DOE F 4600.2
(5/09)
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ATTACHMENT 3
U.S. Department of Energy
FEDERAL ASSISTANCE REPORTING CHECKLIST AND INSTRUCTIONS

1. Identification Number: **DE-FE0002056**	2. Program/Project Title: **Modeling CO2 Sequestration in Saline Aquifer and Depleted Oil Reservoir to Evaluate Regional CO2 Sequestration Potential of Ozark Plateau Aquifer System, South-Central Kansas**		
3. Recipient: University of Kansas Center for Research			
4. Reporting Requirements:	**Frequency**	**No. of Copies**	**Addresses**
A. MANAGEMENT REPORTING			
☒ Progress Report	Q	Electronic Version to NETL>	FITS@NETL.DOE.GOV
☒ Special Status Report	A		
B. SCIENTIFIC/TECHNICAL REPORTING * (Reports/Products must be submitted with appropriate DOE F 241. The 241 forms are available at https://www.osti.gov/elink)			
Report/Product — Form			
☒ Final Scientific/Technical Report — DOE F 241.3	FG	Electronic Version to E-link>	http://www.osti.gov/elink-2413
☒ Conference papers/proceedings/etc.* — DOE F 241.3	A		http://www.osti.gov/elink-2413
☐ Software/Manual — DOE F 241.4			http://www.osti.gov/estsc/241-4pre.jsp
☒ Other (see special instructions) Topical — DOE F 241.3	A		
** Scientific/technical conferences only*			
C. FINANCIAL REPORTING			
☒ SF-425, Federal Financial Report	Q, FG	Electronic Version To NETL>	FITS@NETL.DOE.GOV
D. CLOSEOUT REPORTING			
☐ Patent Certification	FC	Electronic Version To NETL>	FITS@NETL.DOE.GOV
☐ Property Certificate	FC		
☐ Other			
E. OTHER REPORTING			
☒ Annual Indirect Cost Proposal	A	Electronic Version To NETL>	FITS@NETL.DOE.GOV
☒ Annual Inventory Report of Federally Owned Property, if any	A		
☐ Other			
F. AMERICAN RECOVERY AND REINVESTMENT ACT REPORTING			
☐ Reporting and Registration Requirements			http://www.federalreporting.gov

FREQUENCY CODES AND DUE DATES:

A - As required; see attached text for applicability.
FG - Final; within ninety (90) calendar days after the project period ends.
FC - Final - End of Effort.
Q - Quarterly; within thirty (30) calendar days after end of the calendar quarter or portion thereof.
S - Semiannually; within thirty (30) calendar days after end of project year and project half-year.
YF - Yearly; 90 calendar days after the end of project year.
YP - Yearly Property - due 15 days after period ending 9/30.

QUARTERLY PROGRESS REPORT

Award Number: DE-FE0002056

Recipient: University of Kansas Center for Research &

Kansas Geological Survey

1930 Constant Avenue

Lawrence, KS 66047

"Modeling CO2 Sequestration in Saline Aquifer and Depleted Oil Reservoir To Evaluate Regional CO2 Sequestration Potential of Ozark Plateau Aquifer System, South-Central Kansas"

Project Director/Principal Investigator: W. Lynn Watney

Principal Investigator: Jason Rush

Eighteenth Quarter Progress Report

Date of Report: 8-5-14

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

Contributors to this Report: Brent Campbell, Saugata Datta, John Doveton, Mina Fazelalavi, Eugene Holubnayak, Jennifer Raney, Jason Rush, Lynn Watney

EXECUTIVE SUMMARY

The project "Modeling CO_2 Sequestration in Saline Aquifer and Depleted Oil Reservoir to Evaluate Regional CO_2 Sequestration Potential of Ozark Plateau Aquifer System, South-Central Kansas" is focused on the Paleozoic-age Ozark Plateau Aquifer System (OPAS) in southern Kansas. OPAS is comprised of the thick and deeply buried Arbuckle Group saline aquifer and the overlying Mississippian carbonates that contain large oil and gas reservoirs. The study is collaboration between the KGS, Geology Departments at Kansas State University and The University of Kansas, BEREXCO, INC., Bittersweet Energy, Inc. Hedke-Saenger Geoscience, Ltd., Improved Hydrocarbon Recovery (IHR), Anadarko, Cimarex, Merit Energy, GloriOil, and Cisco.

The project has three areas of focus, 1) a field-scale study at Wellington Field, Sumner County, Kansas, 2) 25,000 square mile regional study of a 33-county area in southern Kansas, and 3) selection and modeling of a depleting oil field in the Chester/Morrow sandstone play in southwest Kansas to evaluate feasibility for CO_2-EOR and sequestration capacity in the underlying Arbuckle saline aquifer. Activities at Wellington Field are carried out through BEREXCO, a subcontractor on the project who is assisting in acquiring seismic, geologic, and engineering data for analysis. Evaluation of Wellington Field will assess miscible CO_2-EOR potential in the Mississippian tripolitic chert reservoir and CO_2 sequestration potential in the underlying Arbuckle Group saline aquifer. Activities in the regional study are carried out through Bittersweet Energy. They are characterizing the Arbuckle Group (saline) aquifer in southern Kansas to estimate regional CO_2 sequestration capacity. Supplemental funding has expanded the project area to all of southwest Kansas referred to as the Western Annex. IHR is managing the Chester/Morrow play for CO_2-EOR in the western Annex while Bittersweet will use new core and log data from basement test and over 200 mi^2 of donated 3D seismic. IHR is managing the industrial partnership including Anadarko Petroleum Corporation, Cimarex Energy Company, Cisco Energy LLC, Glori Oil Ltd., and Merit Energy Company. Project is also supported by Sunflower Electric Power Corporation.

PROJECT STATUS

Task Name	Planned Start Date	Actual Start Date	Planned Finish Date	Actual Finish Date	% Complete
1.0 Project Management & Planning	12/8/2009	12/08/09	2/7/2014		90%
2.0 Characterize the OPAS (Ozark Plateau Aquifer System)	1/1/2010	01/01/10	9/30/2013		95%
3.0 Initial geomodel of Mississippian Chat & Arbuckle Group - Wellington field	1/1/2010	01/01/10	9/30/2010	09/30/10	100%
4.0 Preparation, Drilling, Data Collection, and Analysis - Well #1	9/15/2010	12/15/10	3/31/2011	08/30/11	100%
5.0 Preparation, Drilling, Data Collection and Analysis - Well #2	1/1/2011	02/20/11	6/30/2011	08/30/11	100%
6.0 Update Geomodels	5/1/2011	05/01/11	9/30/2011	10/31/12	100%
7.0 Evaluate CO2 Sequestration Potential in Arbuckle Group Saline Aquifer	8/1/2011	08/01/11	12/31/2011	10/31/12	100%
8.0 Evaluate CO2 Sequestration Potential in Depleted Wellington field	10/15/2011	10/15/11	7/30/2013	+++	99%
9.0 Characterize leakage pathways - risk assessment area	1/1/2010	01/01/10	6/30/2012	10/31/12	100%
10.0 Risk Assessment related to CO2-EOR and CO2 Sequestration in saline aquifer	6/1/2012	06/01/12	9/30/2013	**	99%
11.0 Produced water and wellbore management plans - Risk assessment area	1/1/2012	01/01/12	7/30/2013		99%
12.0 Regional CO2 sequestration potential in OPAS	8/1/2012	02/01/12	9/30/2013	***	99%
13.0 Regional source sink relationship	1/1/2010	1/1//2010	9/30/2013	****	98%
14.0 Technology Transfer	1/1/2010	01/01/10	2/7/1014		99%

Milestone	Planned Completion Date	Actual Completion Date	Validation
HQ Milestone: Kick-off Meeting Held	3/31/2010	03/31/10	Completed
HQ Milestone: Begin collection of formation information from geologic surveys and private vendors	6/30/2010	01/01/10	Completed
HQ Milestone: Semi-Annual Progress Report on data availability and field contractors	9/30/2010	07/30/10	Submitted to Project manager
HQ Milestone: Establish database links to NATCARB and Regional Partnerships	12/31/2010	12/31/10	Completed
HQ Milestone: Annual Review Meeting attended	3/31/2011	10/05/10	Completed
HQ Milestone: Complete major field activities, such as drilling or seismic surveys at several characterization sites	6/30/2011	Note: This milestone was met collectively by all projects. No one project was held accountable to the milestone.	Completed
HQ Milestone: Semi-Annual Progress Report (i.e. Quarterly Report ending June 30, 2011)	9/30/2011	09/30/11	Completed
HQ Milestone: Yearly Review Meeting of all recipients; opportunities for information exchange and collaboration	12/31/2011	11/15/11	Attended meeting
HQ Milestone: Complete at least one major field activity such as well drilling, 2-D or 3-D seismic survey, or well logging	3/31/2012	08/15/12	Completed 3D seismic Cutter competed
HQ Milestone: Complete at least one major field activity such as well drilling, 2-D or 3-D seismic survey, or well logging	6/30/2012	10/09/12	Completed cutter well reach TD
HQ Milestone: Semi-annual report (i.e. Quarterly Report ending June 30, 2012) on project activities summarizing major milestones and costs for the project 9/30/2012	9/30/2012	09/30/12	Completed
FOA Milestone: Updated Project Management Plan	3/31/2010	03/31/10	
FOA Milestone: Submit Site Characterization Plan	5/28/2010		Completed
FOA Milestone: Notification to Project Manager that reservoir data collection has been initiated	9/15/2010	01/01/10	Completed
FOA Milestone: Notification to Project Manager that subcontractors have been identified for drilling/field service operations	7/30/2010	01/01/10	Completed
FOA Milestone: Notification to Project Manager that field service operations have begun at the project site	7/1/2010	01/01/10	Completed
FOA Milestone: Notification to Project Manager that characterization wells have been drilled	6/3/2011	03/09/11	Completed
FOA Milestone: Notification to Project Manager that well logging has been completed	6/3/2011	03/09/11	Completed
FOA Milestone: Notification to Project Manager that actvities on the lessons learned document on site characterization have been initiated	7/15/2012		Completed
FOA Milestone: Notification to Project Manager that activities to populate database with geologic characterization data has begun	12/31/2010	12/31/10	Completed, email summary
KGS Milestone 1.1: Hire geology consultants for OPAS modeling	3/31/2010	03/31/10	Completed
KGS Milestone 1.2: Acquire/analyze seismic, geologic and engineering data - Wellington field	6/30/2010	06/30/10	Completed, quarterly rpt
KGS Milestone 1.3: Develop initial geomodel for Wellington field	9/30/2010	09/30/10	Completed, email summary
KGS Milestone 1.4: Locate and initiate drilling of Well #1 at Wellington field	12/31/2010	12/25/10	Completed, email summary
KGS Milestone 2.1: Complete Well#1 at Wellington - DST, core, log, case, perforate, test zones	3/31/2011	08/30/11	Completed, email summary
KGS Milestone 2.2: Complete Well#2 at Wellington - Drill, DST, log, case, perforate, test zones	6/30/2011	08/30/11	Completed, email summary
KGS Milestone 2.3: Update Wellington geomodels - Arbuckle & Mississippian	9/30/2011	10/31/12	Completed
KGS Milestone 2.4: Evaluate CO2 Sequestration Potential of Arbuckle Group Saline Aquifer - Wellington field	12/31/2011	10/31/12	Completed
KGS Milestone 3.1: CO2 sequestration & EOR potential - Wellington field	3/31/2012		98% complete*
KGS Milestone 3.2: Characterize leakage pathways - Risk assessment area	6/30/2012	10/31/12	Completed
KGS Milestone 3.3: Risk assessment related to CO2-EOR and CO2-sequestration	9/30/2012		Completed - **email summary to come**
KGS Milestone 3.4: Regional CO2 Sequestration Potential in OPAS - 17 Counties	12/7/2012		99% complete***
HQ Milestone: Make data set from one site characterization project publicly available.	12/31/12	Note: This milestone was met collectively by all projects. No one project was held accountable to the milestone.	
HQ Milestone: Complete one major field activity to collect additional characterization data from well drilling, 2-D or 3-D seismic surveys, or well logging/testing.	03/31/13	Note: This milestone was met collectively by all projects. No one project was held accountable to the milestone.	
HQ Milestone: Complete, at a minimum, planning for one major field activity, such as well drilling, 2-D or 3-D seismic surveys, or well logging/testing.	06/30/13	Note: This milestone was met collectively by all projects. No one project was held accountable to the milestone.	
HQ Milestone: Yearly Review Meeting of active projects; opportunities for information exchange and collaboration	09/30/13	Attended Annual Review meeting in August	100% complete
HQ Milestone: Complete one field activity to collect characterization data from well drilling, 2-D or 3-D seismic surveys or well logging/testing.	12/31/13	Note: This milestone was met collectively by all projects. No one project was held accountable to the milestone.	
HQ Milestone: Complete analysis of field activity in project-related reservoirs to validate additional storage potential.	03/31/14	Note: This milestone was met collectively by all projects. No one project was held accountable to the milestone.	
HQ Milestone: Semi-annual progress reports for active projects (i.e. Quarterly Report ending March 31, 2014).	06/30/14		
HQ Milestone: Yearly Review Meeting of active projects; opportunities for information exchange and collaboration	09/30/14		

TASK SUMMARY IN PREPARATION FOR COMPLETION OF THE PROJECT

This quarterly report is the last, prior to submitting the final report. All of the tasks and subtasks are listed herein with dialog pertaining to activities conducted in this last quarter.

Task 1: Program Management and Reporting (PMP)

Task 2. Characterize the OPAS

Subtask 2.1. Acquire geologic, seismic and engineering data

Type logs are being checked for completeness prior to final release.

Subtask 2.2. Develop regional correlation framework and integrated geomodel

Final review of framework correlations being completed using Java based correlation application (**Figure 1**).

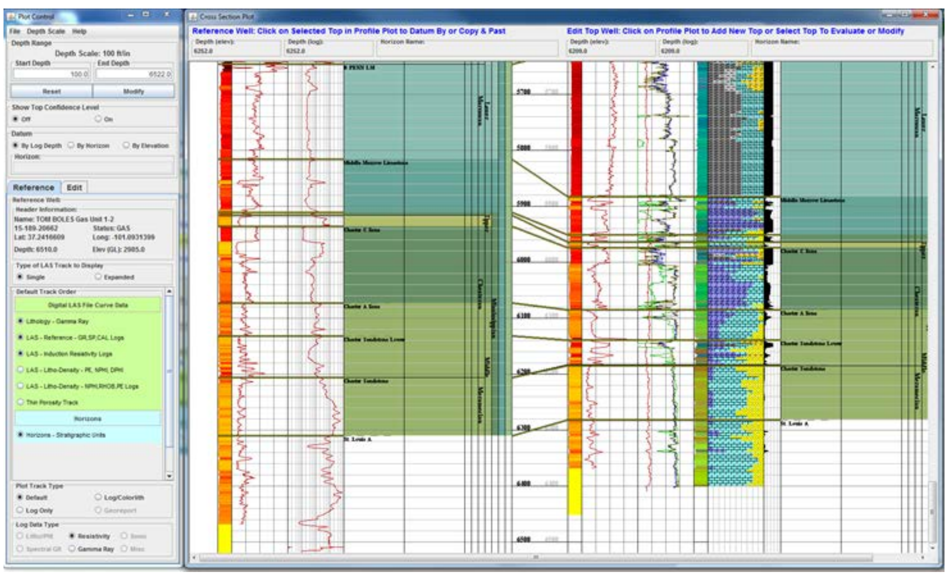


Figure 1. Correlations of type logs being checked.

Subtask 2.3. Subsurface fluid chemistry and flow regime analysis.

Evaluating flow units in 4-Township,
Commercial Scale Simulation of CO_2 Storage, greater Wellington Field

Ten regional sites were selected in southern Kansas for large scale CO_2 storage in the Arbuckle saline aquifer. Estimates of the permeability, vertical and horizontal, were used to establish flow units. The test case for the modeling using the flow units was the greater Wellington Field area. The flow units in Wellington KGS #1-32 were initially defined by Mina Fazelalavi (**Figure 2 left**). Fifteen layers were defined. These are compared with those derived by Paul Gerlach who used vertical permeability to define flow units for the same well (**Figure 2, right**).

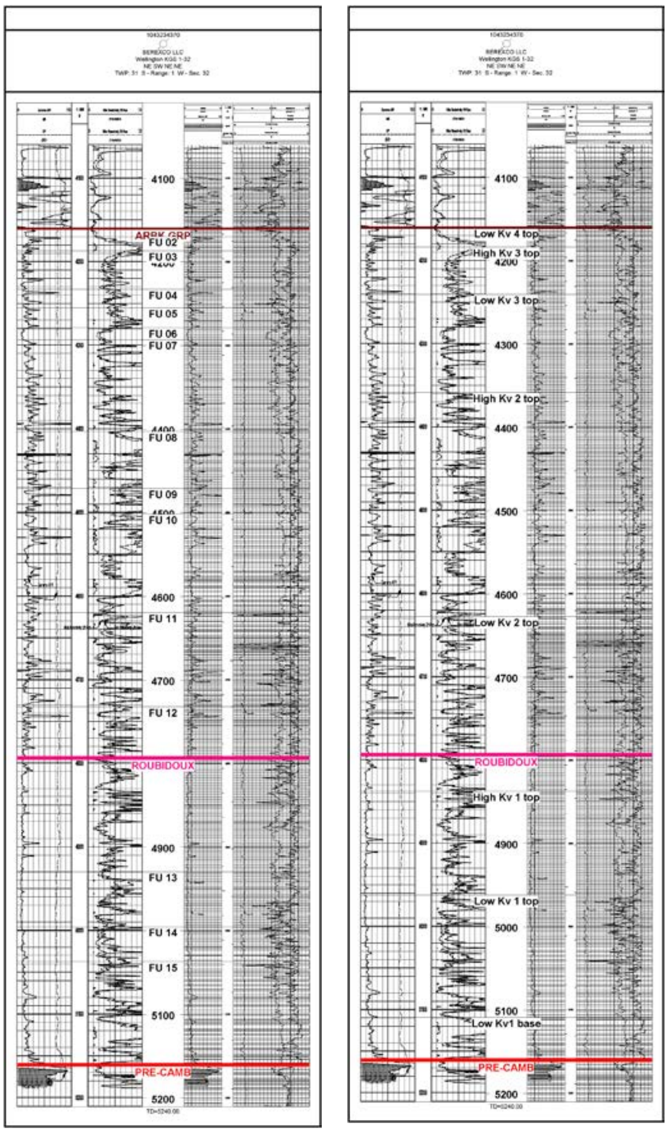


Figure 2. (left) flow units derived from horizontal permeability and (right) derived from vertical permeability for Wellington KGS #1-32.

Mina's approach, the Lorenz method, is often used by engineers. Mina compared this classification of the 15 flow units with a number of attributes as listed below, summarized in **Figure 3**, and illustrated in a depth plot in **Figure 4**.

