U.S. Department of Energy
FEDERAL ASSISTANCE REPORTING CHECKLIST AND INSTRUCTIONS FOR RD&D PROJECTS

DOE F 4600.2
(03/11)
All Other Editions Are Obsolete

1. Identification Number: **DE-FE0006821**	2. Program/Project Title: **Small Scale Field Test Demonstration CO2 Sequestration**	
3. Recipient: **University of Kansas Center for Research, Inc.**		
4. Reporting Requirements:	Frequency	Addressees
A. MANAGEMENT REPORTING		
☒ Research Performance Progress Report (RPPR)	Q	FITS@NETL.DOE.GOV
☒ Special Status Report	A	FITS@NETL.DOE.GOV
B. SCIENTIFIC/TECHNICAL REPORTING		
(Reports/Products must be submitted with appropriate DOE F 241. The 241 forms are available at www.osti.gov/elink)		
Report/Product — Form		
☒ Final Scientific/Technical Report — DOE F 241.3	FG	http://www.osti.gov/elink-2413
☒ Conference papers/proceedings* — DOE F 241.3	A	http://www.osti.gov/elink-2413
☐ Software/Manual — DOE F 241.4		
☐ Other (see special instructions) — DOE F 241.3		
** Scientific and technical conferences only*		
C. FINANCIAL REPORTING		FITS@NETL.DOE.GOV
☒ SF-425 Federal Financial Report	Q, FG	
D. CLOSEOUT REPORTING		
☒ Patent Certification	FC	FITS@NETL.DOE.GOV
☒ SF-428 & 428B Final Property Report	FC	FITS@NETL.DOE.GOV
☐ Other		mailto:FITS@NETL.DOE.GOV
E. OTHER REPORTING		
☒ Annual Indirect Cost Proposal	O	See block 5 below for instructions.
☐ Audit of For-Profit Recipients		
☒ SF-428 Tangible Personal Property Report Forms Family	A	FITS@NETL.DOE.GOV
☒ Other – see block 5 below	A	FITS@NETL.DOE.GOV

FREQUENCY CODES AND DUE DATES:

A - Within 5 calendar days after events or as specified.
FG- Final; 90 calendar days after the project period ends.
FC- Final; End of Effort.
Y - Yearly; 90 calendar days after the end of the reporting period.
S - Semiannually; within 30 calendar days after end of project year and project half-year.
Q - Quarterly; within 30 days after end of the reporting period.
Y180 – Yearly; 180 days after the end of the recipient's fiscal year
O - Other; See instructions for further details.

5. Special Instructions:

Annual Indirect Cost Proposal – If DOE is the Cognizant Federal Agency, then the proposal should be sent to FITS@NETL.DOE.GOV . Otherwise, it should be sent to the Cognizant Federal Agency.

Other – The Recipient shall provide all deliverables as contained in Section D of Attachment 2 Statement of Project Objectives.

QUARTERLY PROGRESS REPORT

To

DOE-NETL

Brian Dressel, Program Manager

Award Number: DE-FE0006821

SMALL SCALE FIELD TEST DEMONSTRATING CO_2 SEQUESTRATION IN ARBUCKLE SALINE AQUIFER AND BY CO_2-EOR AT WELLINGTON FIELD, SUMNER COUNTY, KANSAS

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Date of Revised Report: April 30, 2012

DUNS Number: 076248616

Recipient: University of Kansas Center for Research &
Kansas Geological Survey
1930 Constant Avenue
Lawrence, KS 66047

Project/Grant Period: 10/1/2011 through 9/30/2015

Second Quarterly Report

Period Covered by the Report: January 1, 2012 through March 31, 2012

Signature of Submitting Official:

Willard Lynn Watney
Digitally signed by Willard Lynn Watney
DN: cn=Willard Lynn Watney, o=The University of Kansas, ou=Kansas Geological Survey, email=lwatney@kgs.ku.edu, c=US
Date: 2012.04.30 17:49:00 -05'00'

EXECUTIVE SUMMARY

Project Objectives

The objectives of this project are: (1) inject under supercritical conditions approximately 40,000 metric tons of CO_2 into the Arbuckle saline aquifer; (2) demonstrate the application of state-of-the-art MVA (monitoring, verification, and accounting) tools and techniques to monitor and visualize the injected CO_2 plume; (3) develop a robust Arbuckle geomodel by integrating data collected from the proposed study area, and a multi-component 3D seismic survey; (4) conduct reservoir simulation studies to map CO_2 plume dispersal and estimate tonnage of CO_2 sequestered in solution, as residual gas and by mineralization; (5) integrate MVA data and analysis with reservoir modeling studies to detect CO_2 leakage and to validate the simulation model; (6) develop a rapid-response mitigation plan to minimize CO_2 leakage and a comprehensive risk management strategy; and (7) establish best practice methodologies for MVA and closure. Additionally, approximately 30,000 metric tons of CO_2 shall be injected into the overlying Mississippian to evaluate miscible CO_2-EOR potential in a 5-spot pilot pattern. The CO_2 shall be supplied from the Abengoa Bioenergy ethanol plant at Colwich, Kansas who has operated the facility since 1982 demonstrating reliability and capability to provide an adequate stream and quality of CO_2. The project shall install compression, chilling, and transport facilities at the ethanol plant for truck transport to the injection site.

Project Goals

The proposed small scale injection will advance the science and practice of carbon sequestration in the Midcontinent by refining characterization and modeling, evaluating best practices for MVA tailored to the geologic setting, optimize methods for remediation and risk management, and provide technical information and training to enable additional projects and facilitate discussions on issues of liability and risk management for operators, regulators, and policy makers.

The data gathered as part of this research effort and pilot study will be shared with the Southwest Sequestration Partnership (SWP) and integrated into the National Carbon Sequestration Database and Geographic Information System (NATCARB) and the 6th Edition of the Carbon Sequestration Atlas of the United States and Canada.

<u>Project Deliverables by Task</u>

1.5 Well Drilling and Installation Plan (Can be Appendix to PMP or Quarterly Report)
1.6 MVA Plan (Can be Appendix to PMP or Quarterly Report)
1.7 Public Outreach Plan (Can be Appendix to PMP)
1.8 Arbuckle Injection Permit Application Review go/no go Memo
1.9 Mississippian Injection Permit Application Review go/no go Memo
1.10 Site Development, Operations, and Closure Plan (Can be Appendix to PMP)
2.0 Suitable geology for Injection Arbuckle go/no go Memo

3.0 Suitable geology for Injection Mississippian go/no go Memo
11.2 Capture and Compression Design and Cost Evaluation go/no go Memo
19 Updated Site Characterization/Conceptual Models (Can be Appendix to Quarterly Report)
21 Commercialization Plan (Can be Appendix to Quarterly Report).
30 Best Practices Plan (Can be Appendix to Quarterly or Final Report)

ACCOMPLISHMENTS

ONGOING ACTIVITIES –

TASK 1. PROJECT MANAGEMENT AND REPORTING

Subtask 1.1. Finalize Program Management Plan

A revised Program Management Plan was submitted in February following discussions with EPA on the efficacy of a Class VI permit application for this small scale injection. Modifications were made to the plan in order to begin the pilot CO2-EOR injection in the Mississippian oil reservoir at Wellington Field. This change in order of injection will provide approximately one year for the application and review process for the Class VI Injection in the Arbuckle saline aquifer.

The final PMP will include a copy of the infrastructure requirements for CO2 injection, access documents (surface and subsurface), and a completed contract and commitment for supplying CO2. Contract negotiations with the large subcontractors, Abengoa (supplier of CO2) and Berexco (field activities for small scale test) will be completed next quarter. NEPA environmental questionnaires have been submitted for review for the injection and monitoring boreholes and for the CO2 supply facility.

Subtask 1.5. Drilling and Well Installation Plan

Well Drilling and Installation Plans will be completed early next quarter for all of the wells and boreholes including drilling and installation methods, the well-borehole designs (casing design, centralizer plan, cement design, etc.), method for determining perforation zones, contingencies for anticipated problems encountered during drilling such as loss circulation zones, completion and development plan. Additionally, the drilling and well installation plan will include a description of mud logging, wire line logging, coring, swabbing and laboratory analysis of samples, and any other testing that may be performed on the well-borehole.

Subtask 1.6. Monitoring Verification and Accounting (MVA) and Mitigation Plan:

The MVA and mitigation plans will be completed next quarter as part of the Class VI application and submitted as a separate report.

