ADM CCS Projects
Experience and Lessons Learned

CSLF Technical Workshop

June 17, 2015

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ILLINOIS
INDUSTRIAL CARBON
CAPTURE & STORAGE

Acknowledgements

- The Industrial Carbon Capture and Storage (ICCS) project is administered by the U.S. Department of Energy's Office of Fossil Energy and managed by the National Energy Technology Laboratory (award number DE-FE-0001547) and by a cost share agreement with the Archer Daniels Midland Company, University of Illinois through the Illinois State Geological Survey, Schlumberger Carbon Services, and Richland Community College. This ICCS project received DOE funding from the American Recovery and Reinvestment Act of 2009 ($141.4 million).
- The Midwest Geological Sequestration Consortium is funded by the U.S. Department of Energy through the National Energy Technology Laboratory via the Regional Carbon Sequestration Partnership Program (contract number DE-FC26-05NT42588) and by a cost share agreement with the Illinois Department of Commerce and Economic Opportunity, Office of Coal Development through the Illinois Clean Coal Institute.
- The Midwest Geological Sequestration Consortium (MGSC) is a collaboration led by the geological surveys of Illinois, Indiana, and Kentucky

ADM - Decatur CCS Projects

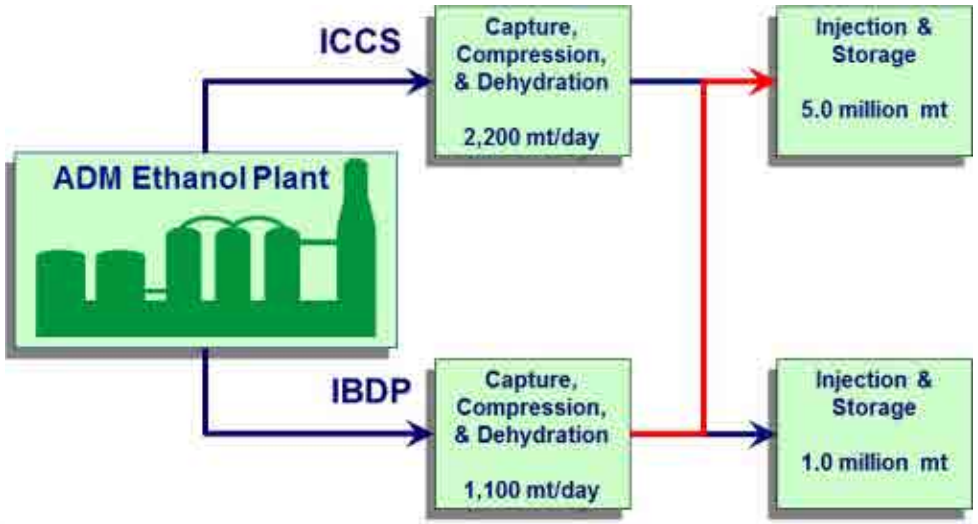
ILLINOIS INDUSTRIAL CARBON CAPTURE & STORAGE

Illinois Basin Decatur Project

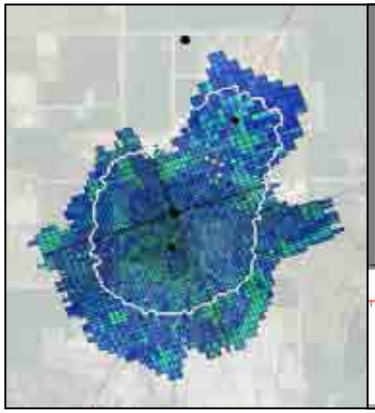
- *Large scale geologic test to inject 1.0 million mt of CO_2 over a three year period (1,000 MT/day).*

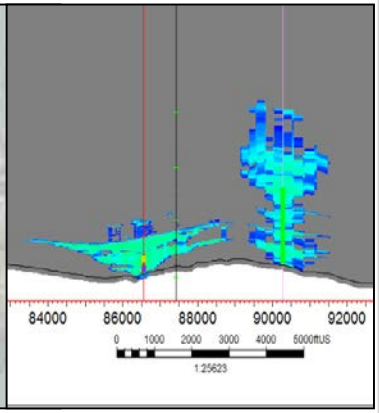
Illinois Industrial CCS Project

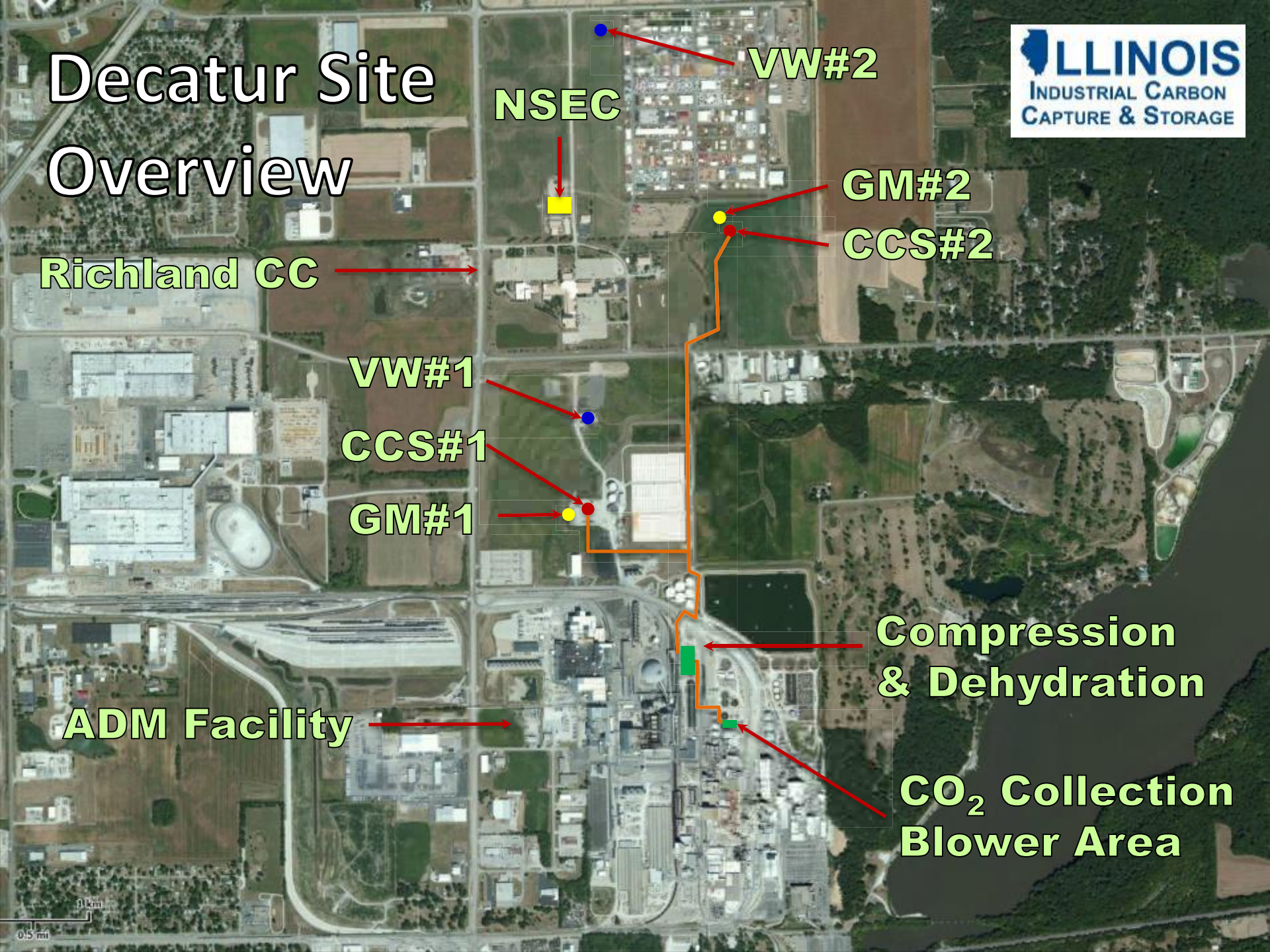
- *Target & demonstrate advanced CCS technologies at industrial scale facilities.*
- *Inject and store 1.0 million mt CO_2 per year (3,000 tons/day).*
- *Study the interaction of two separate plumes.*



ADM NETL Schlumberger Carbon Services Richland Community College

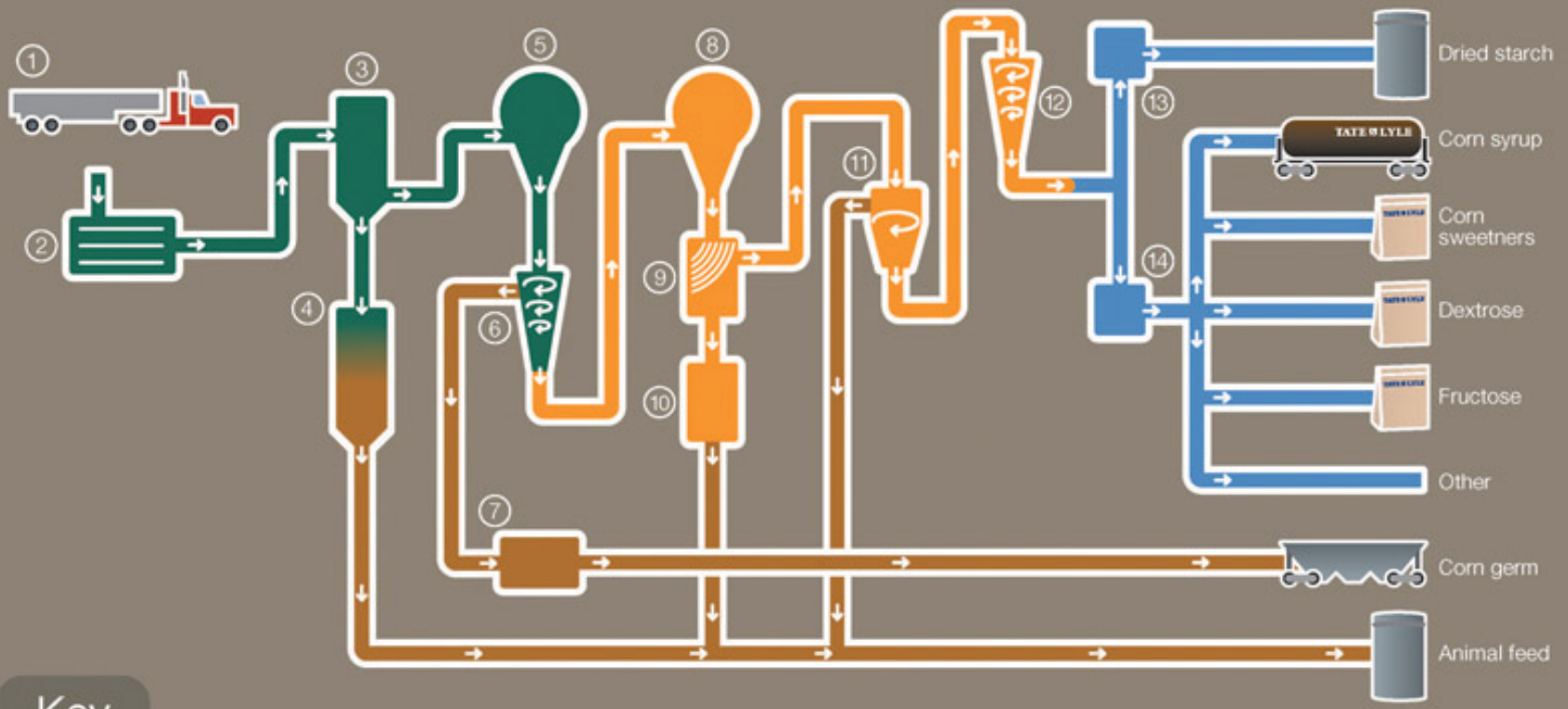





Decatur Site Overview
ILLINOIS
INDUSTRIAL CARBON CAPTURE & STORAGE
VW#2
NSEC
GM#2
CCS#2
Richland CC
VW#1
CCS#1
GM#1
Compression & Dehydration
ADM Facility
CO_2 Collection Blower Area

The corn wet milling process

ILLINOIS
INDUSTRIAL CARBON
CAPTURE & STORAGE

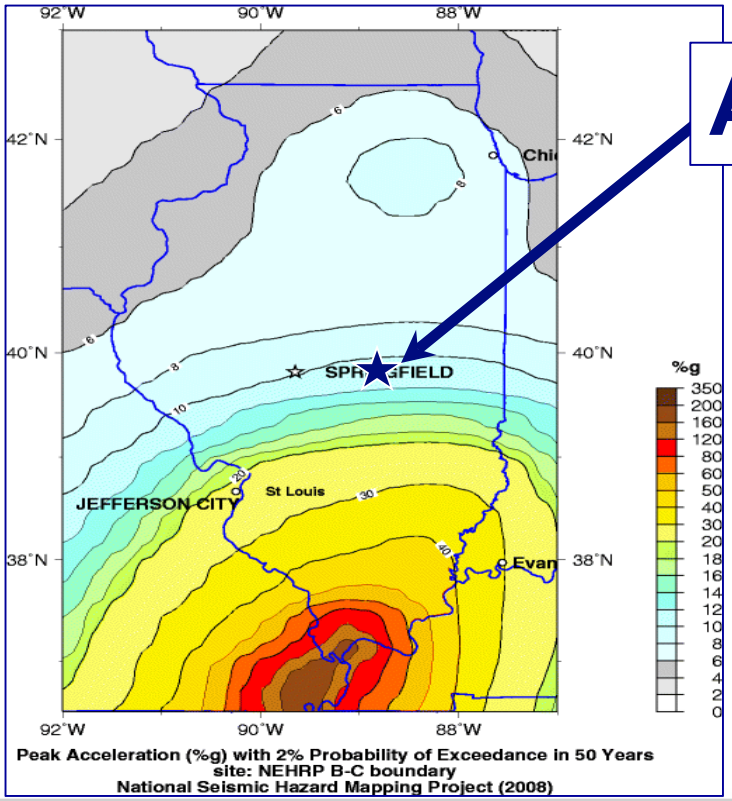


http://www.youtube.com/watoch?v=uE7DJVCa5h0

Site Selection
Regional Geologic Characterization

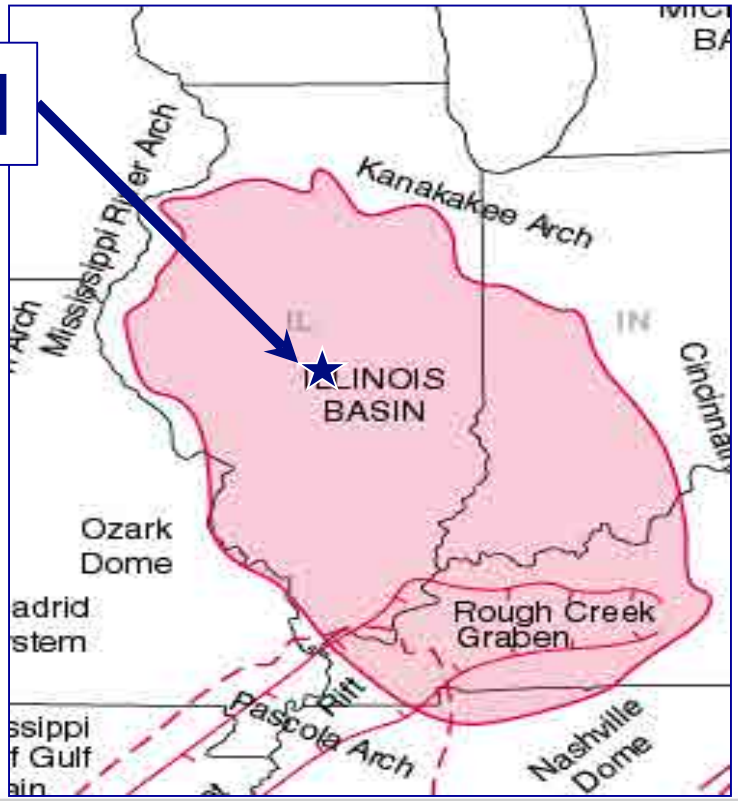
- Cratonic basin
- 60,000 square mile area
- Structurally complex to the south with faulting and seismicity

- ADM Decatur facility is located near the center of this geologic formation
- Estimated CO_2 storage capacity between 27 to 109 billion metric tons



Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary
National Seismic Hazard Mapping Project (2008)