1) flow units derived from Lorenz plot (SLMP)
2) GR
3) lithology
4) T2 distribution which shows pore size
5) K90
6) Kv
7) Arithmetic average of Kh
8) Arithmetic average of Kv
9) Harmonic average of Kv
10) flow capacity %
11) storage capacity %

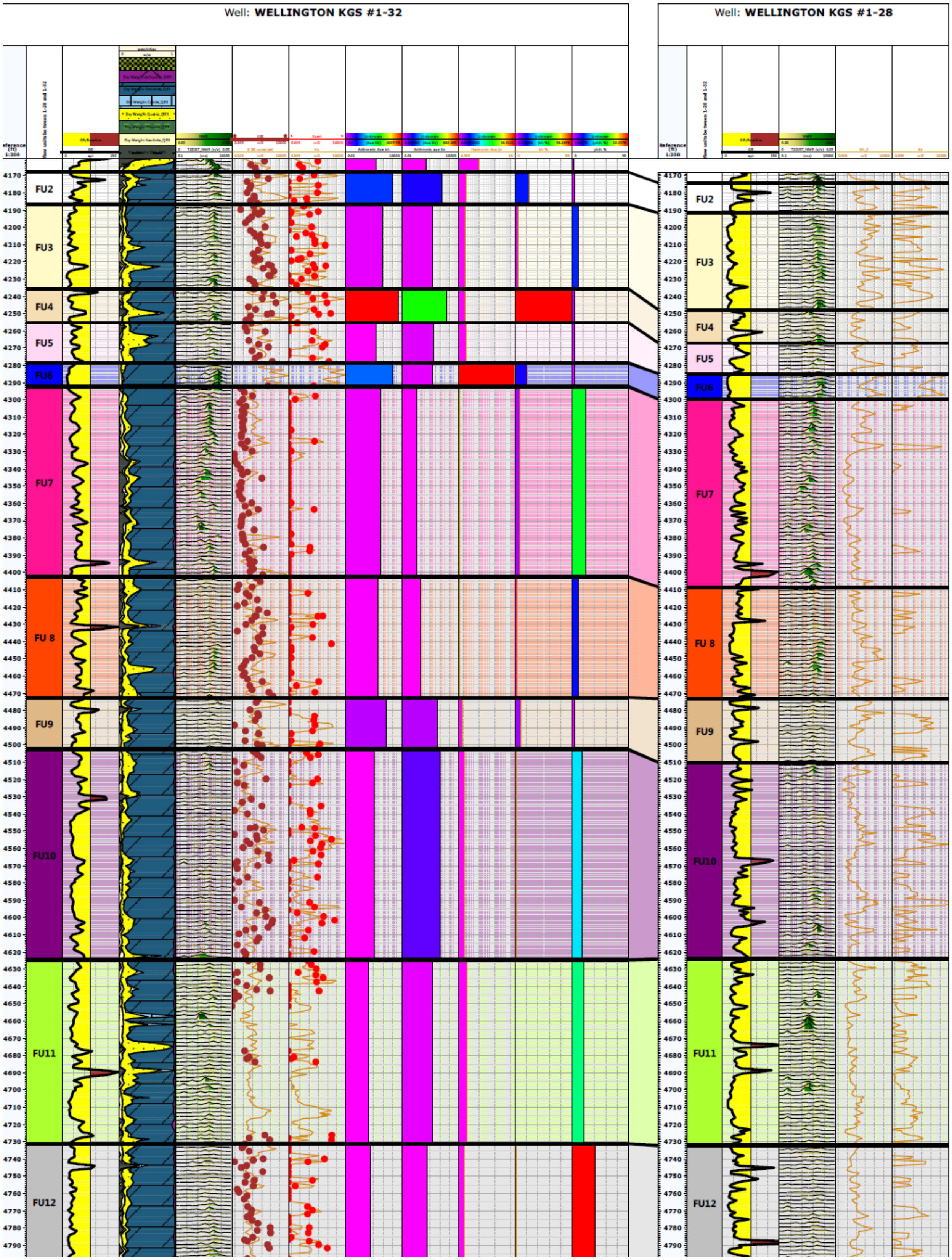
Each flow unit has a distinct permeability (Kv and Kh), flow capacity, and storage capacity. Even pore size distribution, GR, and lithology are indicatives of differences of each layer. However, correlating these detailed flow units beyond the heavily calibrated Wellington Field presents challenges – to do so expeditiously with more limited information.

	Depth						
Flow Unit Number	from	to	ΣKh %	Σ ϕh %	Ave K	Σ Kh/Σ ϕh	flow unit type
FU01	4160	4168	0.096785	1.511252	21.55	0.064042934	baffle
FU02	4168	4186.5	9.490357	2.142572	946.94	4.429422306	Permeable
FU03	4186.5	4235.5	2.129447	5.73142	82.27	0.371539118	fair to low capacity
FU04	4235.5	4256	44.43726	2.514279	4007.55	17.67395686	Very Permeable
FU05	4256	4278	0.199295	2.101346	16.96	0.094841469	baffle
FU06	4278	4292	8.23271	2.002677	1113.22	4.110853325	Permeable
FU07	4292	4300.5	0.004002	1.127471	0.89	0.003549412	baffel
FU08	4300.5	4305.5	6.696173	0.540471	2304.80	12.38952248	Permeable
FU09	4305.5	4397.5	0.560327	9.548474	11.61	0.05868241	baffle
FU10	4397.5	4402	2.566065	0.500545	1078.75	5.126542716	Permeable
FU11	4402	4472	0.975126	5.127107	26.42	0.190190219	Permeable
FU12	4472	4502.5	3.463398	1.953841	211.56	1.772610543	Permeable
FU13	4502.5	4986.5	3.160263	44.88617	9.10	0.070406158	baffle
FU14	4986.5	4996	16.20864	0.95441	3677.33439	16.98289076	Very Permeable
FU15	4996	5034.5	1.465964	4.500618	72.0576278	0.325725091	fair to low capacity
FU16	5034.5	5200	0.314184	14.85735	3.59366448	0.021146683	baffle

Layer Top	Model	Mina Flow Unit
4,160	Layer 01	FU01
4,184	Layer 02	FU02
4,241	Layer 03	FU04
4,359	Layer 04	FU09
4,429	Layer 05	FU11
4,500	Layer 06	FU12
4,571	Layer 07	FU13
4,642	Layer 08	FU13
4,837	Layer 09	FU13
4,879	Layer 10	FU13
4,928	Layer 11	FU13
4,962	Layer 12	FU13
5,109	Base Model	FU16

Figure 3. Wellington KGS #1-32, properties of flow units define by Mina.

Paul's flow units (**Figure 2, right**) are upscaled and the focus on differentiation of vertical permeability. The upscaling has led to some changes in boundaries, but the basic framework of Mina's flow units is still present (**Figures 5-76**). The Lorenz Plot shown in **Figure 6** and are compared in the depth plot of Wellington KGS #1-32 in **Figure 7**.



Well: WELLINGTON KGS #1-32
Well: WELLINGTON KGS #1-28
FU2
FU3
FU4
FU5
FU6
FU7
FU 8
FU9
FU10
FU11
FU12

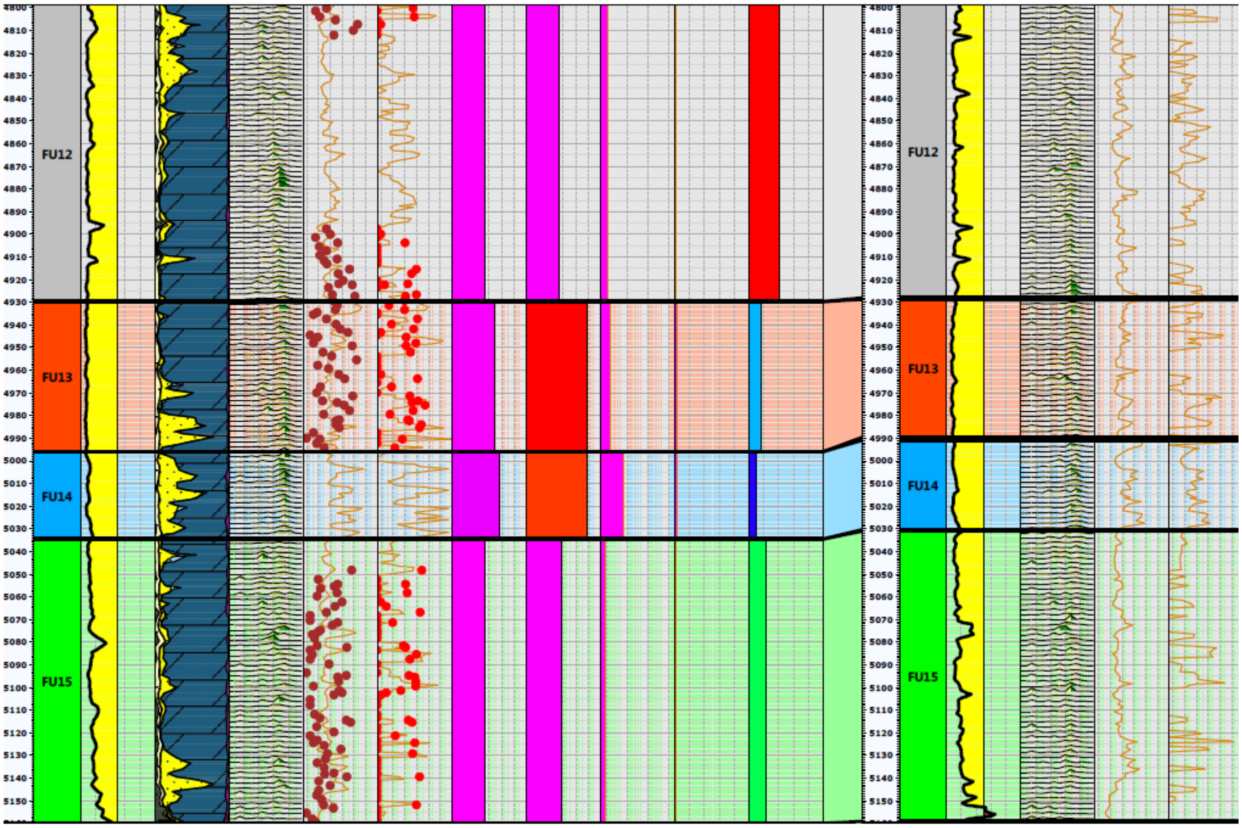


Figure 4. Comparison of Mina's 15 flow units between wells #1-32 and #1-28.

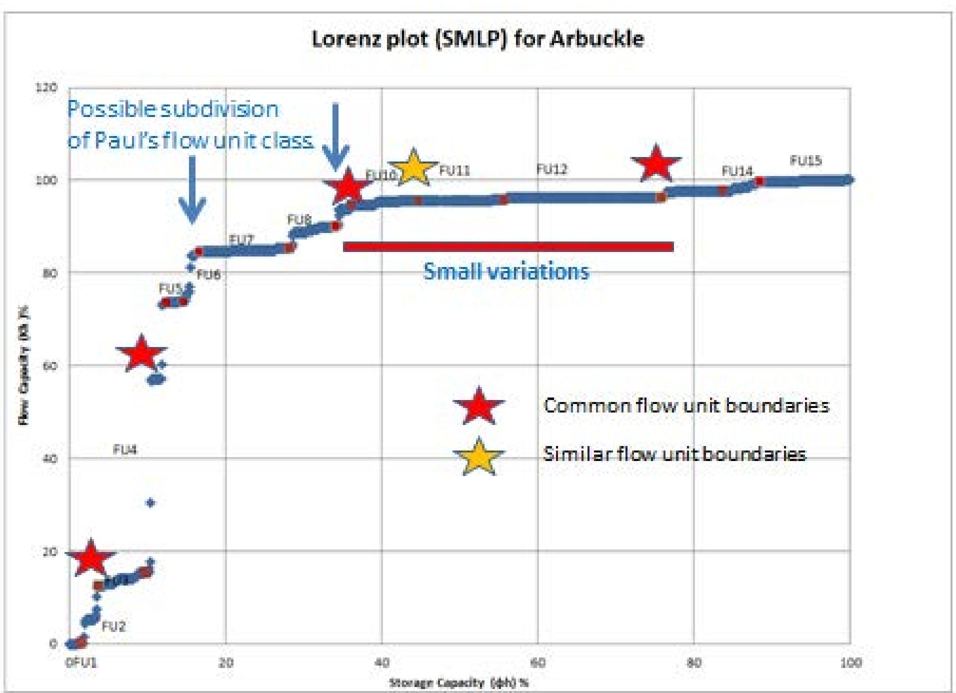


Figure 5. I have labeled the common flow unit boundaries. These units capture a lot of the variability. Mina's flow unit is based on Kh and Paul includes use of Kv to distinguish the layers. It is my understanding that Kv is very important so it needs to be factored into the flow unit classification.

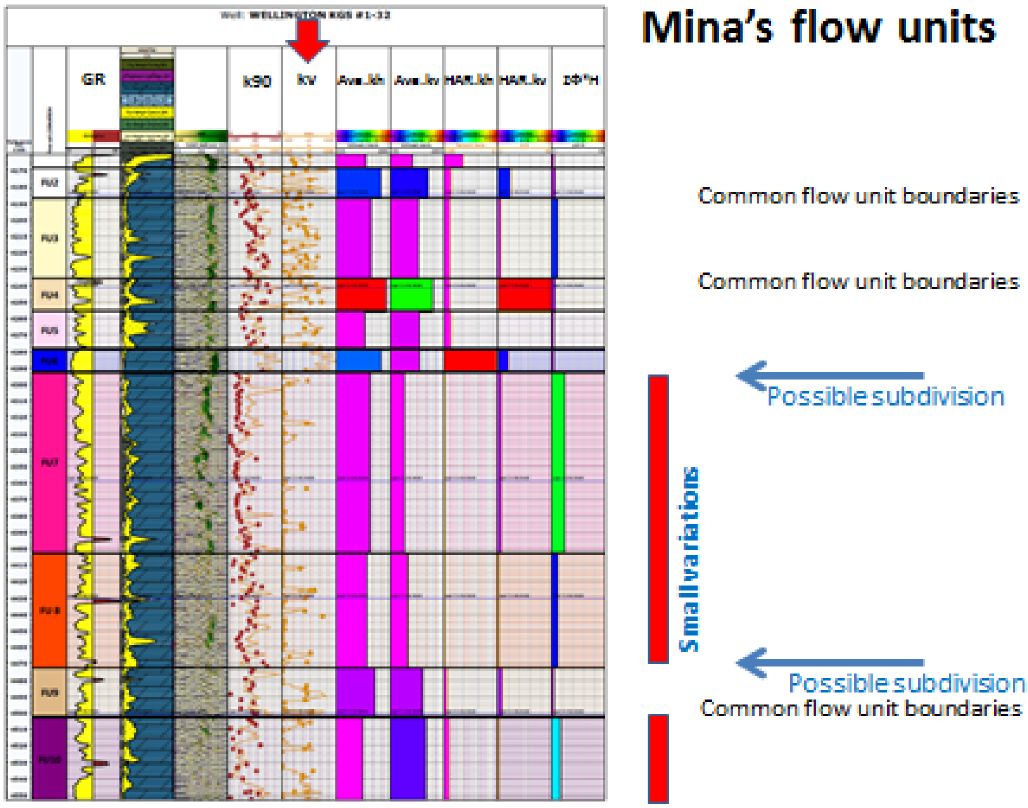


Figure 6. Comparison of Mina's and Paul's (faint blue dashed line) flow units indicate potential to add flow unit boundaries in the latter. Two of Paul's boundaries are included in Mina's FU7 and FU8. The boundary between FU7 and FU8 is very minor as also seen in Figure 6 and noted by the red bar (small variations).

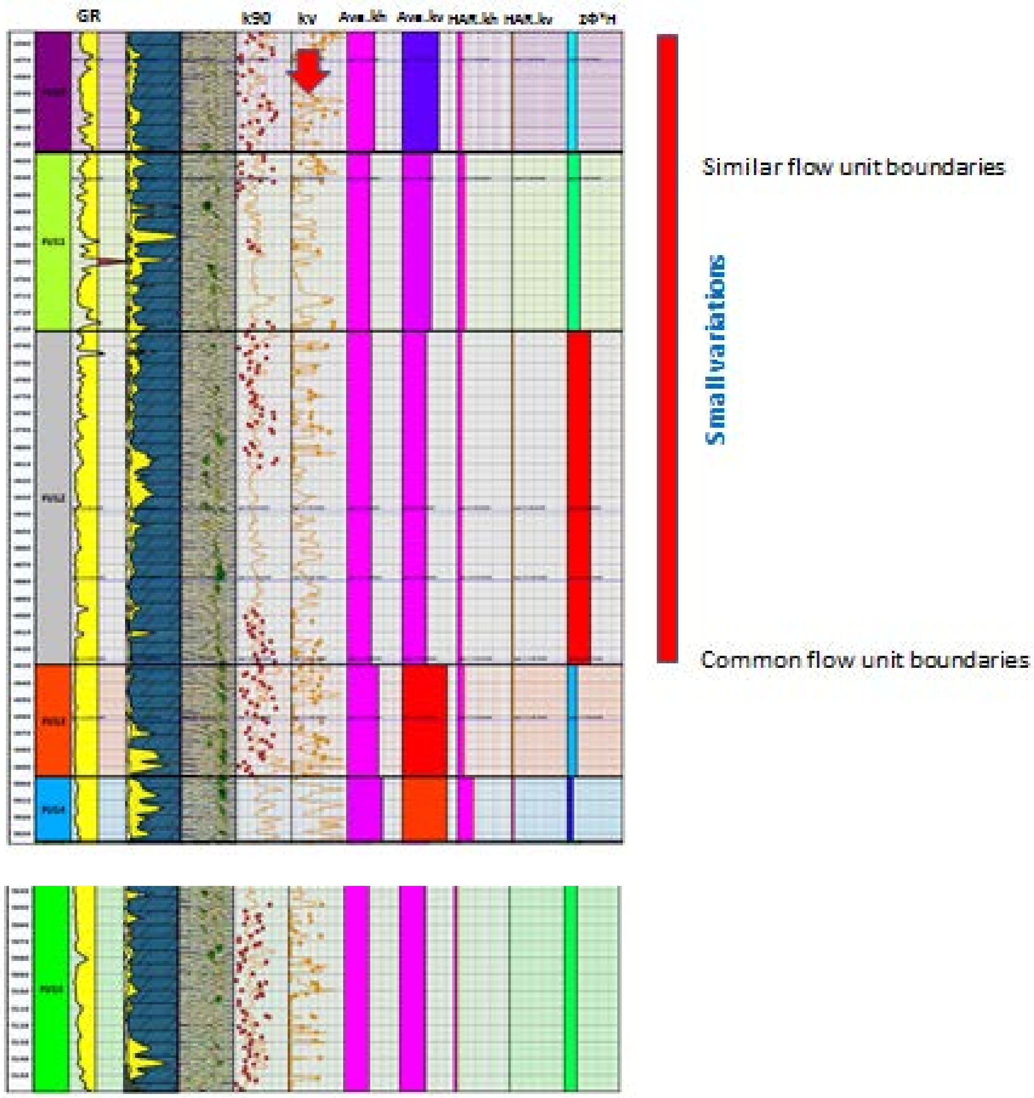


Figure 7. Mina's and Paul's flow units (faint blue dashed lines) have subdivided Arbuckle into multiple flow units in the interval noted as "small variations".

The flow unit delineation was investigated early on using depth-constrained cluster analysis (*http://www.kgs.ku.edu/stratigraphic/ZONATION/*), comparing results with Wellington KGS #1-32 and #1-28 (**Figure 8 and 9**). Technique does not examine interwell correlation so flow unit designation varies between wells and becomes problematic.