Subtask 1.7. Public Outreach Plan:

The Public Outreach Plan will also be submitted next quarter as part of the Class VI application. The document will describe workshops, presentations, and publications in technical and trade journals to be used to transfer lessons learned best practices, geomodels, simulation results, MVA data and observations to the public, regulators, legislators, and local industry.

Subtask 1.8. (Go-No Go Decision for CO2 saline formation sequestration) Arbuckle Injection Permit Application

An application for a Class VI underground injection control (UIC) permit for injecting CO_2 into the Arbuckle Group will be submitted next quarter. Substantial progress is being made to ensure timely completion. Key issues to be addressed in the permit application have been addressed as described below.

The final draft permit, after all negotiations are completed, shall be reviewed and a short report submitted to the DOE with a copy of the permit, indicating any potential implementation issues that may arise. This report shall be used to support a go/no go decision by the DOE on continuing this test injection into the Arbuckle.

Key issues in the Class VI injection permit have been discussed with EPA, DOE, and others who are applying for Class VI permit as well as review of pending permits. This has provided an understanding of the course being taken to successfully negotiating the application and to successfully implement the project under these new regulations. Issues identified and addressed include: 1) length of application process with EPA Region 7, 2) monitoring requirements in the context of the funds and duration of the project, and 3) financial assurance requirements. Discussions have included phone conversations, emails, and personal visits with EPA staff in Kansas City's Region 7 and EPA's Washington Headquarters. PI met with key EPA officials from Washington at the Annual Groundwater Protection Council Annual UIC Meeting in Houston in January 2012 to specifically meet and discuss the issues expressed by participants in this project and DOE regarding pursuit of the Class VI permit. The questions posed and comments of EPA are briefly summarized below. Following these discussions, the decision was made by all parties to move ahead with a better understanding by all of the specific attributes of this small scale injection. It was also a joint decision with DOE to delay deployment of the Arbuckle saline formation injection until after the Mississippian CO2-EOR test injection to allow more time to obtain the Class VI injection permit.

Key questions posed to EPA to address decision to proceed or not with application for a Class VI permit –

- What exactly does EPA need to see in our modeling/monitoring results?
- What corresponding relief in the monitoring/bonding obligations can we expect?
- We need a better idea about the expected duration of the Class VI application phases.

- Need concrete numbers associated (to the best extent possible) with these key modeling, monitoring, and application parameters and processes.

Key comments of discussions with EPA --

- Provision in Class VI Final Rule to reduce the monitoring period by demonstrating through modeling/monitoring that there is no danger to the freshwater aquifers.
- 50-yr period monitoring is by default.
- Show by modeling and monitoring that the pressures and plume have "stabilized".
- Up to applicant to demonstrate by modeling that there will be minimal impacts.
- If the pressures and the CO2 plume have stabilized and that no alarming trends have been observed in the monitoring network, then the monitoring can also be shortened.
- Bonding is a function of risk, duration, and type of monitoring needed to reach closure.
- Recognition that saline aquifer beneath oil field inherently reduces uncertainty of containment.

Information shared on project pertinent to making decision to pursue Class VI permit

- Operator of oil field, Berexco, LLC, is single owner of 12 mi2 field (unitized).
- Berexco has purchased pore space from land owner in area of CO2 plume in the Cambro-Ordovician Arbuckle saline formation.
- Berexco has accepted the liability and risk for CO2 injection into saline formation and the overlying oil field.
- Berexco has operated Wellington Field since late 1980's and plans to do so for years to come, ~20 yrs at current operations and longer if CO2-EOR is implemented.
- Berexco has suggested that they could monitor for CO2 after 4-yr project with acceptable cost-effect monitoring technologies and additional funds to do so.
- Mississippian oil reservoir is a continuous stratigraphic layer in Wellington Field that is also currently underpressured relative to underlying saline formation and can act as a pressure trap for any CO2 migrated from beneath.
- Demonstrated sealing caprock above 20 million barrel oil reservoir with 1000's of feet of shale and 200 ft of evaporite separating intervals of CO2 injection from marginal, thin unconfined shallow freshwater overlying Wellington Field and the area of review.
- Comprehensive geologic, geophysical, and geochemical data from existing study (FE0002056) being used to provide a refined geomodel (Petrel-based geocellular static model) and simulation (CMG full compositional simulator) with nearly complete core and extensive core testing being used in calibration of models.

- Proposed CO_2 injection interval in Arbuckle ~5000 ft lies ~1300 ft below the Mississippian oil reservoir and ~900 ft below the top of Arbuckle with intervening caprocks and measured high and low permeable hydrostratigraphic units that comprise the mid and upper Arbuckle saline formation.
- Initial basic dynamic model injected 40,000 tonnes of CO_2 into lower permeable 120 ft thick Arbuckle over a 12-month period resulted in a CO_2 plume with lateral extent under 300 ft radius of injection well with vertical migration within the confines of the lower Arbuckle formation.
- Initial dynamic model does not include geochemical trappings, brine solubility, and imbibition (capillary entrapment mechanisms) that would lead to further degradation of the plume.
- Step-rate flow test in 20 ft interval within proposed injection zone conducted between two boreholes drilled in project DE-FE0002056 confirmed conformable communication of the hydrostratigraphic unit a low injection pressures.
- Small experimental scale of injection relative to others with extensive testing, modeling, monitoring would be a beneficial for this emerging technology and demonstration to stakeholders by providing quantitative parameters on the potential for storage of CO_2 in a saline formation.
- Data will be used to further calibrate regional characterization of storage capacity of the Arbuckle saline formation underway in project DE-FE0002056.

It is also understood that EPA officials desire to have test injections of CO_2 to evaluate new geologic sequestration regulations. A successful small scale test at Wellington Field will provide this information. EPA continues to develop rule-related guidance for in areas of financial responsibility, public participation, site characterization, area of review and corrective action, well construction, testing and monitoring, and project plan development. Our project will address these new guidelines and contribute to the continuing dialog with stakeholders.

The Class VI application for this small scale injection includes fundamental components that closely address the EPA guidelines and recommendations, focused on reduction of uncertainties.

- The small scale test involves injecting CO_2 in deep saline aquifer beneath existing Wellington Field inherit with assurances of the integrity of the caprock overlying the oil field (**Figure 1**).
- Significant past and ongoing characterization in project DOE-FE0002056 will provide 2^{nd} generation static and dynamic models to further improve quantification and prediction of flow, storage, and sealing associated with a CO_2 plume. Information to be included in application will sufficiently reduce the risk and uncertainty of the small scale injection, and develop compliance with EPA regulations and anticipated flexibility required for a successful project that meets budget and practical implementation.

- Monitoring, verification, and accounting (MVA) methodologies developed for this study are cost effective and practical, yet state-of-the-art techniques providing a comprehensive system to characterize CO2 plume to be compared with and to calibrate the 2nd generation simulation. *In situ* and remote monitoring of the injection zone; the immediate overlying portions of the saline formation; oil reservoir; shallow, near surface brine formation beneath shallow evaporite; the unconfined freshwater aquifer; soil zone; and surface deformation will all provide means of rapid detection of any unanticipated movement of CO2 plume, so action can be quickly taken to cease operation and mitigate (**Figure 2**).
- Project will utilize best practices in geology and engineering to manage the CO2, protect freshwater aquifers, and avoid contamination of other subsurface natural resources.

