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Geologic Storage of CO_2 – Research Status and Trends in Midwestern USA

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NETL

U.S. Department of Energy/NETL

Battelle's operation of major energy labs provides insights into energy challenges

Pacific Northwest

Idaho

Columbus

Brookhaven

Lawrence Livermore

NBACC

Oak Ridge

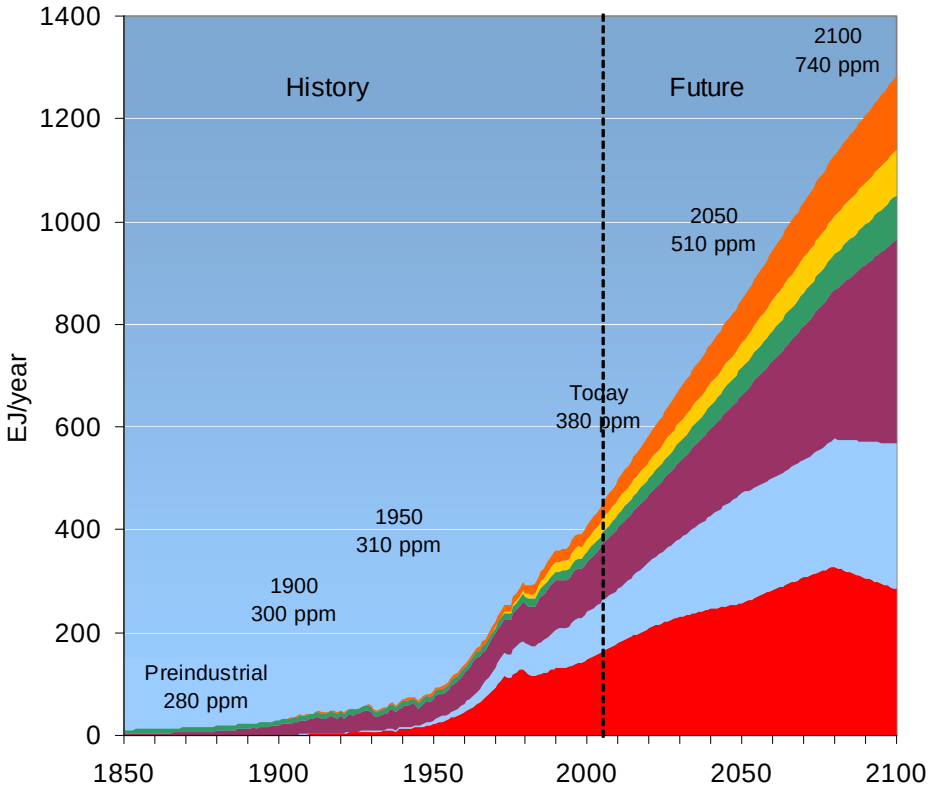
National Renewable Energy Lab

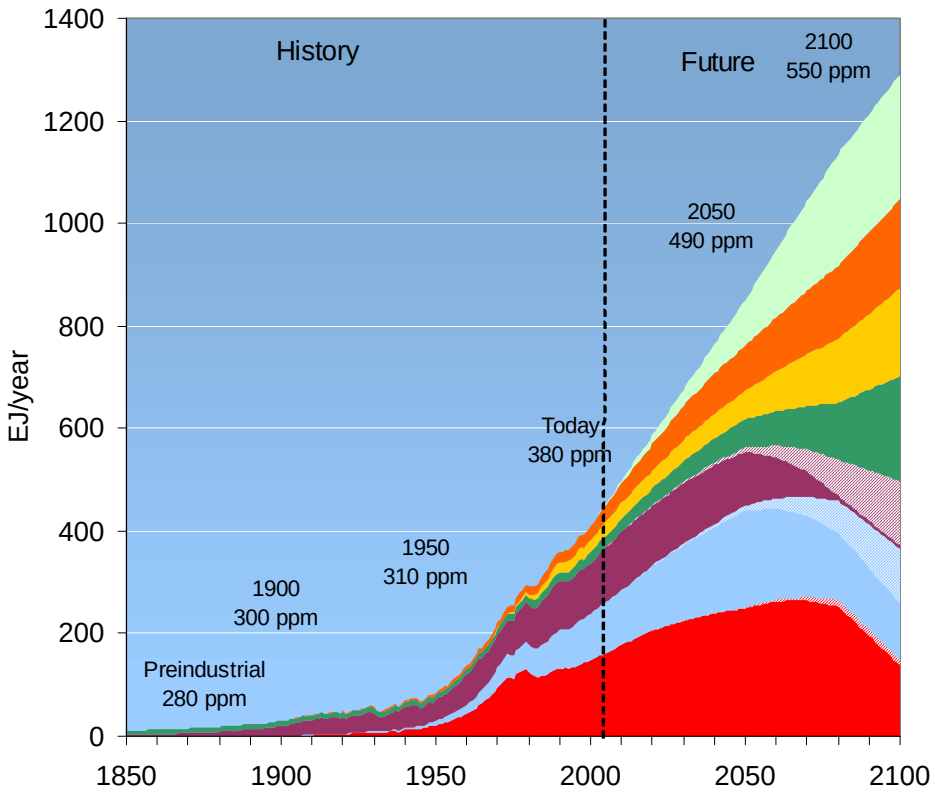
BEST Center

$4.0 billion R&D volume
20,000 staff
31 scientific user facilities

Stabilization of CO_2 concentrations means fundamental change to the global energy system

GTSP Program





Historical Perspective for Midwest

- National CCS program is now over 10 years old
- Midwestern US has been a key area of evaluation under DOE and industry initiatives:
  - Started with small paper studies – literature reviews, modeling data from UIC wells, laboratory experiments
  - MIDCARB project – precursor to partnerships
  - AEP Mountaineer site assessment
  - MRCSP and MGSP Phases I, II, and III
  - FutureGen siting process (**IL**, KY, OH, WV)
  - Ohio and KY state efforts
  - Regional characterization, organic shales, ECBM studies
  - Capture studies, IGCC, oxy-fuel combustion etc.

Ongoing Initiatives – Progressing to Field Implementation and Deployment

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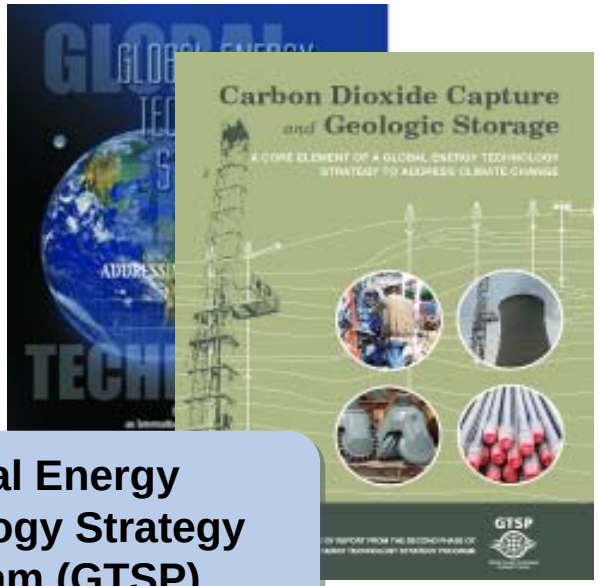
Mountaineer

Regional Reservoir Characterization "Piggyback Drilling"

Regional Partnerships

MRCSP
MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

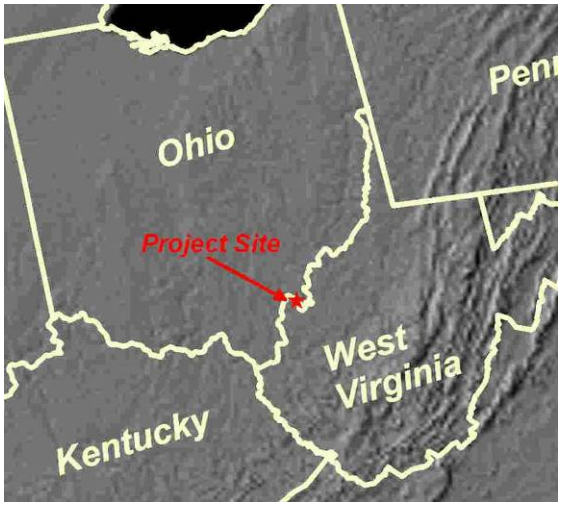
FutureGen Alliance



Global Energy Technology Strategy Program (GTSP)

AEP – Mountaineer Project – Site Assessment to Deployment?

- 1300 MW pulverized coal plant with NOx and SOx control
- An area of intense power production and future expansion
- AEP has announced a major scale-up and a multi-pronged CCS deployment at this and other sites.



Site-Specific Characterization

Essential for Safe and Effective Operations

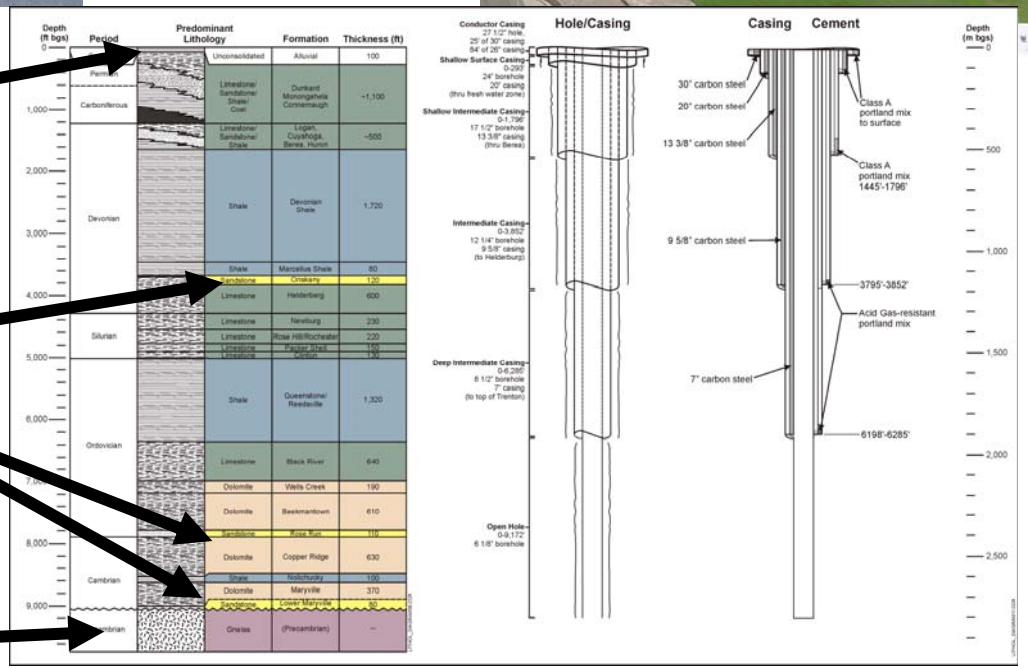
Seismic Survey

Drilling Test Well

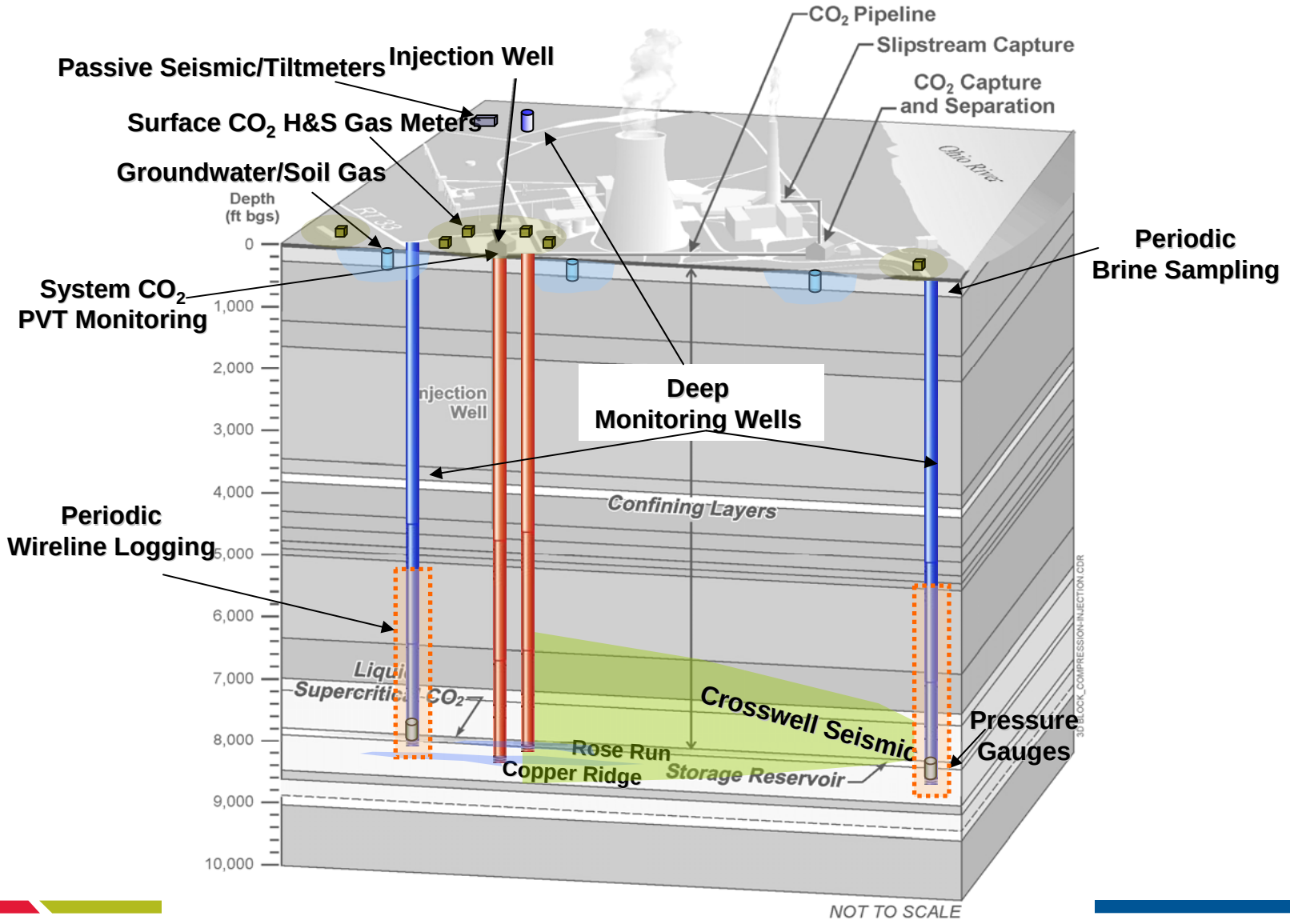
Ground level

Possible storage formations > 2,500 ft deep

9,000 feet below the surface



Mountaineer Storage and Monitoring System Design



Piggy Back Program - Leveraging the Oil & Gas Exploration Industry

- Team up with oil and gas industry to collect data
- DOE gets access to existing drilling operations – saves significant cost (counts as cost share)
- Oil and gas operators get detailed wireline logs
- Data go back to build regional understanding of geology and improved capacity assessment

9000 ft deep stratigraphic test well in Tuscarawas County Ohio

MRCSP's mission: be the premier resource for sequestration knowledge in its region