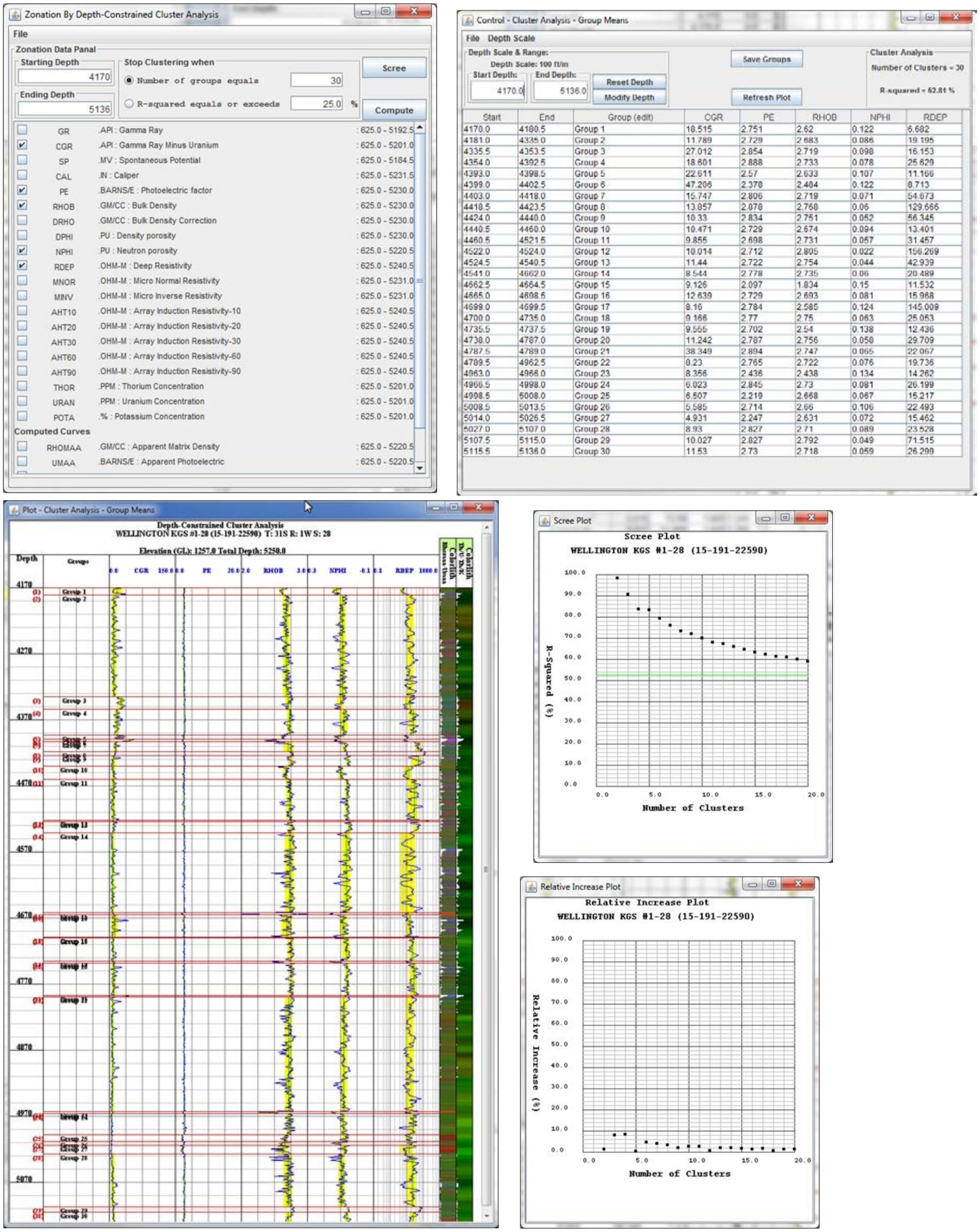


Figure 8. Computation of zonation by depth-constrained clustering for Wellington KGS #1-28.

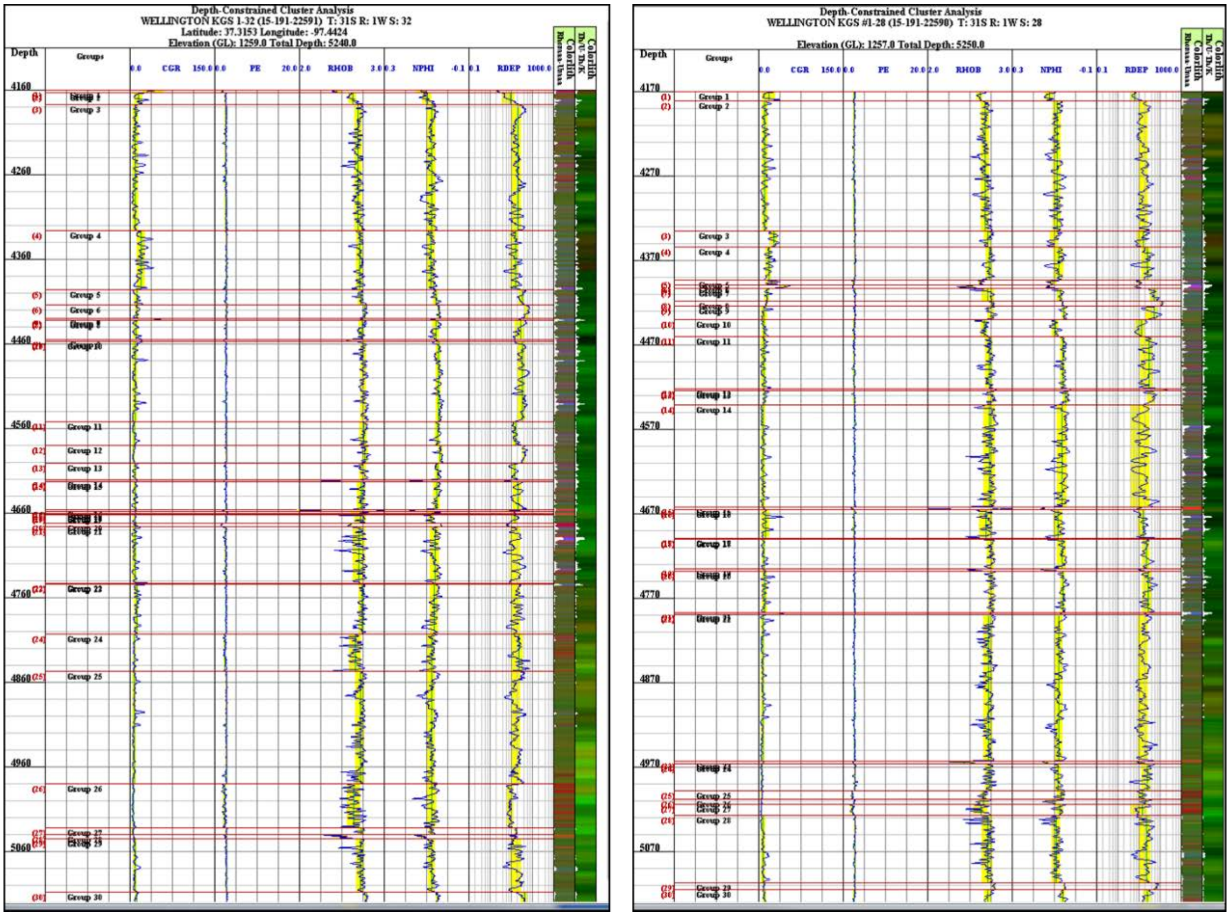


Figure 9. Zonation by depth-constrained clustering for #1-32 (left) and #1-28 (right).

Subtask 2.4. Gather and interpret KGS's gravity and magnetic data

Subtask 2.5. Remote sensing analysis for lineaments

Task 3. Geomodel of Mississippian Chat & Arbuckle Group - Wellington field.

Subtask 3.1. Collect geologic & engineering data
Subtask 3.2. Collect 3D seismic data
Subtask 3.3. Process 3D seismic data
Subtask 3.4. Collect gravity and magnetic data
Subtask 3.5. Interpret seismic, gravimetric, and magnetic data
Subtask 3.6. Initial geomodel - Wellington

Task 4: Preparation, Drilling, Data Collection and Analysis – Test Borehole #1

Subtask4.1. Locate Test Borehole #1
Subtask 4.2. Permitting for Test Borehole #1
Subtask 4.3. Drill, retrieve core, and run DST – Test Borehole #1
Subtask 4.4. Openhole Wireline Logging – Test Borehole #1
Subtask 4.5. Wellbore Completion – Test Borehole #1
Subtask 4.6. Analyze wireline log - Test Borehole #1
Subtask 4.7. Test and sample fluids (water) from select intervals – Test Borehole #1
Subtask 4.8. Analyze Arbuckle core from Test Borehole #1
Subtask 4.9. Analyze Mississippian core from Test Borehole #1
Subtask 4.10. PVT analysis of oil and water from Mississippian chat reservoir
Subtask 4.11. Analyze water samples from Test Borehole #1
Subtask 4.12. Microbiological studies on produced water
Subtask 4.13. Correlate log and core properties
Subtask 4.14. Examine diagenetic history of fracture fill

Task 5. Preparation, Drilling, Data Collection, and Analysis - Test Borehole #2

Subtask 5.1. Locate Test Borehole #2
SubTask 5.2. Permitting for Test Borehole #2
Subtask 5.3. Drill, and run DST – Test Borehole #2
Subtask 5.4. Openhole wireline logging - Test Borehole #2
Subtask 5.5. Complete well and perforate selectively to test and sample fluids – Test Borehole #2
Subtask 5.6. Analyze wireline log – Test Borehole #2

Task 6. Update Geomodels

Subtask 6.1. Hydrogeologic studies
Subtask 6.2. 2D shear wave survey
Subtask 6.3. Process & interpret 2D shear
Subtask 6.4. Revise 3D seismic interpretation
Subtask 6.5. Update geomodel - Arbuckle & Miss

Update in Step Rate Test - Mina Fazelalavi

Step-rate test and interference tests were re-analyzed and better results are obtained. Results of the recent well test analysis discussed below. Calculated permeability from step-rate test and interference tests are almost in agreement with log derived permeability. Skin is negative due to either fracture around the wellbore caused by injection or acidizing before the injection. The former statement seems to be more valid.

Step-rate test was modeled with FEKETE software and permeability and skin were calculated. Interference test was also modeled with FEKETE. A composite model was considered for this test due to change in permeability and flow capacity at some distance from the wellbore.
Two permeabilities were calculated for two radii (regions) from Wellington KGS 1-32.

The calculated permeability from step-rate test is 113 mD for 30 ft interval that has vertical communication based on Lorenz plot that was used to designate flow units (as previously discussed). There are vertical barriers above and below this interval. 25 ft of this interval is perforated. This permeability is close to log derived average permeability (74mD) for the same interval. Results are described in **Figure 10**.

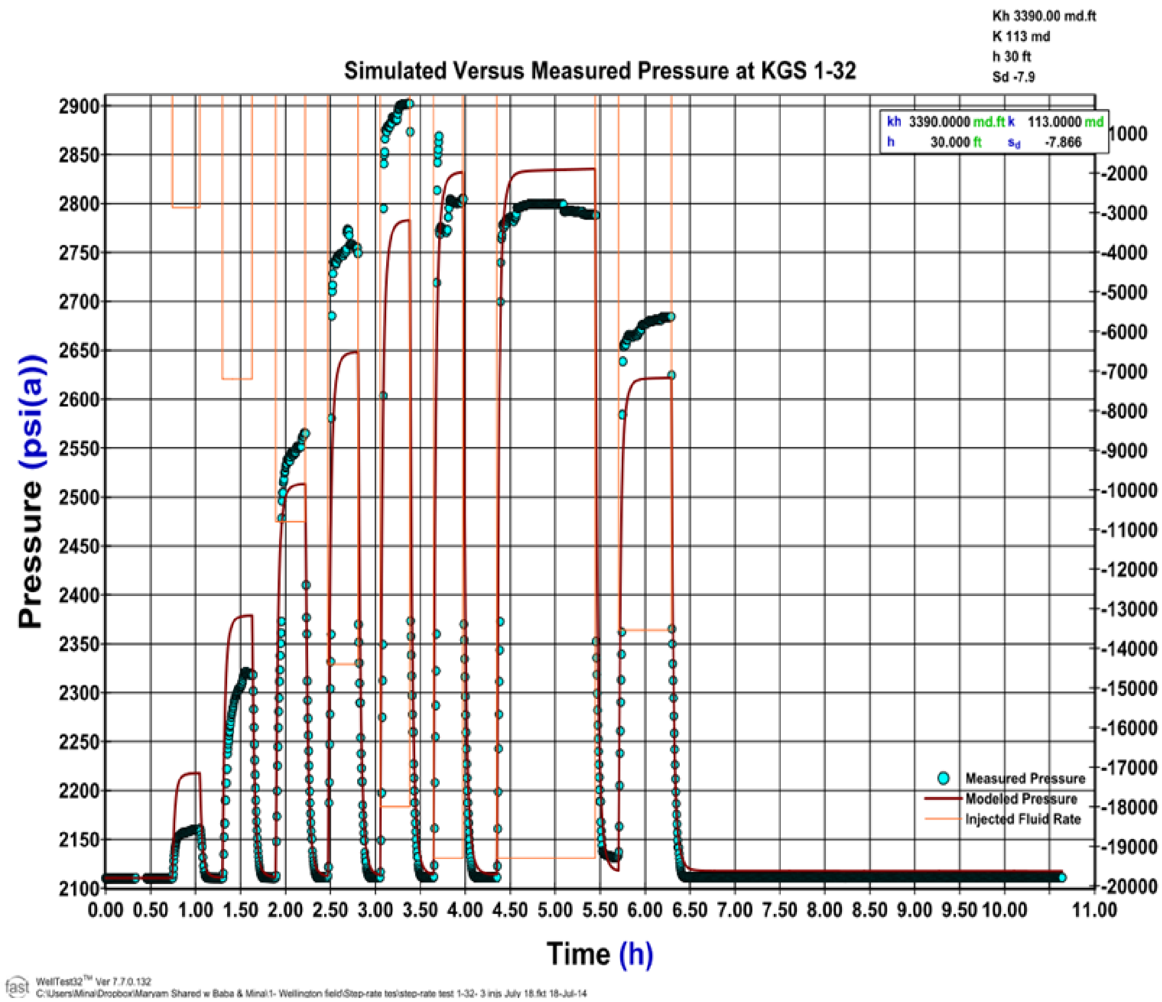


Figure 10. Step-rate test analysis revised, simulated vs. matched.

Well 1-32 was the injection well and 1-28 was the observation well. Distance between 1-32 and 1-28 is 3500ft (**Figure 11**). Better results were obtained when composite model with dual porosity-permeability was considered. Based on this model, permeability around well 1-32 to a radius of 2493 ft (region 1) has a lower value (100 mD) for 30 ft interval that is in vertical communication.

Permeability is 124 D from radius of 2493ft to the vicinity of 1-28. Permeability derived from the interference test is close to log derived average permeability (74mD). Bigger permeability for the farther radius can be associated with fracture or fault between two wells.

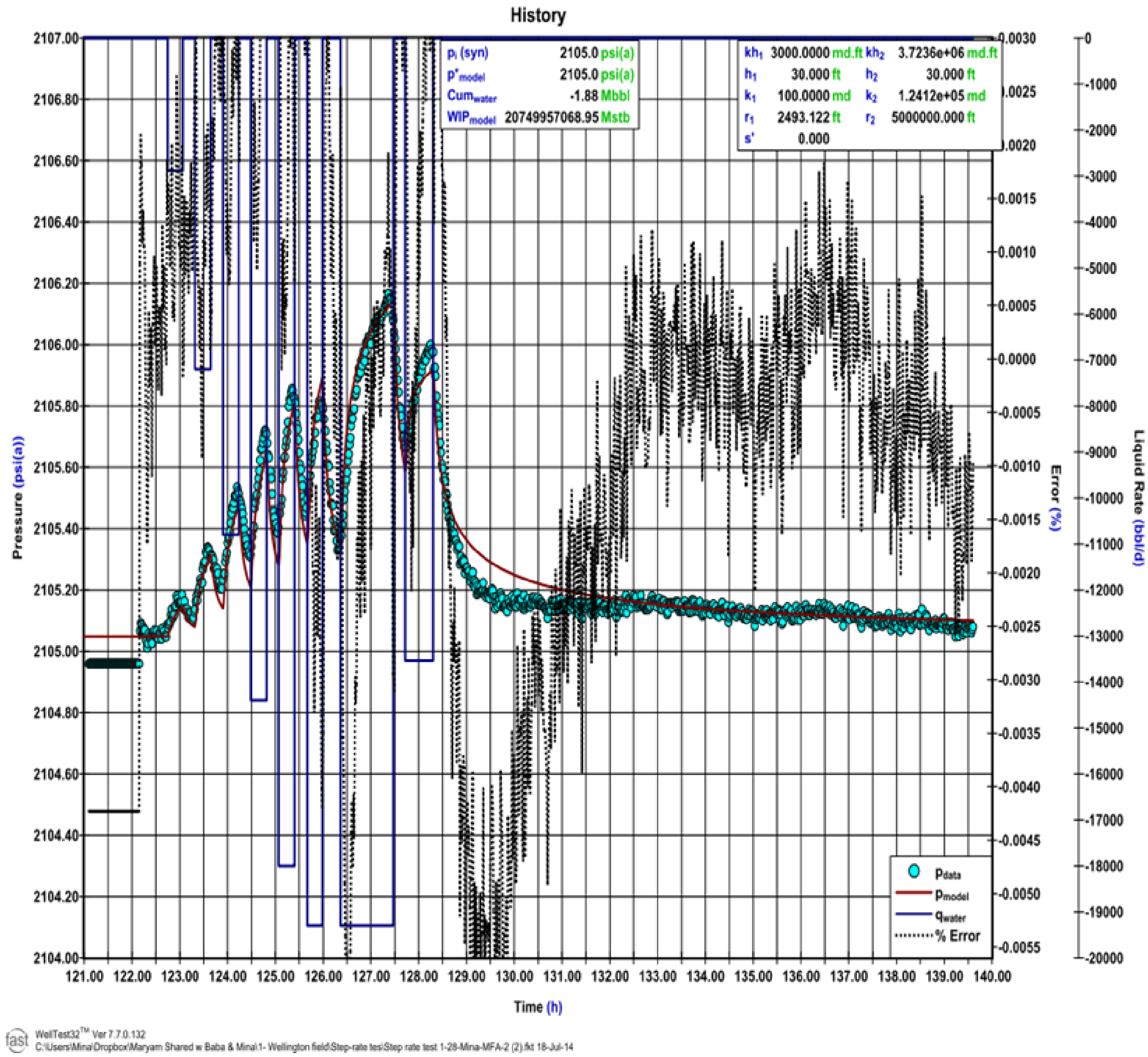


Figure 11. Interference test results in 1-32 and choosing 1-28 as an observation well.

This model shows the two zones with different radius and permeabilities. Zone 1 is from well 1-32 to a radius of 2493ft and zone 2 is from 2493ft to well 1-28 (**Figure 12**).

