

Wabash CarbonSAFE

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Addressing the Nation's Energy Needs Through Technology Innovation – 2019 Carbon Capture,
Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting

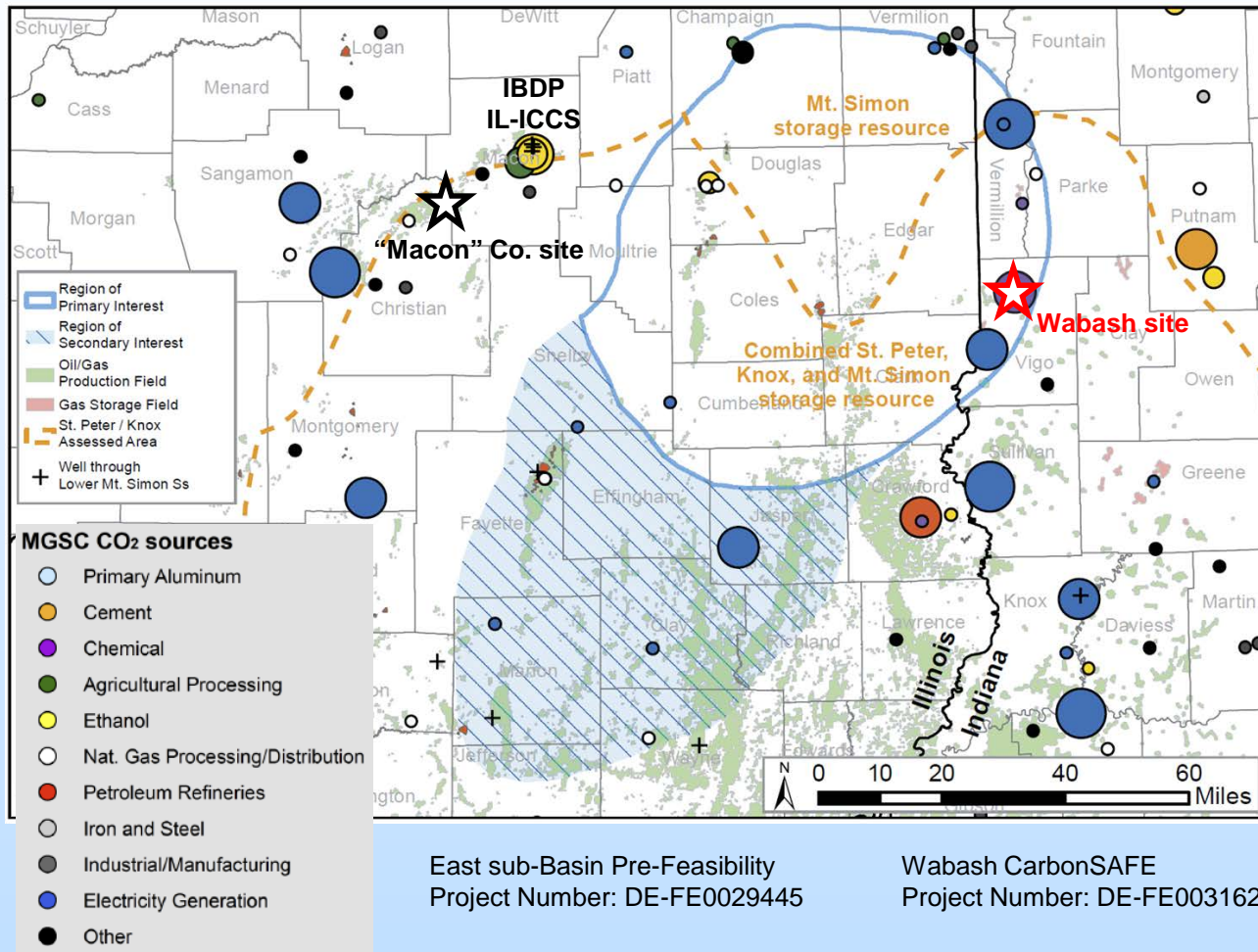
August 26-30, 2019

Presentation Outline

- Phase I (Illinois East Sub-Basin):
 - Overview, Accomplishments
- Phase II (Wabash): Technical Status
 - CO₂ Source and Site Host
 - Storage Complex
 - Data Gaps and Acquisition
 - Selected Tasks: Current Work
- Project Challenges
- Summary, Accomplishments, Next Steps

Phase I: Overview

CarbonSAFE Illinois – East Sub-Basin

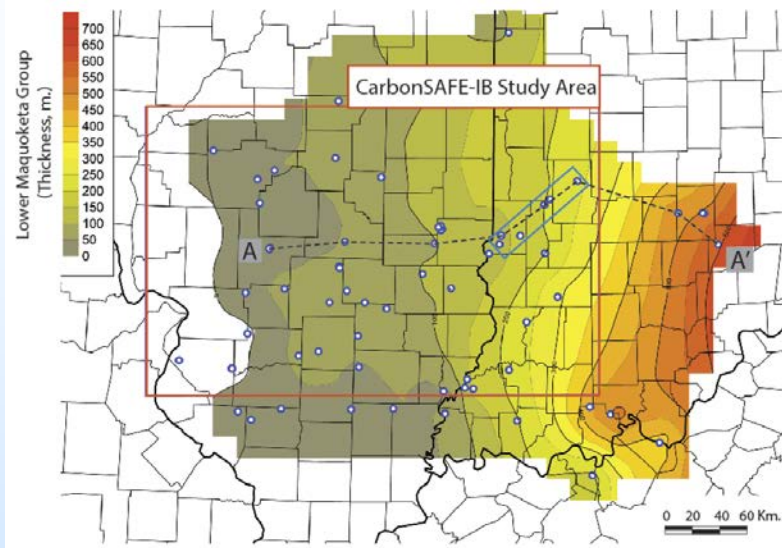


- 04/01/2017–10/31/2019
- Regional assessment of CO₂ sources and saline storage reservoirs/seals
- Building on regional partnership work...
- Primary/secondary areas of geological interest
 - Saline storage options
 - EOR potential



Phase I: Overview

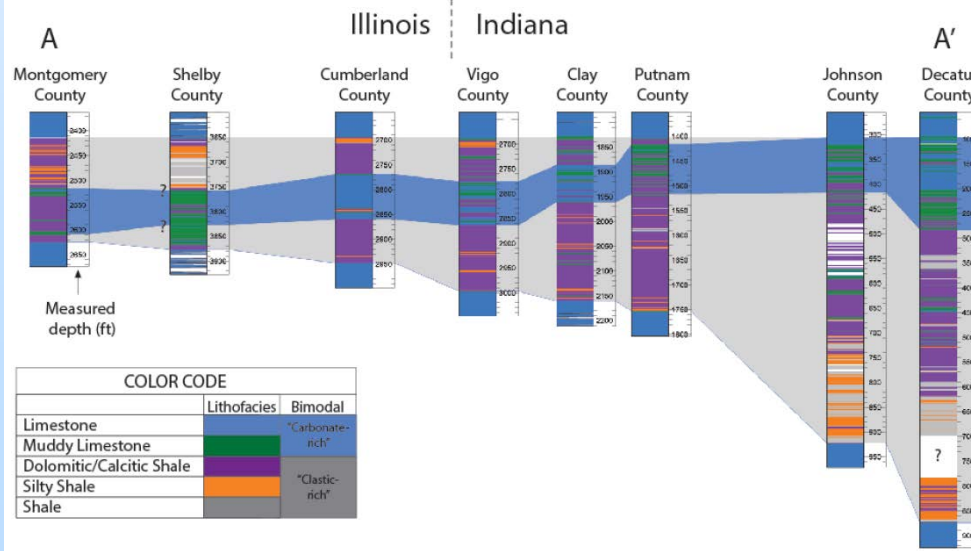
CarbonSAFE Illinois East Sub-Basin (DE-FE0029445)



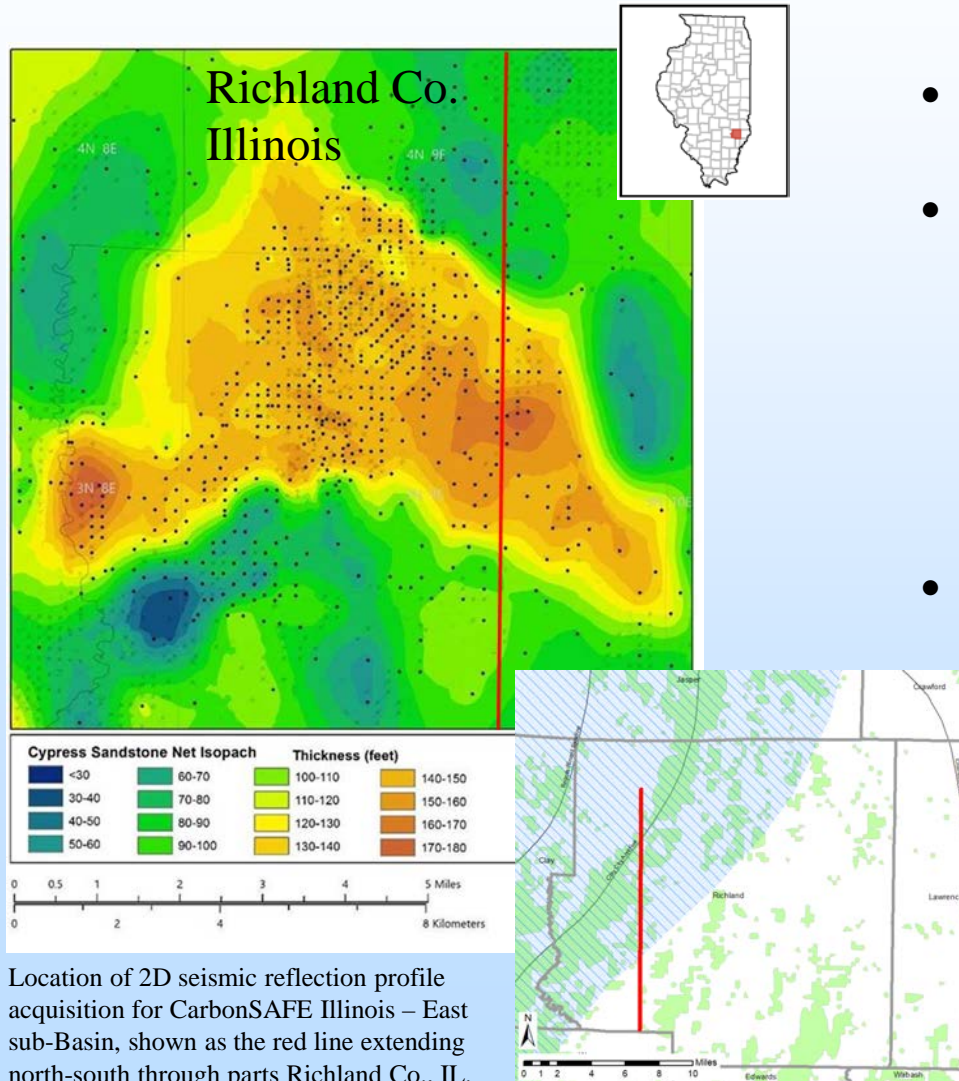
*Regional
thickness of
Lower
Maquoketa Gp*