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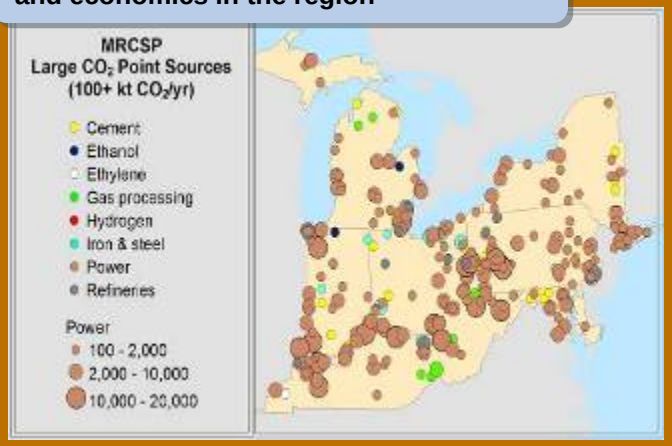
Characterization, Phase I, 2003 - 2005

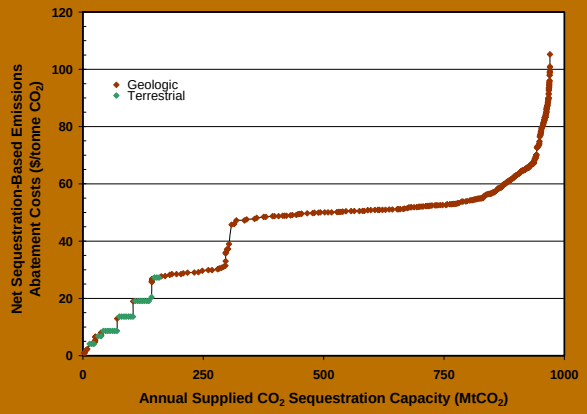
Quantifying CO2 sources, demographics and economics in the region



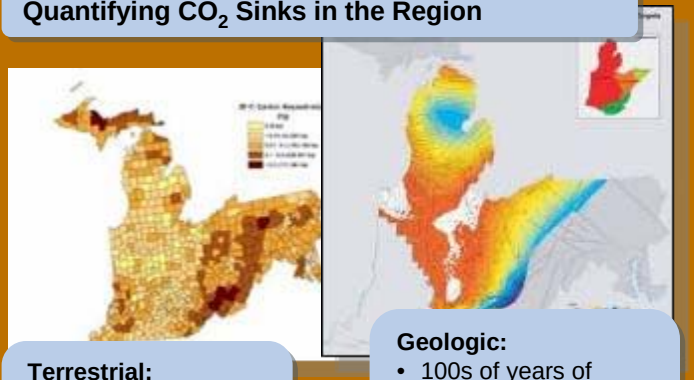
Reaching Out To and Educating Stakeholders

www.mrcsp.org

Developing a Regional Model of the Economics of Sequestration



Quantifying CO_2 Sinks in the Region



Terrestrial:
- Potential for 20% annual offset for large point sources

Geologic:
- 100s of years of capacity for large point sources in deep saline alone

Validation, Phase II, 2005 - 2009

Implementation

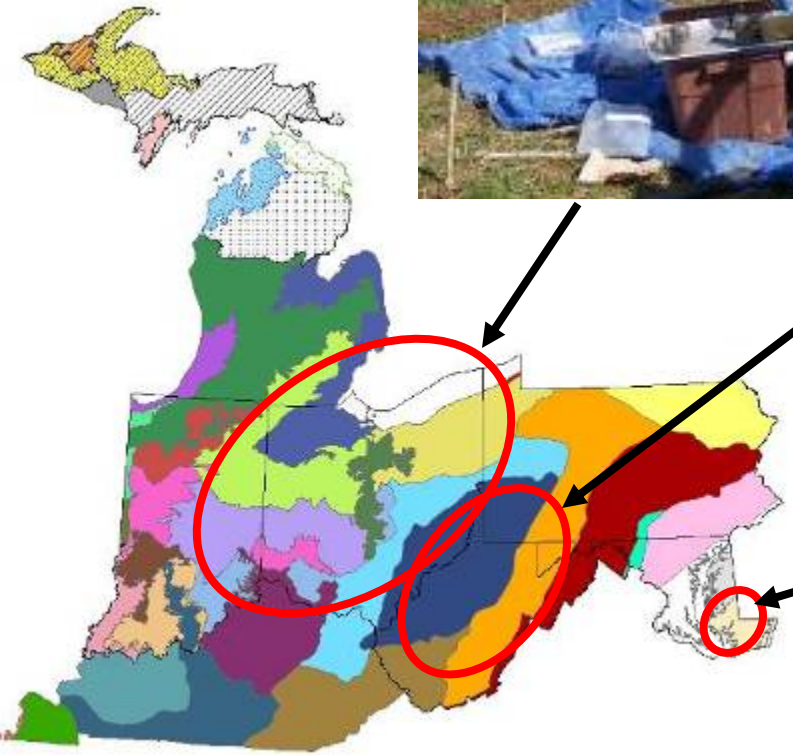
Geological

Terrestrial

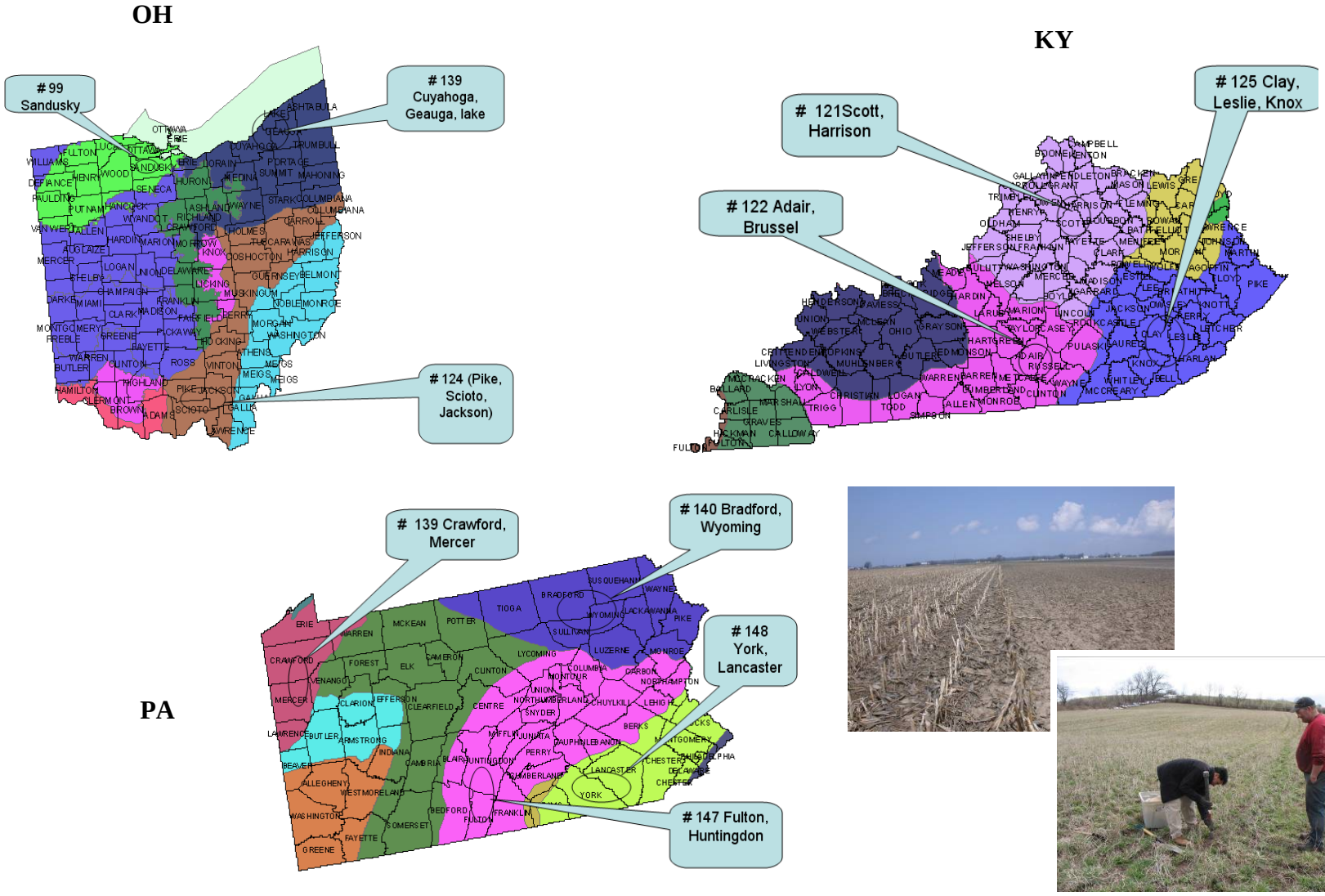
MRCSP membership

U.S. Department of Energy/NETL

Terrestrial Sequestration – Three field projects being pursued



Croplands test sites (Ohio State Univ.)



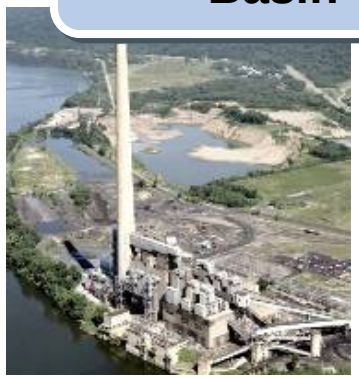
MRCSP Phase II Geologic Tests

Michigan Basin

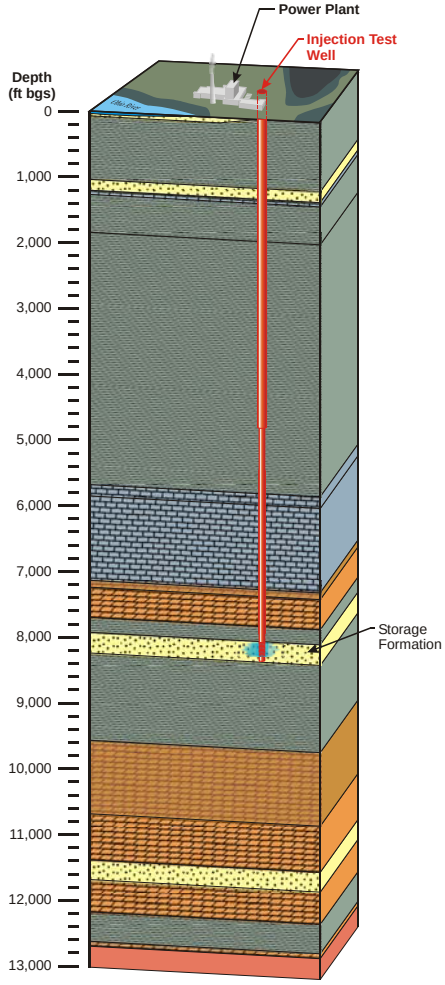
Ohio Strat Well

Cincinnati Arch

Appalachian Basin



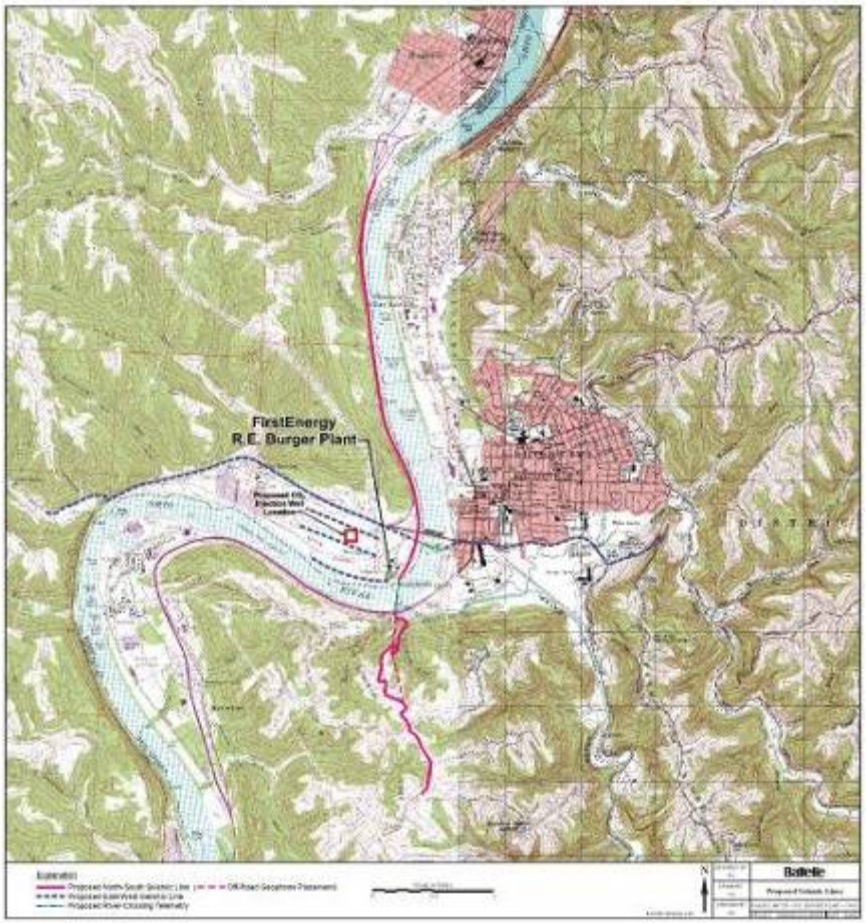
RE Burger Power Plant (FirstEnergy)

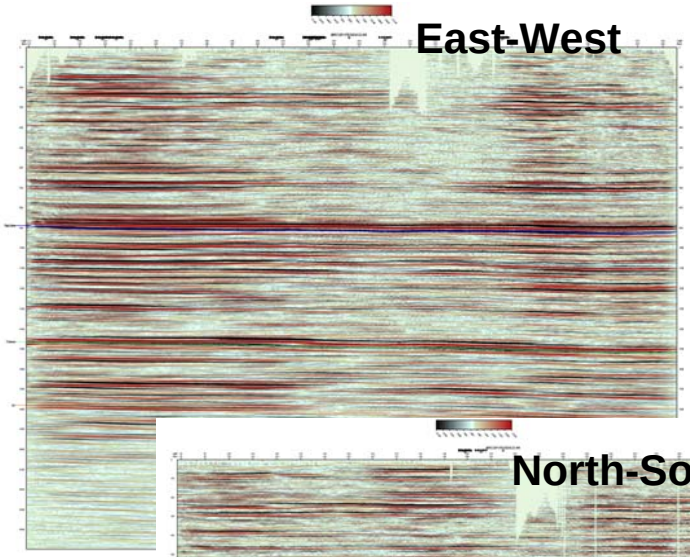


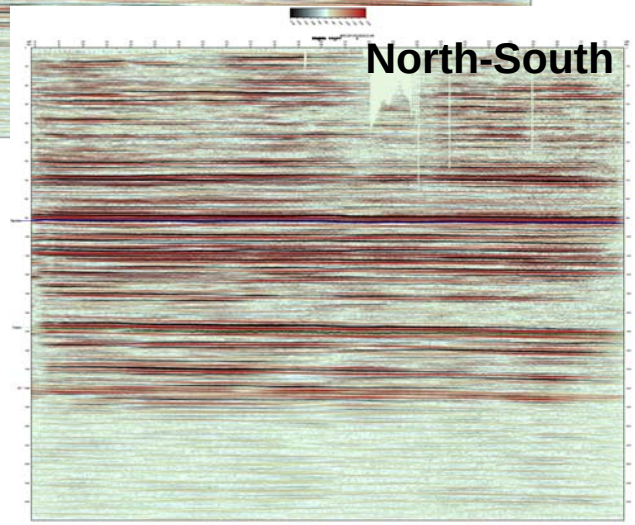
8000 Foot Test Well

Site Characterization - Example for R.E. Burger Plant

- 10-mile seismic survey completed in August 2006
- Additional 1-mile of “quasi-3D” to investigate reservoirs and 3D options