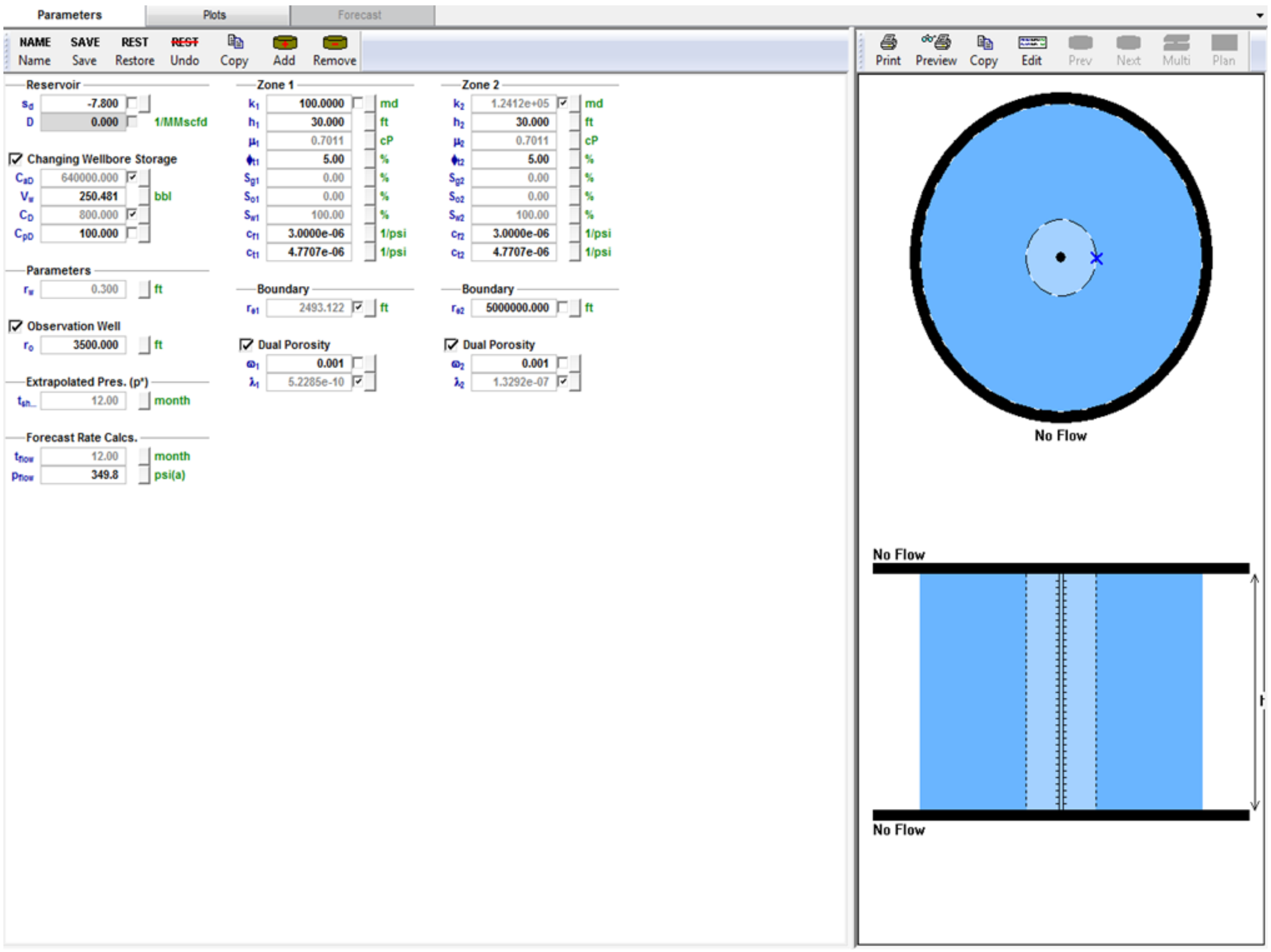


Figure 12. Composite model diagram and parameters.

Comparison of Step Rate Test analysis with DST results

DST 1 and 4 are only suitable for analysis. The Horner Plot is shown in **Figure 13**. DST 2 and 3 are not suitable for analysis. In DST 2, the flowing pressure is equal to shut-in pressure therefore; there is no build-up to analyze. Just temperature and pressure are useful. For DST 3, flowing pressure is equal to shut-in pressure therefore, there is no build up to analyze.

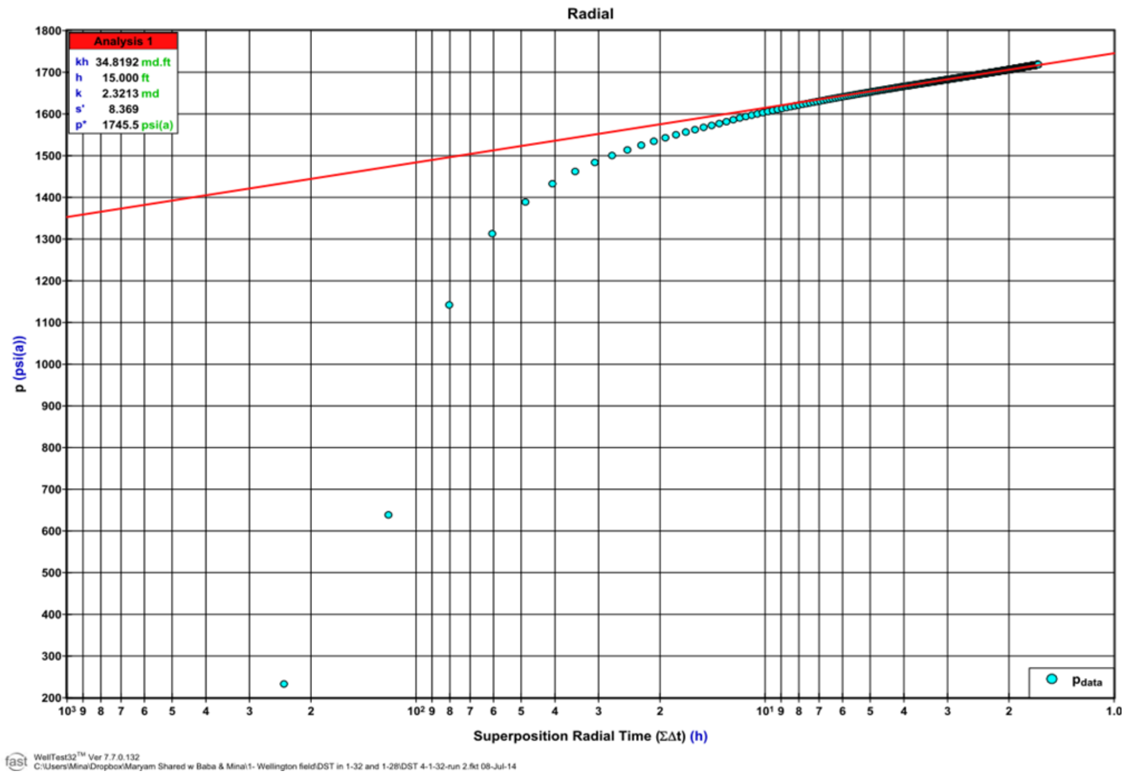


Figure 13. Horner plot for DST 4 in Wellington KGS #1-32, interval 4175 to 4190 ft.

Of the DSTs in Wellington KGS #1-28, only DST 1 is suitable for analysis **(Figure 14**).

DSTs 2, 3 and 4 are not suitable for analysis. DST 2 has a short flow transient period. Pressure from this test is useful. -DST 3: Like DST 2 has a short transient time. Pressure from this test is useful. DST 4 is not suitable for the same reasons as 2 and 3.

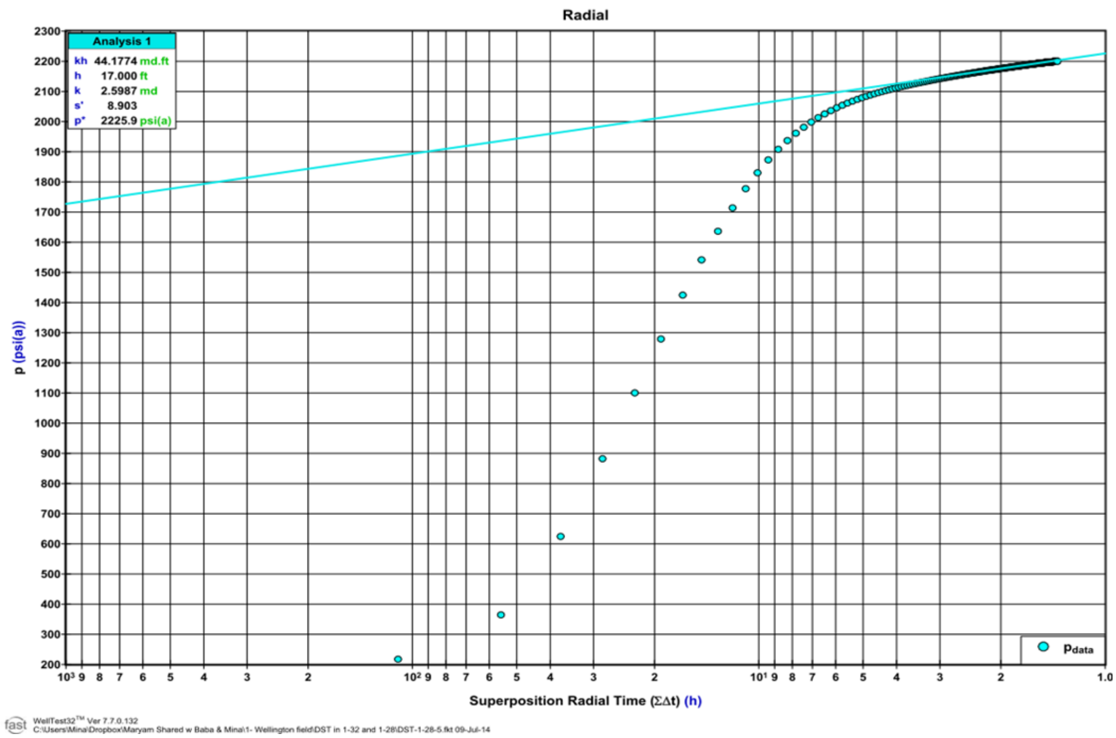


Figure 14. DST 1 in Wellington KGS #1-28, interval: 5133-5250ft.

The results of the step rate and drill stem tests are summarized in **Figure 15**.

Well 1-32				
DST Interval	K from DST	Log connectivity	Average Log derived K90	Average Core K90
ft	mD	ft	mD	mD
4175-4190	2.32	4175-4090	4.61	4.59

Well 1-28				
DST Interval	K from DST	Log cennectivity	Average Log derived K90	Average Core K90
ft	mD	ft	mD	mD
5133-5250	2.60 mD	5133-5160	2.17 (5133-5160)	NA

Step-Rate Test results				
Interval	Gauge depth@	K from Step-rate test	Average log derived K90	Average Core K90
ft	ft	mD	mD	mD
30	4869	113	74	NA

Interference test result				
Interval	K for zone 1	K for zone 2	Ave K90 from log for zone1	Average Core K90
ft	mD	D	mD	mD
30	100	124	74	NA

Figure 15. Results of step rate and drill stem tests.

Summary of updated step rate test --

- Permeability calculated from Step-rate test and interference test are almost in agreement with log derived permeability.
- Permeability calculated from DST tests in 1-32 and 1-28 are in agreements with core data.
- Permeability of 124D from the interference test is associated with a radius farther away from 1-32 to the vicinity of well 1-28 which can be related to fault or fracture.
- Appropriate model and correct thickness were not selected in the former analysis. Skin was large and therefore, calculated permeability was affected by the large skin.
- Results can be improved if correct model and thickness selected.

Comments Regarding the Previous Step Rate Test analysis

- Thickness of injection zone was assumed 200 feet which is not right. Perforated interval is 25 feet and it is in the middle of FU 14 according to Lorenz plot. Thickness of this unit is only about 30 ft and it is bounded by almost impermeable layers which are above and below the unit.
- Calculated skin factor (s) is 200. This high s is very abnormal in carbonate reservoirs.
- Since the skin is very high, to obtain pressure match, calculated permeability times thickness (kh) had been increased to 4.24E+5 which is not correct.

Comments Regarding the Previous Interference Test analysis

- Thickness of injection interval was assumed 200 ft which is not correct. Actual thickness of affected interval by injection is 30 ft or less as was discussed.
- Volume of reservoir affected by injection had been increased by a factor of 6.66. Therefore, pressure signal at well 28 is reduced by a factor of 6.66. To compensate for this reduction, higher permeability had been calculated.

Please refer to additional discussion in Key Findings near the end of this report.

Task 7. Evaluate CO2 Sequestration Potential in Arbuckle Group Saline Aquifer - Wellington field

Subtask 7.1. CO2 sequestration potential
Subtask 7.2. Long-term effectiveness of cap rock
Subtask 7.3. CO2 sequestered in brine
Subtask 7.4. CO2 sequestered as residual gas
Subtask 7.5. CO2 sequestered by mineralization
Subtask 7.6. Field management - max CO_2 entrapment
Subtask 7.7. Monte Carlo - total CO_2 seq capacity

Task 8. Evaluate CO2 Sequestration Potential by CO2-EOR in Depleted Wellington field

Subtask 8.1. CO2-EOR potential
Subtask 8.2. Long-term effectiveness of cap rock
Subtask 8.3. CO2 sequestered in brine and residual gas
Subtask 8.4. CO2 sequestered by mineralization
Subtask 8.5. Field management - optimize CO2-EOR
Subtask 8.6. Monte Carlo - total CO2 seq capacity

The full-field simulation has yet to be completed. As described above the field-wide geomodel for the Mississippian is underway.

Task 9. Characterize leakage pathways - Risk assessment area

Subtask 9.1. Collect reservoir characterization data - external sources
Subtask 9.2. Map fracture-fault network
Subtask 9.3. Verify seal continuity and integrity
Subtask 9.4. Inventory well status
Subtask 9.5. Gather expert advice on well integrity

Wells have been inventoried and well integrity has been defined. The newest geomodel will be used to further model the fractures and faults that are now being resolved as previously described above.

Task 10: Risk Assessment Related to CO_2-EOR in Mississippian Chat Reservoir and CO_2 Sequestration in Arbuckle Aquifers

Subtask 10.1. Model CO_2 plume for 100, 1000, and 5000 yrs after injection stops
Subtask 10.2. Model plume attenuation during and after injection
Subtask 10.3. Model effects of natural aquifer flow on CO_2 plume
Subtask 10.4. Estimate time frame for free phase CO_2 to become negligible
Subtask 10.5. Model effectiveness of cap rocks to contain leakage
Subtask 10.6. Leakage modeling through abandoned wells
Subtask 10.7. Model worst-case CO_2 leakage scenario
Subtask 10.8. Estimate surface environmental effects due to leakage

Simulations with leakage has been examined, but will be updated using the final geomodel.

Task 11: Produced Water and Wellbore Management Plans
Subtask 11.1. Identify at-risk wells in Wellington Field
Subtask 11.2. Outline Best Practices and well recompletion plans for at-risk wells
Subtask 11.3. Outline Best practices and well completion plans for new CO_2 injector wells
Subtask 11.4. Summarize practices in place for disposal of produced water

Wells have been examined for at-risk characteristics. Steps will be taken to plug a well in close proximity to the CO2 plume generated by the small scale injection test. Other wells lie significantly beyond this area that would need to be addressed if larger scale disposal would be considered. The criteria followed in this assessment will become the best practice. If there is any doubt, remedial action will be necessary.

Task 12. Regional CO2 Sequestration Potential in OPAS - 17 Counties

Subtask 12.1. Map reservoir compartments in Arbuckle aquifer in a regional context

The development of flow units was previously discussed. Establishing flow units for the regional type logs was accomplished and tie well with the regional stratigraphic subdivisions and correlations previously established (e.g., **Figures 16 and 17**).

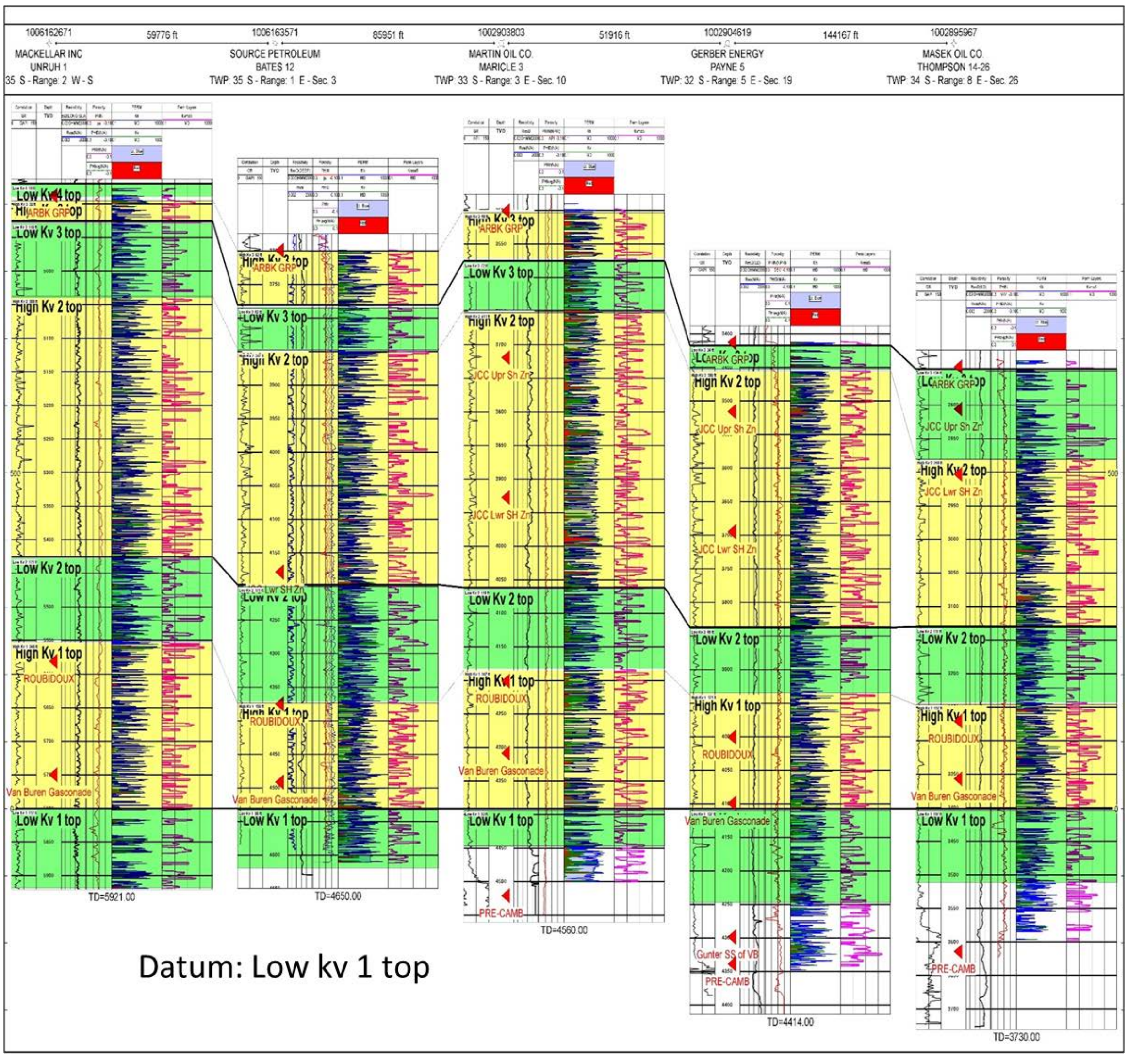


Figure 16. Example of correlation of major regional correlatable flow units in the Arbuckle in area 5 including Wellington Field.

