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

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

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		
☒ SF-425 Federal Financial Report	Q, FG	FITS@NETL.DOE.GOV
D. CLOSEOUT REPORTING		
☒ Patent Certification	FC	FITS@NETL.DOE.GOV
☒ SF-428 & 428B Final Property Report	FC	FITS@NETL.DOE.GOV
☐ Other		
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

Project Director/Principal Investigator:
W. Lynn Watney
Senior Scientific Fellow
Kansas Geological Survey

Ph: 785-864-2184, Fax: 785-864-5317
lwatney@kgs.ku.edu

Joint Principal Investigator:
Jason Rush

Prepared by Lynn Watney and Tiraz Birdie

Date of Report: August 7, 2014
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 9/30/2016

Eleventh Quarterly Report

Period Covered by the Report: April 1, 2014 through June 30, 2014

Signature of Submitting Official:

W. Lynn Watney Digitally signed by W. Lynn Watney
DN: cn=W. Lynn Watney, o=The University of Kansas, ou=Kansas Geological Survey, email=lwatney@kgs.ku.edu, c=US
Date: 2014.09.04 20:26:19 -05'00'

EXECUTIVE SUMMARY

Project Objectives

The objectives of this project are to understand the processes that occur when a maximum of 70,000 metric tonnes of CO_2 are injected into two different formations to evaluate the response in different lithofacies and depositional environments. The evaluation will be accomplished through the use of both *in situ* and indirect MVA (monitoring, verification, and accounting) technologies. The project will optimize for carbon storage accounting for 99% of the CO_2 using lab and field testing and comprehensive characterization and modeling techniques.

CO_2 will be injected under supercritical conditions to demonstrate state-of-the-art MVA tools and techniques to monitor and visualize the injected CO_2 plume and to refine geomodels developed using nearly continuous core, exhaustive wireline logs, and well tests and a multi-component 3D seismic survey. Reservoir simulation studies will map the injected CO_2 plume and estimate tonnage of CO_2 stored in solution, as residual gas, and by mineralization and integrate MVA results and reservoir models shall be used to evaluate CO_2 leakage. A rapid-response mitigation plan will be developed to minimize CO_2 leakage and provide comprehensive risk management strategy. A documentation of best practice methodologies for MVA and application for closure of the carbon storage test will complete the project. The CO_2 shall be supplied from a reliable facility and have an adequate delivery and quality of CO_2.

Scope of Work

Budget Period 1 includes updating reservoirs models at Wellington Field and filing Class II and Class VI injection permit application. Static 3D geocellular models of the Mississippian and Arbuckle shall integrate petrophysical information from core, wireline logs, and well tests with spatial and attribute information from their respective 3D seismic volumes. Dynamic models (composition simulations) of these reservoirs shall incorporate this information with laboratory data obtained from rock and fluid analyses to predict the properties of the CO_2 plume through time. The results will be used as the basis to establish the MVA and as a basis to compare with actual CO_2 injection. The small scale field test shall evaluate the accuracy of the models as a means to refine them in order to improve the predictions of the behavior and fate of CO_2 and optimizing carbon storage.

Budget Period 2 includes completing a Class II underground injection control permit; drilling and equipping a new borehole into the Mississippian reservoir for use in the first phase of CO_2 injection; establishing MVA infrastructure and acquiring baseline data; establishing source of CO_2 and transportation to the injection site; building injection facilities in the oil field; and injecting CO_2 into the Mississippian-age spiculitic cherty dolomitic open marine carbonate reservoir as part of the small scale carbon storage project.

In Budget Period 3, contingent on securing a Class VI injection permit, the drilling and completion of an observation well will be done to monitor injection of CO_2 under supercritical conditions into the Lower Ordovician Arbuckle shallow (peritidal) marine dolomitic reservoir. Monitoring during pre-injection, during injection, and post injection will be accomplished with MVA tools and techniques to visualize CO_2 plume movement and will be used to reconcile simulation results. Necessary documentation will be submitted for closure of the small scale carbon storage project.

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

1. Class VI application submitted and accepted by EPA and Deliverable in Subtask 1.8 "Arbuckle Injection Permit Application Review go/no go Memo" was submitted.

-- Permit application was submitted to EPA and accepted on June 19th.

2. CO2 suppliers have been secured.

-- Praxair and Linde Group have been secured as vendors to supply CO_2 under the Berexco subcontract.

3. **Science further enhanced with receipt of 15 seismometers for IRIS-PASSCAL Seismic array deployment and three active 3-component active seismometers purchased with KGS funds to compliment other monitoring including high-resolution seismic, high-resolution cGPS/InSAR, and downhole U-tube sampling and CASSM.**

4. **Important science questions directed toward to improved prediction and evaluation of dynamic changes in the CO_2 plumes are anticipated using recent refinements in existing Petrel-CMG models.**

5. **Increased relevancy of this project to the DOE Portfolio.**

6. **With submittal of the Class VI application, securing CO_2 supply, and level of scientific study related to the Mississippian injection, DOE agreed to proceed with plans for Mississippian injection ahead of the Arbuckle.**

Milestone Status Report

Task	Budget Period	Number	Milestone Description
Task 2.	1	1	Site Characterization of Arbuckle Saline Aquifer System - Wellington Field
Task 3.	1	2	Site characterization of Mississippian Reservoir for CO2 EOR - Wellington Field
Task 10.	2	3	Pre-injection MVA - establish background (baseline) readings
Task 13.	2	4	Retrofit Arbuckle Injection Well (#1-28) for MVA Tool Installation
Task 18.	3-yr1	5	Compare Simulation Results with MVA Data and Analysis and Submit Update of Site Characterization, Modeling, and Monitoring Plan
Task 22.	3-yr1	6	Recondition Mississippian Boreholes Around Mississippian CO2-EOR injector
Task 27.	3-yr2	7	Evaluate CO2 Sequestration Potential of CO2-EOR Pilot
Task 28.	3-yr2	8	Evaluate Potential of Incremental Oil Recovery and CO2 Sequestration by CO2-EOR - Wellington field

Project Schedule

Decision was made by DOE in May to move forward with the Mississippian injection as highlighted in the schedule shown in **Figure 1**.

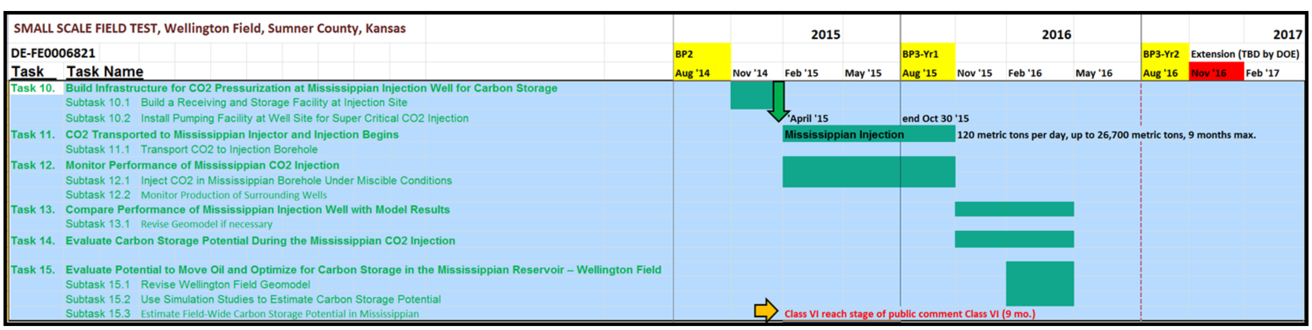


Figure 1. Budget period 2 would begin with preparations to injection CO_2 into the Mississippian oil reservoir.

Decision to move forward was made after Berexco's CFO signed the Class VI permit and the Class VI permit application was submitted to EPA. It is understood that the permit must be submitted to the EPA and deemed administratively complete prior to conducting any field work.

The SOPO was revised and the full schedule of the project was modified to fit the end date of funding, September 30, 2016. The portion of the schedule with the Arbuckle injection is shown in **Figure 2**.

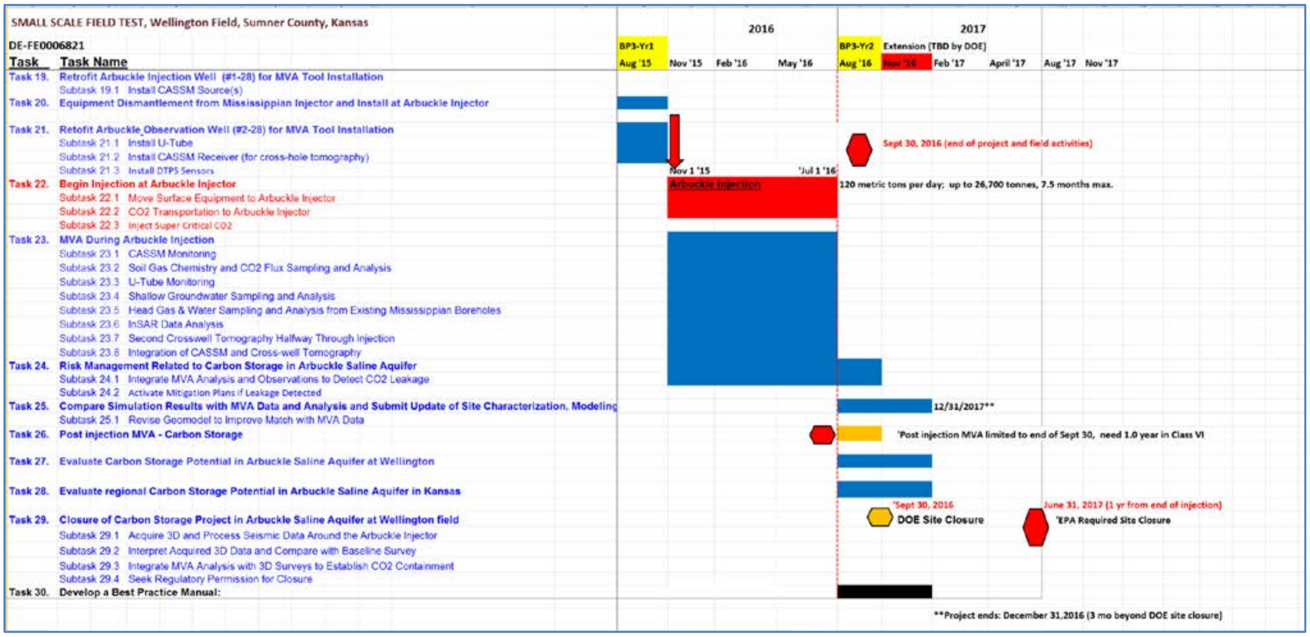


Figure 2. Project schedule for pre- and post-Arbuckle injection at Wellington Field.

Activities of Lawrence Berkeley National Lab

No work has been completed or funds expended during this quarter by LBNL.

ONGOING ACTIVITIES

TASK 1. PROJECT MANAGEMENT AND REPORTING

Subtask 1.7. Public Outreach Plan

Please see Appendix A.

Subtask 1.8. Arbuckle Injection Permit Application Review go/no go Memo (See Appendix A-4 Permit Application)

1. Class VI Injection Application submitted and accepted.

Subtask 1.8 Arbuckle Injection Permit Application:

As noted in SOPO: During the first budget period the Recipient shall submit an application for a Class VI underground injection control (UIC) permit for injecting CO_2 into the Arbuckle Group. 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 the project.

GO/NO-GO DECISION POINT #1

This deliverable was met by administrative acceptance of Class VI application by EPA on June 19 and Memorandum shared with Program Manager on June 27th. Application was submitted by Jennifer Raney, KGS, on behalf of Berexco, LLC, the project's industry partner and operator of Wellington Field.

The following is the electronic confirmation of a successful upload of the application to EPA website.

EPA Class VI UIC Permit Application Upload

This permit application is for:

Project ID: R07-KS-0001

Project Name: Kansas Small Scale Test Wellington Field

General Information

Number of proposed Class VI wells: 1

Brief description of the project: US Department of Energy sponsored pilot scale project to gain a better scientific understanding of the carbon storage process by incorporating advanced characterization, modeling, and monitoring techniques.