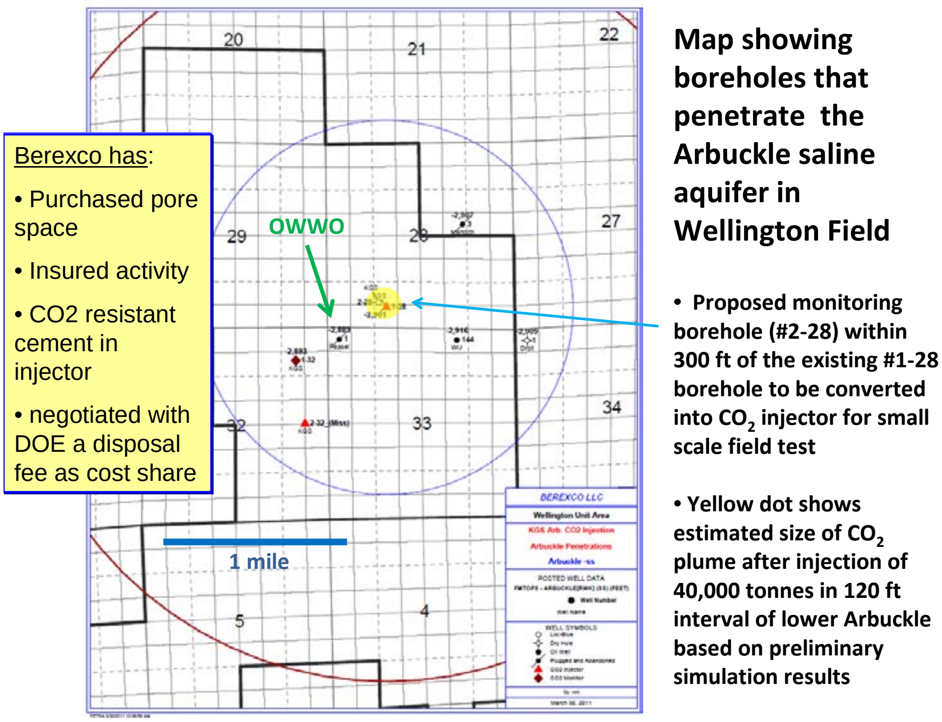


Figure 1. Proposed injection site into Arbuckle saline formation at Wellington Field identifying initially modeled lateral extent of CO2 plume (yellow) and location other Arbuckle boreholes in the area.

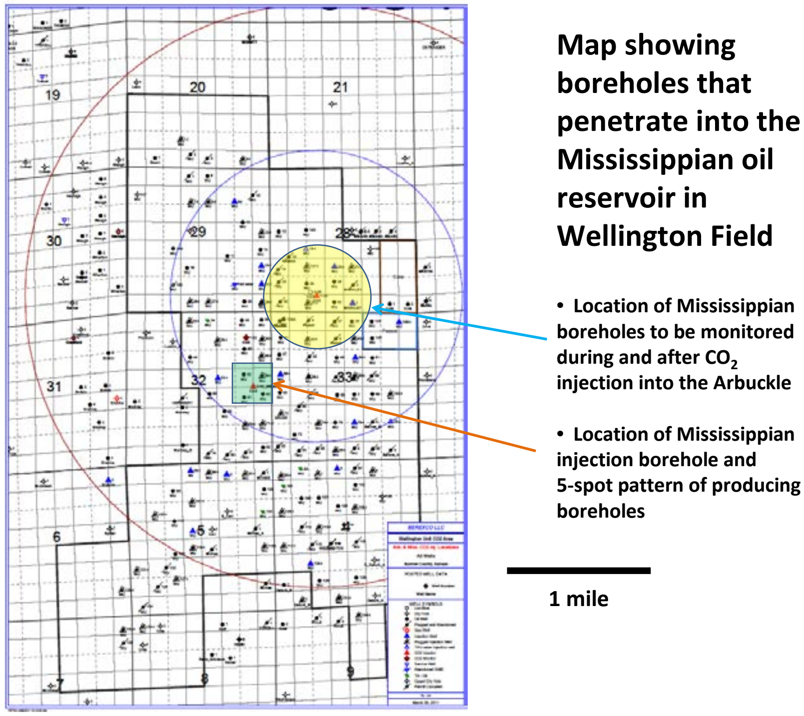


Figure 2. Map locating boreholes penetrating the Mississippian in Wellington field and location of Mississippian wells to be monitored above and beyond the predicted CO2 plume around the location of the Arbuckle injection borehole (yellow-filled circle).

Guidelines from other stakeholder groups such as Carbon Sequestration Council are being reviewed, e.g., resolving means to establish that CO2 storage is "permanent" as noted as follows from the CSC (Van Voorhees, 8-9-11 to MRSCP Partner Meeting):

- Delineate the maximum monitoring area (MMA) – the area expected to contain the free phase CO2 plume until injected CO2 is not expected to migrate in the future in a manner likely to result in surface.
- Identify potential surface leakage pathways in the MMA and assess the likelihood, magnitude, and timing, of surface leakage of CO2 through these pathways.
- Strategy for setting monitoring baselines for surface leakage.
- Strategy for detecting and quantifying any CO2 surface leakage.
- For Class VI, develop emergency and remedial response plan.

Also information provided by the Carbon Sequestration Council (http://www.carbonsequestrationcouncil.org/) cites considerations for obtaining a successful Class VI application including:

- EPA's focus on site selection and characterization.
- Additional focus on performance standards, site specificity, flexibility and adaptability [*up to the application to carefully establish this perspective*].
- Design permit applications to maximize flexibility.
- State permitting programs should use flexibility.

- Permits plans key to adaptation and site specificity.
- Plans define how performance standards apply.
- Plan modifications key adaptations to project learning.

Subtask 1.10. Site Development, Operations, and Closure Plan

A draft of the plan will be developed in the next quarter (*during BP1 as specified by DOE*) to describe the details of the site development, operations, and site closure including:

- list of available infrastructure in and around Wellington Field related to small scale CO2 injection;
- identify all major activities, roles of responsibility, and environmental health and safety issues that the Applicant will face during all stages of the project;
- identify the necessary permits and respective agencies;
- describe the information required for each permit;
- schedule of when permit applications shall be submitted and anticipated approval dates.
- A list of responsible persons for completion and negotiation of the permits shall be identified for each permit.

Task 2. Site Characterization of Arbuckle Saline Aquifer System - Wellington Field

A considerable amount of geologic, geophysical, core and log based petrophysical and geochemical information is being compiled and interpreted in project DE-FE0002056 to quantify the hydrostratigraphic units in the Arbuckle saline formation and overlying caprocks and Mississippian oil reservoir. This information is being used produce the 2nd generation static geocellular model and dynamic simulation for the Class VI application. New models will be obtained in the next quarter for use in the application. Further updates and refinements will be shared with EPA and stakeholders during the evaluation process as per communications with Region 7 EPA officials.

An example for the variability of the permeability in the Arbuckle saline formation, a very key element in the modeling, is illustrated by results of whole core analysis obtained during the quarter from Wellington KGS #1-32 (**Figure 3**).

Seismic processing to obtain conversion of time to depth and to interpret the converted shear wave data in Wellington Field has taken additional time (**Figure 4)**. The depth conversion is now completed and will be used without the shear wave interpretation in the model used in the initial submittal of the Class VI application.