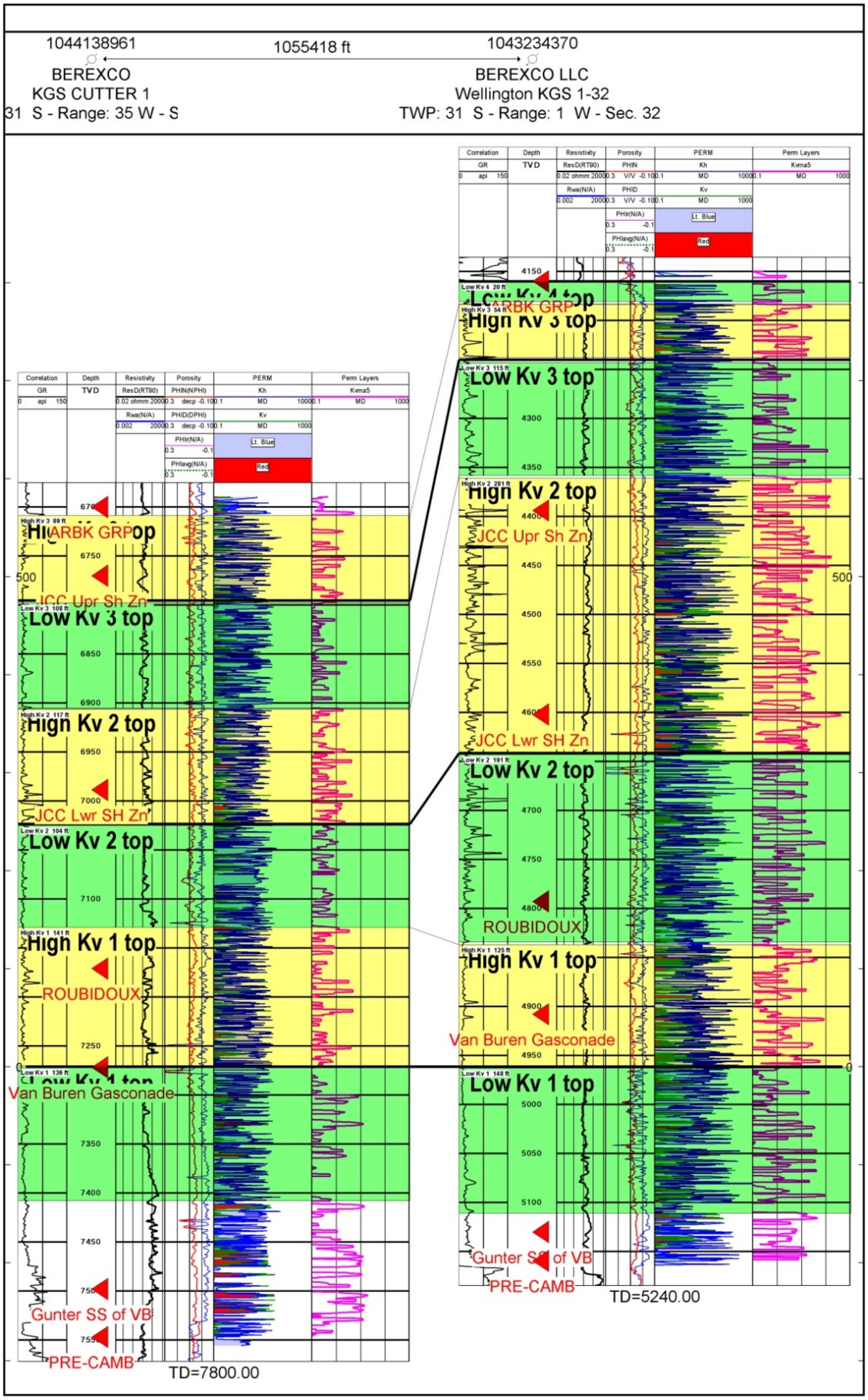


Figure 17. Correlation of flow units between Cutter KGS #1 and Wellington KGS #1-32. Distance of correlation is 200 miles, but does not imply continuous continuity. Several of units are truncated or pinch out between these anchor wells.

Regional flow units are being used to simulate commercial scale injection in 10 sites in southern Kansas and eventually the entire region of southern Kanas. An example of the input grids for the 4-township simulation is illustrated in **Figure (18)**.

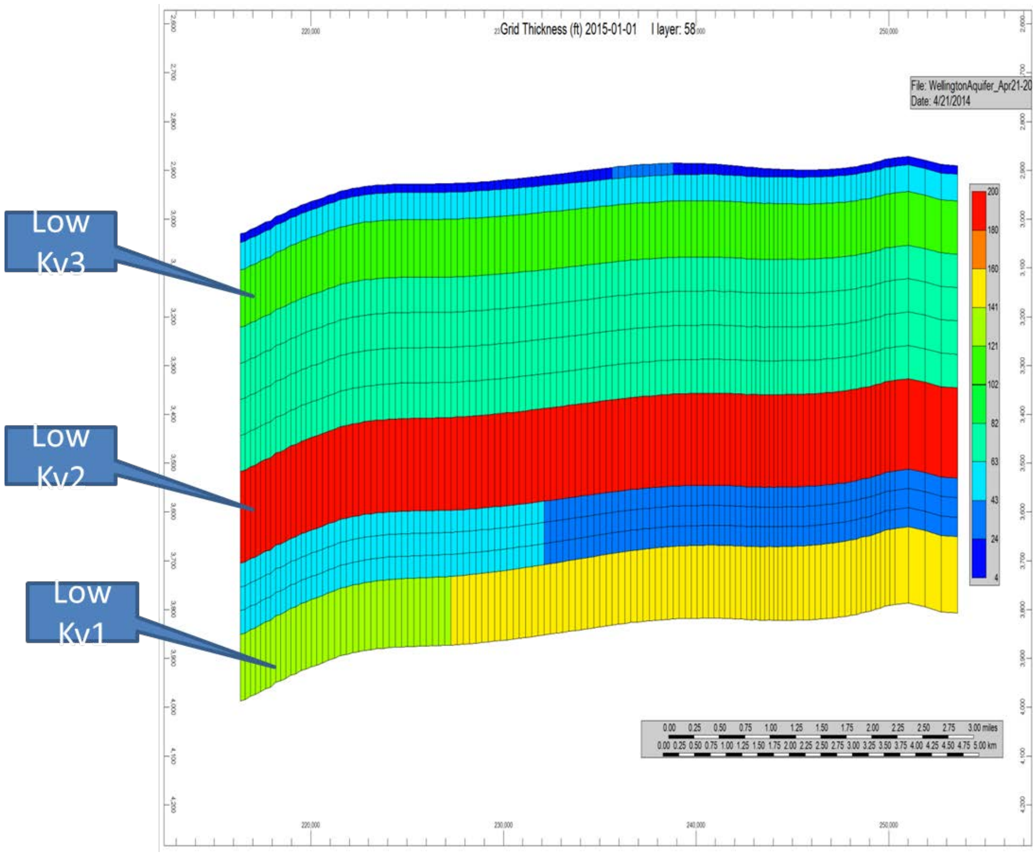


Figure 18. Initial simulation layers for the Arbuckle in the regional 4-township scale simulation of commercial scale CO_2 storage in the four-township area including Wellington.

Distribution of the 14 high and low kv layers created by P. Gerlach in southern Kansas are illustrated as a series of isopachs, first the high Kv (**Figures 19-24)**, followed by the low kv layers (**Figures 25-32)**. These large regional layers were exported as grids to CMG-GEM compositional simulator and will be used to compute the CO_2 storage capacity in southern Kansas.