Other relevant environmental permits, including state permits

Permit Type(s) and ID: Kansas Corporation Commission drilling permits: Notice of Intent to Drill (C-1), Well Completion Form (ACO-1), Temporary Abandonment (CP-111)

Facility Information

Facility name: Wellington Field Small Scale Carbon Capture and Storage Project

Facility mailing address: 2020 N. Bramblewood Street Wichita, KS 67206

Facility location: Latitude: 37.319485   Longitude: -97.433459

Up to four Standard Industrial Classification (SIC) codes for the products/services provided by the facility [40 CFR 144.31(e)]: 1311, 1321, 1381, 1382

Facility located on Indian lands [40 CFR 144.31(e)]: No

Facility contact information

Contact person: Dana Wreath, Vice President Berexco LLC

Contact phone number: 316-265-3311

Contact email: dwreath@berexco.com

Owner/Operator Information

Operator's name: Dana Wreath

Operator's address: Berexco LLC 2020 North Bramblewood Dr. Wichita, KS 67206

Operator's phone number: 316-265-3311

Operator's status: Private

Ownership status: NOT Owner

Owner's name: Kansas Geological Survey

Owner's address: 1930 Constant Ave Lawrence, Kansas 66047

Owner's phone number: 785-864-2184

Permit Application

Site Characterization Information: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/projects/Submissions/R07-Ks-0001/PermitApp/Submission-06-19-2014-131321/A-----Site--Characterization--Information.pdf

Proposed Project Plans

Proposed AoR and Corrective Action Plan: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/projects/Submissions/R07-Ks-0001/PermitApp/Submission-06-17-2014-143933/B-----Proposed--Area--of--Review--and--Corrective--Action--Plan.pdf

Proposed Testing and Monitoring Plan: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/projects/Submissions/R07-Ks-0001/PermitApp/Submission-06-17-2014-143933/C-----Proposed--Testing--and--Monitoring--Plan.pdf

Proposed Injection Well Plugging Plan: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/projects/Submissions/R07-Ks-0001/PermitApp/Submission-06-17-2014-143933/D-----Proposed--Injection--Well--Plugging--Plan.pdf

Proposed PISC and Site Closure Plan: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/projects/Submissions/R07-Ks-0001/PermitApp/Submission-06-17-2014-143933/E-----Proposed--PISC--and--Site--Closure--Plan.pdf

Proposed Emergency and Remedial Response Plan: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/projects/Submissions/R07-Ks-0001/PermitApp/Submission-06-17-2014-143933/F-----Proposed--Emergency--and--Remedial--Response--Plan.pdf

Financial Responsibility Demonstration: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/projects/Submissions/R07-Ks-0001/PermitApp/Submission-06-17-2014-143933/G-----Financial--Responsibility--Demonstration.pdf

Proposed Formation Testing Program: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/projects/Submissions/R07-Ks-0001/PermitApp/Submission-06-17-2014-143933/H-----Proposed--Formation--Testing--Program.pdf

Proposed Well Construction
Information: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/projects/Submissions/R07-Ks-0001/PermitApp/Submission-06-17-2014-143933/I-----Proposed--Injection--Well--Construction--Information.pdf

Proposed Operating
Information: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/projects/Submissions/R07-Ks-0001/PermitApp/Submission-06-17-2014-143933/J-----Proposed--Operating--Information.pdf

List of Contacts for States, Tribes, Territories within the
AoR: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/projects/Submissions/R07-Ks-0001/PermitApp/Submission-06-17-2014-143933/K-----List--of--Contacts--within--the--AoR.pdf

YES - Other Information Required

Other Required
Information: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/projects/Submissions/R07-Ks-0001/PermitApp/Submission-06-19-2014-131321/L-----Other--Required--Information--by--UIC--Director.zip

YES - Alternative PISC Timeframe Requested

Alternative PISC Timeframe
Demonstration: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/projects/Submissions/R07-Ks-0001/PermitApp/Submission-06-17-2014-143933/M-----Alternative--PISC--Timeframe.pdf

Complete Submission

Authorized submission made by: Jennifer Raney

Optional comments regarding this submission: Third attempt to officially submit KGS Class VI application. File "A - Site Characterization Information" was resubmitted to resolve upload errors. No changes were made to the actual file.

For confirmation a read-only copy of your submission will be emailed to: lwatney@kgs.ku.edu

If you have any questions, please contact your permitting authority.

2. CO_2 suppliers have been secured.

Task 5. Secure CO2 source -- GO/NO-GO DECISION #5

Subtask 5.1 CO_2 Supply
Subtask 5.2 CO_2 Transportation

Linde Group and Praxair expressed interest to participating since last fall and both are very interested in commercialization opportunities, initially in the CCUS field. KGS has had multiple contacts with their company representatives that led to reaching this field deployment phase. Both companies have an international presence and both companies have worked with DOE on similar types of projects. The familiarity and expertise that they bring to the project from CO_2 source to sink are vital to the project and CO_2 utilization in Kansas.

Linde and Praxair have a nonbinding agreement to supply CO_2 under the subcontract with Berexco with and official contract to be negotiated by Berexco and KGS at a date closer to the actual injection. Details on costs, volume, and rate have been conveyed to Program Manager as part of current budget negotiations.

3. Science further enhanced with receipt of 15 seismometers for IRIS-PASSCAL seismic array deployment and three active 3-component active seismometers purchased with KGS funds to compliment other monitoring including high-resolution seismic, high-resolution cGPS/InSAR, and downhole U-tube sampling and CASSM.

Task 6. Establish MVA Infrastructure - Around CO_2 Injector for Carbon Storage
Subtask 6.2. Install CGPS and Seismometers near Injection Borehole

The Kansas Geological Survey took receipt of 15 IRIS seismometers in March 2014 and three 3-component active accelerometers in June 2014 to be installed as a passive seismic array for the Mississippian and Arbuckle CO_2 injection. KGS funds were used to purchase the accelerometers and the IRIS equipment was donated to the KGS for 3-yrs of data recording. Equipment will be installed in an array as shown in **Figure 3**. All of this monitoring equipment is to be fully active during the month of August.

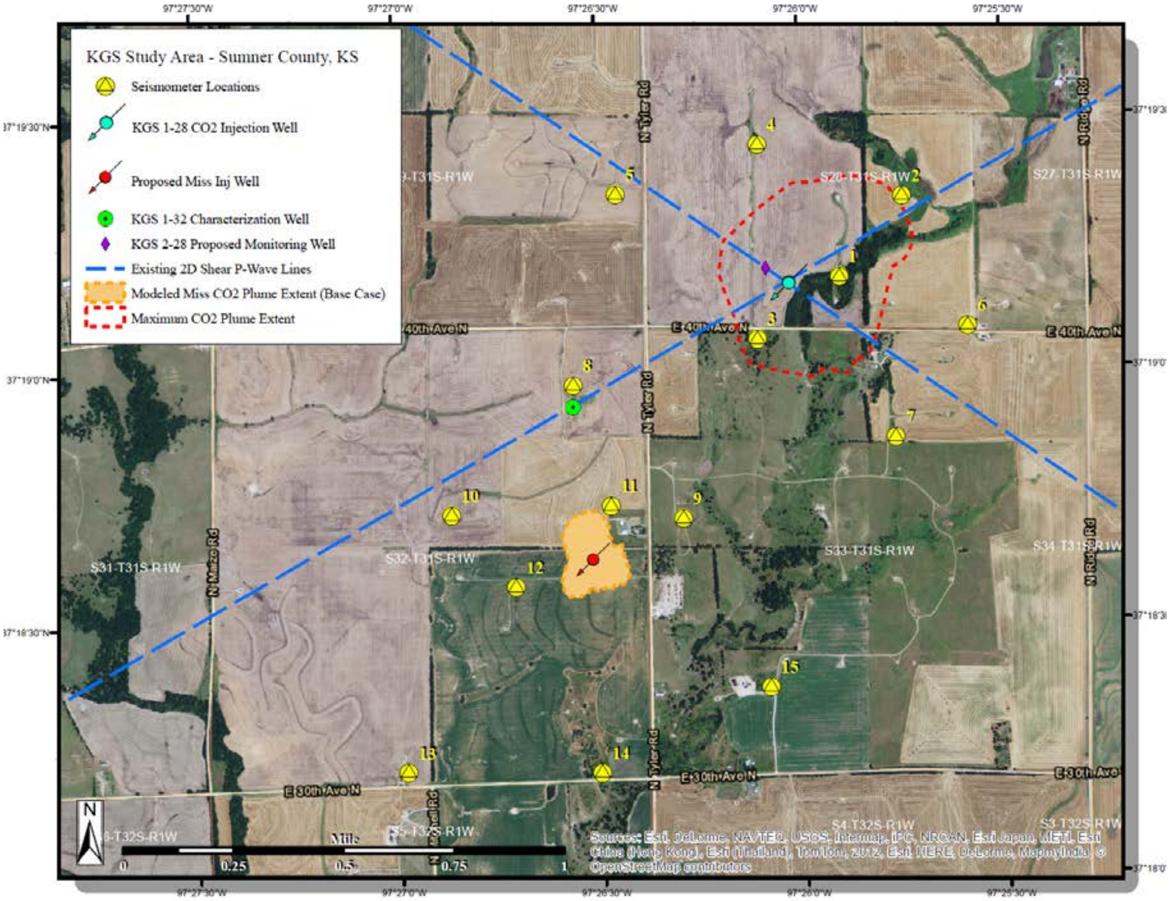


Figure 3. Location of IRIS seismometers, CO_2 injection wells, and CO_2 plumes for the Mississippian and Arbuckle injections.

The passive seismic deployment will complement the extensive technical information available for this oil field that is and will continue to be public domain. Existing data in place includes:

a. 12 mi^2 multicomponent seismic that is uniquely available for ongoing and continued research
    i. Demonstrated mapping of phi-k mapping aided by seismic
    ii. Well suited for integrating geomechanical analysis, discrete fracture network
b. 2D shear and p-wave seismic calibration lines adding to uniqueness and rigor of the seismic program (see **Figure 3**),
c. 1600 ft of continuous core providing unique view of entire caprock, strata comprising reservoir, and context stratigraphic data for continued analysis
d. Two newly drilled basement wells, 3000 ft apart, with well testing, extensive whole core C/A including geomechanical analysis, geochemical analyses, petrophysical analysis
    i. Established unique petrophysical analysis techniques (including one with patent applied for) to predict capillary pressure, relative permeability, and kv and kh using extensive dataset

e. Three research groups, each with a different focus, are conducting laboratory studies of the rock under *in situ* conditions with CO_2
    i. KU – in situ work with caprock, reservoir, and brines studying both microbial and isotope that is rather unique including effects of CO_2 on microbial community
    ii. KSU – focus on understanding brines and reactions with CO_2
    iii. Lawrence Livermore (Susan Carroll) – in situ micro CT imaging of CO_2 with plans to examine oil reservoir; objective is to obtain reaction kinetics suited for improving simulation with discussions of upscaling results to geomodel using NMR technology

4. Important science questions directed toward improved prediction and evaluation of dynamic changes in the CO_2 plumes are anticipated using recent refinements in existing Petrel-CMG models

Task 2. Site Characterization of Arbuckle Saline Aquifer System - Wellington Field (GO/NO-GO DECISION #3)

Task 3. Site characterization of Mississippian Reservoir - Wellington Field -- (Class II Application & GO/NO-GO DECISION #4)

The active, 24-bit, 3 component state-of-the art accelerometers will be placed with the seismometer array to 1) increase the bandwidth/frequency range of the events that will be monitored, 2) increase the sensitivity of the passive seismic monitoring by measuring far field, lower frequency events that will compliment seismometers and increase understanding of the mechanisms, and 3) and record 3-components of movement.

The accelerometers are the technology of choice to optimize detection of fluid movement and will further enhance the opportunity to bolster the science for the Mississippian test. Assurances for success in their use to image the CO_2 plume in the Mississippian include:

1. Rick Miller will install installation the accelerometers with advice of Tom Daley at LBNL and George Tsoflias in KU Geology. Daley has extensive experience in installation, monitoring, and interpretation of accelerometers.
2. The accelerometer deployment in the shallower Mississippian will establish baseline acoustic properties that will be highly beneficial to optimize installation and recording for the other high-resolution surface and downhole seismic technologies to be used in monitoring the Arbuckle injection.
3. Surface-based passive seismic monitoring will help to locate the CO_2 plume, but also provide precise timing of events. Understanding acoustics and testing of the surface passive seismic during the Mississippian will provide the encouragement to use CASSM and pseudo 3D seismic with fiber optic cable in a passive mode.

4. The shallower nature of the Mississippian injection will be a critical test of detection levels and resolution. Monitoring would commence prior to and during pressurization of the Mississippian reservoir. Short-term experiments such as varying water injection rates prior to the startup of the CO_2 injection will assist in evaluating the seismic array.
5. We anticipate the seismometer array will generate at point cloud of seismic events from which we can track the CO_2 movement.

Events detected by microseismic methods in the Mississippian can be verified by: a) tracer and sampling of produced fluid to detect the direction of the CO_2 front, b) high resolution 2D seismic lines to image the CO_2 front (*The IVI Minivib II used as the source is a high-frequency 15,000-lb vibrator that has a factory-specified sweep range from 15 Hz to 300 Hz*), and c) InSAR coupled with continuous GPS to detect surface ground motion associated with the CO_2 plume down to sub mm levels. This redundancy of methods will help to evaluate the effectiveness of the monitoring methods. A conservative tracer will also permit understanding of the distribution of CO_2 within the reservoir and the sweep efficiency of the CO_2 and oil bank.

A comparison between modeled and actual Mississippian CO_2 injection will improve the understanding of the behavior of CO_2 in brine, oil, in the carbonate matrix. Moreover, fractures will likely be most easily detected by the passive seismic array if a portion of the CO_2 plume undergoes focused flow along a system. The early detection of these deviations in the oil reservoir could permit real-time modification of the injection pattern to increase the contact of CO_2 with the reservoir leading to both additional oil recovery and increased trapping of the CO_2 in the reservoir.

Coupled with improved detection of the characteristics of the injected plume, better characterization of the effects of CO_2 on the matrix carbonate will likely provide more accurate and predictable fluid flow simulations. Imaging, NMR scanning and characterization, and reactive transport modeling of core samples from Wellington by Susan Carroll, Megan Smith, and colleagues at LLNL, is currently underway and will continue in the early portion of this project. KSU is now an active collaborator with that team to aid KGS in integrating this information into the reservoir simulator.

Other considerations in monitoring of the Mississippian and the Arbuckle:

- *Opportunity for multiple experiments* – Anticipated routine shutdown and startup of the CO_2 injection in the Arbuckle would offer unparalleled experiments to evaluate the utility of the passive seismic monitoring.
- *Improved understanding of seismicity* -- Monitoring both Mississippian and Arbuckle injections with seismometers, 2D seismic, InSAR will likely be very useful in understanding stress-strain and geomechanical behavior in general associated with the Wellington structure (dome). There is added interest in this monitoring due to the increased seismicity that is occurring in the OK-KS region. This interest spans state, federal, academic, and industry and a proactive response by the DOE-KGS team to address seismicity in addition to fluid monitoring with the seismometer deployment will help the

community understand the mechanisms of the nearly seismic events. Information gained from this project and its predecessor DE-FE0002056 is absolutely critical to KGS and DOE's participation in this discussion.

