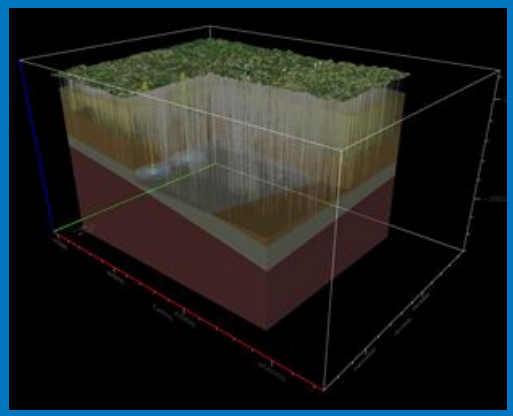
Case Study on Methods to Leverage Operational Data from Class II UIC Wells to Evaluate Class VI CO_2 Injection Well Performance

Joel Sminchak, Manoj Valluri, Neeraj Gupta and Glenn Larsen
Battelle, Columbus, Ohio, USA

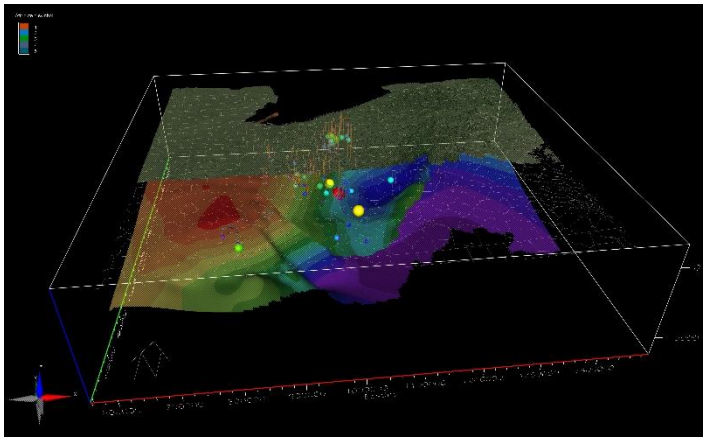


Ground Water Protection Council Annual Forum
September 28-30, 2020

BATTELLE

Presentation Outline

1. Background
2. Geotechnical parameters for injection zones
3. Class II UIC operational data & injection performance
4. Class VI CO_2 injection evaluation
5. Conclusions



Acknowledgments

- This material is based upon Central Appalachian Basin CarbonSAFE work supported by the U.S. Department of Energy (DOE) under Award DE-FE0029466 with co-funding by The Ohio Coal Development Office in the Ohio Development Services Agency (Grant D-17-02).
- Many thanks to team members: American Electric Power (AEP), Buckeye Brine, The Energy Cooperative, Three Rivers Energy, BHGE, LLNL, LANL, PNNL, PKM Energy, Vorys, Sater, Seymour, and Pease LLP (Vorys), and Wade LLC.
- Additional support provided by the U.S. DOE Midwest Regional Carbon Initiative (DE-FE0031836).

