Integrated Midcontinent Stacked Carbon Storage Hub

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U.S. Department of Energy
National Energy Technology Laboratory
Carbon Capture Front End Engineering Design Studies and CarbonSafe
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Project Overview

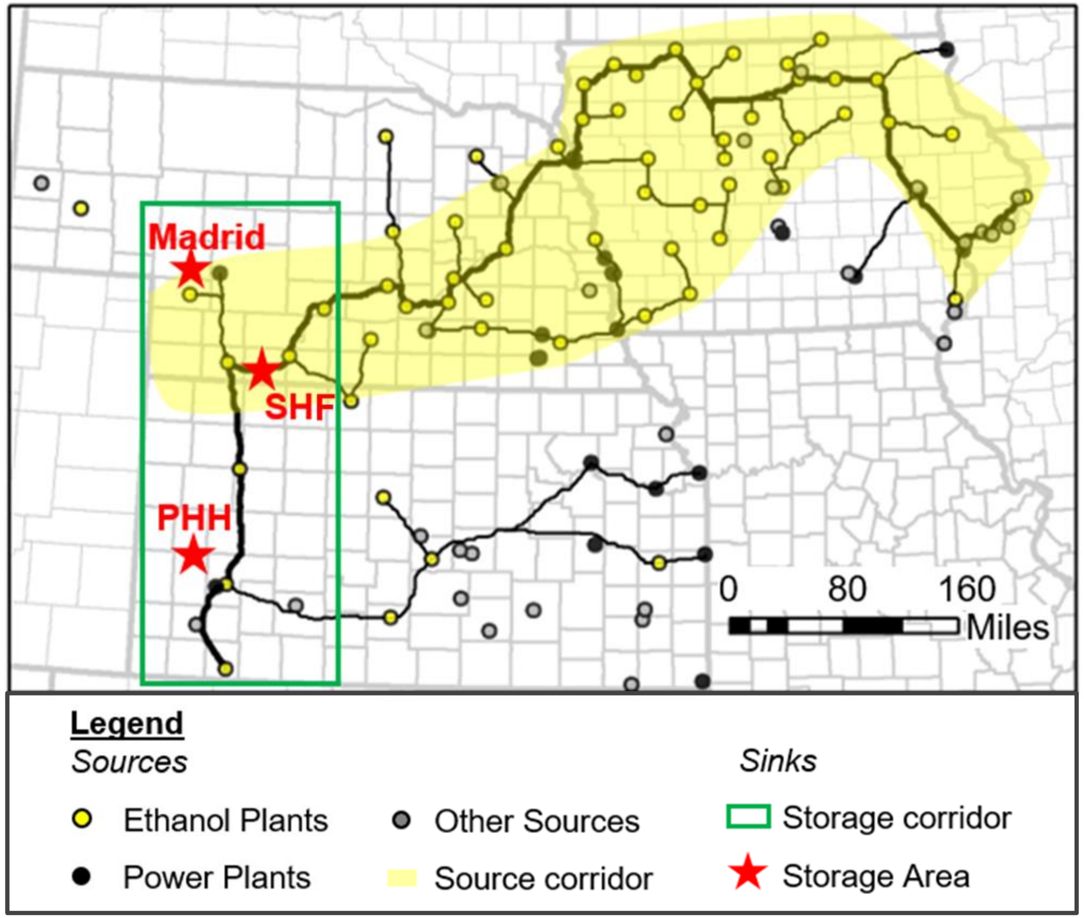
- The Integrated Midcontinent Stacked Carbon Storage Hub plans to gather CO_2 from eastern and central NE and transport it southwest toward Red Willow County, NE along a CO_2-source collection corridor. The CO_2 will then be piped south into central KS along a stacked storage corridor.
- CarbonSAFE Program Objective: Develop a midwestern carbon storage facility having multiple sites with a 50-Mt or greater capacity to safely, permanently, and economically store CO_2 by 2025.
- $9.4M funding with $3M cost share. POP: Aug 10, 2020

Phase II IMSCS-HUB Objectives

- Objective 1: Demonstrate multiple 50 Mt storage sites for the IMSCS-HUB concept by evaluating a Kansas and Nebraska site, each with the ability to safely, permanently, and economically store anthropogenic CO_2 through stacked-storage.
- Objective 2: Develop 50 Mt+ storage scenarios and provide a basis for UIC permitting.
- Objective 3: Demonstrate long-term seal integrity and minimize induced seismicity.
- Objective 4: Develop strategies to manage and store CO_2 from multiple sources.
- Objective 5: Leverage the data collected to scale the project to develop a regional commercial enterprise (three to ten 50 Mt+ storage sites).
- Objective 6: Identify and mitigate public outreach and regulatory barriers
- Objective 7: Develop a detailed commercial development plan.

Project Area: Source Corridor

- Optimize/maximize the number of sources/amount of CO_2 to develop market and infrastructure for CCUS
  - Ethanol plants in the corridor with annual emissions of greater than 5 Mt. Capture in the $12/t range
  - Saline storage at many of the ethanol plants in NE
  - Bring in electric utility generated CO_2 as capture comes on- line. Existing market from ethanol derived CO_2 will provide certainty that a utilization market and storage is possible
  - 5 other sources (4 electric utility and 1 refinery) with 20 Mt annual emissions. Capture in the $57/t range (NETL, 2015)



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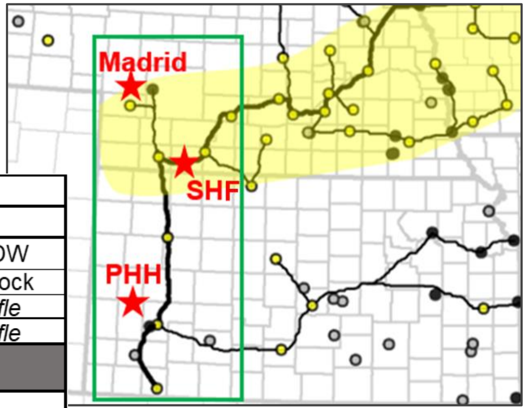
Stacked Storage Corridor

- Three candidate sites evaluated:
  - Madrid Site, Perkins County, NE – existing data study only
  - Sleepy Hollow Field (SHF), Red Willow County, NE – new well
  - Patterson-Heinitz-Hartland (PHH), Kearny County, KS –Seismic and new well
- Great stacked storage potential
  - Alternating sequences of deep saline formations, oil-bearing reservoirs, shale, and evaporite units
- Co-locate infrastructure for saline and CO_2 EOR



IMSCS-HUB STRATIGRAPHY*

Era	Period	Southwestern Nebraska		Western Kansas	
Cen.	Neogene	Ogallala	USDW	Ogallala	USDW
Mesozoic	Cretaceous	Montana	caprock	Montana	caprock
		Colorado		Colorado	*baffle*
		Dakota[1]	deep saline	Kiowa	*baffle*
	Jurassic	Morrison	*baffle*		
	Triassic				
Paleozoic	Permian	Blaine	caprock	Blaine	caprock
		Flowerpot		Flowerpot	
		Cedar Hills	deep saline	Cedar Hills	
		Salt Plain	caprock	Salt Plain	
		Sumner		Sumner	
		Chase	*baffle*	Chase	gas-bearing
	Pennsylvanian	Council Grove	caprock	Council Grove	
		Admire		Admire	*baffle*
		Wabaunsee	deep saline	Wabaunsee	
		Shawnee		Shawnee	
		Douglas		Douglas	
		Lansing-Kansas City	oil-bearing	Lansing-Kansas City	oil-bearing
		Pleasanton	deep saline	Pleasanton	*baffle*
		Marmaton		Marmaton	
		Cherokee		Cherokee	caprock
		basal sandstone	oil-bearing	Atoka	
				Morrow	oil-bearing
	Mississippian			Chester	oil-bearing
				Meramec	*baffle*
				Osage	deep saline
				Kinderhook	*baffle*
	Devonian				
	Silurian				
	Ordovician			Maquoketa	caprock
				Viola	deep saline
				Simpson	
				Arbuckle	
	Cambrian			Reagan	*bottom*
Precambrian		crystalline basement			

** formal lithostratigraphic group and stage names used unless otherwise noted; not to scale*

[1] At the SHF, Dakota = USDW

LEGEND:
- *shale + limestone*
- *shale + limestone ± evaporite*
- *shale + sandstone*
- *limestone ± shale*
- *sandstone + limestone ± shale*
- *sandstone*
- *dolomite*
- *igneous and metamorphic rocks*
- *major unconformity*

New Feasibility Data Collection

Sleepy Hollow Field

- **Drilled one new characterization well**: Sleepy Hollow Reagan Unit 86A
- **Whole core** for specialized core analysis (e.g. rel. perm, geomechanics)
  - 110 ft from Admire, Wabaunsee, Oread, Marmaton
  - 28 sidewall core samples
- **Advanced wireline log data:** e.g. elemental spectroscopy, nuclear magnetic resonance, micro-imagers.
- **Well tests** – DSTs, mini-frac, to evaluate injectivity, permeability, pressure response.