- Improve geological mapping, regional analysis
- 8 Formations re-mapped
 - Update basic mapping of structure and/or isopach
 - Faults, structures
 - Uncertainty, data gaps/needs
- Evaluation of caprock integrity
 - Secondary seal: Maquoketa Gp

*Maquoketa Gp
Lithofacies
model*



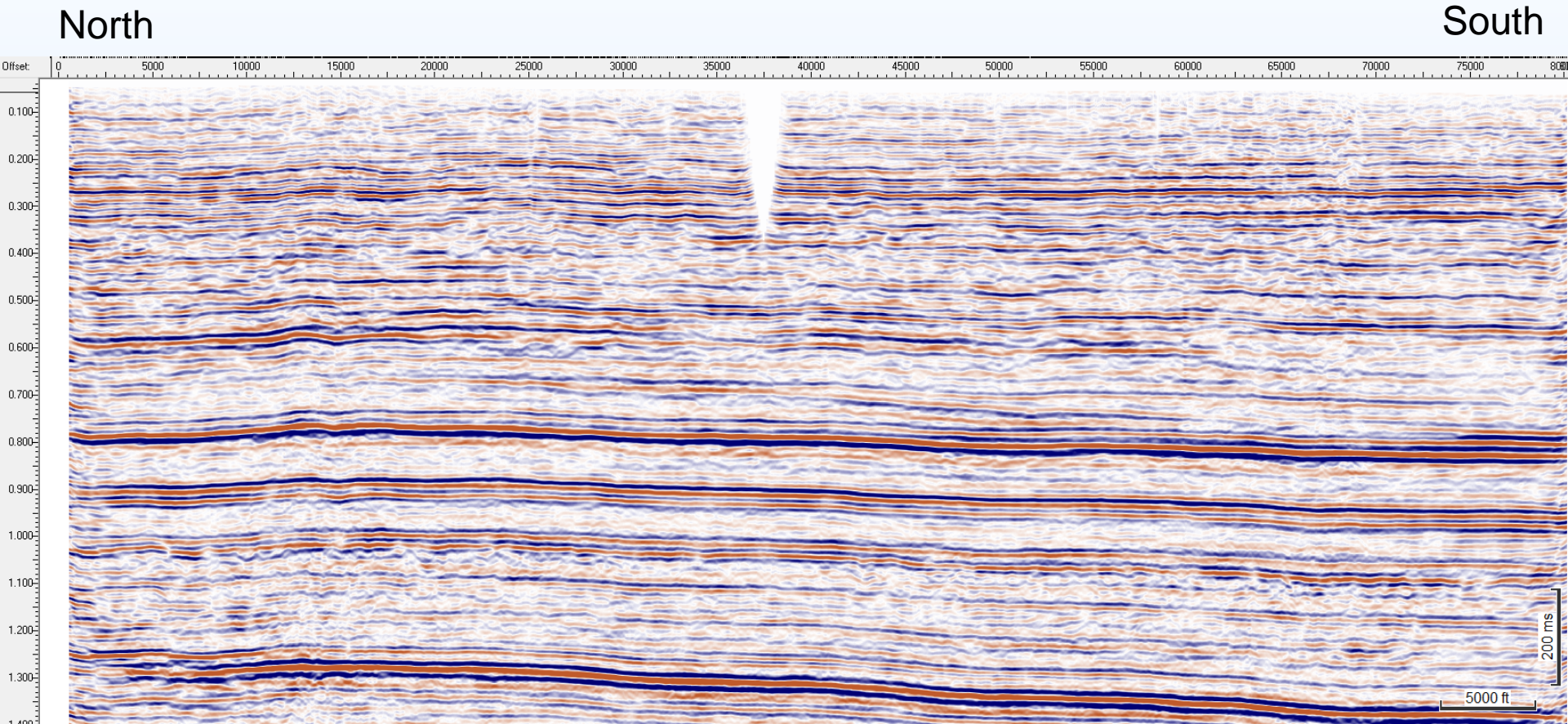
2D Seismic Acquisition



- 15 miles acquired 7/27-29
- Storage Options in Deep Basin
 - Multiple saline storage options
 - Clay City Anticline (faulted?)
 - Saline storage in Miss. Cypress SS
 - 0.2 to 2.3 billion tonnes (Atlas 2012)
 - Evaluate seismic for Cypress thickness
- Synergistic with:
 - Cypress ROZ work in region
 - Stacked Greenfield and Brownfield ROZ Fairways (N. Webb @ 2:40p Thursday)

Processed 2D Example (Phase I)

Pre-interpretation



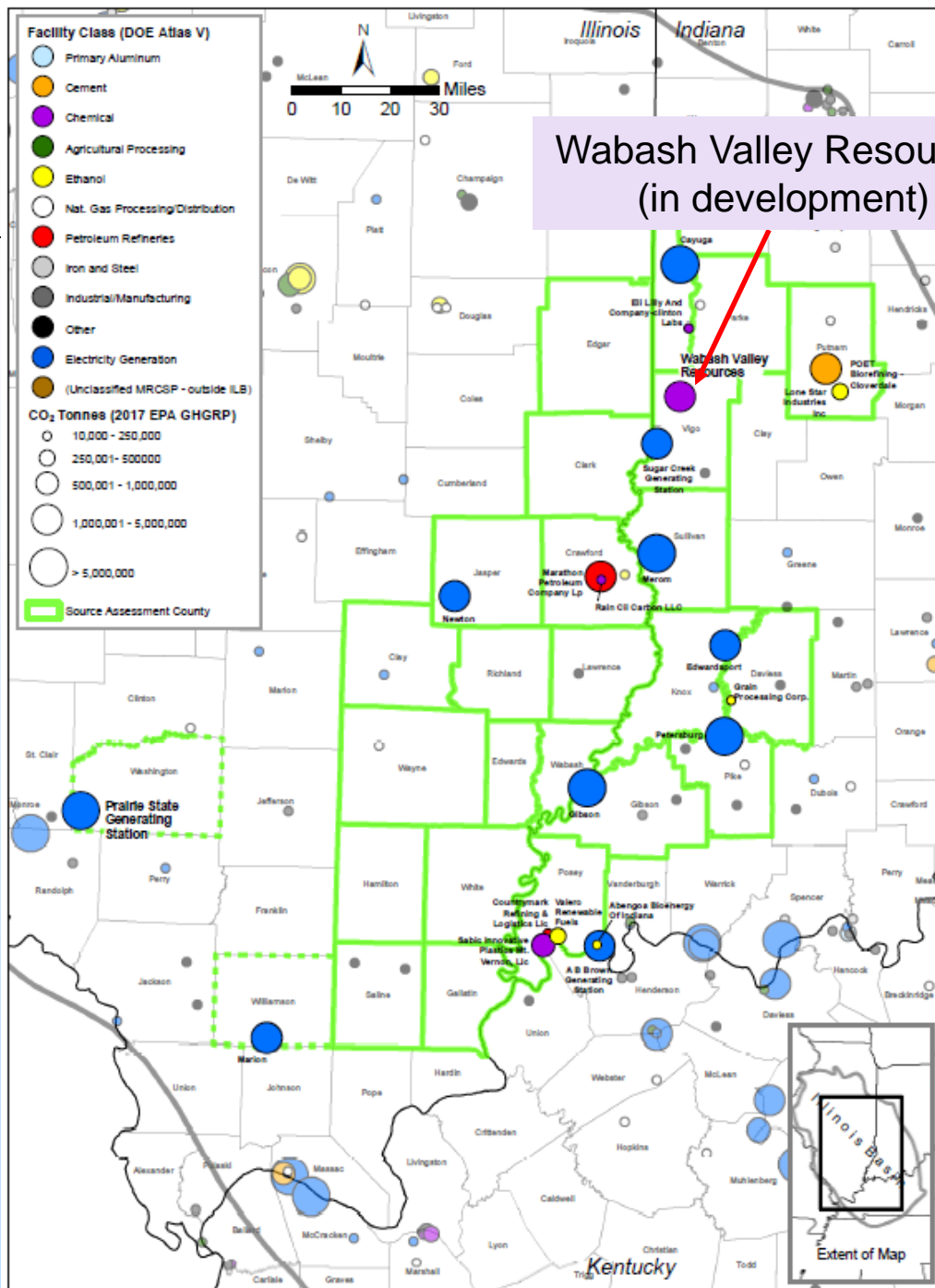
CarbonSAFE Phase I

Accomplishments / Remaining Work

Task #	Description	% Complete
1	Project management and planning	95
2	Establish CCS Coordination Team	100
3	Develop Plan to Address Challenges of Commercial- Scale CCS Project	80
4	Conduct High-Level Technical Sub-Basin Evaluation	95
5	CO2 Source and Transportation Assessment	100
6	National Risk Assessment Partnership (NRAP) Screening	100

- Topical reports:
 - (11) Geological char., NRAP evaluation, legal/permitting, stakeholder engagement, source/transport char., ...
 - Site feasibility plan (Wabash)
- 2D Seismic (~15 miles acquired 7/27-29)
- Remaining:
 - Seismic interpretation
 - Finish sub-Basin evaluation, Risk Assessment
 - Final reporting
Development scenario for integrated CCS