Background

Class II UIC vs. Class VI UIC Carbon Storage

Example: Central Appalachian Basin

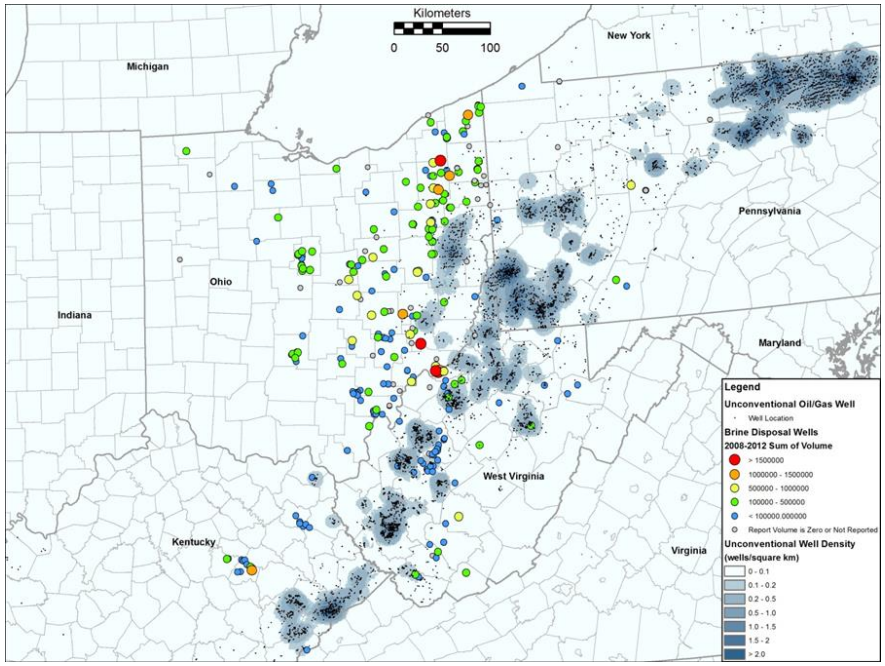
Class II Brine Disposal

- ~200 Class II UIC wells
- ~20 million BBL brine/year

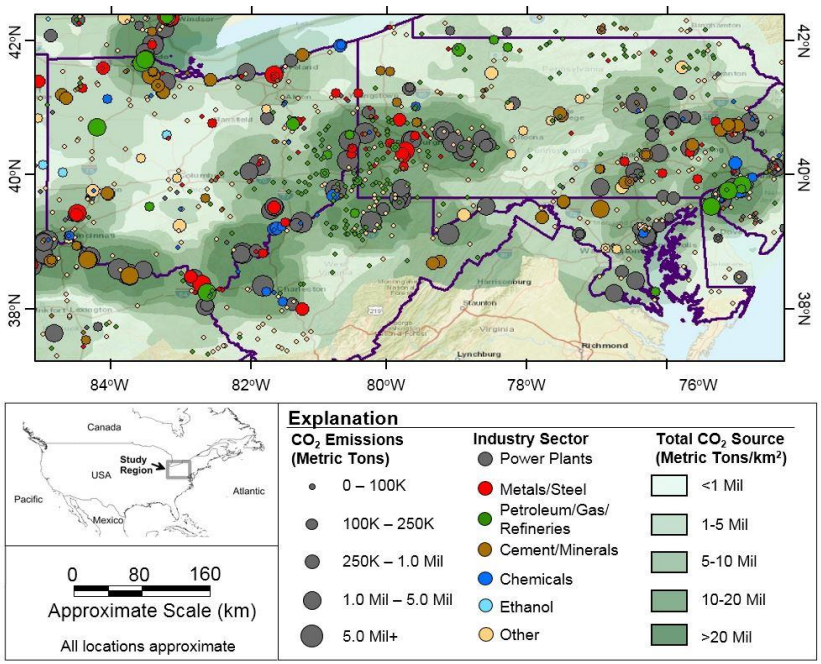
Class VI CO_2

- ~200 large CO_2 point sources
- ~200 million metric tons CO_2/year

Class II Brine Disposal Wells



Industrial CO_2 Point Sources



BATTELLE

Background

Class II UIC vs. Class VI Carbon Storage

Example: Central Appalachian Basin

Class II Brine Disposal

- Best injection wells have total annual injection approx. ~1,000,000-2,000,000 BBL/year
- Commercial well max. injection rates ~10,000-15,000 BBL/day
- Limited area of review (1/2-mile radius), wellhead monitoring, subsurface rights.

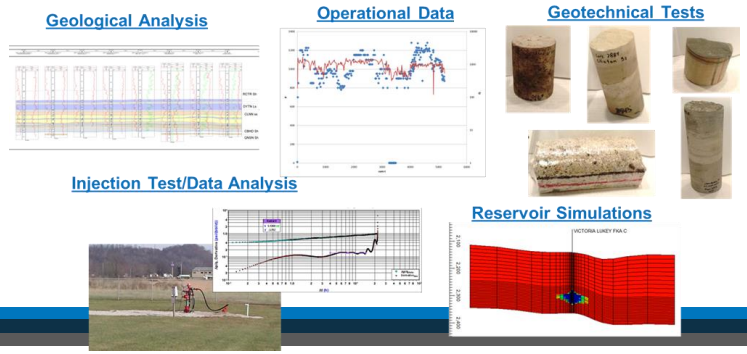
Class VI CO_2

- Industrial source may inject 1-2 million metric tons CO_2/year (or 9-18 million BBL/year)
- Maintain injection rate of 2,800-5,600 metric tons CO_2/day
- Large area of review, monitoring, subsurface rights requirements.

Background

Objectives-

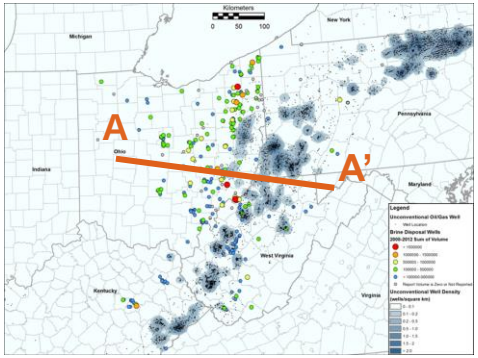
- Determine maximum, sustainable CO_2 injection rates for CO_2 storage intervals given maximum allowable surface injection pressure constraints.
- Estimate number of wells, well spacing necessary to support industrial scale CO_2 storage 1.6 million metric tons CO_2/year (~50 million metric tons CO_2 over 30 years).
- Use Class II UIC well operational data, flow meter tests, & pressure falloff tests to validate reservoir simulations.

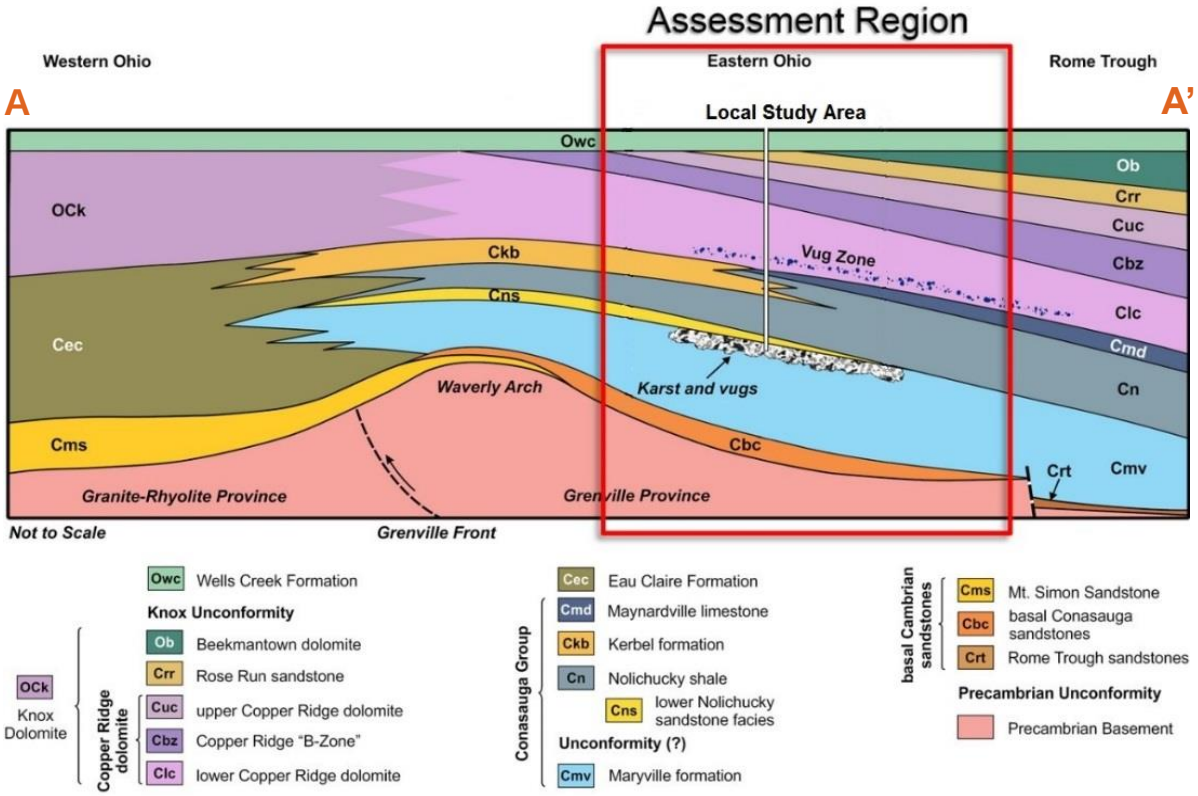


BATTELLE

Geotechnical parameters for Injection Zones

- Stacked reservoir (carbonates and sandstones)
- 6,000-8,000 deep; 200,000-300,000 mg/L salinity
- Extensive caprock