Patterson-Heinitz-Hartland

- **3D seismic acquisition** for structural framework & characterization well siting (26 mi^2)
- **Drilled two new characterization wells:** Patterson KGS 5-25 and Hartland KGS 6-10
- **Whole core acquisition & testing**
  - 778 ft of core from Atoka, Morrow, Merimecian, Osage, Kinderhook, Viola, Simpson, Arbuckle, Reagan/Granit Wash, and Precambrian Granite
- **Advanced wireline log data**
- **Well tests**

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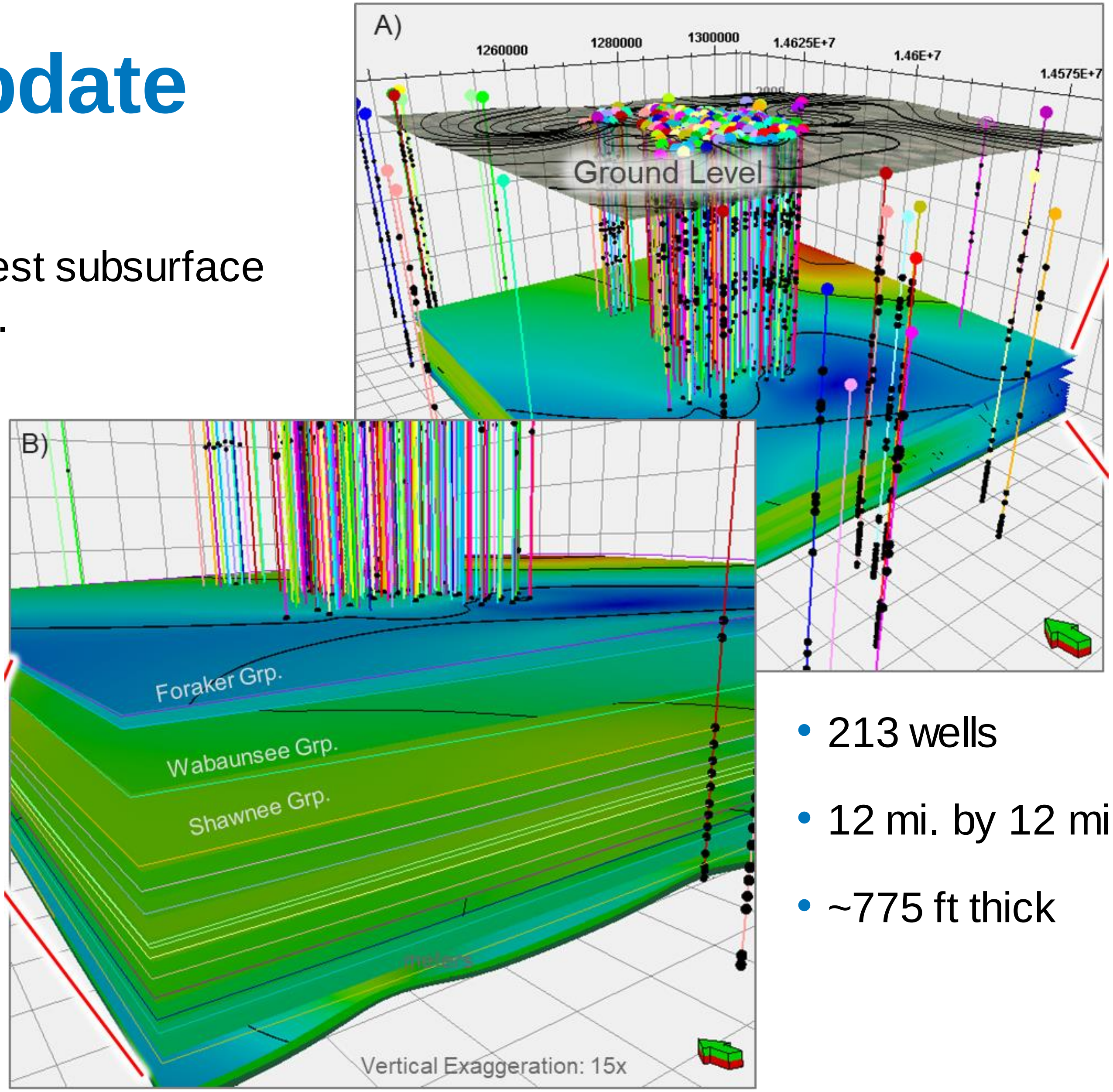
Static Earth Modeling Update

Sleepy Hollow Field

- In this model update, the SEM incorporates the latest subsurface interpretations derived from the SHRU 86A well data.
- The new GR facies model used as the basis for partitioning the Pennsylvanian
- Porosity and permeability were adjusted, so that reservoir quality was in alignment with the cyclic facies concept describing Pennsylvanian rock in this area[1].
- These adjustments ensure that mudstones and shales are correctly represented and have low effective porosity and low permeability.



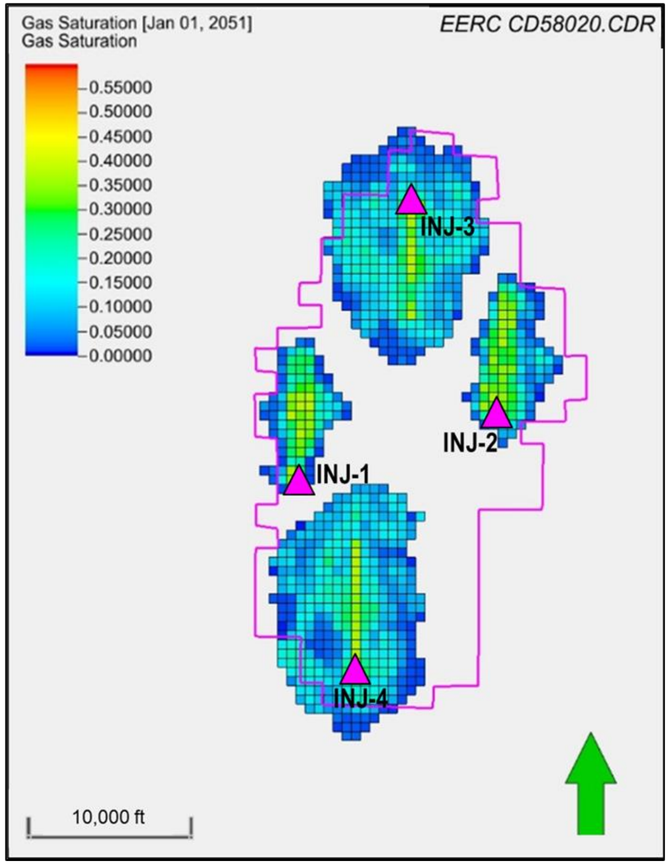
- 213 wells
- 12 mi. by 12 mi.
- ~775 ft thick

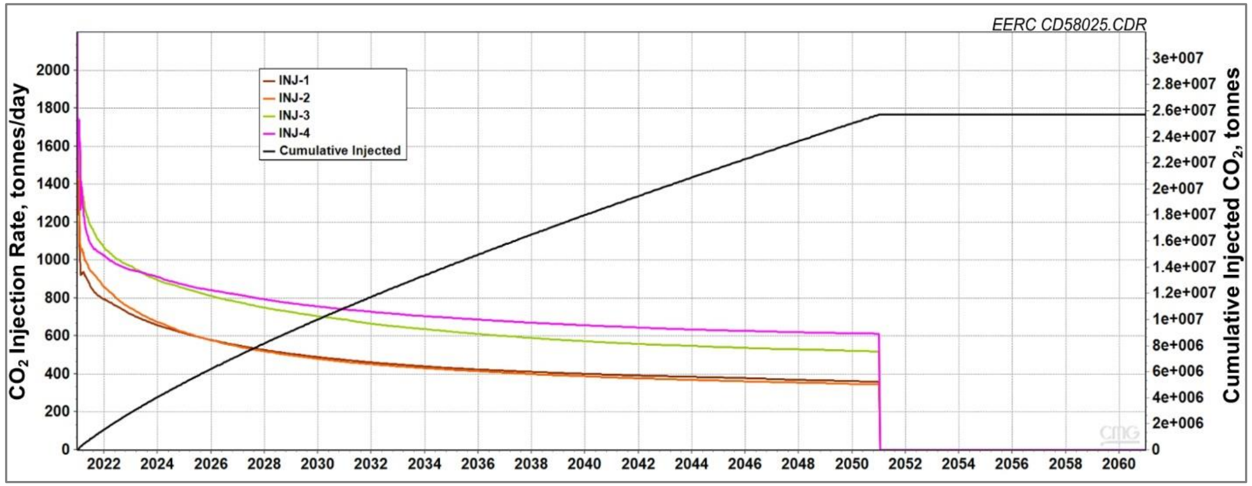
[1](Dubois, 1985; Watney, 1980; Young, 2011)