ADM

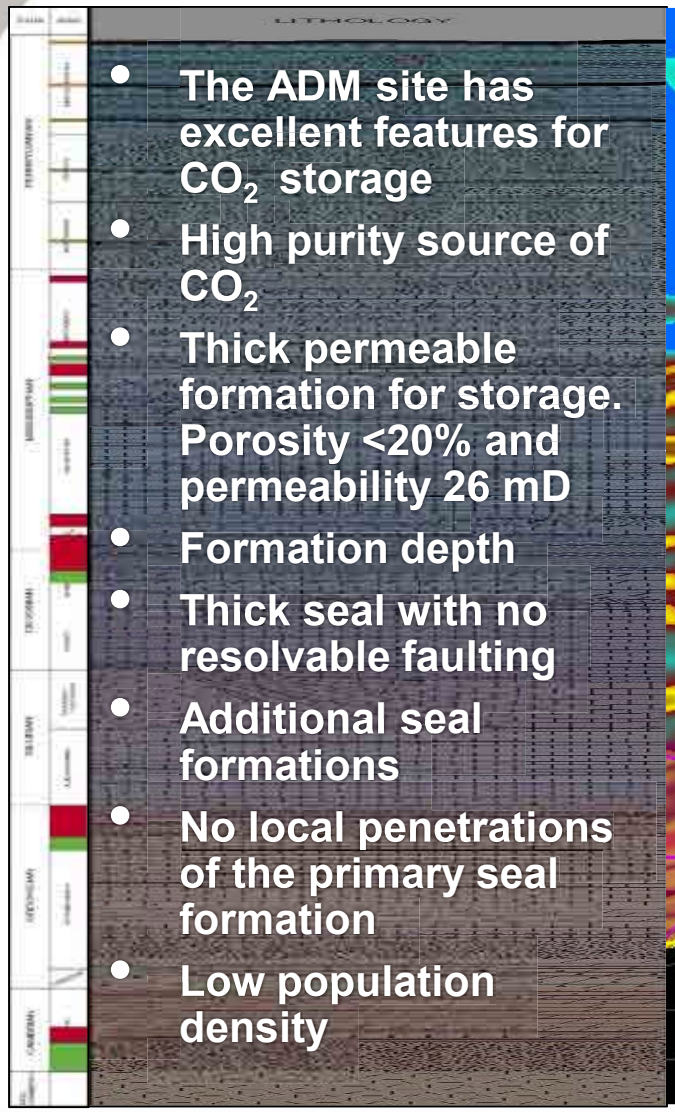


Site Characterization

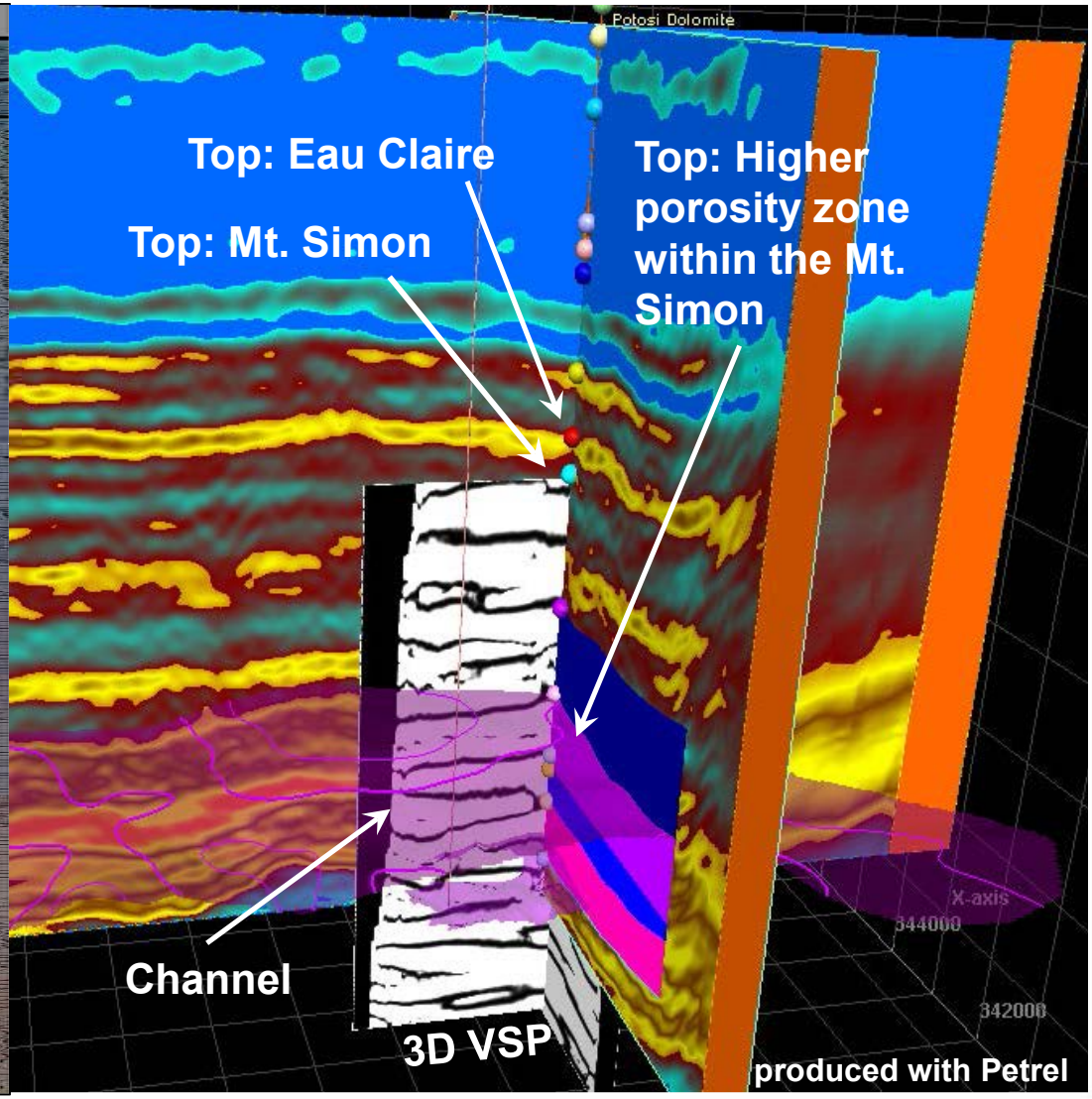
Seismic Acquisition

Site Characterization

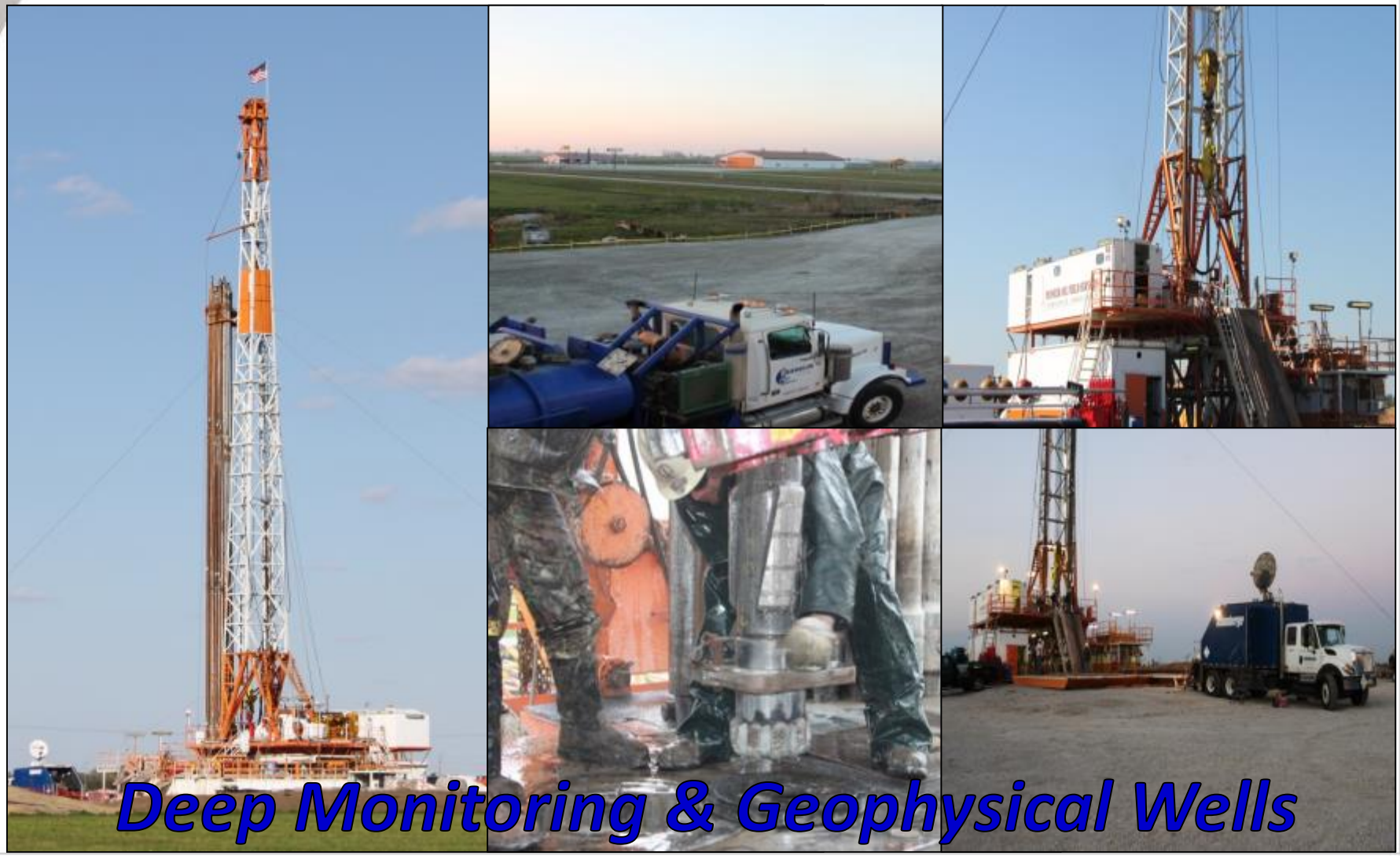
Evaluation of the Decatur Site



- The ADM site has excellent features for CO_2 storage
- High purity source of CO_2
- Thick permeable formation for storage. Porosity <20% and permeability 26 mD
- Formation depth
- Thick seal with no resolvable faulting
- Additional seal formations
- No local penetrations of the primary seal formation
- Low population density



Test Well Construction



Coring and Well Logging

Core Analysis Results

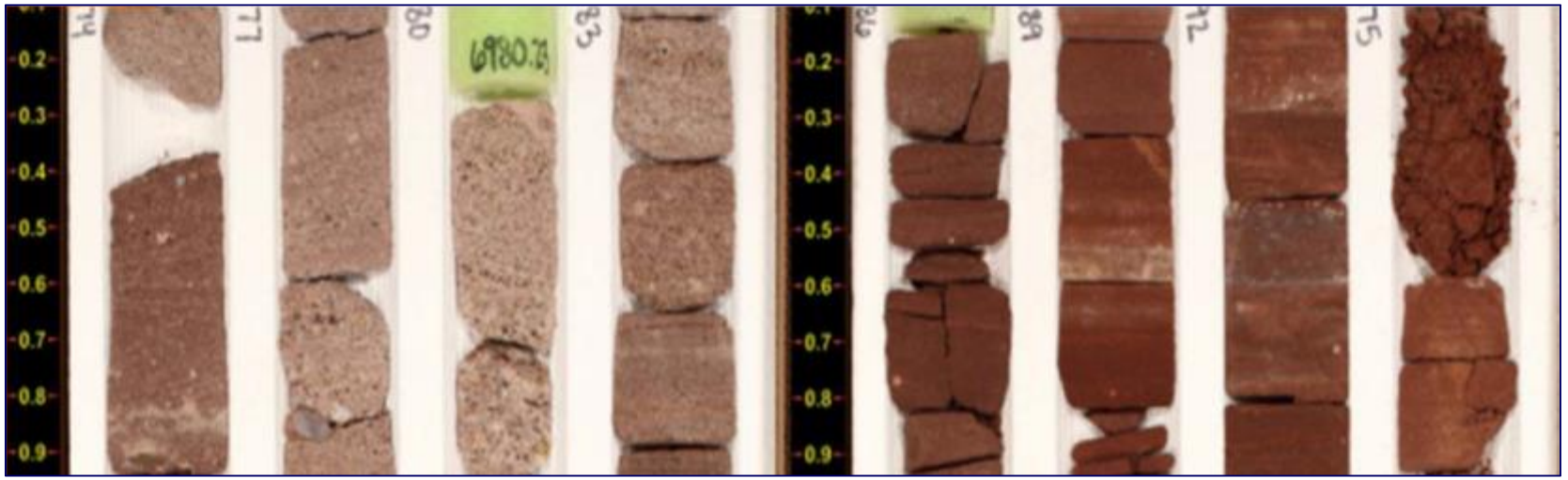
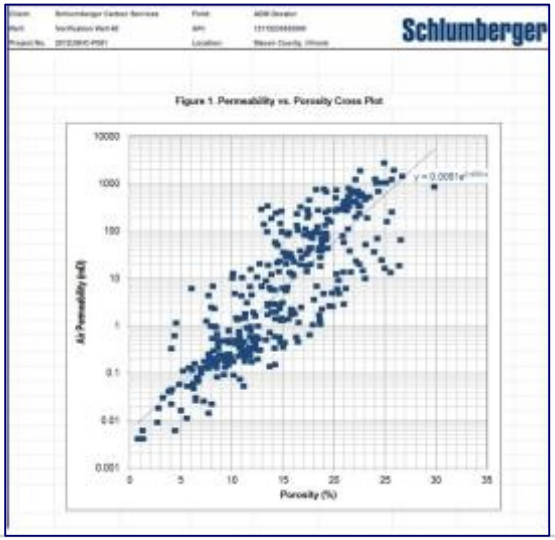
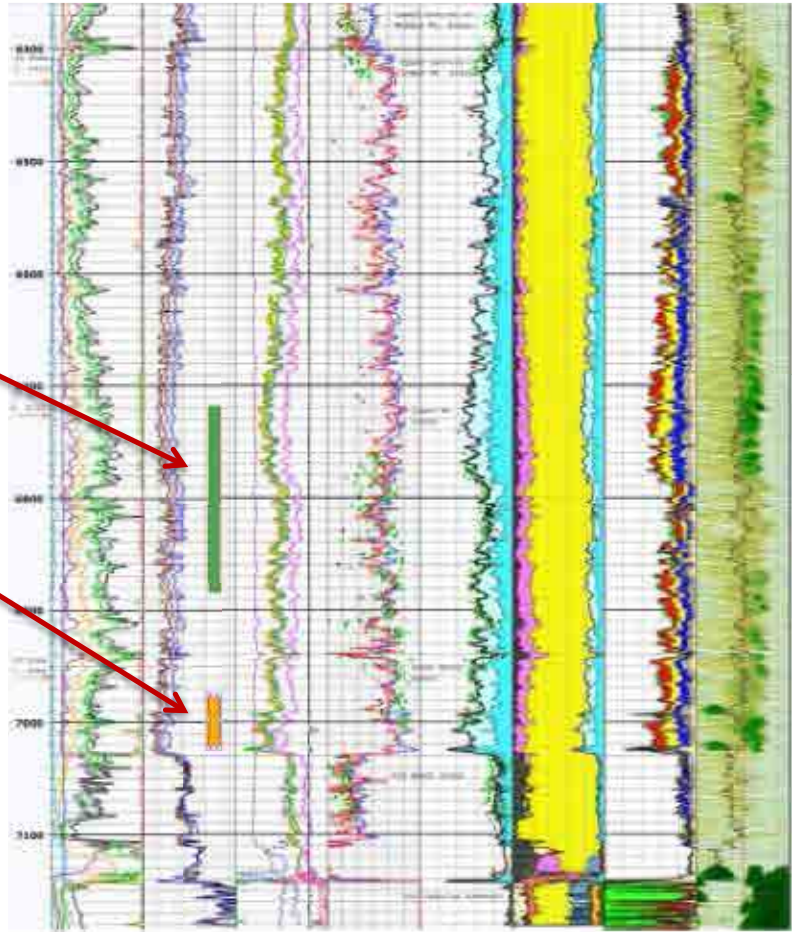


TABLE 1. SUMMARY OF WHOLE ROCK MINERALOGY BY X-RAY DIFFRACTION (% BY WEIGHT)