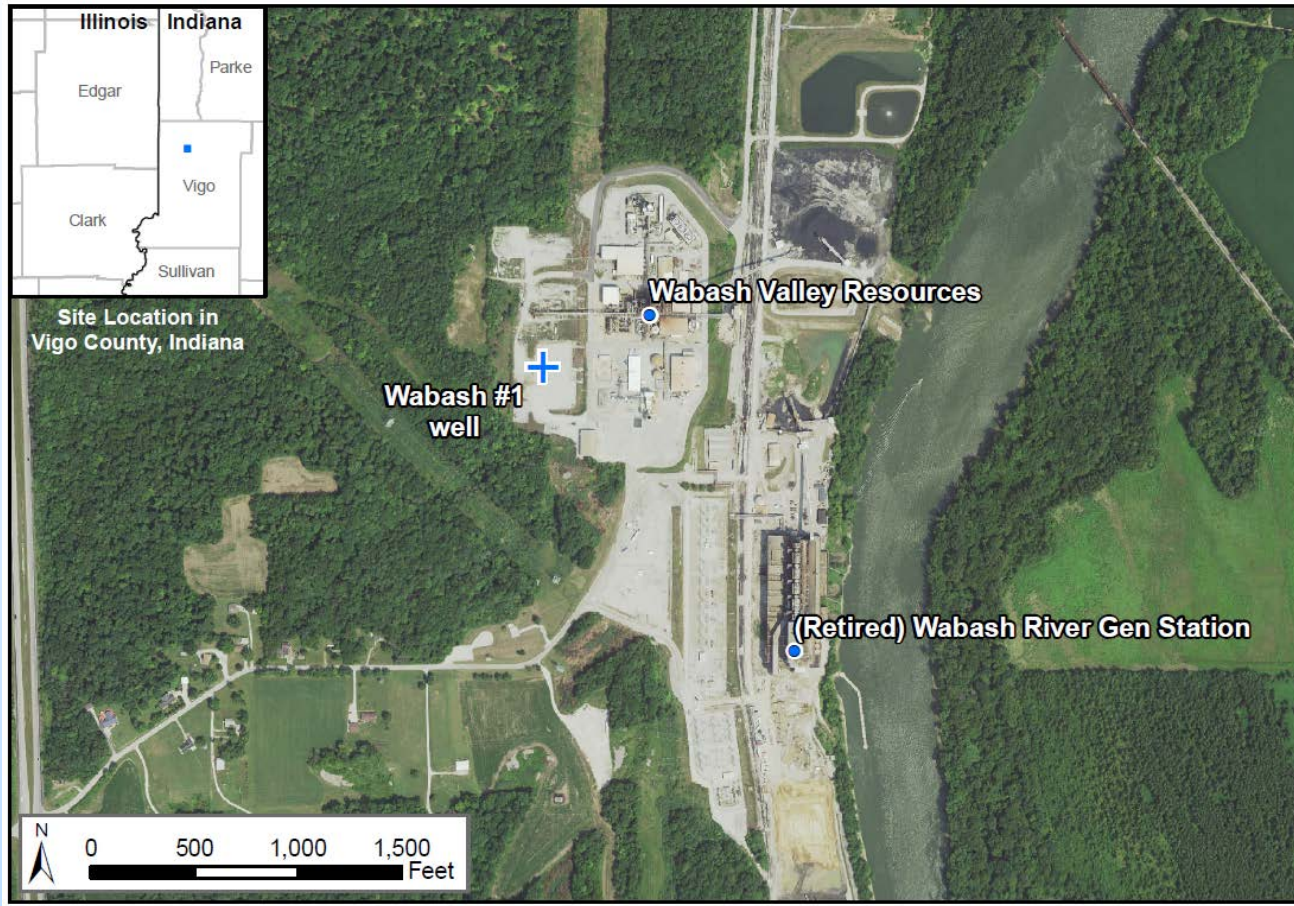
Background: CO₂ Sources



- Phase I CO₂ sources screened for age, emissions, capture-readiness, interest in participation
- Wabash Valley Resources industrial site identified
- Phase II partner discussions began in August 2017, proposal
- Phase II study awarded (Feb 2019)

Phase II: CO₂ Source and Storage Site

Wabash Valley Resources (WVR; formerly Quasar Syngas)

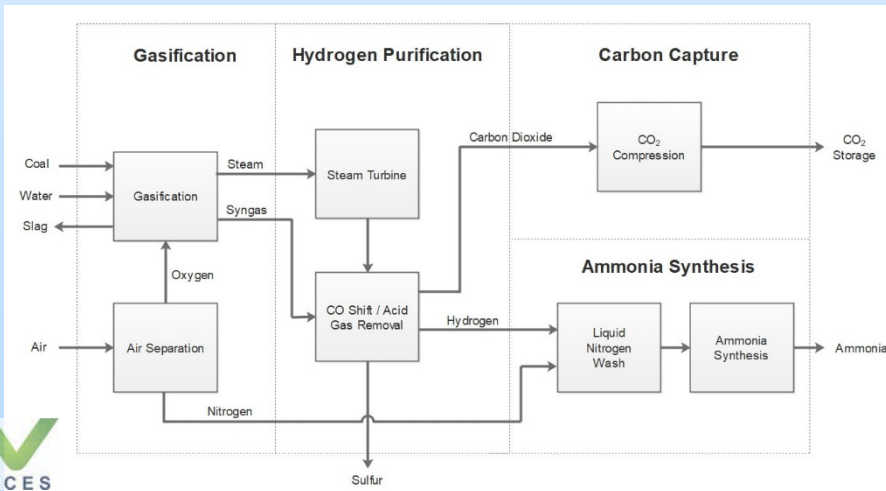


- Site at former Wabash River Generating Station
- IGCC Unit 1A (DOE repowering 1993-1995)
 - Clean Coal Technology Program, Round IV Demonstration Project
- Ownership changes, operations suspended (May '16, “mothballed”)
- WVR purchased plant May '16 for ammonia production from petcoke. Conversion in progress...

Wabash Valley Resources

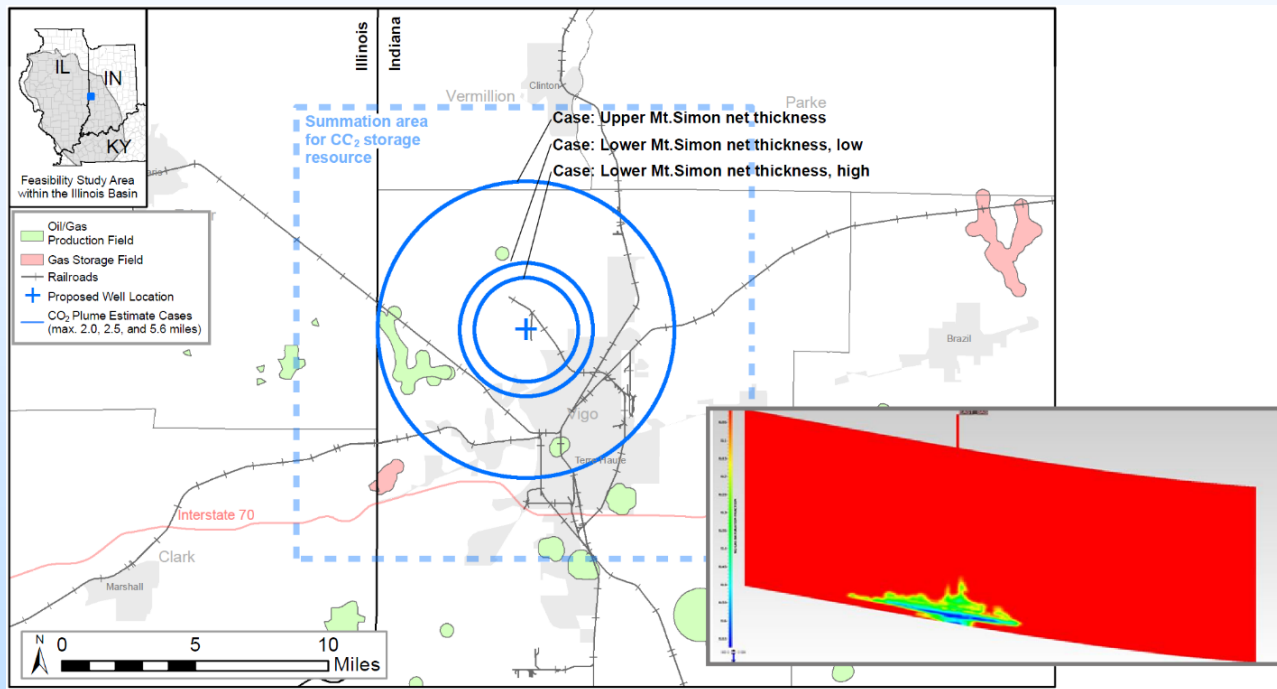


Aerial view of the WVR facility with various components of the syngas to ammonia process.



- Target 2023 commercial operation
- Petcoke -> Syngas -> H₂ -> Ammonia + CO₂
- WVR business model: change plant design to maximize CO₂ recovery for storage or EOR sale (45Q credits)
 - 65% -> 98% CO₂ recovery
- >95% pure stream CO₂ @ 1.65 million tonnes/yr
 - 1630 tonnes/day anhydrous ammonia

Phase II: WVR Site Characterization



Region surrounding Feasibility site centered in Vigo County, Indiana. 50 MT CO₂ plume size estimates (the maximum of 3 cases) circle the proposed Wabash well location.

- Evaluate CO₂ stream/requirements, regulations, permitting; perform stakeholder analysis, further study WVR's business case for CO₂ storage
- Characterize geology at WVR site location for saline storage
- New data will inform static/dynamic models and risk assessment, reduce uncertainties

Storage Complex

SYSTEM	SERIES	LITHOLOGY	FORMATION	NOTES
PENNSYLVANIAN	OSAGEAN		SPRING	Pennsylvanian coal seams
	ATOKA		ATOKA	
	MAZDAHAN		GADESVILLE	
MISSISSIPPIAN	OSAGEAN		GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
	ATOKA		GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
DEVONIAN	ATOKA		GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
	ATOKA		GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
SILURIAN	ATOKA		GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
	ATOKA		GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
ORDOVICIAN	ATOKA		GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
	ATOKA		GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
CAMBRIAN	ATOKA		GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
	ATOKA		GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	
			GADESVILLE	

SYSTEM	GROUP	FORMATION	Storage Elements	
Ordovician	Maquoketa	Brainard	Secondary Seal	
		Ft. Atkinson		
		Scales		
	Galena	Kimmswick		
		Decorah		
	Plateville			
	Ancell	Joachim		Potential target
		St. Peter		
	Knox	Shakoppee	Secondary Seal/Reservoir	
		New Richmond		
		Oneota		
Gunter				
Cambrian		Eminence	Potential target	
		Potosi		
		Franconia		
		Ironton-Galesville		
		Eau Claire		Primary Seal
		Mt. Simon	Target reservoir	
Precambrian				

St. Peter-Knox Storage Complex

Mt. Simon Storage Complex

Cambro-Ordovician Storage Complex

St. Peter-Knox Storage Complex

Mt. Simon Storage Complex

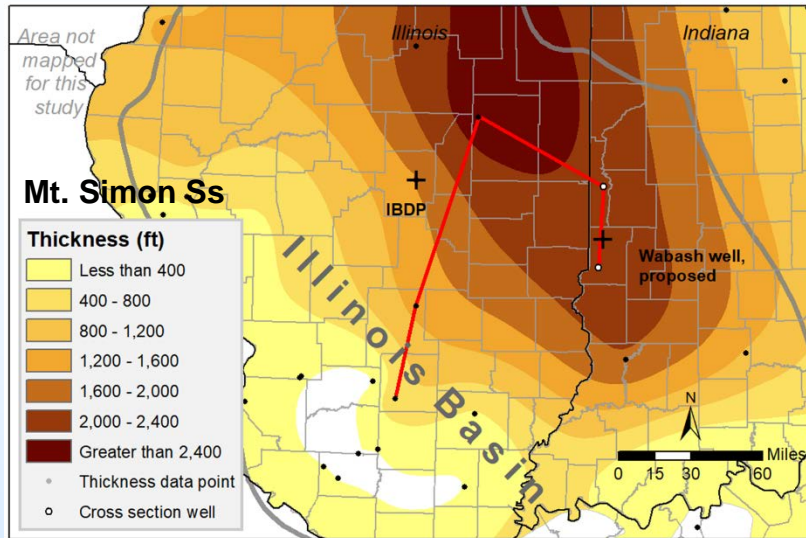
Cambro-Ordovician Storage Complex

- Wabash: Mt. Simon Sandstone reservoir, seals
- Lower Mt. Simon: IBDP/IL-ICCS CO₂ injection
- CarbonSAFE IL – Macon Co. work