Dynamic Modeling Update

Sleepy Hollow Field

- The newly acquired data from SHRU-86A, including the formation pressure and temperature gradients, salinity, and capillary pressure data, etc. were integrated into the simulation model.
- Of 10 potential storage formations, 4 were selected for the simulations (Wabaunsee, Topeka, Oread, and Deer Creek)
  - LKC intervals did not significantly contribute to total injection capacity, and thus were excluded
  - Pleasanton–Marmaton groups were excluded despite having favorable permeability due to simulated CO_2 leakage to the underlying non-injection, oil-bearing basal sandstone unit, which raised the concern of “out-of-injection-zone” leakage





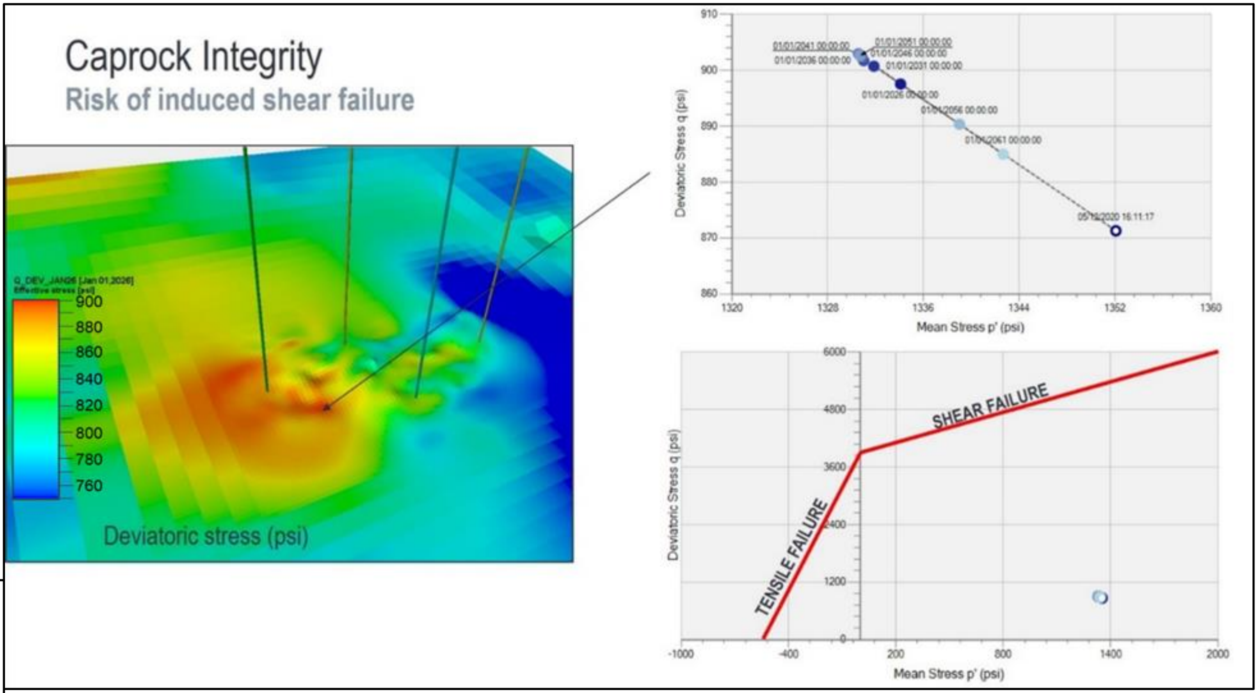
Scenario	No. of Injection Wells	CO_2 Injected in 30 yrs (Mt)	AoR (mi^2)
1	4	25.7	155
2	10	30	200

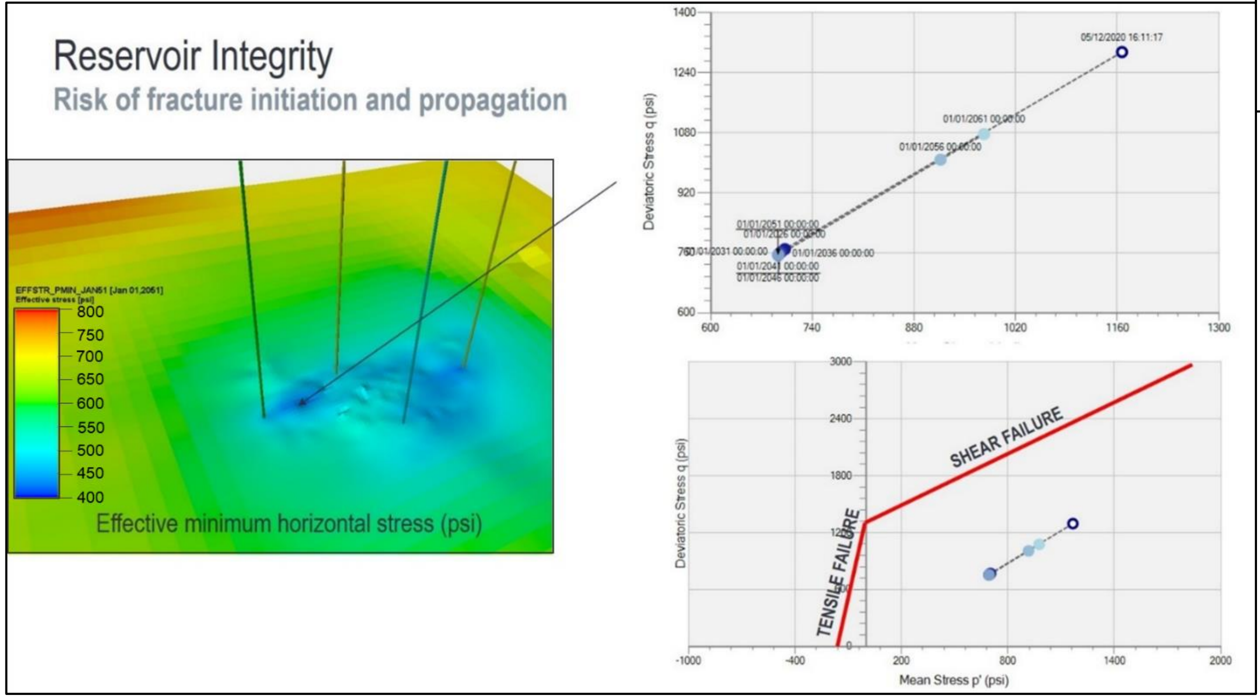
Geomechanical Modeling

Sleepy Hollow Field

- Modeling efforts included coupled geomechanical simulations with 4- and 10-well injection configurations and a sensitivity analysis.

- In both the 4- and 10-well injection cases, geomechanics simulation results did not compromise formation integrity within the caprock nor reservoir.