Sample ID	Depth (ft)	Silicates			Carbonates				Other			TOTAL NON-CLAY	Clays					TOTAL CLAY	GRAND TOTAL
		QUARTZ	K-FELDSPAR	PLAGIOCLASE	CALCITE	SIDERITE	ANKERITE/FE-DOLOMITE	DOLOMITE	PYRITE	FLUORAPATITE	HEMATITE		SMECTITE	ILLITE/SMECTITE (I/S)	ILLITE + MICA	KAOLINITE	CHLORITE		
4-4 XRD	6766.50	70	17	4	0	1	1	0	2	0	1	96	0	4	0	0	0	4	100
5-48 XRD	6877.75	63	22	4	0	1	0	1	1	1	0	93	0	1	6	1	0	8	100
6-2 XRD	6890.75	73	10	8	2	0	1	0	0	0	1	95	0	0	0	0	5	5	100
9-1 XRD	6981.30	79	6	4	0	0	0	1	0	0	1	92	0	2	3	0	3	8	100
9-2 XRD	7002.20	79	10	5	0	0	1	1	0	0	1	97	0	0	3	0	0	3	100



VW2: Petrophysical Analysis and Completion Plan



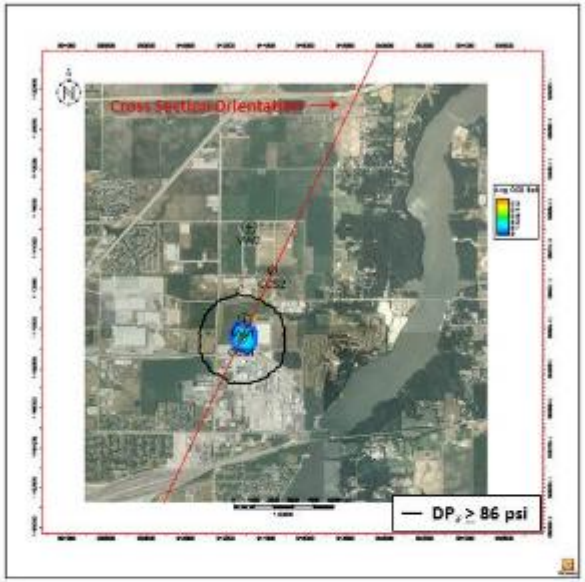
Compared to Petrophysical Analysis

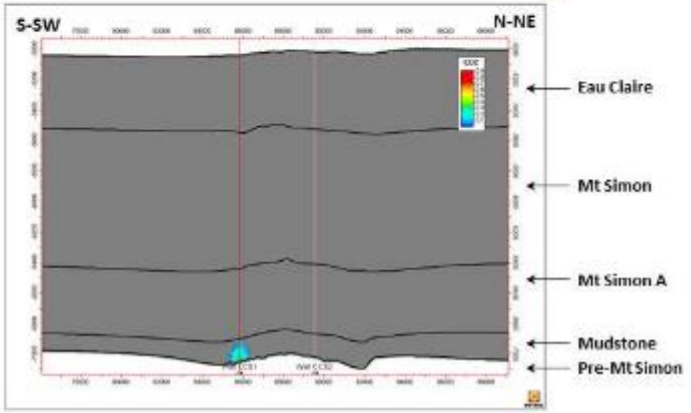
- Zones of Interest
- Mount Simon
  - (Upper, Middle, Lower)
- Pre Mount Simon
  - Weathered Pre Cambrian
  - Pre Cambrian Basement
- IC zones 1,2,3 in lower Mt Simon
- IC zones 4,5 in upper Mt Simon

Geophysical Modeling

ILLINOIS INDUSTRIAL CARBON CAPTURE & STORAGE

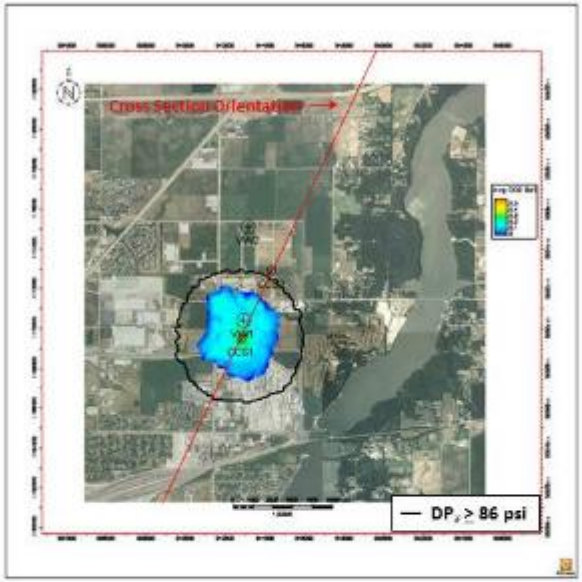
Extent of Plume & Saturation Cross Section
January 1, 2012 [$DP_{if} \geq 86$ psi, $SCO_2 \geq 1.0\%$]

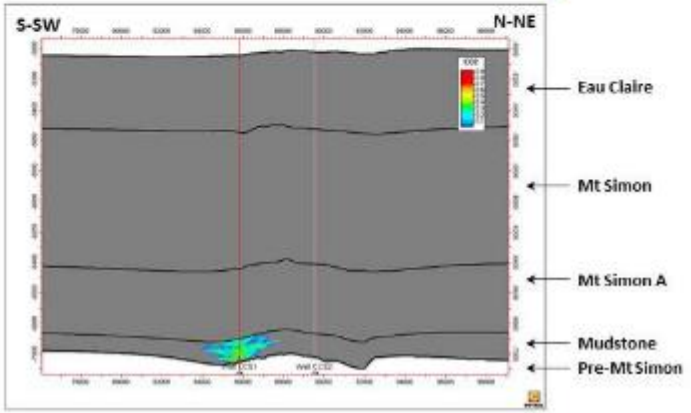




Geophysical Modeling

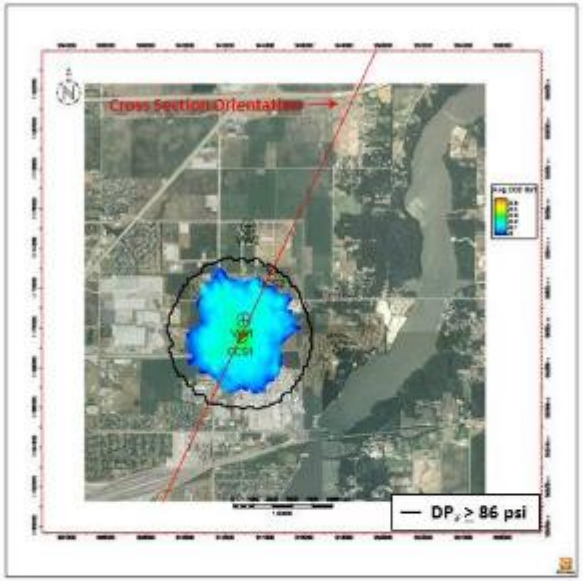
Extent of Plume & Saturation Cross Section
January 1, 2013 [$DP_{if} \geq 86$ psi, $SCO_2 \geq 1.0\%$]

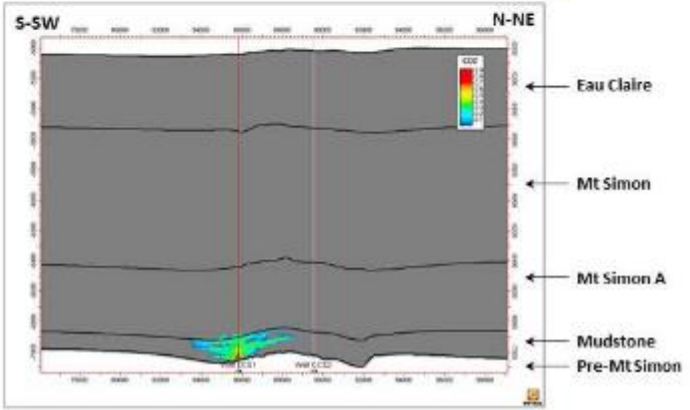




Geophysical Modeling

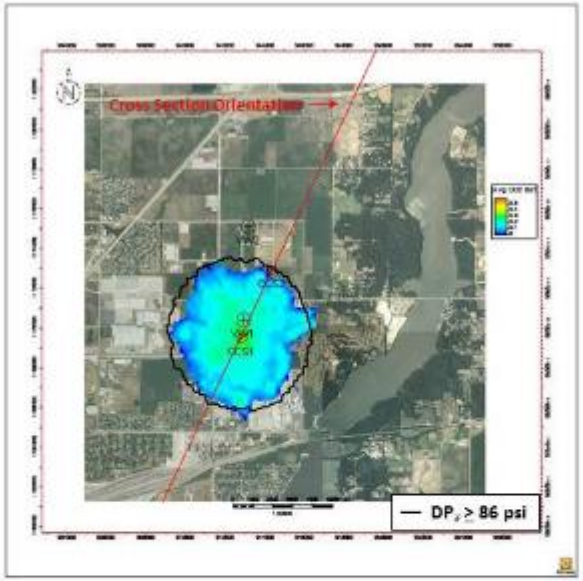
Extent of Plume & Saturation Cross Section
January 1, 2014 [$DP_{if} \geq 86$ psi, $SCO_2 \geq 1.0\%$]

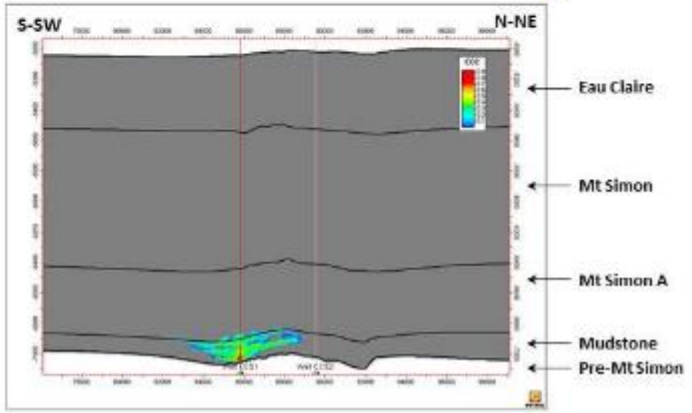




Geophysical Modeling

Extent of Plume & Saturation Cross Section
January 1, 2015 [$DP_{if} \geq 86$ psi, $SCO_2 \geq 1.0\%$]

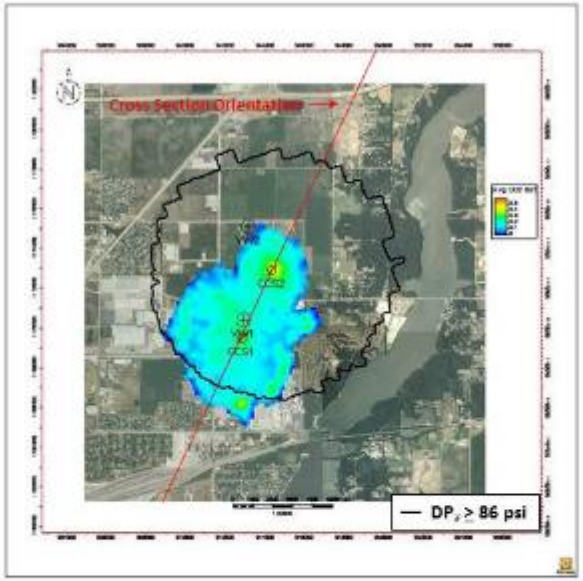


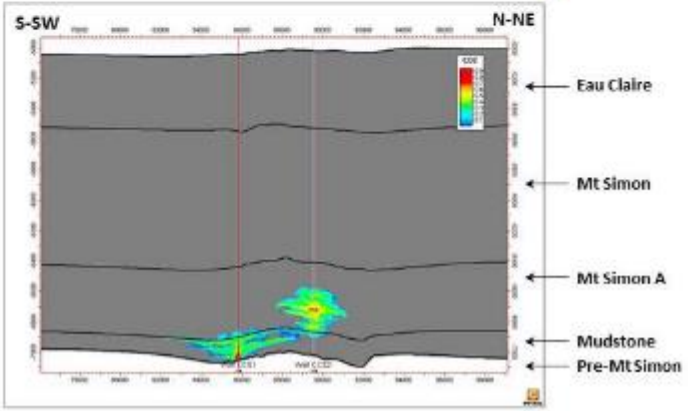


Geophysical Modeling

ILLINOIS INDUSTRIAL CARBON CAPTURE & STORAGE

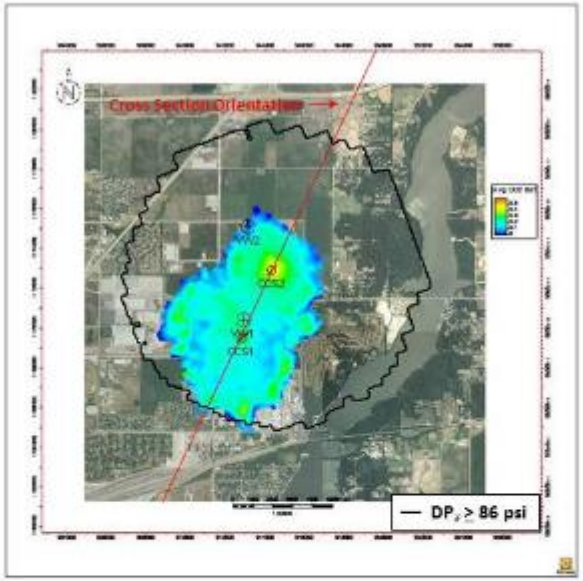
Extent of Plume & Saturation Cross Section
January 1, 2016 [$DP_{if} \geq 86$ psi, $SCO_2 \geq 1.0\%$]

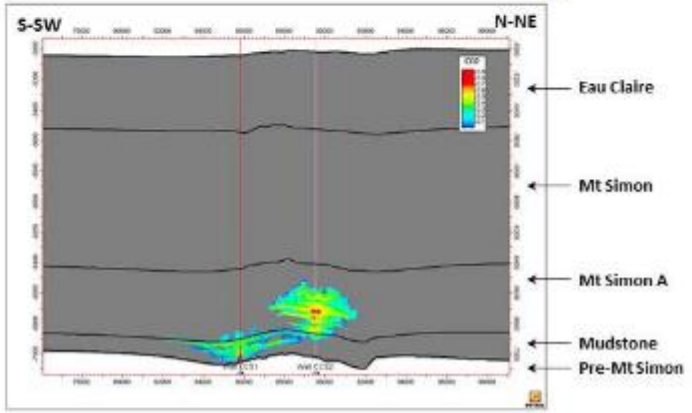




Geophysical Modeling

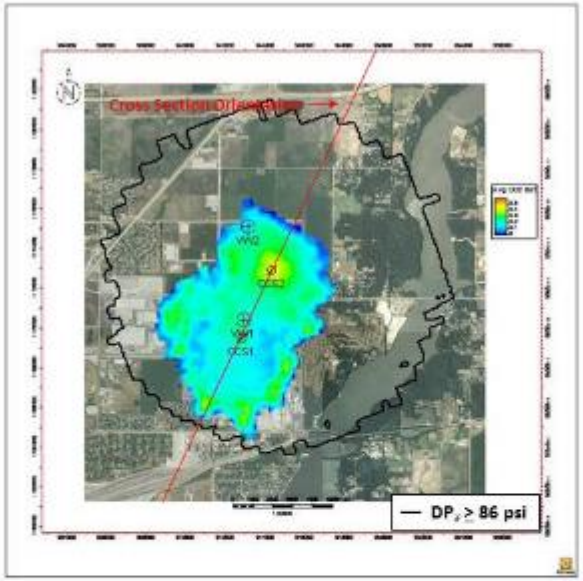
Extent of Plume & Saturation Cross Section
January 1, 2017 [$DP_{if} \geq 86$ psi, $SCO_2 \geq 1.0\%$]