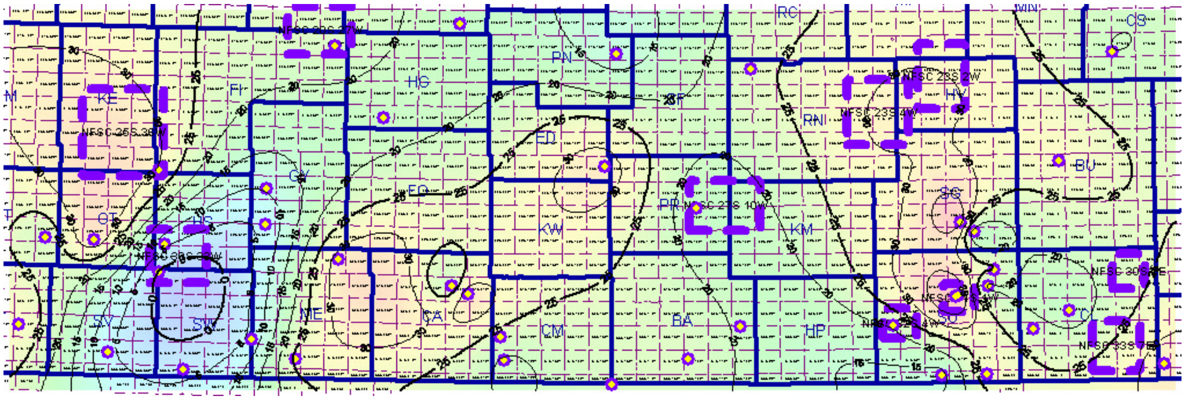


Figure 19. High Kv1 layer kh

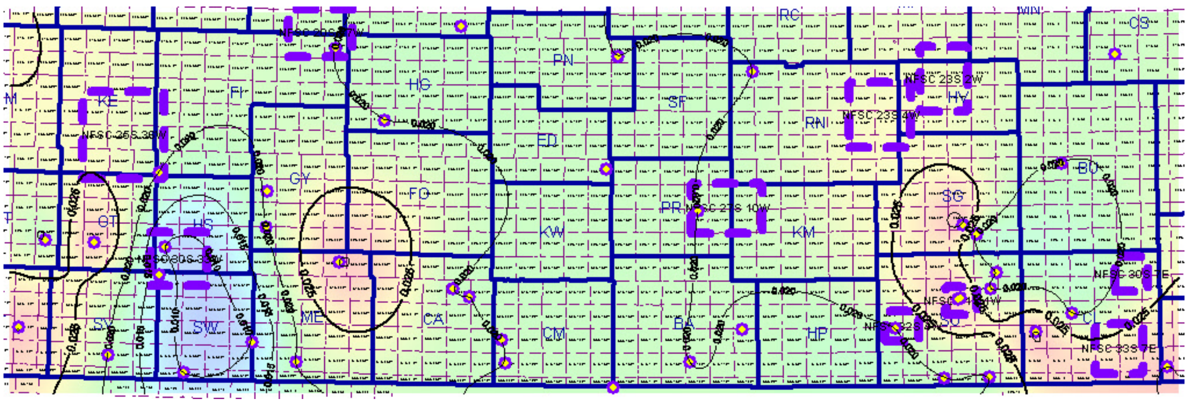


Figure 20. High Kv1 layer kv

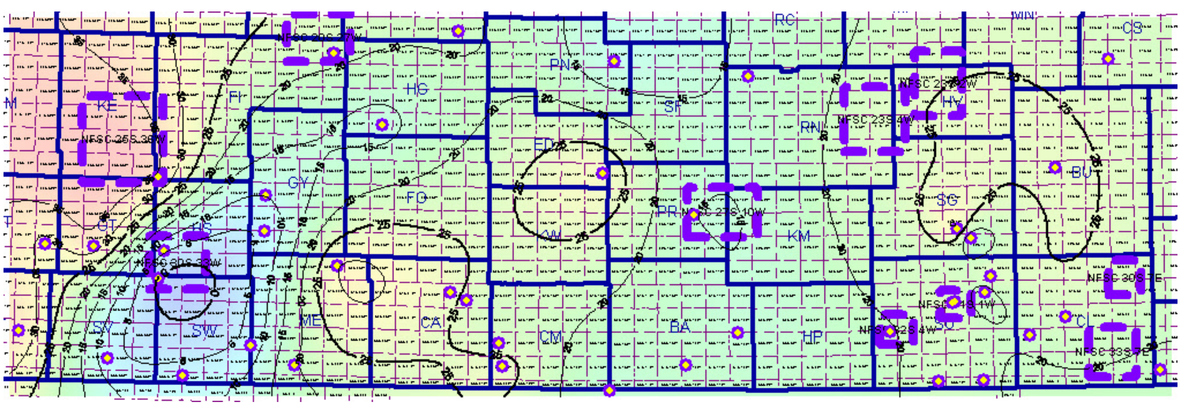


Figure 21. High Kv2 layer kh

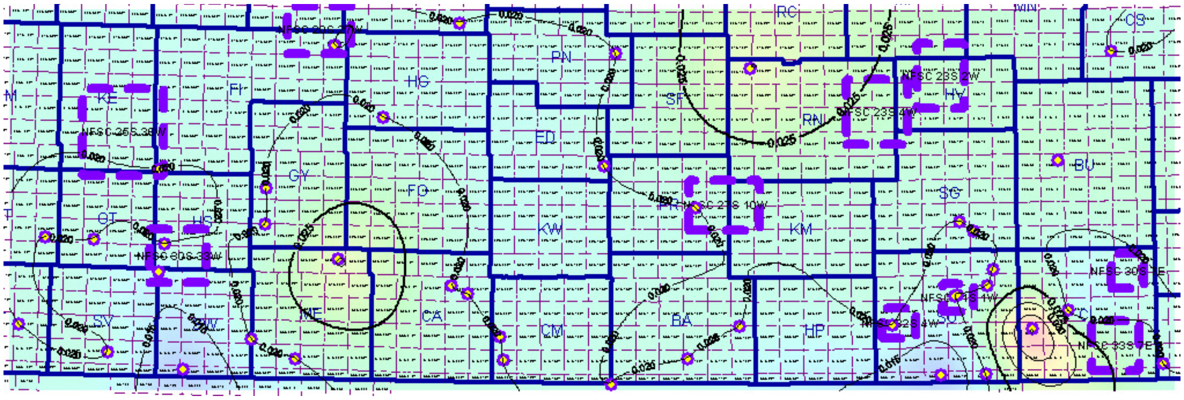


Figure 22. High kv2 layer kv

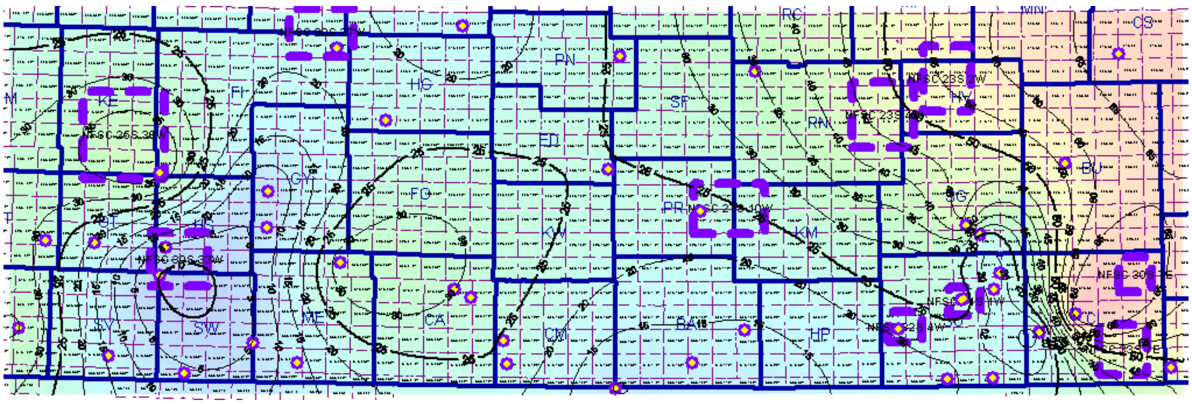


Figure 23. High kv3 layer kh

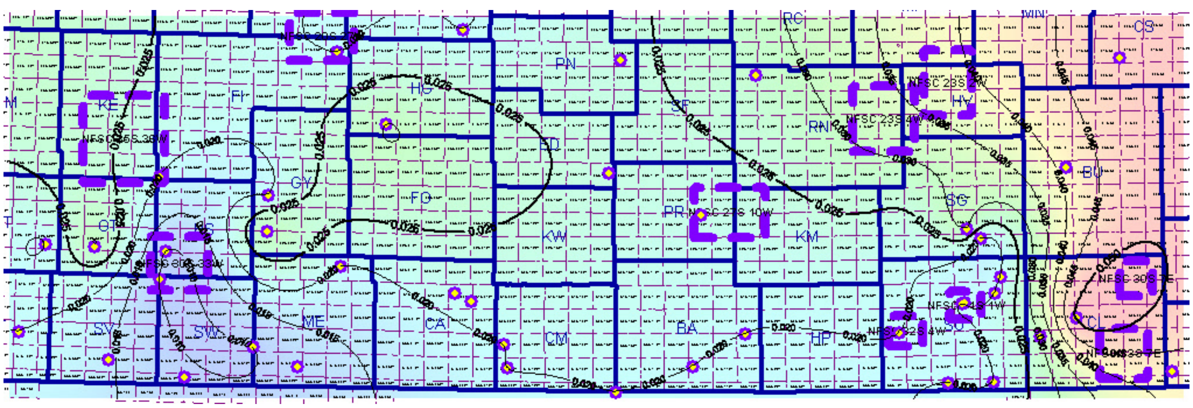


Figure 24. High kv3 layer kv

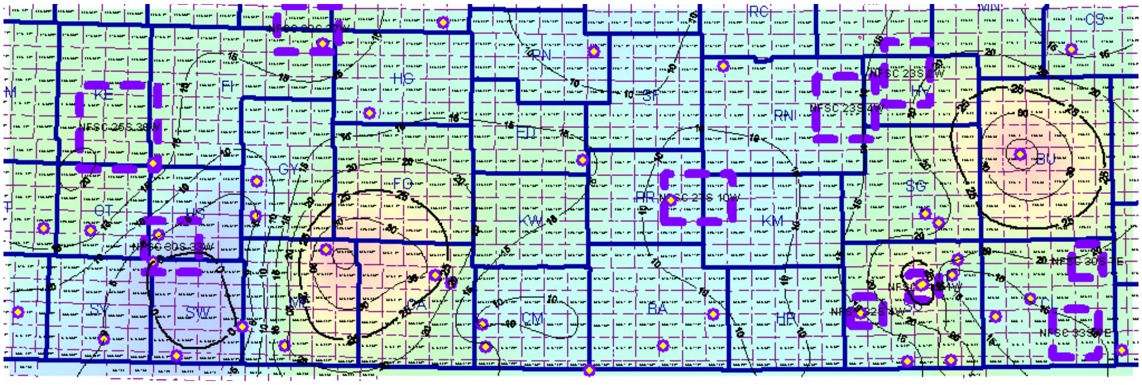


Figure 25. Low kv1 layer kh

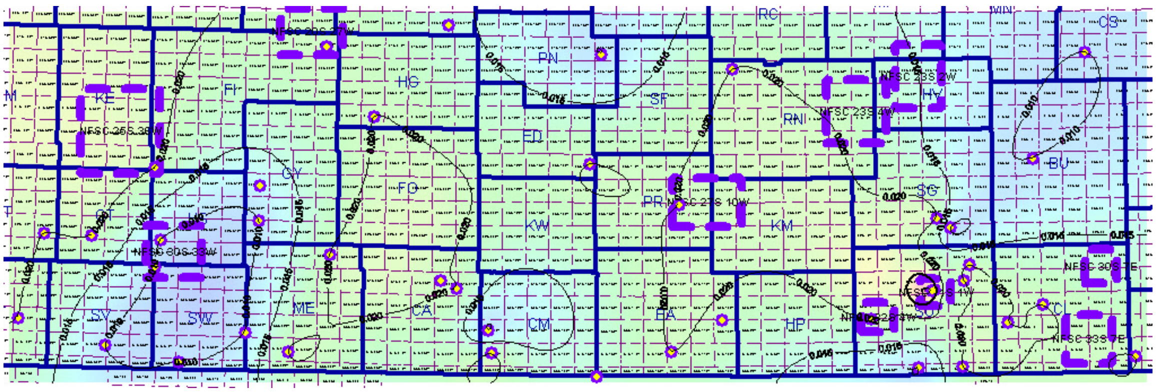


Figure 26. Low kv1 layer kv

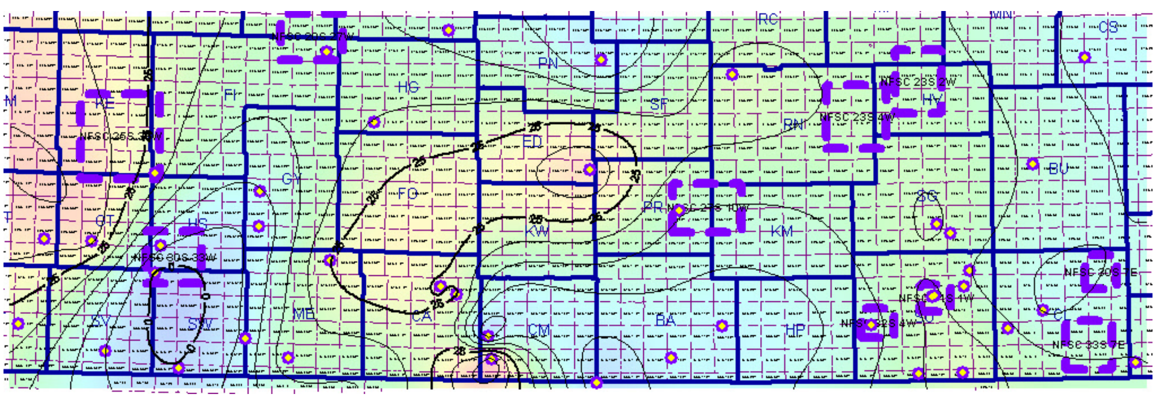


Figure 27. Low kv2 layer kh

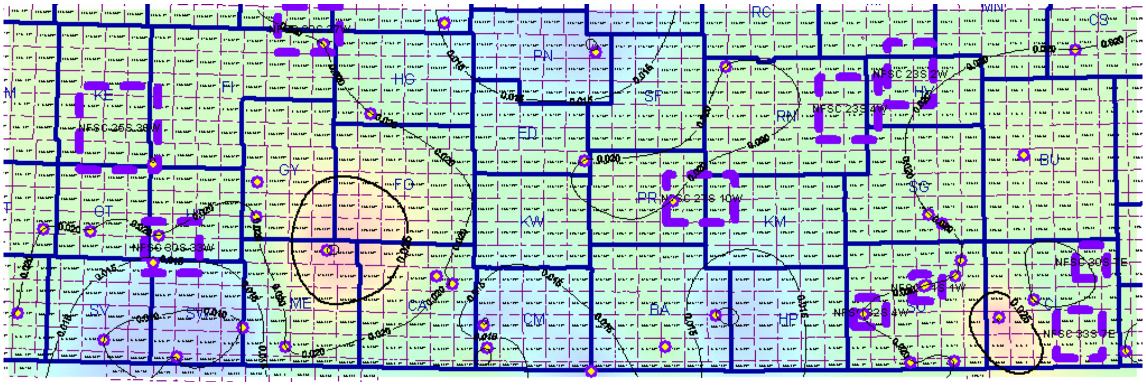


Figure 28. Low kv2 layer kv

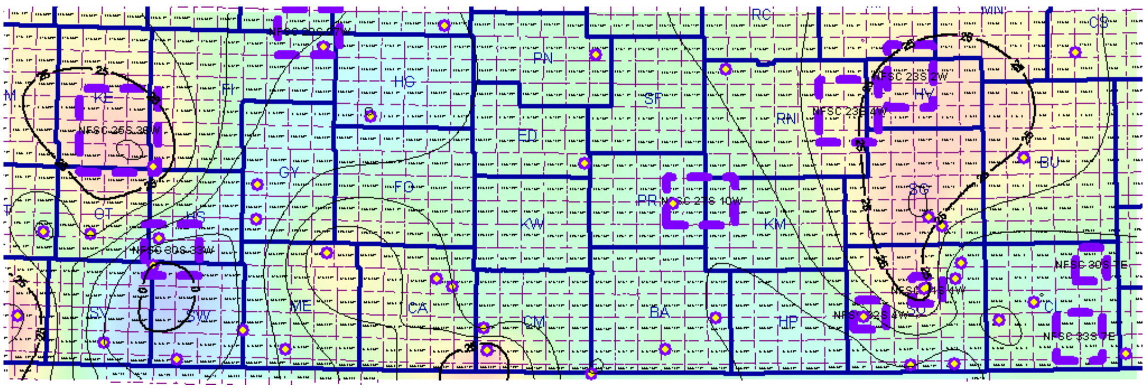


Figure 29. Low kv3 layer kh

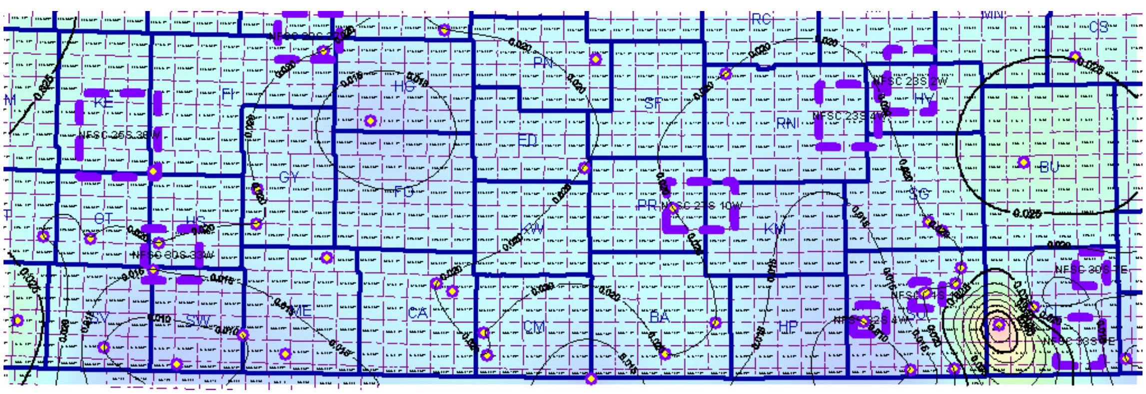


Figure 30. Low kv3 layer kv

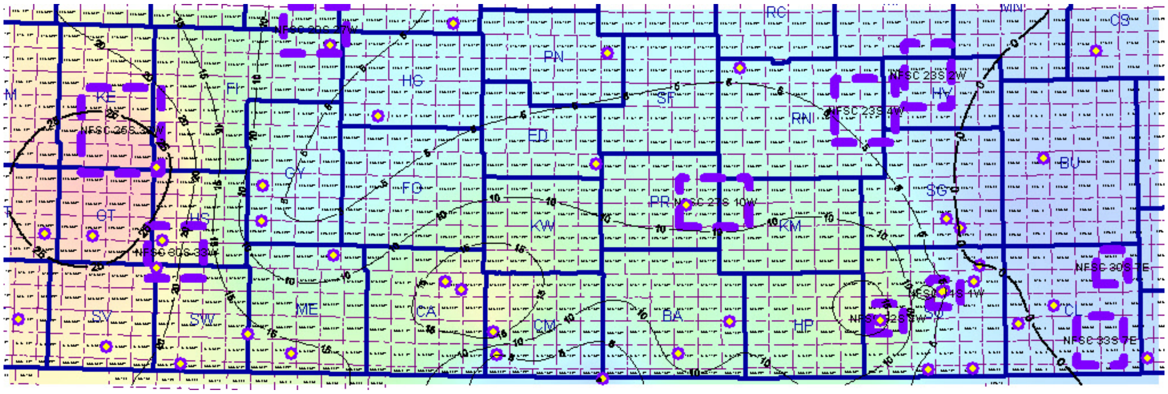


Figure 31. Low kv4 layer kh

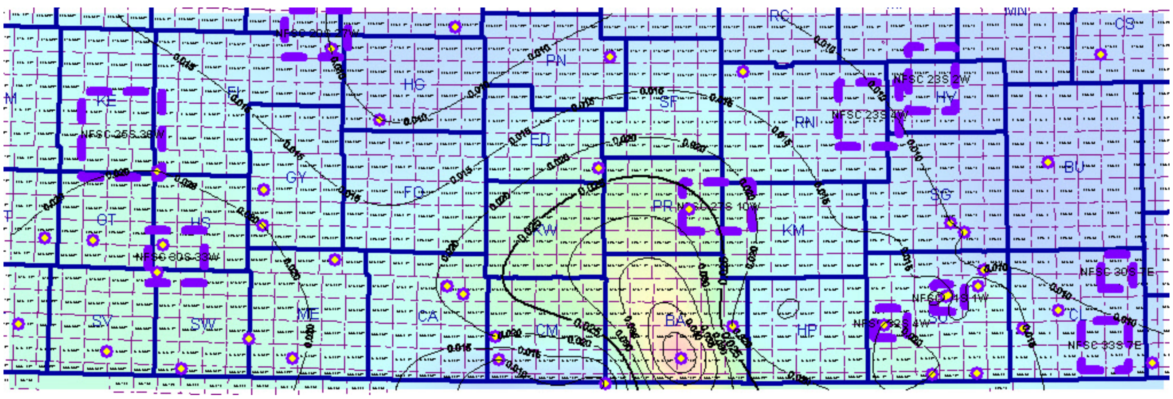


Figure 32. Low kv4 layer kv

Subtask 12.2. Coarse grid simulation over select OPAS areas to estimate regional CO_2 sequestration potential

The regional grid to be used over southern Kansas is 2500x2500 ft and 12 layers, thus there will be 1.64 MM coarse grid cells in the model. It is anticipated that at least 100K cells will be added for local grid refinement at each injection area (highlighted in yellow in **Figure 33**) this would add another million cells. Initial estimate is that the model should be roughly 2.6 MM cells. The structural configuration and a 3D view of the model grids for the CMG simulator are shown in **Figures 33-35**. Finer gridding was carried out at each of the 10 regional modeling sites as illustrated in **Figure 36**. This finer gridding reflects the greater level of detail in these regions and the individual models that were separately run in each of these injection sites.

A west-to-east structural cross section (**Figure 37)** shows the vertical distribution of the grid layers with color depicting thickness of each layer.

These regional views the Arbuckle saline aquifer will be extended to include the many other stratigraphic layers and their attributes, gravity and magnetic and remote sensing to bring together the full geologic perspective.

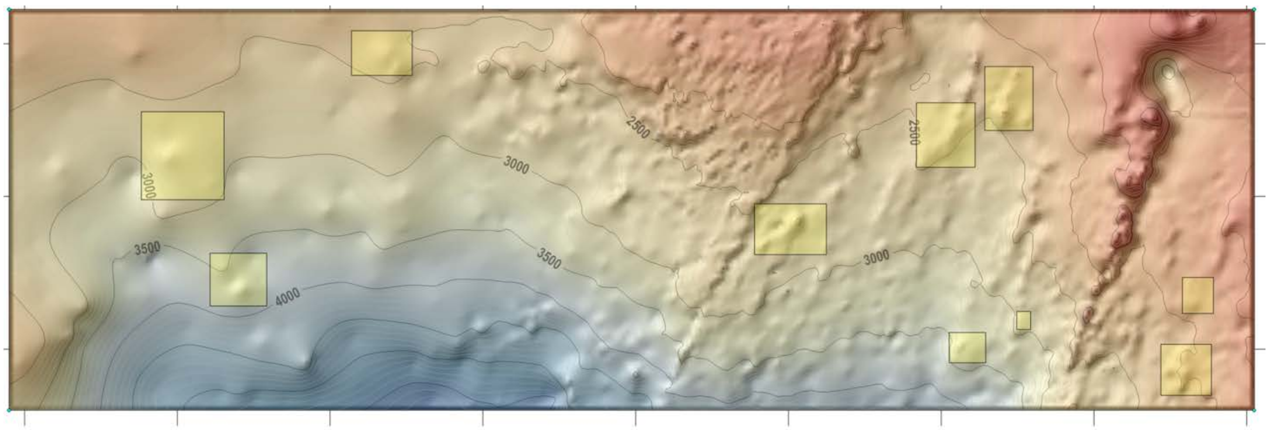


Figure 33. Structure map top of Arbuckle showing Study areas

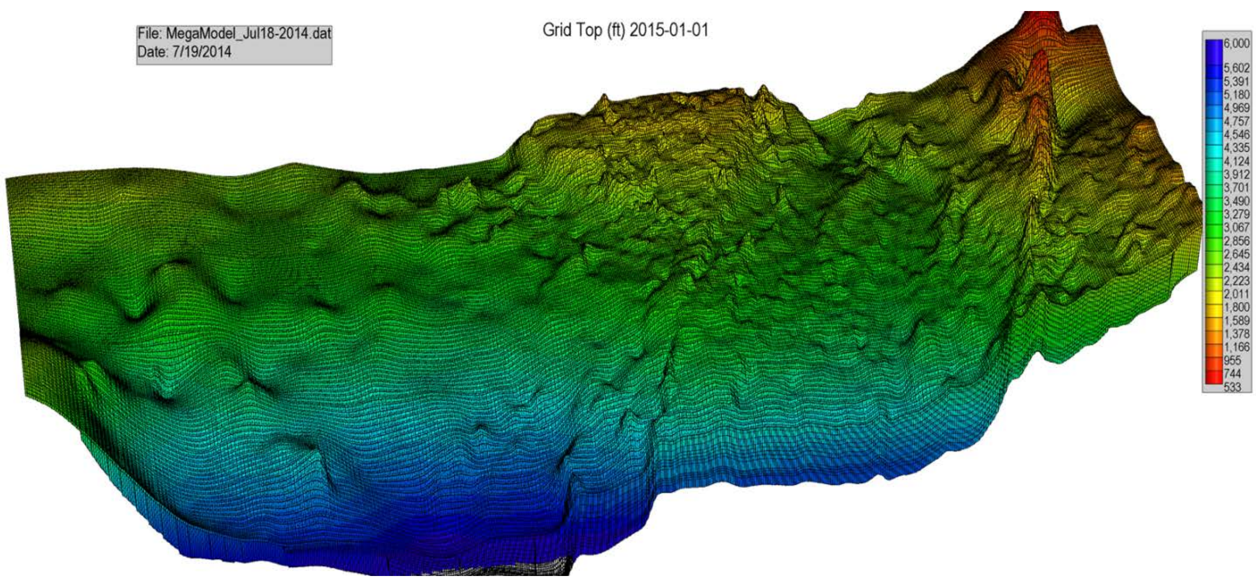


Figure 34. Initial coarse grid of Arbuckle and flow units, 7/18/2014.

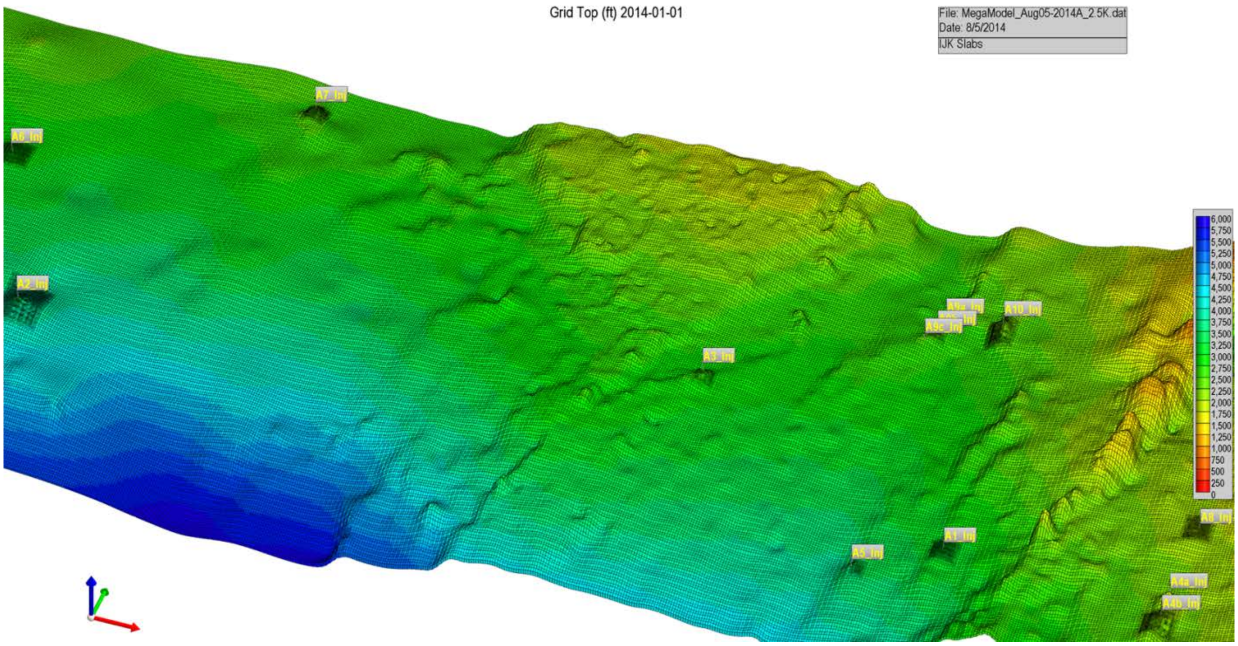


Figure 35. Megagrid (2500 x2500) showing local refinement at 10 sites with commercial sized CO2 injection simulations.

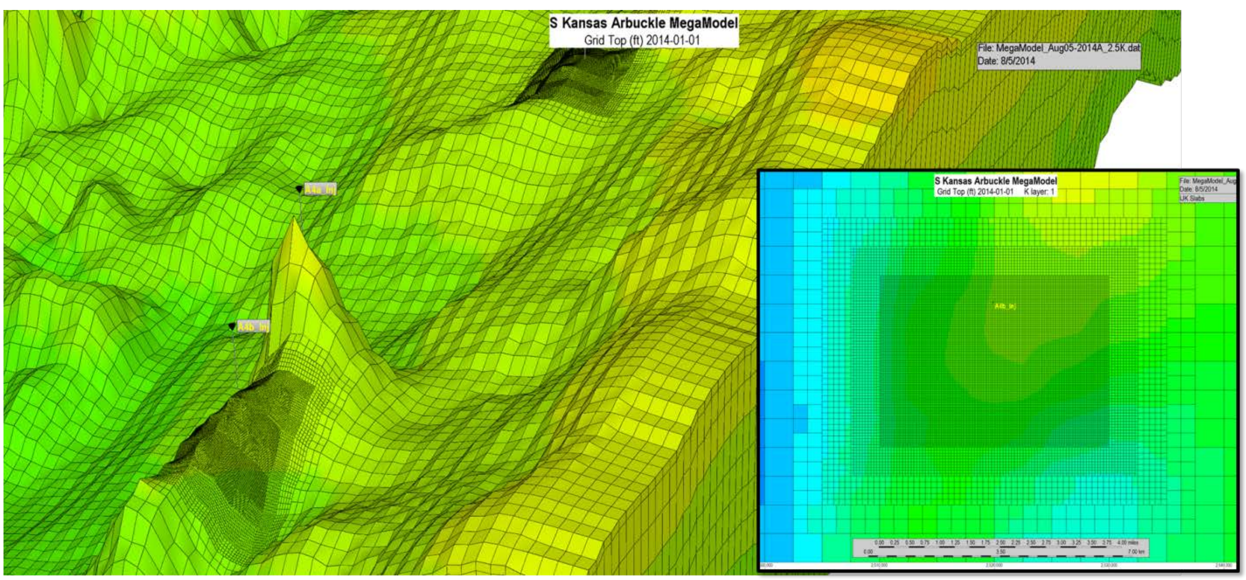


Figure 36. Illustration of local grid refinement. Injection site is A4a and A4b in extreme southeastern portion of the study area in the Cherokee Basin, located east of the Nemaha Uplift.