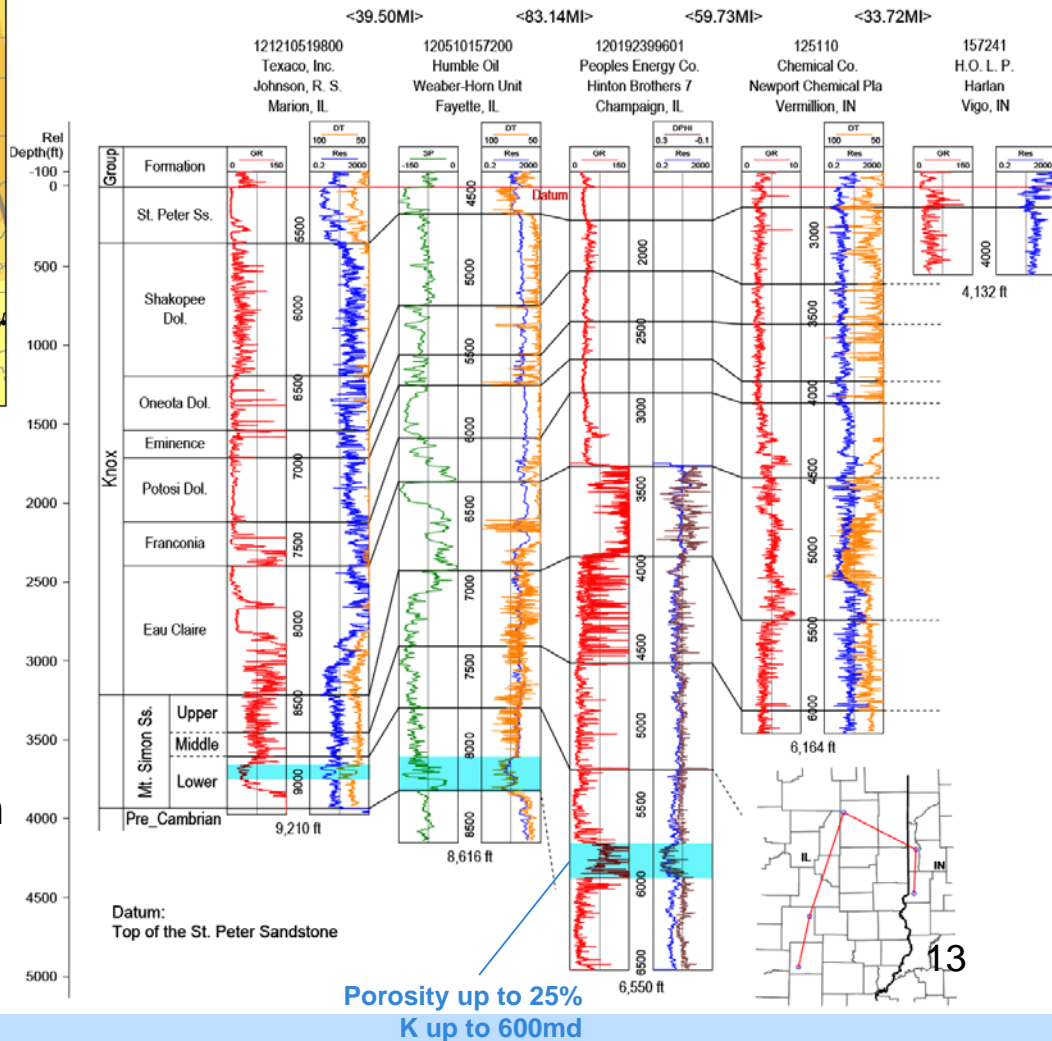
Mt. Simon Storage Capacity: IL BASIN

12 (E=0.4%) to 172 (E=5.5%) billion metric tons (2015)

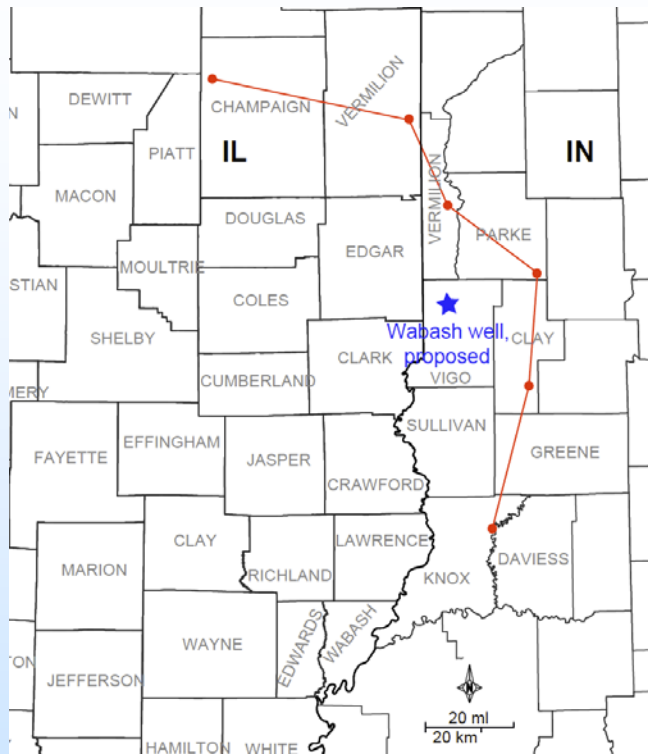
Mt. Simon Sandstone



- Few complete Mt. Simon penetrations in ILB
- Regional thickness trend
- Zone of high porosity in Lower Mt. Simon seen in IL
- Wabash data gap: lower Mt. Simon reservoir quality uncertain...



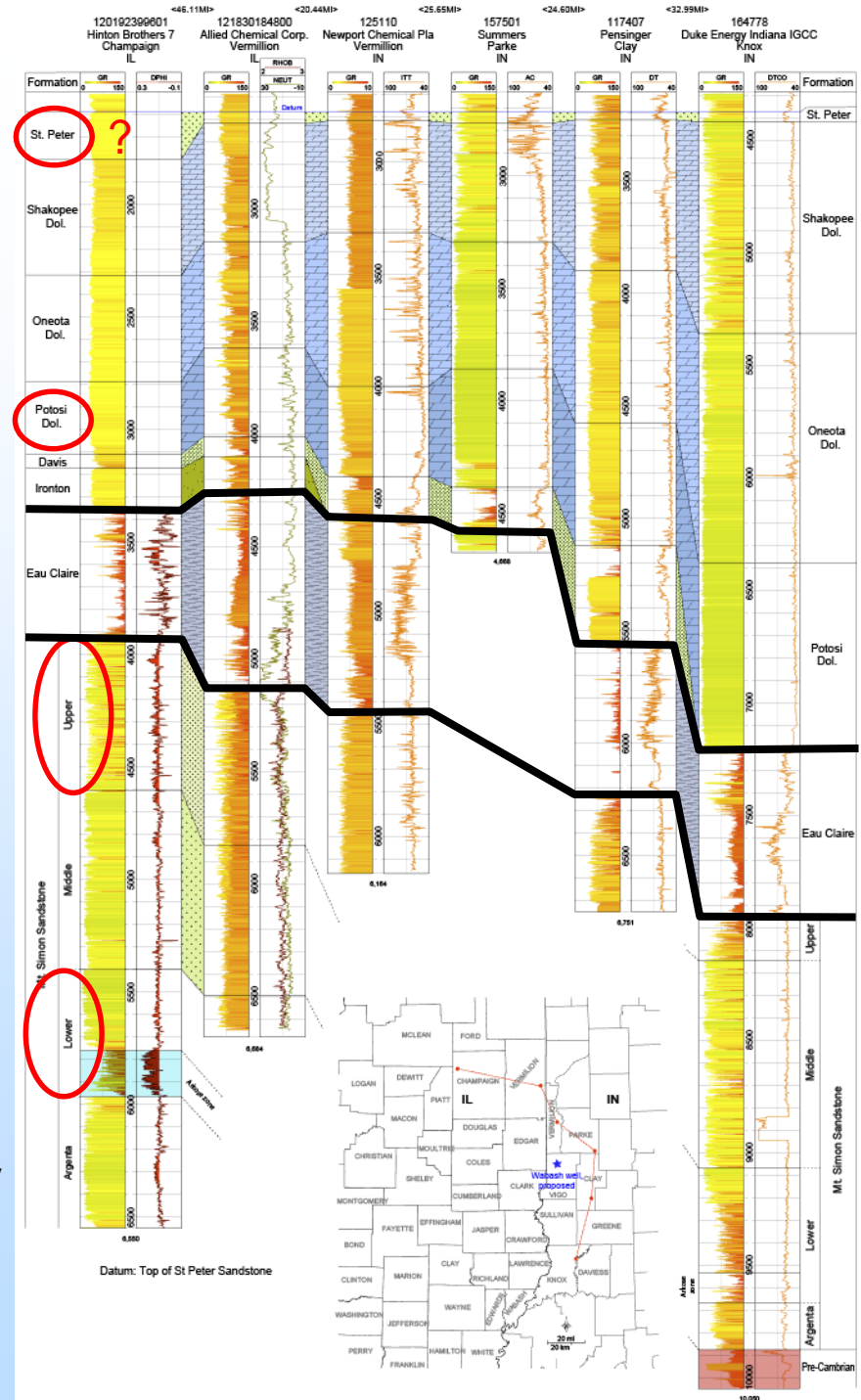
Mt. Simon at Wabash



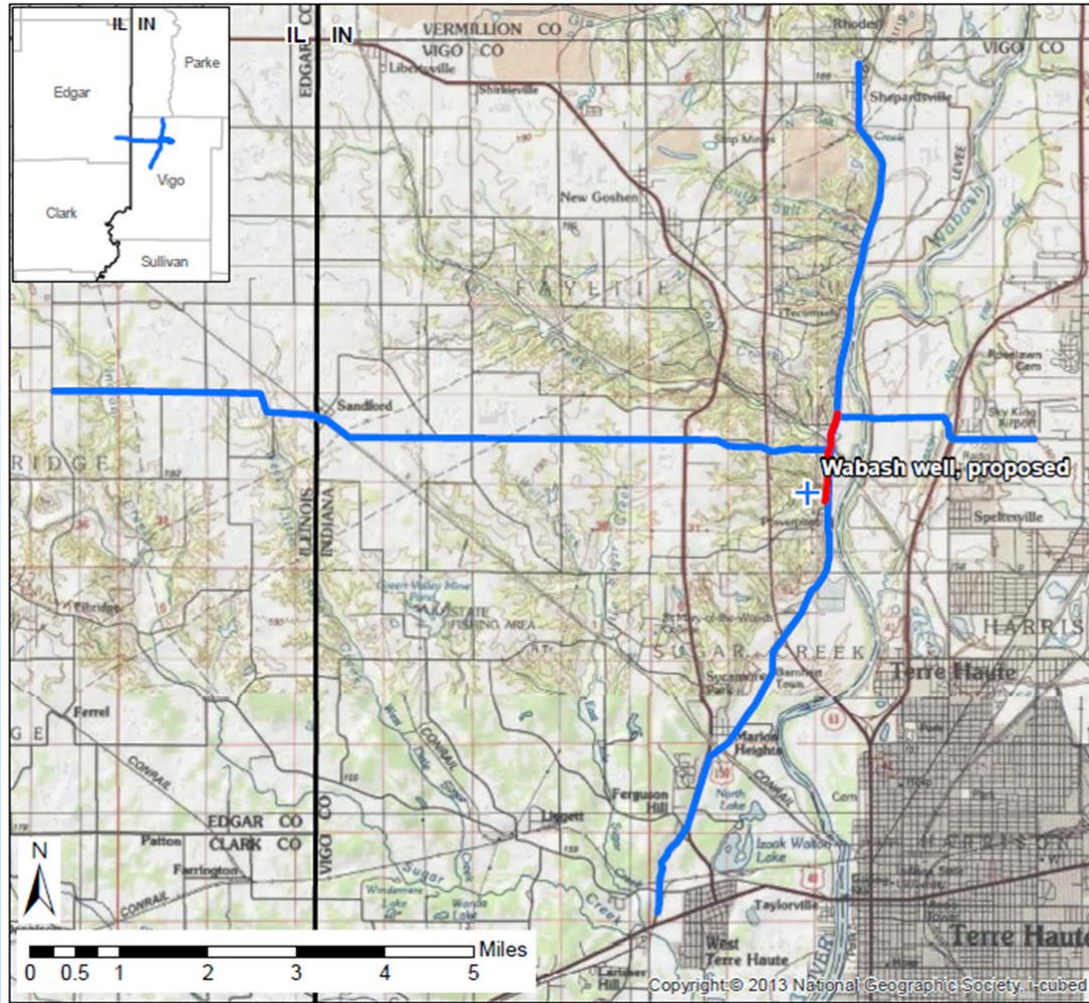
Nearest deep well(s) to Wabash:

- 75mi NW: lower Mt. Simon, zone of high porosity
- 22mi N: upper Mt. Simon only, disposal
- 25mi SE: upper Mt. Simon
- 50mi S: lower Mt. Simon, deeper and lower porosity

Data collection necessary, characterization
Fill data gaps, expand storage resource



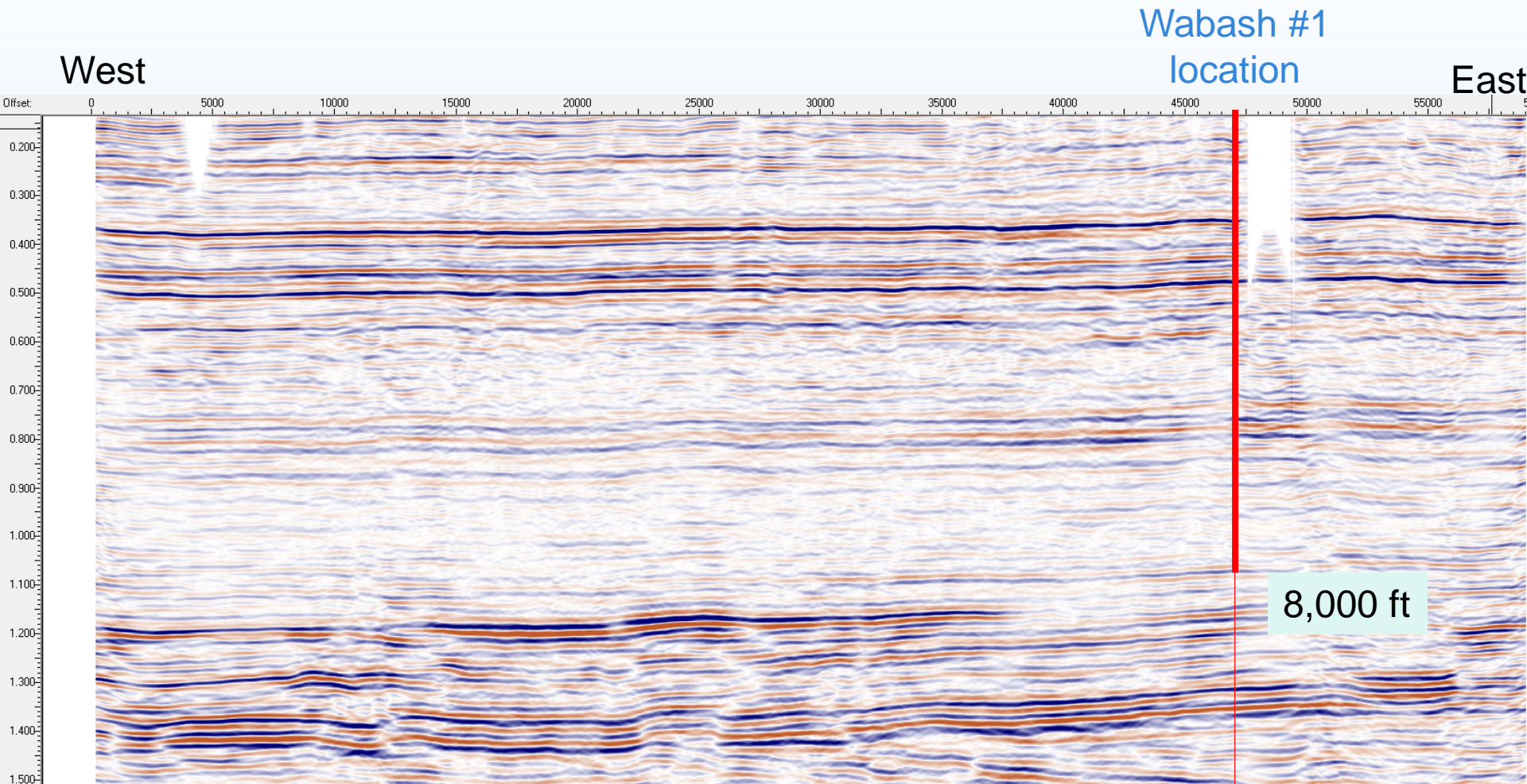
New Data: 2D Seismic Acquisition



- Test line, 1mi (02/19/2019):
 - Mines, topo/streams, river
 - Test signal quality, synergy with Macon Co.
 - Preliminary deep reflectors
- 2 x 10 miles
 - Flooding delay...
 - Acquired 7/22-26
 - Synergy with IL East Sub-Basin
- Tie-in to well, site to region
 - Formation continuity, reservoir and seal
 - Geologic structures

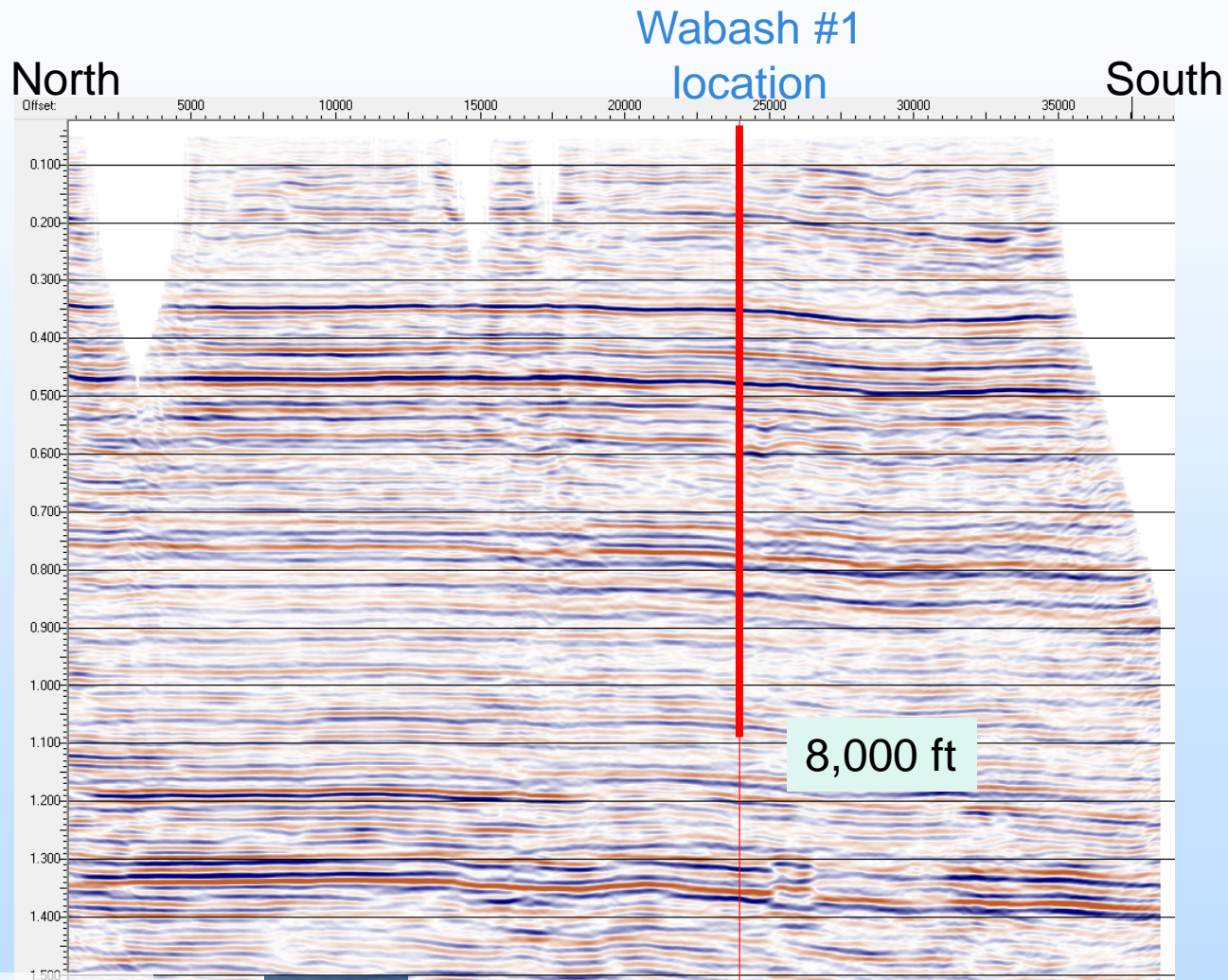
Processed 2D Example (I)

Pre-interpretation



Processed 2D Example (II)