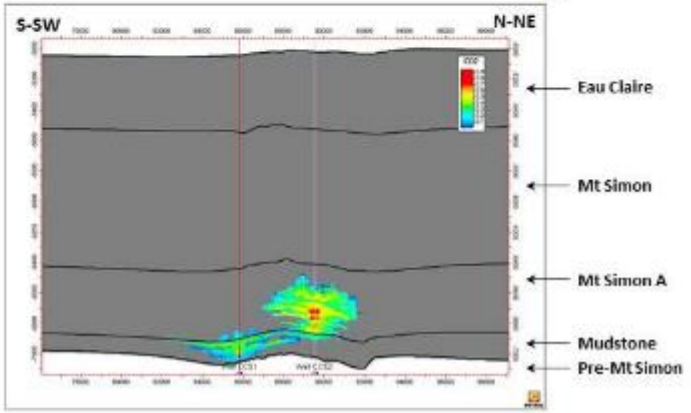




Geophysical Modeling

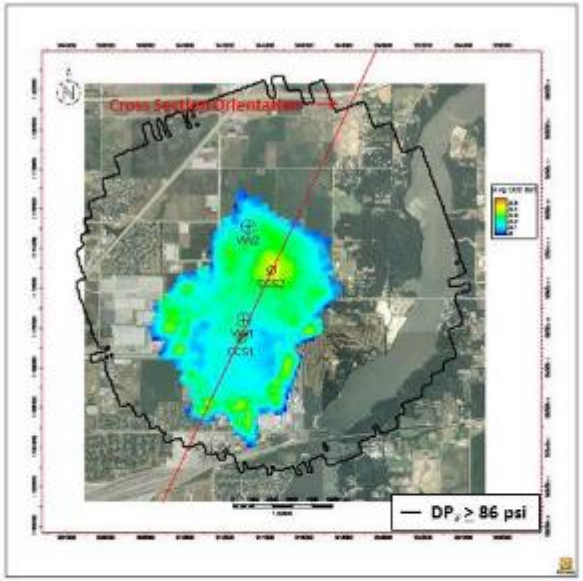
Extent of Plume & Saturation Cross Section
January 1, 2018 [$DP_{if} \geq 86$ psi, $SCO_2 \geq 1.0\%$]

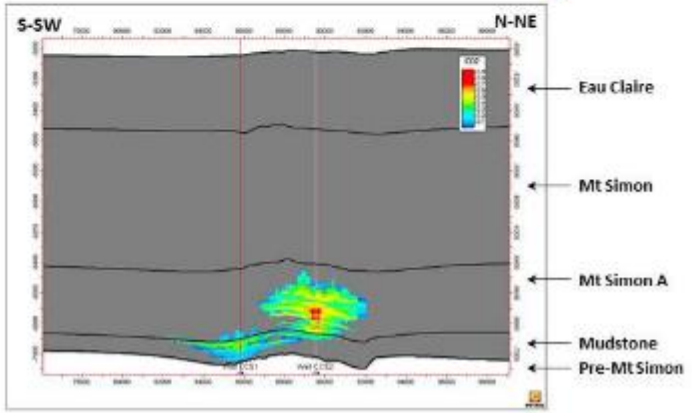




Geophysical Modeling

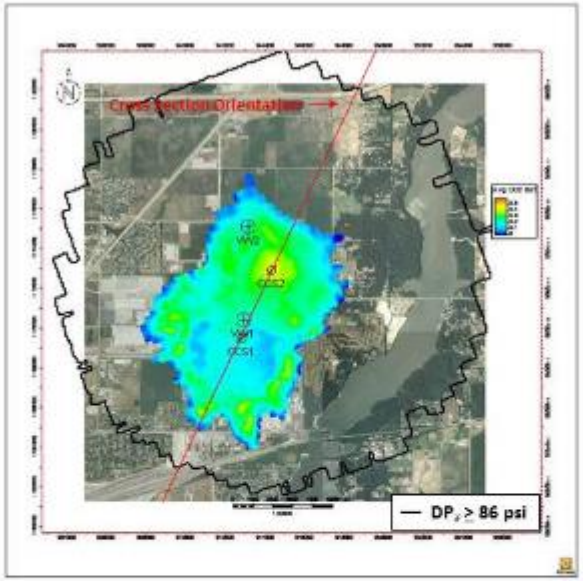
Extent of Plume & Saturation Cross Section
January 1, 2019 [$DP_{if} \geq 86$ psi, $SCO_2 \geq 1.0\%$]

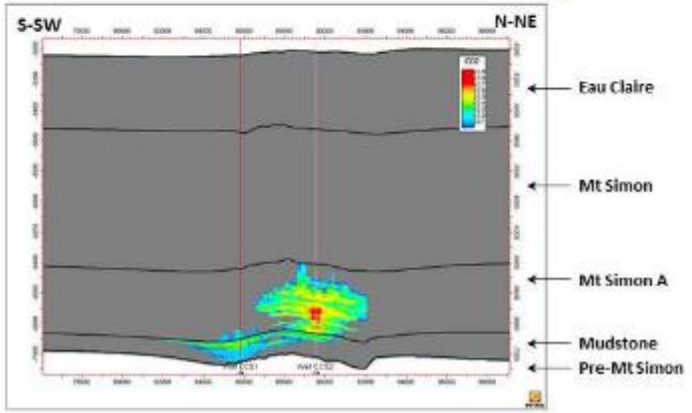




Geophysical Modeling

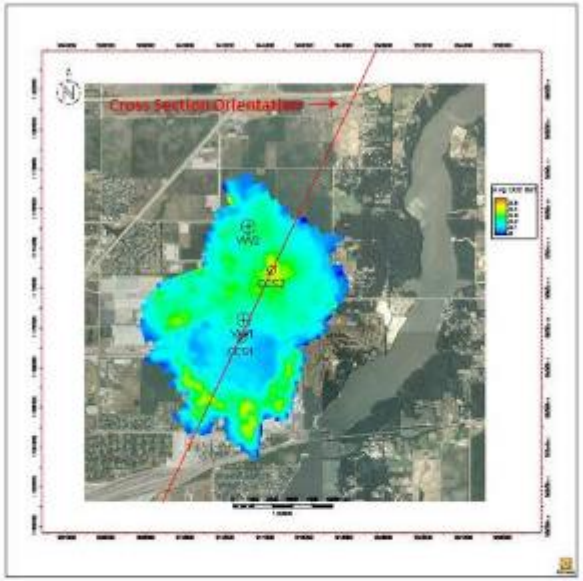
Extent of Plume & Saturation Cross Section
January 1, 2020 [$DP_{if} \geq 86$ psi, $SCO_2 \geq 1.0\%$]

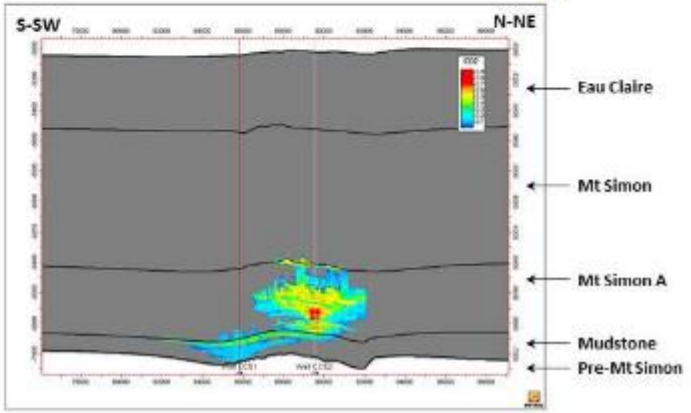




Geophysical Modeling

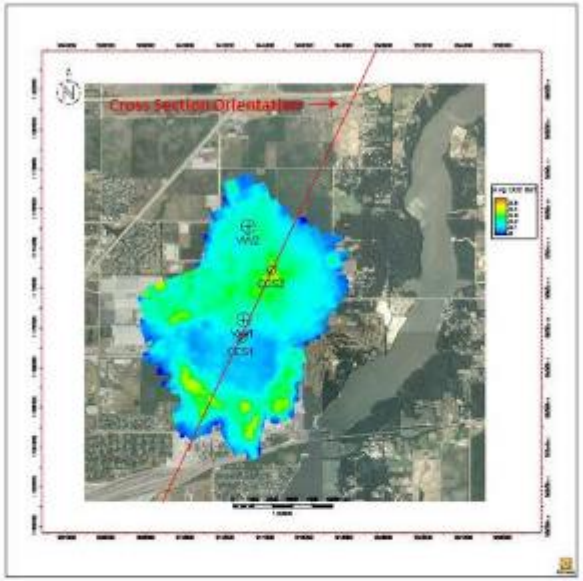
Extent of Plume & Saturation Cross Section
January 1, 2025 [$SCO_2 \geq 1.0\%$]

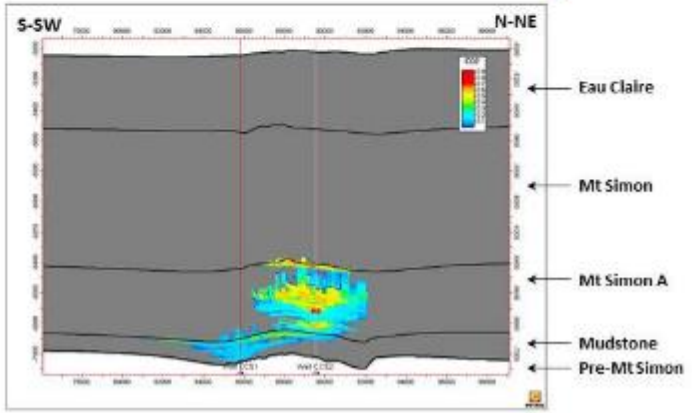




Geophysical Modeling

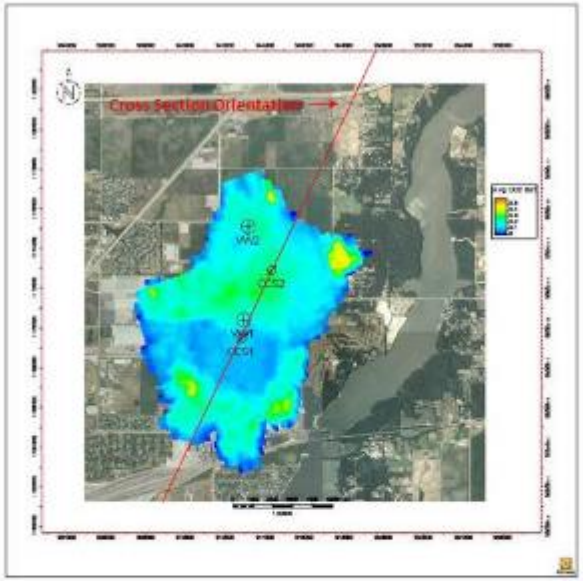
Extent of Plume & Saturation Cross Section
January 1, 2030 [$SCO_2 \geq 1.0\%$]

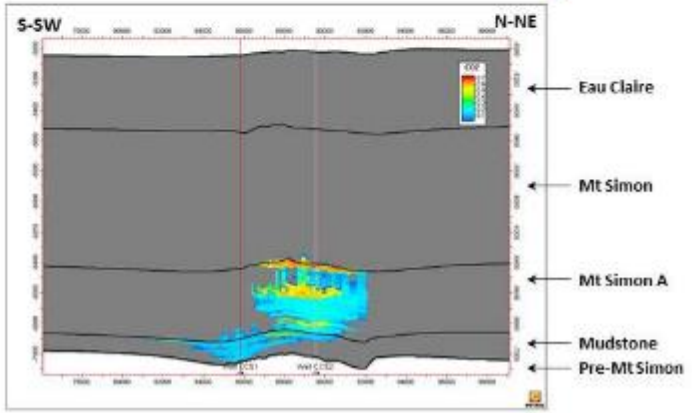




Geophysical Modeling

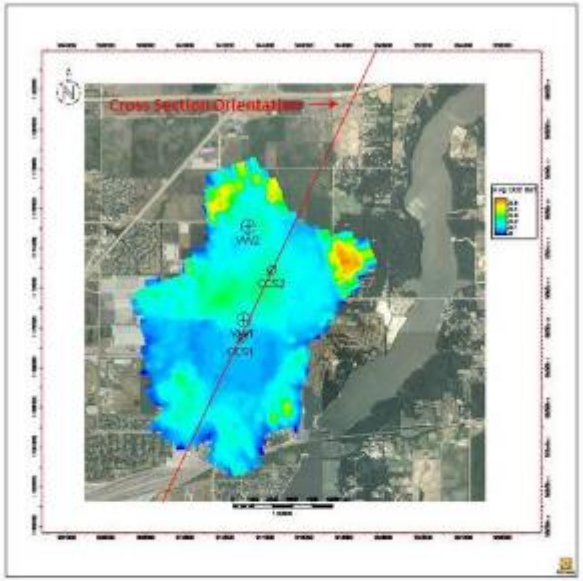
Extent of Plume & Saturation Cross Section
January 1, 2040 [$SCO_2 \geq 1.0\%$]

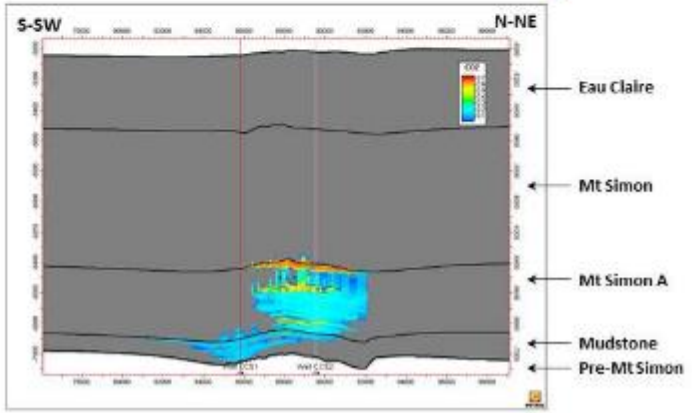




Geophysical Modeling

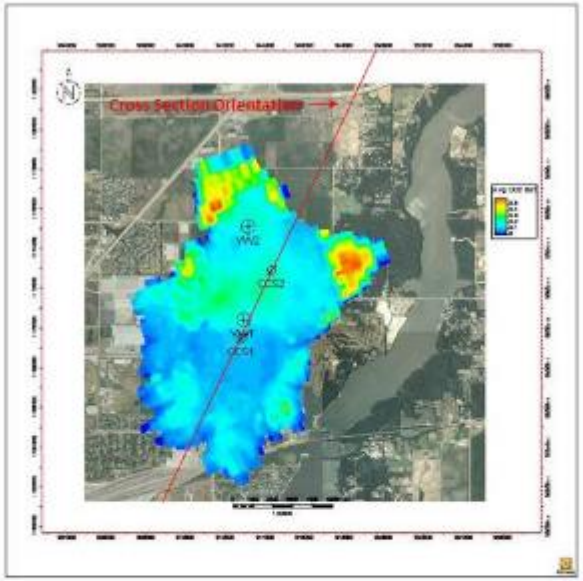
Extent of Plume & Saturation Cross Section
January 1, 2050 [$SCO_2 \geq 1.0\%$]

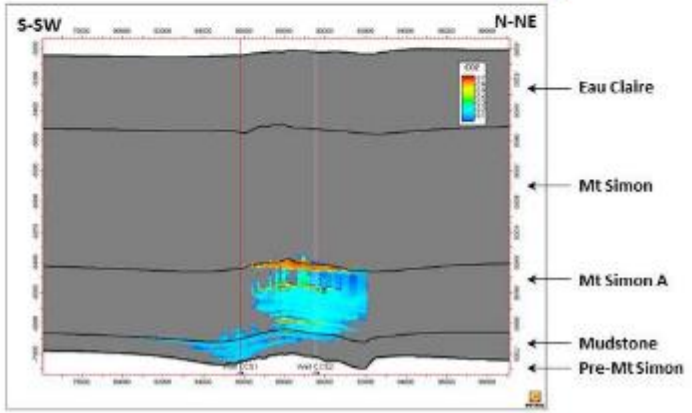




Geophysical Modeling

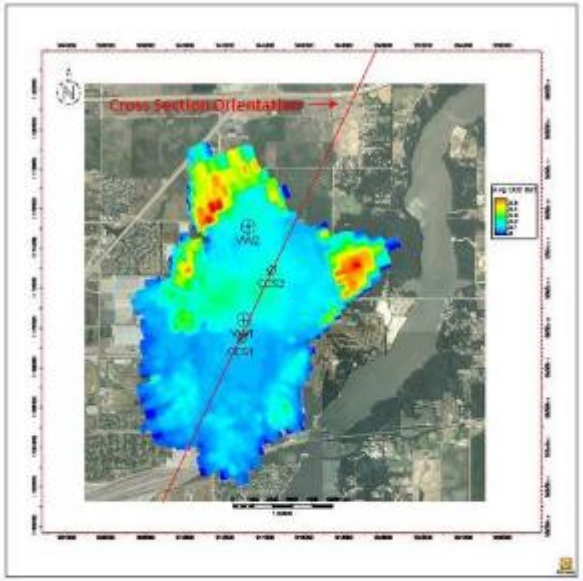
Extent of Plume & Saturation Cross Section
January 1, 2060 [$SCO_2 \geq 1.0\%$]