5. Increased relevancy of this project to the DOE Portfolio

Depositional environment – Marine shelf sandstone (Lower Ordovician Gunter Sandstone) and peritidal shelf carbonate (Lower Ordovician Arbuckle Group). This highly dolomitized aquifer is an archetype example of the peritidal carbonate with #1-32 having cut core from most of the 1000 ft Arbuckle interval and enhanced DOE's portfolio of primary sandstone reservoirs.

Vast storage capacity of the Arbuckle -- Many sites beneath developed oil fields provide infrastructure and potential for improved economics for carbon storage by first taking advantage of incremental oil production gained by injecting CO_2. The existing infrastructure and data used to characterize the oil field markedly reduces the uncertainty for the storage of CO_2. When the oil field sites reach depletion of oil, they could be be converted to saline aquifer storage. Nine sites that lie beneath oil fields in southern Kansas that are very similar to Wellington's geologic setting have been modeled in DE-FE0002056 to evaluate commercial scale (>30 MM tonnes) injection. What is learned in this small scale test could be readily transferred to these other areas.

Order of injection – Injecting in the oil field first is well suited for Kansas and similar oil-rich states due to the widespread distribution of the oil fields across the state and potential economic benefits. This is coupled with the wide expanse of the thick underlying saline aquifer beneath these fields. Thus -

- Kansas needs a successful CO_2 injection into an oil reservoir where data are shared openly with the public to permit better more rigorous scoping models to reduce uncertainties for economic interests and to encourage continued interest and generate new interest by the CO_2 suppliers.
- The Class VI permit is expected in a timeframe that is consistent with the revised schedule for Arbuckle injection following the Mississippian.
- Costs for the Arbuckle injection are avoided until needed after the Class VI is approved and the benefits of the Mississippian injection are realized up front to gain experience, understanding, and set the stage for a successful Arbuckle test.

6. With submittal of the Class VI application, securing CO_2 supply, and level of scientific study related to the Mississippian injection, DOE agreed to proceed with plans for Mississippian injection ahead of the Arbuckle.

A. Addressed concerns about detection of CO_2 plume from injection of 26,300 metric tons of CO_2

2. Seismic detection of the CO_2 injected into the Mississippian reservoir in Wellington Field -- Many examples are available of the high-resolution seismic studies in the literature using the KGS Vibroseis. Also, the recognition by peers attests to the quality of the work by the KGS seismic team under Rick Miller.

3. The KGS successfully obtained a 4D seismic survey using the Vibroseis to monitor a very small scale CO_2 injection (110MMCF, 5810 metric tons) at Hall-Gurney Field in Russell County Kansas. Watney served on this team as a Co-I as the geologist and the work was published and reported on as being able to resolve CO_2 that was injected into a 15 ft thick bed of oomoldic grainstone. The shallow peritidal carbonate is complex, consisting of stacked and shingled ooid shoals that underwent early diagenesis and oomoldic developing that further complicated this reservoir. The high-resolution Vibroseis served as the seismic source that resolved the CO_2 plume. While the project got cut short of injecting the full amount of CO_2 due to extreme budget issues in 2001, the team believed the test was a technical success for such a small scale test.

4. Key observations from the seismic aspect at Hall-Gurney Field include –
   - accurate indication of solvent "CO_2" breakthrough in well 12,
   - predicted delayed response in well 13,
   - interpretation of a permeability barrier between wells 13 and CO2I#1, and

- The final report on Hall-Gurney Field is found at –
  http://www.kgs.ku.edu/CO2/Reports/Final_Report_March2010.pdf
  TITLE: FIELD DEMONSTRATION OF CARBON DIOXIDE MISCIBLE FLOODING IN
  THE LANSING-KANSAS CITY FORMATION, CENTRAL KANSAS
  DOE Contract No. DE-AC26-00BC15124

B. Seismic detection of the CO_2 injected into the Arbuckle saline aquifer in Wellington Field

-- Based on the previous experience of DOE in other projects, the detection of sub 100,000 metric ton injections of CO_2 have not been detectable using surface-based seismic surveys. This is a concern for both detecting and characterizing the CO_2 plume in both the Mississippian and Arbuckle injections, of 26,357 metric tonnes each. We considered this risk in monitoring reduced amounts of CO_2 and conclude that we will be able to resolve the CO_2 plume via four surface based seismic methods and two downhole seismic methods.

5. The surface based seismic methods include: a) a repeat optimized 1 square mile conventional 3D seismic survey to be used to close the Arbuckle injection, b) if funded in another contract, repeat pseudo VSP surveys of the Arbuckle injection using borehole and surface fiber optic cable using the same high resolution research-grade vibroseis of the KGS as described above, c) 2D seismic surveys using KGS vibroseis to monitor CO_2 injection in the Mississippian, and d) passive microseismic survey using 15 IRIS seismometers and 3 active three-component accelerometers to monitor both the Mississippian and the Arbuckle injections.
6. Two downhole seismic monitoring methods include two crosshole tomography surveys and a series of CASSM surveys, both types as 2D imaging between the Arbuckle injector and nearby observation well.

7. Dense Plume within Arbuckle reservoir— The injection plan has been carefully designed to control and focus plume growth within a permeable flow unit within the Arbuckle in such a way that the highest level of detection will occur with the selected monitoring technology.
8. The perforation depth (4910’-5050’ feet) within the injection wellbore targets a narrow interval of the Arbuckle reservoir which has demonstrated higher homogeneity and greater porosity and permeability than surrounding layers. This injection method will encourage growth of a densely saturated CO_2 plume in close proximity to the wellbore, meaning that CO_2 will not be dispersed into thinner stratigraphic units based on extensive whole core Kv measurements, nuclear magnetic resonance logging, and 3D seismic information. Flow unit mapping has been carefully addressed in both the field and regional Arbuckle mapping (contract DE-FE0002056). All modeling simulations have confirmed this behavior, and we can confidently predict that the smaller, dense CO_2 plume will be easily detected by downhole measurements. The injection test will be the means to validate the model. Being a dolomitic carbonate on a structure and results from a 2000 ft horizontal well drilled in the Arbuckle in Bemis-Shutts oil field (DE-FE0004566), fractures are likely to be affecting the plume development and is a topic of keen interest by the team.
9. This level of MVA technology combined with a highly experienced team will provide an unparalleled experiment to demonstrate the performance of the most advanced technologies for monitoring CO_2.
10. A new member of the KGS staff, Tandis Bidgoli, enhances expertise in quantitative structural analysis and geomechanical characterization and modeling.
11. Additional testing as required by EPA will also be performed as described in **Table 1**.

Table 1. Listing of monitoring activities to be conducted at Wellington Field.

Monitoring Activity	Pre-Injection	Injection	Post-Injection
CO_2 Fluid Chemical Analysis	x	x	-
CO_2 Injection Rate and Volume[1]	-	x	-
CO_2 Injection Pressure at Wellhead[1]	-	x	-
CO_2 Injection Pressure at Well Bottom[1]	x	x	x
Internal MIT (Anulus Pressure Test)	x	-	-
External MIT (Temperature Log)	x	x	x
Continuous Annular Pressure	-	x	-
Corrosion	-	x	x
Pressure Fall Off Test	x	-	-
Pressure in Arbuckle Monitoring Well (Direct Arbuckle Monitoring)	x	x	x
INSAR (Indirect Arbuckle Pressure Monitoring)	x	x	x
USDW Geochemistry	x	x	x
Mississippian Geochemistry	x	x	x
U-Tube (Direct Arbuckle Geochemistry Monitoring)	x	x	x
CASSM (Indirect Arbuckle Plume-Front Monitoring)	x	x	x[2]
Crosswell Seismic (Indirect Arbuckle Plume-Front Monitoring)	x	x	-
3D Seismic Survey (Indirect Arbuckle Plume-Front Monitoring)	x	-	x

[1] Monitored continuously

[2] If CO_2 plume is detected at KGS 2-28 during the injection phase, then CASSM will not be conducted during the post-injection phase.

12.

3D multicomponent survey at Wellington

The fold of the multi-component 3D seismic survey at Wellington is around 40 with the spacing of the geophones optimized to resolve the deep reflectors in the Arbuckle. As noted above, this has not compromised resolution in the Mississippian. The quality of the data is very good and with exhaustive well log suites, core, and test data, the behavior of the CO_2 plume should be detected by multiple, independent methods of monitoring as described above.

ADM – Decatur site **Wellington – multicomponent 3D**

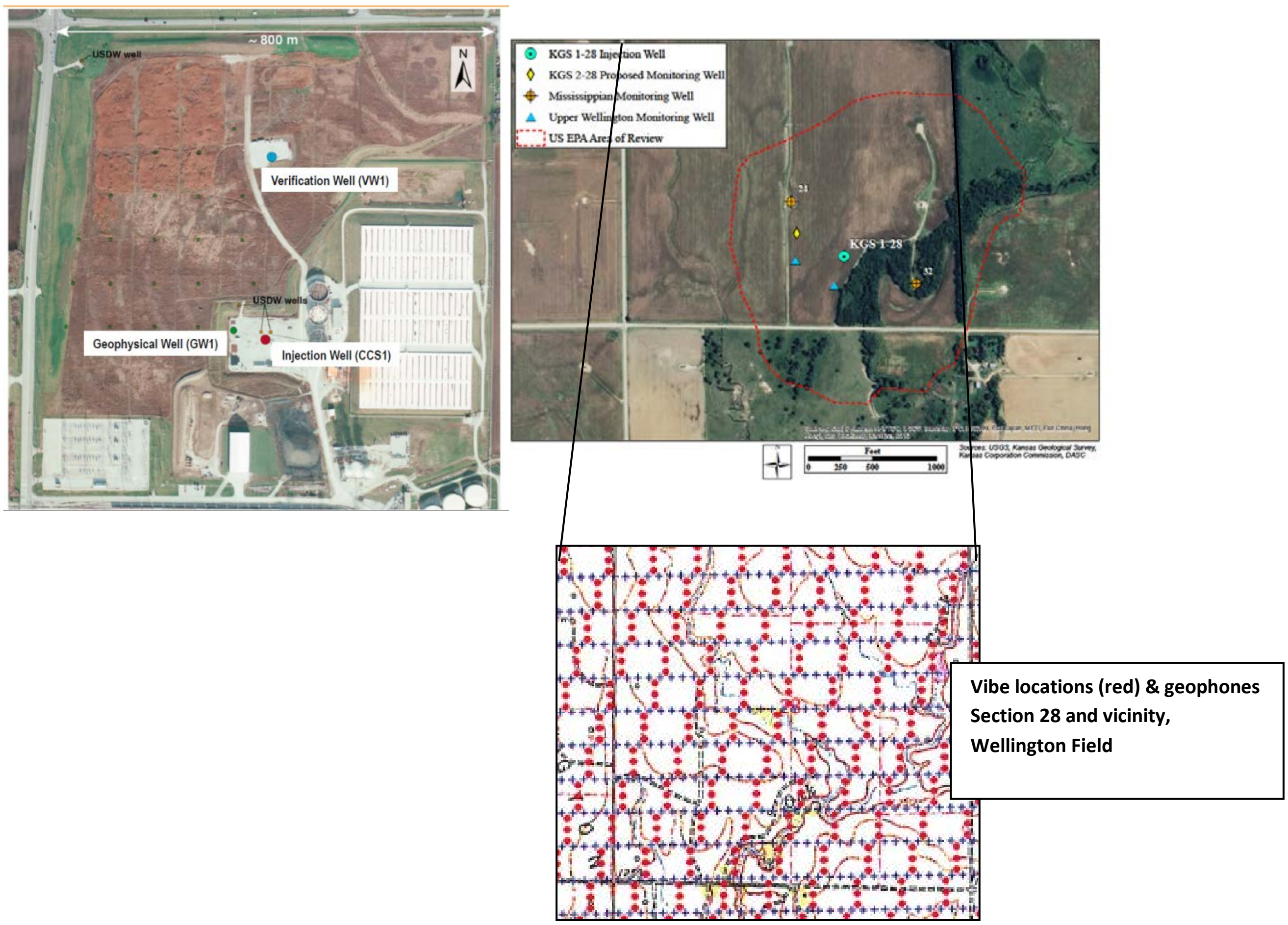


Figure 4. Comparison of the Decatur project injection site and the Arbuckle injection site at Wellington with the seismic acquisition inset for Wellington. Key point -- Land surrounding the Wellington site is almost exclusively used as farmland and is completely undeveloped within the Area of Review.

The 3D multicomponent seismic is "well behaved" and continues to provide valuable information at the attribute and inversion works continues including work on the shear wave data. What is learned can be applied to the repeat 3D multicomponent survey to successfully close the CO_2 injection into the Arbuckle.