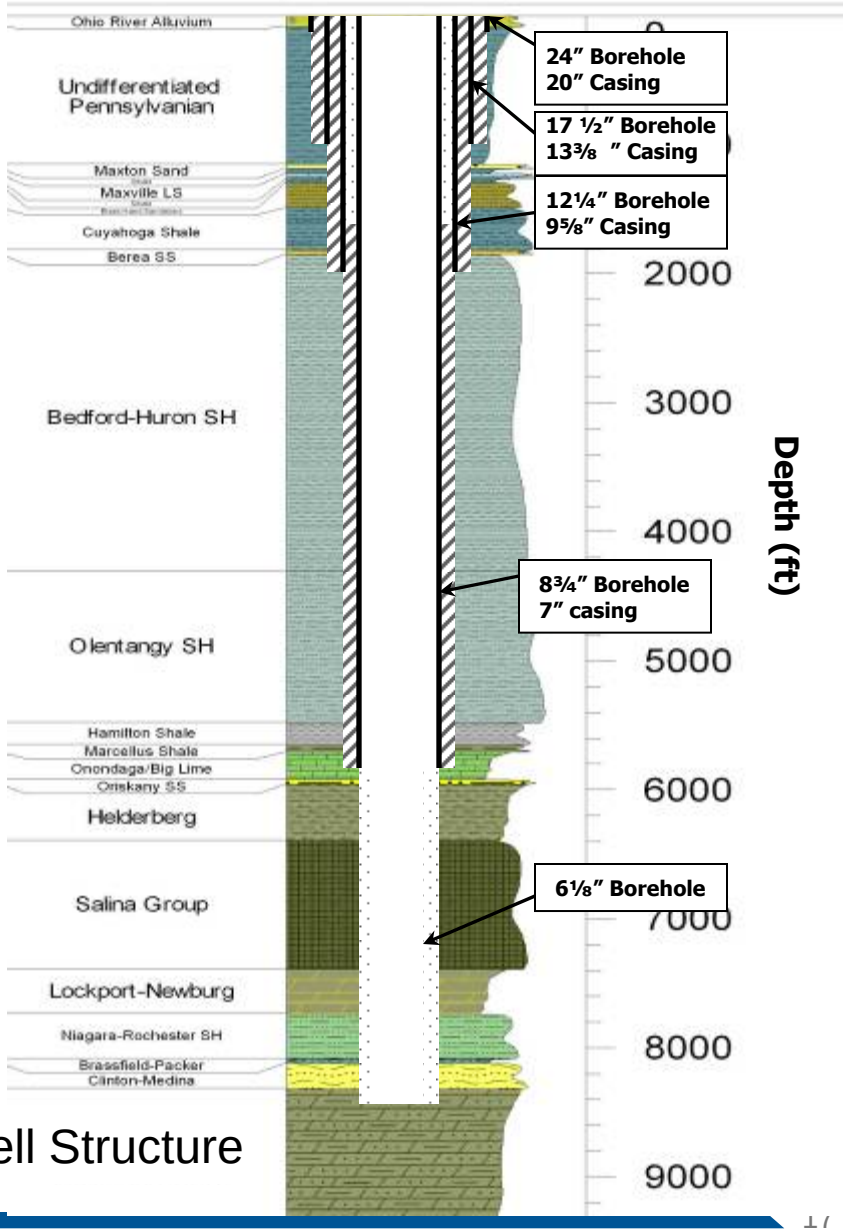






Site Infrastructure, Burger

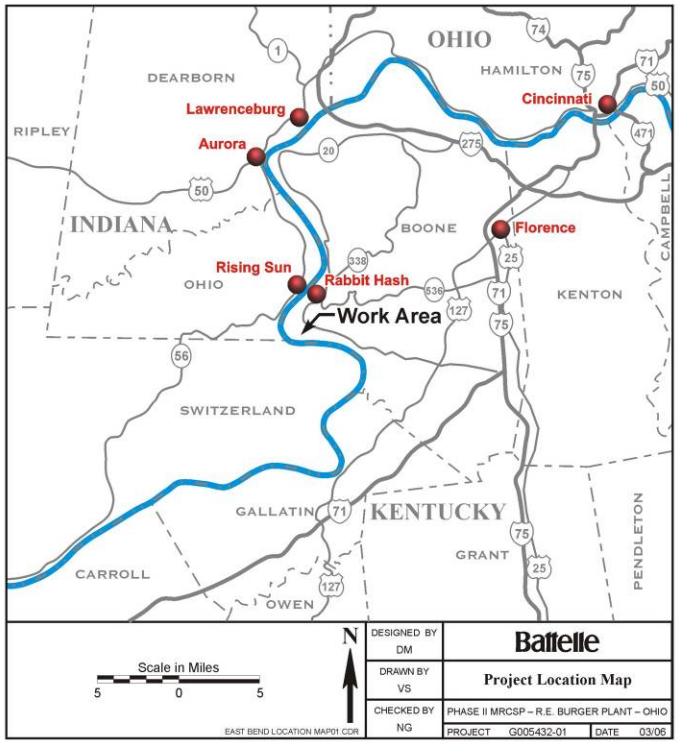
Photos Courtesy of Praxair and BOC

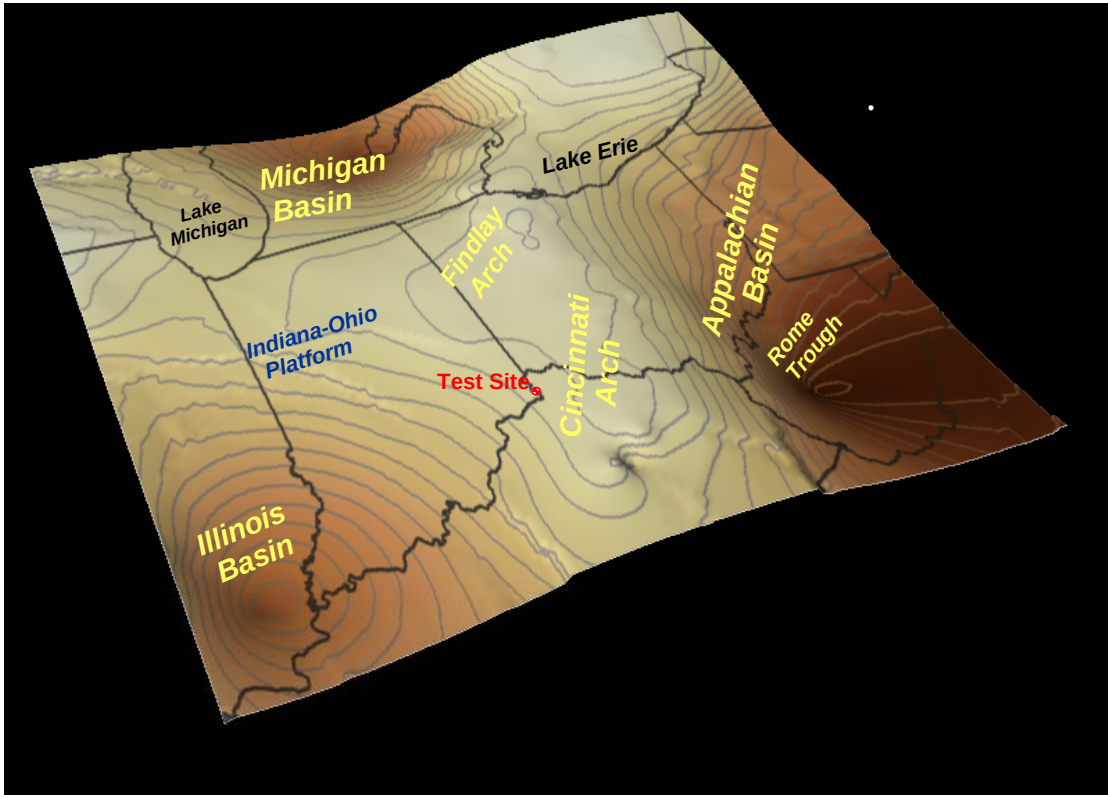


Well Structure

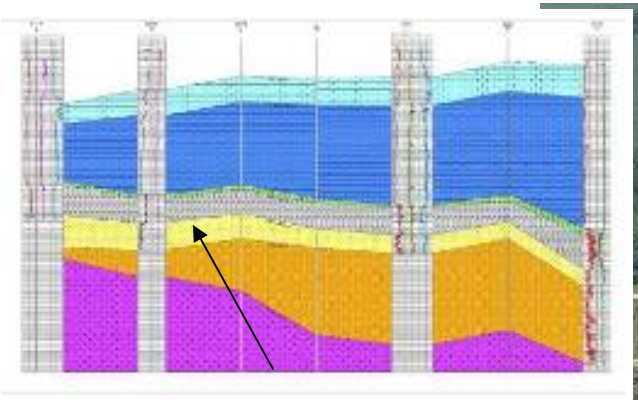
East Bend Test Site

- Duke Energy East Bend Plant outside of Rabbit Hash, Kentucky, 20 miles southwest of Cincinnati
- Located on the western flank of the Cincinnati Arch, a regional geologic structure between the Appalachian and Illinois basins.



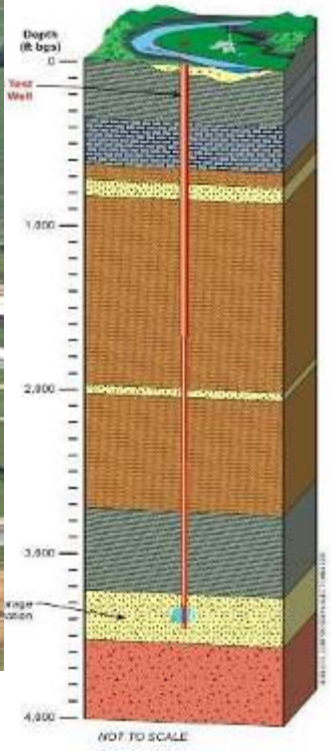


East Bend Station (Duke Energy)



Injection Target,
Mt. Simon Formation

East Bend Station



Test Well Design

Seismic Survey
October, 2006

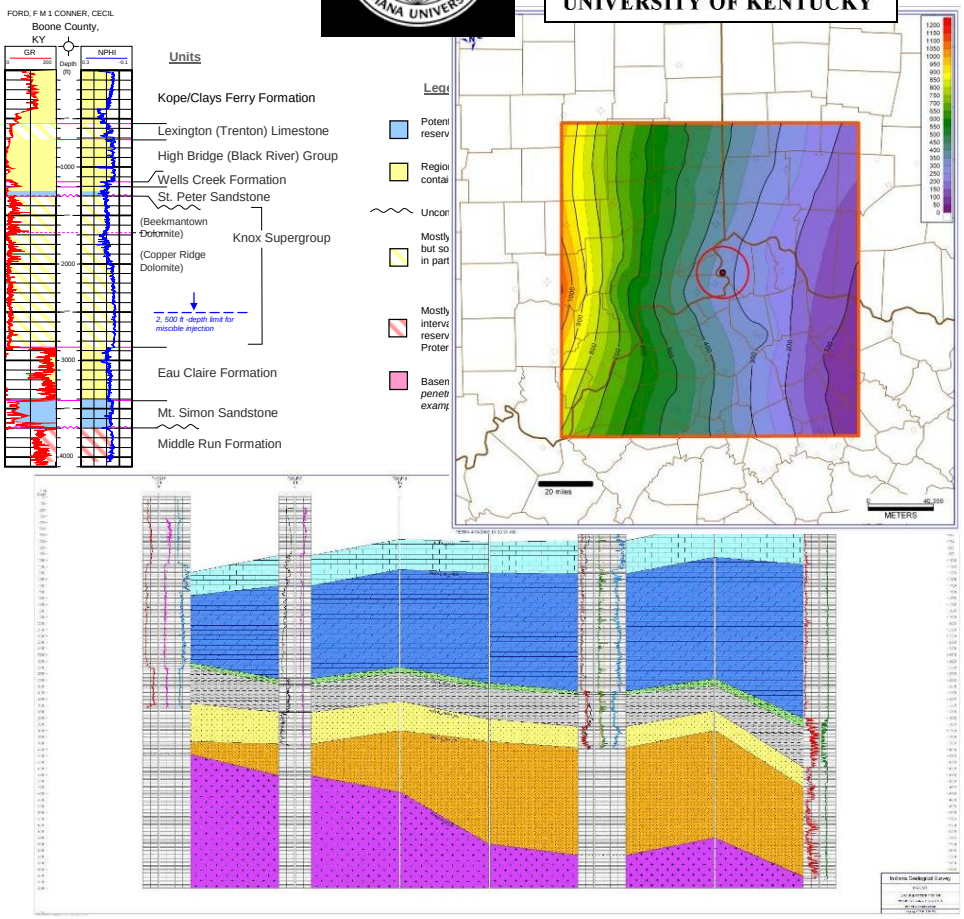
Site Characterization- Preliminary Geologic Assessment

- Preliminary geological assessment completed by Indiana and Kentucky Geological Surveys

- Paleozoic age sedimentary rocks ~3500 ft deep and overlie Precambrian arenite Middle Run Formation.

- Primary injection target is the Mt. Simon estimated at a depth of 3200-3500 ft.

- This formation is a major CO_2 storage target throughout the MRCSP region.