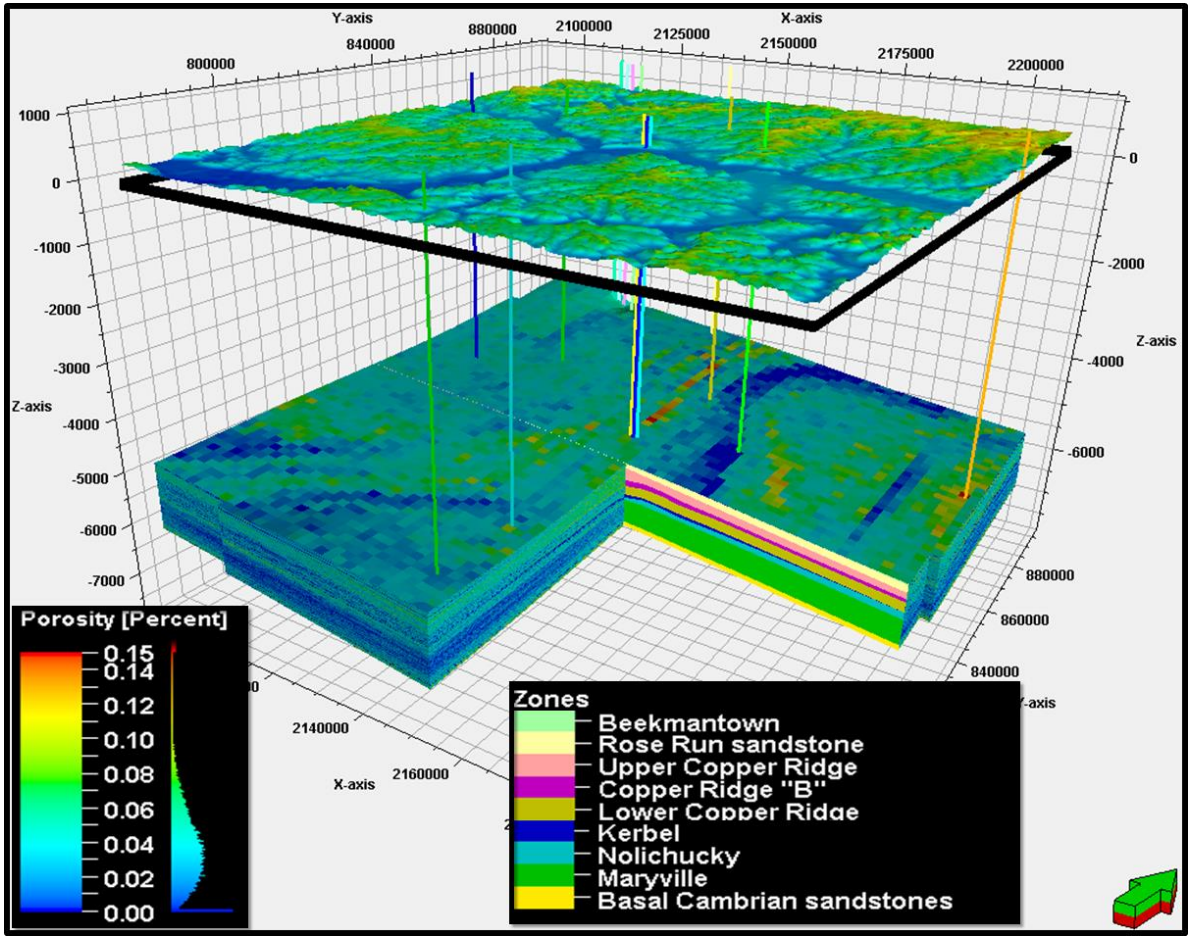




BATTELLE

Geotechnical parameters for injection zones

- Vugular, karst porosity zones appear to have the best injection potential.
- Porosity zones are difficult to detect with geophysical logs, seismic.



Static Earth Model of Porosity

BATTELLE

Geotechnical parameters for injection zones

- Injection interval and caprock properties estimated based on regional maps, nearby wells, core tests, geophysical logs.