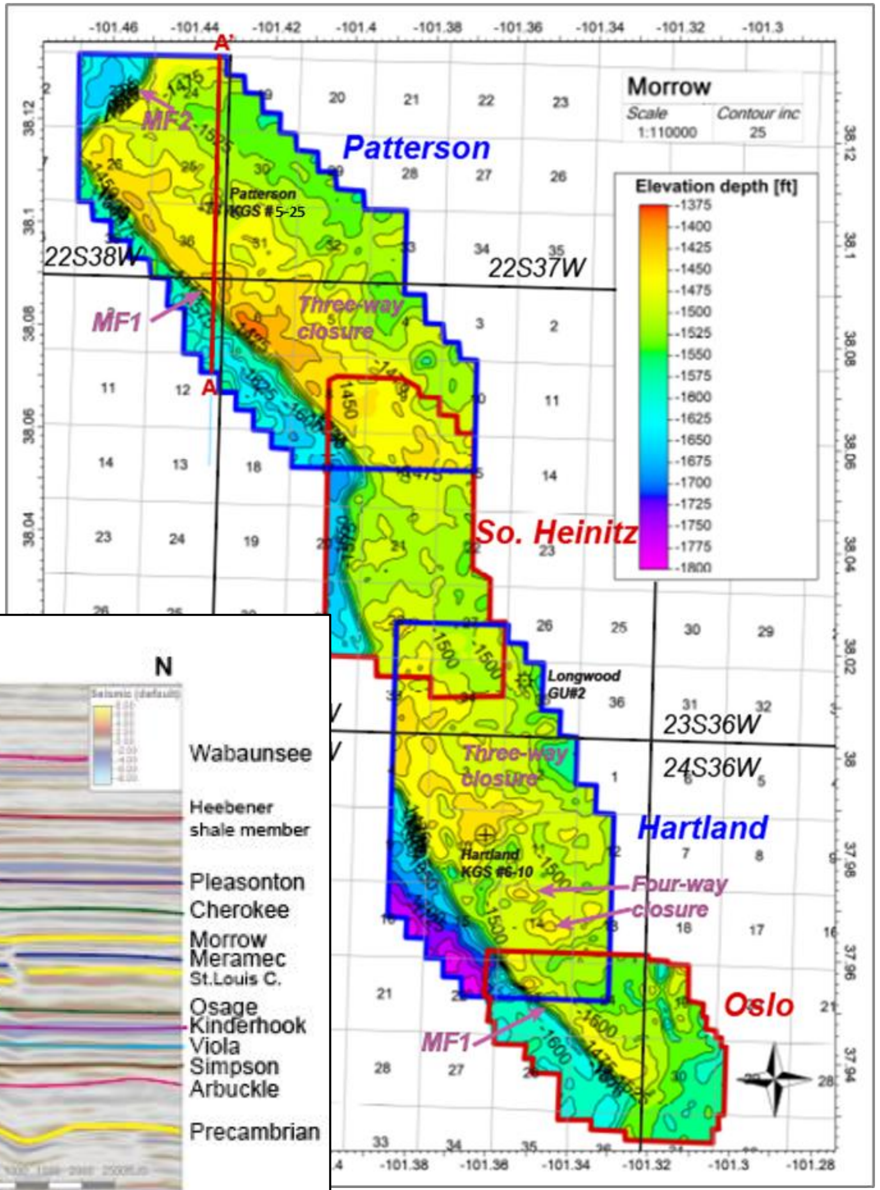




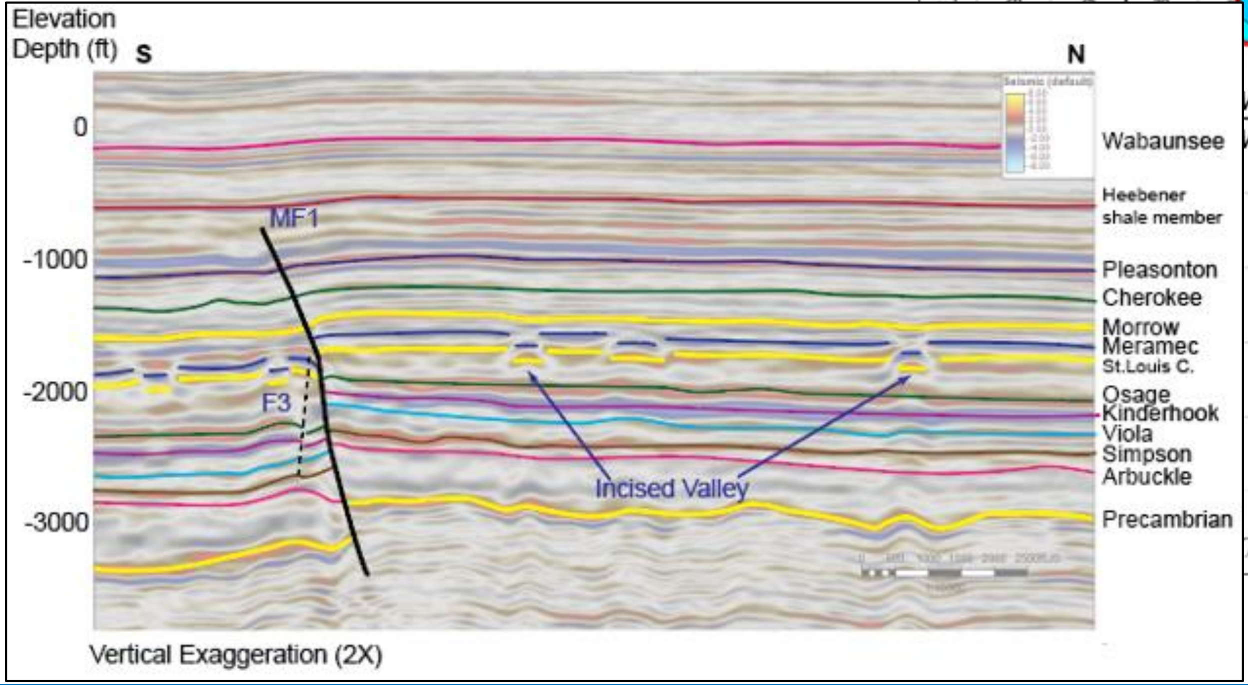
- Geomechanics results between the 4 well and 10 well injection cases do not differ significantly.
- Additional injection in the Topeka and Deer Creek with 10 well case can dissipate the additional CO_2 volume without developing localized stress concentrations that would result in formation integrity issues.

New 3D Seismic Analysis

Patterson-Heinitz-Hartland



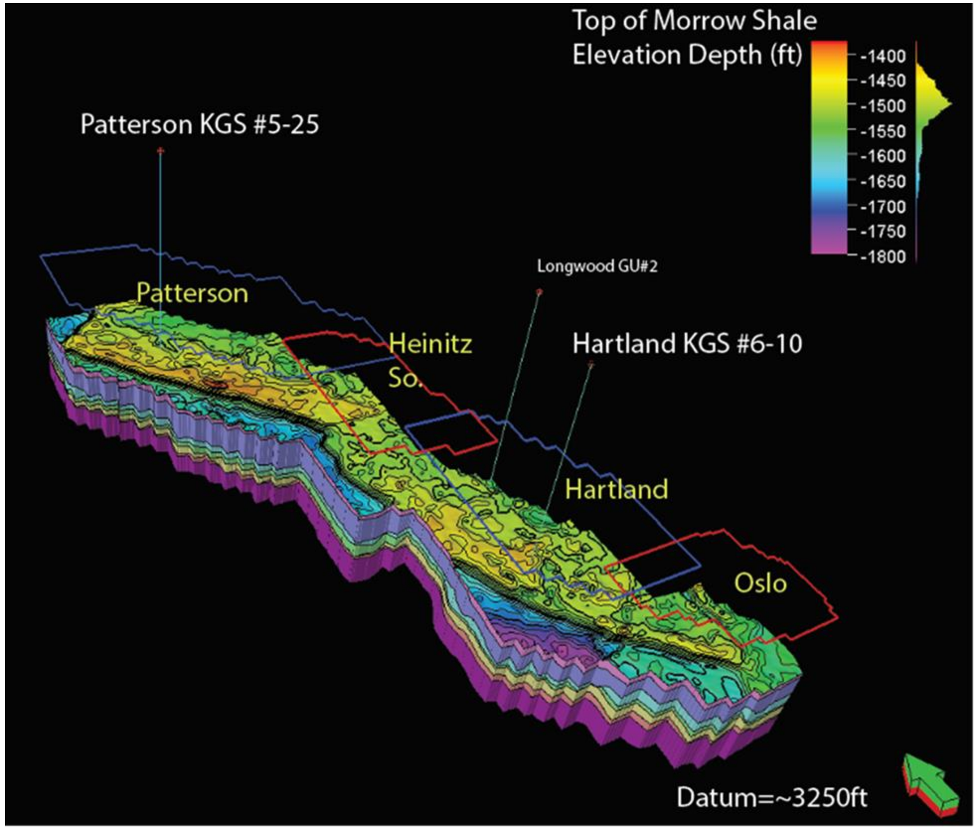
- Two major reverse faults exist at the PHH Site that offset the reservoir and seal intervals and constitute an uplifted block in the Patterson Area.
- Fault displacements are maximum at the Precambrian basement and decrease upward.
- Identified three- and four-way structural closures at the Patterson Site can assist trapping CO_2 in the Arbuckle-Osage reservoirs.
- Further research should focus on fault reactivation tendency and fault sealing characteristics of the pre-existing faults