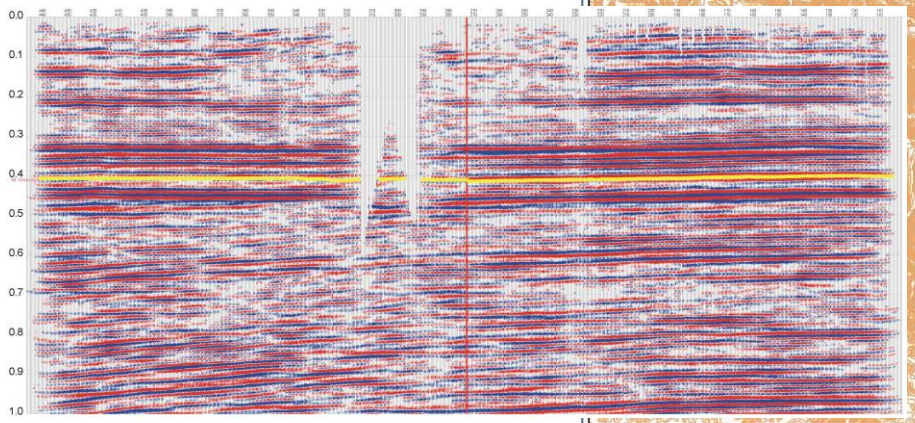


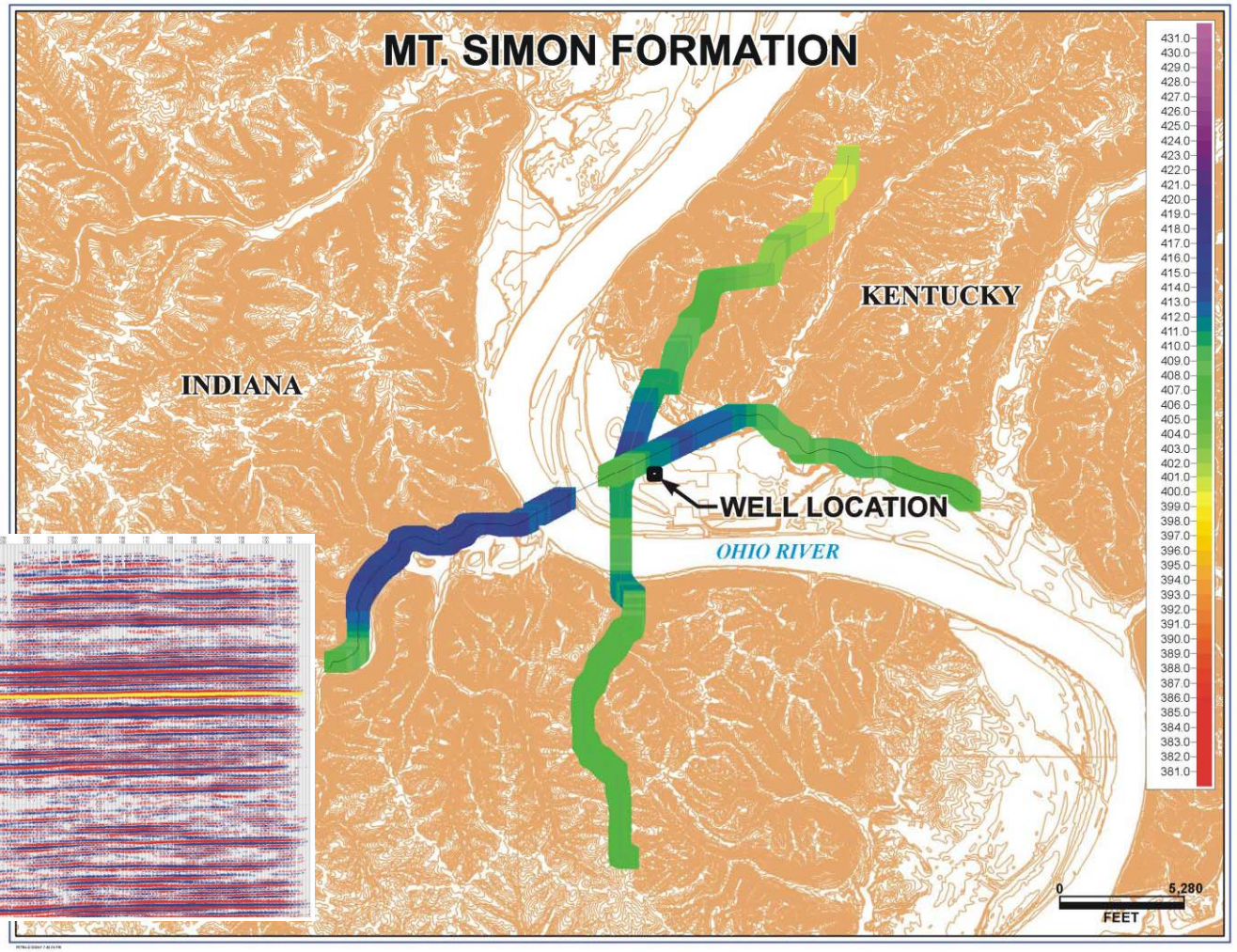
East Bend Test Site- Public Outreach

- Summer 2006:
  - Coordinated with Duke Energy in planning interactions and developing a series of informational materials to introduce project and describe future seismic and other activities (neighbor letter, fact sheet, briefings)
  - At request of local officials, conducted a briefing for local officials and Open House for nearby residents, including a series of exhibits, seismic video and take-home materials, as well as opportunities for one-on-one discussions with technical staff
- Now preparing additional materials and planning for an informational meeting to be held prior to publication of the Notice of Availability of the draft permit for public review by EPA Region 4

Site Characterization- Seismic Analysis of Mt. Simon SS

- 10-mile survey in 2006
- There is a gentle deepening to the north west.
- No indication of any structure through the formation

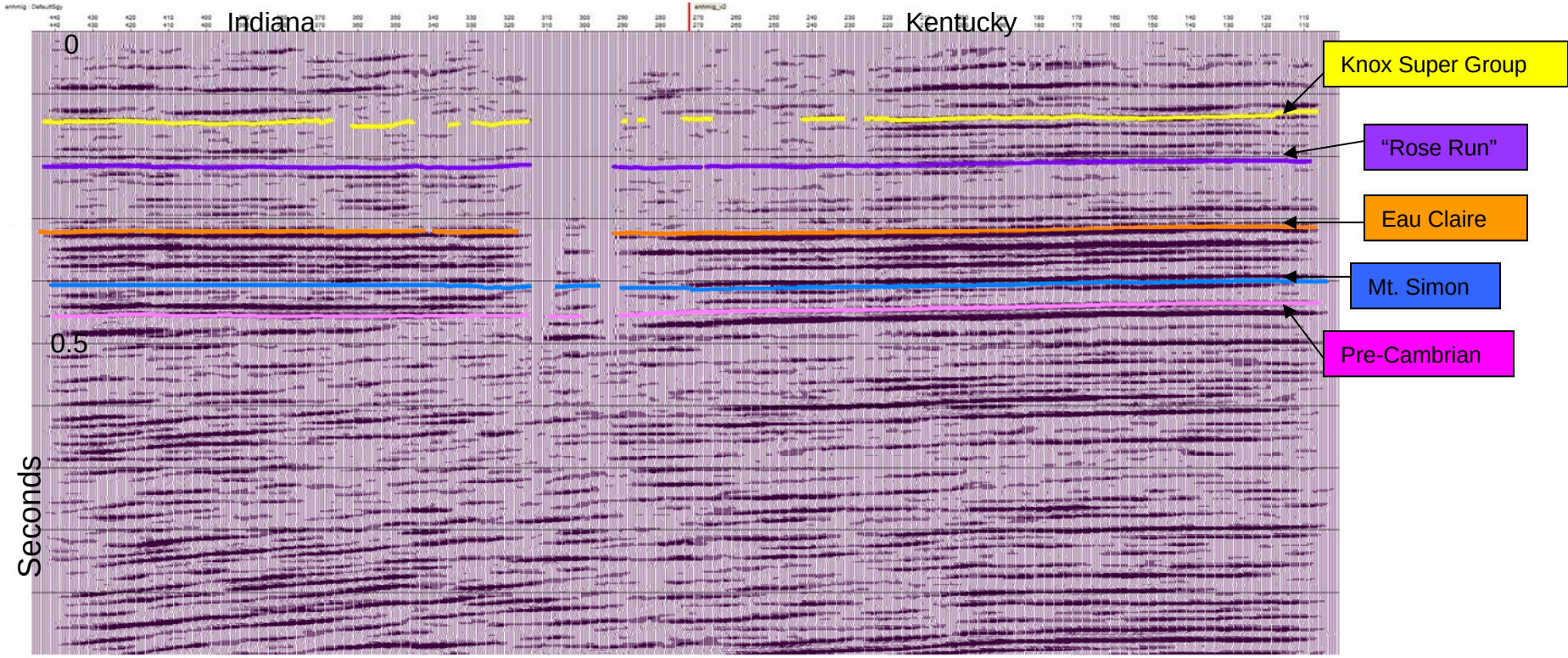




Color represents travel time ranging from red (shorter) to purple (longer)

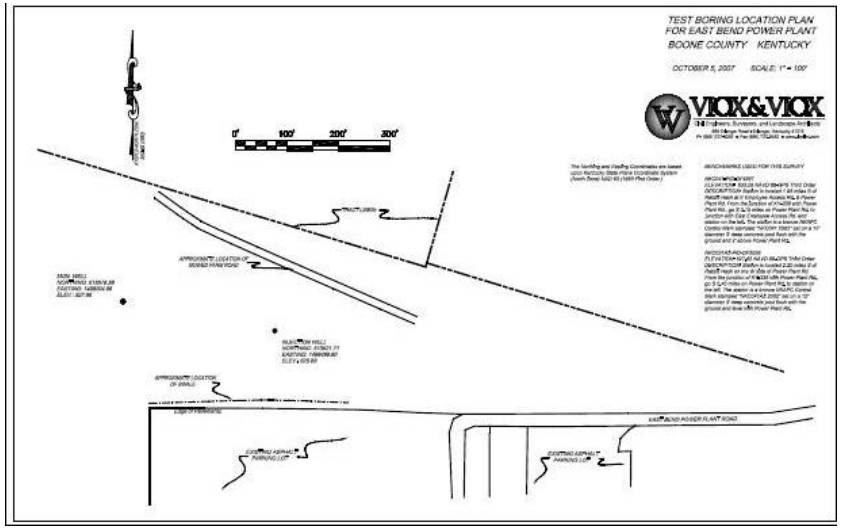
Site Characterization- East Bend Seismic Section (S→N)

- A tighter bin size (55 ft) may have increased data quality in the flood plain
- Interpretation will need to be validated after drilling
- Numerous processing schemes were used to verify formation structure

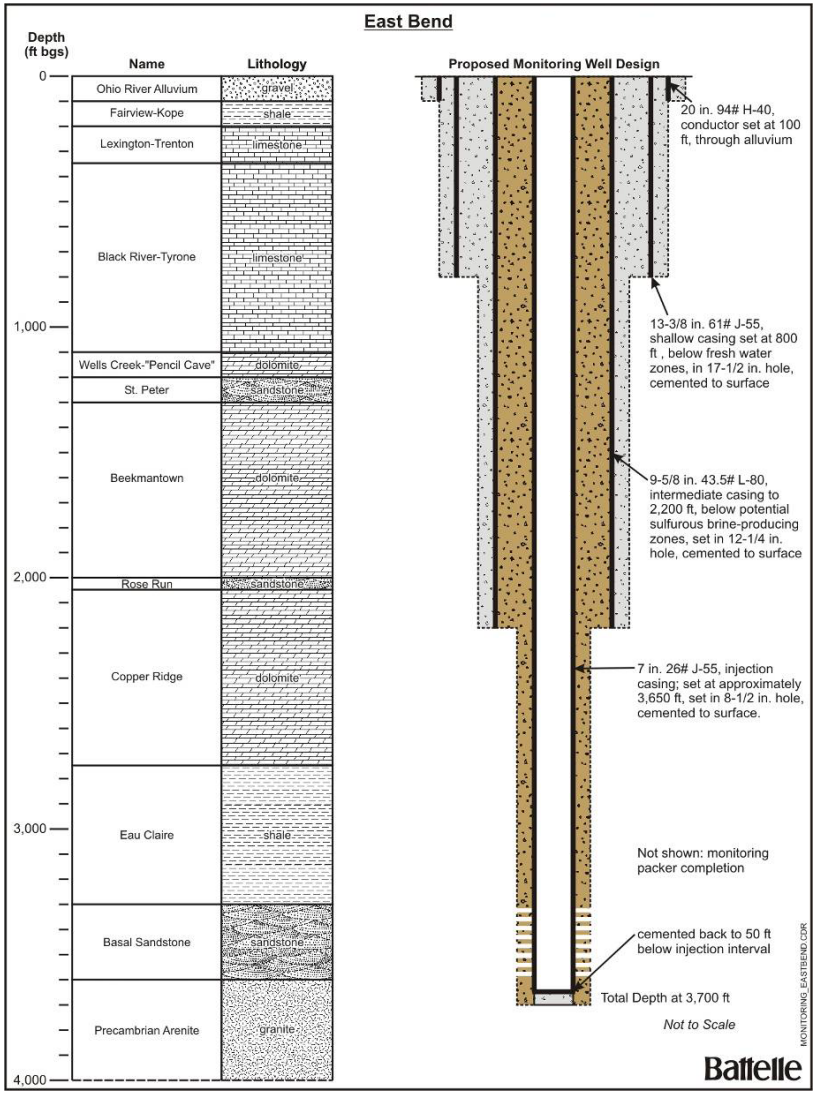


Site Characterization- Test Well Drilling and Testing

- Injection site at the East Bend Plant has been finalized and surveyed.
- Test well design and procurement has been mainly completed.
- Drilling at the East Bend site is scheduled for early summer 2008.
- A nearby monitoring well is being considered with multi-level Westbay monitoring system.



Injection System Design

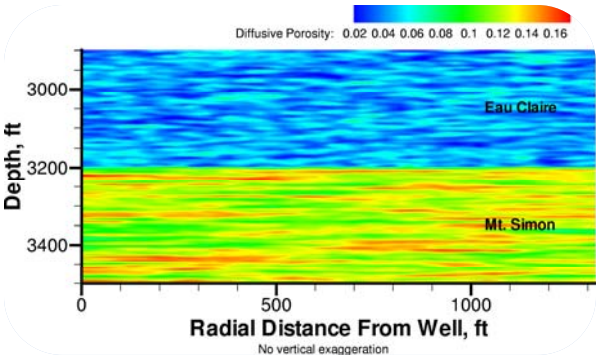


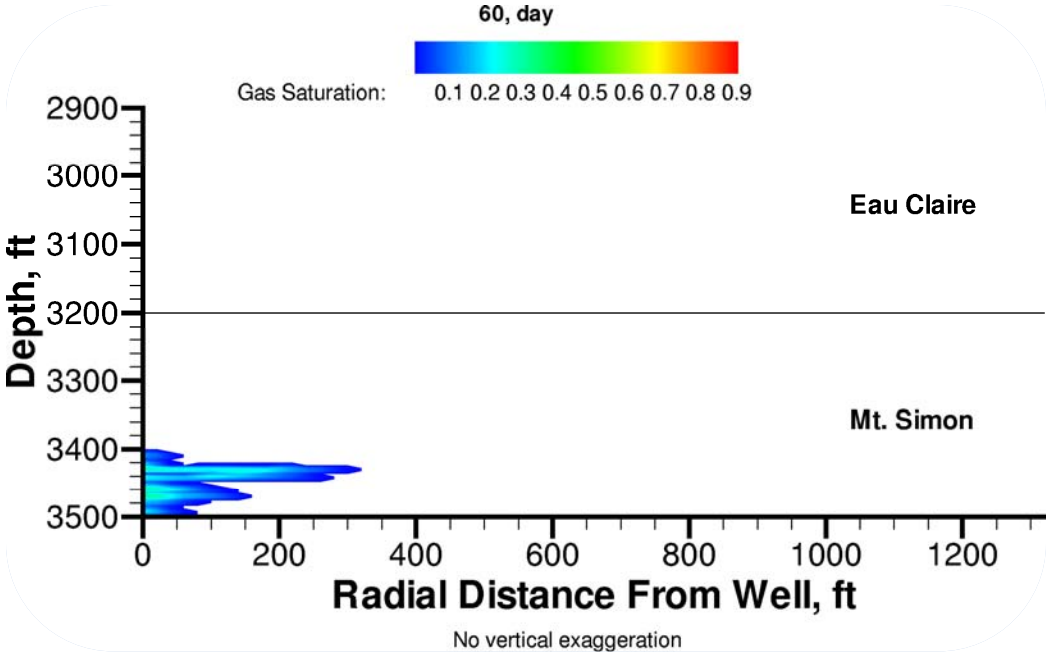
Developing Preliminary Conceptual Models

- Conceptual models are being developed based on regional data on the Mt. Simon Sandstone and Eau Claire

- These models will be used to provide guidance on MMV and permitting items.