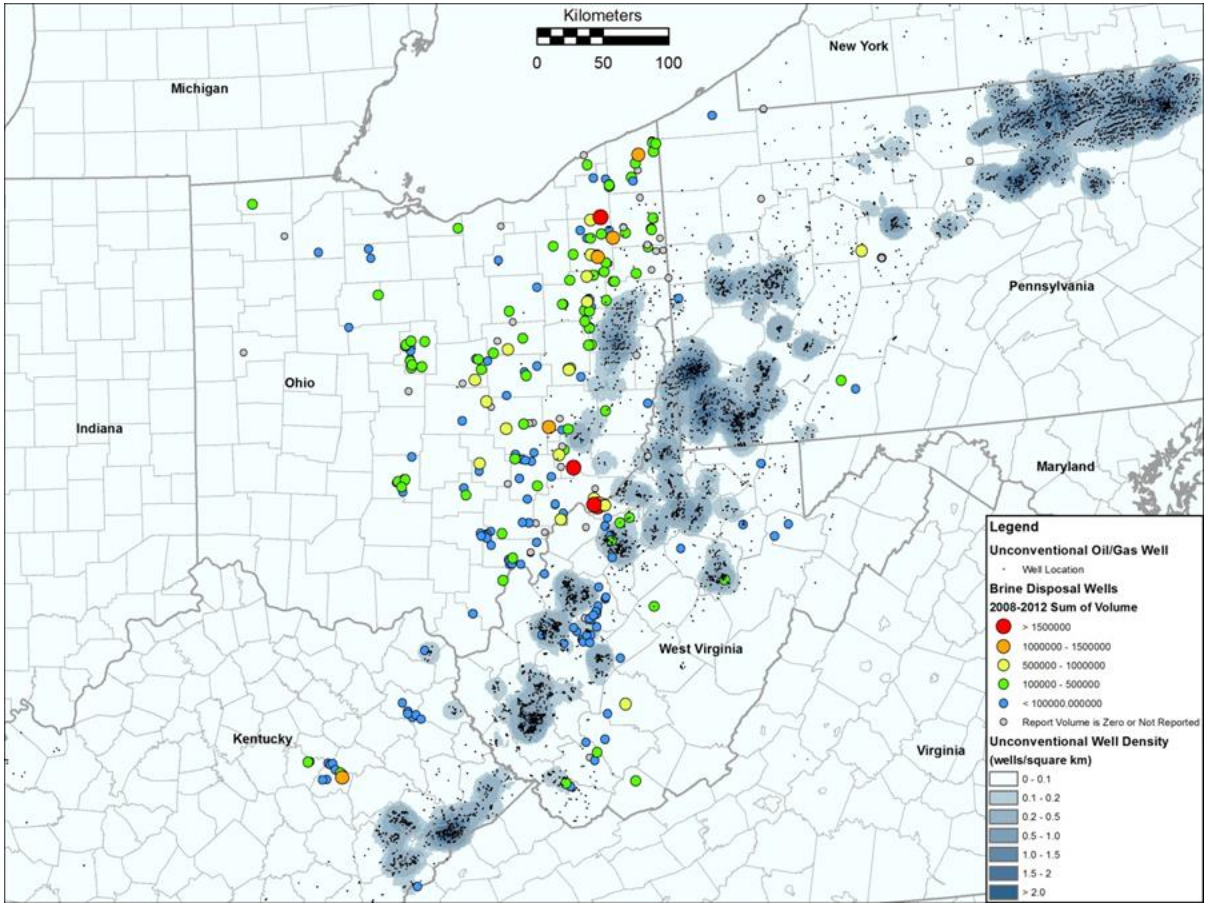
Injection zone properties of Selected Area B.

	Stratigraphic Column			Formation Data			
	System	Formation Lithologies	Stratigraphy (Colored by Unit Type)	Depth (ft)	Elevation (ft MSL)	Thickness (ft)	Average Porosity (decimal)
Caprock	Ordovician	LS, DOL	Black River Group	5,395	-4,620	446	0.006
		LS		5,841	-5,066	109	0.001
		DOL, LS, SH	Wells Creek Formation	5,950	-5,175	50	0.019
Reservoir	Cambrian	SS	**Rose Run sandstone**	6,000	-5,225	78	0.05
		DOL	Upper Copper Ridge dolomite	6,078	-5,303	195	0.055
		DOL, SLT	Copper Ridge B-zone	6,273	-5,498	67	0.061
		DOL	Lower Copper Ridge dolomite	6,340	-5,565	120	0.037
			Lower Copper Ridge Flow Zone	6,460	-5,685	43	0.115
			Lower Copper Ridge dolomite	6,503	-5,728	79	0.037
		SS, DOL, SH	Kerbel sandstone	6,582	-5,807	26	0.037
		DOL, SH	Nolichucky shale	6,608	-5,833	18	0.023
		SS, DOL SS	**Nolichucky Flow Zone**	6,626	-5,851	42	0.15
		DOL	Maryville formation	6,668	-5,893	82	0.024
			Maryville Flow Zone	6,750	-5,975	35	0.10
			Maryville formation	6,785	-6,010	400	0.024
		SS	basal Cambrian sandstone	7,185	-6,410	102	0.066
	Precambrian	Igneous and metamorphic rocks	Grenville Complex	7,287	-6,512	-	-

Note: Bold indicates major injection zones, LS = limestone, DOL = dolomite, SH = shale, SLT = siltstone, SS = sandstone.

Class II UIC operational data & injection performance

- Class II injection well testing and operational data provide assurance on injection performance.



BATTELLE

Class II UIC operational data & injection performance

- Class II wells provide empirical data on injection potential.

2015

County	Operator	Lease Name	Brine Vol. (bbl/yr)	CO_2 (tons/yr)*
Tuscarawas-Oxford	Elkhead Gas&Oil Co.	Mozena #1	2,151,488	325,580
Coschocton-Keene	Buckeye Brine LLC	Adams #3	1,940,139	293,460
Muskingum-Union	Heckman Waters Res	Goff SWD #1	1,403,135	212,430
Coshocton-Kenee	Buckeye Brine LLC	Adams #2	1,332,557	201,845
Athens-Troy	K&H Partners LLC	K&H Partners #2	1,327,271	201,115