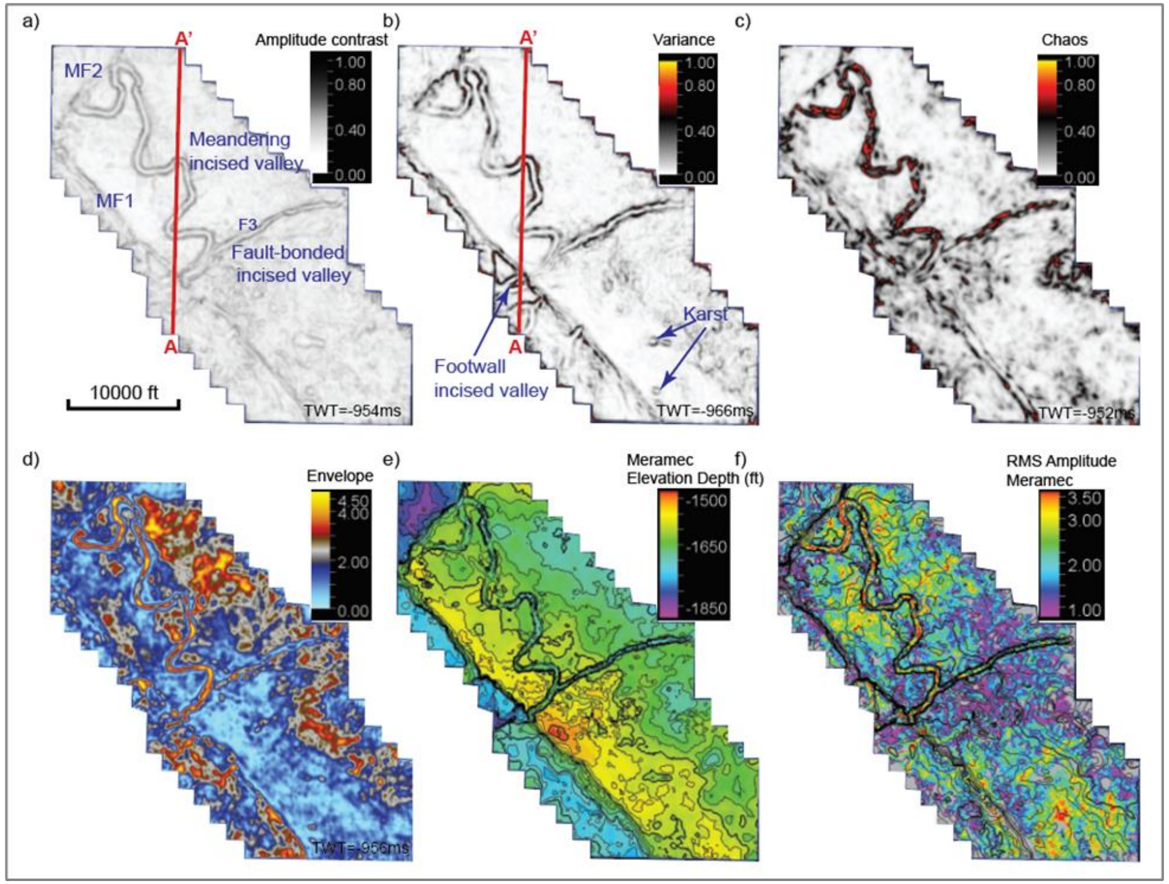


Static Earth Model Updates

Patterson-Heinitz-Hartland

- Newly acquired 3D seismic reflection surveys allowed for more accurate definition of the structural model (i.e., traps and seals) for at the PHH Site.





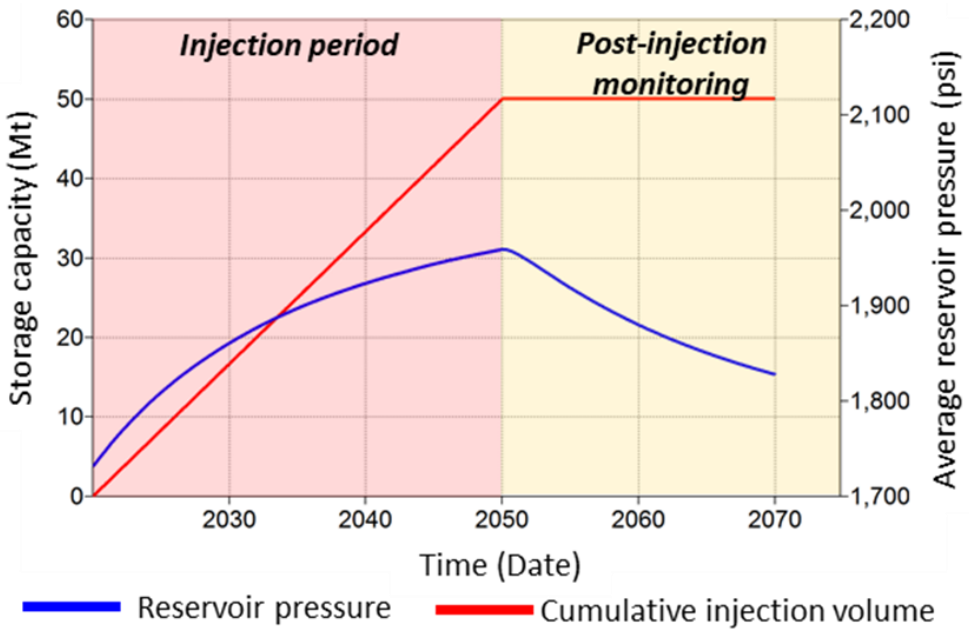
- A new element of the stratigraphic model: meandering valley system incised into the Meramecian surface was discovered through seismic attribute analysis

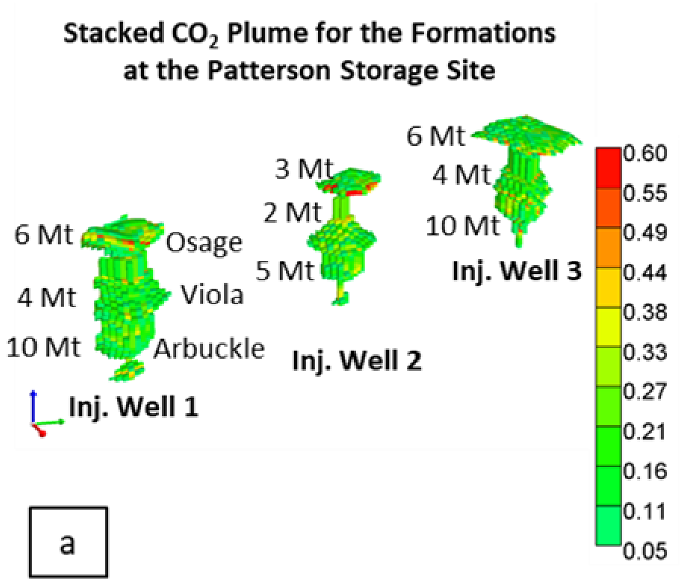
Dynamic Modeling Updates

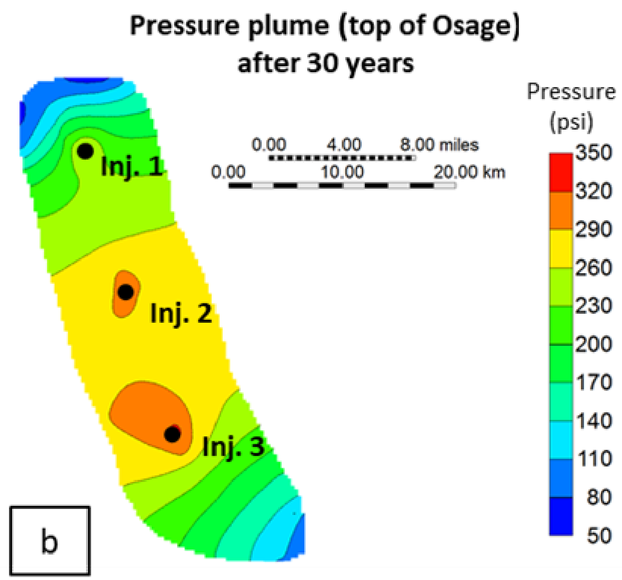
Patterson-Heinitz-Hartland

- Dynamic reservoir modeling demonstrates that 50 Mt of CO_2 can be injected within 30 years with three injection wells at the Patterson site

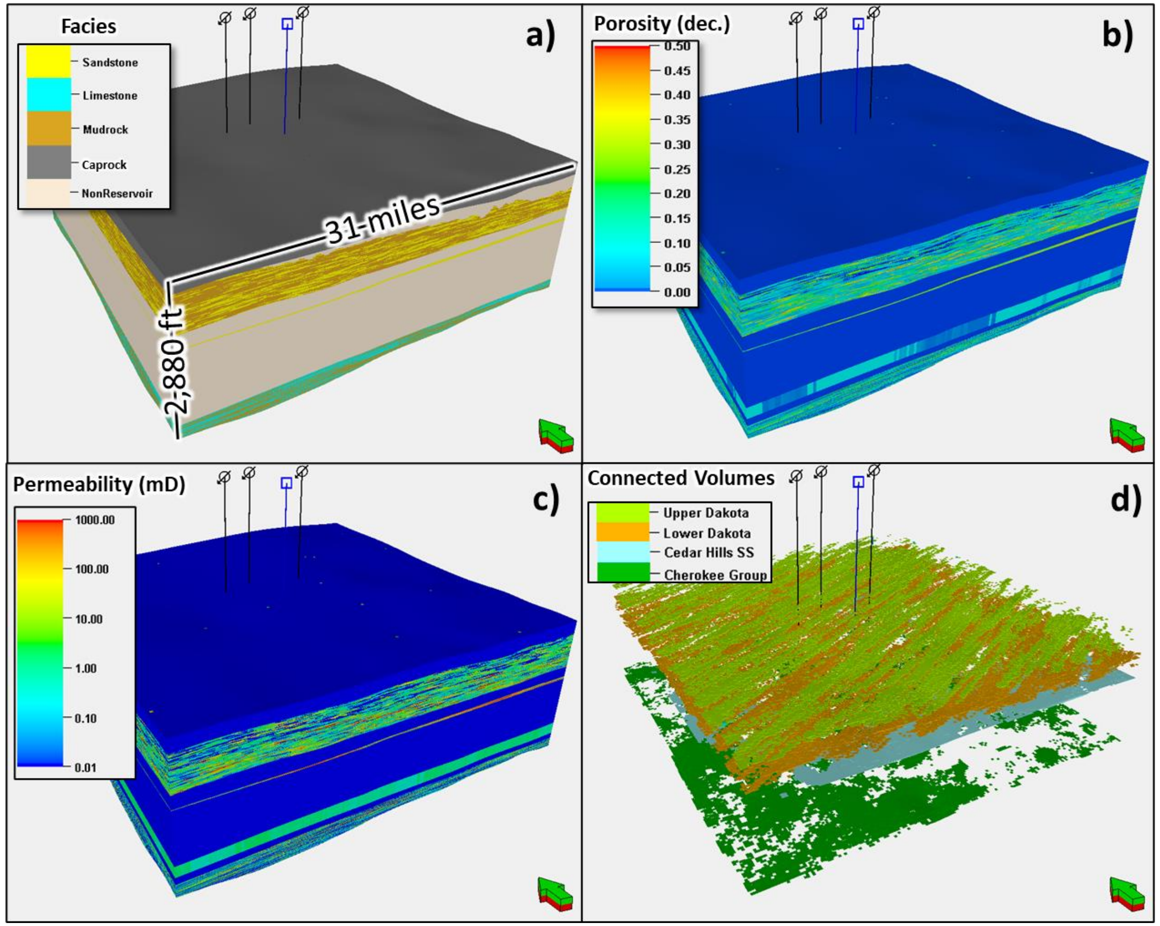
- Data from the city of Lakin wastewater injection well were used for injectivity analysis to obtain reservoir-scale carbonate permeabilities, compare with nearby wells, history match the pressure increase, and update geologic models and dynamic simulations to refine the CO_2 storage capacity in Phase II