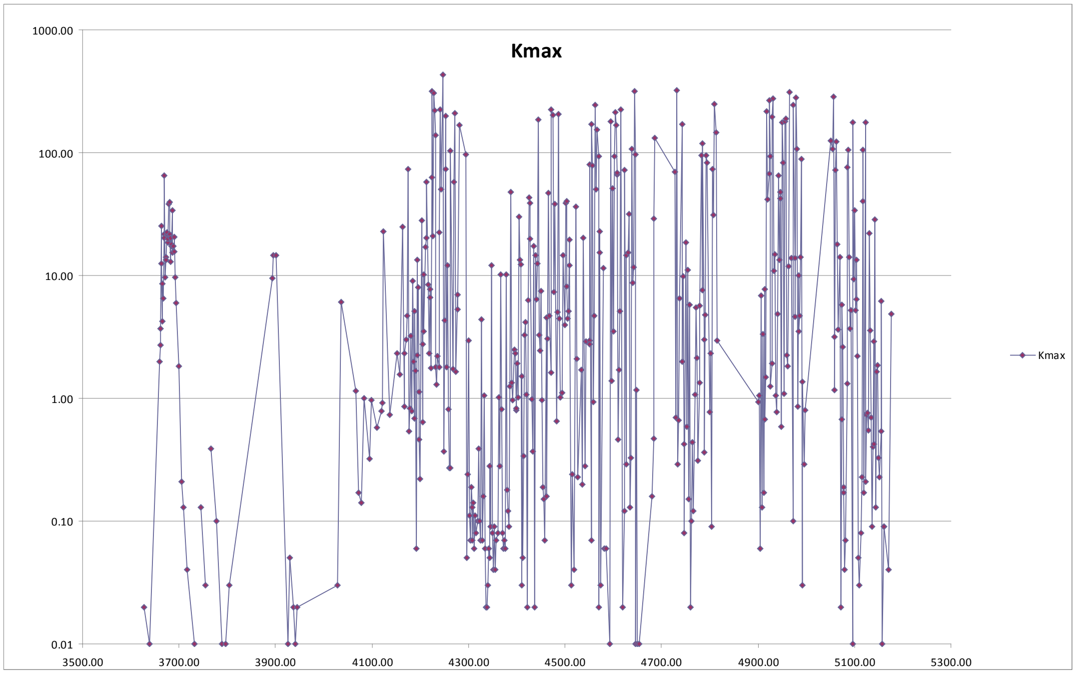


Figure 3. Simple plot (log permeability in millidarcies vs. depth in feet) of whole core analysis of maximum permeability (Kmax) measured in the Mississippian, Chattanooga, and Simpson Group (above 4160 ft depth, left side of plot) and the Arbuckle saline formation, below 4160 ft. Entire 1600 ft interval was cored in this plot from Wellington KGS #1-32. Fewer whole rock samples were analyzed above the Arbuckle in what were visually determined to be low visual permeability. Instead, CT scans were obtained in the low permeable intervals. Entire interval was logged with nuclear magnetic resonance (NMR) tool that is being used to calibrate effective porosity, pore size, and permeability that will be used to quantify the permeability. Moreover, special core analysis of tight zones has being done at NETL labs that have obtained permeability in the microdarcy to picodarcy permeability range in the lower organic argillaceous carbonates of the Mississippian. Note the considerable vertical heterogeneity of permeability in the Arbuckle with Kmax varying from less than 0.10 millidarcy to several hundred millidarcies. No core samples have measured permeability that has reached the 1 Darcy level or above, which is consistent with the estimates of permeability from the NMR tool. Moreover, fracture heights measured in the core indicate that they are closely correlated to the hydrostratigraphic linked lithofacies, i.e., enhance the matrix pores, but closely constrained by the stratigraphic zonation. Larger matrix pores, and particularly, thin inter-formational breccias have more fractures.

Remaining Seismic Work at Wellington Field

Activity-Entity / Timeline	Nov-11	Dec-11	Jan-12
Wellington Area			
PreStack Depth Migration (PSDM) -FarifieldNodal	X		
PSDM Volumetric Curvature Processing - Geo-Texture			
PSDM Volumetric Curvature Interpretation - Nissen			
PSDM Interpretation -HS Geo		X	
Impedance Inversion - PSDM input-HS Geo		X	
Elastic Inversion - Pre-stack Time Migration (PSTM) Input-HS Geo		X	
Spectral Decomposition (Frequency Domain Processing)-HS Geo			X
2D Shear Wave Processing-FairfieldNodal	X		
2D Shear Wave Interpretation-HS Geo		X	
Converted Wave Processing-FairfieldNodal	X	X	
Converted Wave Interpretation- HS Geo		X	

Figure 4. Prior estimates of the extensive geophysical processing and interpretation being done for Wellington 3D multicomponent seismic survey in project DE-FE0002056. All of the activities will be completed in the next quarter.

Task 3. Site characterization of Mississippian Reservoir for CO2 EOR -Wellington Field

New seismic processing and interpretations as described above are underway and will be integrated in the second quarter for use in the Class II injection permit for the CO2-EOR test injection into the Mississippian oil reservoir at Wellington Field. The new prestack depth migration volume will be of major importance in the simulation of the CO2-EOR flood (**Figures 4 and 5**). The additional seismic profile in **Figure 6** illustrates the detailed information from the seismic in the Paleozoic interval down to the Precambrian surface at the base of the Arbuckle saline formation.

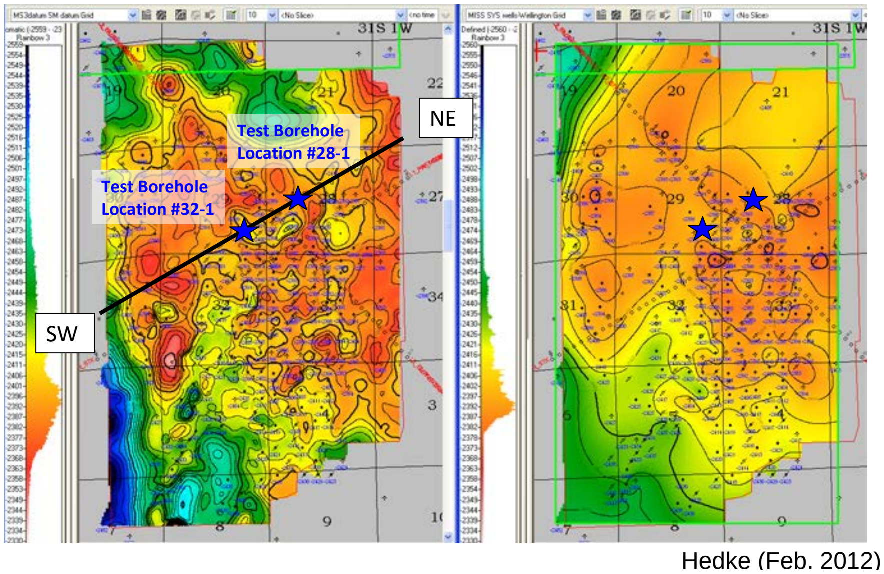


Figure 4. Prestack depth migration top Mississippian (left) compared to the Mississippian structure map using well control only (right). Correspondence of the two maps is excellent with additional resolution provided by the seismic data. Both sets of data will be integrated into the geocellular static model of the Mississippian reservoir. Note index line locating the shear wave survey shot at Wellington for calibration of the converted wave of the 3D seismic survey. 2D survey is shown in Figure 5.

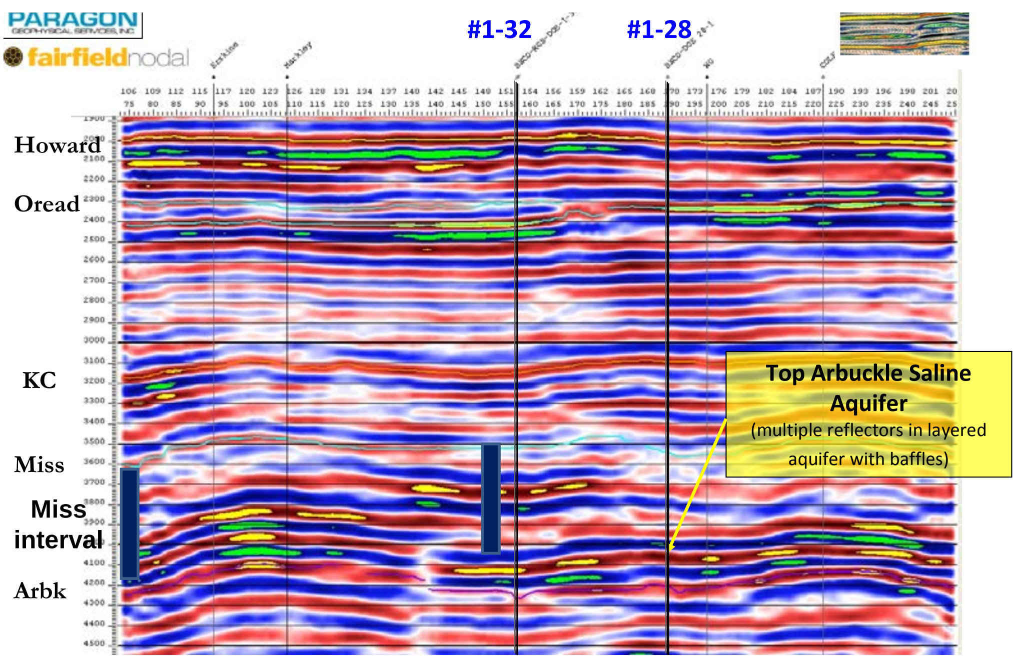


Figure 5. Preview of the converted shear wave, prestack depth migrated multi-component 3D seismic volume in Wellington Field coincident with southwest-to-northeast oriented shear wave line #1 identified in Figure 4.