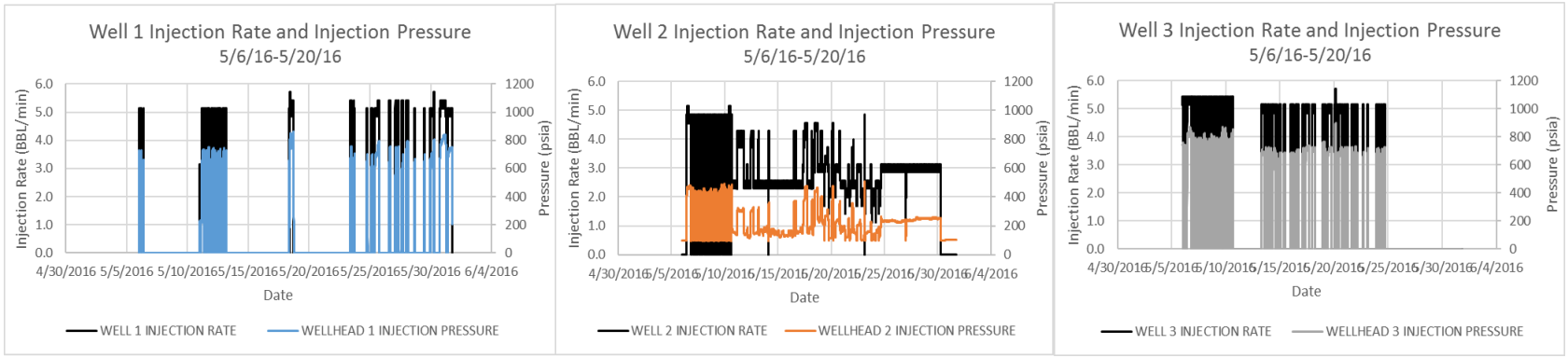
2016

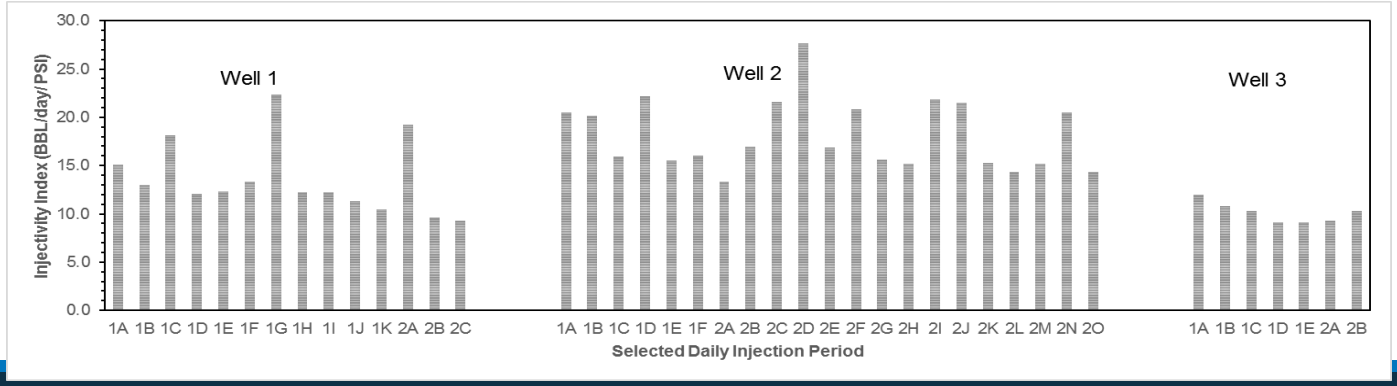
County	Operator	Lease Name	Brine Vol. (bbl/yr)	CO_2 (tons/yr)*
Washington	Redbird Development	Red Brid (SWIW #18)	1,937,197	293,095
Muskingum	Environmental Energy Solutions	Pattison Trust (SWIW #30)	1,697,250	256,960
Tuscarawas	Elkhead Gas&Oil	Mozena (SWIW #13)	1,498,932	227,030
Guernsey	Clearwater Three LLC	Clearwater 111 (SWIW #15)	1,486,103	224,840
Guernsey	Clearwater Three LLC	BO (SWIW #20)	1,372,107	207,685

*Potential injection rate assuming brine density: 62.48 lb/ft^3, supercritical CO_2 density: 30 lb/ft^3, 8.6 bbl of fluid per ton

Class II UIC operational data & injection performance

- High performing Appalachian Basin commercial Class II wells sustain injection rates of 5,000 to 9,000 BBL/day at wellhead pressures of 300 to 900 psi.
- Injectivity indexes (rate/delta P) = 10 to 20 barrels per day/psi.

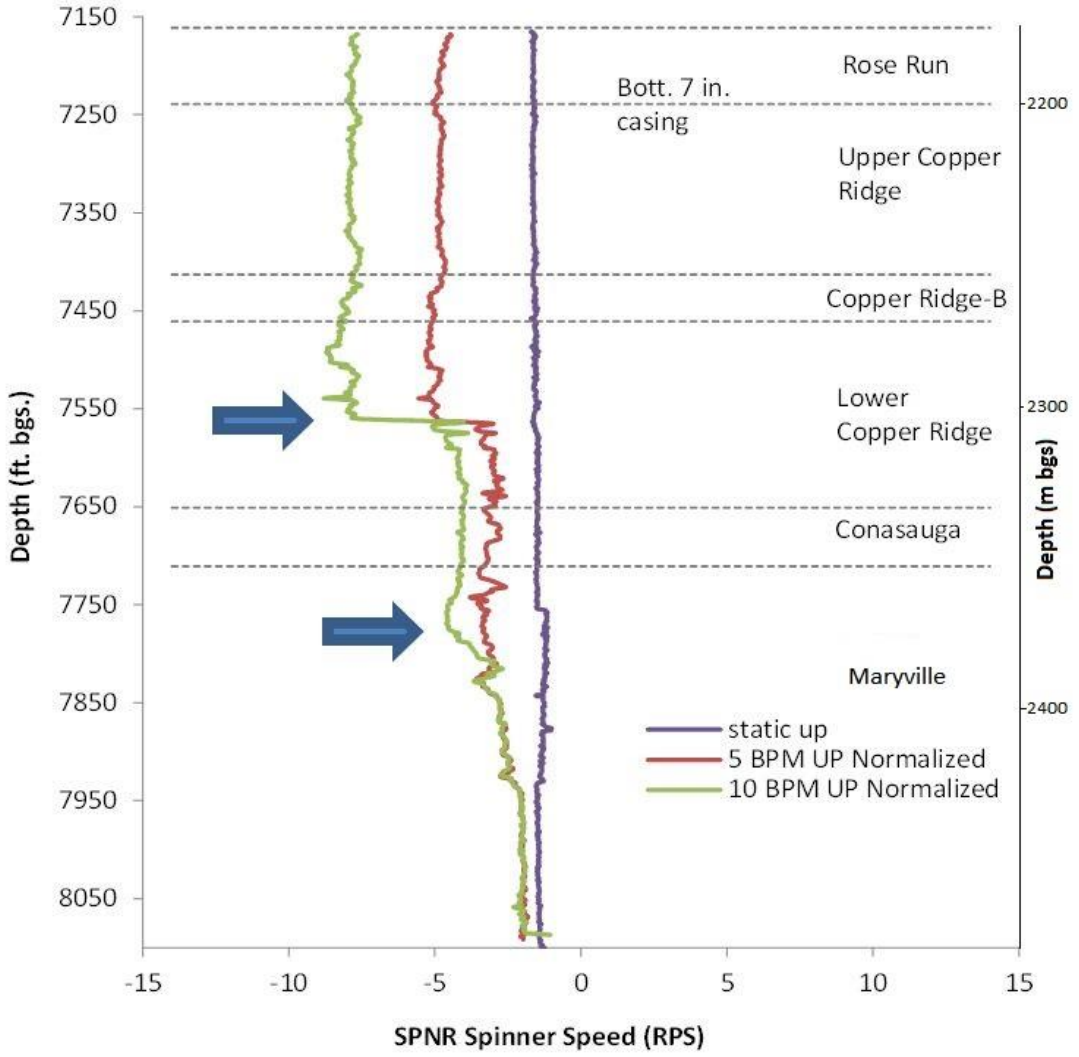




BATTELLE

Class II UIC operational data & injection performance

- Flow zones are difficult to identify with geophysical logs.
- Flowmeter injection tests help define injection flow zones in carbonate layers in open hole injection intervals.