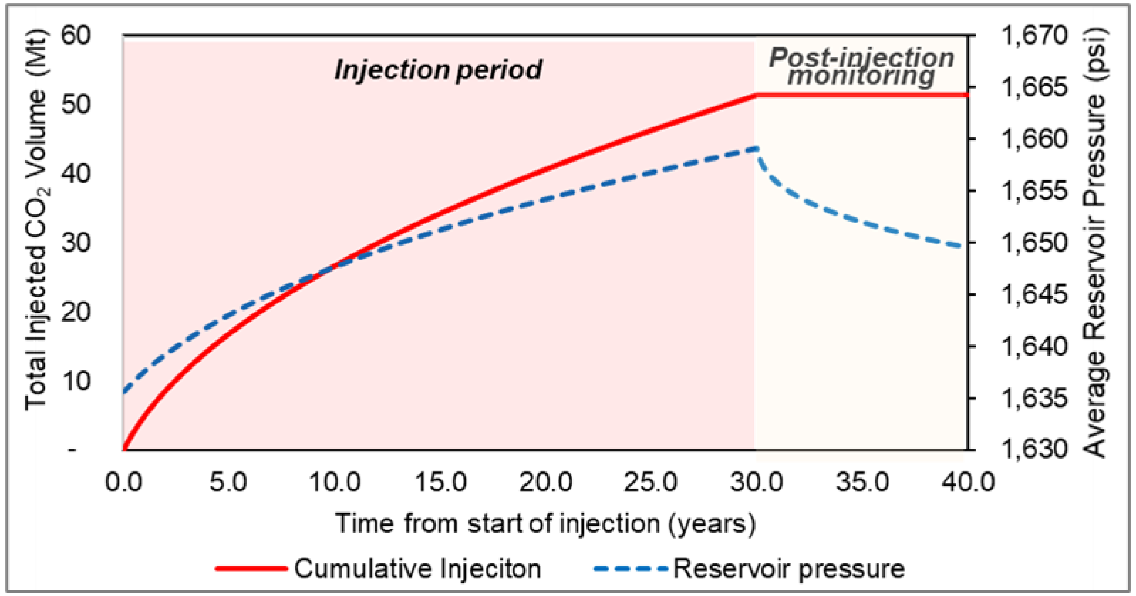






Madrid, Nebraska Site

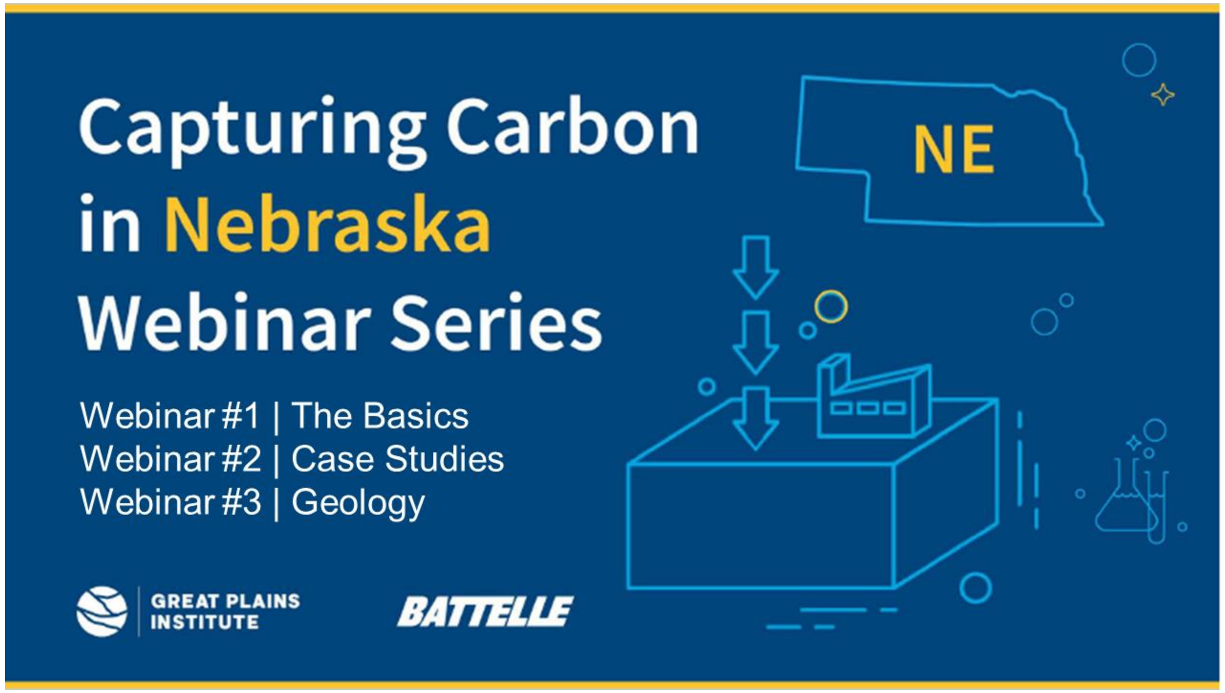




- Simulations run on 30 mi. by 30 mi. model
- Using three injection wells, **51 Mt of CO_2 can be injected over 30 years** into Upper Dakota, Lower Dakota, and Cedar Hills sandstone units, and Lansing-Kansas City Group and Cherokee Group
- Future characterization plans would include 3D seismic acquisition and characterization well

Outreach

- Outreach Webinar Series with Nebraska stakeholders began in late May 2020
  - Webinar 1: The Basics
  - Webinar 2: Case Studies
  - Webinar 3: Geology
- Each webinar was attended by >80-100 interested stakeholders from ethanol plants, power plants, and industry trade groups, federal and state regulatory agencies, and research institutes



- A social site characterization was performed to determine the issues of potential concern to stakeholders in the IMSCS-HUB region and to determine the demographics of the communities affected by project activities.
- Strategies for media management and available outreach resources are being developed
- Public acceptance of the project is being foster by engaging local advocacy groups and organizing local public meetings

Risk Assessment and Mitigation

Risk	Mitigation
Subsurface leakage from legacy wellbores	- Definition of a secondary caprock increases the apparent risk. - Additional well records may present a more accurate subsurface risk.
Perception of Induced seismicity	- Seismic monitoring at Patterson did not detect any local seismicity. - Public outreach / Education.
3D seismic survey revealed faults at the PHH site	- Do not reach the deepest USDW or intersect the modeled CO_2 plume. - Additional work must be done to ensure that the faults will not be reactivated.
Pipeline construction is the highest risk (not unique to CCUS)	- Using contractors with proven safety records, and planning.
CO2 pipeline operations are relatively low risk	- Careful routing to avoid high-consequence areas. - Monitoring to ensure pipeline leaks are found early. - Adhering to all operational constraints and safety standards.
Non-technical risks remain the least defined	- Legislative and regulatory efforts on the state level. - Effective and adaptive public outreach plan. - Contractual obligations and offtake clearly outlined.