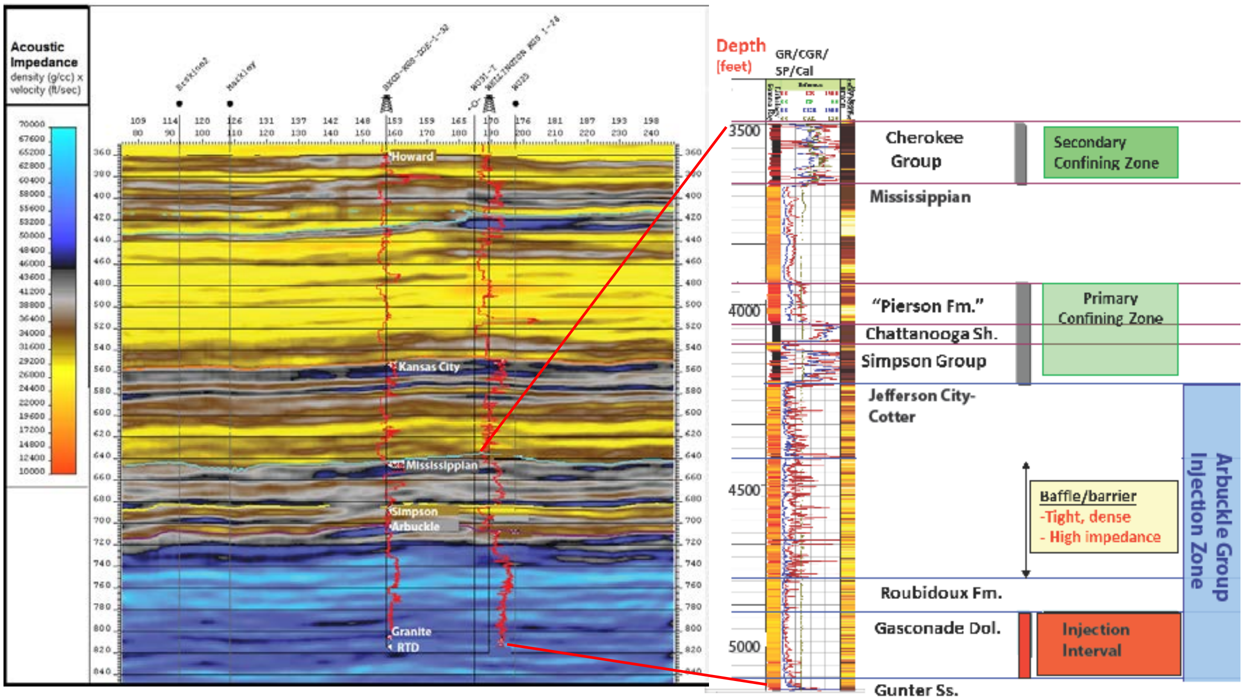


Figure 5. Seismic impedance and stratigraphic profile from well log of the #1-28 injection well at Wellington (information from DE-FE0002056).

The hydrogeologic layer/flow unit that will be perforated to inject CO_2 should allow the CO_2 move in a conformable manner, confined above and below by fluid flow barriers as deemed by core, log, and testing (**Figure 5**).

The simulated plume is based on injection into a confined flow unit based on many lines of evidence. The core-log-seismic calibration gives us confidence of the predicted plume characteristics. The confinement and the expected conformance of the plume to this flow unit will be very important for its seismic detection with multiple surface and subsurface, active and passive seismic sources (**Figures 6 and 7**).

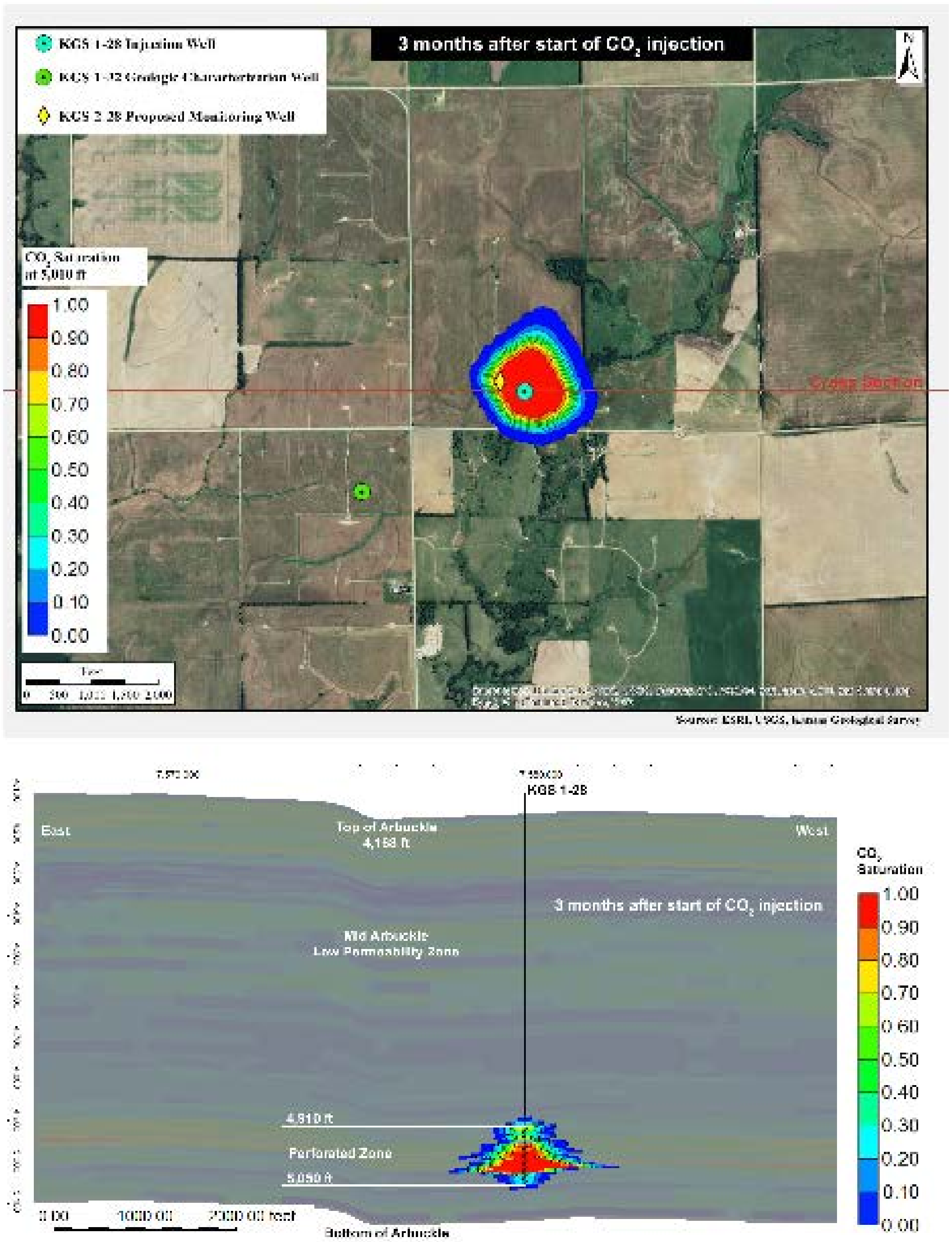


Figure 6. Three months injection at Wellington.

One year of CO_2 injection has a significant area of CO_2 with modeled saturations near one (**Figure 7**). Gassman fluid substitution models indicate gas concentrations need only to be less than 10% to provide seismically resolvable changes in seismic velocity. Resolution of our 3D seismic is adequate to resolve this velocity change and other seismic will also assist the same.

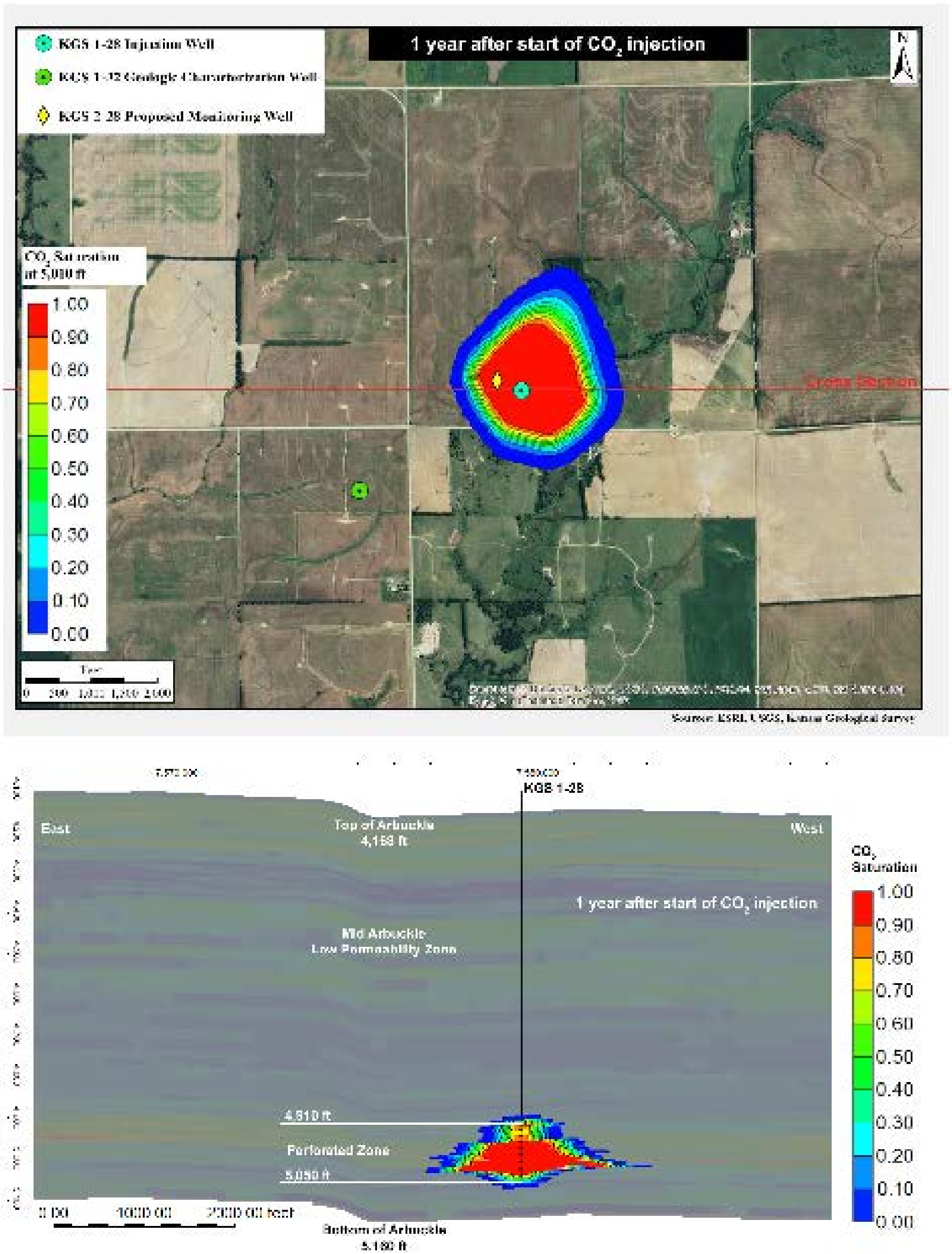


Figure 7. One year of injection of CO2 into the Arbuckle at Wellington.

Seismic resolution at Wellington appear to be considerably greater compared to other projects in the DOE portfolio as attested by results of detailed analysis of the seismic, e.g. the velocity inversion at Wellington in the Mississippian (**Figure 8**). In this example, we are getting a match between seismic well log derived porosity at a resolution of 2 ft!

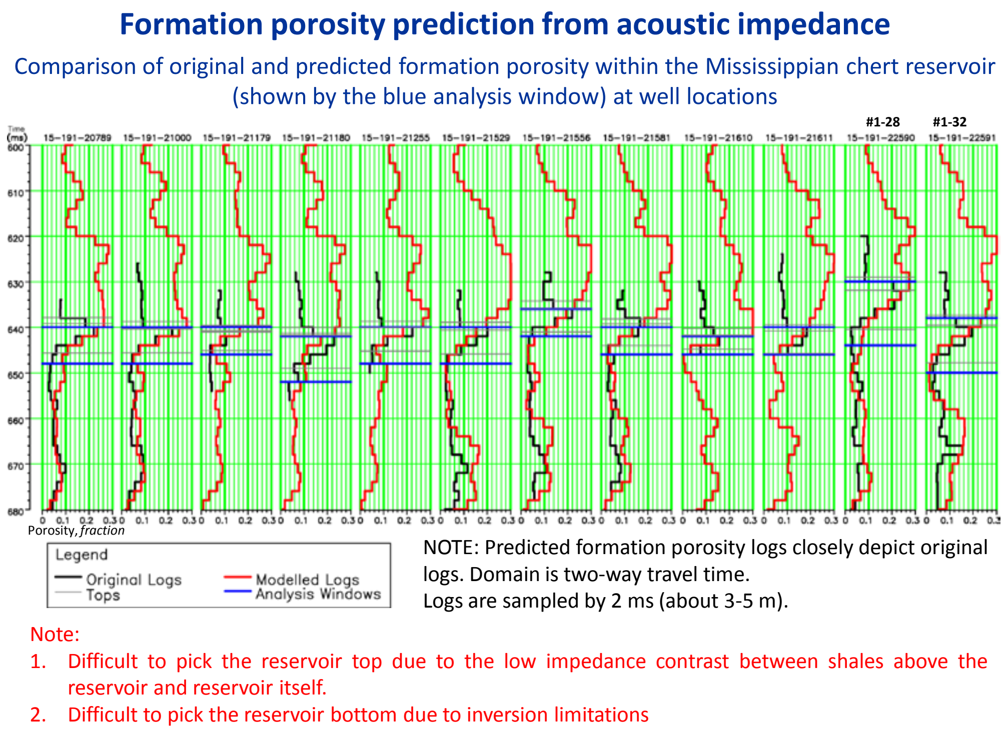


Figure 8. Comparison between seismic and log porosity profiles.

