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Performance and Safety Screening for the Ohio River Valley CO_2 Storage Site Using Features, Elements, and Processes Database

Joel Sminchak, Mark Kelley, and Neeraj Gupta

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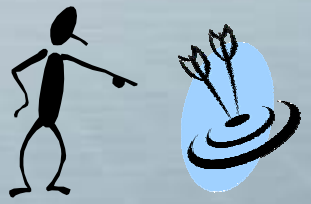
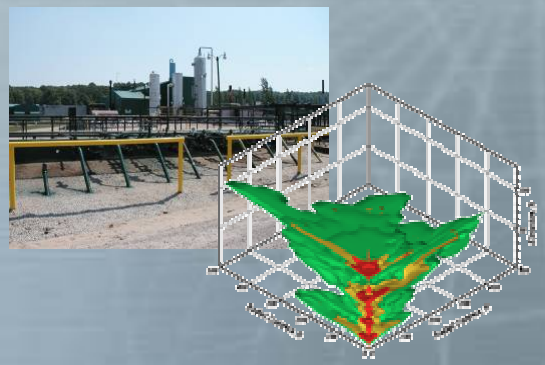
- Regional Geologists: *Bill Rike, John Forman, Amy Lang*

Objectives

1. Apply systematic screening procedure to the Ohio River Valley Carbon Dioxide Storage site for geologic storage of CO_2.



2. Identify potential performance and safety risk items.



3. Provide guidance on injection system design, monitoring program, reservoir simulations, and other risk assessment efforts.

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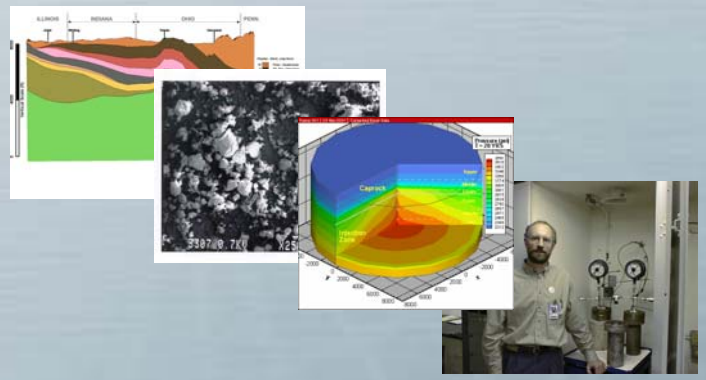
Mountaineer Project Background

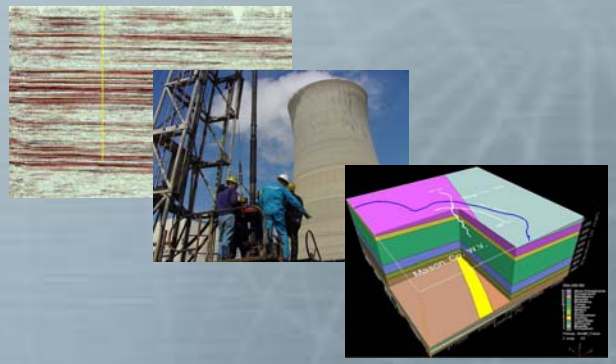
a.k.a. "Ohio River Valley CO_2 Storage Site"

Overall Objective- Provide an understanding of the viability of carbon sequestration as greenhouse gas reduction technology by performing an integrated demonstration of CCS in Ohio R. Valley.

- ✓ **Phase I- Regional capacity evaluation.**
- ✓ **Phase II- CO_2 injection modeling, economic & engineering assessment, geochemical experiments.**
- ✓ **Phase III- Test well drilling, seismic, reservoir testing, rock coring at Mountaineer Power Plant. Design and feasibility study.**

Potential Future Effort- Small-scale carbon capture and storage (CCS) at power plant, injection, storage monitoring.





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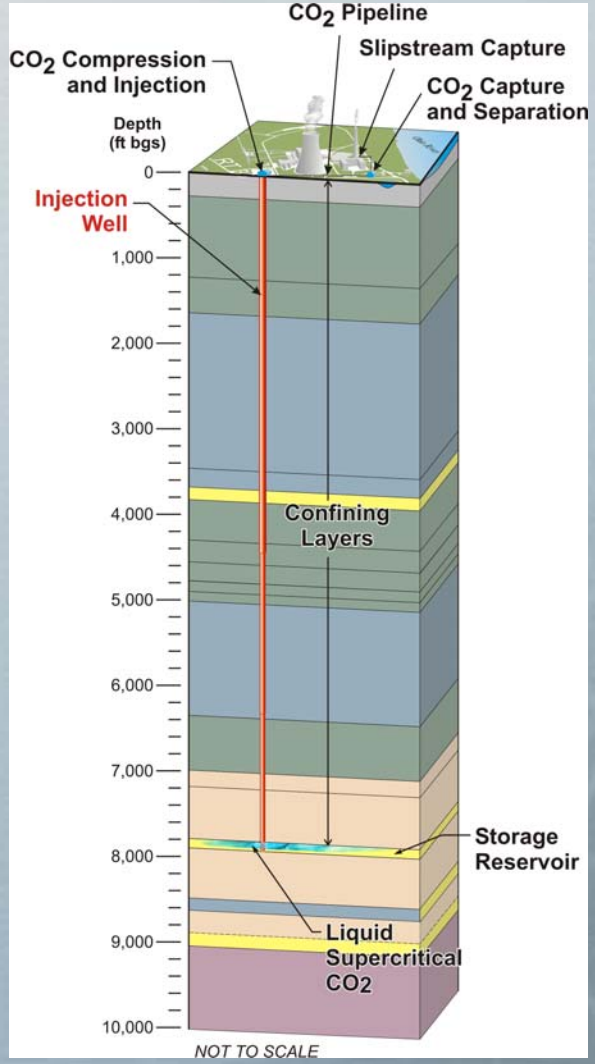
Mountaineer Project Potential Plans