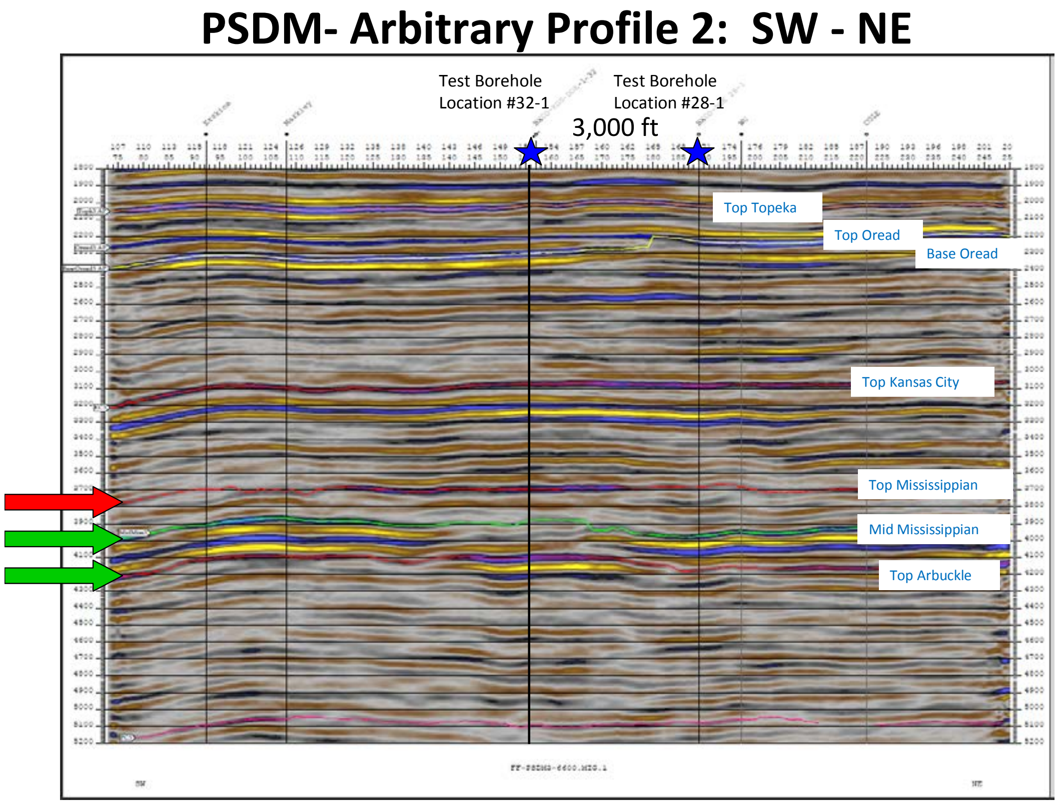


Figure 5. PSDM of an arbitrary profile running southwest to northeast intersecting the two test boreholes drilled under DE-FE0002056. Stratigraphic horizons are identified. Precambrian basement is the lower pink line at the base of the Arbuckle saline formation.

The rich core and log petrophysical database at Wellington KGS #1-32 borehole located 3000 feet southwest of the CO2 injection well, #1-28, provides an exemplary view of the strata extending from the 100 ft thick Cherokee Shale above the Mississippian into the upper Precambrian. These data are summarized in **Figures 6-10**.

The 430-foot thick Mississippian interval includes both the oil reservoir at its top (**Figures 6, 7, and 8**) and a lower 110 ft interval (**Figure 10**, referred to as dark Cowley facies) that is comprised of dark, organic-bearing argillaceous quartz and dolomite siltstone that is being characterized as added caprock to the underlying shales in the Simpson Group and Chattanooga Shale.

- <u>Vertically stacked siliceous dolo-siltites</u> reflect upward-shallowing, retrogradationally/progradationally stacked cycles comprising a depositional sequence.
- Cycles consist of argillaceous dolo- and lime mudstone and wackestones, siliceous dolo-siltites, and increasingly sponge-rich, skeletal wacke–packstones that cap shallowest portions of cycles on higher portions of the ramp.

- <u>Shallowest cycles deposited along higher edges of ramp were affected by bottom currents and were subaerially exposed after deposition.</u>

- <u>Rock properties typically change systematically upward</u> through the reservoir succession with molds and vugs, pore throat size, and connectedness varying between each successive cycle affecting cementation exponent & bound water.

Cored Well, Berexco Wellington KGS #1-32
Top Mississippian to Kinderhook Shale

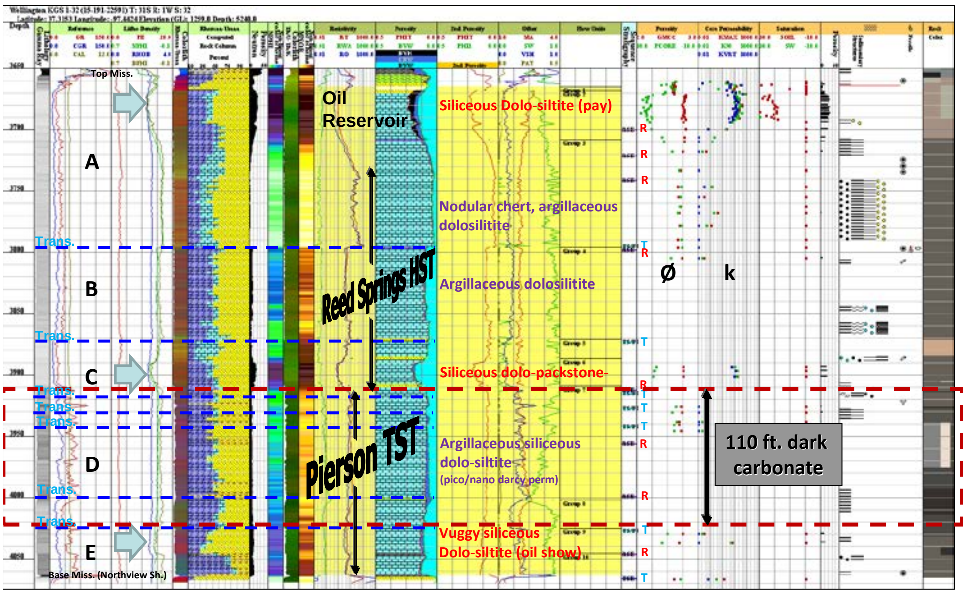


Figure 6. Well log and interpreted lithologic profile from logs on left. Right side illustrates porosity and permeability measurements from core, sedimentary structures, and color for Wellington KGS #1-32 borehole.

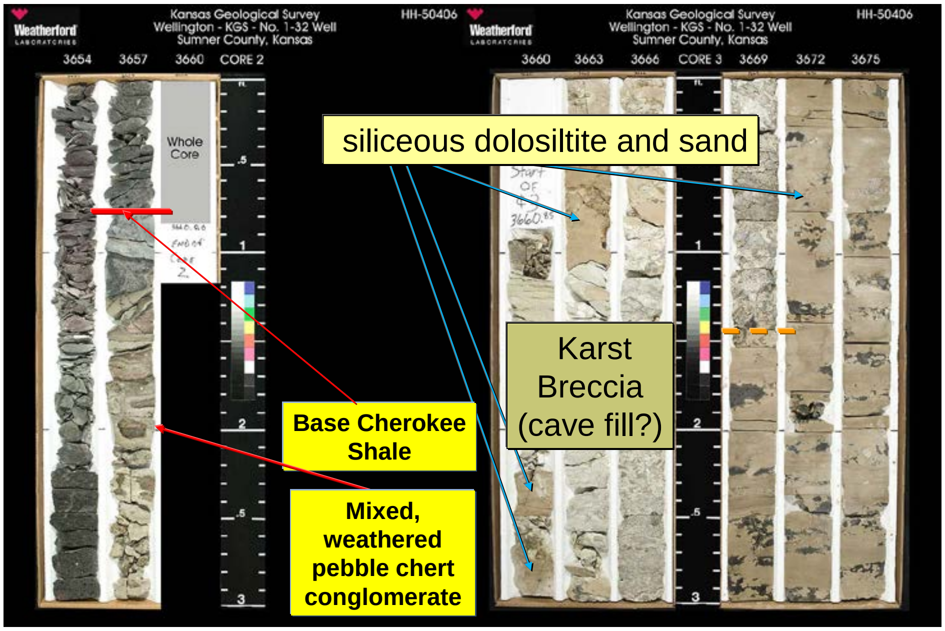


Figure 7. Three boxes of slabbed core (3 ft long) from Wellington KGS #1-32 borehole showing upper portion of the oil reservoir in Wellington Field overlain by shales of the Pennsylvanian Cherokee Group.