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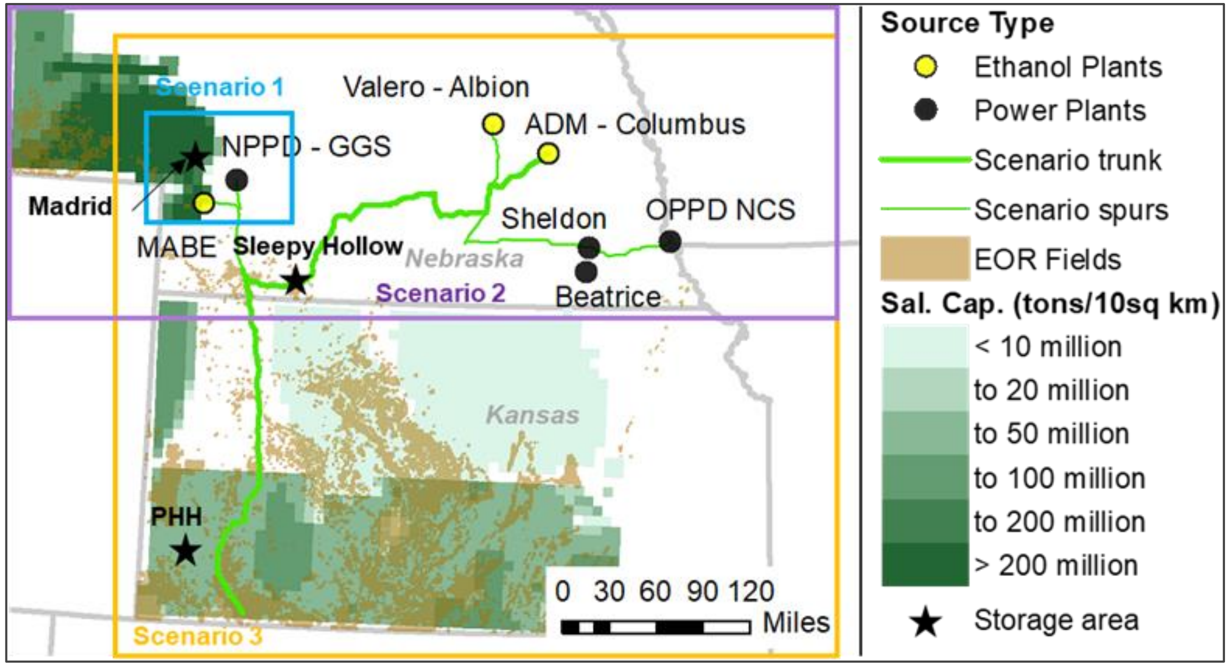
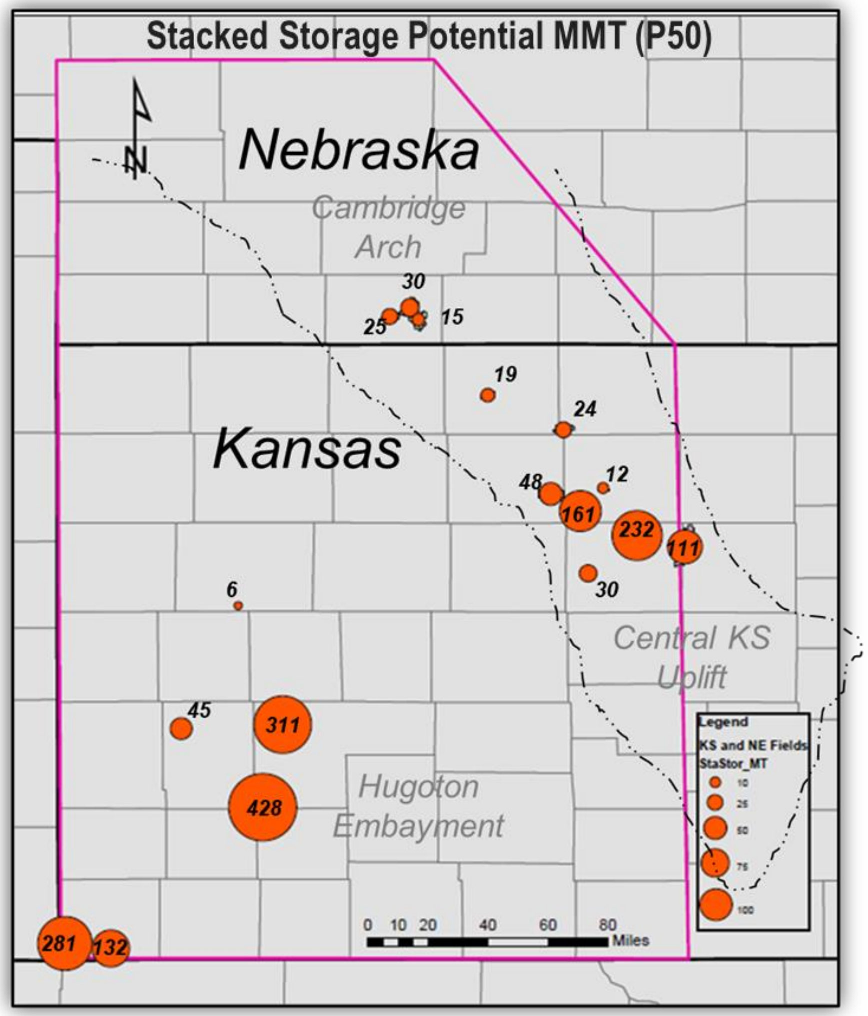
Scenario Modeling

- Three scenarios were developed:
  1. **Perkins County:** Potential for a single storage project (near-term commercial scale opportunities)
  2. **Nebraska Stacked Storage:** Limited hub concept using participating sources and sinks in Nebraska
  3. **Nebraska-Kansas Stacked Storage:** Expanded regional hub concept using participating sources and sinks in Nebraska



CO_2 Management and Commercial Development Strategy

- IMSCS-HUB storage corridor was screened for commercially viable CO_2-EOR opportunities using ARI's Big Oilfield DB
- **17 technically and economically feasible oilfields**, including the Sleepy Hollow Field and Patterson
- Storage resource estimates: combined **577.4 Mt of CO_2** and potential to **produce 181.9 MMbbls of oil** via EOR
- Gross revenue for stacked storage + EOR at the 17 fields is $30.9 Billion



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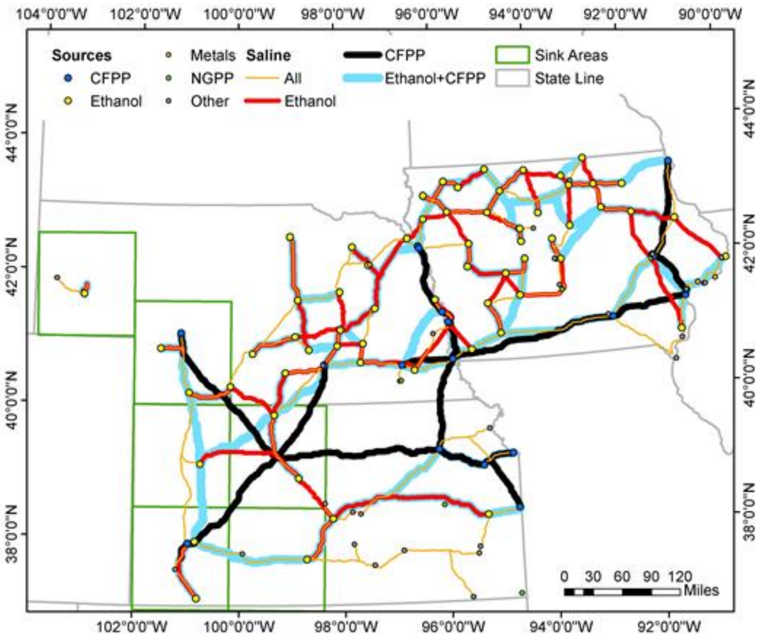
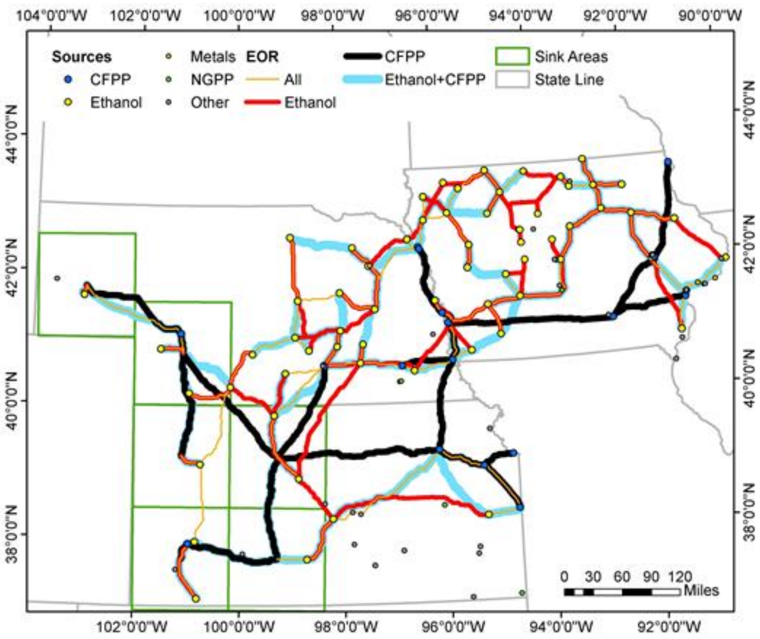
Commercial Pipeline Planning

- Development of feasible pipeline routes connecting sources along the source corridor to sinks in the storage corridor, accounting for environmentally and culturally sensitive areas