- Develop pilot-scale integrated carbon capture and storage system.
- Capture and injection of <0.5% plant emissions into deep saline formation (rate depends on slipstream capture specs).
- Several years of continuous injection & monitoring.
- Entire system to be contained on plant site.



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Features, Events, and Processes (FEP) Database for Geologic Storage of CO_2

- "*Generic FEP Database for the Assessment of Long-Term Performance and Safety of the Geological Storage of CO_2*" **developed by Quintessa (Savage et al., 2004).**

- **Database includes possible features, events, and processes that should be considered in a storage project.** (Only addresses *geologic storage*, capture and transport are not included.)

- **This systems analysis approach has been used for several applications, most notably radioactive waste disposal. Used for CO_2 storage evaluation at Weyburn Project (Stenhouse, 2002).**

- **High level systematic analysis to focus quantitative risk analysis.**

Screening Methods

FEP Screening Methods for this Study-

A stepwise approach was utilized to identify the FEPs that should be considered for the Ohio River Valley CO_2 Storage Project:

1. **Compile site-specific conceptual model.**
2. **Level 1 screening for non-applicable/unlikely items.**
3. **Level 2 screening based on general site conditions or site characterization results.**
4. **Level 3 screening using site testing and/or system specifications.**
5. **Providing recommendations on addressing remaining FEPs into system design, monitoring, and analysis.**

Note- database for geologic storage only.
Capture and transport are not covered.

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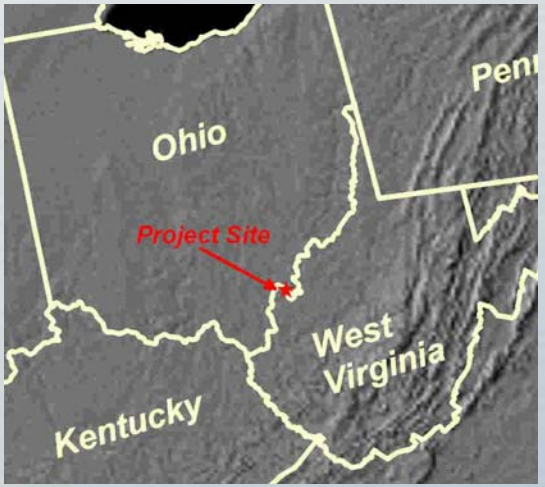
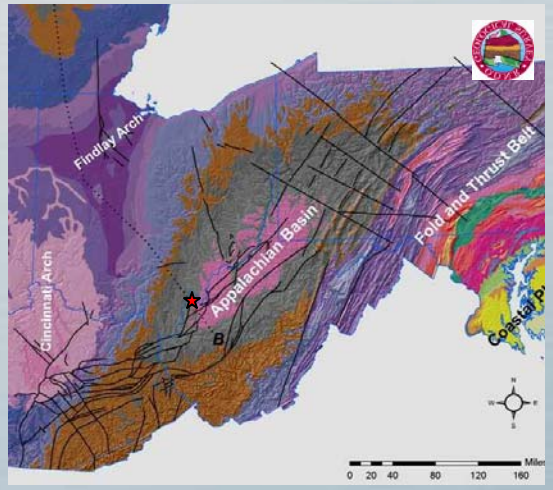
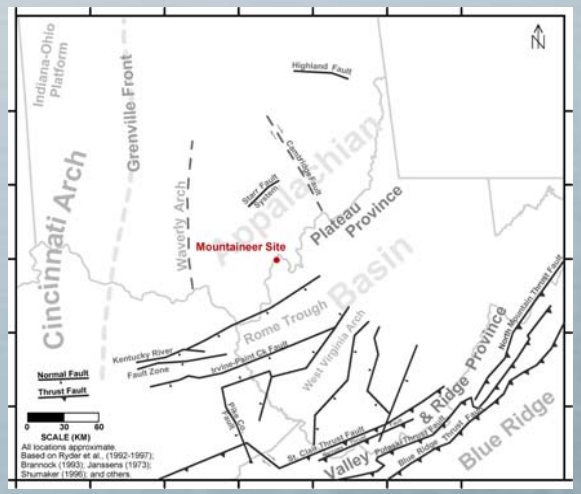
Conceptual Model-
Site Location / Environmental Setting