- Models will be updated with site specific data once test well has been drilled.

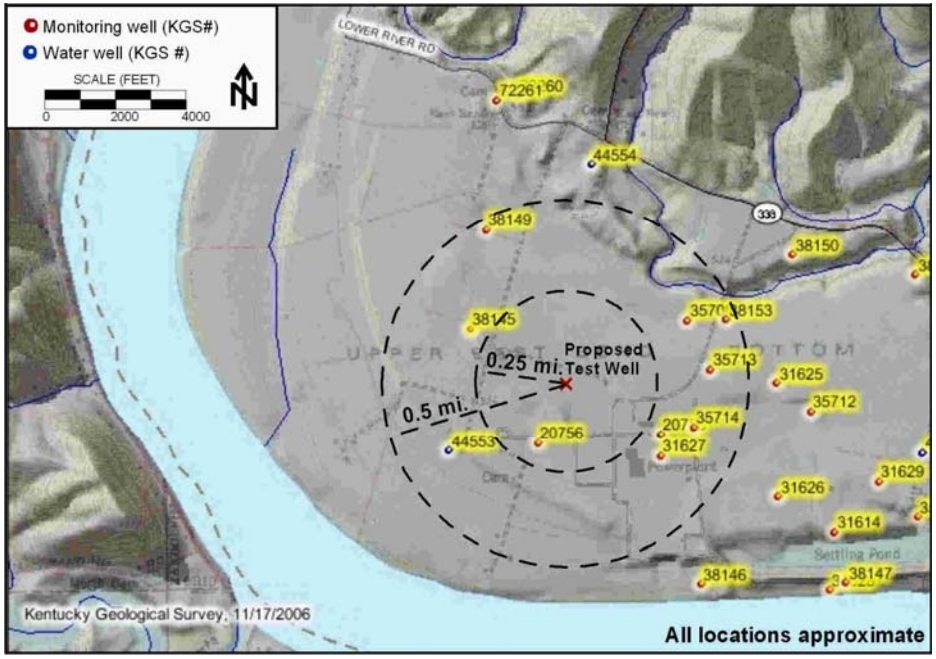




Regulatory Track

- Pursuing UIC Class V injection permit under Region 4 EPA UIC program out of Atlanta (also working with Kentucky EPPC DNR Div. of Oil and Gas Conservation)
- Several meetings/calls have been held with Region 4 EPA, Duke Energy to discuss project schedule and objectives
- Class V injection permit application is in preparation prior to drilling test well.

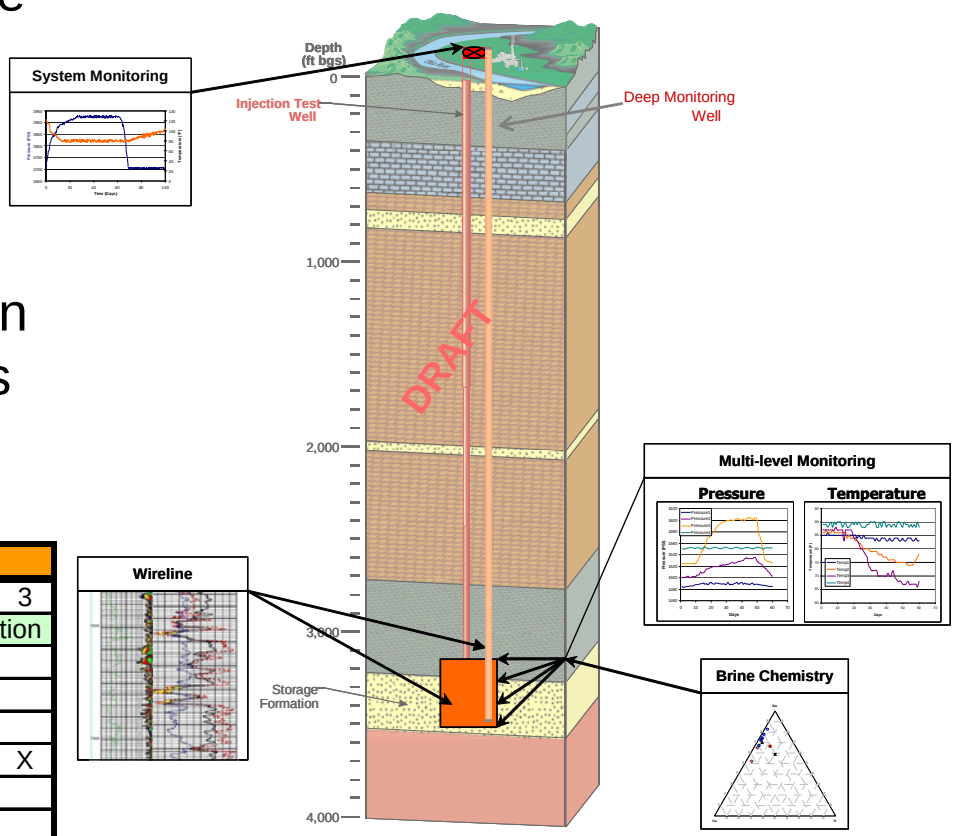
Large property area should aid in permitting and monitoring.



MMV Program

- Complete monitoring plan and schedule will be determined after site characterization efforts are finished.

- Since the injection interval is fairly thick, the monitoring approach may involve tracking the upward migration (if any) of the injected CO_2 to assess CO_2 behavior in Mt. Simon.



Cincinnati Arch									
Time (Months)	-3	-2	-1	1	2	3	1	2	3
Phase	Pre Demo			Active Injection			Post Injection		
Injection System (PVT)				X	X	X			
Health and Safety				X	X	X			
Repeat Wireline (RST, PEX)			X		X		X		X
Tiltmeters			X	X	X	X			
Time Lapsed VSP		X						X	
Reservoir Sampling			X				X		
Surface Geochemical	X	X	X	X	X	X	X	X	X

DRAFT

The Michigan site has key infrastructure needed to support CO_2 injection

DTE's Turtle Lake Gas Processing Plant

Core Energy's Compression Plant and CO_2 Pipeline

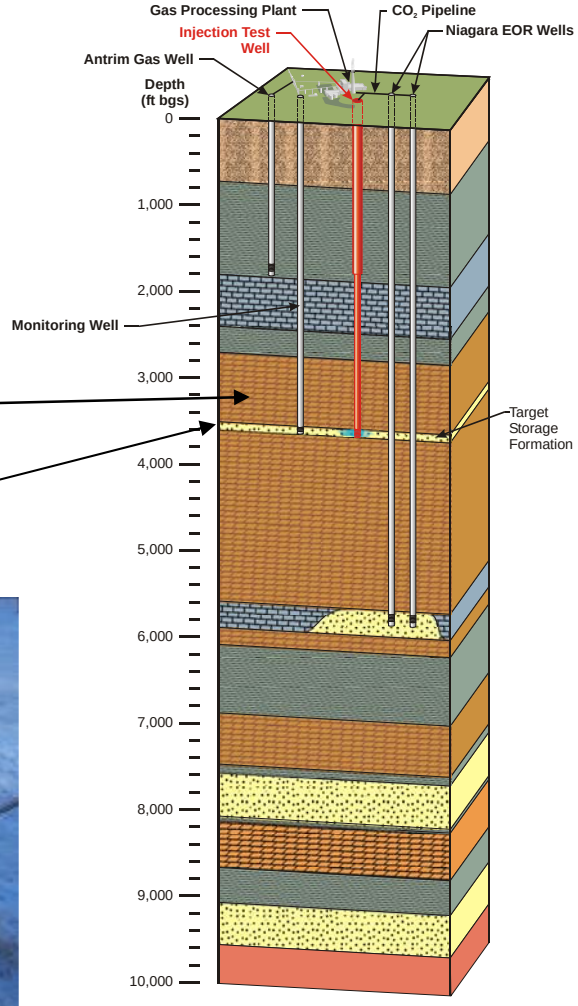
6" Diameter CO_2 pipeline leaving compression plant

The lessons learned in operating this system will carry over directly to Phase III

At our Michigan site we completed injection of 10,000+ tonnes of CO_2 in March '08

5000 Foot Deep Test Well Drilled in November 2006

180 feet of core taken



Confining Layer: Amherstburg Limestone

Injection Target: Bass Islands Dolomite

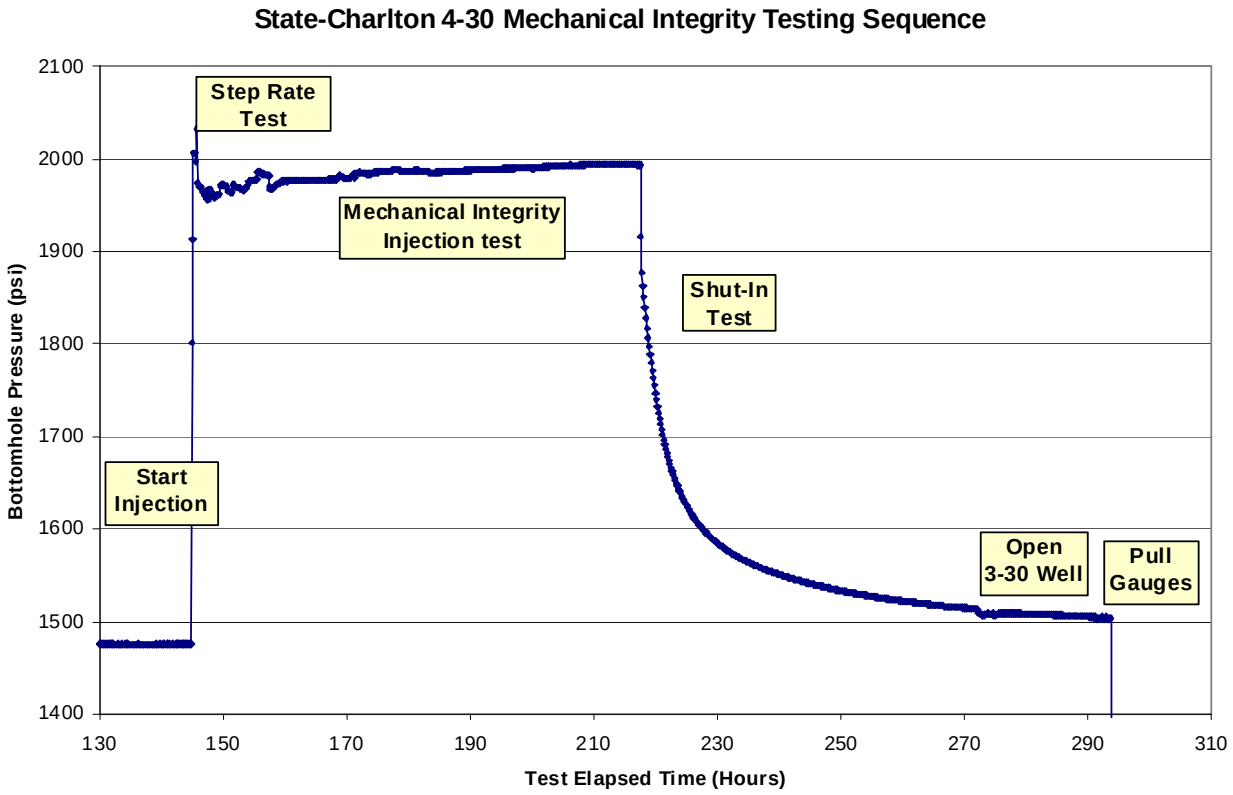
Well Column

Injection Operations

Starting Injection

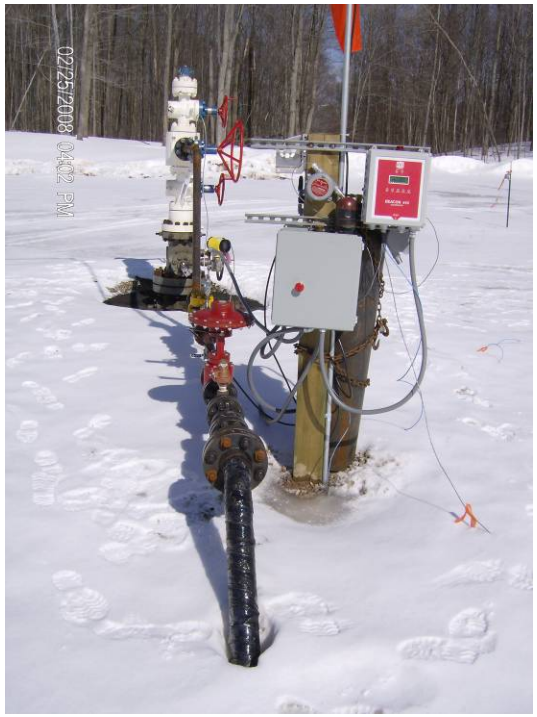
CO_2 Mechanical Integrity Testing – Example from MRCSP MI Site

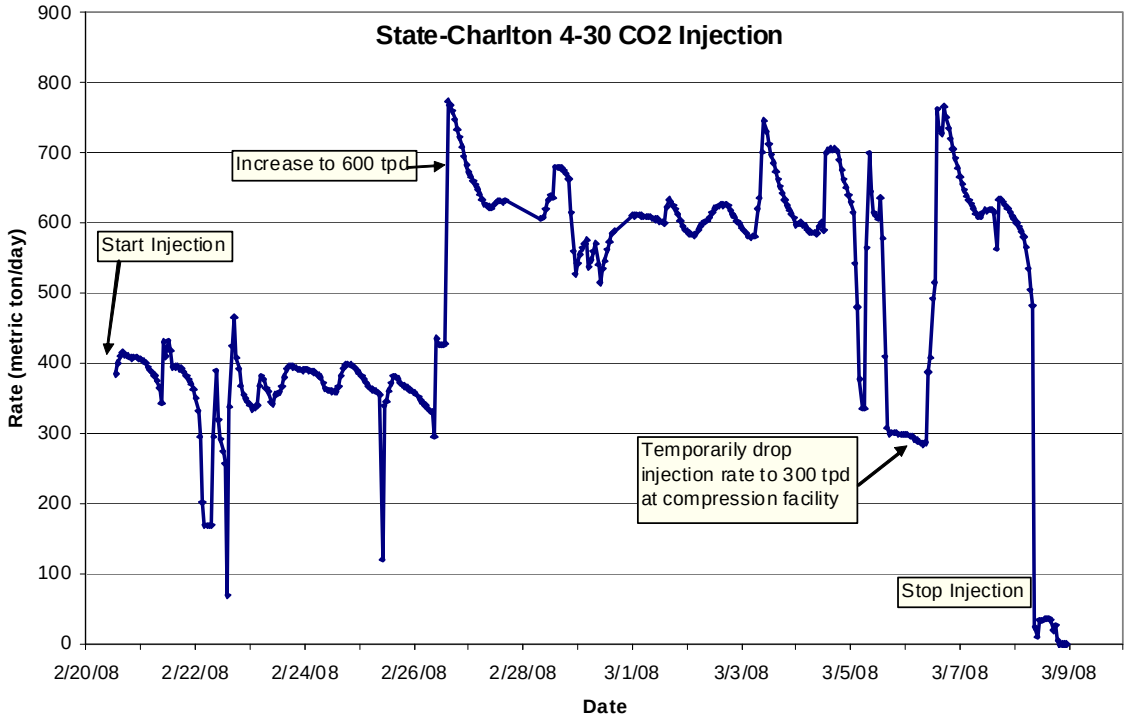
- Initial step-rate test and shut-in test completed with CO_2 prior to sustained injection as part of UIC mechanical integrity testing, February 7-13, 2008.
- Testing provides data on hydraulic behavior of the reservoir system.