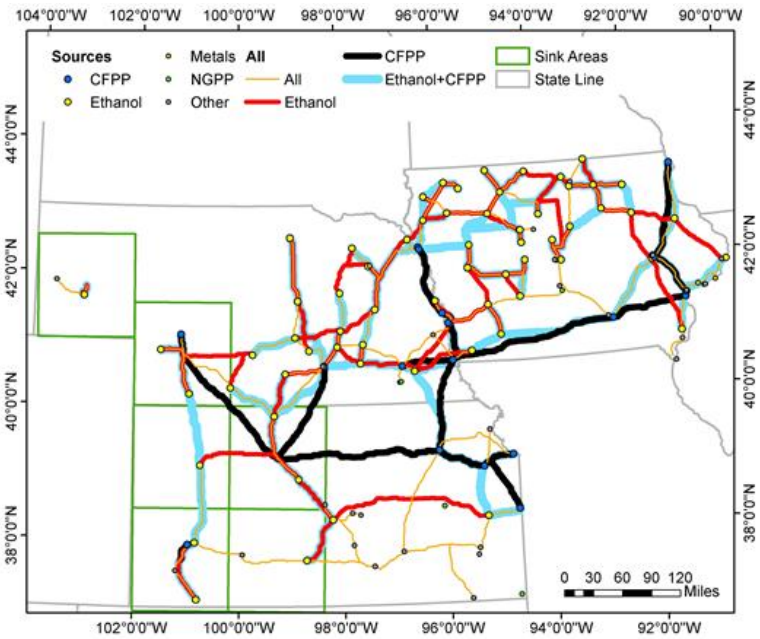
- Scalable Infrastructure Model for Carbon Capture Storage (SimCCS) model
  - 12 distinct scenarios comprised of **4 different 45Q-eligible source configurations** (ethanol only, coal-fired only, ethanol and coal-fired, and all sources) and **3 different storage configurations** (saline only, CO_2-EOR only, and saline and CO_2-EOR)



Saline Sinks



CO_2-EOR Sinks



All Sinks

Summary

- Commercial-scale CCUS sites are feasible at :
  (1) Madrid Site in Perkins Co., NE and (2) Patterson-Heinitz-Hartland Field in Kearny Co., KS
  - Sleepy Hollow Field in Red Willow Co., NE is an attractive candidate for CO_2-EOR
- Outreach efforts found interest among industry stakeholders
- Project risk assessment showed that all components of a CCUS project are feasible
- The permitting and regulatory plan developed for region. The contractual assessment showed many options.
- Stacked storage potential found in 17 oilfields
- The pipeline assessment found viable routes that connected variable sources along corridor
- The economic assessment study showed promising results.
- Future Work: fault analysis at PHH, 3D seismic and characterization well at Madrid, additional work on Non-technical risks, outreach, and economic scenarios

Thank you!

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Appendix

- These slides will not be discussed during the presentation, but are mandatory.

Project Overview 2

- Total funded amount $9.4M
  - Spent to date $9.1M

- POP
  - Originally 8-10-2020
  - 3 months extension till 11-10-2020 given to finish core work and integrate testing and seismic data collected over July –Aug 2020 into reports.

Benefit to the Program

- The objectives of the IMSCS-HUB program build on the lessons learned from the RCSP's and extend the framework for geologic storage site characterization and development to the commercial scale. The IMSCS HUB Project will systematically address the technical challenges of commercial-scale CO_2 storage and will aid DOE in meeting their Carbon Storage Research and Development Program goals:
- (1) Develop and validate technologies to ensure 99 percent storage permanence.
- (2) Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness.
- (3) Support industry's ability to predict CO_2 storage capacity in geologic formations to within ±30 percent.
- (4) Develop best practice manuals for site characterization, public outreach, risk management and operations for geologic storage

Introduction

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Phase 2 Organization

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US Department of Energy National Energy Technology Laboratory

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Principal Investigator

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Mr. Neil Wildgust (EERC)

Technical Advisor
Dr. Neeraj Gupta (Battelle)

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Project Leader/Manager: Mr. Jared Walker (Battelle)

Task 2: Site Access and Permitting
Leader: Mr. Jared Hawkins (Battelle)

Task 3 Feasibility Data Collection Planning
Co-Leader (Geologic Feasibility): Ms. Isis Fukai (Battelle)
Co-Leader (Reservoir Simulation): Mr. Larry Pekot (EERC)

Task 4: Storage Complex Feasibility Data Collection
Leader: Dr. Andrew Duguid (Battelle)

Task 5 Storage Complex Analysis and Modeling
Co-Leader (Geologic Characterization): Ms. Mackenzie Scharenberg (Battelle)
Co-Leader (Reservoir Simulation): Dr. Chantsalmaa Dalkhaa (EERC)

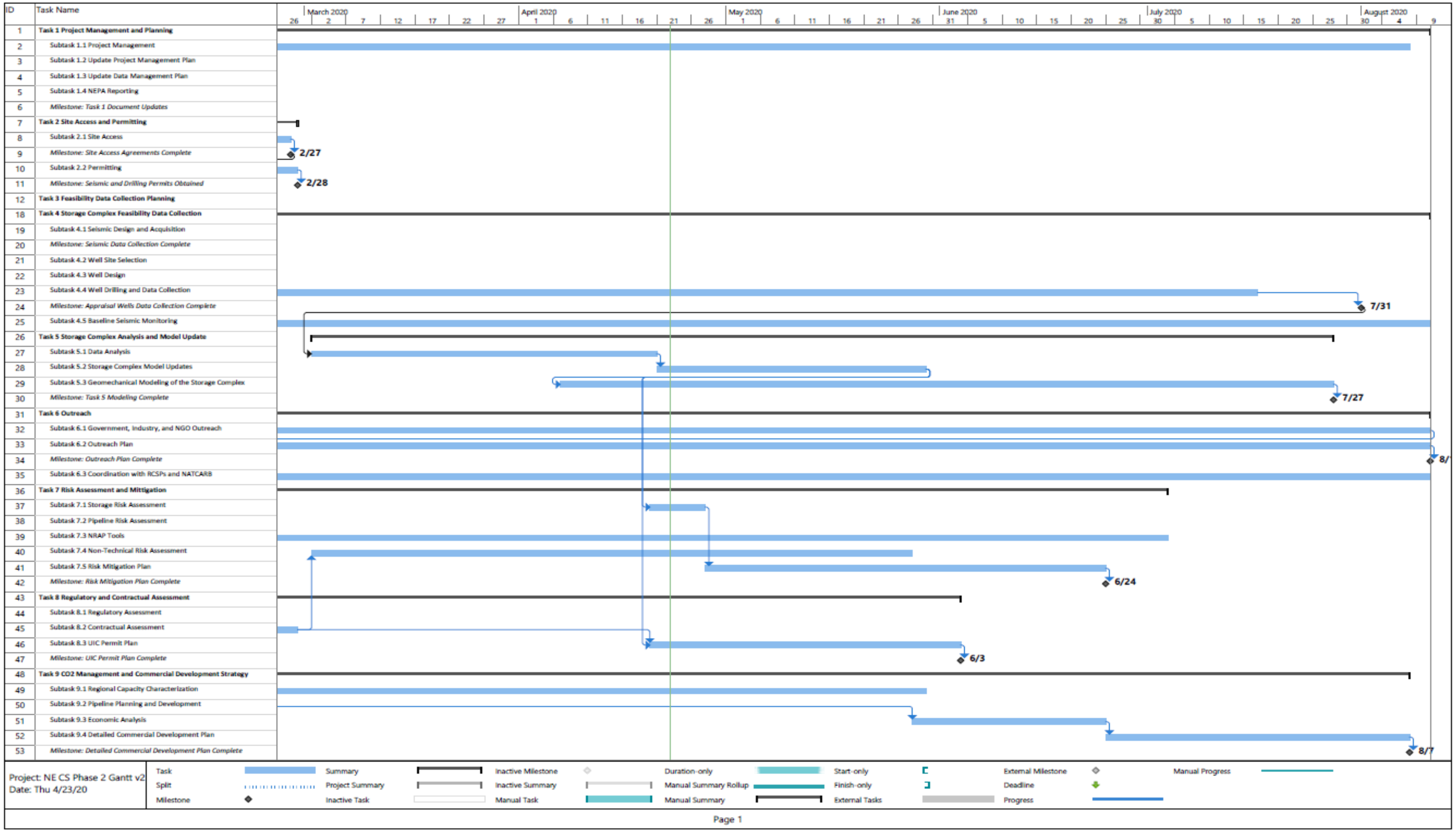
Task 6: Outreach
Task Leader: Brendan Jordan (GPI)

Task 7: Risk Assessment and Mitigation
Leader: Mr. Jared Hawkins (Battelle)

Task 8: Regulatory and Contractual Requirements Assessment
Co-Leader: Mr. Scott McDonald (ADM)
Co-Leader: Mr. Jared Hawkins (Battelle)

Task 9: CO_2 Management and Commercial Development Strategy
Co-Leader: Dr. Andrew Duguid (Battelle)
Co-Leader: Mr. Scott McDonald (ADM)

Gantt Chart



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