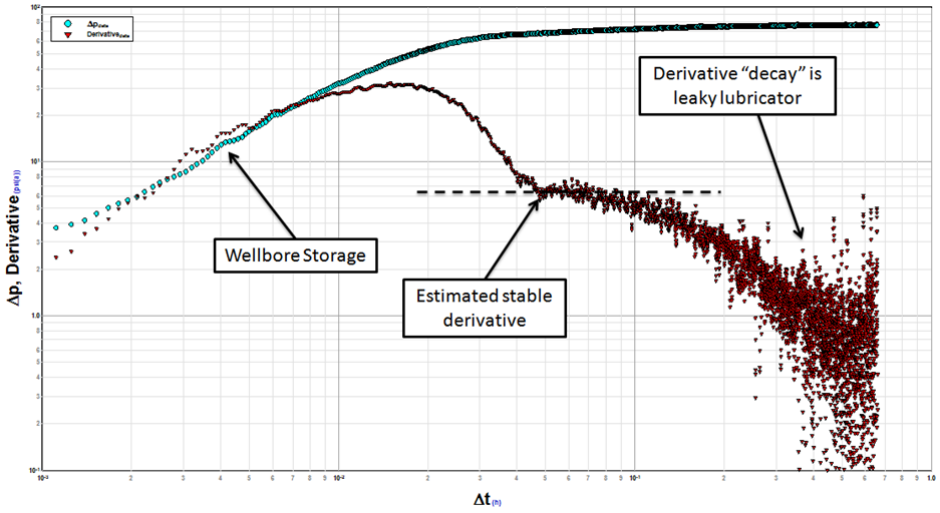


BATTELLE

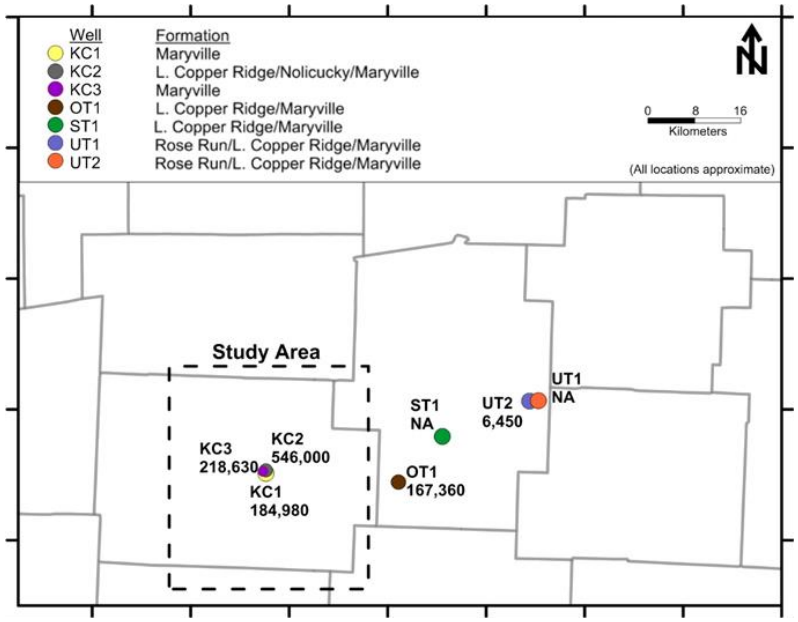
Class II UIC operational data & injection performance

- Well tests on Class II injection wells provides additional information on transmissivity of injection zones
- Also reservoir features (open, closed, faults).

Pressure Fall-Off Derivative Plot



Transmissivity Plot (mD-ft)



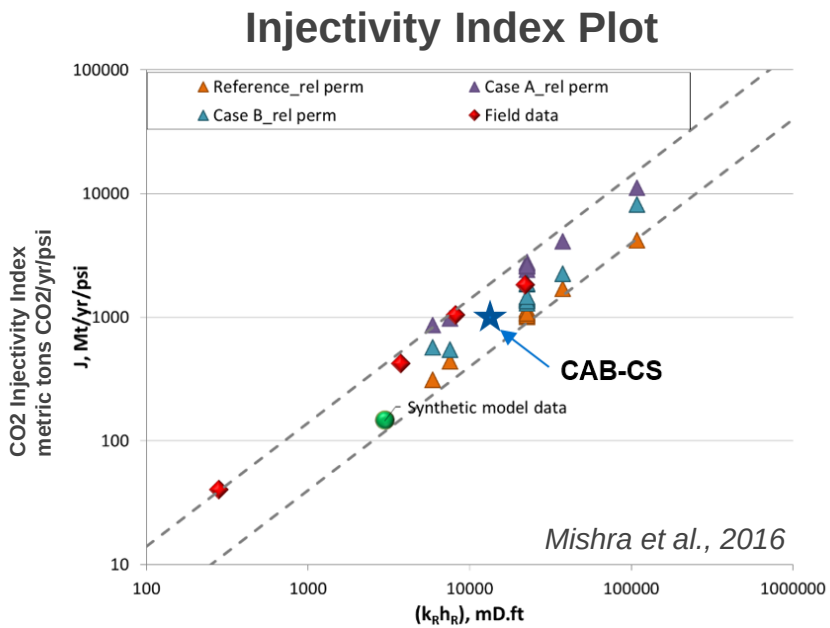
BATTELLE

Class II UIC operational data & injection performance

- Class II injectivity index or well test transmissivity may be used to evaluate Class VI CO_2 well performance.
- Example- ~800,000 metric tons CO_2/year (or 18,000 BBL/day) and injectivity index 'J' = 15 BBL/psi.