The following is a brief summary of each type of seismic recording to support our conclusion on being able to observe the CO_2 plumes.

A. 1 square mile conventional 3D seismic survey

The conventional 3D survey was acquired by Paragon Geophysical out of Wichita, Kansas with processing done by Fairfield-Nodal in Denver CO office. Fairfield conducted a series of 28 sweep tests before the survey was started to optimize sweep time and frequency range (**Figure 9**) (funded under DE-FE0002056). The field record of Sweep Test #23 was selected for the survey (**Figure 10**).

RECORDING PARAMETERS

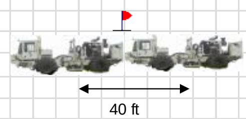
SAMPLE RATE	2	ms
LOW CUT FILTER/SLOPE	3	hz
ANTI-ALIAS FRQ./SLOPE	187	hz .8 Nyquist, Linear
PREAMP GAIN	36	db (G-6)
NOISE EDIT	Diversity Stack	
DATA TO TAPE TYPE	Correlated after stack	
RECORD LENGTH	3	sec
LINE TYPE	3D	
ACTIVE LINES	18	
ACTIVE CHAN / LINE	64	
MAXIMUM ACTIVE CHAN	1152	
ROLL ON / OFF	Roll on Roll off with 10 Lines live	
RP / SQUARE MILE	346	
RCV LINE INTERVAL	495	
RCV GROUP INTERVAL	165	
TOTAL RCV LINES	49	
TOTAL RCV GROUPS	3822	
RCV ORIENTATION	W-E	
SP/ SQUARE MILE	256	
SRC LINE INTERVAL	660	
SRC POINT INTERVAL	165	
TOTAL SRC LINES	22	
TOTAL SRC POINTS	2825	
SRC ORIENTATION	SW - NE Staggered Brick	
TOTAL SQUARE MILES	11.05	

SOURCE PARAMETERS

ENERGY SRC TYPE	Vibrators	
VIBRATORS		
TYPE / MODEL	ION AHV-I V	
INSTRUMENTS	Pelton - Vib Pro	
HOLD DOWN WEIGHT	60,00	lbs
DRIVE LEVEL	80	%
PHASE LOCK	Ground Force	
FORCE CONTROL	Fundamental Grnd Force	
NUMBER VIBRATORS	2	
PATTERN	40 ft. centered on stake	

SWEEP

NUM. SWEEPS	2	
MOVE UP	Stacked	
START FREQ.	6	hz
END FREQ.	150	hz
SWEEP LENGTH	40	sec
NON LINEARITY	+3db/oct	post corr.
START TAPER	300	ms
END TAPER	300	ms



PROCESSING

Fairfield Industries 1776 Lincoln St. #1200, Denver, CO 80203 Attn: Bruce Karr 720-963-2119 bkarr@fairfield.com
Echo Geophysical Corporation 1999 Broadway, # 3100, Denver,CO 80202 Attn: Rick Steineck 720-528-9299 rsteineck@echogeo.com

One copy of field data to:

```
Lynn Watney
Kansas Geological Survey
1930 Constant Avenue - Campus West
The University of Kansas
Lawrence, KS 66047
Ph: 785-864-2184
```

Figure 9. Configuration selected for the original 3D seismic acquisition for Wellington Field.

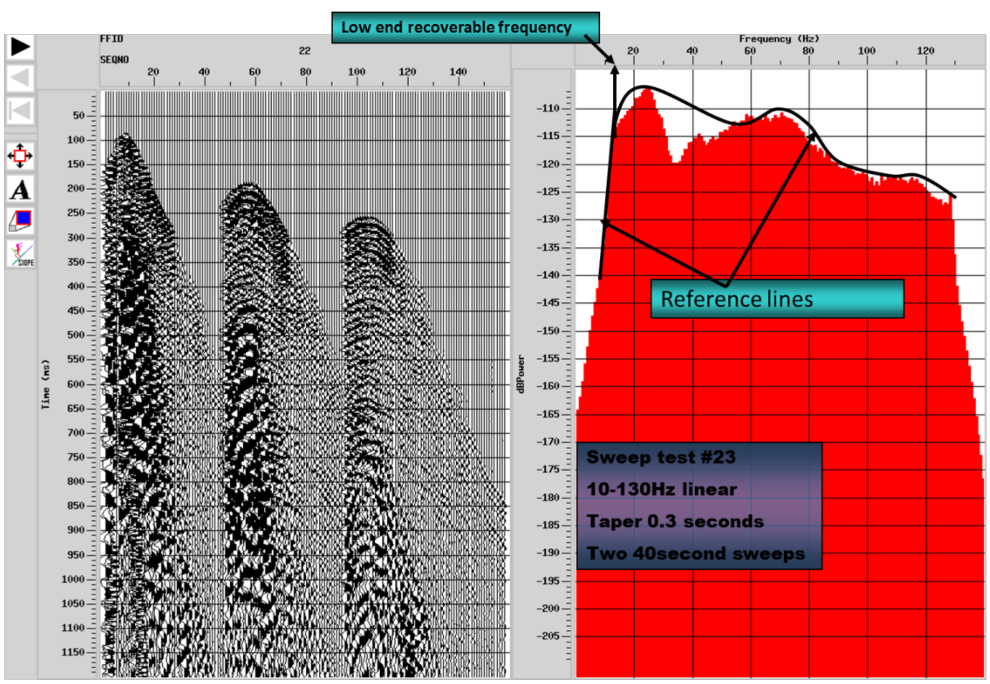


Figure 10. Sweep test used in the original 3D seismic survey at Wellington.

The extended sweep test to establish the best design for the 3D survey involved a team who are intimately familiar with the geophysical framework, working daily in Kansas with the local petroleum industry. The team knew that this was to be a showcase for the quality of work that they routinely conduct in this region.

A fluid substitution was used with log derived impedance to examine whether CO_2 could be observed in the Arbuckle using parameters of the conventional repeat 3D seismic survey as described above. The fold map of a 1-mile square 3D survey is shown in **Figure 11**. This seismic survey is expected to have at least 20-fold data up to 1320 ft from the CO_2 injection well and 49 fold at the center. Increasing the size of the 3D survey will bring the fold of the area encompassed by the plume to full fold or ~46 fold as the original multi-component 3D survey. The level of this fold is important since it has led to a solid baseline seismic survey that has been used to build our geomodels and simulation. This is not a partial 3D survey with data gaps or a low fold VSP, so it is not easy to compare our results with other projects unless we sort out the details of the seismic utilized starting from the ground up.

In addition, the 3D survey was a multi-component acquired with digital 3-component geophones. The repeat 3D survey will be acquired in exactly the same manner and processed for the converted (shear wave). The presence of CO_2 will be further resolved with ongoing analysis of Vs/Vp ratio and AVO (under DE-FE0002056). Moreover, the dynamics of the CO_2 behavior will likely have an opportunity to be resolved with this kind of acquisition and processing. It should be noted that the basis for the multi-component survey was the use of 4D, multi-component acquisition in Vacuum Field in New Mexico that was used image the CO_2 movement and distinguish fracture vs. matrix flow. This research was conducted by Tom Davis' Reservoir Characterization Project (http://rcp.mines.edu/) at Colorado School of Mines. Their go-to acquisition company is the same Wichita-based company, Paragon, that was contracted for Wellington and Cutter fields 3D multi-component surveys in DE-FE0002056. We consulted with CSM before we deployed and it is no accident that we have a reliable seismic acquisition group.

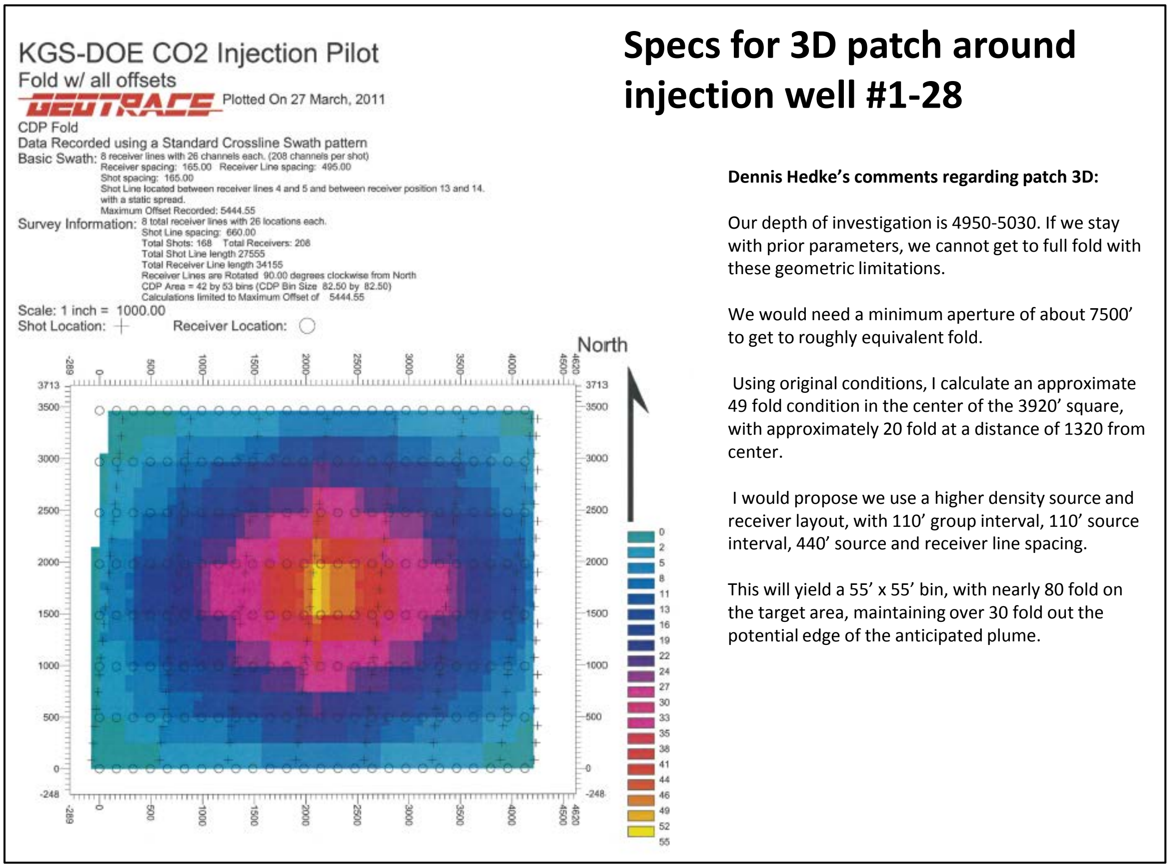


Figure 11. Fold map used to plan the repeat 3D seismic survey to image the Arbuckle CO2 plume.

The fluid substitution was accomplished by using Gassman equation ranging the gas composition between zero and 50% saturation. The seismic impedance was calculated using the well log data of KGS #1-32 at Wellington. **Figure 12** shows the changing velocity as gas is substituted in the injection interval in the lower Arbuckle at a depth of 4950 and 5053. It is primarily the lower portion of the injection interval near 5000 ft that undergoes a most reduction in velocity as the gas concentration is increased to 50% illustrated as a brightening (**Figure 12**)