- New Haven, West Virginia
- 1300 MW AEP Mountaineer Power Plant







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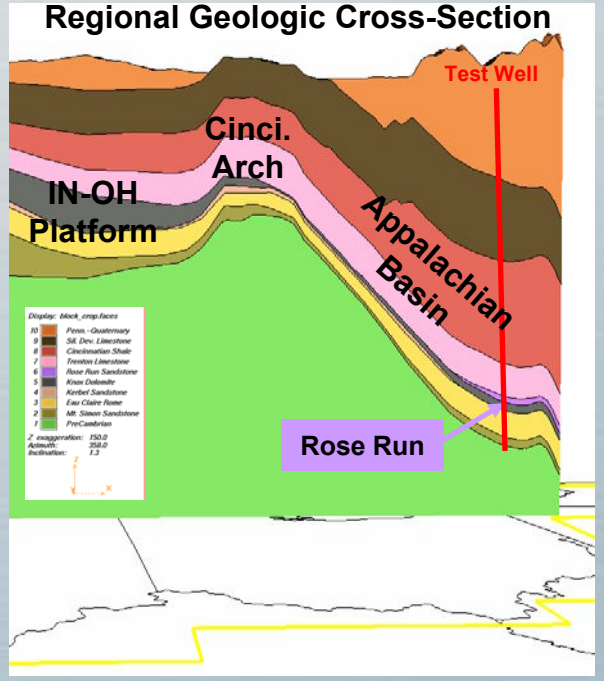
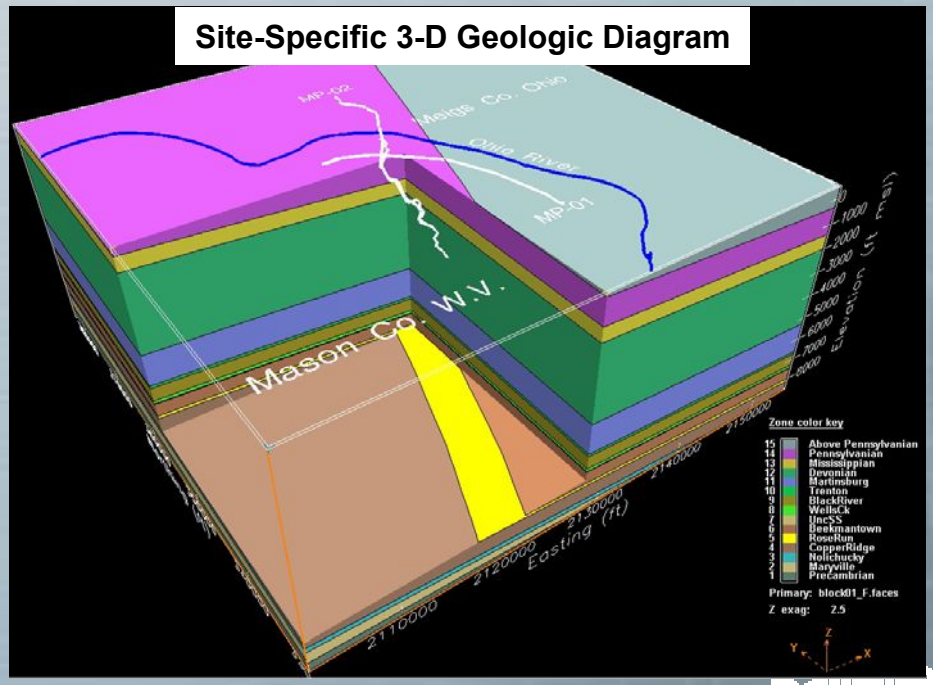
Conceptual Model- Geologic Setting

- Thick sequences of Paleozoic age sedimentary rocks
- Stable setting, no major faulting in survey area, little seismic activity.
- Target storage reservoirs = Rose Run Sandstone and Copper Ridge Dolomite. Mainly stratigraphic trapping mechanisms.
- Thick, extensive, and diverse series of containment units.





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FEP Screening Categories

(Savage et al., 2004)

Category	Class	Description	# Items
Assessment Basis	0	Assessment Basis	8
External Factors	1.1	Geological Factors	7
	1.2	Climatic Factors	8
	1.3	Future Human Actions	10
CO2 Storage	2.1	CO_2 Storage Pre-Closure	10
	2.2	CO_2 Storage Post-Closure	5
CO2 Properties, Interactions, and Transport	3.1	CO_2 Properties	3
	3.2	CO_2 Interactions	19
	3.3	CO_2 Transport	7
Geosphere	4.1	Geology	16
	4.2	Fluids	3
Boreholes	5.1	Drilling and Completion	5
	5.2	Borehole Seals and Abandonments	5
Near Surface Environment	6.1	Terrestrial Environment	8
	6.2	Marine Environment	5
	6.3	Human Behavior	6
Impacts	7.1	System Performance	1
	7.2	Impacts of Physical Environment	8
	7.3	Impacts on Flora and Fauna	5
	7.4	Impacts on Humans	4