$$\text{delta pressure (psi)} = \frac{Daily\ injection\ Volume\ (BBL)}{Injectivity\ Index\ (\frac{BBL}{psi})} = \frac{18{,}000\ BBL}{15\ BBL/PSI} = 1{,}200\ \text{psi}$$

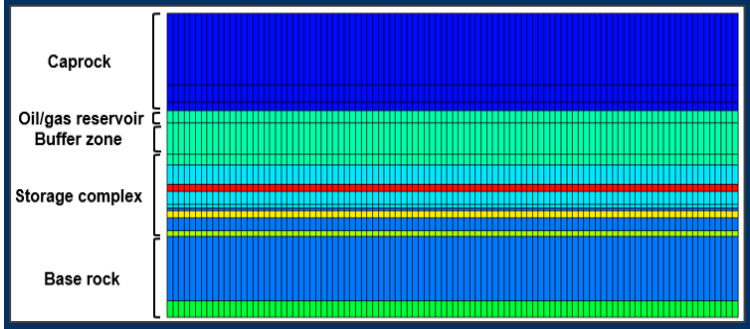
Rough Estimates



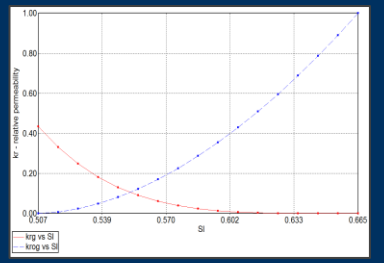
BATTELLE

Class VI CO_2 injection evaluation

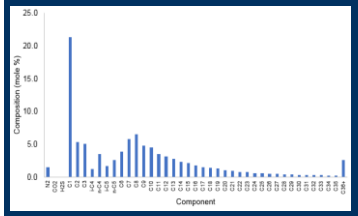
- Advanced reservoir simulations completed to estimate "area of review" based on CO_2 pressure/saturation & geotechnical parameters for the study area.



Geological model

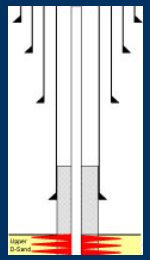


Rock-fluid behavior

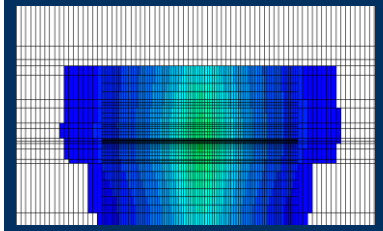


Fluid model

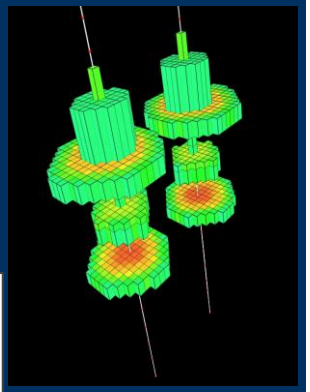
Injection/monitoring schedule



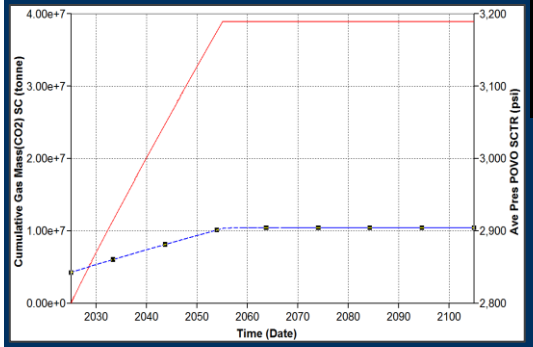
Completion data



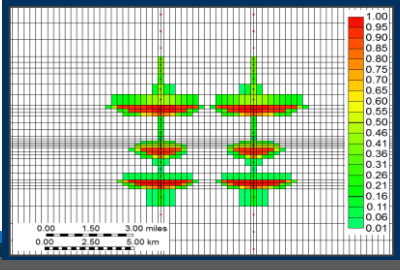
Pressure buildup



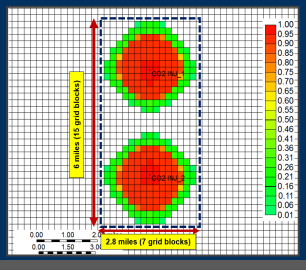
Gas saturations



Storage estimates



Plume extent



BATTELLE

Class VI CO_2 injection evaluation

- Reservoir simulation input based on geologic models & well tests.

Parameter	Value	
	Site B (primary)	Site A (secondary)
Geological Model		
Reservoir depth (top layer)	5395 ft	7187 ft
Pressure (top layer)	2536 psi	3127 psi
Temperature (top layer)	109 °F	127°F
Caprock thickness	605 ft	639 ft
Storage zone thickness	707 ft	651 ft
Injection Data		
Injection wells needed	2	2
CO2 injected	50 million metric tons	50 million metric tons
Injection duration	30 years	30 years
Monitoring duration	50 years	50 years
Plume radius	1.2 miles	1.2 miles
Pattern area	16.8 sq. miles	16.8 sq. miles
Pressure Data		
Final average reservoir pressure buildup	80 psi	75 psi
Maximum allowable bottom-hole pressure	3952 psi	5062 psi
Maximum well bottom-hole pressure	3741 psi	4515 psi
Maximum pressure buildup near wellbore	270 psi (at t = 30y)	260 psi (at t = 30y)
Maximum pressure buildup at model boundary	85 psi	90 psi
Pressure buildup in oil and gas zone	85 psi	NA
Pressure buildup in buffer zone	85 psi	0

Class VI CO_2 injection evaluation

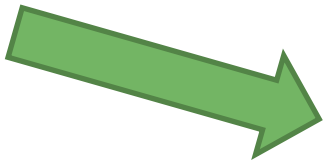
- Initially, the model's permeability distribution was based on neutron & density logs as interpreted in the geologic model & results of injection pressure falloff/flowmeter test data from wells.
- This initial model iteration had anomalously high transmissivities when compared to operational data. Simulation results were also overly optimistic in terms of injection rates and pressures.
- Consequently, injection zone transmissivity was adjusted using "transmissivity multipliers" based on long-term injection performance.

$$Transmissivity\ Multiplier = \frac{(kh)_{flow-test}}{(kh)_{operational}}$$

Transmissivity multipliers for permeability analysis.