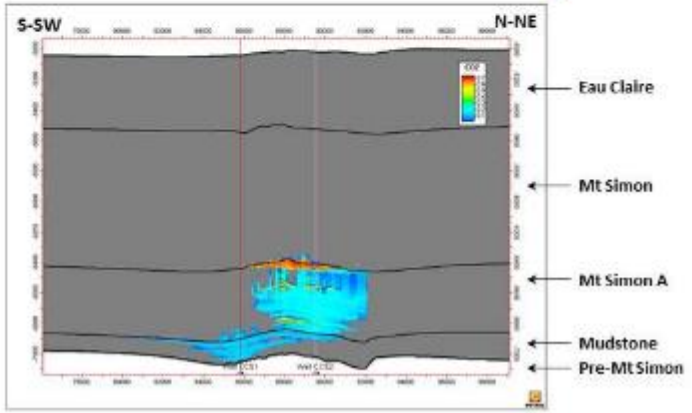




Geophysical Modeling

Extent of Plume & Saturation Cross Section
January 1, 2070 [$SCO_2 \geq 1.0\%$]





Site Permitting

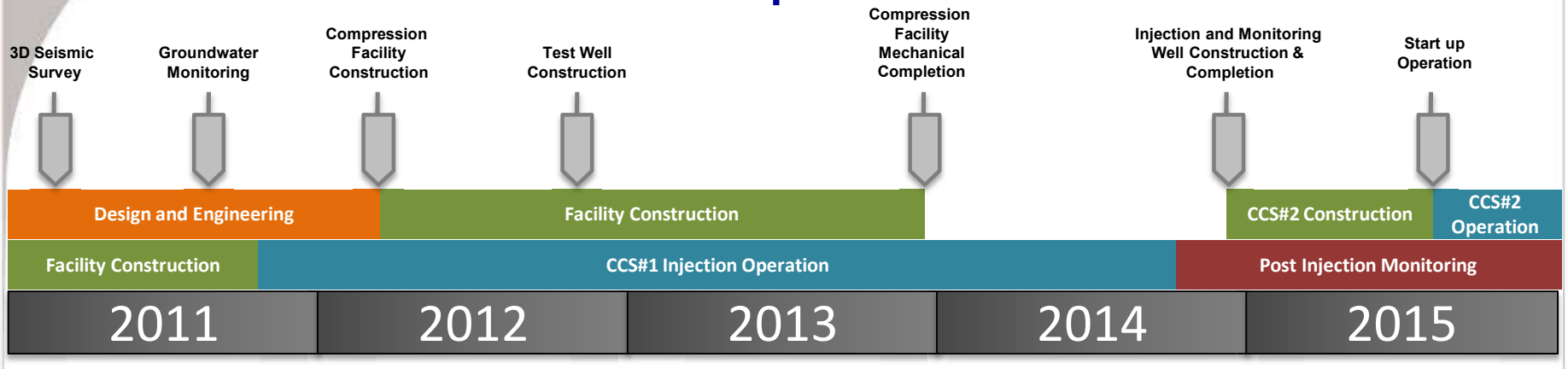
USEPA: UIC Class VI Permit

1st UIC Class VI Permit Application Reviewed by the USEPA

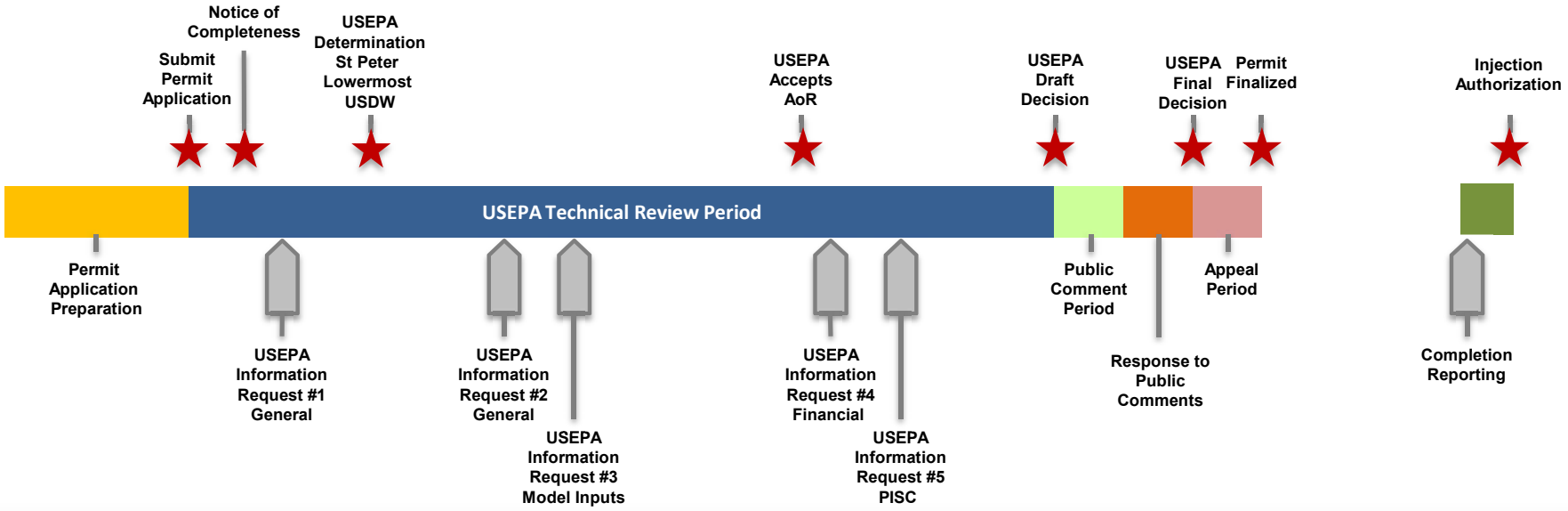
- **UIC Class VI permit application submitted on July 25, 2011.**
- **US EPA Region V issued a draft permit on April 15, 2014.**
- **Public hearing conducted on May 21, 2014.**
- **Public Comment Period concluded May 31, 2014.**
- **Final permit issued December 28, 2014.**

ICCS & IBDP Project Timelines

ICCS & IBDP Construction and Operations Timeline



ICCS Permitting Timeline

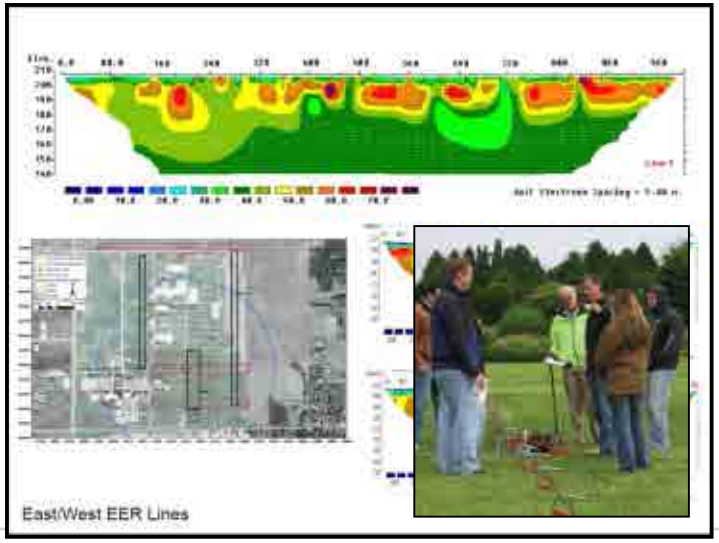


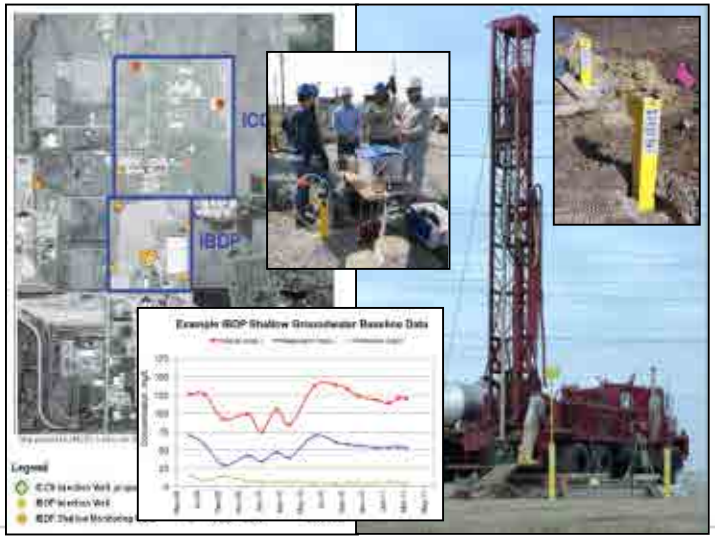
Environmental Monitoring (MVA)
Conceptual Framework

Near Surface		Deep Subsurface	
Soil and Vadose Zone	Ground Water	Above Seal	Injection Zone
Aerial Imagery Soil CO_2 Flux	Geochemical Sampling P/T Monitoring	Geophysical Surveys Seismic Monitoring P Monitoring	Geophysical Surveys Geochemical sampling P/T Monitoring

Environmental Monitoring
Near Surface Monitoring

- Near infrared aerial imagery will be used to evaluate plant stress
- Soil resistivity characterized shallow depths for identification of optimum GWM locations
- GWM for baseline conditions and operational surveillance
- Surface soil CO_2 flux monitoring





Environmental Monitoring
Deep Subsurface Monitoring

- CCS#1 & CCS#2 T/P monitoring
- Distributed Temp Sensor
- VW#1 Westbay system
- VW#2 IntelliZone System
- Multi-level sampling ports reservoir fluid collection and T/P monitoring
- P/T sensors to monitor above the reservoir seal
- GM#1 has 31 sensor array
- GM#2 5 level 20 sensor array w P/T at 3500’
- Allow offset or walkaway Vertical Seismic Profile (VSP)
- Well logging (RST)

Surface Seismic Monitoring

SM#5

VW#2

ILLINOIS INDUSTRIAL CARBON CAPTURE & STORAGE

SM#3

GM#2

CCS#2

SM#1

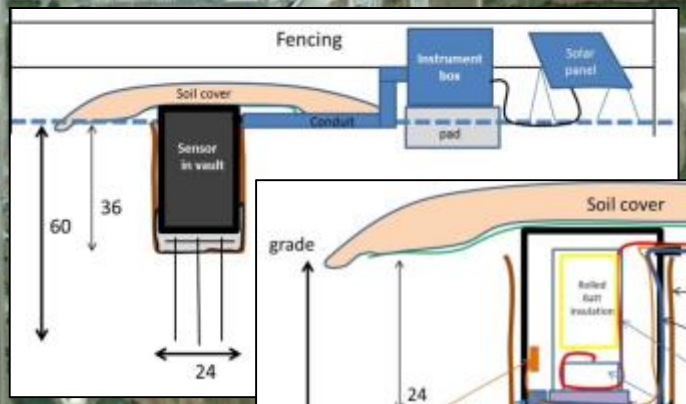
VW#1

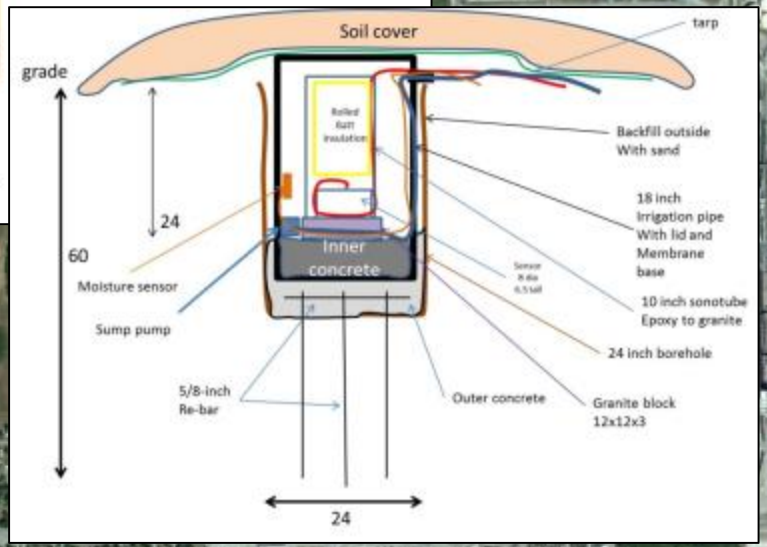
CCS#1

GM#1

SM#2

SM#4





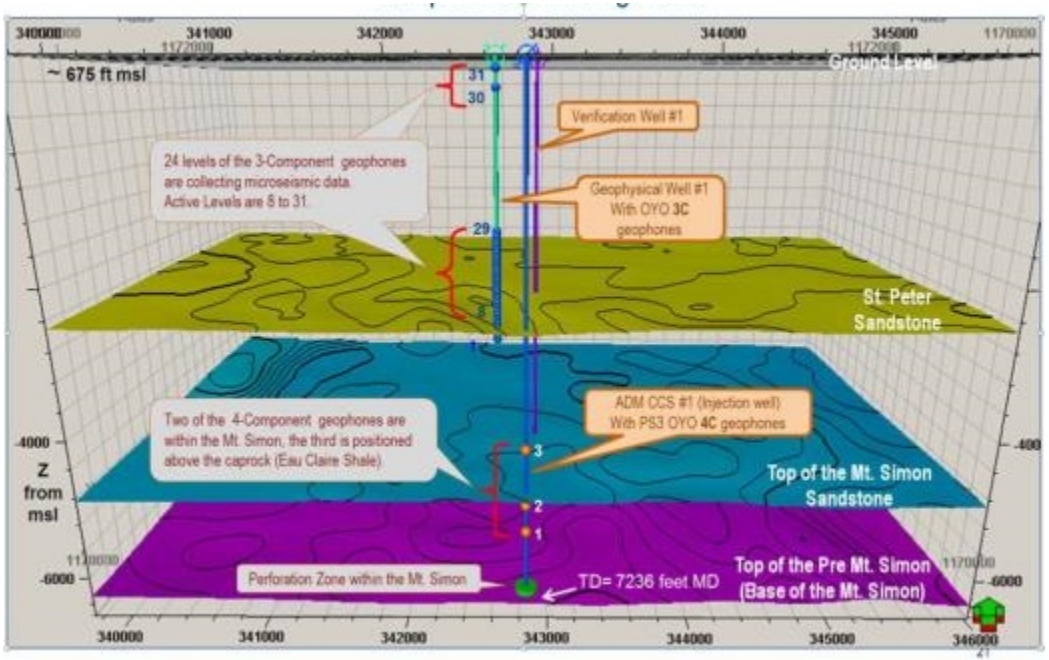
Seismic Monitoring

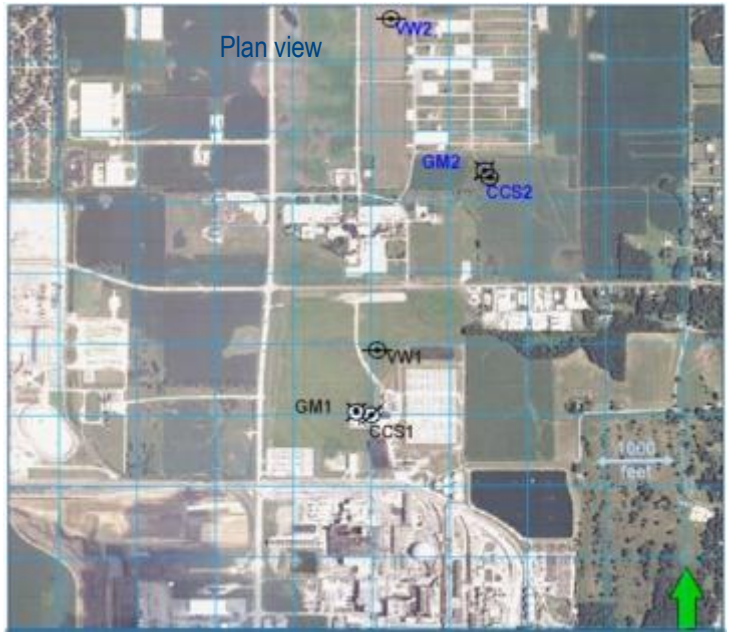
USGS Site Monitoring

Deep Seismic Monitoring

- 3 4C Geophones in CCS1
- 24 Active Geophones in GM1
- Monitoring Started May 2010
- Geoware LTD is processing data
- SCS analyzing results
- Processing of pre-injection data