CO_2 Injection Testing – MRCSP MI Site

- 10,241 metric tons CO_2 injected from February 18-March 8, 2008 (including initial mechanical integrity test volume).
- Injection Rate increased from 400 to 600 metric tons/day after 1 week (some fluctuations in injection rate due to compression facility).
- Injection well was shut-in for 1 month after injection to track reservoir pressures decline and allow stabilization.





The Michigan monitoring suite has worked well under adverse winter conditions

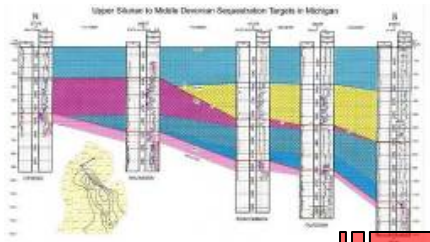
Acoustic Array

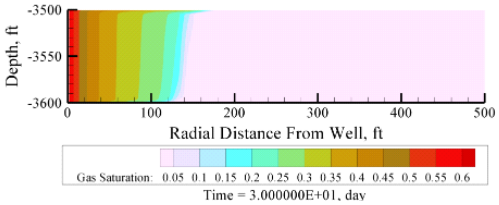
Monitoring Well
(about 500 feet from injection well)

Cross Well Seismic Analysis

Results from Michigan have already allowed us to take our models to the next step

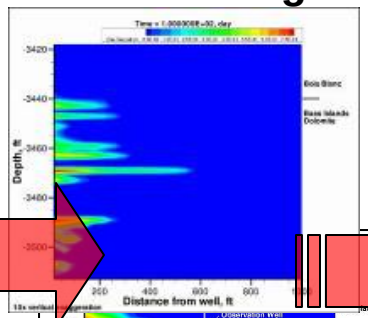
Preliminary Modeling Based on Regional Data

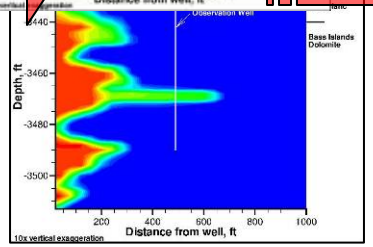




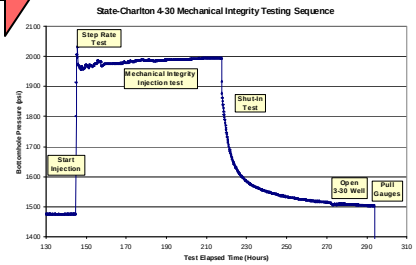
Site Drilling and Testing

Site Specific Modeling





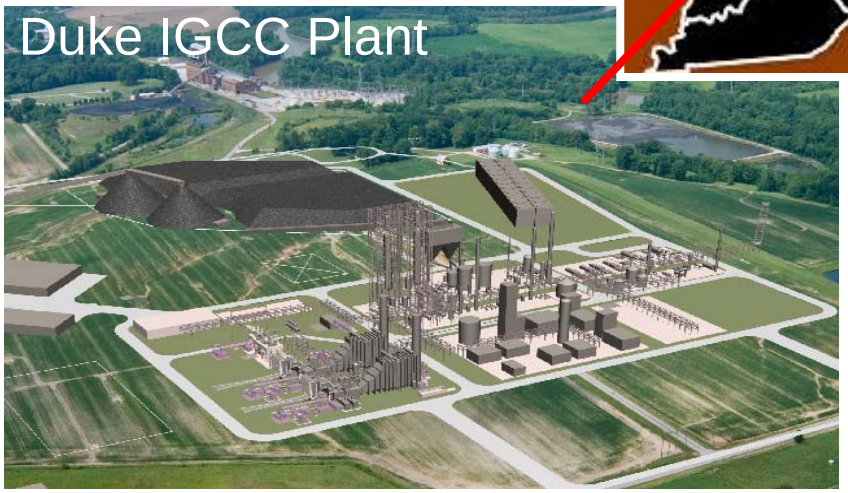
Post-Injection Calibration/Validation



Conceptualize → Characterize → Design → Monitor → Calibrate → Validate

----------Communicate----------

MRCSP Phase III proposed sites



Primary site

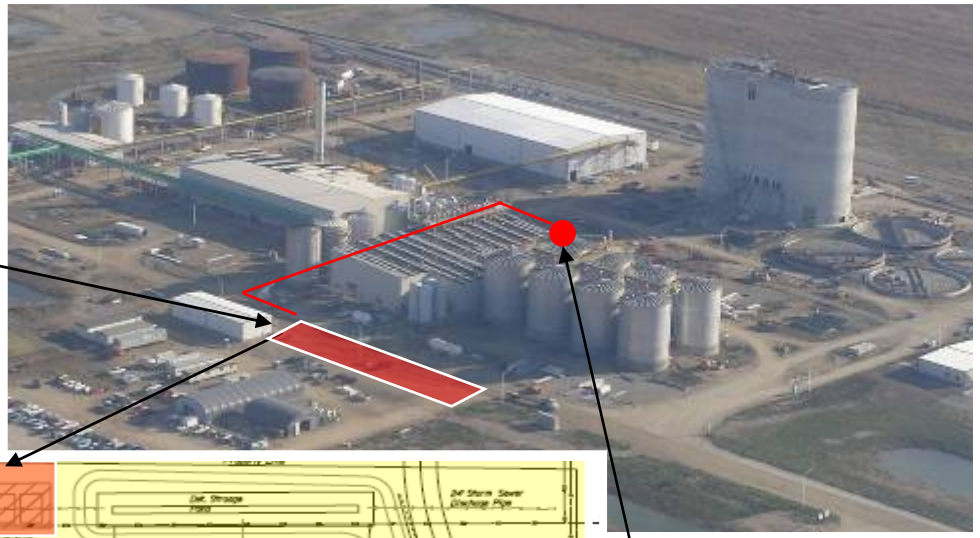
- Host: TAME, a joint venture of The Andersons and Marathon Petroleum
- Plant operational: February 2008.
- Injection start: FY2010
- Scale: 1 million tonnes of CO_2 over a four-year period
- Target: Mt. Simon at ~3500 ft.

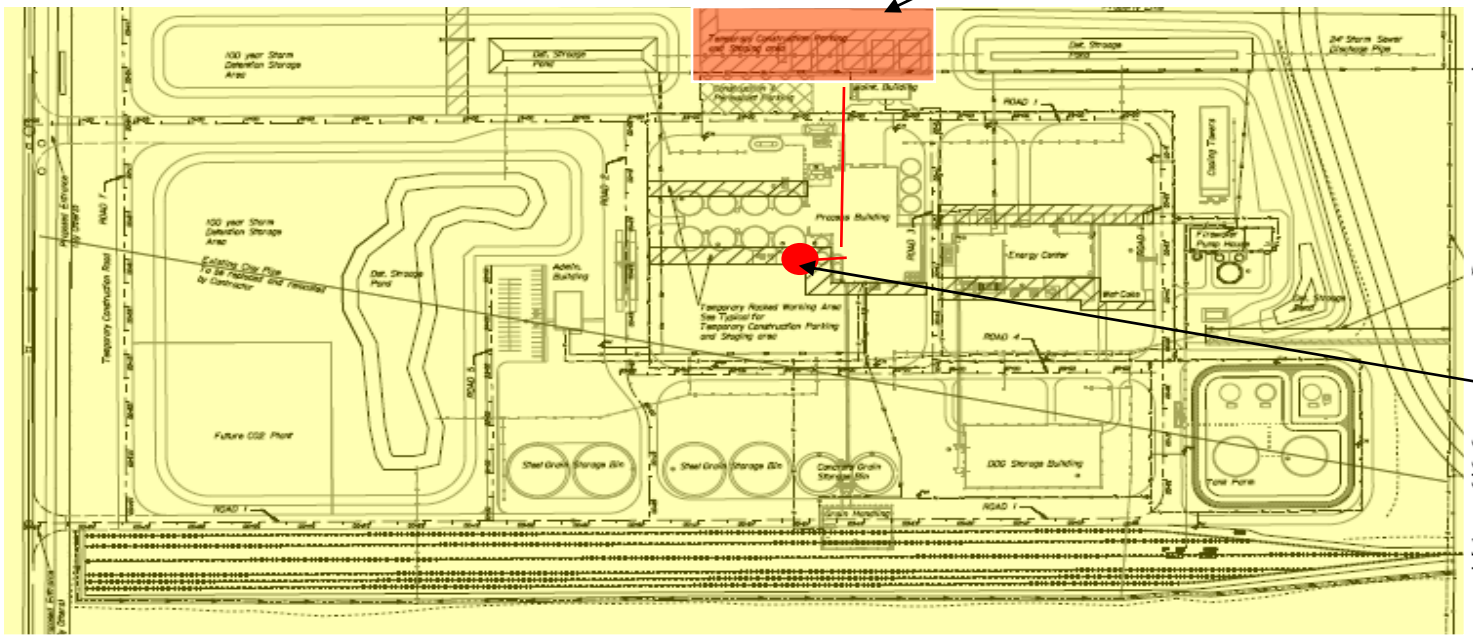
Optional site

- Host: Duke Energy
- Plant operational: FY 2012
- Possible injection start: FY 2012
- Scale: Possible 2 million tonnes over four-year injection period
- Target: Mt. Simon at ~8000 ft.
  - Multiple injection zones and caprock layers

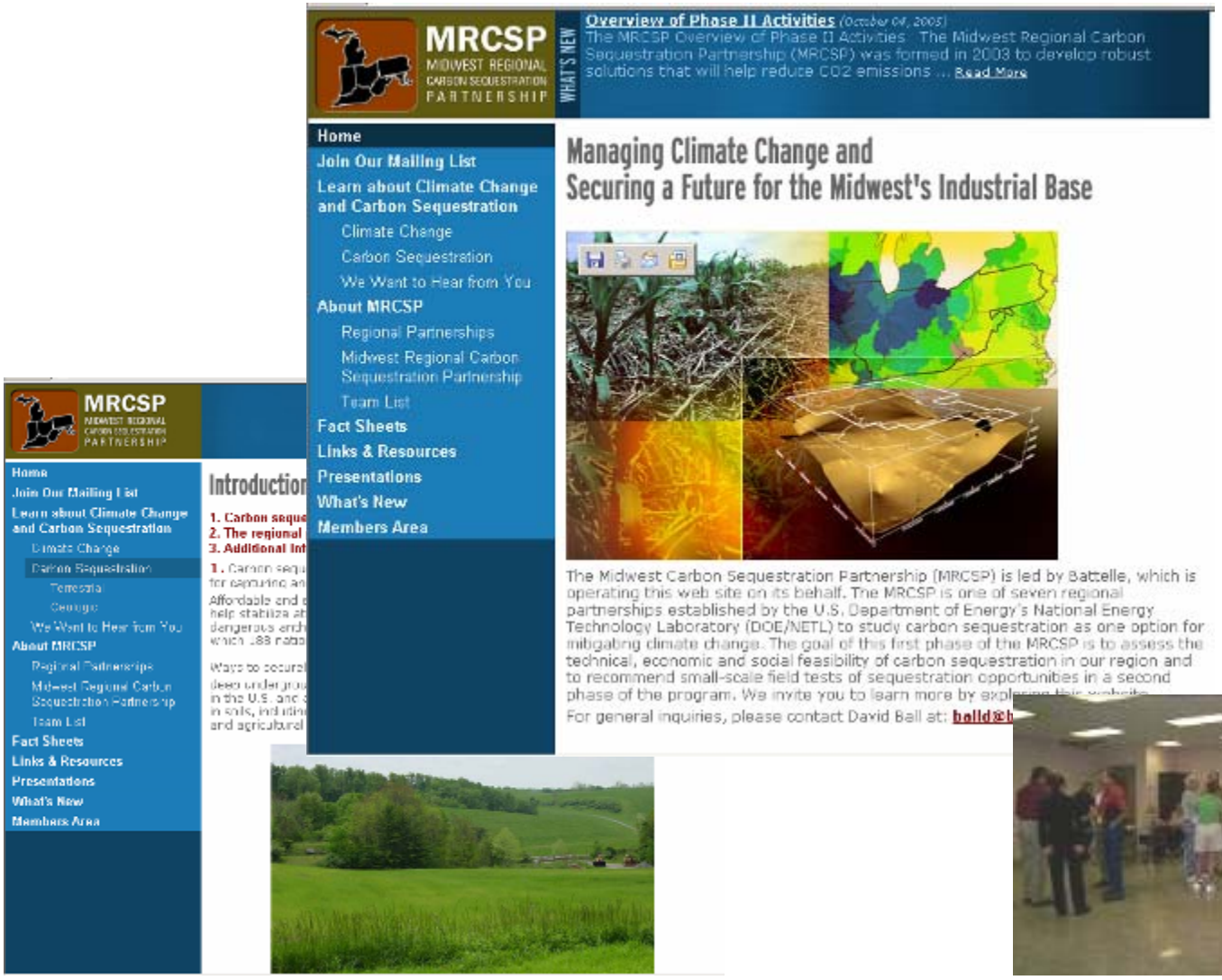
Candidate site plan for ethanol site

- The TAME Ethanol plant sits on about 80 acres
- Candidate location for compression plant and injection well site
- A CO_2 transfer line will be needed to move the raw CO_2 from the vent stack to the compression plant.