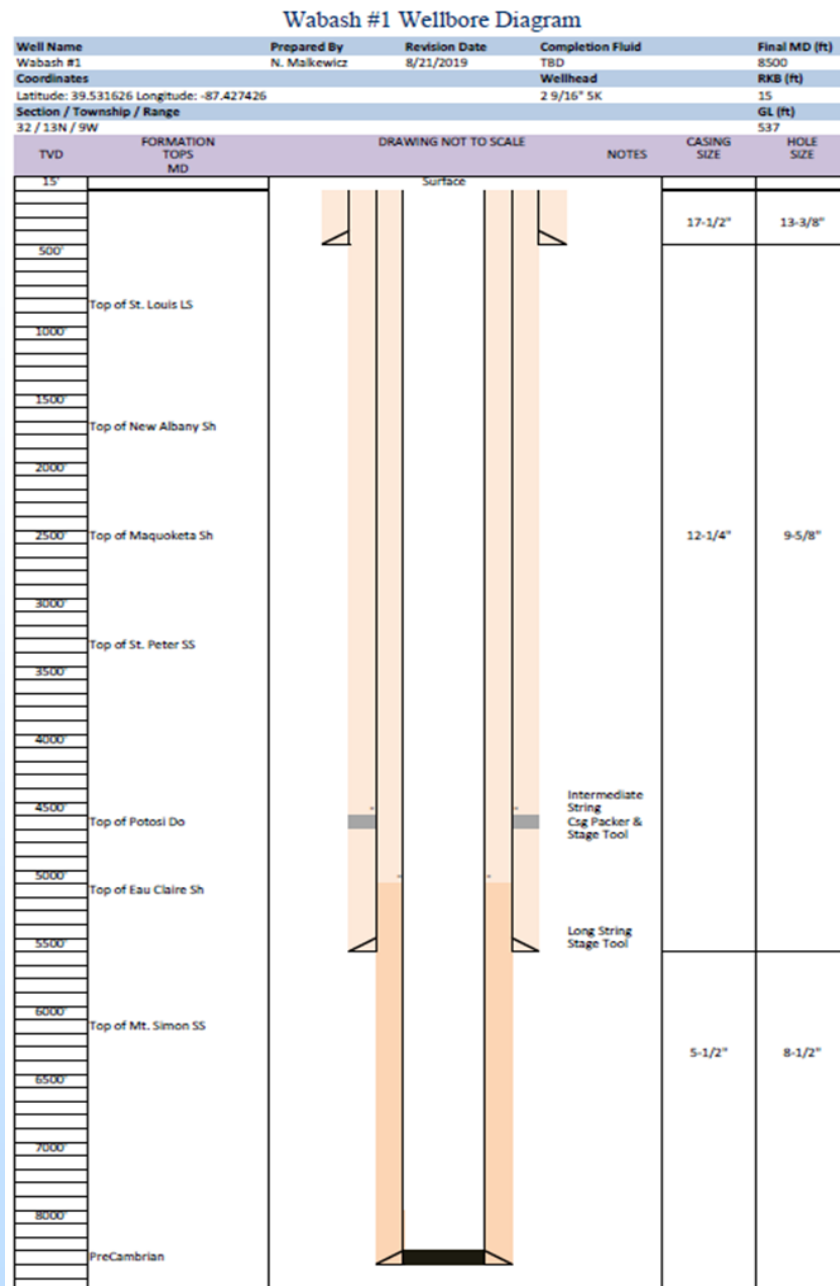
Pre-interpretation



Stratigraphic Test Well

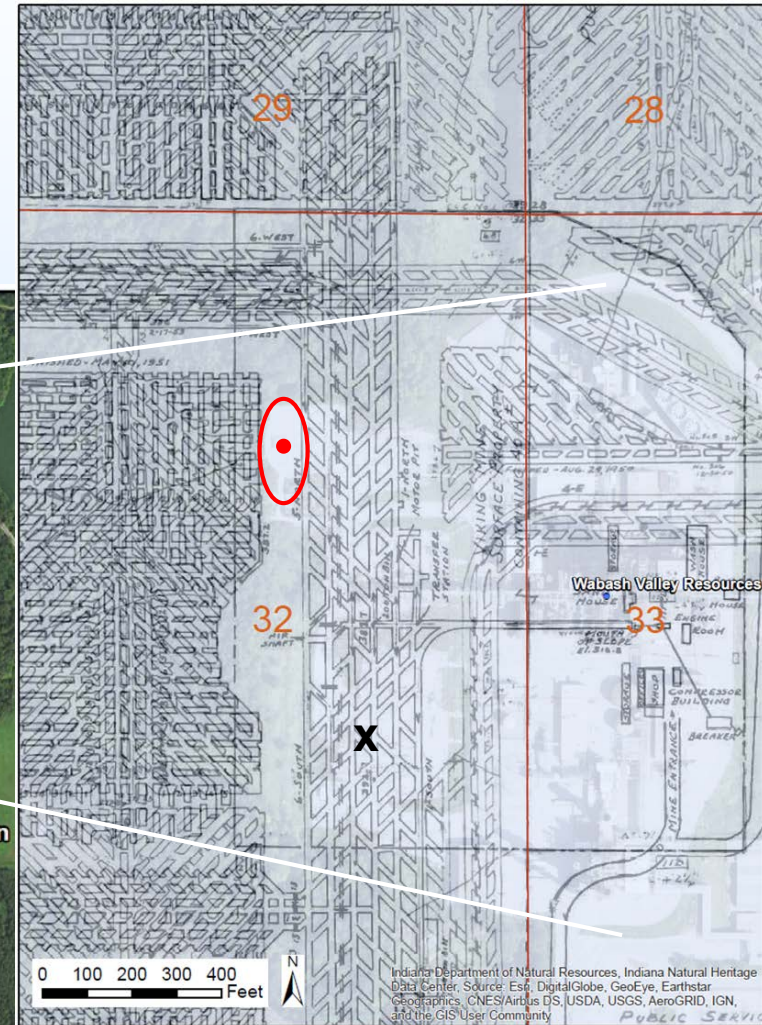
Preliminary Well Plan

- Drill to ~8,300-8,500 ft
 - Mt. Simon + Precambrian basement
- Whole core
 - Maquoketa Shale 60 ft
 - Eau Claire – Upper Mt. Simon 120 ft
 - Lower Mt. Simon 180+ ft
- Sidewall cores in TD section
- Full suite of wireline log acquisition
- VSP
- Well testing, design based on drilling/logging outcome
 - DST/Sampling
 - Step Rate Tests
 - Pressure Falloff
 - Vertical Interference



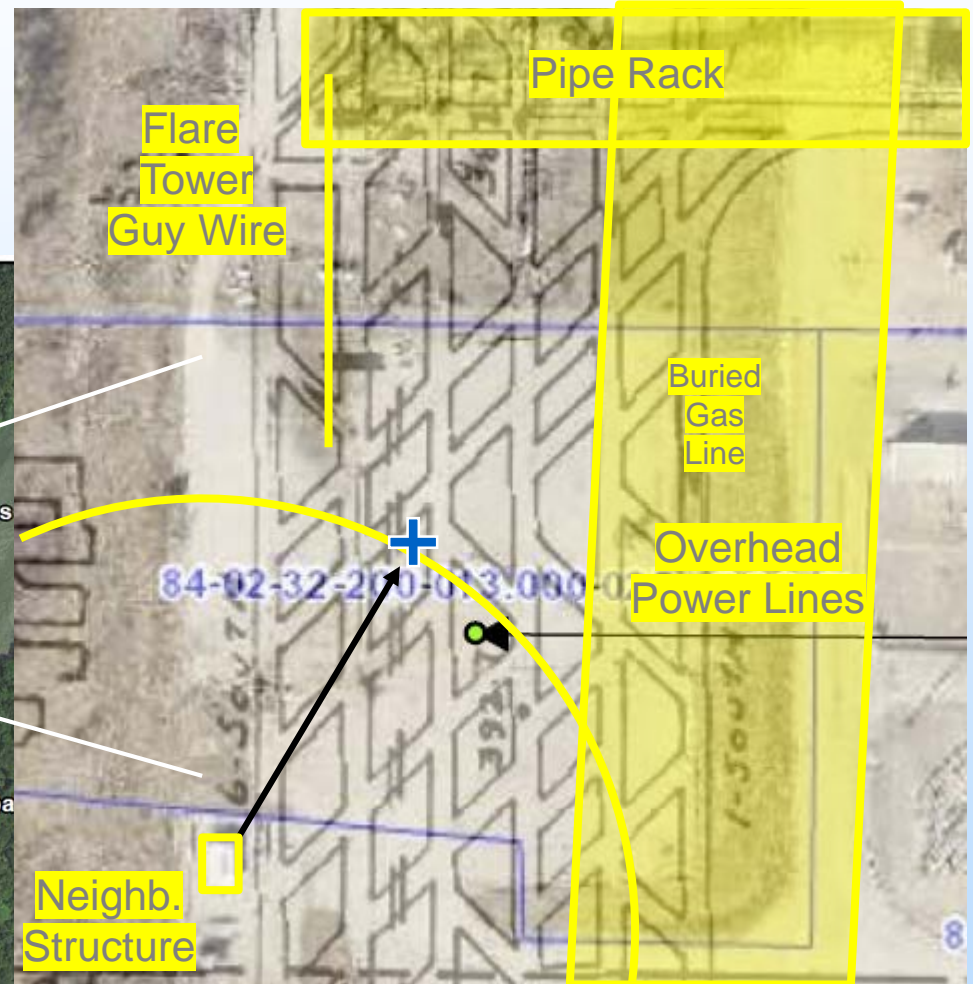
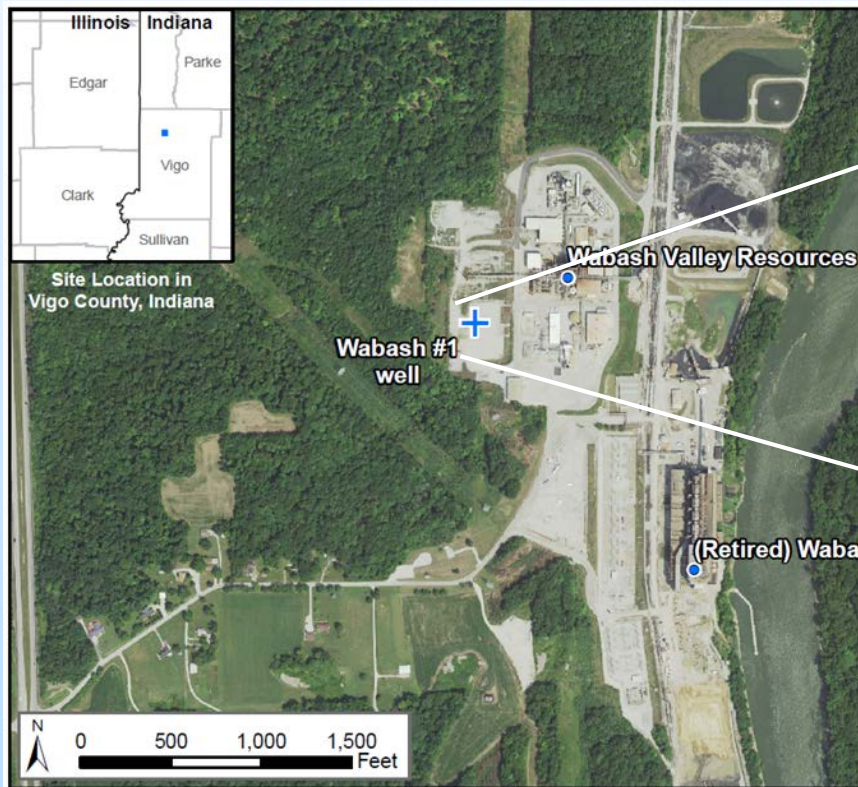
Well Siting I

- Abandoned underground coal mines
 - Adjust planned location of stratigraphic well
 - Mine map georeferencing issues, section corner
 - Proximity to neighbor/property line...



