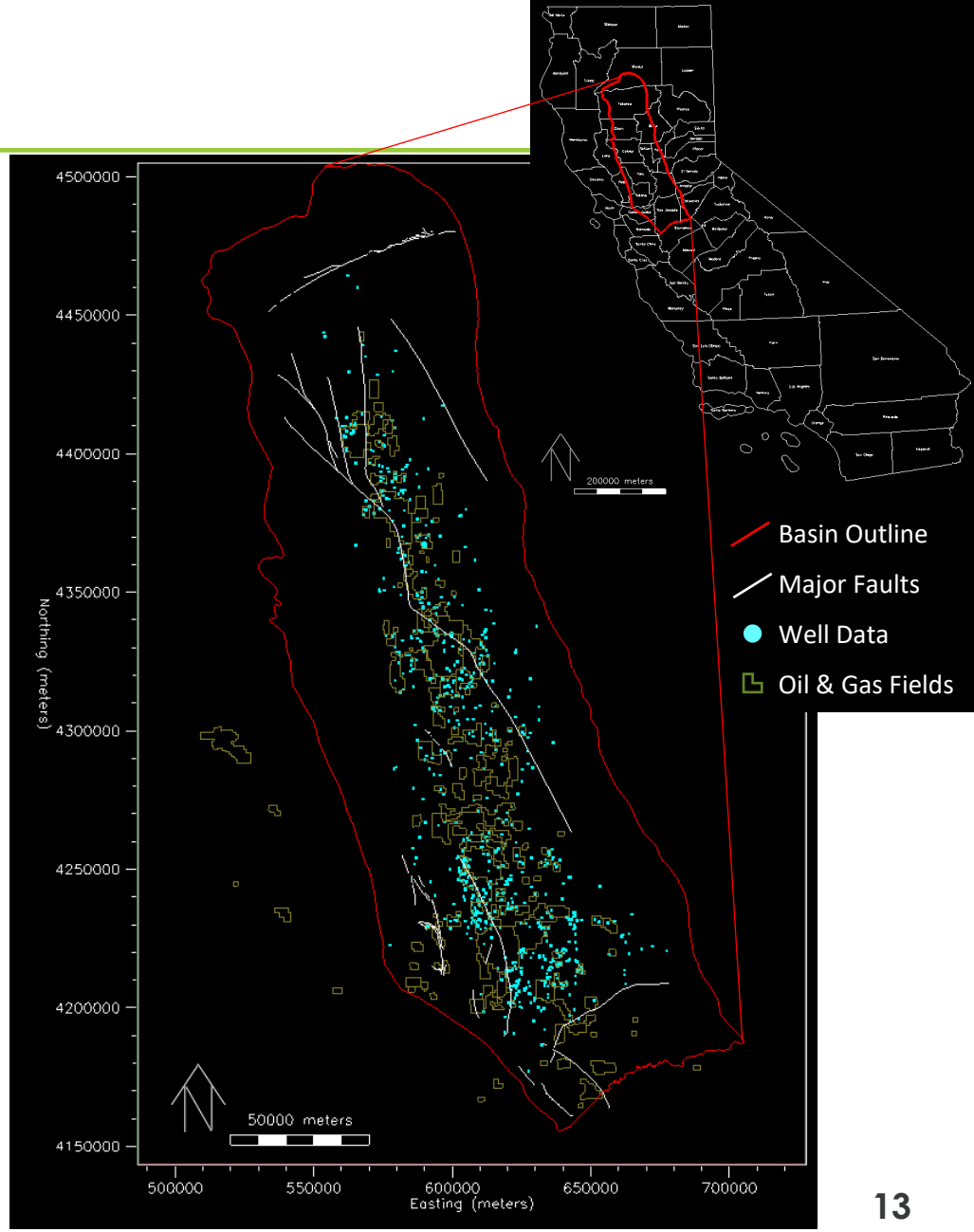




Next Steps

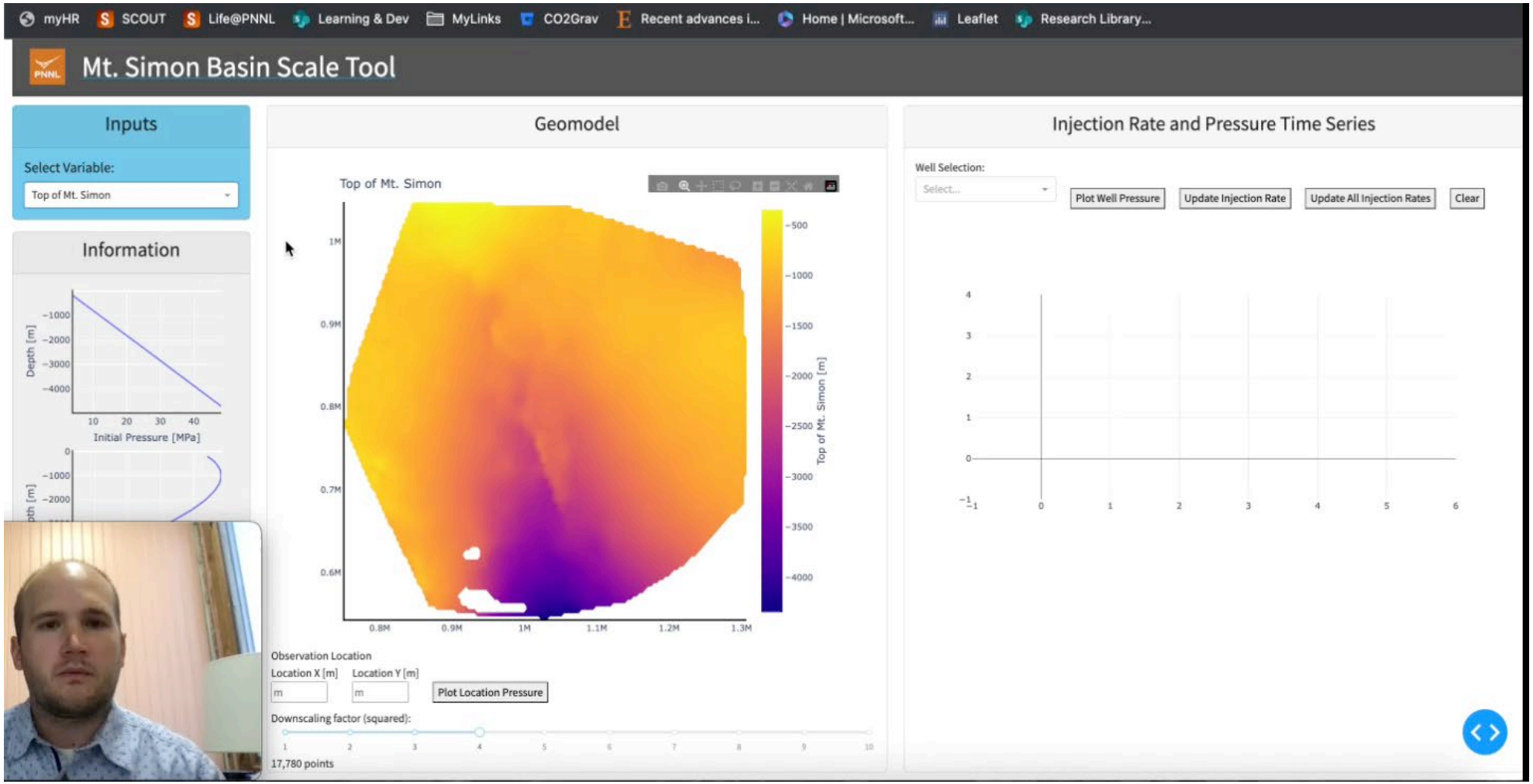
For Project

- **Sacramento Basin**
  - Available Data:
    - ~6000 well tops for ~1000 wells
    - Stratigraphically important faults
    - Depth to Base of Fresh Water (3000 ppm TDS)
    - Water well depths
    - Casing diameters and setting depths & total well depth
    - For each "pool" in oil and gas fields: initial production rates, initial pressure, reservoir temperature, initial oil/gas content, porosity, oil/water/gas saturation, permeability, salinity
  - Significance:
    - Five potential target storage formations
    - 7 Class VI project permit applications in process at EPA-R9 (31 wells)
    - 1 CarbonSAFE: Phase II Project
    - California's Central Valley is the only large saline geologic carbon storage resource in the western United States



Next Steps

After Project/Scale-up potential



Basin Scale Risk Assessment

Lessons Learned

- **Key Development Challenges**
  - Hosting of web-based tool
  - Extending to other basins (data collection)
  - Enabling user to model new basin
  - Visualizing local changes at the basin scale
- **Key Gaps**
  - Lack of data and staff for fault leakage risk estimation

Thank you!

Comments and Questions:

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NRAP Website: https://edx.netl.doe.gov/nrap/