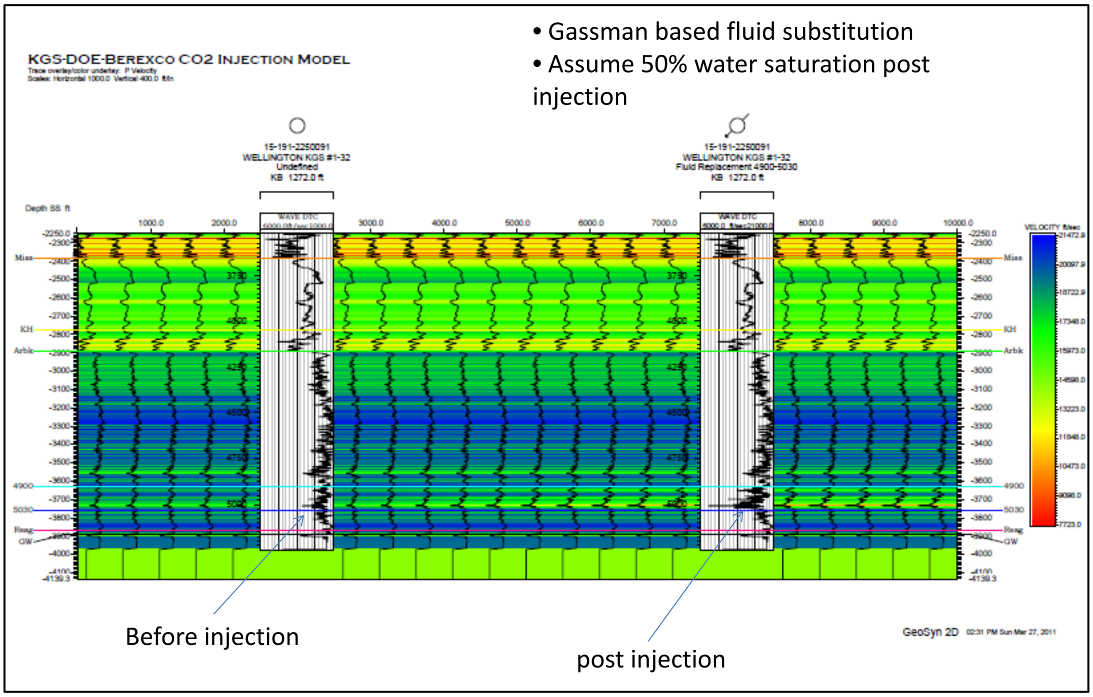
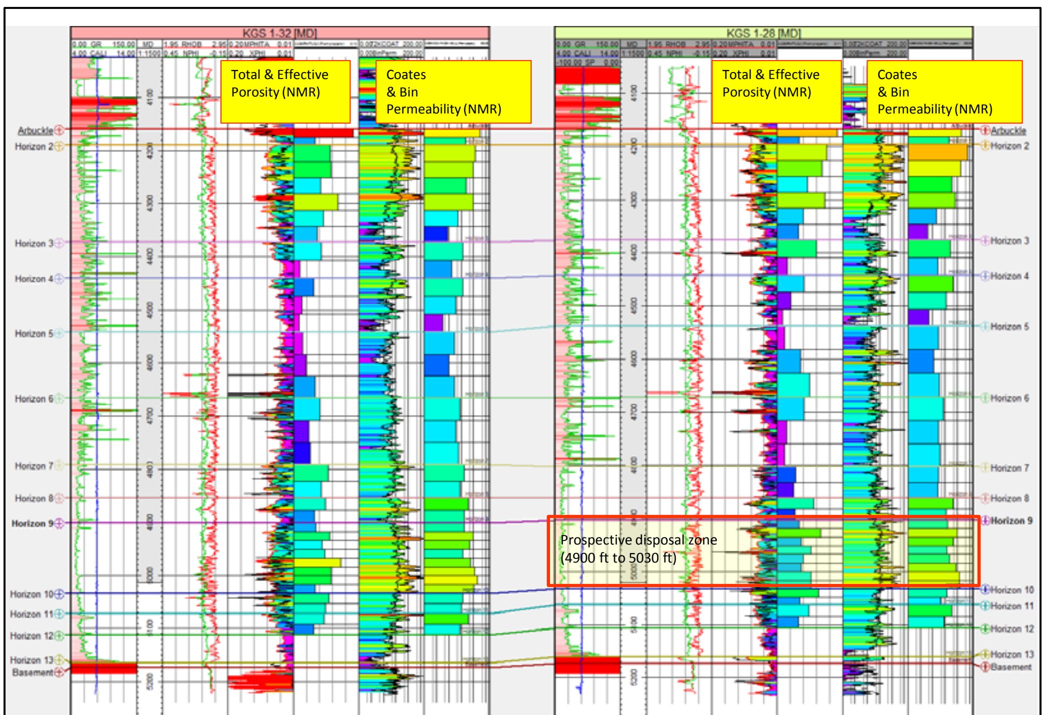


Figure 12. Velocity structure from sonic log in well #1-32 focused on the Arbuckle interval as the injection interval (4950-5030) underwent substitution of brine to 50% gas moving from left to right side of the illustration. Note brightening toward the right corresponding to a decrease in the velocity of the injection interval.



Upscaled hydrostratigraphic units in Arbuckle Group in KGS #1-32 (left) and #1-28 (right)

Figure 13. Stratigraphic well log cross section between wells #1-32 and #1-28 highlighting the injection interval in the lower Arbuckle. NMR derived porosity and permeability clearly identify the injection interval.

The injection interval has the largest pores including vugs that have been documented in core, well logs, and whole core analysis (**Figure 13**). Water chemistry indicates that the brine in the injection unit is distinct and a separate hydrostratigraphic unit from overlying strata and we have some certainty that cross flow and migration of the CO_2 injected into this interval will not occur.

The isolation of the injection interval in the timeframe of this small scale test is further indicated by the seismic data showing a higher impedance/baffle interval that continuously overlies the injection zone in the area of the injection well. An arbitrary section through the 3D survey showing seismic impedance illustrates this relationship (**Figure 14**). We anticipate conformance and a plume that is rather well behaved, vs. a less confined diffuse vertically migrating plume. The choice of the injection interval is clear - a) perforate an interval that should concentrate the CO_2, b) optimize for conformance so that CO_2 plume has best opportunity to be predicted and to be seen with the monitoring methods including seismic.

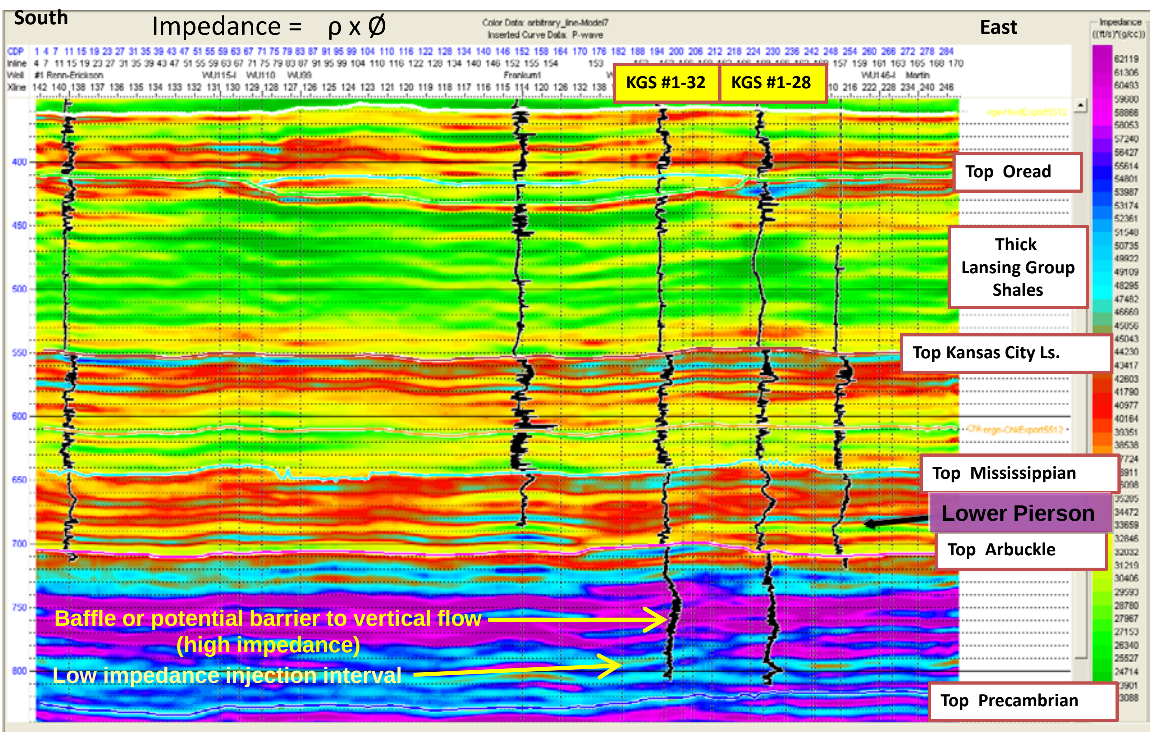


Figure 14. Arbitrary section showing impedance inversion for Wellington 3D seismic. Note the clear distinction and continuity of the injection zone and the overlying baffle/barrier.

Key Findings

1. Highly constrained integrated Petrel model and CMG simulations and a skilled research team (KGS and beyond) with expertise in geology, engineering , and geophysics working with high quality data
   a. Well suited to conducted experiments directed toward <u>next generation CO_2-EOR</u> in smaller (<50 million bbls) carbonate reservoirs common to the upper Midcontinent.
   b. Utilization of very high resolution seismic from KGS vibroseis to image the smaller quantities of CO_2 utilizing a solid multicomponent 3D survey as the baseline.
   c. Will deploy the passive seismic monitoring before BP2 begins for dual purpose --
      i. installing three 3-component accelerometers purchased with KGS funds to aid in detecting CO_2 and provide unique potential to adjust the CO_2 flood in real-time; also staff to handle data being hired by KGS (unique timely leveraging and commitment)
      ii. Use of 15 IRIS seismometers and 3 accelerometers to understand the recent increase in earthquake activity in the area, integrate data with the existing seismic network coordinating with USGS, state agencies, and Oklahoma Geological Survey; provide knowledge and insights to improve the science
2. <u>Unique integration</u> of Wellington Field with the Kansas CO_2 Initiative engaging the entire community – petroleum industry, CO_2 suppliers, lawmakers and regulators – over the course of the next year with Wellington Field serving as the focal point
   a. Use of Wellington Field as a calibration site and field demonstration to engage petroleum industry in overcoming need and requirements in use of anthropogenic sources of CO_2
   b. Test best practice, cost-effective monitoring to aid in applying next-generation CO_2-EOR methods, refine model predictions, and to permit CO_2 use to be optimized for CO_2 sequestration
   c. <u>Uniquely couple</u> the oil field and the underlying saline aquifer to increase the CO_2 sequestration capacity using Wellington to help calibration with Cutter field, 8 other sites in Kansas being completed in DE-FE0002056.

Plans for Third Quarter 2014 (anticipated start of BP2, September 1, 2014)

Begin field activities as per revised schedule shown in **Figure 15**.

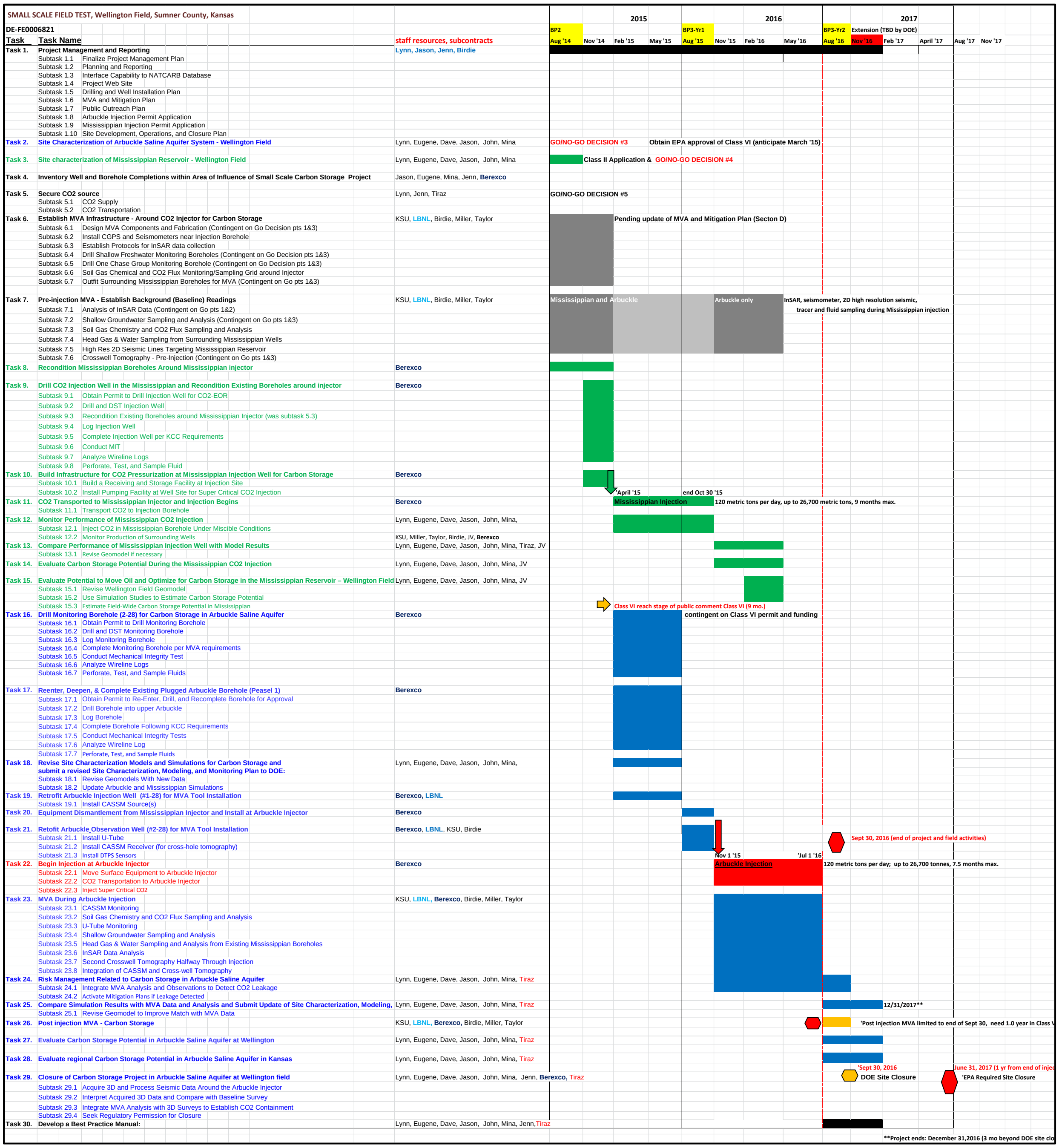


Figure 15. Revised Gantt chart.