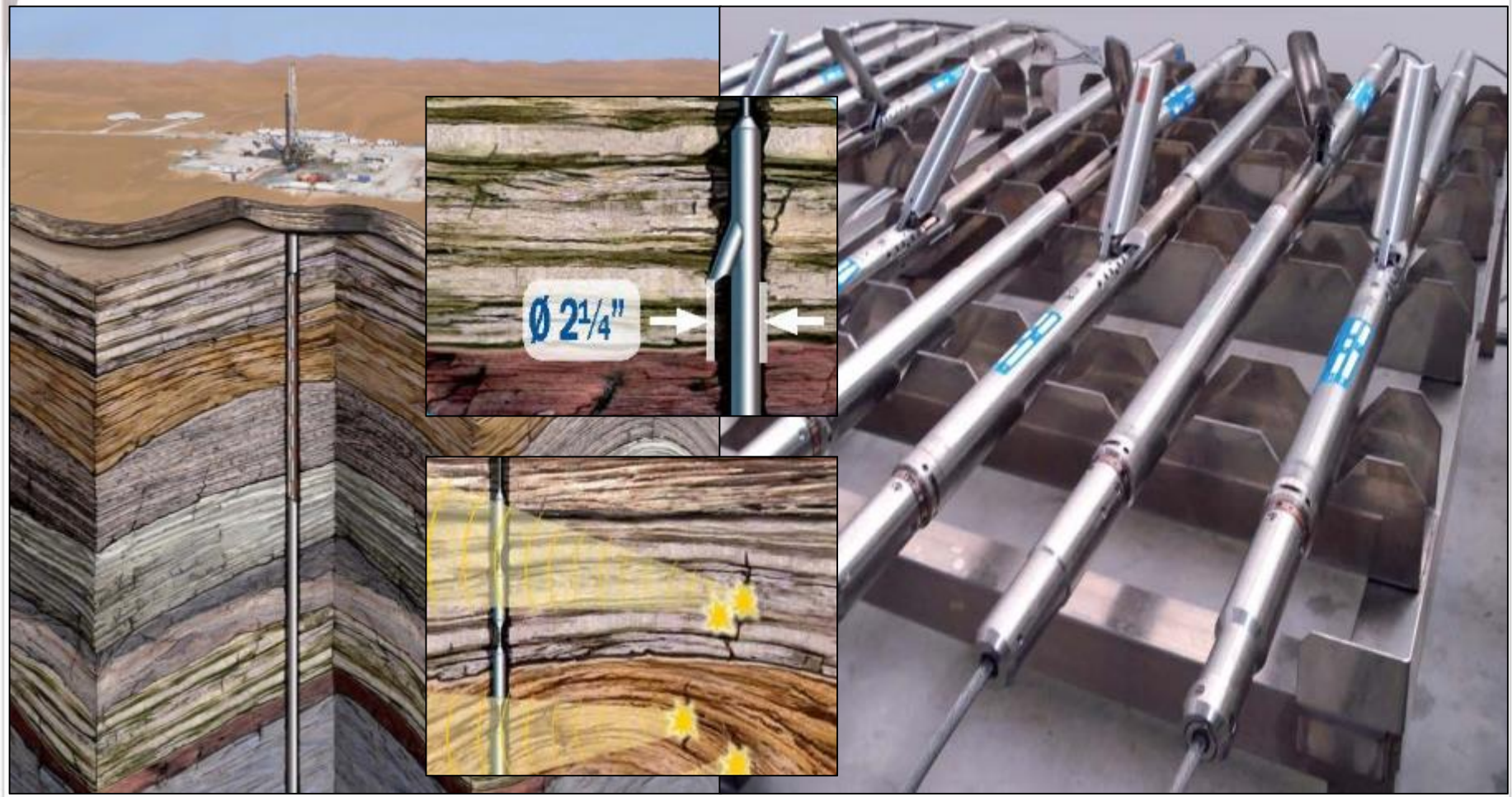
Schlumberger Carbon Services



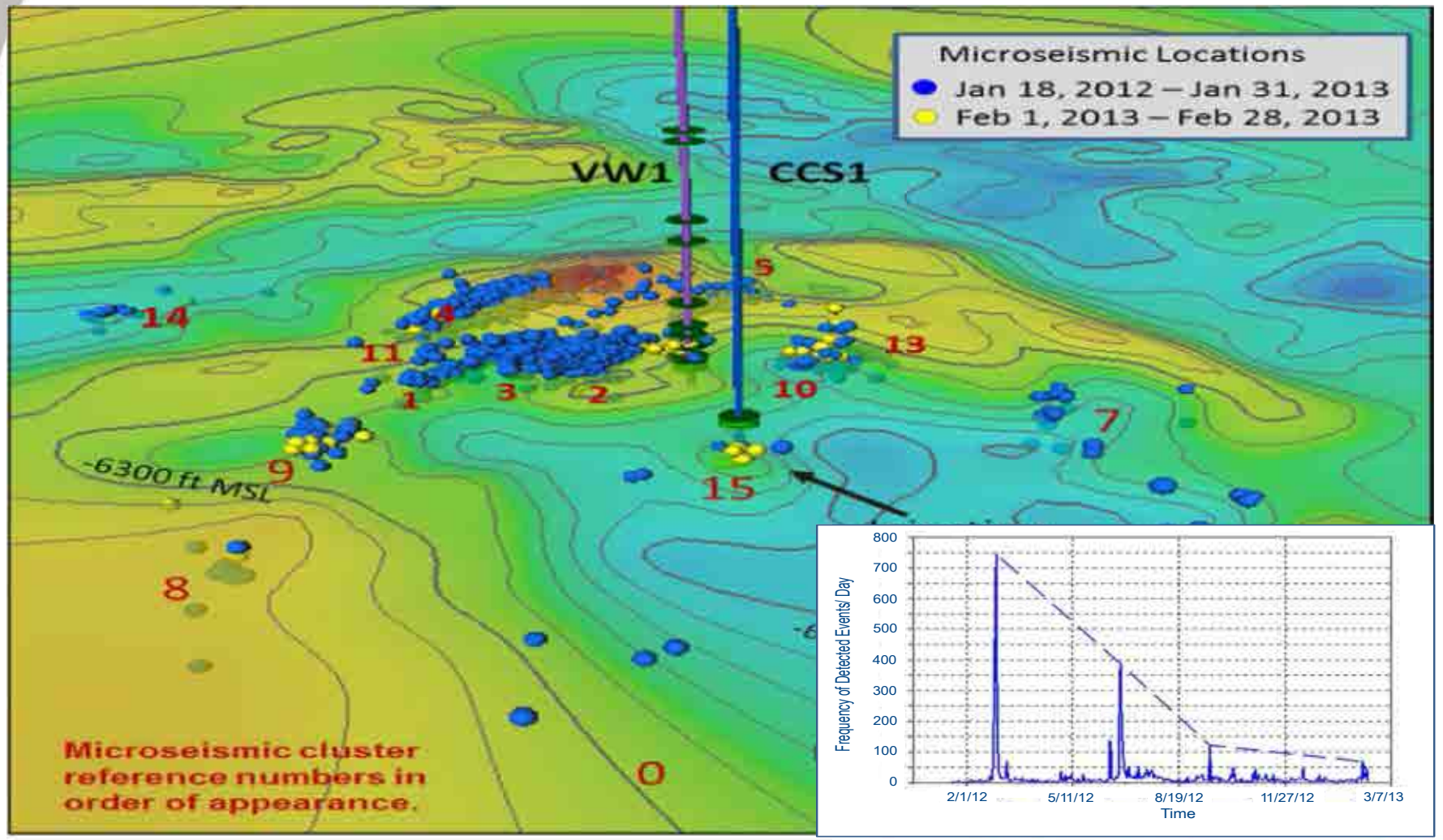


Deep Seismic Monitoring

"Slim Wave" Retrievable Geophones



Seismic Monitoring Data

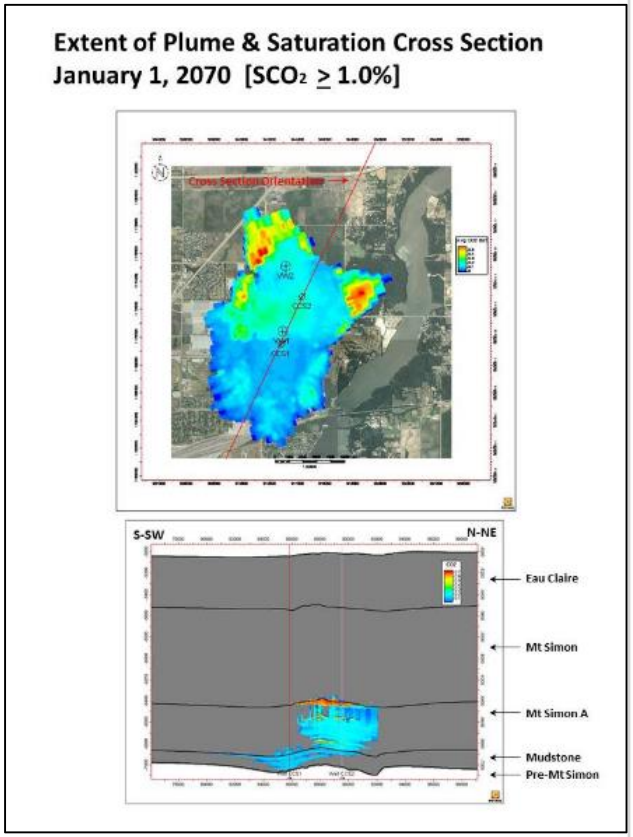


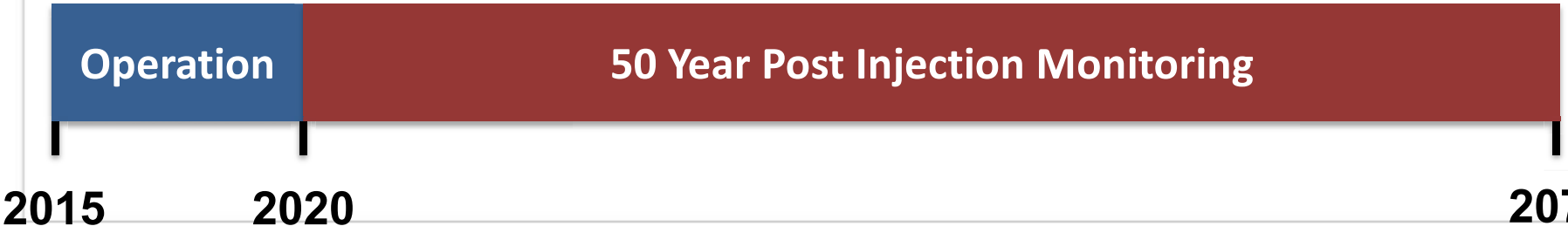
Main Challenges

Alternative PISC Timeframe

ILLINOIS INDUSTRIAL CARBON CAPTURE & STORAGE

- **Default PISC is 50 Years**
- **Applicant allowed to petition for an alternative timeframe**
- **ADM Proposed 10 Year PISC**
  - **Reservoir Pressure Decline**
  - **Plume Stabilization**
  - **CO_2 Partitioning**





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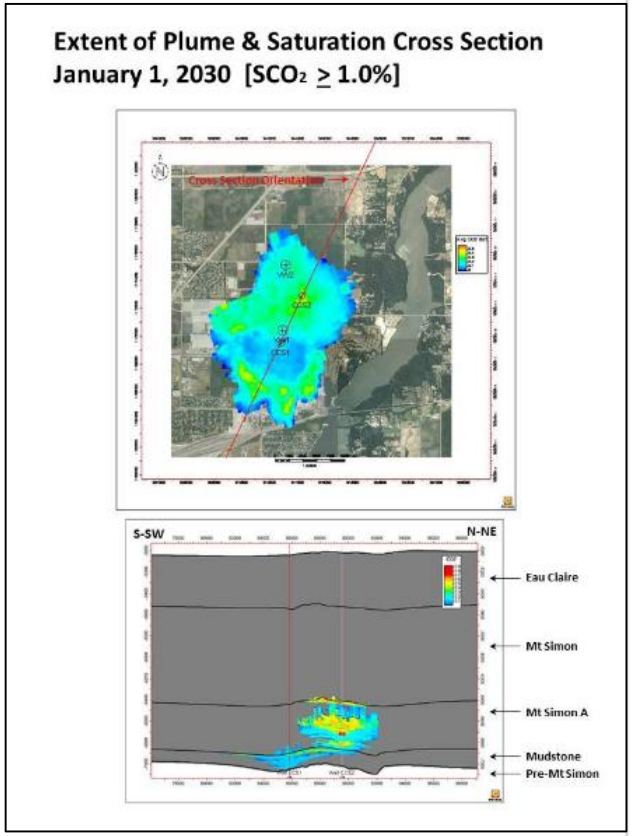
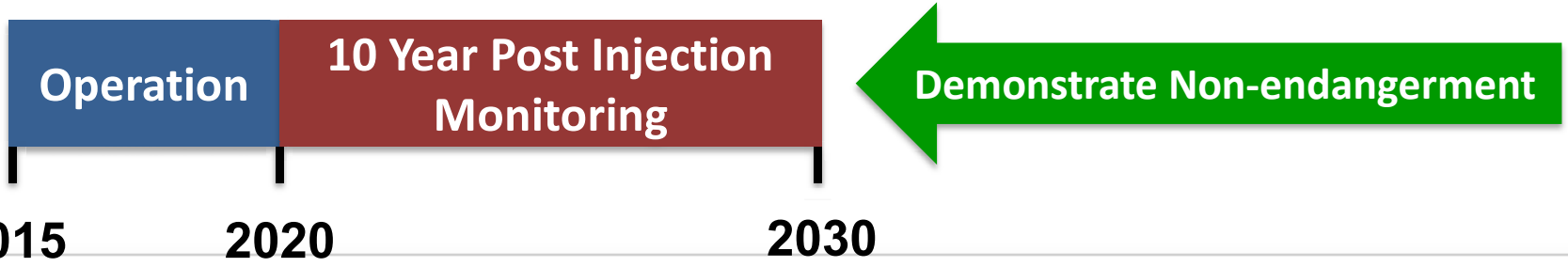


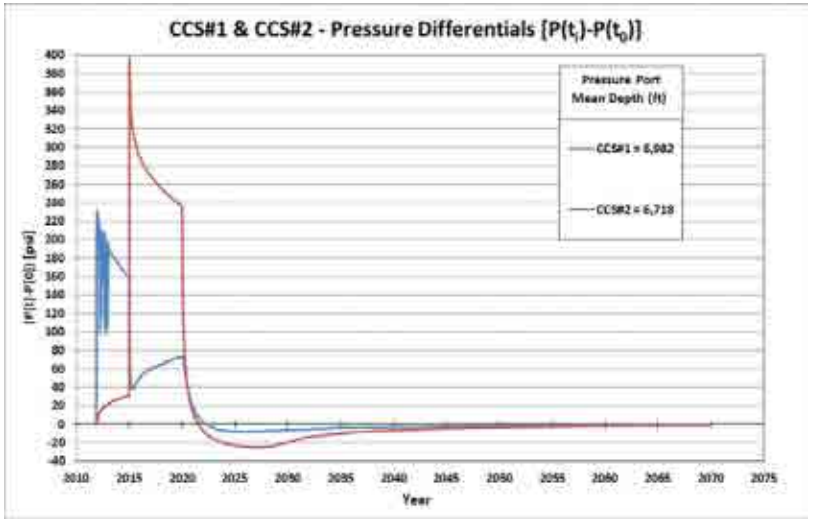


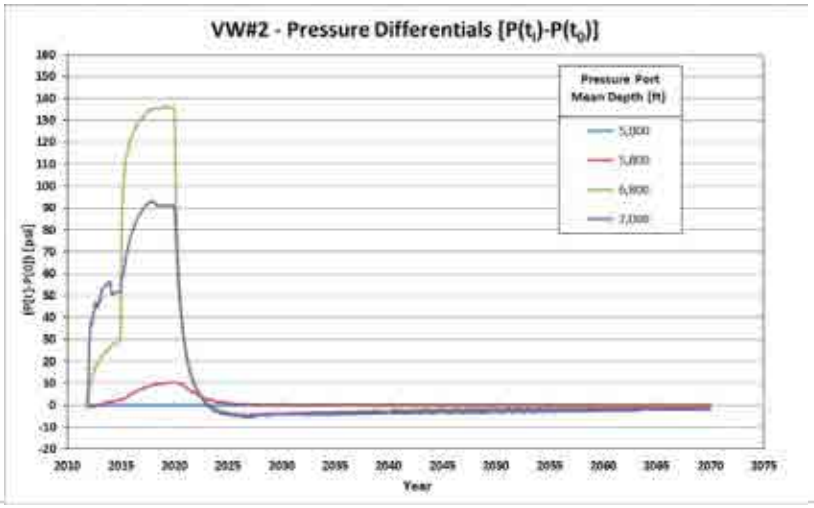
Demonstrate Non-endangerment

Alternative PISC Timeframe

Reservoir Pressure Decline

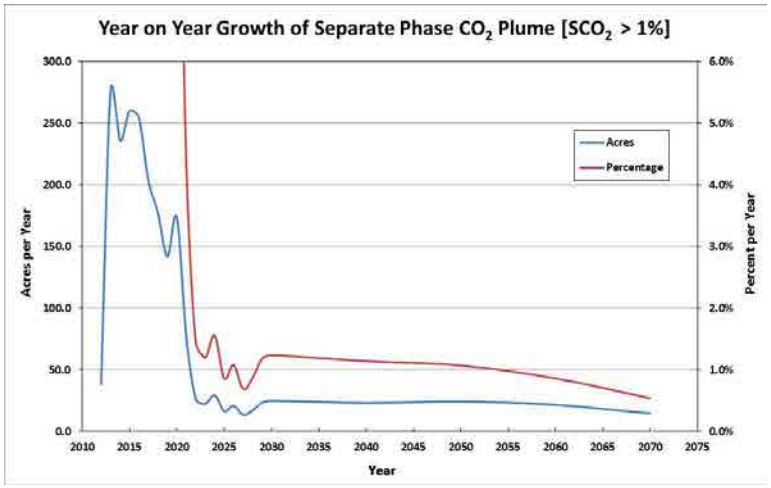
Aggregate differential pressure contours at the end of the operational period.