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Example FEP Screening Items

- **Total of 143 items covering wide range of FEPs that could affect performance or safety of geologic storage.**
- **Everything from neotectonics to record-keeping.**

FEP Items- Examples

Description	Explanation
Drilling Activities	Events related to any type of drilling activity in the vicinity of the CO2 sequestration system. These may be taken with or without knowledge of the disposal and may include activities such as: - exploratory and/or exploitation drilling for natural resources; - attempted recovery of residual hydrocarbon resources; - drilling for water resources; - drilling for site characterization or research; - drilling for further disposal; and - drilling for hydrothermal resources.
Effects of Pressurization of reservoir on caprock	A storage reservoir will experience enhanced pressure due to injection of CO2. This may exceed original 'natural' pressurisation due to hydrocarbon emplacement, or clay mineral transformations during diagenesis.
Dissolution in formation fluids	The process of dissolution of CO2 in formation fluids. The rate of dissolution depends on factors such as the interfacial area between the CO2 and the formation fluids and temperature.

Savage et al., 2004

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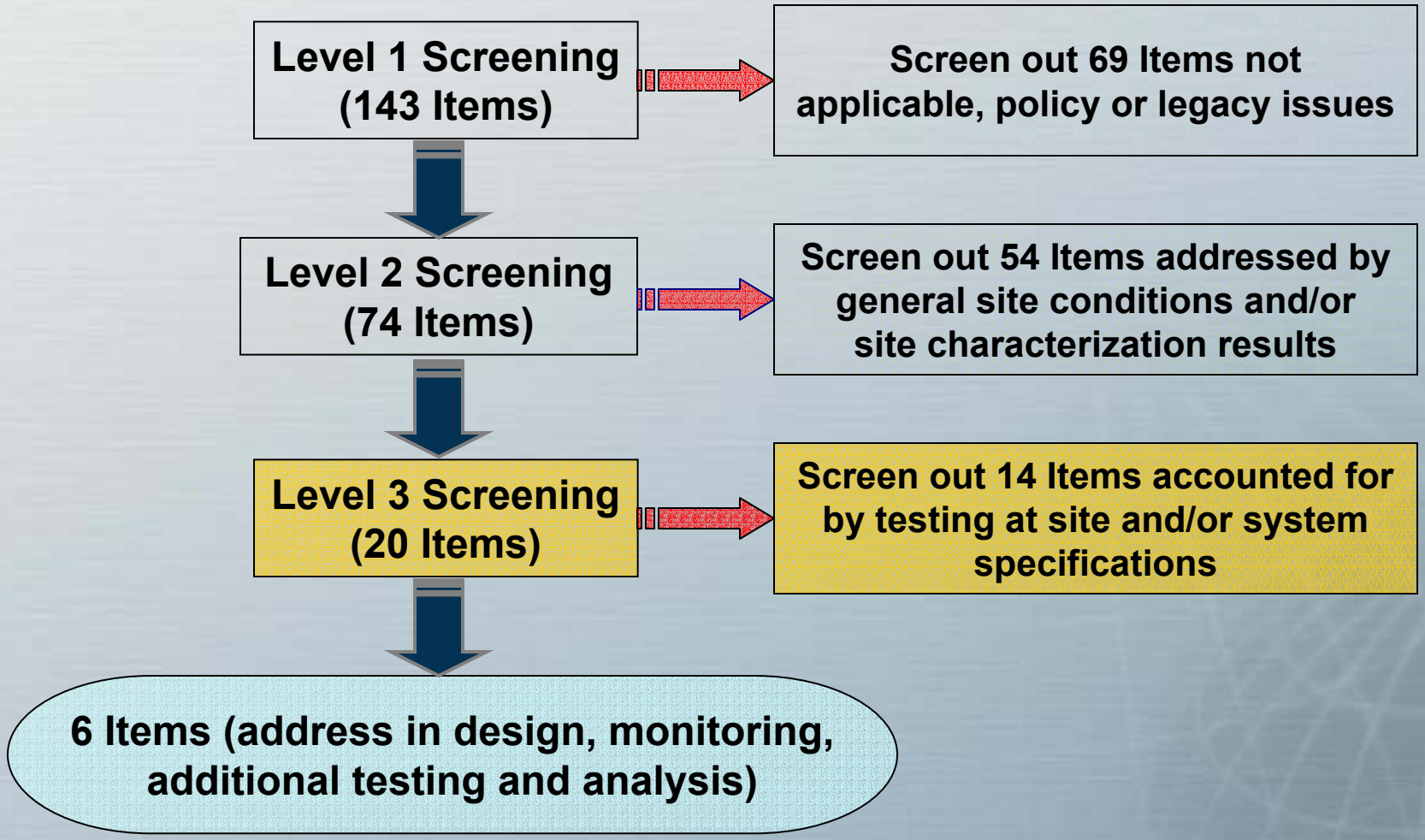
FEP Screening Process



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Example- Level 1 Screening

Screen out 69 Items not applicable, policy or legacy issues

- **Example- Marine features**
- **Response- Not applicable...not a marine setting.**