PRODUCTS

Publications, conference papers, and presentations

Papers were presented in Lawrence at an industrial associates meeting. In addition, the Wellington KGS #1-32 core was displayed and discussed. Presentations included:

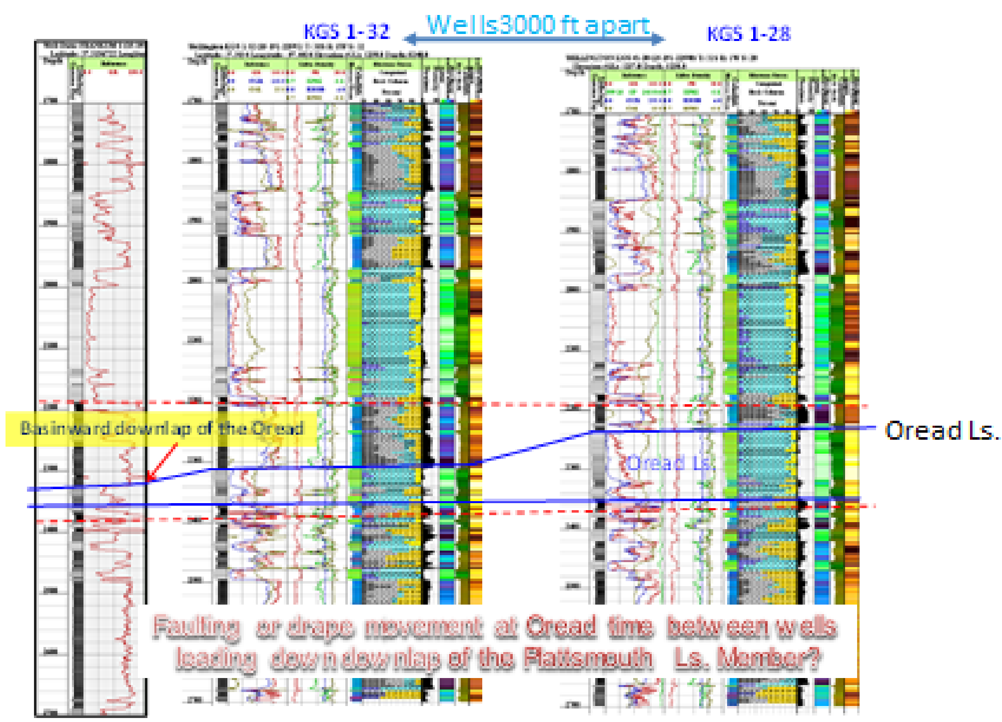
> Jason Rush --"Basement-Rooted Faults, Paleokarst, and Mississippian Flexures: A Compelling Story for PSDM Seismic Volumetric Curvature
>
> Jason Rush -"The Mississippian at Wellington and Development of a Middle Eastern Giant (Idd El Shargi Field) ☐ Déjà vu?
>
> W. Lynn Watney, Jason Rush, John Doveton, Mina Fazelalavi, Eugene Holubnyak, Bob Goldstein, Brad King, Jen Roberts, David Fowle, Christa Jackson, George Tsoflias, et al., Overview, current research, and major findings for two long Paleozoic cores – Berexco Wellington KGS #1-32, Sumner County, KS and Berexco Cutter KGS #1, Stevens County, Kansas
>
> W. Lynn Watney, Jason Rush, John Doveton, Mina Fazelalavi, Eugene Holubnyak, Bob Goldstein, Brad King, Jen Roberts, David Fowle, Christa Jackson, George Tsoflias, et al., Overview, current research, and major findings for two long Paleozoic cores – Berexco Wellington KGS #1-32, Sumner County, KS and Berexco Cutter KGS #1, Stevens County, Kansas - four posters (2 each for Wellington and Cutter)
>
> Mina Fazelalavi, W. Lynn Watney, John Doveton, Mohsen Fazelalavi, and Maryem Fazelalavi - Determination of Capillary Pressure Curves in the Mississippian Limestone, Kansas
>
> Yousuf Fadolalkarem and George Tsoflias - Pre-stack Seismic Attribute Analysis of the Mississippian Chert and the Arbuckle at the Wellington Field, South-central Kansas
>
> Christa Jackson, David Fowle, Brian Strazisar, W. Lynn Watney, Aimee Scheffer, and Jennifer Roberts - Geochemical and Microbiological Influences on Reservoir and Seal Material During Exposure to Supercritical CO2, Arbuckle Group, Kansas
> Luis Montalvo, Luis Gonzalez, Lynn Watney, Diagenesis and distribution of diagenetic facies in the Mississippian of south-central Kansas
>
> Bradley King and Robert Goldstein -- Controls on Hydrothermal Fluid Flow and Porosity Evolution in the Arbuckle Group and Overlying Units (3 panels)

Presentation at Geological Society of America, Regional Meeting (April 2014) – illustrating the stratigraphic and sedimentologic effects of episodic structural movement at Wellington Field:

> DOVETON, John H., Kansas Geological Survey, University of Kansas, 1930 Constant Ave, Lawrence, KS 66047, doveton@kgs.ku.edu, MERRIAM, Daniel F., University of Kansas, 1930 Constant Ave, Campus West, Lawrence, KS 66047, and WATNEY, W. Lynn, Kansas Geological Survey, Univ of Kansas, 1930 Constant Avenue, Lawrence, KS, 66047, 2014,

Petrophysical Imagery of the Oread Limestone in Subsurface Kansas, Paper #237642, 48th Annual Meeting, North Central Geological Society of America, Program With Abstracts. (Episodic nature of structural activity at Wellington Field)

The Oread Limestone is recognized widely as an archtypal Pennsylvanian cyclothem that has been investigated extensively over its eastern Kansas outcrop for more than a century. Knowledge of the geology of the Oread in the subsurface has been restricted almost entirely to drill-cuttings, while wireline logs have provided the correlative framework for mapping structure and thickness. The curves of traditional logs are the time-honored medium for correlation, but the rich data of more recent petrophysical measurements are presented increasingly as image logs which portray geology in novel ways. FMI logs are conversions of multiple microresistivity curves into a high-resolution conductivity image of the borehole wall. MRI logs measure magnetic resonance relaxation times that are presented as contour map images of pore-size distribution. Natural and capture gamma-ray spectra logs estimate elemental concentrations of potassium, thorium, uranium, calcium, magnesium, titanium, aluminum, iron, sulfur, and manganese. Interpretations of these logs in the Oread in south-central Kansas present new opportunities in Pennsylvanian cyclothem research that can be integrated with conventional outcrop studies. As a case in point, log imagery of the anomalously thick and variable "Super-Plattsmouth" regressive limestone (anomalously thick and variable) in Sumner County provides intriguing insights into mound internal architecture (**Figure 16**).



Log cross section is located along similar location as the preceding seismic image. Note downlapping carbonate and thickening of the overlying shale.

Figure 16. Notable changes in stratigraphy at the Oread Limestone horizon. Paper describes differences between the two wells in the Oread Limestone and overlying Kanwaka Shale.

National Groundwater Association Groundwater Summit

Watney, W.L., 2014, Integrating Modern Suite of Geophysical Logs, Geochemistry, and Seismic Data for Characterizing Deep Aquifers, NGWA Conference on Characterization of Deep Groundwater, May 8, 2014

Watney, W.L., 2014, Using Drill Stem Test Data to Construct Regional Scale Potentiometric Surface in Deep Aquifers, NGWA Conference on Characterization of Deep Groundwater, May 8, 2014

Tiraz Birdie, TBirdie Consulting, Inc., Lawrence, KS, W. Lynn Watney, Ph.D., Kansas Geological Survey, University of Kansas, Lawrence, KS and Paul Gerlach, Charter Consulting, Miramar, FL, Using Drill Stem Test Data to Construct Regional Scale Potentiometric Surface in Deep Aquifers, NGWA Conference on Characterization of Deep Groundwater, May 8, 2014

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

A project organization chart follows (**Figure 17**). The work authorized in this budget period includes office tasks related to preparation of reports and application for a Class VI permit to inject CO_2 into the Arbuckle saline aquifer. Tasks associated with reservoir characterization and modeling are funded in contract DE-FE0002056.

ORGANIZATION CHART

Name	Project Job Title	Primary Responsibility
	Kansas Geological Survey	
Lynn Watney	Project Leader, Joint Principal Investigator	Geology, information synthesis, point of contact
Yevhen Holubnyak	Petroleum Engineer	Reservoir engineer, dynamic modeling, synthesis
Jason Rush	Joint Principal Investigator	Geology, static modeling, data integration, synthesis
John Doveton	Co-Principal Investigator	Log petrophysics, geostatistics
Dave Newell	Co-Principal Investigator	Fluid geochemistry
Rick Miller	Geophysicist	2D seismic acquire & interpretation LiDAR/InSAR support, water well drilling/completion
TBN	Geology Technician	Assemble and analyze data, report writing
Tiraz Birdie	President, TBirdie Consulting, Inc.	Hydrogeologic modeling, permitting, MVA, integration
	KU Department of Geology	
Michael Taylor	Co-Principal Investigator	Structural Geology, analysis of InSAR, LiDAR, seismometer array
TBN	Graduate Research Assistant	Structural Geology, analysis of InSAR and LiDAR, seismometer array
	Kansas State University	
Saugata Datta	Principal Investigator	
TBN	Graduate Research Assistant	Aqueous geochemistry
TBN	3- Undergraduate Research Assistants	
	Lawrence Berkeley National Laboratory	
Tom Daley	Co-Principal Investigator	Geophysicist, analysis of crosshole and CASSM data Hydrogeology, analysis of soil gas measurements
Barry Freifeld	Co-Principal Investigator	Mechanical Engineer, analysis of U-Tube sampler
	Sandia Technologies, Houston	
Dan Collins	Geologist	Manage CASSM and U-Tube operation
David Freeman	Field Engineer	Manage field install of CASSM and U-Tube
	Berexco, LLC	
Dana Wreath	VP Berexco, LLC	Engineering, Manager of Wellington Field
Randy Koudele	Reservoir engineer	Engineering
Staff of Wellington Field		Field operations
Beredco Drilling team		Mississippian and Arbuckle drilling operations
	Abengoa Bioenergy Corp.	
Christopher Standlee, Danny Alllison		CO2 supply Colwich Ethanol Facility

Figure 17. Organizational Chart.

IMPACT

See earlier discussion.

CHANGES/PROBLEMS

Please refer to earlier discussion.

BUDGETARY INFORMATION

Cost Status Report

See figure on the following page for the cost status for quarters 1-9.

BP1 Ends 8/31/14		BP2 Starts 9/1/14	Ends 8/31/15			BP3 Starts 9/1/15	Ends 9/30/16			
1/1/14 - 3/31/14 Q10	4/1/14 - 6/30/14 Q11	7/1/14 - 9/30/14 Q12	10/1/14 - 12/31/14 Q13	1/1/15 - 3/31/15 Q14	4/1/15 - 6/30/15 Q15	7/1/15 - 9/30/15 Q16	10/1/15 - 12/31/15 Q17	1/1/16 - 3/31/16 Q18	4/1/16 - 6/30/16 Q19	7/1/16 - 9/30/16 Q20
$1,997,070.75	$1,997,070.75	$1,997,070.75	$325,087.75	$325,087.75	$325,087.75	$325,087.75	$325,087.75	$325,087.75	$325,087.75	$325,087.75
$258,982.75	$258,982.75	$258,982.75	$184,656.00	$184,656.00	$184,656.00	$184,656.00	$0.00	$0.00	$0.00	$0.00
$2,256,053.50	$2,256,053.50	$2,256,053.50	$509,743.75	$509,743.75	$509,743.75	$509,743.75	$325,087.75	$325,087.75	$325,087.75	$325,087.75
$6,132,302.78	$8,388,356.28	$10,644,409.78	$11,154,153.53	$11,663,897.28	$12,173,641.03	$12,683,384.78	$13,008,472.53	$13,333,560.28	$13,658,648.03	$13,983,735.78
$12,053.49	$9,400.96	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
$12,053.49	$9,400.96	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
$292,169.50	$301,570.46	$301,570.46	$301,570.46	$301,570.46	$301,570.46	$301,570.46	$301,570.46	$301,570.46	$301,570.46	$301,570.46
$1,985,017.26	$1,987,669.79									
$258,982.75	$258,982.75									
$2,244,000.01	$2,246,652.54									
$5,833,657.43	**$8,080,309.97**									

APPENDIX A

PUBLIC OUTREACH PLAN

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

Project Director/Principal Investigator:

W. Lynn Watney
Senior Scientific Fellow
Kansas Geological Survey

Ph: 785-864-2184, Fax: 785-864-5317
lwatney@kgs.ku.edu

Joint Principal Investigator:
Jason Rush

Prepared by Lynn Watney and Tiraz Birdie

Date of Report: August 7, 2014
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 9/30/2016

Signature of Submitting Official:

W. Lynn Watney Digitally signed by W. Lynn Watney
DN: cn=W. Lynn Watney, o=The University of Kansas, ou=Kansas Geological Survey, email=lwatney@kgs.ku.edu, c=US
Date: 2014.09.04 20:26:58 -05'00'

Tiraz Birdie[1], Jennifer Raney[2], and Lynn Watney[2]

Executive Summary

A Public Outreach Plan has been developed for the Wellington project with the goal of establishing communication between KGS and the host community in order to provide a means to solicit community input, build trust, and assure the general public and all stake holders that the project will be executed safely and responsibly.

The outreach activities and communications will be conducted through the project web site, project fact sheet, technical publications, site visits, tours, workshops, community events, and open houses.   Key constituents include public officials, legislators, environmental regulators, business interests, landowners and neighbors, civic groups, educators, and the media. All communication with the stakeholders will be managed by the project's Principal Investigator, Lynn Watney.   The Principal Investigator of the project, Lynn Watney, has already conducted several meeting with citizens and legislators to inform them of the proposed project. He has met separately with the Kansas Governor, Kansas state representative, officials of the Kansas Department of Commerce, and the general public and local officials at the proposed injection site. Additionally, a number of technical presentations have been and workshops held to inform the scientific and technical communities of the project goals and benefits.