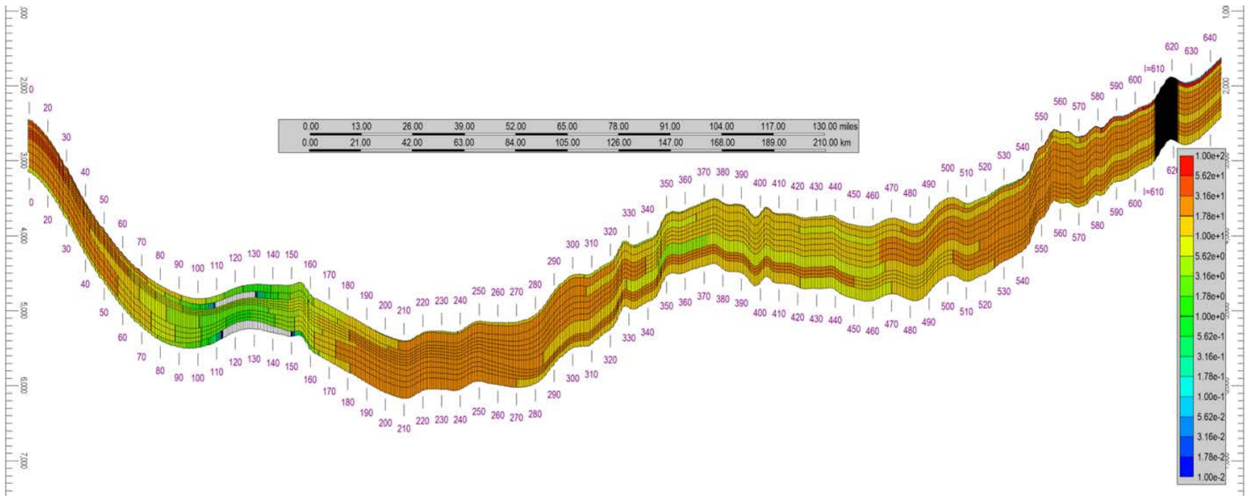


Figure 37. Cross section showing layers with layer thickness highlighted in color. Layers proportional with surface truncation.

Besides flow units and their properties, input parameters for the compositional simulations have been addressed with the information acquired from the core and fluid analyses, petrophysical data, and tests. An important parameter is mineral composition utilized by the CMG simulator to estimate the interaction for the CO_2. The geochemical logs run in Wellington KGS #1-28 and #1-32 were calibrated with core analysis to provide a continuous profile of major and minor minerals (**Figure 38**). These abundances are to be used in ongoing simulations to approximate the reaction kinetics at in situ conditions as summarized in **Figure 39**.

Another important variable in the simulation is to address the imbibition of the CO_2 in the finer pore space based on capillary entry pressure of supercritical CO_2. Analyses of core and petrophysical data, in particular, nuclear magnetic resonance (NMR) were used to derive an imbibition Pc table for the Arbuckle (**Figure 40**). Calculated imbibition Pc is plotted versus reservoir quality index (**Figure 41**).

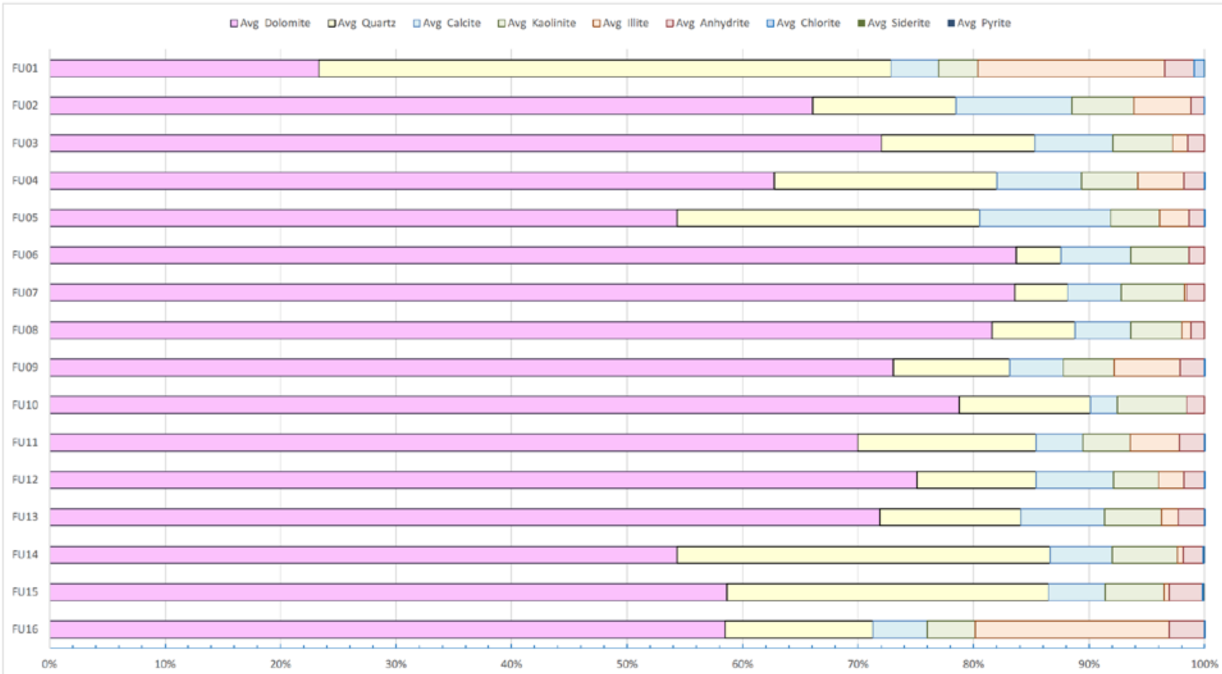


Figure 38. Wellington #1-32, Major mineral phases of the flow units in the Arbuckle based on geochemical log backed by XRD. Major dolomite, followed by quartz, calcite, kaolinite, illite, anhydrite, chlorite, siderite, and pyrite.

Mineral	Average In Permeable Flow Units
Avg Siderite	0.004%
Avg Pyrite	0.007%
Avg Chlorite	0.021%
Avg Anhydrite	1.708%
Avg Illite	1.850%
Avg Kaolinite	4.956%
Avg Calcite	5.839%
Avg Quartz	15.315%
Avg Dolomite	70.300%

Reactions

Dolomite + $2H^+ = Ca^{2+} + Mg^{2+} + 2\ HCO_3^-$

$CO_2(aq) + H_2O = H^+ + HCO_3^-$

$MgHCO_3^+ = Mg^{2+} + HCO_3^-$

$CaCO_3(aq) + H^+ = Ca^{2+} + HCO_3^-$

$CaHCO_3^+ = Ca^{2+} + HCO_3^-$

Figure 39. Major and minor chemical reactions with CO_2 considered for the simulations.

a 1.00E-06	b 0.898	Imbibition PcTable in Arbuckle							
RQI	25	6.25	1.75	0.75	0.45	0.35	0.25	0.15	0.055
Pe	0.011	0.057	0.255	0.691	1.261	1.696	2.521	4.602	15.005
CO2r	0.314	0.275	0.231	0.198	0.175	0.164	0.148	0.122	0.065
swir	0.007	0.016	0.037	0.063	0.088	0.103	0.128	0.178	0.339
Pc	swi								
0	0.685741	0.725	0.769	0.802	0.825	0.836	0.852	0.878	0.935
0.1	0.092574	0.301	0.581	0.718	0.776	0.799	0.827	0.865	0.931
0.2	0.054945	0.199	0.472	0.652	0.733	0.766	0.804	0.852	0.928
0.3	0.04075	0.153	0.401	0.598	0.696	0.736	0.783	0.840	0.924
0.4	0.033204	0.125	0.350	0.554	0.663	0.709	0.763	0.828	0.921
0.5	0.028492	0.108	0.313	0.517	0.634	0.684	0.744	0.816	0.918
0.6	0.025256	0.095	0.284	0.485	0.607	0.662	0.726	0.805	0.914
0.7	0.022891	0.086	0.260	0.458	0.584	0.641	0.709	0.795	0.911
0.8	0.021082	0.078	0.241	0.434	0.562	0.621	0.694	0.784	0.908
0.9	0.019653	0.072	0.225	0.413	0.542	0.603	0.679	0.774	0.904
1	0.018493	0.068	0.212	0.394	0.524	0.587	0.665	0.765	0.901
2	0.013043	0.045	0.140	0.281	0.402	0.467	0.557	0.684	0.871
3	0.011103	0.036	0.111	0.228	0.335	0.397	0.486	0.624	0.845
4	0.010095	0.032	0.095	0.196	0.292	0.350	0.437	0.577	0.821
5	0.009473	0.029	0.085	0.175	0.263	0.317	0.400	0.540	0.799
6	0.009049	0.027	0.078	0.160	0.241	0.292	0.371	0.509	0.779
7	0.008741	0.026	0.073	0.148	0.224	0.272	0.348	0.483	0.761
8	0.008506	0.025	0.069	0.139	0.211	0.256	0.329	0.461	0.745
9	0.008321	0.024	0.066	0.132	0.200	0.244	0.313	0.443	0.730
10	0.008171	0.023	0.063	0.126	0.191	0.233	0.300	0.426	0.716
12	0.007944	0.022	0.059	0.117	0.177	0.216	0.278	0.399	0.690
14	0.007778	0.021	0.056	0.111	0.166	0.203	0.262	0.378	0.669
20	0.007472	0.020	0.051	0.098	0.146	0.178	0.230	0.333	0.617
30	0.007224	0.019	0.047	0.088	0.129	0.156	0.201	0.292	0.561
40	0.007096	0.018	0.044	0.082	0.120	0.145	0.185	0.269	0.524
50	0.007017	0.018	0.043	0.079	0.114	0.137	0.176	0.254	0.498
60	0.006963	0.018	0.042	0.077	0.110	0.132	0.169	0.243	0.479
70	0.006924	0.017	0.041	0.075	0.108	0.129	0.164	0.235	0.464
80	0.006894	0.017	0.041	0.074	0.105	0.126	0.160	0.229	0.452
90	0.006871	0.017	0.040	0.073	0.104	0.124	0.157	0.224	0.443
100	0.006852	0.017	0.040	0.072	0.102	0.122	0.154	0.220	0.434
150	0.006794	0.017	0.039	0.069	0.098	0.116	0.146	0.208	0.408
200	0.006763	0.017	0.039	0.068	0.096	0.113	0.142	0.201	0.393
300	0.006732	0.017	0.038	0.066	0.093	0.110	0.138	0.194	0.377

	RQI		
RT	**from RQI**	**To RQI**	**Ave RQI**
1	40	10	25
2	10	2.5	6.25
3	2.5	1	1.75
4	1	0.5	0.75
5	0.5	0.4	0.45
6	0.4	0.3	0.35
7	0.3	0.2	0.25
8	0.2	0.1	0.15
9	0.1	0.01	0.055

Figure 40. (upper table) - Irreducible water saturation vs. capillary pressure for individual reservoir quality indices (RQI). (lower table) – RQI, reservoir quality index classes 1-9.

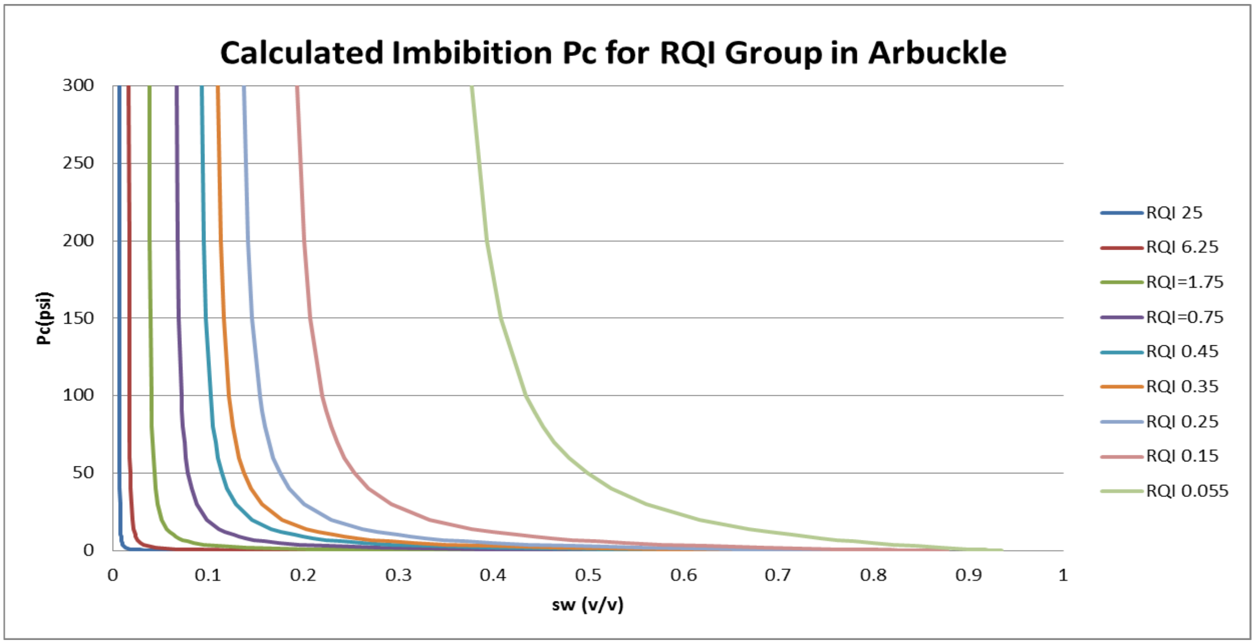


Figure 41. Imbibition Pc curves for reservoir quality indices used for hysteresis modeling to determine capillary entrapment of CO2 in pore space.

Simulation results of the 10 commercial scale injection sites is highlighted with a closer look at three of the sites, Area #5, #6, and #7. Area #5 encompasses all of Wellington Field and the surrounding area (**Figures 42 and 43**). The CO2 plume approximately 30 million tonnes in size is shown on the right side of **Figure 42** and a closer look at the structure is shown in **Figure 43**.

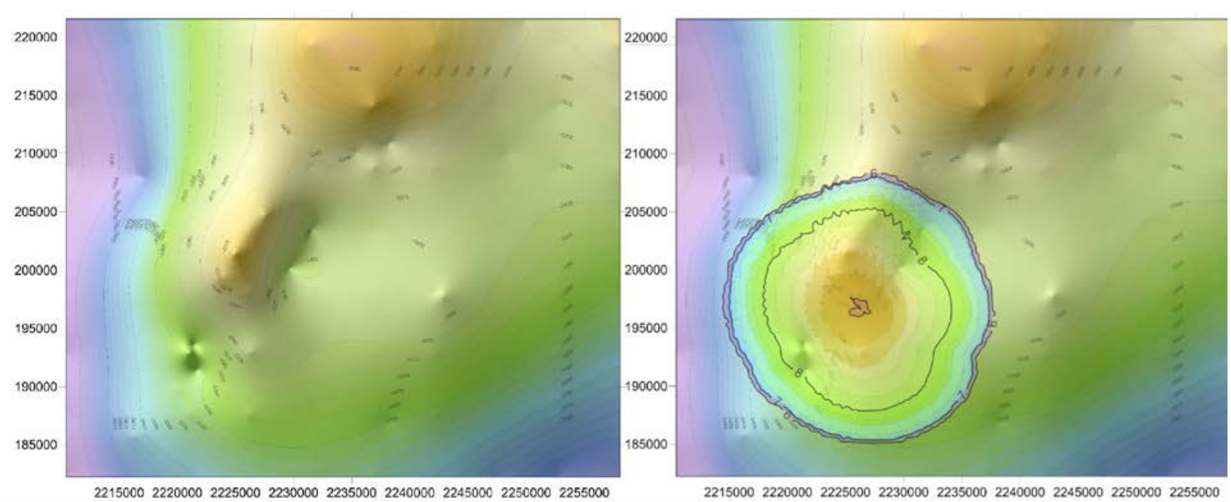


Figure 42. Simulation map of Area 5 (32S 04W) structure (left) including Wellington Field and CO_2 plume at 1/1/2066 (right).

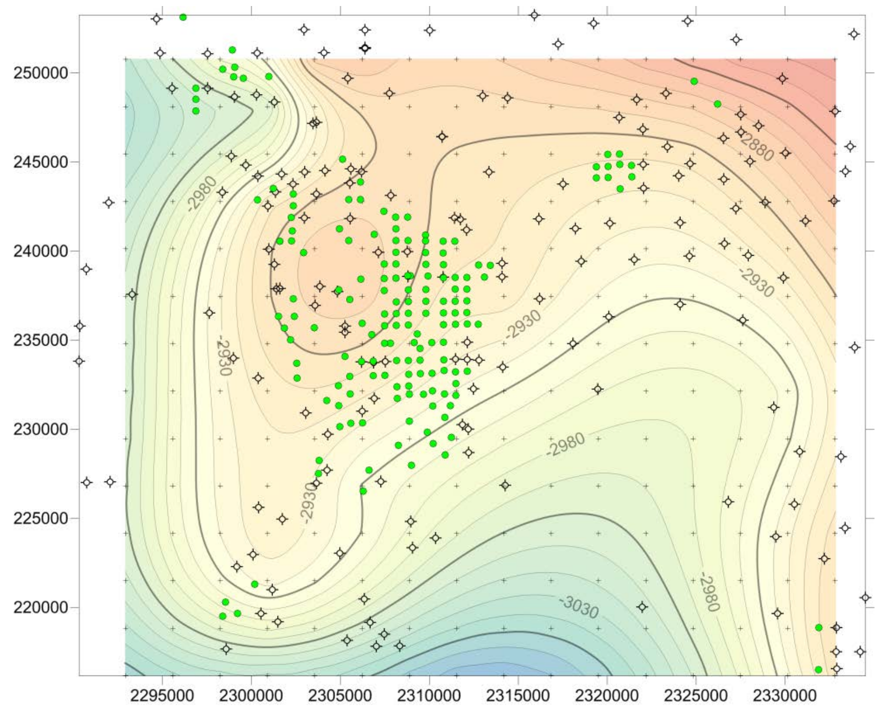


Figure 43. Map of the structure, top of Arbuckle showing all wells including productive Mississippian wells (green dots) in Wellington Field (left center).

Area #6 is in west central Kansas, another isolated structure (**Figure 44**) as is Area #7 (**Figure 45**). Details of the simulations will be share in the final report.

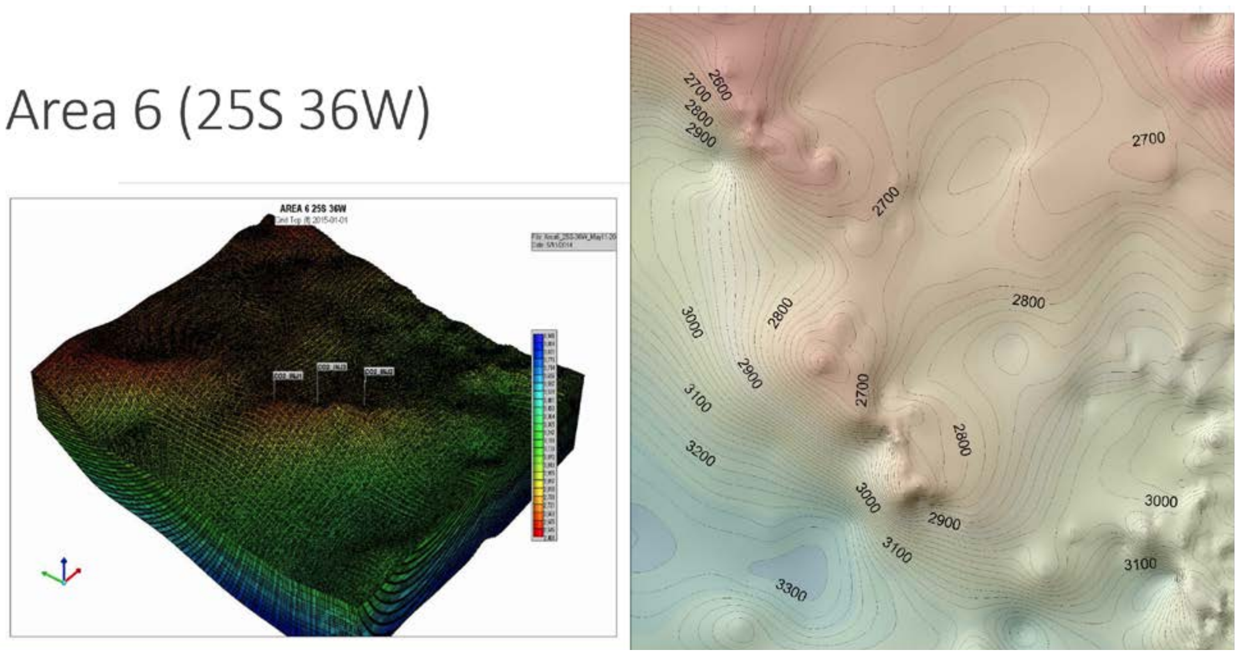


Figure 44. Simulation area #6 – (left) grid volume and (right) structural surface of Arbuckle.