FEP#	Description	Explanation	Response
6.2.3	Marine Sediment	Features and processes associated with sediments in the marine environment. This includes both the physical and chemical characteristics of the sediments, along with sedimentation and resuspension processes.	Not applicable

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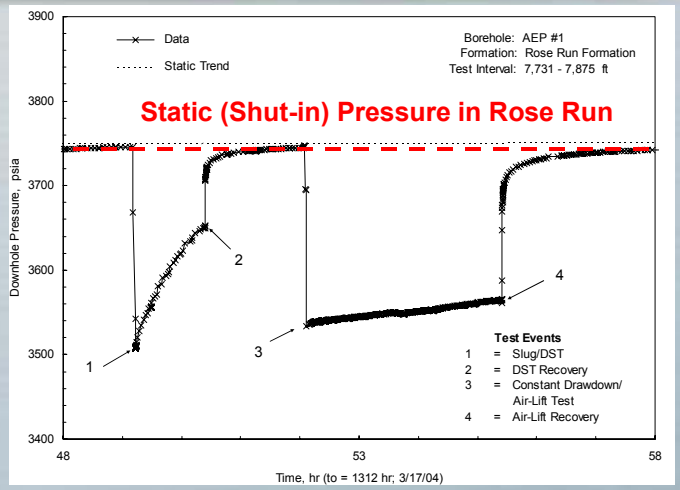
Example- Level 2 Screening

Screen out 54 Items addressed by site conditions or site characterization results

- **Example- Depth necessary to retain CO_2 at supercritical pressure?**

- **Response-**
  - **-Target reservoirs are more than 2,200 m deep.**
  - **-Reservoir testing shows pressures over 25 MPa (3700 psi) in storage intervals**



FEP#	Description	Explanation	Response
4.1.14	Formation Pressure	The pressure of fluids within the pores of a formation, normally hydrostatic pressure, or the pressure exerted by a column of water from the formations depth to the sea level prior to the injection of CO2. The critical pressure of CO2 is 7.38 mega-Pascals. The average underground hydrostatic pressure increases with depth by approximately 10.5 mega-Pascals per kilometre for aquifers that are in open communication with surface water. Applying this average gradient, the critical pressure of CO2 will be reached at a depth of around 690 metres. However, aquifers or hydrocarbon reservoirs that are sealed off from the rest of the sub-surface may be under- or overpressured. Savage et al., 2004	Storage reservoirs are over 2200 m deep, easily meeting the critical pressure of CO2.

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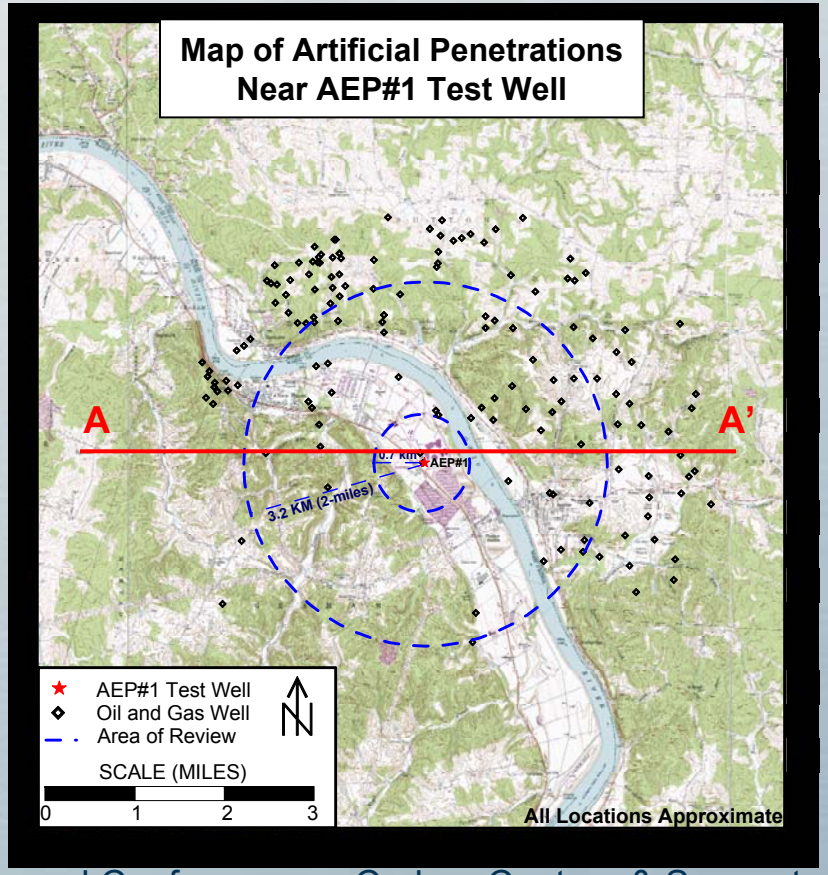
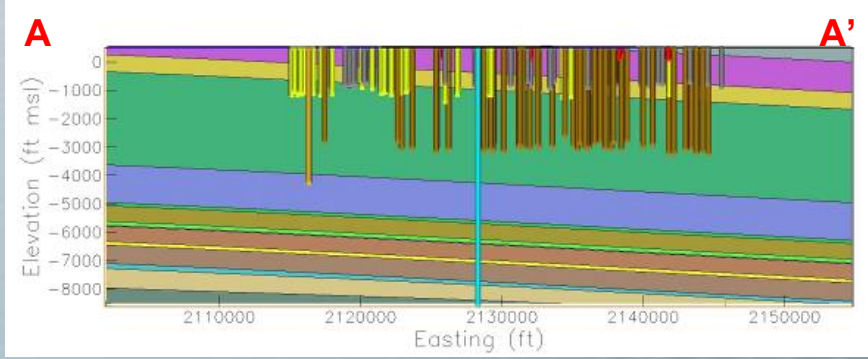
Example- Level 3 Screening