Table of Contents

Executive Summary ... 37
Public Outreach Plan ... 39
1. Introduction ... 39
2. Outreach Team ... 39
3. Key Outreach Messages ... 39
4. Methods of Communication ... 40
4.1 Project web site ... 40
4.2 Printed Project Fact Sheet ... 40
4.3 Web Based Project Fact Sheet ... 41
4.4 Technical Publications and Presentations ... 41
4.5 Site Visits, Tours, Workshops, Community Events, and Open Houses ... 41
5. Project Stakeholders ... 41
6. Completed Outreach Activities ... 43
6.1 Meeting with Legislators ... 43
6.2 Meeting with Kansas State Governor ... 43
6.3 Meeting with Stakeholders ... 43
6.4 Publications in Technical Journal ... 44
6.5 Presentations at Scientific Conferences ... 44
6.6 Workshops ... 45
7. Future Outreach Activities ... 45
8. Press Release Template ... 46

Public Outreach Plan

1. Introduction

Public outreach is an integral part of the Wellington CO_2 project. Being a federally funded pilot project, KGS intends to follow all guidelines in the DOE/NETL publication, Best Practices for Public Outreach and Education for Carbon Storage Projects (DOE, 2009). The goal of the outreach program is to establish communication between KGS and the host community in order to provide a means to solicit community input, build trust, and assure the community that the project will be executed safely and responsibly. Specific goals include:

- Educate citizens how CO_2 storage works, how it can contribute to global climate change mitigation, and that the project is part of a national strategy to reduce greenhouse gas emissions.
- Assure the community that KGS and the project operator, Berexco, have the appropriate expertise to safely execute the project.
- Allow the public to express their views.
- Proactively and constructively address community concerns.

2. Outreach Team

All communication with the stakeholders will be managed by the project's Principal Investigator, Lynn Watney. Project team members, Jennifer Raney and Tiraz Birdie, along with the KGS document production staff will assist in preparing the necessary outreach material, conducting surveys with stakeholders, and other outreach activities.

3. Key Outreach Messages

The Principal Investigator of the project, Lynn Watney, has already conducted several meeting with citizens and legislators to inform them of the proposed project. The key messages that are being communicated include:

- There is a well understood approach to site selection and characterization to ensure that geologic conditions are suitable for long term storage without leaks.
- Why Wellington, KS is a safe place to store CO_2.
- Standard practices will be followed to guarantee safety and to ensure that CO_2 storage will not cause harm to health or jeopardize the environment.
- How a computer simulation of the Wellington Field subsurface is developed, validated, and calibrated, and what simulated CO_2 injection results indicate.

- Role of EPA in overseeing/regulating CO_2 storage.
- Potential costs and benefits to the community from CO_2 storage.
- Natural geologic CO_2 storage has occurred for millions of years.
- Engineered geologic storage of CO_2 has been safely practiced for 40 years. Over three billion cubic feet (176 thousand metric tons) of natural CO_2 is injected daily into west Texas oil fields to recover additional oil. The limited supply of natural CO_2 hinders expansion of this technology in Kansas, and the use of anthropogenic and largely ignored CO_2 is a natural next step.
- Injection and reservoir monitoring are mature technologies. The experience in the oil and gas exploration and development industry is being used to ensure sequestration success. Injection and reservoir management in Kansas oil fields has been ongoing for decades since oil production peaked in 1956.
- There are similarities between the major expansion of oil and natural gas systems after World War II with respect to pipeline and natural gas storage, and the expected deployment of CO_2 storage projects.

4. Methods of Communication

4.1 Project web site

In order to facilitate the outreach efforts, KGS has developed a dedicated web site for the project (http://www.kgs.ku.edu/PRS/Ozark/small_scale.html). In addition to a planned future Outreach page, the web site also contains geologic characterization data, model simulation results, permit documents, and compliance documents submitted to the EPA.

4.2 Printed Project Fact Sheet

A project fact sheet is under preparation which will emphasize the following:

- project goals emphasizing small pilot-scale test and DOE collaboration,
- project team partners,
- how CSS works – invoking the analogy with safe natural gas storage over millennia,
- why the site has necessary geologic characteristic for successful storage – multiple confining zones, a porous injection zone, and absence of open faults and fractures in the caprock,
- preliminary modeling results and the small footprint of the of the plume,

- implausibility of CO_2 escaping into shallow aquifers or atmosphere,
- the depleted Mississippian oil and gas reservoir above the Mississippian providing an additional level of protection against CO_2 escape in the unlikely event of caprock breach,
- EPA oversight and regulatory compliance – EPA permitting process -transparent collaboration between KGS/Berexco and EPA,
- Extensive and state of the art monitoring of plume movement, pore pressures, and seismic activity in order to ensure safety and regulatory compliance,
- post-injection site care and site closure plan,
- emergency remedial response plan,
- project timeline,
- economic benefits of CCS and EOR,
- planned outreach activities, and
- Frequently Asked Questions

4.3 Web Based Project Fact Sheet

The web based project fact sheet will be the same as the printed fact sheet except that it will have more details, videos, interactive features, and frequently asked questions section.

4.4 Technical Publications and Presentations

KGS plans to publish at least four publications annually in peer reviewed scientific/technical journals, and make four presentations annually at technical conferences. The goal of these efforts will be to disseminate project findings during the pre-injection, injection, and post-injection phases.

4.5 Site Visits, Tours, Workshops, Community Events, and Open Houses

Workshops and other outreach events will be held periodically to inform the public, academic community, and stake holders of the objectives and benefits of CCS and progress on the Wellington project.

5. Project Stakeholders

Key constituents include public officials, legislators, environmental regulators, business interests, landowners and neighbors, civic groups, educators, and the media.
The following stakeholders have been identified who may be most affected and interested in the project operations and outcome.

Elected Officials	Kasha Kelly (KS State Representative - District 80) Steve Abrams, (KS Senate – District 32) Mike Pompeo, (US House of Representatives, District 4) Jerry Moran (US Senate) Pat Roberts (US Senate) (Mayor - Wellington)	kasha.kelley@house.ks.gov Steve.Abrams@senate.ks.gov (202) 225-6216 (202) 224-6521 (202) 224-4774
Safety Officials	Bill Hellard (City of Wellington Safety Officer); James Fair, Sumner County Emergency Management	 620-326-7376, jfair@co.sumner.ks.us
Environmental Regulators	Mike Tate, Chief, Bureau of Water (Kansas Department of Health and Environment) Thomas Day, Acting Executive Director, (Kansas Corporate Commission) Kurt Hildebrandt, (US EPA Region 7 UIC Director)	(785)296-5500, mtate@kdheks.gov (785) 271-3190; District 2, (316) 630-4000 (913)-551-7413
Business Community	Shelley Hansel-Williams (Wellington Chamber of Commerce	
Media	James Jordan (Wellington Daily News)	
Land Owners/ Farmers		
Law Enforcement	Darren Chambers (Sheriff)	
Emergency Organizations	Jay Fair (Sumner County Emergency Management)	219 W 8th St, Wellington, KS 67152 jayfair@co.sumner.ks.us
Environmental Groups	Clean Air Task force: Dr. Bruce Hill	bruce@catf.us (603)466-2448 sanderson@environmentaldefense.org

	Environmental Defense fund: Scott Anderson Natural Resources Defense Council: George Peridas	(512) 699-1077 gperidas@nrdc.org (415) 875-6181
Economic Development	Kansas Independent Oil and Gas Association (KIOGA); Kansas Geological Society	
Oil and Gas Operators	Kansas Independent Oil and Gas Association (KIOGA); Kansas Geological Society	
US Department of Energy	Brian Dressel	Brian.dressel@netl.doe.gov
Education Groups	(KU, WSU, Kansas State U., Emporia State U.)	
Geologic Interest Groups	Kansas Geological Society, Wichita Chapter of Society of Petroleum Engineers	

6. Completed Outreach Activities

6.1 Meeting with Legislators

The Wellington project PI, Lynn Watney, met with Kansas House Energy and Utilities in Topeka in 2012 and 2013 on the topic of carbon management in Kansas.

6.2 Meeting with Kansas State Governor

Lynn Watney met with the governor of Kansas in December 2013 to discuss reception for a Governor's Conference on "Implementing CO2 Utilization and Storage (CCUS) in Kansas" Follow up meeting in February 2014 with Kansas Department of Commerce on Governor's Conference with decision to first meet with stakeholders to establish level of interest and to demonstrate positive results with CO_2-EOR test at Wellington Field.

6.3 Meeting with Stakeholders

The above meeting with stakeholders will be conducted once Wellington test begins in anticipation of the CO_2 injections. Information contacts with stakeholders have been gained through meetings with CO_2 suppliers and petroleum industry representatives and also through presentations and short courses conducted by Watney.

6.4 Publications in Technical Journal

Several papers pertaining to the implementation of the monitoring and plans for small scale injections at the Wellington project will be published in technical journals and publically accessible media.

6.5 Presentations at Scientific Conferences

The Wellington project team has made the following presentations about the suitability of the site for CSS purposes based on detailed characterization of the injection zone and caprock, and associated computer model simulation results:

NETL Carbon Storage R&D Meeting
Watney, Lynn, Rush, Jason, Raney, Jennifer, Small Scale Field Test Demonstrating CO_2 Sequestration in Arbuckle Saline Aquifer and by CO_2 –EOR at Wellington Field Sumner County, Kansas. Presentation at the annual NETL Carbon Storage R&D meeting in Pittsburgh, PA (August 2014)

National Groundwater Association Groundwater Summit
Watney, W.L., 2014, Integrating Modern Suite of Geophysical Logs, Geochemistry, and Seismic Data for Characterizing Deep Aquifers, NGWA Conference on Characterization of Deep Groundwater, May 8, 2014

Watney, W.L., 2014, Using Drill Stem Test Data to Construct Regional Scale Potentiometric Surface in Deep Aquifers, NGWA Conference on Characterization of Deep Groundwater, May 8, 2014

Tiraz Birdie, TBirdie Consulting, Inc., Lawrence, KS, W. Lynn Watney, Ph.D., Kansas Geological Survey, University of Kansas, Lawrence, KS and Paul Gerlach, Charter Consulting, Miramar, FL, Using Drill Stem Test Data to Construct Regional Scale Potentiometric Surface in Deep Aquifers, NGWA Conference on Characterization of Deep Groundwater, May 8, 2014

Geological Society of America, Regional Meeting
DOVETON, John H., Kansas Geological Survey, University of Kansas, 1930 Constant Ave, Lawrence, KS 66047, doveton@kgs.ku.edu, MERRIAM, Daniel F., University of Kansas, 1930 Constant Ave, Campus West, Lawrence, KS 66047, and WATNEY, W. Lynn, Kansas Geological Survey, Univ of Kansas, 1930 Constant Avenue, Lawrence, KS, 66047, 2014, Petrophysical Imagery of the Oread Limestone in Subsurface Kansas, Paper #237642, 48th Annual Meeting, North Central Geological Society of America, Program With Abstracts. (Episodic nature of structural activity at Wellington Field) Presentation at Geological Society of America, Regional Meeting (April 2014) – illustrating the stratigraphic and sedimentologic effects of episodic structural movement at Wellington Field.

6.6 Workshops

To date, the following workshops have been conducted in order to acquaint target audiences with the Wellington project objectives and plans:

University of Kansas Core Workshop
W. Lynn Watney, Jason Rush, John Doveton, Mina Fazelalavi, Eugene Holubnyak, Bob Goldstein, Brad King, Jen Roberts, David Fowle, Christa Jackson, George Tsoflias, et al., Overview, current research, and major findings for two long Paleozoic cores – Berexco Wellington KGS #1-32, Sumner County, KS and Berexco Cutter KGS #1, Stevens County, Kansas - four posters (2 each for Wellington and Cutter). Presented at a research and industrial associates core workshop at the University of Kansas.

KU KICK Meeting
W. Lynn Watney, Jason Rush, John Doveton, Mina Fazelalavi, Eugene Holubnyak, Bob Goldstein, Brad King, Jen Roberts, David Fowle, Christa Jackson, George Tsoflias, et al., Overview, current research, and major findings for two long Paleozoic cores – Berexco Wellington KGS #1-32, Sumner County, KS and Berexco Cutter KGS #1, Stevens County, Kansas. Presentation at a KU KICK meeting in Lawrence, KS.

7. Future Outreach Activities

Stage	**Activities**
Current (pre-permit)	Complete Project Fact Sheet and mail to identified stake holders
Current (pre-permit)	Initial meeting with stakeholders
Current (pre-permit)	Post a brief summary of permit contents on the project web page
Ongoing and Public Comment Period	Borrow physical CCS model developed by Midwest Geological Sequestration Consortium and NETL in order to inform stakeholders and general public of how storage occurs in the subsurface

Public Comment	Participate with EPA in public comment process, proactively inform stakeholders of EPA's opinion of the safety and feasibility of the project
Permit Approval	Announcement to press and stakeholders.
Injection	Post quarterly reports submitted to EPA on web site and summarize findings
Post Injection	Post quarterly reports submitted to EPA on web site and summarize findings
Site Closure	Announce site closure activities and communicate successful closure and future monitoring plans
Ongoing	Publication of technical findings/research pertaining to CCS and Wellington project in scientific and technical journals, conferences, and workshops
Ongoing	Site visits and tours, interaction with media, community events and open houses
Crisis Communication	Prepare list of responders, responsibilities for specific tasks in the event of an emergency, how emergencies will be handled including safety procedures to be followed

8. Press Release Template

The following template will be followed for formal communication with media

- Release Date
- Contact information
- Headline
- Body Text (To be limited to 1-2 pages)