Well	Well Test Transmissivity (mD-ft)	Operational Transmissivity* (mD-ft)	Mean Transmissivity Multiplier
KC1	184,980	2,517	74
KC2	546,000	9,909	55
KC3	218,630	2,212	99

Note: mD-ft = millidarcy-foot. *$kh_{operational}$ = injection index / 0.0014



Permeability values assigned for flow zones.

Flow Zone	Initial Permeability (mD)	Final Permeability (mD)
Lower Copper Ridge	1,879	661
Nolichucky	3,900	74
Maryville	13,236	289

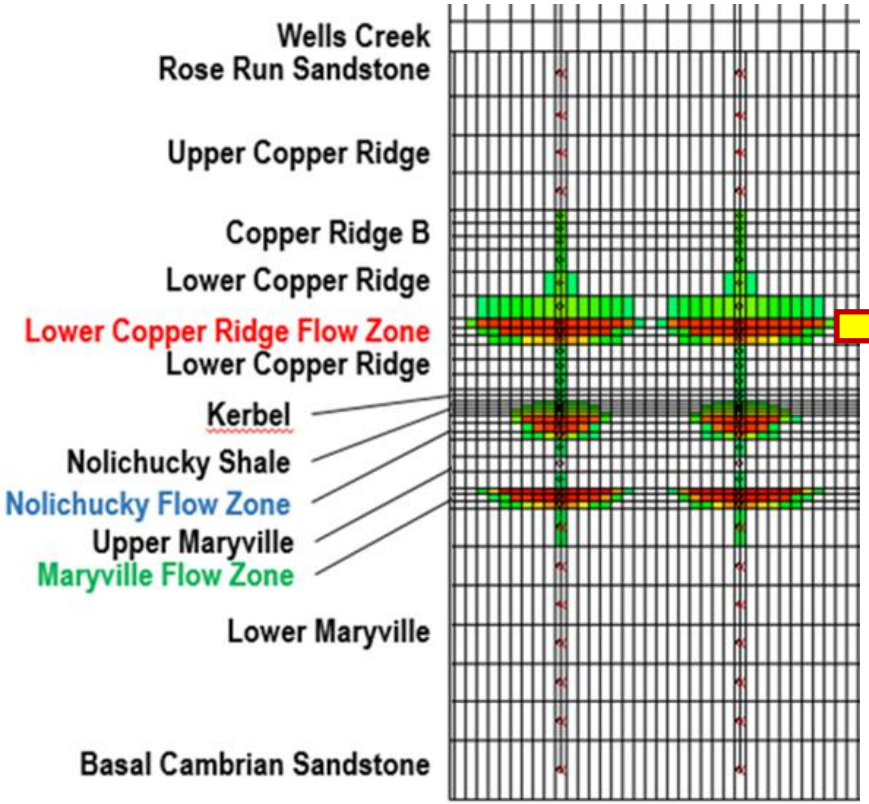
*accounts for thickness of injection zone at candidate site

Class VI CO_2 injection evaluation

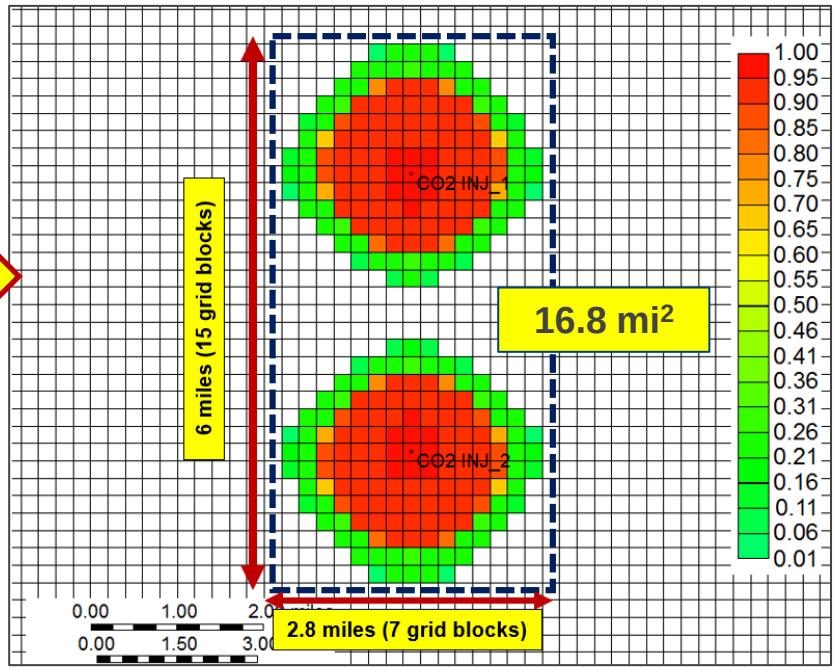
Calibrated Simulation Results – CO_2 Plume Saturation

1.6 million metric tons CO_2 injection for 30 years (50 million mtons total)

Vertical view



Areal view



BATTELLE

Conclusions

- This workflow presents a method to integrate wastewater injection operational data to validate CO_2 storage feasibility.
- In the study area, deep Cambrian-age vugular carbonate zones have high transmissivity, but the flow zones are difficult to evaluate with geophysical methods.
- These flow zones have been utilized for wastewater disposal wells in the region, and long-term operational data from these wells was a critical piece of information.
- Operational flow rates and pressures in wastewater disposal wells provide a practical validation of injectivity. In this case, reservoir transmissivity estimates from geologic models and well tests were almost 70 times higher than the transmissivities indicated by day-to-day operational metrics observed at nearby wells.

Thanks!

https://onlinelibrary.wiley.com/doi/abs/10.1002/ghg.1964

BATTELLE