Well Siting II

- Industrial site challenges
 - Plant infrastructure
 - High-voltage power lines
 - Neighboring structures (Permit)



Well Permitting/Status

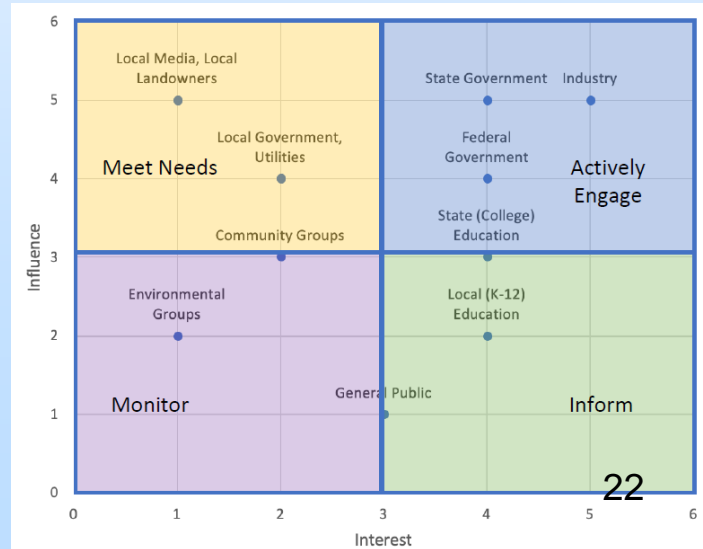
- Geologic / Structure Test (GST) well permit
 - No Indiana precedent for CO₂-related reservoir characterization
 - Indiana Dept. of Nat. Resources (DNR), Div. of Oil & Gas
 - Working with DNR on permit pathway, supporting information
 - CarbonSAFE test well is separate from WVR industrial project plan
 - Legislation enacted specific for WVR industrial pilot project
 - DNR review current CarbonSAFE needs, well/testing plan, timeline
- Current Well Status:
 - Well spot location surveyed 8/14
 - Completing Well Plan
 - Permit guidance -> completing application & supporting documentation
 - Anticipated spud date in October



Stakeholder Engagement

- Phase I work
 - Identified stakeholders, needs, searched social media
 - Mapped engagement types and priorities
- Recommendations
 - Systematic way to implement social site characterization, monitor social media
 - Understand local/regional concerns:
 - Some public concerns are location-specific:
 - Environmental legacy = Coal ash, coal mines
 - Land management, combined sewer & overflow

Group	Local	State	Federal
	<ul style="list-style-type: none"> Templeton Coal Co., Inc. Local Manufacturers¹ 		
<i>Local Landowners</i>	<ul style="list-style-type: none"> Private Homeowners Residents Terre Haute Regional Hospital Farmers Business Landowners Union Hospital Local Health Insurance 		
<i>Education (K-12, Colleges, etc.)</i>	<ul style="list-style-type: none"> St. Mary of the Woods College Saint Patrick School Vigo County Public Library Vigo County School System Vigo County Extension Service 	<ul style="list-style-type: none"> Rose Hulman Institute of Technology Ivy Tech Terre Haute Indiana State University Indiana University Purdue University University of Notre Dame 	
<i>Utilities</i>	<ul style="list-style-type: none"> Terre Haute Wastewater Utility WIN Energy REMC Indiana-American Water Company Nustar Pipeline Operating Partnership Midwest Gas Transmission Co. Buckeye Partners L.P. Boardwalk Pipeline Partners BP Marathon Meridian Brick 	<ul style="list-style-type: none"> Duke Energy Vectren Corp. Indianapolis Power and Light 	<ul style="list-style-type: none"> Midcontinent Independent System Operator
<i>Media (Television, Radio, Newspapers)</i>	<ul style="list-style-type: none"> Tribune-Star News 10 – WTHI-TV WTWO-TV WAWV-TV W250BZ (WIBQ-AM) 	<ul style="list-style-type: none"> Indy Star 13 WTHR Indianapolis Rtv6 or WRTV Fox 59 	



Stakeholder Engagement

- Local engagement, project-related
- Interaction with landowners

Wabash CarbonSAFE
Geological Characterization

A seismic survey for a CarbonSAFE Illinois project by Illinois State Geological Survey and National Energy Technology Laboratory (DOE)

What is CarbonSAFE Illinois?
CarbonSAFE Illinois is a research program funded by the US Department of Energy studying the use of storing greenhouse gases in geological reservoirs rather than emitting them to atmosphere. As part of this program, the Illinois State Geological Survey (ISGS) along with research colleagues, including the Indiana Geological & Water Survey (IGWS), will drill a research well at Wabash Valley Resources' Integrated Gasification Combined Cycle (IGCC) plant in Vigo County, Indiana. The stratigraphic test well is expected to be about 8,200 feet deep. The well will pass through near-surface sediments deposited by glaciers, limestones, dolostones and sandstones formed during the Paleozoic Era from around 250 to over 500 million years ago, and ends in Precambrian granites and volcanic rocks (rhyolites) over 1 billion years old. The ISGS and IGWS are mapping the distribution of resources in the rock column including water, hydrocarbons, and minerals. A major research focus is on assessing the deepest sandstones for their porosity and potential to store greenhouse gases. While this research well will never be used for storage of greenhouse gases, it provides us with a rare view into the deep earth of the mid-continent.

How Will The Seismic Survey Be Performed?
Seismic surveys are non-invasive methods that provide scientists with an image of rocks in the subsurface. Seismic surveys use vibrations

What Is Geological Storage of Carbon?
Storing carbon dioxide underground is one possible response to the challenge of global climate change. The process involves capturing carbon dioxide emissions and preventing their release to the atmosphere. Geological storage of carbon dioxide is taking place at multiple locations across North American including near Decatur Illinois at the ADM facility which represents one of the world's foremost sites for this technology.

NETL
ENERGY
ILLINOIS
Illinois State Geological Survey
PRAIRIE RESEARCH INSTITUTE

INDIANA ENVIRONMENTAL REPORTER
CLIMATE & ENERGY

Vigo County Residents
Concerned About Planned
Ammonia Fertilizer Plant
and Carbon Sequestration

Proposed \$450 million project would allow company to store millions of tons of carbon dioxide underground near Terre Haute

Enrique Saenz
July 8, 2019

f t e

- Different opinions regarding project(s)
- Robust stakeholder engagement
 - Talk to + engage people who have opposing voices
 - Provide facts and information

Project Challenges

- CarbonSAFE Characteriation + WVR industrial project
 - IBDP → IL-ICCS sequential; CarbonSAFE / WVR in parallel
 - Underscores need for close communication between CarbonSAFE Team & WVR
 - Consistent messaging
 - Some WVR info may be confidential/business-sensitive
 - ISGS/IGWS maintain objectivity and remain trusted sources of information
- Well siting on WVR industrial property; permitting and timeline
- Lack of data (no Lower Mt. Simon penetrations within 50 miles):
 - Thickness/quality of reservoir? Contingencies?
 - Evaluation of multiple zones...
 - Where to take core? How much core? Costs?
 - What well testing to be done?

Project Summary

- Wabash CarbonSAFE Goal:
 - Assess commercial-scale CO₂ storage feasibility at Wabash Valley Resources' ammonia plant near Terre Haute, Indiana; CO₂ source and saline storage location.
- Accomplishments to Date
 - Acquire 2D seismic reflection data
 - Prepare stakeholder engagement materials, begin local engagement
 - Well site surveyed, well plan nearing completion, met with potential drillers
 - Dialogue with Indiana DNR, begin Geol. Struc. Test well permit application

Tasks/Partners

Task 1.0 – Project Management and Planning

Task 2.0 – Risk Assessment and Monitoring

Task 3.0 – National Risk Assessment Partnership (NRAP) Screening

Task 4.0 – Stakeholder Engagement and Public Outreach

Task 5.0 – Business and Economic Development Assessment

Task 6.0 – Permitting and Compliance

Task 7.0 – Subsurface Characterization

Task 8.0 – Drilling and Well Testing

Task 9.0 – Storage Complex Modeling

Task 10.0 – Infrastructure Development

Task 11.0 – Storage Complex Development Planning



TRIMERIC CORPORATION



Next Steps

- Permit and drill test well / coring, logging, testing...
- Interpret 2D seismic info, tie to well stratigraphy
- Integration of data: Modeling, NRAP
 - Pre-drilling work complete or in progress, to be updated
 - Informed by new well data, reduce uncertainties
- Risk Assessments: pre-drilling; post-well modeling/simulation
- Source Assessment, Storage Complex Development
 - CO₂ source, infrastructure and transport; SimCCS
 - Consider saline at WVR; regional (poss. EOR, EGR, other plants, economics)
 - Business and Economic Development Assessment
 - Permitting and Compliance Needs Case Study





Illinois State Geological Survey

PRAIRIE RESEARCH INSTITUTE

Thank You!



This project is funded by the U.S. Department of Energy through the National Energy Technology Laboratory (NETL), under agreement DE-FE0031626.



Appendix

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

Benefit to the Program (Phase II)