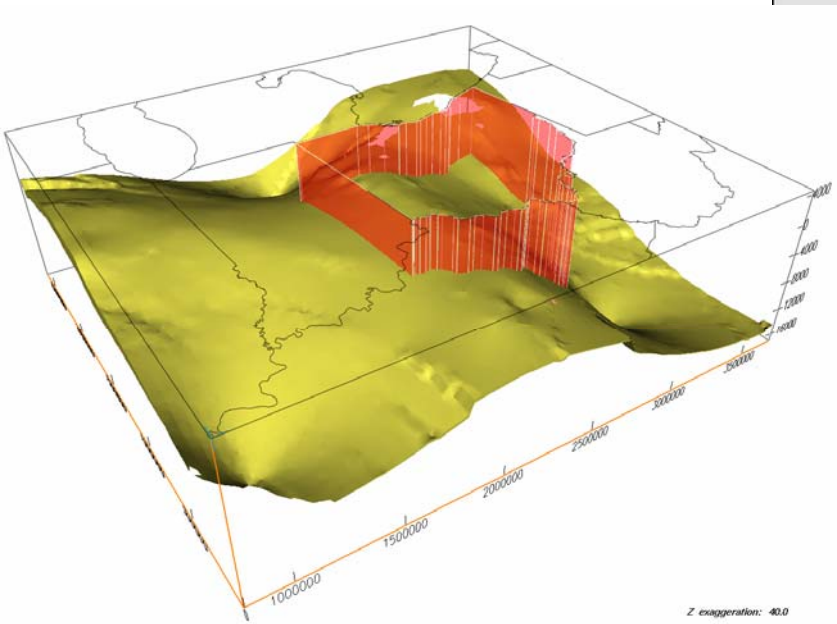
Outreach and public education is an important part of our overall program

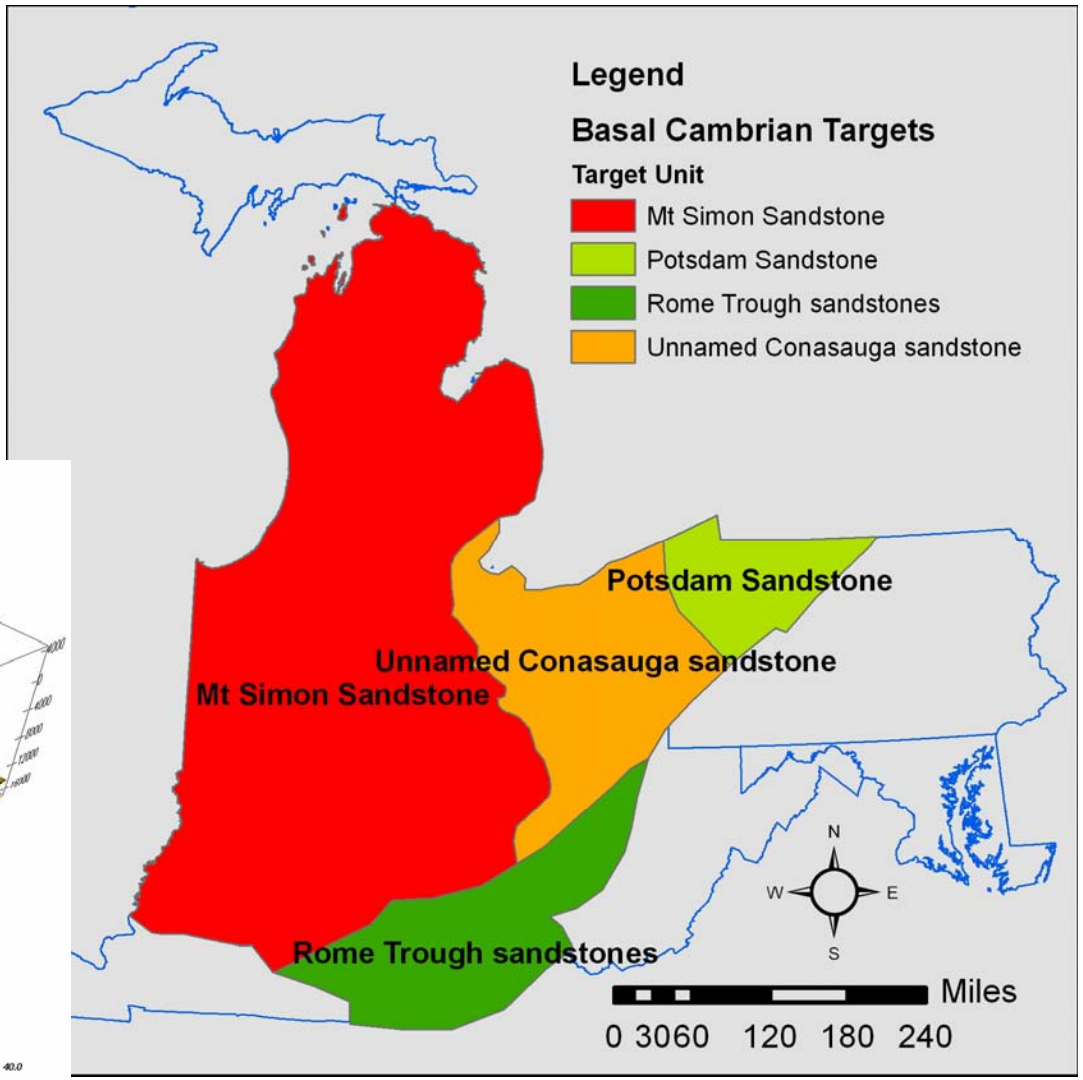


Our web site:
www.mrcsp.org

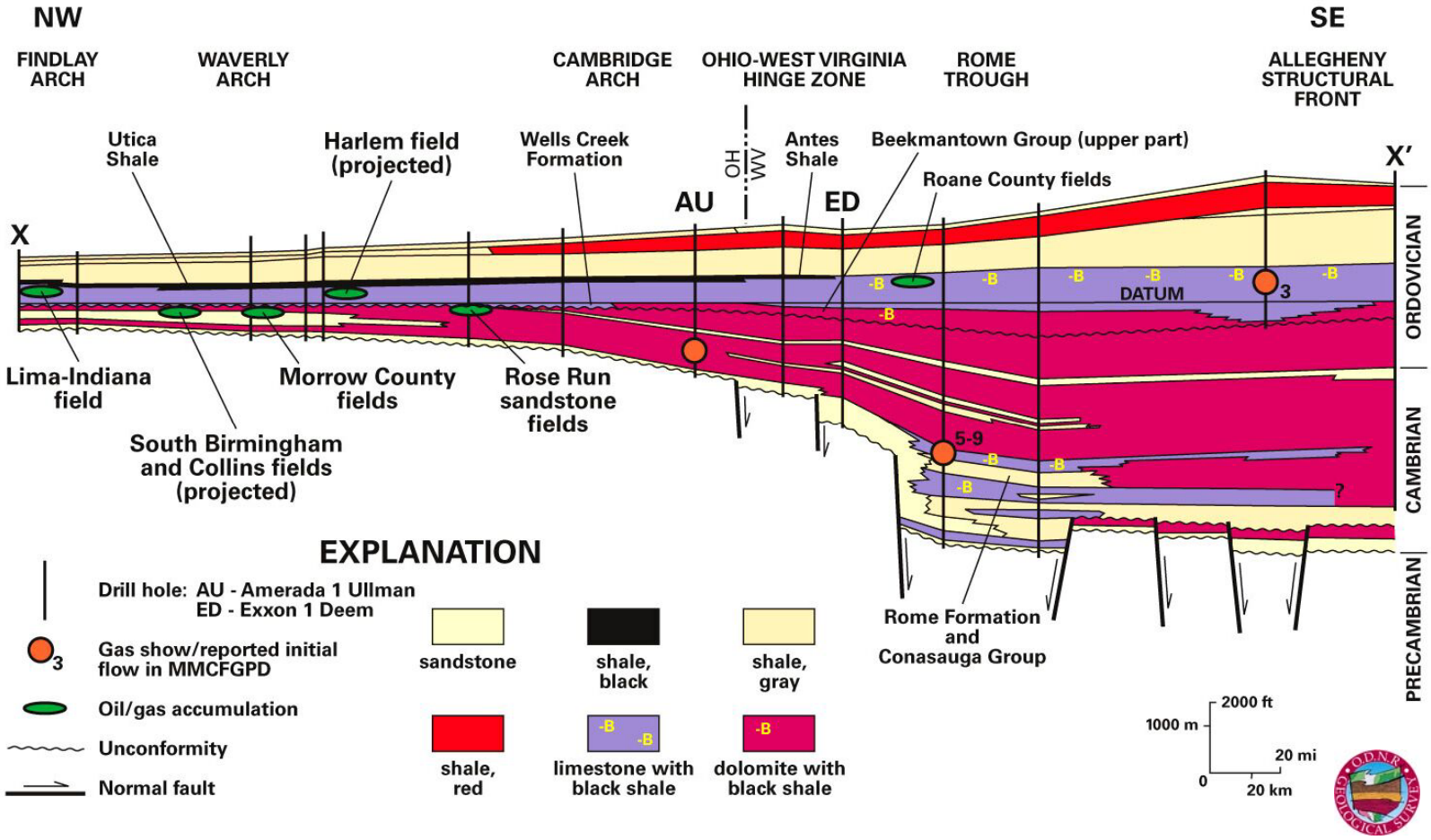
Open house at one of our geologic test sites

Trends – Regional Variability in Key Sinks Must be Understood





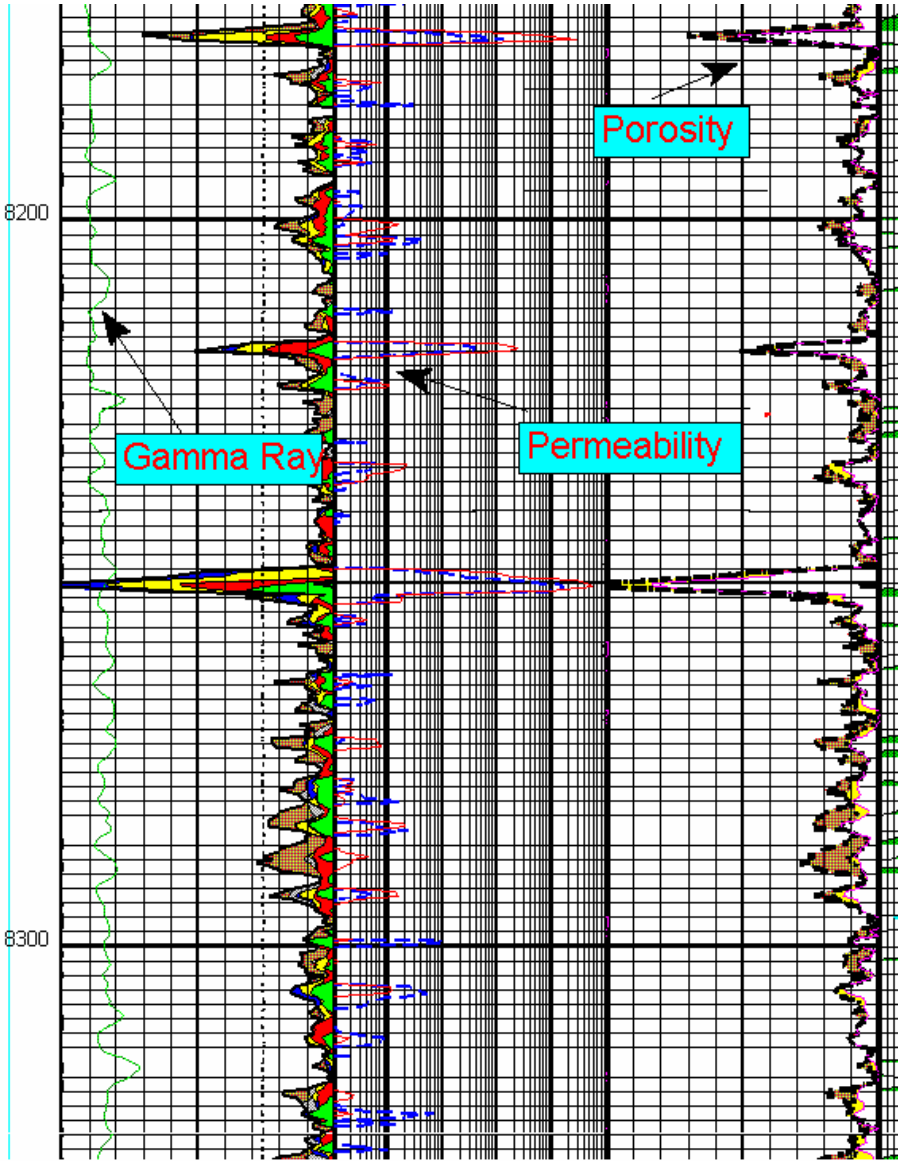
Challenge – Continued Regional Geology Mapping with Wellbore and Seismic Data



- Extremely low data availability in deeper Appalachian, Michigan, and Illinois Basin is a challenge

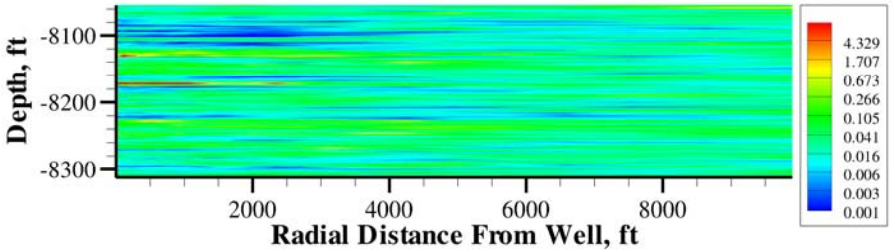
Trends – Every Potential Storage Zone is Important

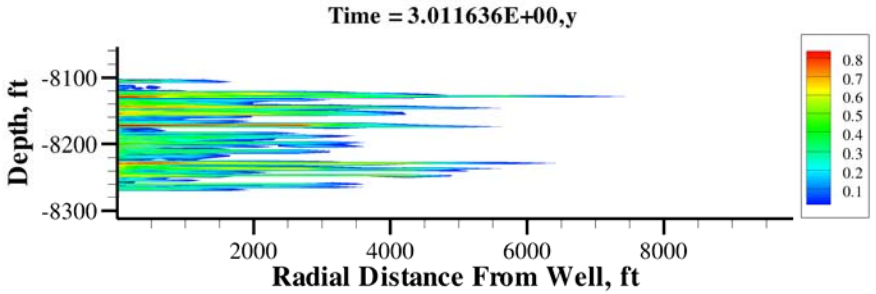
- Example – Mountaineer project storage potential was observed in part of Copper Ridge Dolomite (B-Zone at 8100-8300 ft depth) based on detailed NMR logging and reservoir testing
- Similar high permeability zone observed in several wells, including one near Gavin plant. This is promising for regional storage potential
- Lesson - We have learned a lot about characterization tools and feasibility in the region