Screen out 14 Items accounted for by testing at site and/or general system specifications

- **Item= Existing Artificial Penetrations**
- **Response = Few deep wells nearby, mostly Devonian Shale gas wells less than 4,000 ft deep.**



Geologic cross section showing well depths near AEP#1 (in blue).



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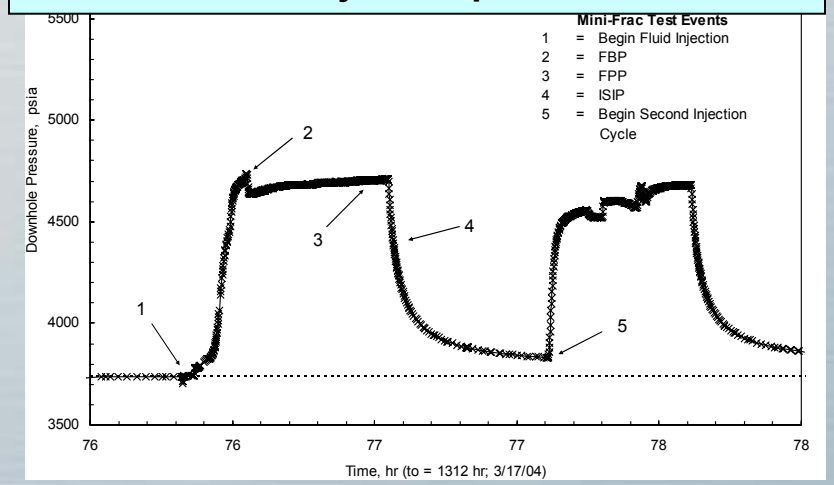
FEP Items Retained for Further Analysis

Category	FEP Item	Description	Response
CO_2 Storage	CO_2 Storage Pre-Closure	High injection rates and over pressuring may affect storage reservoirs and containment units	The injection pressure will be kept under fracture gradients (as determined from fracture testing of reservoir and caprocks). Modeling indicates that injection will not overpressurize the storage reservoir.
CO_2 Properties, Interactions, and Transport	CO_2 Properties	CO_2 solubility and aqueous speciation	Storage will not rely on CO_2 dissolution as most CO_2 is anticipated to remain as a supercritical liquid in place due to highly saline formation fluids. These processes have been addressed with geochemical analysis of brine samples from the well and equilibrium models that predict the effect of introducing CO_2 to the formation fluids.
	CO_2 Transport	-Advection of CO_2 due to injection -Buoyancy-driven flow/migration -Displacement of formation fluids	Movement of the injected CO_2 will be contained in the storage reservoirs as confirmed by injection modeling. The need for a separate monitoring well is being considered for the project, which would be able to monitor migration of injected fluid.
Geosphere	Geology	Reservoir geometry variations and heterogeneity	These features were accounted with stochastic injection simulations to see how they may affect storage over a range of potential conditions such as thickness, permeability variations, and layering.
Boreholes	Drilling and Completion	Durability of well casing and cements	Special cements and tubing are planned for the final well completion, and additional monitoring of the well materials will be built into the project. Injection well design will include interannulus fluid and a surface monitoring system that will automatically detect any damage to the well materials.
	Borehole Seals & Abandonments	Degradation of borehole materials used to abandon the injection well	Acid-resistant cement mixtures were used to complete the proposed injection well. System monitoring will be used to detect any degradation in well materials and well workover may be included to see if well materials altered during the project.