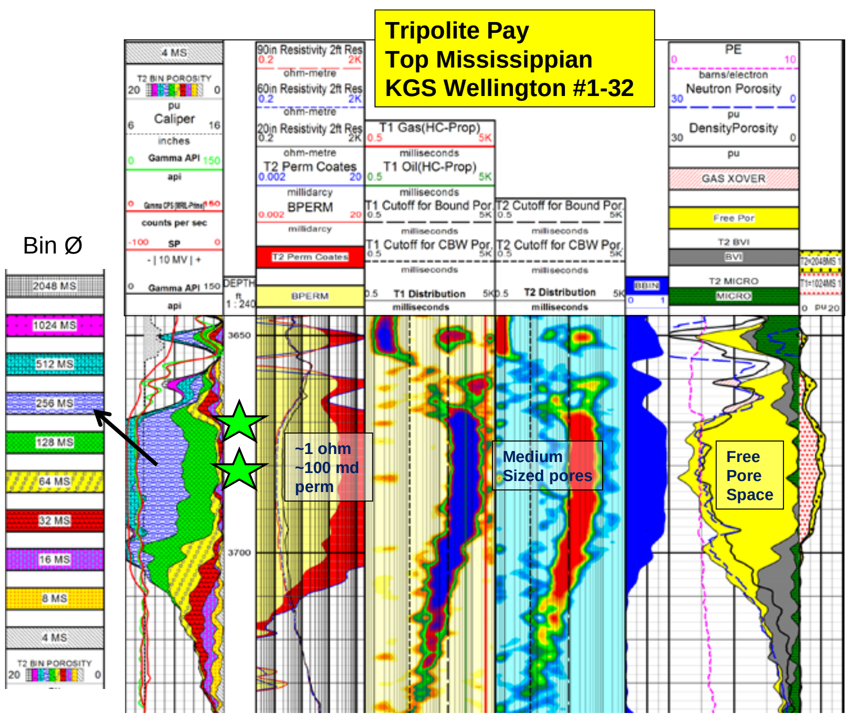
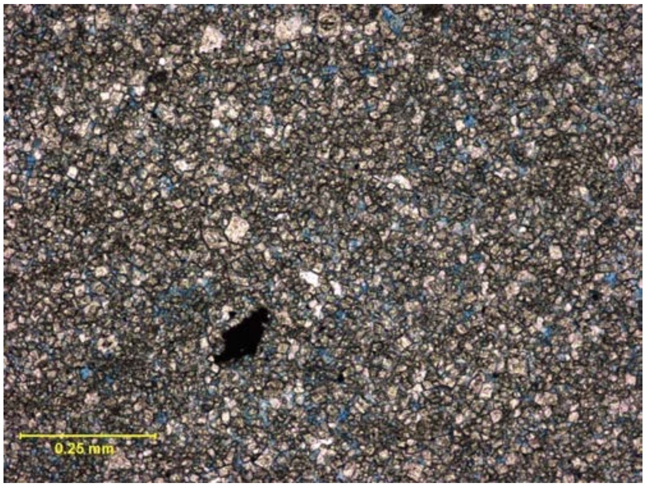


Figure 8. Interpreted nuclear magnetic resonance (NMR) log profile of the Mississippian oil zone in Wellington KGS #1-32 borehole, annotated with summary information: low one ohm-m resistivity, moderate porosity of around 100 md,

medium sized pores (intercrystalline dolomite), most of which is free pore space with minor bound water.

3670.6’



- Plain Light (10x zoom)
- Fine grained dolomite with intercrystalline porosity
- Opaque oxide/sulfide (?) present

TS provided by Datta & Barker, KSU

Figure 9. Thin section photomicrograph with blue epoxy impregnation of Mississippian oil reservoir from Wellington KGS #1-32 borehole. Reservoir is a finely crystalline dolomite with mottling of silica cement and replacement of the dolomite.

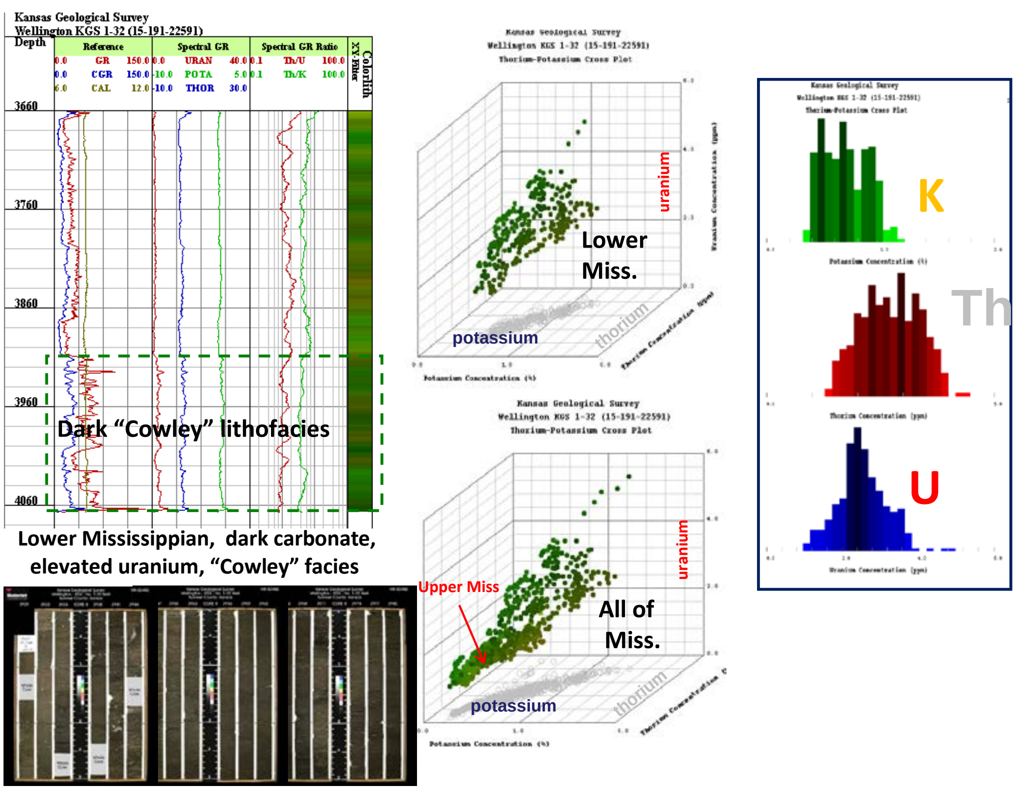


Figure 10. (*previous page*) Spectral gamma ray profile (uranium, potassium, and thorium) of the Mississippian strata in Wellington KGS #1-32 borehole and comparison of these elements in cross plots to right show elevated uranium content in lower Mississippian "Cowley lithofacies. Photos of 3 ft high core boxes illustrating the dark colored, tight, low permeability argillaceous siltstones of the "Cowley" lithofacies shown in lower left.

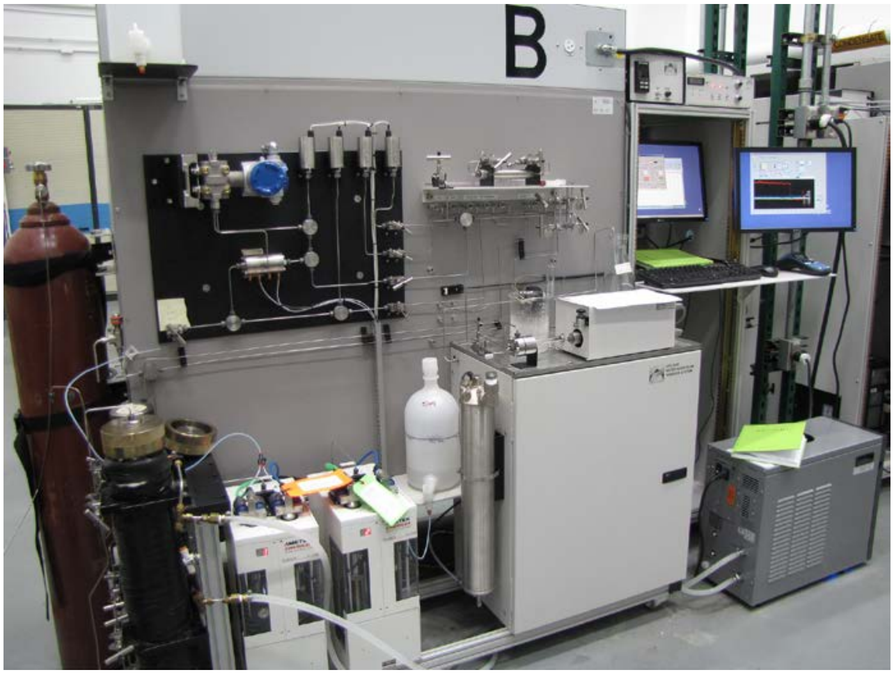


Figure 11. Core flow apparatus used at NETL in Pittsburgh to measure the microdarcy and picodarcy permeability in the lower Mississippian organic bearing, argillaceous quartz/dolomitic siltstones that are being evaluated to serve as additional caprock that overlies the Arbuckle saline formation.

Subtask 9.2. Install LIDAR Survey Reflectors, CGPS, and Seismometers in a Grid Pattern near the Injection borehole.