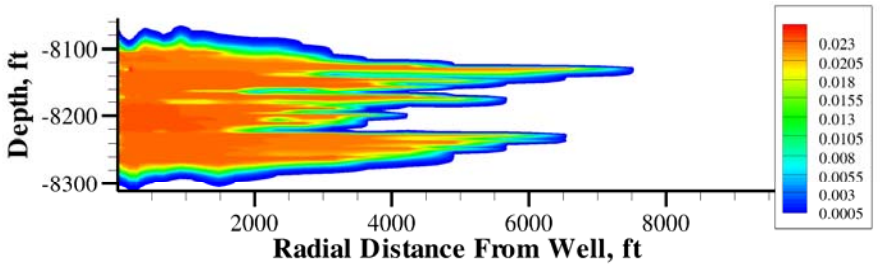


Challenge - Mapping and Modeling Storage in Carbonate Zones

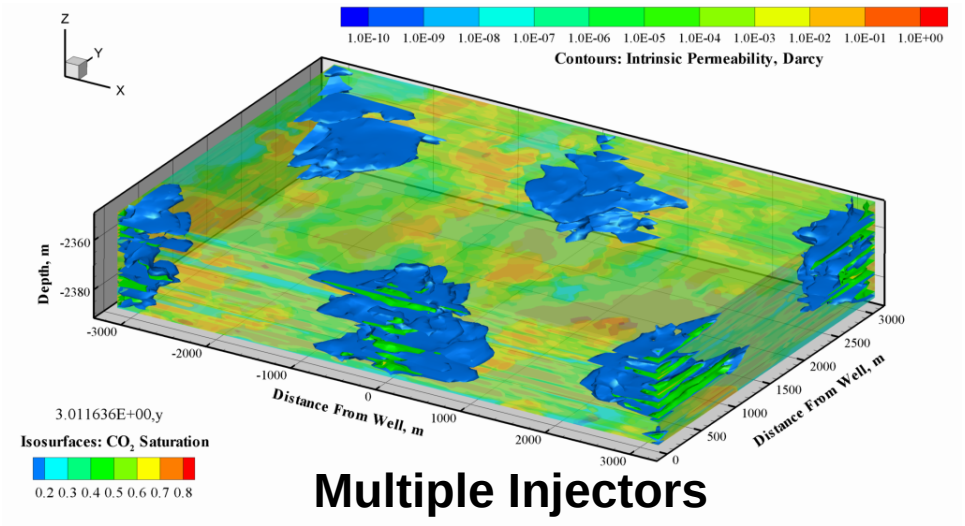
- Example – Copper Ridge/Knox Dolomite at Mountaineer site
- Potentially thin but very high permeability zones in carbonates throughout the region
- Need to understand geologic continuity and geochemical behavior
- Estimating capacity in discontinuous carbonates can be difficult

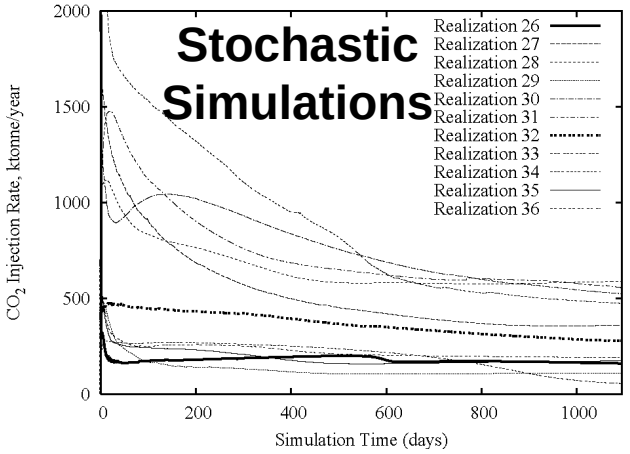


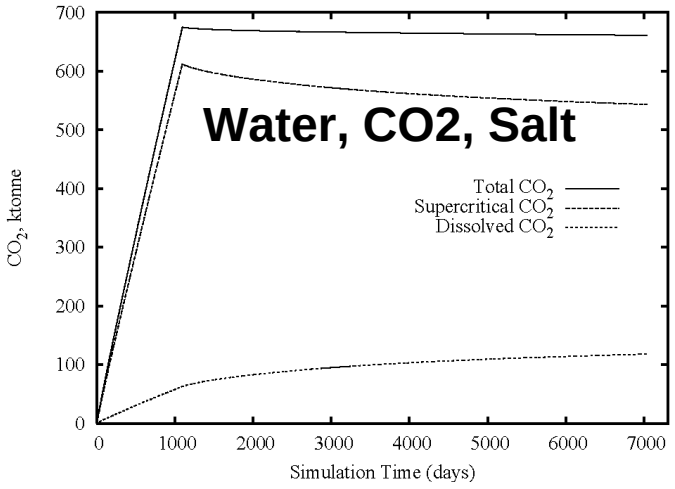


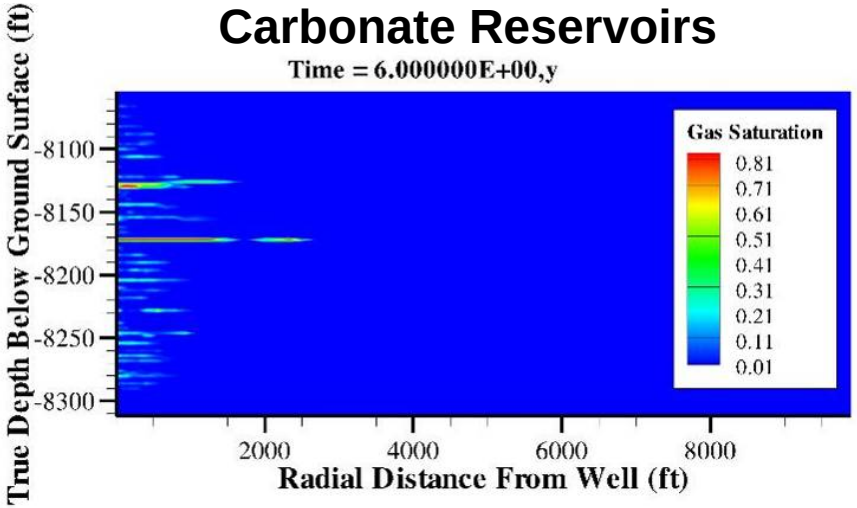


Trends – Detailed Simulations to support permitting, outreach, MMV, and Facility Design are now Underway

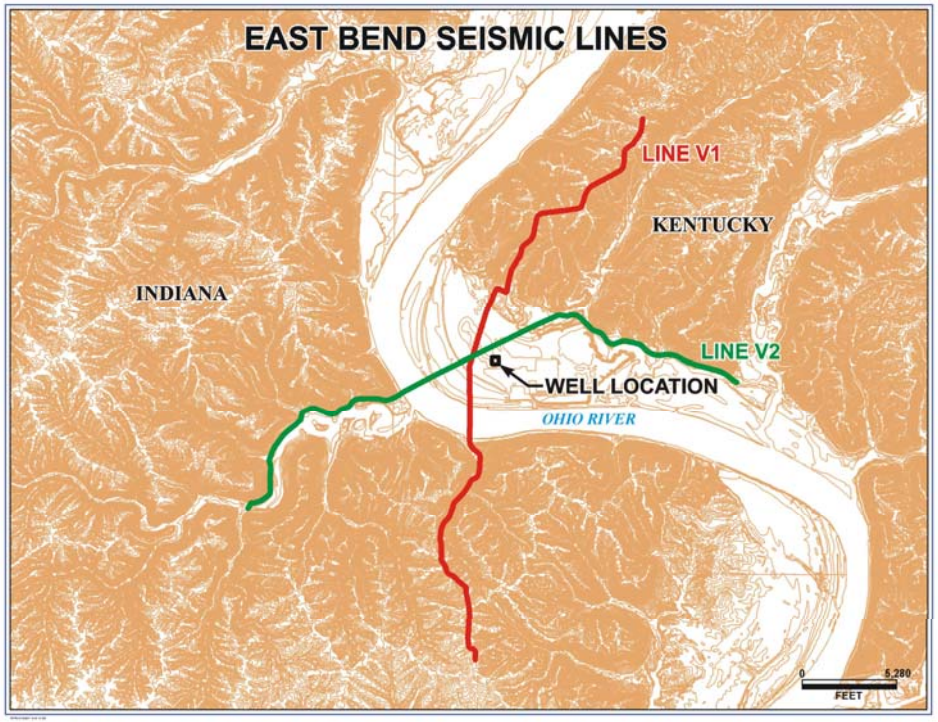








Trends – Characterization 3D Seismic Surveys and Well Logging

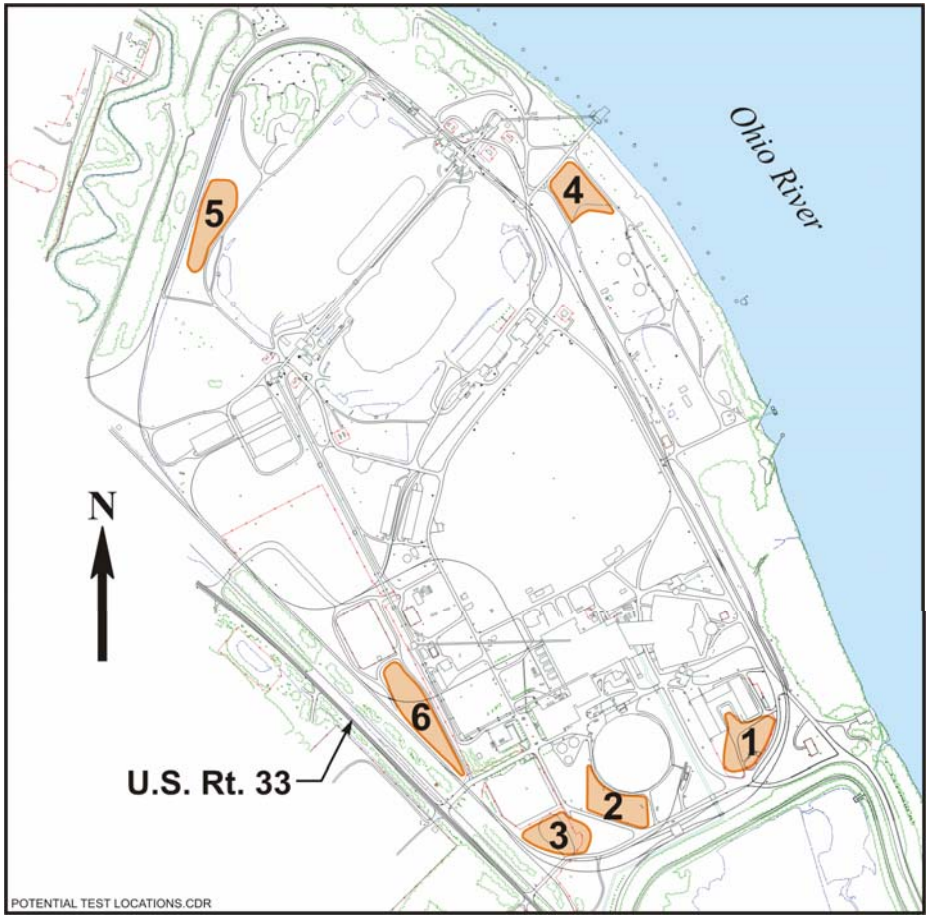


- 3D surveys in complex topography offers numerous challenges
  - Data loss across the river
  - Twisted survey lines offer significant processing challenges

- Possible solutions include:
  - Taking data at the bottom of the river using modified off shore techniques
  - Collaboration between acquisition and processing to try and straighten the lines as much as possible

Trends - Integration of CCS with Plant Operations and Site Logistics

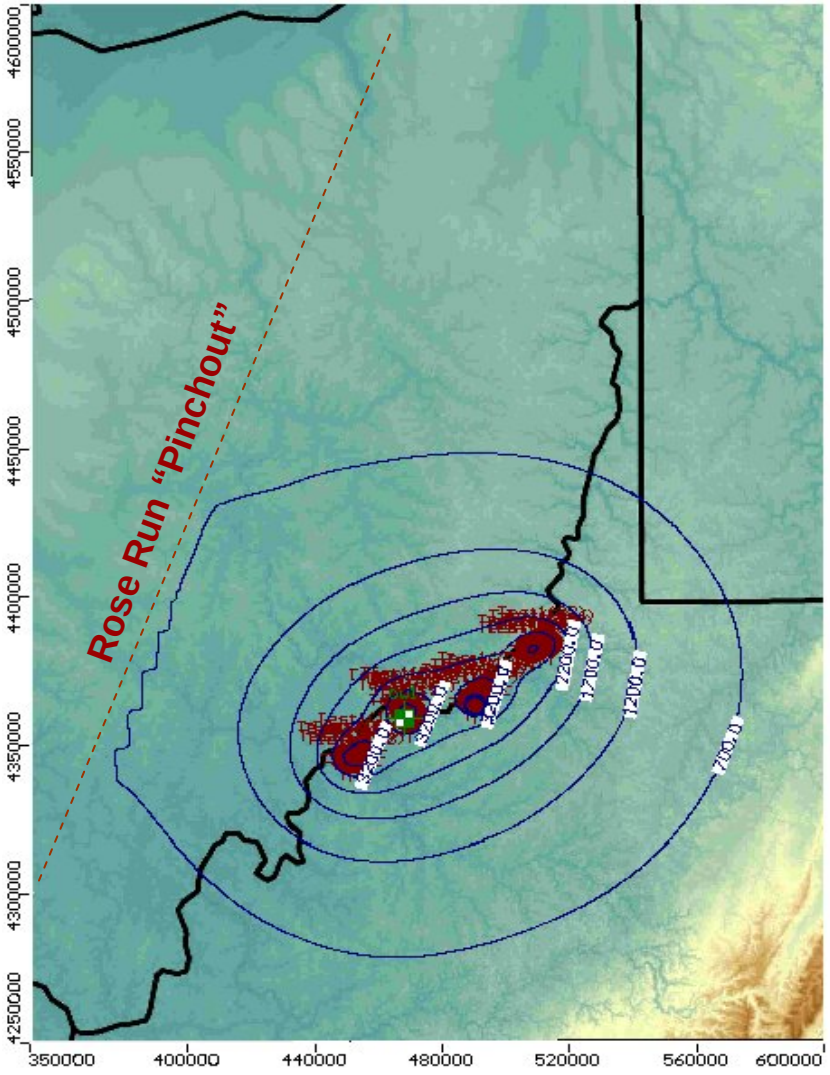
- Logistics of drilling and MMV at and near industrial facility are a major challenge



Challenge – Developing Regional Deployment Plans

- Important for evaluating regional capacity, pressure, geomechanical, and brine mobilization issues.
- Will be required for regional infrastructure planning – inter-facility spacing and transport network

- Example - Simulated pressure buildup @ 20 million tons/year for 20 years in 40 **water** injection wells in Rose Run Sandstone



Trends and Challenges - Institutional/Regulatory Aspects

- A regulatory framework is emerging for deep well injection through extensive interactions with federal and state authorities under ongoing projects
- Public utility commissions and policymakers are becoming increasingly aware of the technical and economic issues related to CCS. The CCS potential is discussed routinely in PUC deliberations
- Several states and other organizations are considering long-term liability and ownership issues
- There is a strong need for faster progress on these issues as we move towards large-scale testing

Summary of Trends – We are Now in a Critical Phase for Future Success of CCS

- During last few years, CCS has attracted growing interest and support from regional industry and policymakers, this momentum must continue
- Emerging Issues:
  - A major effort to expedite capture technology development and integrated capture and storage demonstrations
  - Regional planning for transport and storage networks
  - ***Developing regulatory, policy, and risk management framework in parallel with large-scale testing***
  - ***Building public acceptance as we proceed to deployment***

Thank You

MRCSP
MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

The sight and sound of 600 tonnes/day of CO_2 being injected at 3,500 ft in Northern Michigan