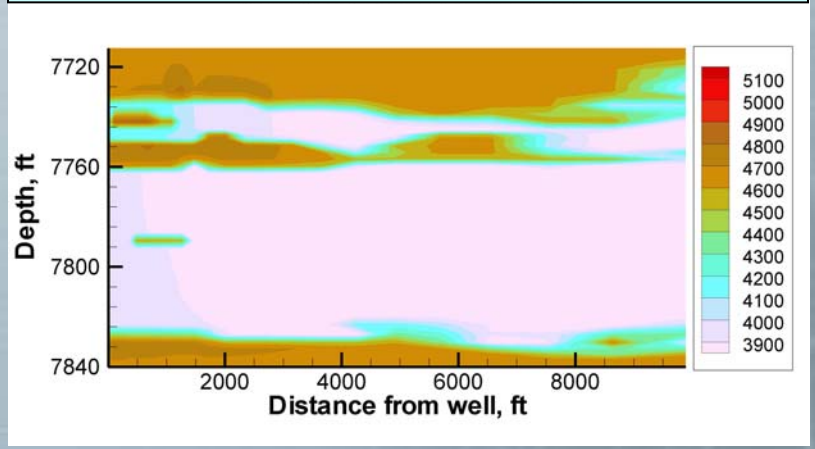
Results & Implications- Item 1

CO_2 Storage	CO_2 Storage Pre-Closure	High injection rates and over pressuring may affect storage reservoirs and containment units	The injection pressure will be kept under fracture gradients (as determined from fracture testing of reservoir and caprocks). Modeling indicates that injection will not overpressurize the storage reservoir.

Mini-fracture Tests in Rose Run Sandstone -Used to define injection pressure limits



Reservoir Simulations indicate Injection will not Cause Unacceptable Increase in Reservoir Pressure



Implications- Include automated (SCADA) monitoring system with injection well to track injection pressures.

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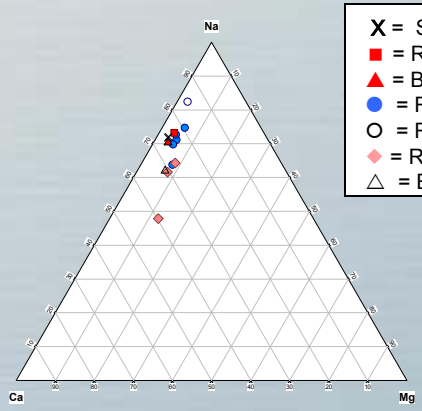
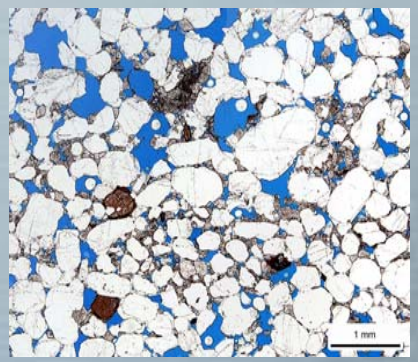
Results & Implications- Items 2&3

CO_2 Properties, Interactions, and Transport	CO_2 Properties	CO_2 solubility and aqueous speciation	Storage will not rely on CO_2 dissolution as most CO_2 is anticipated to remain as a supercritical liquid in place due to highly saline formation fluids. These processes have been addressed with geochemical analysis of brine samples from the well and equilibrium models that predict the effect of introducing CO_2 to the formation fluids.
	CO_2 Transport	-Advection of CO_2 due to injection -Buoyancy-driven flow/migration -Displacement of formation fluids	Movement of the injected CO_2 will be contained in the storage reservoirs as confirmed by injection modeling. The need for a separate monitoring well is being considered for the project, which would be able to monitor migration of injected fluid.



X = Swab sample, AEP #1
■ = Rose Run fm, AEP #1
▲ = Basal fm., AEP #1
● = Rose Run, Coshocton Co.
○ = Rose Run, Ashtabula Co.
◆ = Rose Run, Scioto Co.
△ = Basal fm., Scioto Co.

- **Brine Samples collected and analyzed during Reservoir testing to define reservoir conditions**



- **Detailed examination of pore space to define trapping mechanism**

Implications- Obtain samples from reservoir to see how injection CO_2 interacts with in-situ brines.

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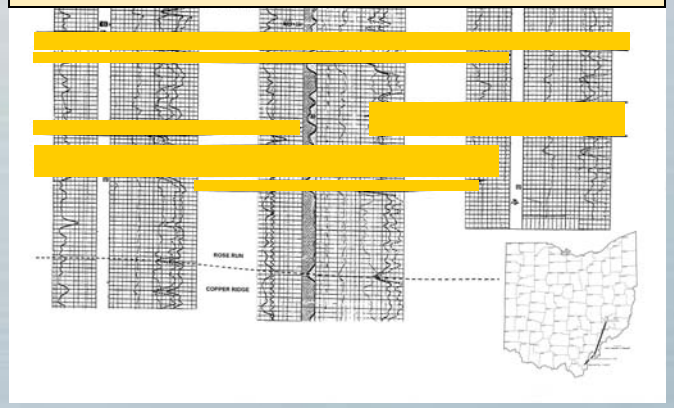
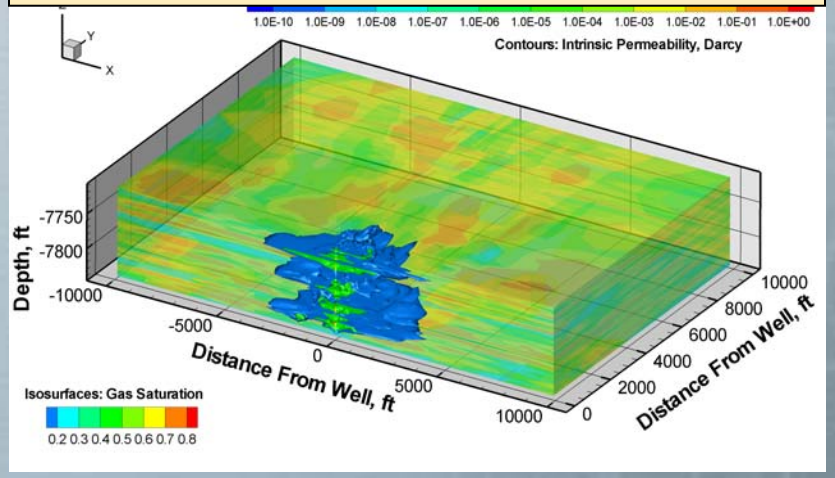
Results & Implications- Item 4