Mike Taylor constructed a base station on the KU campus in February 2012 and received training during Spring Semester for the operation of the CGPS (continuous GPS that is used to calibrate InSAR and LiDAR surveys), and a seismograph station. The equipment installation in Lawrence is essential for training on the use of equipment and to test materials before being sent to the field before equipment is deployed in Wellington Field. Issues such as earthquakes and fracking are on everyone's mind and these surveys will insure that we are not doing either.

Figure 12. CGPS and seismometer training station installed at KU campus for instruction and testing of equipment before deploying to the field.

Schedule and Budget Update

Schedule - Seismic processing of converted shear wave and interpretation of the seismic at Wellington Field continues. We will update the Petrel geocellular geomodel and run the 2nd generation CMG simulations in the next quarter to include in the application for the Class VI injection permit. Our objective of the new model will be to reduce excessive default monitoring and financial bonding by adequately characterizing the geology of the saline aquifer, caprocks, and overlying oil reservoir.

The provisional schedule to inject CO2 into the Mississippian oil reservoir ahead of the Arbuckle is provided in the series of Gantt charts included in **Figures 12 through 15**.

Expenses -- The expenses charged to the DoE for January 1, 2012 through March 31, 2012 on this project total $17,208.52, and include supplies (such as cowhide and leather gloves, scratch brush, fasteners, bars, ear plugs and wire); Galetzka airfare and mobile welder (an expense provided by Geology Dept); TBirdie Consulting; travel to San Francisco, Pittsburgh, Houston, and Long Beach; and associated F&A. Cost share contribution for in-kind appointments for Watney. Rush and Newell total $6,475.85.

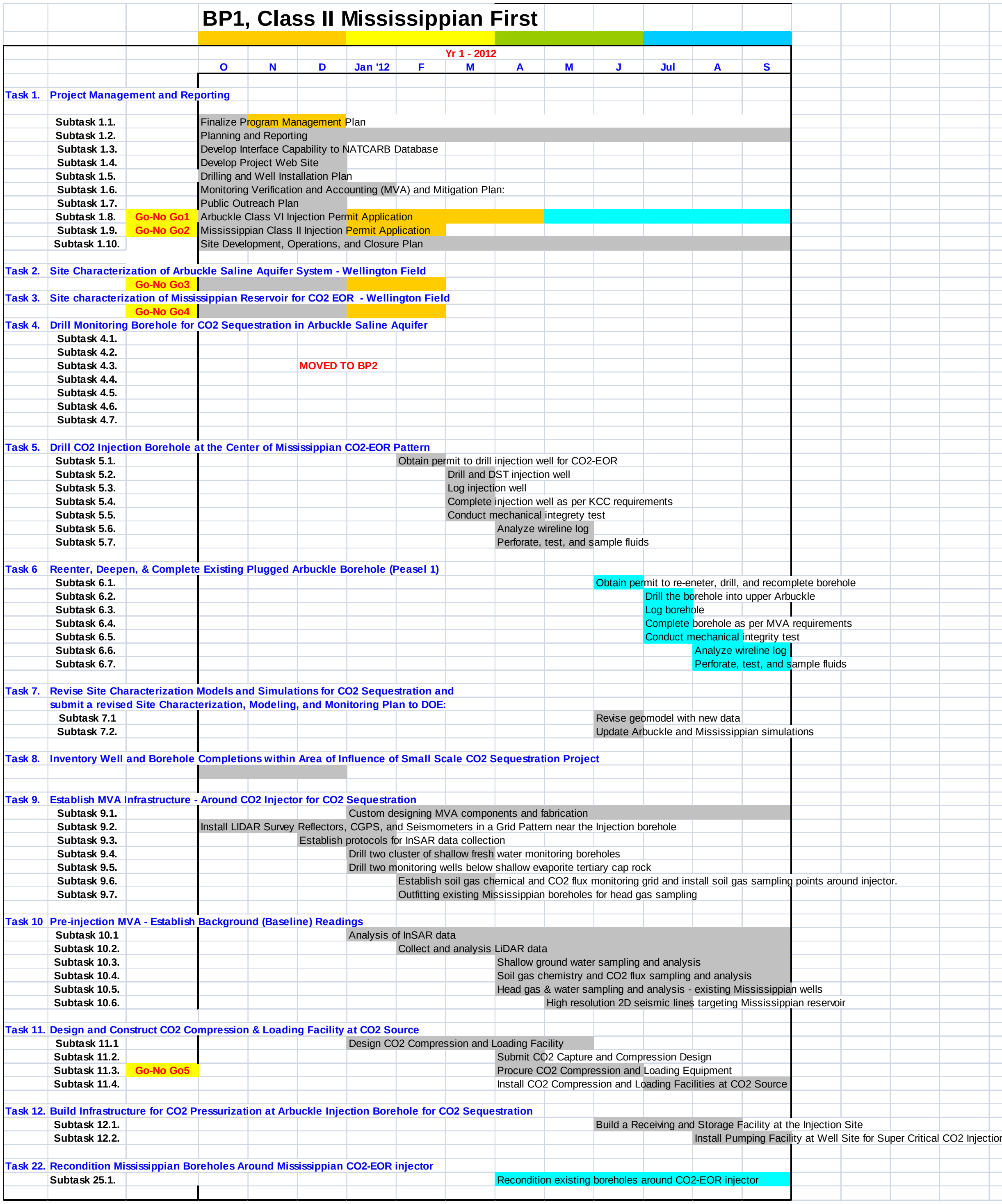


Figure 12. Revised schedule BP1.

BP2 - Class II Mississippian first

Yr 2 - 2013

O | N | D | Jan '13 | F | M | A | M | J | Jul | A | S

Task 1.	Project Management and Reporting		
	Subtask 1.2.		Program management and reporting
	Subtask 1.8.	Go-No Go1	Arbuckle Class VI Injection Permit Application *******
	Subtask 1.10.		Site Development, Operations, and Closure Plan
Task 4.	Drill Monitoring Borehole for CO2 Sequestration in Arbuckle Saline Aquifer		
	Subtask 4.1.		Obtain permit to drill monitoring well
	Subtask 4.2.		Drill and DST monitoring well
	Subtask 4.3.		Log monitoring well
	Subtask 4.4.		Complete monitoring well as per MVA requirements
	Subtask 4.5.		Conduct mechanical integrity test
	Subtask 4.6.		Analyze wireline log
	Subtask 4.7.		Perforate, test, and sample fluids
Task 6	Reenter, Deepen, & Complete Existing Plugged Arbuckle Borehole (Peasel 1)		
	Subtask 6.1.		Obtain permit to re-eneter, drill, and recomplete borehole
	Subtask 6.2.		Drill the borehole into upper Arbuckle
	Subtask 6.3.		Log borehole
	Subtask 6.4.		Complete borehole as per MVA requirements
	Subtask 6.5.		Conduct mechanical integrity test
	Subtask 6.6.		Analyze wireline log
	Subtask 6.7.		Perforate, test, and sample fluids
Task 10.	Pre-injection MVA - establish background (baseline) readings		(Delete 3 months of pre-injection monitoring)
	Subtask 10.1		Analysis of INSAR data
	Subtask 10.2.		Collect and analysis LIDAR data
	Subtask 10.3.		Shallow ground water sampling and analysis
	Subtask 10.4.		Soil gas chemistry and CO2 flux sampling and analysis
	Subtask 10.5.		Head gas & water sampling and analysis - existing Mississippian wells
	Subtask 10.7.		1st crosshole tomograpahy - pre-injection
Task 13.	Retrofit Arbuckle Injection Well (#1-28) for MVA Tool Installation		
	Subtask 13.1.		Install CASSM source(s)
Task 14.	Retrofit Arbuckle Observation Well (#2-28) for MVA Tool Installation		
	Subtask 14.1.		Install U-tube
	Subtask 14.2.		Install CASSM receiver (applicable for cross-hole tomography)
	Subtask 14.3.		Install DTPS sensors
Task 15.	Begin Injection at Arbuckle Injector		
	Subtask 15.1.		
	Subtask 15.2.		
Task 16.	MVA During Injection - Mississippian and Arbuckle CO2 Sequestration		
	Subtask 16.1.		~~CASSM monitoring~~
	Subtask 16.2.		Soil gas chemistry and CO2 flux sampling and analysis
	Subtask 16.3.		~~U-tube monitoring~~
	Subtask 16.4.		Shallow ground water sampling and analysis
	Subtask 16.5.		Head gas & water sampling and analysis - existing Mississippian boreholes
	Subtask 16.6.		LiDAR surveys
	Subtask 16.7.		InSAR data analysis
	Subtask 16.8.		~~Second Crosswell Tomography Halfway Through Injection~~
	Subtask 16.9.		~~Integration of CASSM and Crosswell Tomography~~
Task 24.	CO2 Transported to Mississippian Injector		
	Subtask 24.1.		Transport CO2 to injection borehole
	Subtask 24.2.		Inject CO2 at CO2-EOR injection borehole under miscible conditions
Task 25.	Monitor Performance of CO2-EOR Pilot		
Task 26.	Compare Pilot EOR Performance with Model Results		
	Subtask 26.1.		Compare field performance with simulation studies
	Subtask 26.2.		Revise geomodel - if necessary
	Subtask 26.3.		Update simulation - if necessary