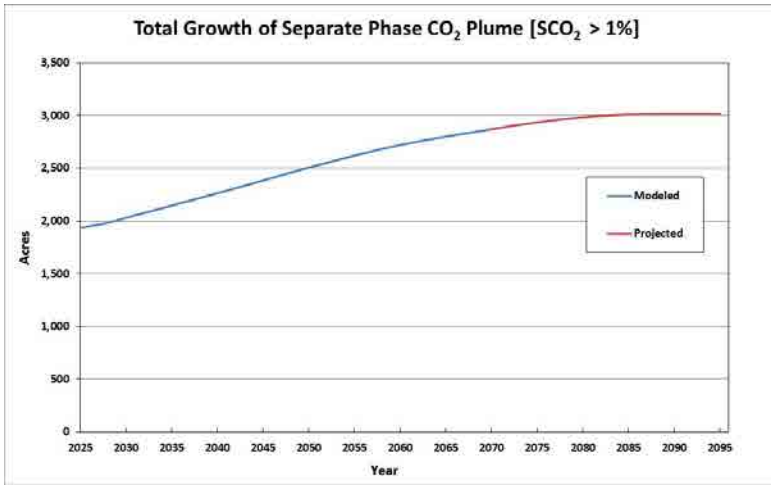


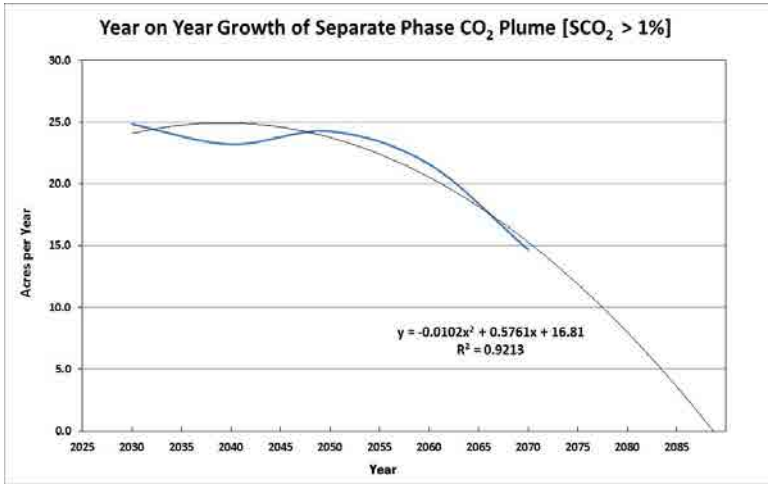


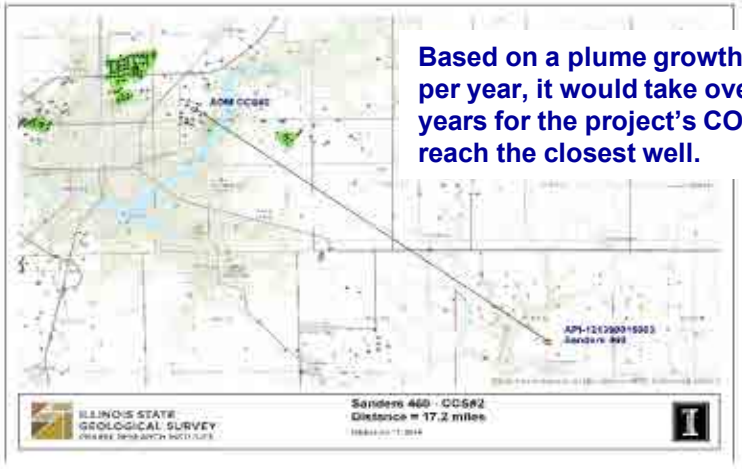
Alternative PISC Timeframe

CO_2 Plume Stabilization



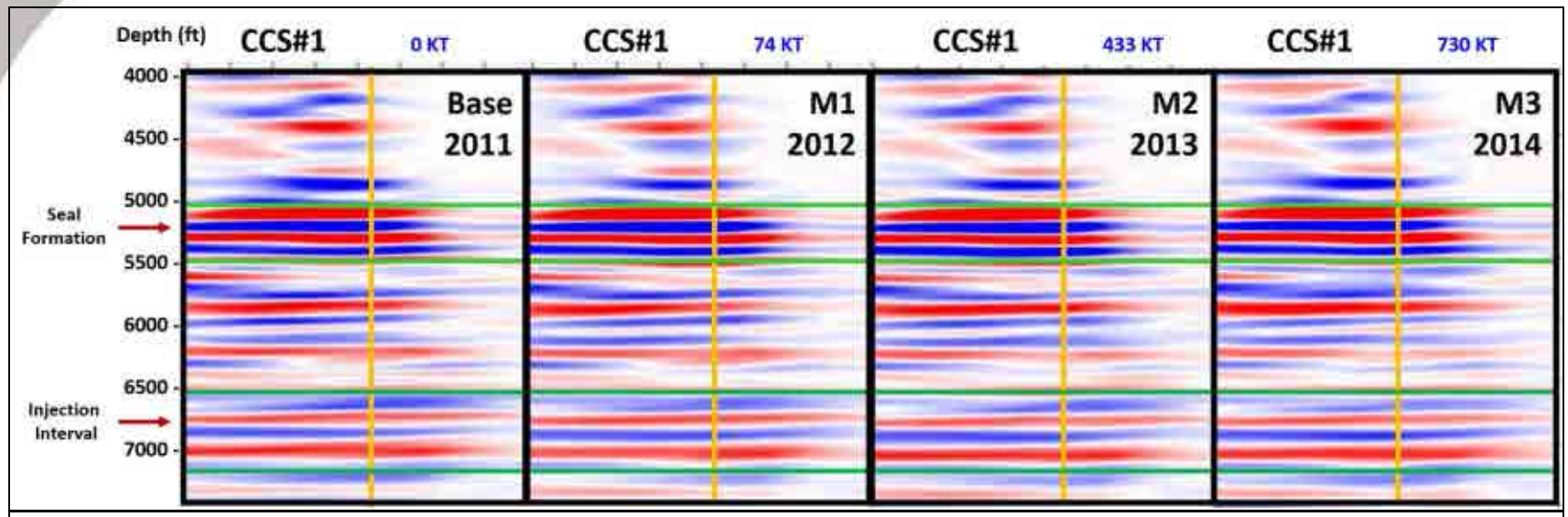


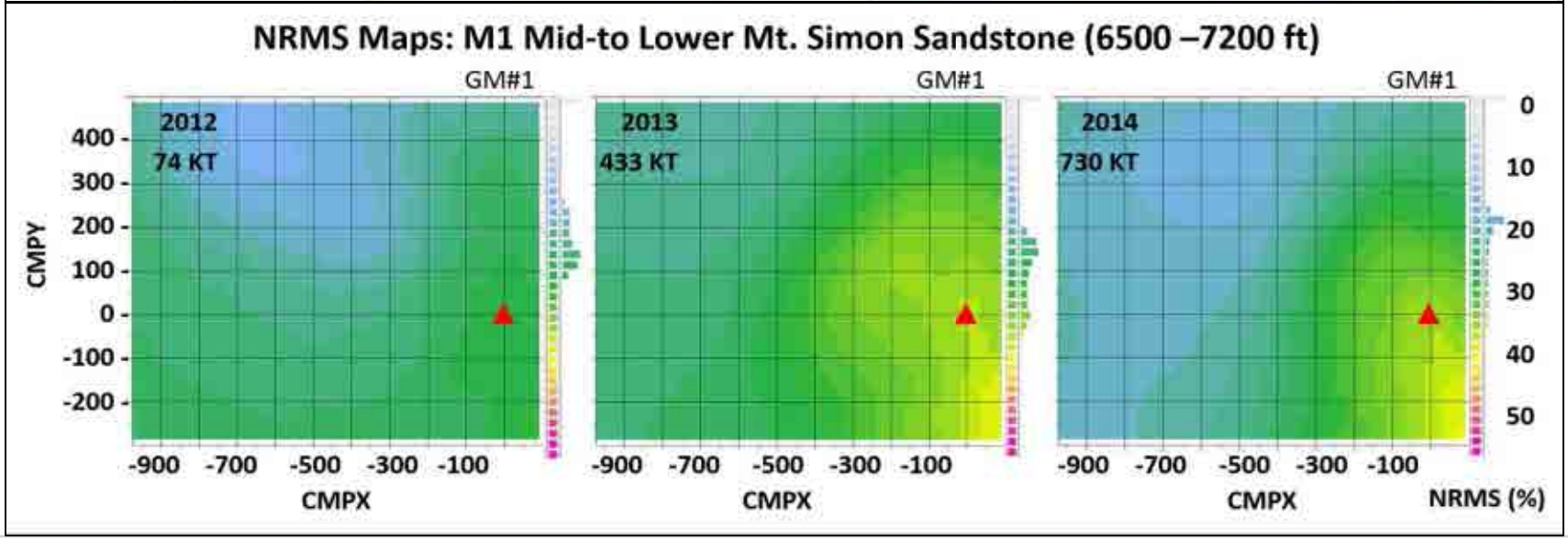




Based on a plume growth of 1.0% per year, it would take over 600 years for the project's CO2 plume to reach the closest well.

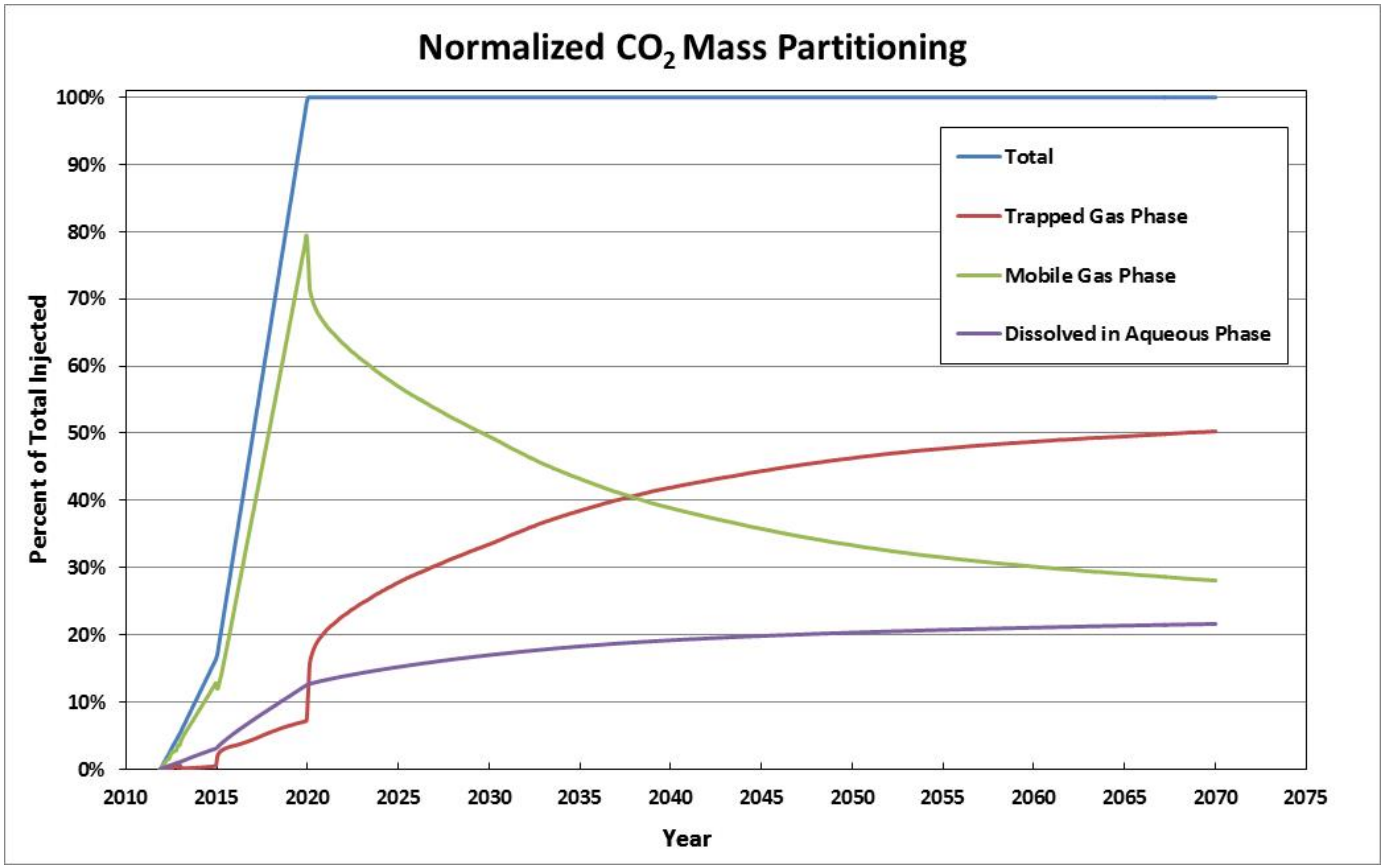
Time Lapse VSP Surveys





Alternative PISC Timeframe

CO_2 Mass Partitioning



Over 50% of the CO_2 is trapped within the reservoir after 10 years.