Benefits Statement, Wabash CarbonSAFE

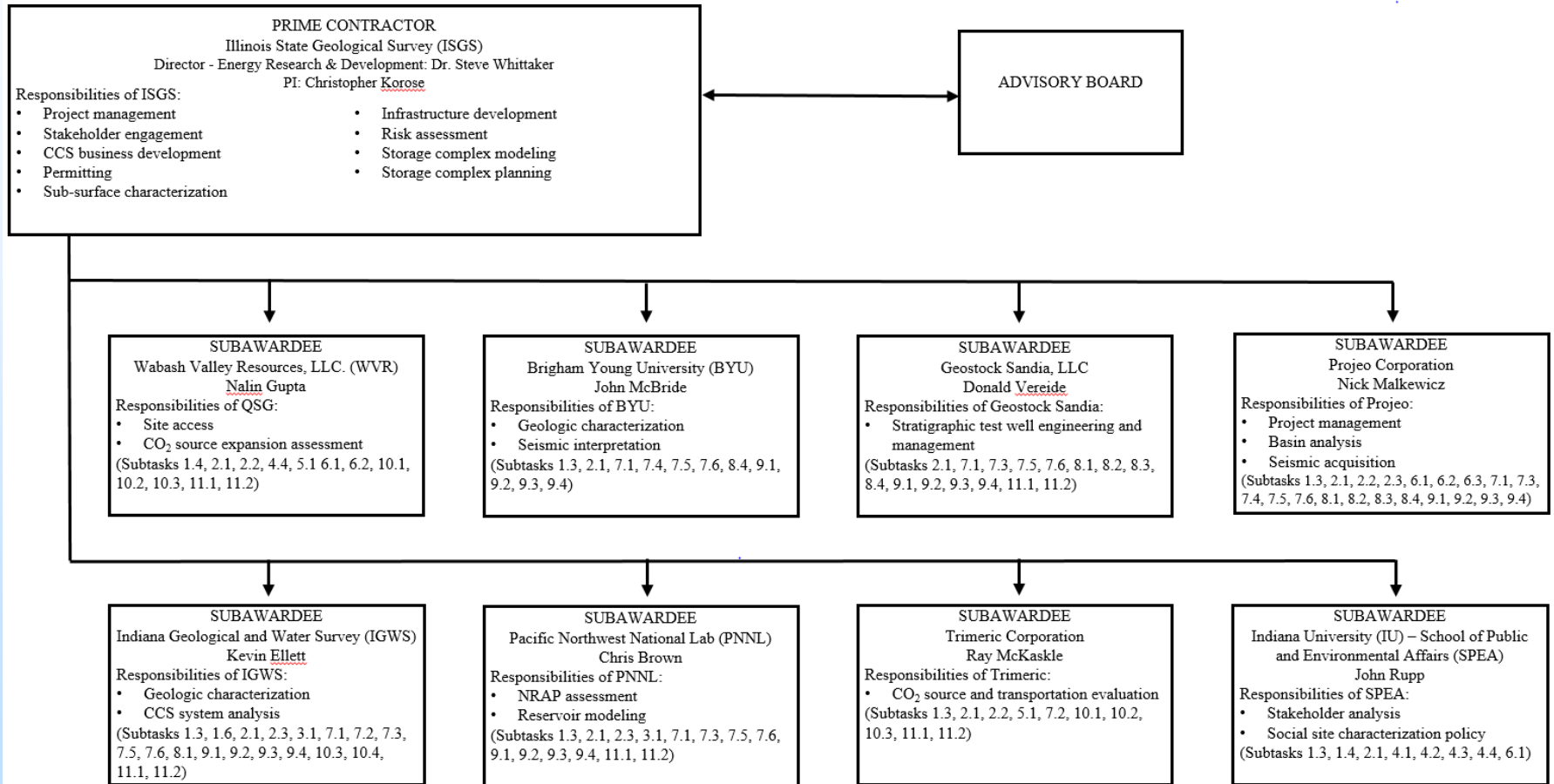
This project will determine the feasibility of developing a commercial-scale CCS project capable of storing over 50 million tonnes of anthropogenic CO₂ in the U.S. Midwest. Wabash CarbonSAFE will demonstrate the transfer of technology to apply CCS to ammonia production thereby broadening the portfolio of industries that may benefit from integrating CCS into their operations. The project will address the development gap in upscaling CCS to commercial-scale as there are still relatively few large carbon storage projects globally using deep saline reservoirs. Our work will address improving storage capacity estimates to attain an industry standard of $\pm 30\%$ or better for investment decisions. The data from this study will be used within the NRAP Toolkits to move toward validating technologies to ensure storage permanence and to improve reservoir storage efficiency. The project will determine the potential for transporting and utilizing CO₂ for EOR in oil fields of the Illinois Basin. The knowledge gained will contribute to greater development of regional CCS assets, best practice manuals about CCS technology, and issues that will be of broad use to other sites and future commercialization efforts.

Wabash CarbonSAFE Overview:

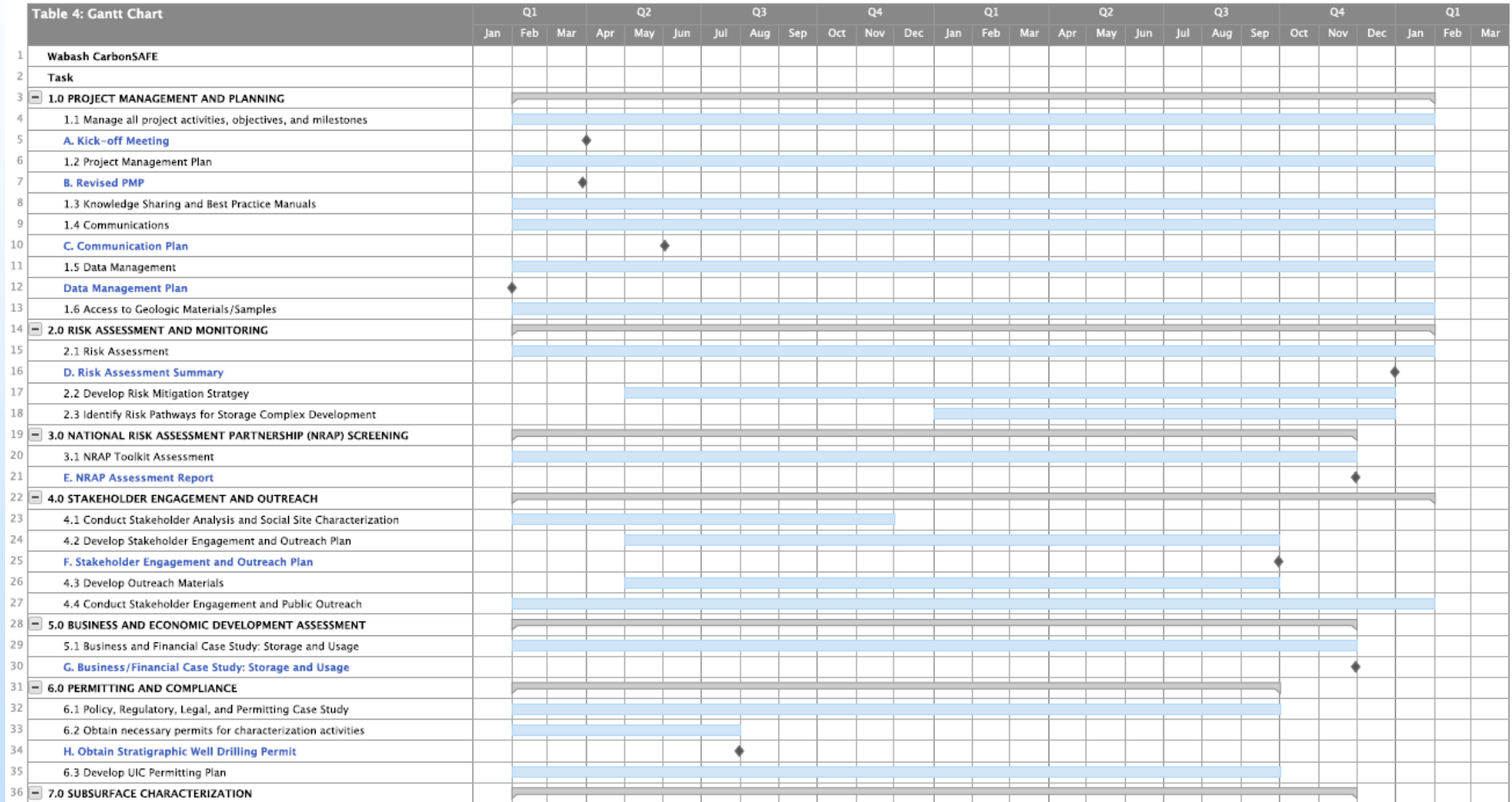
Project Objectives and Program Goals

- Establish the feasibility of developing a commercial-scale geological storage complex near Terre Haute IN, that could store up to 50 million tonnes of industrially-sourced CO₂.
 - Address gap in knowledge around developing large-scale geological storage complexes
 - 1) Validate technologies to ensure 99% storage
 - 2) Validation of NRAP toolkits using field site data
 - 3) Improve storage capacity estimations for industry investment decision
 - 4) Contribute to best practice manuals to inform future commercialization efforts
- Address technical and non-technical questions around developing commercial-scale storage complexes.
 - Assess Public Outreach needs
 - Analyze Regulatory Issues
 - Characterize the Subsurface Storage Complex
 - Construct Storage Complex Model
 - Site Development Plan

Organization Chart (Phase II)

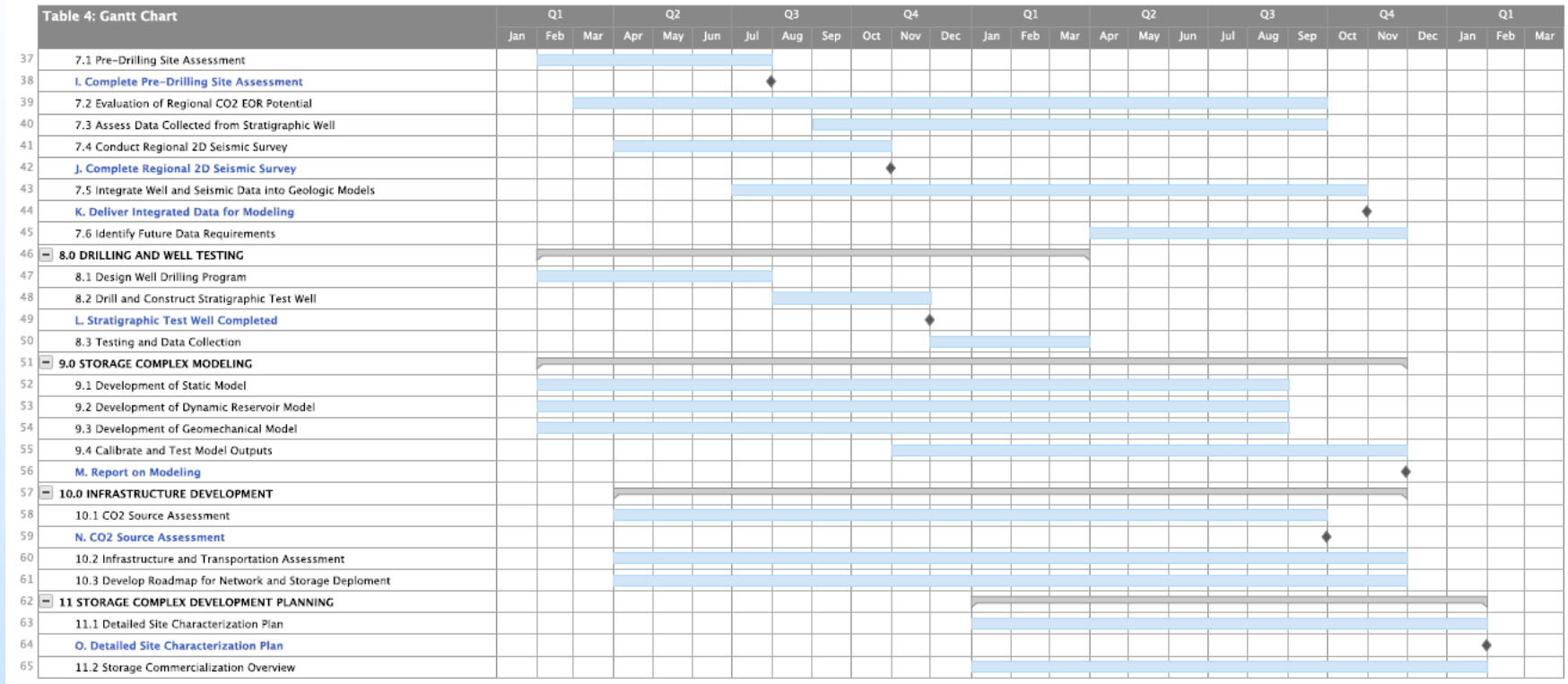


Phase II Project Schedule (1 of 2)



(continues)

Phase II Project Schedule (2 of 2)



Bibliography (Phase I)

Phase I Topical Reports (CarbonSAFE Illinois – East Sub-Basin):

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Medina, C., Rupp, J., Lahann, R., and Eldridge, J., 2019 Evaluation of Caprock Integrity of the Upper Ordovician Units within the CarbonSAFE Prefeasibility Study Region, Topical Report: DOE-FE0029445-11. U.S. Department of Energy.