Begin injection as Class II into Mississippian January 2013, 3 months ahead of original injection
inject for 9 months to end of BP2

Figure 13. Revised schedule BP2

BP3, Year 1 - Class II Mississippian first

Yr 3 - 2014

O | N | D | Jan '14 | F | M | A | M | J | Jul | A | S

Task 1.	Project Management and Reporting	
	Subtask 1.1.	Program management and reporting
Task 15.	Begin Injection at Arbuckle Injector	
	Subtask 18.1.	CO2 Transportation to Arbuckle Injector
	Subtask 18.2.	Inject supercritical CO2
Task 16.	MVA during injection - CO2 Sequestration site	
	Subtask 16.1.	CASSM monitoring
	Subtask 16.2.	Soil gas chemistry and CO2 flux sampling and analysis
	Subtask 16.3.	U-tube monitoring
	Subtask 16.4.	Shallow ground water sampling and analysis
	Subtask 16.5.	Head gas & water sampling and analysis - existing Mississippian wells
	Subtask 16.6.	LiDAR surveys
	Subtask 16.7.	InSAR data analysis
	Subtask 16.8.	2nd crosshole tomography halfway through injection (optional)
	Subtask 16.9.	Integration of CASSM and crosswell tomography
Task 17.	Risk Management Related to CO2 Sequestration in Arbuckle Saline Aquifer	
	Subtask 17.1.	Integrate MVA analysis and observations to detect CO2 leakage
	Subtask 17.2.	Activate mitigation plans if leakage detected
Task 18.	Compare Simulation Results with MVA Data and Analysis and Submit Update of Site Characterization, Modeling, and Monitoring Plan	
	Subtask 18.1.	Revise Geomodel to Improve Match with MVA Data
~~Task 19.~~	~~Post injection MVA - Arbuckle CO2 Sequestration~~	
~~Task 20.~~	~~Evaluate CO2 Sequestration Potential in Arbuckle Saline Aquifer at Wellington~~	
~~Task 21.~~	~~Evaluate Regional CO2 Sequestration Potential in Arbuckle Saline Aquifer in Kansas~~	
~~Task 22.~~	~~Recondition Mississippian Boreholes Around Mississippian CO2-EOR injector~~	
	~~Subtask 25.1.~~	~~Recondition existing boreholes around CO2-EOR injector~~
Task 23.	Equipment Dismantlement	
Task 24.	CO2 Transported to Mississippian Injector (if Class VI permit not granted)	
	Subtask 24.1.	Transport CO2 to injection borehole
	Subtask 24.2.	Inject CO2 at CO2-EOR injection borehole under miscible conditions
Task 25.	Monitor Performance of CO2-EOR Pilot (if Class VI permit not granted)	
Task 26.	Compare Pilot EOR Performance with Model Results (if Class VI permit not granted)	
	Subtask 26.1.	Compare field performance with simulation studies
	Subtask 26.2.	Revise geomodel - if necessary
	Subtask 26.3.	Update simulation - if necessary

Begin Class VI injection into Arbuckle, October 2013 for 12 months to end of BP3 Yr1

Figure 14. Revised schedule BP3-Year 1.

BP3, Year 2 - Class II Mississippian first

Yr 4 - 2015

O | N | D | Jan '15 | F | M | A | M | J | Jul | A | S

Task 1.	Project Management and Reporting	
	Subtask 1.1.	Program management and reporting
~~Task 16.~~	~~MVA during injection - CO2 Sequestration site~~	
	~~Subtask 16.1.~~	~~CASSM monitoring~~
	~~Subtask 16.2.~~	~~Soil gas chemistry and CO2 flux sampling and analysis~~
	~~Subtask 16.3.~~	~~U-tube monitoring~~
	~~Subtask 16.4.~~	~~Shallow ground water sampling and analysis~~
	~~Subtask 16.5.~~	~~Head gas & water sampling and analysis - existing Mississippian wells~~
	~~Subtask 16.6.~~	~~LiDAR surveys~~
	~~Subtask 16.7.~~	~~InSAR data analysis~~
	~~Subtask 16.8.~~	~~2nd crosshole tomography halfway through injection (optional)~~
	~~Subtask 16.9.~~	~~Integration of CASSM and crosswell tomography (done in BP3 Yr1)~~
Task 17.	Risk Management Related to CO2 Sequestration in Arbuckle Saline Aquifer	
	Subtask 17.1.	Integrate MVA analysis and observations to detect CO2 leakage
	Subtask 17.2.	Activate mitigation plans if leakage detected
Task 19.	Post injection MVA - CO2 sequestration site	
Task 20.	Evaluate CO2 Sequestration Potential in Arbuckle Saline Aquifer at Wellington	
Task 21.	Evaluate regional CO2 Sequestration Potential in Arbuckle Saline Aquifer in Kansas	
~~Task 24.~~	~~CO2 Transported to Mississippian Injector~~	
	~~Subtask 24.1.~~	~~Truck CO2 to injection well~~
	~~Subtask 24.2.~~	~~Inject CO2 at CO2-EOR injection well under miscible conditions~~
~~Task 25.~~	~~Monitoring Performance of CO2-EOR Pilot~~	
~~Task 26.~~	~~Compare Pilot EOR Performance with Model Results~~	
	Subtask 26.1.	~~Revise geomodel - if necessary~~
Task 27.	Evaluate CO2 Sequestration Potential of CO2-EOR Pilot	
Task 28.	Evaluate Potential of Incremental Oil Recovery and CO2 Sequestration by CO2-EOR - Wellington field	
	Subtask 28.1.	Revise Wellington field geomodel
	Subtask 28.2.	Use simulation studies to estimate field-wide CO2-EOR potential
	Subtask 28.3.	Estimate field-wide CO2 sequestration potential of CO2-EOR
Task 29.	Closure of CO2 Sequestration Project in Arbuckle Saline Aquifer at Wellington field	
	Subtask 29.1	Acquire and process 3D seismic data around Arbuckle injector (#1-28)
	Subtask 29.2	Interpret newly acquired 3D data and compare with baseline survey
	Subtask 29.3.	Integrate MVA analysis results with 3D survey to establish CO2 containme
	Subtask 29.4.	Seek regulatory permission for closure
Task 30.	Develop a Best Practice Manual:	

Will have full year of no injection to monitor before closure of the project

Figure 15. Revised schedule BP3, Year 2.

Presentations

Invited presentation on Mississippian reservoir at AAPG GeoScience Technology Workshop (GTW), "New Directions in Carbonates", February 27-29, 2012, Fort Worth, Texas

Invited presentation on DOE projects including small scale injection to Kansas Geological Society technical meeting, March 6, 2012.

Key Findings

Discussions early in the quarter (January) with EPA and others who are applying for Class VI injection permit have allowed us to move forward to prepare the application. Large contracts are nearing final negotiations so that field operations can begin. Environmental questionnaires for drilling and CO_2 source plant have been submitted for review.

Plans

1. Submit revised Program Management Plan
2. Finalize and submit application for Class VI injection permit with updated geomodel and simulation of the Arbuckle saline formation
3. Submit well drilling and installation plan
4. Submit MVA plan.
5. Submit Public Outreach Plan
6. Submit Mississippian Injection Permit Application (Class II injection well under Kansas primacy, regulated by Kansas Corporation Commission) using updated geomodel and simulation of the Mississippian oil reservoir.
7. Once permission granted for field deployment, install LiDAR, InSAR, CGPS, seismometers, groundwater monitoring wells above and below evaporite beds, drilling of Mississippian CO_2 injection well, and construction of facility at Abengoa Biofuels ethanol plant to capture CO_2.