CO_2 Collection Facility

1750 hp Centrifugal Compressor

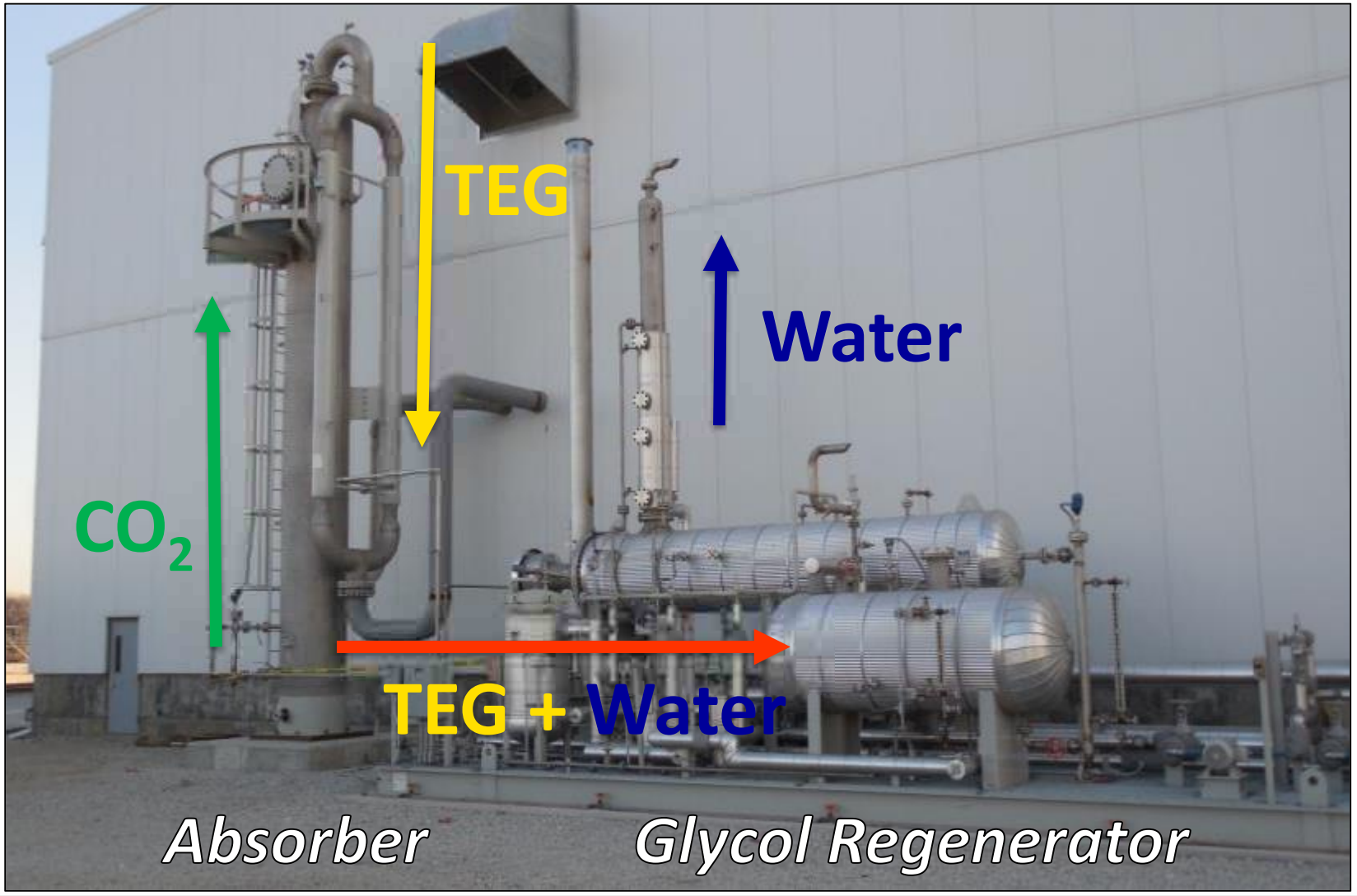
Low Pressure CO_2 Delivery

Main Compression Building

Main Compression Building

Main Compression Building

CO_2 Dehydration Unit



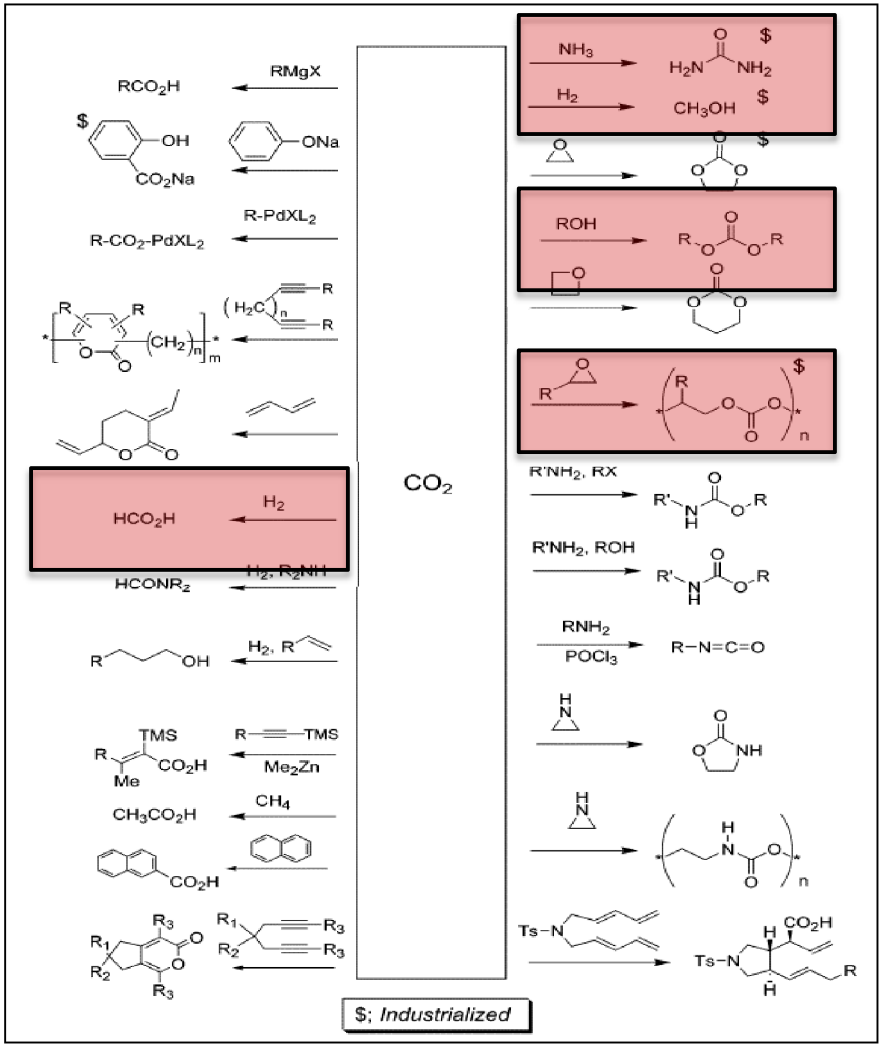
Main Compression Building

HP CO_2 Transmission Line

IBDP Injection Well

CO_2 Based Chemicals

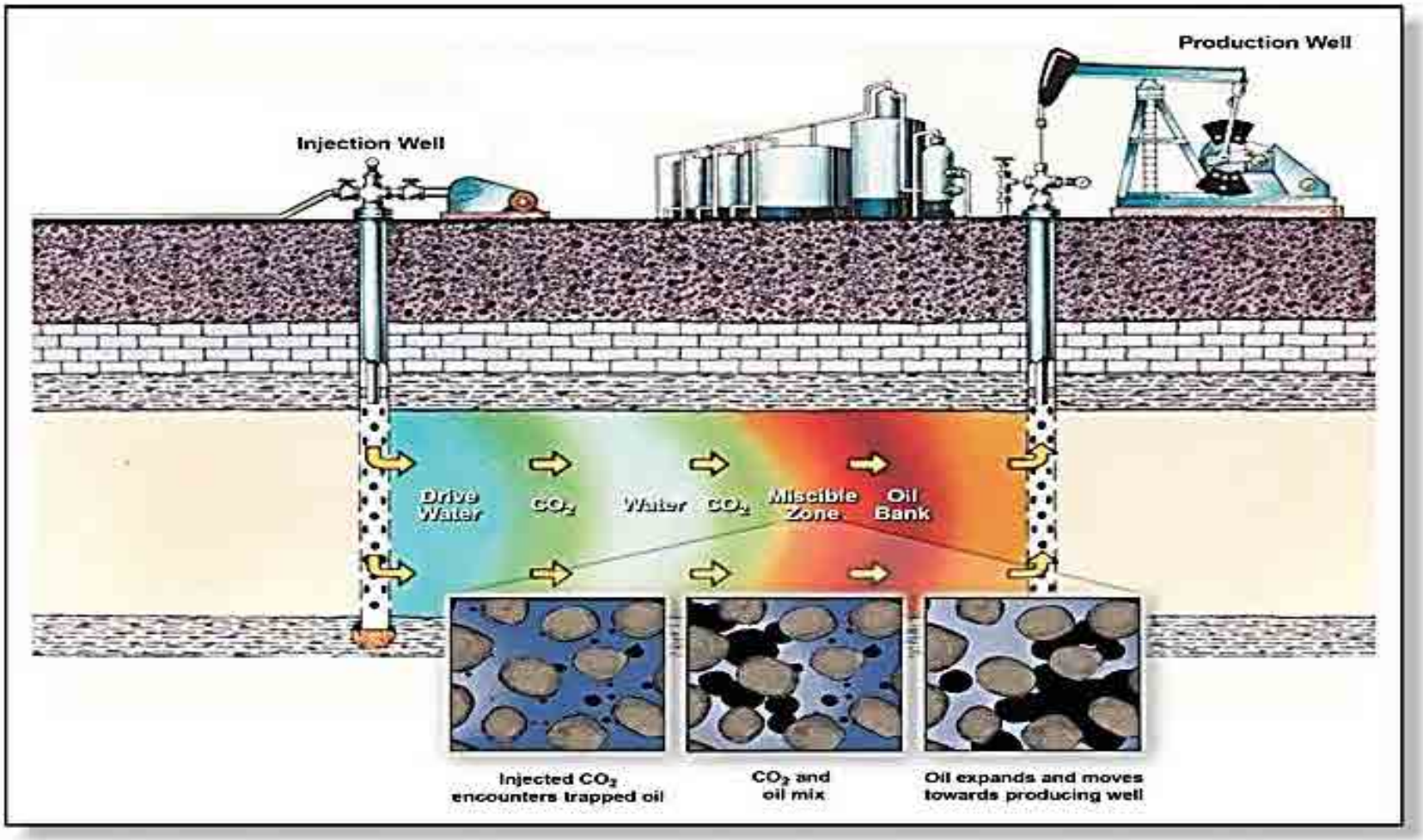
- **Carbonates**
  - Glycerol Carbonate
  - Propylene Carbonate
  - Dimethyl Carbonate
- **Fertilizers**
- **Alcohols**
- **Fuels**
- **Acids**
- **Others**



Transformation of Carbon Dioxide, Sakakura, Choi, & Yasuda, 2007

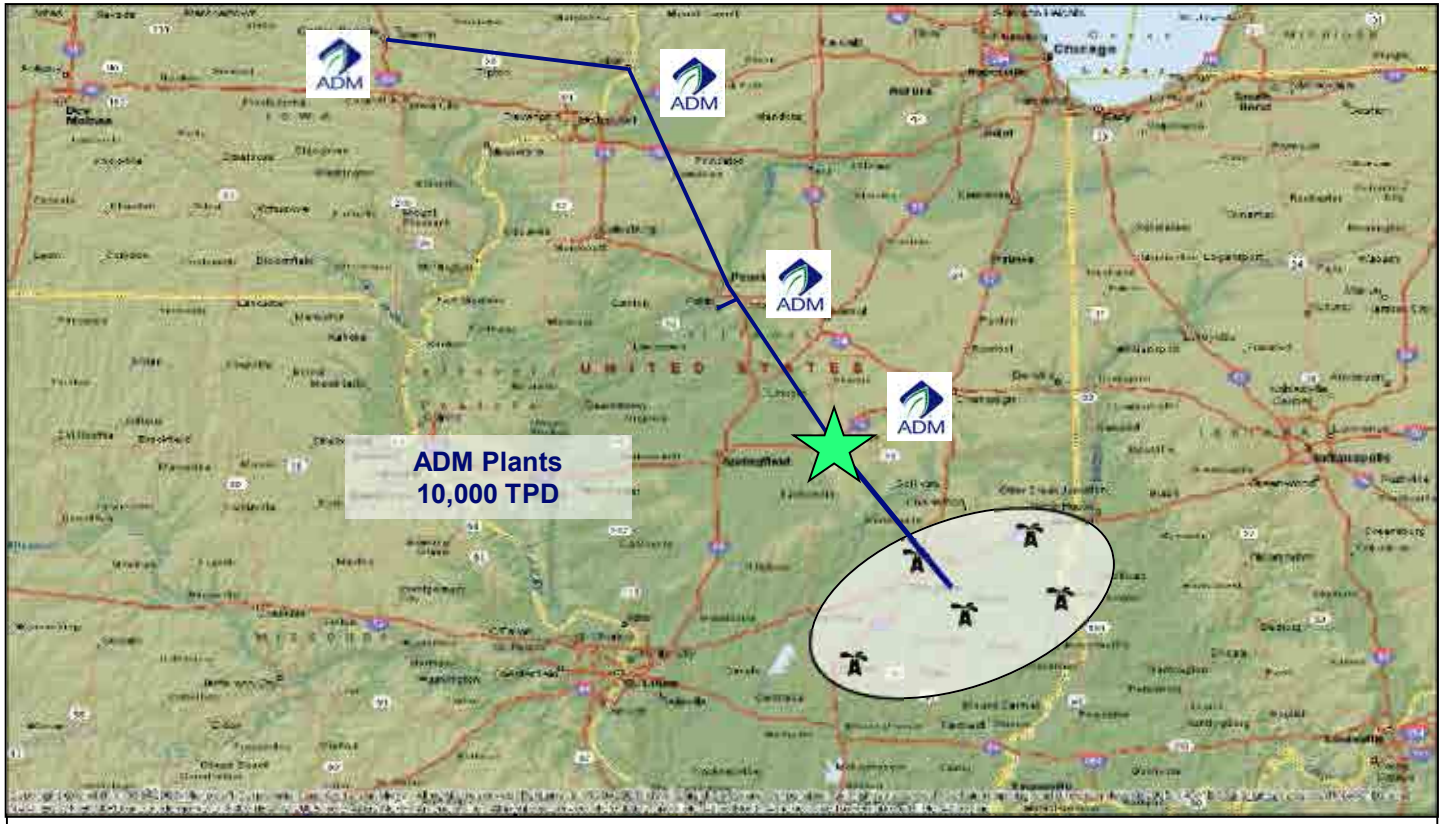
Enhanced Oil Production

http://www.youtube.com/watch?v=azLVjYij5U4



Cross-section illustrating how carbon dioxide and water can be used to flush residual oil from a subsurface rock formation between wells

Illinois Basin Potential



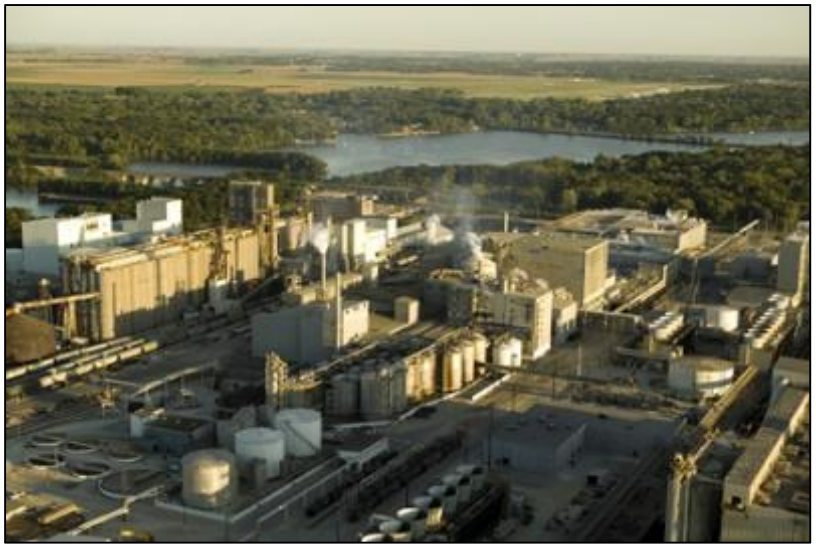
- Illinois Basin - Oil Producing Region
- Est. Recoverable Oil = 700 million bbls(1)
- Est. CO_2 Requirements = 150 million tons

(1) BASIN ORIENTED STRATEGIES FOR CO2 ENHANCED OIL RECOVERY: ILLINOIS AND MICHIGAN BASIN OF ILLINOIS, INDIANA, KENTUCKY AND MICHIGAN; Advanced Resources International, February 2006

Future Commercial Potential

- Direct Application
  - EOR
  - CO_2 Liquids
- Product Development
  - CO_2 Based Chemicals
- Process Development
  - SC Extraction
  - Solvent Applications
- Carbon Management
  - Storage
  - Trading & Risk Management

Environmental and Cost Benefits
GHG Reduction & Fuel LCA



- Reduction in site's CO_2 emissions.
- Process has a GHG reduction efficiency of 94% based on using Midwest electricity grid average.
- Reduction of the carbon footprint of fuel ethanol.
- The operational expense is significantly lower than other forms of CO_2 capture.
- 15 billion gallons annually, represents about 40 million metric tons of CO_2.

Thank You!

Industrial Carbon Capture and Storage Project:

- U.S. Department of Energy Award No. DE-FE-0001547
- Administered by the DOE's Office of Fossil Energy
- Managed by the National Energy Technology Laboratory
- DOE cost share from American Recovery and Reinvestment Act of 2009

Cost Share Agreements:

- Archer Daniels Midland Company
- University of Illinois through the Illinois State Geological Survey
- Schlumberger Carbon Services
- Richland Community College

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