Geosphere	Geology	Reservoir geometry variations and heterogeneity	These features were accounted with stochastic injection simulations to see how they may affect storage over a range of potential conditions such as thickness, permeability variations, and layering.

CO_2 Exploration Wells Suggest Rose Run is a regional Unit, but some degree of heterogeneity is expected.



Reservoir Simulations incorporate reservoir variability.



Implications- Assess CO_2 movement in target reservoir with monitoring program.

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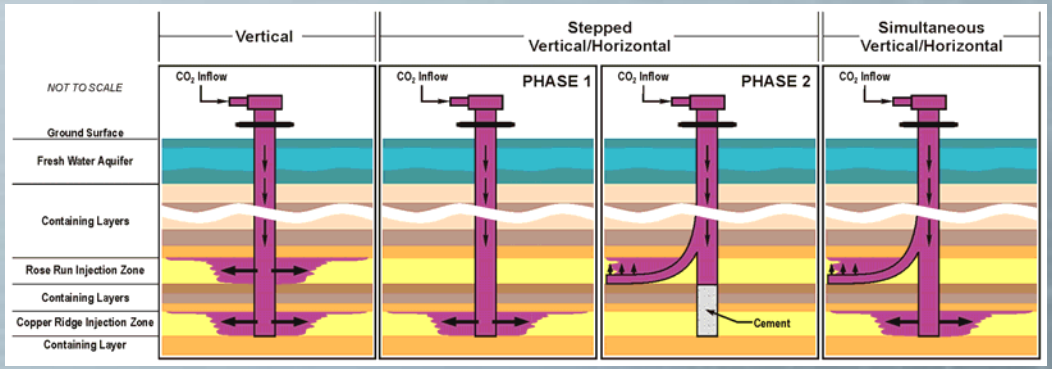
Result and Implications- Items 5&6

Boreholes	Drilling and Completion	Durability of well casing and cements	Special cements and tubing are planned for the final well completion, and additional monitoring of the well materials will be built into the project. Injection well design will include interannulus fluid and a surface monitoring system that will automatically detect any damage to the well materials.
	Borehole Seals & Abandonments	Degradation of borehole materials used to abandon the injection well	Acid-resistant cement mixtures were used to complete the proposed injection well. System monitoring will be used to detect any degradation in well materials and well workover may be included to see if well materials altered during the project.

Well design to incorporate resistant materials and capability to test some well materials.



Implications- Monitor well integrity, utilize acid-resistant cement, and other material for well completion.

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Conclusions

- *FEP Database Applications*- The "Generic FEP Database for the Assessment of Long-Term Performance and Safety of the Geological Storage of CO_2" is a useful tool for evaluating a site specific CO_2 storage project.
- *Systematic Approach*- Database is an exhaustive list of features, events, and processes that could affect a project. The systematic analysis reduces chances of omitting items which could affect a project.
- *Ohio River Valley CO_2 Storage Project*- It was discovered that the database aided in focusing remaining system design, monitoring, additional risk analysis, and storage application efforts.

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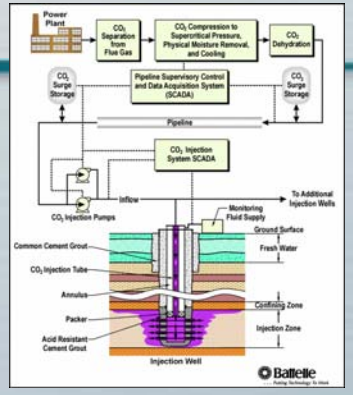
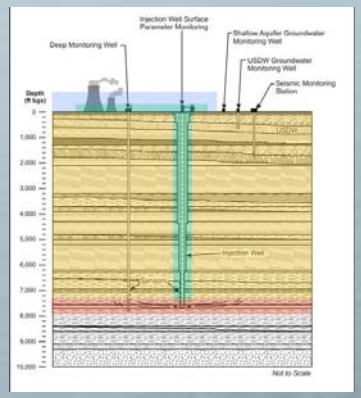
Path Forward

- Integrate FEP results into design and feasibility activities.
- Incorporate FEP suggestions into well completion, monitoring, and injection system construction work.
- Evaluate system performance in relation to items identified in the screening process.





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The End

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