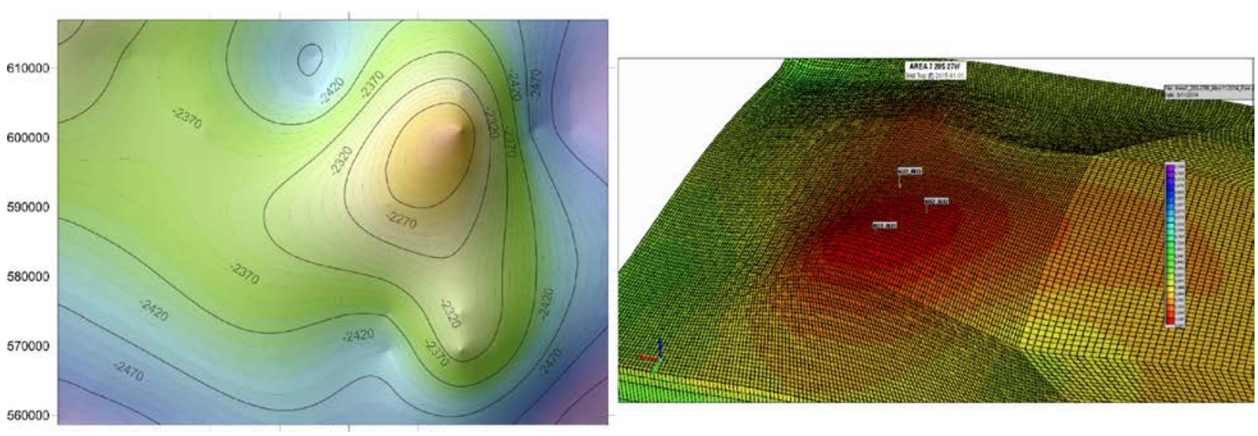


Figure 45. Simulation area #7. – (left) structural surface of Arbuckle and (right) grid volume

Subtask 12.3. Generalized estimates of miscible CO_2-EOR in similar and larger oil fields in approximately 17 counties

Subtask 12.4. Estimate regional CO_2 sequestration potential of OPAS

Task 13: Regional Source-Sink Relationships in approximately 17 Counties in South-Central Kansas

Subtask 13.1. Map major point CO_2 sources in Kansas
Subtask 13.2. Map major CO_2 sinks in Kansas

Task 14: Technology Transfer

Subtask 14.1. Build and maintain project website with interactive access to data and analyses via graphic display and analytical web tools
Subtask 14.2. Link project web-site to relevant DOE databases
Subtask 14.3 Submit project results to peer reviewed journals for publication

Task 15: Extend Regional Study of Ozark Plateau Aquifer System (OPAS) to the Western Border of Kansas – "Western Annex" and extend the type log database to include the whole state of Kansas to address fluid flow under commercial scale CO2 sequestration.

Subtask 15.1. Extend regional study by evaluating CO_2 sequestration potential in 5000 mi^2 area west of the existing 17+ county area and extend the type log database to the whole state of Kansas to address fluid flow under commercial scale CO_2 sequestration.

Subtask 15.2. Create consortium of companies

Subtask 15.3. Encourage development of business plan to sequester emitted CO_2

Task 16: Collect and Analyze Existing Data for Developing Regional Geomodel for Arbuckle Group Saline Aquifer in Western Annex

Subtask 16.1. Assemble, reprocess, and interpret existing 3D seismic and other data

Subtask 16.2. Analysis of KGS's gravity and magnetic data
Subtask 16.3. Remote sensing analysis

Task 17. Acquire (New) Data at a Select Chester/Morrow Field to Model CO2 sequestration Potential in the Western Annex

Subtask 17.1. Collect existing seismic, geologic, and engineering data – Chester/Morrow fields
Subtask 17.2. Select Chester/Morrow field to acquire new data

Subtask 17.3. Collect new multicomponent 3D seismic survey
Subtask 17.4. Process multi-component 3D seismic survey
Subtask 17.5. Develop initial geomodel for the selected Chester/Morrow field

Subtask 17.6. Select location for Test Borehole #3
Subtask 17.7. Complete permitting requirements for Test Borehole #3
Subtask 17.8. Drill, retrieve core, log, and run DST – Test Borehole #3
Subtask 17.9. Openhole Wireline Logging – Test Borehole #3
Subtask 17.10. Wellbore Completion – Test Borehole #3
Subtask 17.11. Analyze wireline log - Test Borehole #3
Subtask 17.12. Test and sample fluids (water) from select intervals – Test Borehole #3
Subtask 17.13. Analyze Arbuckle core from Test Borehole #3

Brent Campbell visited LLNL Lab in June to work with Susan Carroll and Megan Smith to analyze a series of core plugs using facilities to permit injection of CO2 saturated brine at reservoir pressures to examine reactions and changes in porosity and permeability that occur during the injection. Measurements of brine effluent and CT scans before and after, and measurements of rates, volume, and differential pressures are used to detect changes. Susan's work on "enhanced porosity and permeability within carbonate CO2 storage reservoirs: An experimental and modeling study" is supported by DOE, but expenses for travel are carried by this project.

The samples selected for analysis come from the Arbuckle from the Cutter KGS #1 and Wellington KGS #1-32 cores and are summarized below in **Figure 46**.

Cutter Sample	Depth Ft.	Weight grams	Length&Dia. inches	Kmax mD	Porosity %	Description
1 (22-32)	7,209.90	156.67	1 15/16, 1.5	32.668	7.2	Exhibited high permeability (Kmax=32.668), high porosity (7.2%), and a moderately fractured surface area with secondary shaley accumulations along fracture pathway boundaries. New thin sections are being ordered at this depth and water chemistry was sampled and analyzed from a depth within 8' (Swab 3). Isotope data is also available.

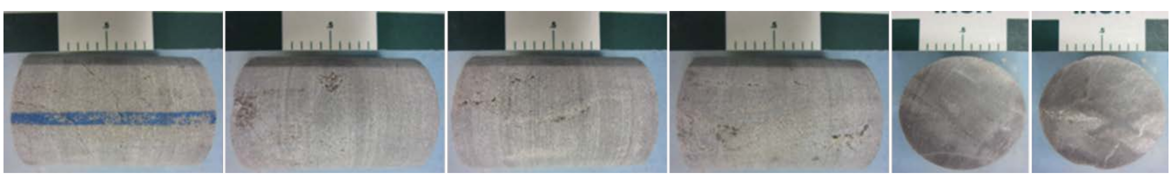
Cutter	Depth	Weight	Length&Dia.	Kmax	Porosity	Description
Sample	Ft.	grams	inches	mD	%	
2 (24-7)	7,340.55	168.92	2 1/8, 1.5	20.488	6.7	Light gray fine grained dolomite mudstone; 0.5cm vug infilled with secondary crystalline dolomite along side, otherwise tight; faint fractures extend longitudinally and latitudinally across sample; sparite; tight porosity aside from single vug; white powdery carbonate accumulation on ends (especially within fracture).

Cutter	Depth	Weight	Length&Dia.	Kmax	Porosity	Description
Sample	Ft.	grams	inches	mD	%	
3 (20-9)	7,098.85	160.51	2 1/8, 1.5	2.849	3.6	Light gray fine grained dolomite mudstone; large (2.5x2x2cm) chert nodule along side-end boundary; similar 2.5x1cm chert nodule along other side/end; pinpoint vugs throughout; white powdery carbonate material along chert-dolomite boundaries and as fracture/vug infillings on ends; possible Fe-oxide stain (from cutting); slightly fractured (especially along dolomite-chert boundary of larger nodule); low vuggy porosity.

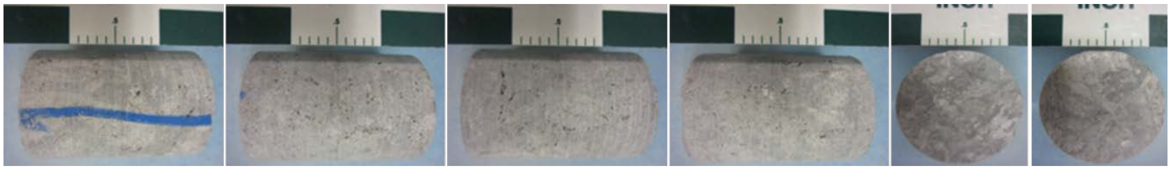
Cutter	Depth	Weight	Length&Dia.	Kmax	Porosity	Description
Sample	Ft.	grams	inches	mD	%	
4 Extra (20-55)	7,144.50	161.79	2 1/16, 1.5	7.904	3	Light gray fine grained dolomite packstone with large 2.5cm vitreous euhedral dolomite infilled vug; mm wide fracture traverses from top to bottom; lighter colored carbonate packstone dispersed throughout in wavy arrangement; folded fracture pathways occur along side.

Cutter	Depth	Weight	Length&Dia.	Kmax	Porosity	Description
Sample	Ft.	grams	inches	mD	%	
5 Extra (20-21)	7,110.35	168.72	2 1/8, 1.5	0.614	2.40%	Light gray fine grained dolomite packstone that is moderately fractured; fractures infilled with chert material that precipitated radially perpendicular to fracture pathways in splotchy fashion; large white ~2cm wide chert nodule; tight aside from fractures.

Wellington	Depth	Weight	Length&Dia.	Kmax	Porosity	Description
Sample	Ft.	grams	inches	mD	%	
1 (13-46)	4,230.30	161.48	2 1/16, 1.5	219.73	2.6	Light grey with sharp contact to light brown, faint but numerous longitudinal fracture, dolomite crystals filling vugs, white chalks material filling some fractures.



Wellington	Depth	Weight	Length&Dia.	Kmax	Porosity	Description
Sample	Ft.	grams	inches	mD	%	
2 (14-4)	4,247.00	156.29	2, 1.5	430.6	8.4	Light-med grey, mottled with white Si rich material, chalk, fine grained, pin point vugs, fluid enhanced discontinuous fractures, Fe-oxidation, no bedding present, some sparite visible.



Weight	Length&Dia.	Kmax	Porosity	Description
grams	inches	mD	%	
145.74	2, 1.5	317.43	4.5	Med gray to bluish grey, fine grained tight, vuggy, interconnected vugs, vugs have chalky material growing (possible anhydrite), some vugs have sparry calcite visible, highly variable mottled, clastic, brecciated, indistinct bedding, possible large fracture filled with dark chert.

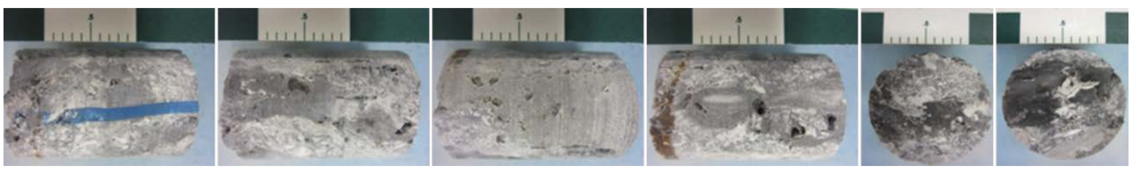


Figure 46. Properties of core plugs taken to LLNL lab for in situ studies of reactions with injection of CO_2 saturated brine.

Subtask 17.14. Analyze Chester/Morrow core from Test Borehole #3
Subtask 17.15. PVT analysis of oil and water from Chester/Morrow oil reservoir
Subtask 17.16. Analyze water samples from Test Borehole #3

Water samples from Cutter KGS #3 (Test Borehole #3) have been analyzed by KSU and the KGS. The following are the results from KSU as summarized in **Figure 47**.

Cutter				Ba		Al		K	Mg	Mn	Si		Ag		As		Be		Bi
Unit Symbol	Depth	Depth	Avg Depth	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L
SWAB 1	7,543.00	7,532.00	7,537.50	1860	1.86	< 5	0	1460	1190	4.4	< 5	0	< 300	0	< 2000	0	< 100	0	< 1000
SWAB 2	7,442.00	7,430.00	7,436.00	1690	1.69	< 5	0	1360	1140	2.85	8.2	8.2	< 300	0	< 2000	0	< 100	0	< 1000
SWAB 3	7,234.00	7,218.00	7,226.00	1310	1.31	< 5	0	987	896	2.01	20.2	20.2	< 300	0	< 2000	0	< 100	0	< 1000
SWAB 4 FA	7,056.00	7,046.00	7,051.00	< 2000	0	< 10	0	1100	898	2.13	13.2	13.2	< 500	0	< 3000	0	< 200	0	< 2000
SWAB 5	6,904.00	6,880.00	6,892.00	1790	1.79	< 5	0	1410	1470	1.41	< 5	0	< 300	0	< 2000	0	< 100	0	< 1000
SWAB 6	6,686.00	6,676.00	6,681.00	1750	1.75	< 5	0	1250	1300	1.58	6.2	6.2	< 300	0	< 2000	0	< 100	0	< 1000
SWAB 7	6,558.00	6,543.00	6,550.50	< 1000	0	< 5	0	1060	247	5.29	< 5	0	< 300	0	< 2000	0	< 100	0	< 1000
SWAB 8	6,204.00	6,194.00	6,199.00	< 1000	0	< 5	0	814	865	0.93	16.9	16.9	< 300	0	< 2000	0	< 100	0	< 1000
SWAB 9	6,010.00	6,000.00	6,005.00	< 1000	0	< 5	0	803	1020	0.7	16.8	16.8	< 300	0	< 2000	0	< 100	0	< 1000
SWAB 10	5,680.00	5,670.00	5,675.00	< 1000	0	< 5	0	830	363	2.33	28.9	28.9	< 300	0	< 2000	0	< 100	0	< 1000
SWAB 11	5,622.00	5,545.00	5,583.50	< 1000	0	< 5	0	930	1290	0.63	9.6	9.6	< 300	0	< 2000	0	< 100	0	< 1000
DST 1	7,735.00	7,522.00	7,628.50	1610	1.61	< 5	0	1280	1070	4.12	< 5	0	< 300	0	< 2000	0	< 100	0	< 1000
DST 2	7,234.00	7,218.00	7,226.00	1460	1.46	< 5	0	963	858	3.37	11.6	11.6	< 300	0	< 2000	0	< 100	0	< 1000

Ca	Cd		Ce		Co		Cr		Fe		Cu		Li	Mo		Na	Ni	
mg/L	µg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	µg/L	mg/L	mg/L	µg/L	mg/L
9010	< 100	0	< 2000	0	< 100	0	< 1000	0	< 0.5	0	455	0.455	24.3	< 300	0	52600	< 300	0
8400	< 100	0	< 2000	0	< 100	0	< 1000	0	< 0.5	0	130	0.13	23	< 300	0	49700	< 300	0
6090	< 100	0	< 2000	0	< 100	0	< 1000	0	2.85	2.85	< 100	0	19.6	< 300	0	35600	< 300	0
6510	< 200	0	< 3000	0	< 200	0	< 2000	0	< 1	0	720	0.72	16.2	< 500	0	34700	< 500	0
9100	< 100	0	< 2000	0	< 100	0	< 1000	0	4.43	4.43	< 100	0	23.8	< 300	0	47600	< 300	0
8810	< 100	0	< 2000	0	< 100	0	< 1000	0	7.85	7.85	< 100	0	16.7	< 300	0	40000	< 300	0
2430	< 100	0	< 2000	0	< 100	0	< 1000	0	1.2	1.2	156	0.156	7.23	< 300	0	19800	< 300	0
5410	< 100	0	< 2000	0	< 100	0	< 1000	0	8.82	8.82	< 100	0	21.5	< 300	0	28700	< 300	0
5420	< 100	0	< 2000	0	< 100	0	< 1000	0	7.34	7.34	< 100	0	30	< 300	0	23700	< 300	0
1650	< 100	0	< 2000	0	< 100	0	< 1000	0	4.13	4.13	134	0.134	12	284	0.284	15900	< 300	0
6950	< 100	0	< 2000	0	< 100	0	< 1000	0	1.05	1.05	< 100	0	36.6	< 300	0	29700	< 300	0
7820	< 100	0	< 2000	0	< 100	0	< 1000	0	44.3	44.3	< 100	0	21.7	< 300	0	46600	< 300	0
5640	< 100	0	< 2000	0	< 100	0	< 1000	0	53	53	< 100	0	17.8	< 300	0	34300	< 300	0

P		Pb		Sb		S	Se		Sn		Sr		Te		Ti		Tl	
mg/L	mg/L	µg/L	mg/L	µg/L	mg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L	mg/L
< 1	0	< 500	0	< 500	0	203	< 1000	0	< 500	0	223000	223	< 500	0	< 500	0	< 500	0
< 1	0	< 500	0	< 500	0	206	< 1000	0	< 500	0	213000	213	< 500	0	< 500	0	< 500	0
< 1	0	< 500	0	< 500	0	192	< 1000	0	< 500	0	155000	155	< 500	0	< 500	0	< 500	0
< 2	0	< 1000	0	< 1000	0	264	< 2000	0	< 1000	0	139000	139	< 1000	0	< 1000	0	< 1000	0
< 1	0	< 500	0	< 500	0	178	< 1000	0	< 500	0	229000	229	< 500	0	< 500	0	< 500	0
< 1	0	< 500	0	< 500	0	194	< 1000	0	< 500	0	232000	232	< 500	0	< 500	0	< 500	0
1.37	1.37	< 500	0	< 500	0	446	< 1000	0	< 500	0	73400	73.4	< 500	0	< 500	0	< 500	0
< 1	0	< 500	0	< 500	0	196	< 1000	0	< 500	0	140000	140	< 500	0	< 500	0	< 500	0
< 1	0	< 500	0	< 500	0	277	< 1000	0	< 500	0	146000	146	1100	1.1	< 500	0	< 500	0
< 1	0	< 500	0	< 500	0	731	< 1000	0	< 500	0	51400	51.4	< 500	0	< 500	0	< 500	0
< 1	0	< 500	0	< 500	0	268	< 1000	0	< 500	0	189000	189	< 500	0	< 500	0	< 500	0
< 1	0	< 500	0	< 500	0	189	< 1000	0	< 500	0	200000	200	< 500	0	< 500	0	< 500	0
< 1	0	< 500	0	< 500	0	201	< 1000	0	< 500	0	145000	145	< 500	0	< 500	0	< 500	0

U		V		W		Y		Zn		Br		Cl	F	NO2 (as N)	NO3 (as N)	PO4 (as P)	SO4
mg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
< 3	0	< 500	0	< 500	0	< 500	0	23700	23.7	< 60	0	107000	< 20	< 20	< 20	< 40	714
< 3	0	< 500	0	< 500	0	< 500	0	34700	34.7	159	159	103000	< 20	< 20	< 20	< 40	603
< 3	0	< 500	0	< 500	0	< 500	0	13200	13.2	< 60	0	78600	< 20	< 20	< 20	< 40	557
19	19	< 1000	0	< 1000	0	< 1000	0	5700	5.7	161	161	72300	< 20	< 20	< 20	< 40	705
< 3	0	< 500	0	< 500	0	< 500	0	22700	22.7	< 60	0	103000	< 20	< 20	< 20	< 40	475
< 3	0	< 500	0	< 500	0	< 500	0	13800	13.8	< 60	0	89800	< 20	< 20	< 20	< 40	734
< 3	0	< 500	0	< 500	0	< 500	0	< 300	0	< 60	0	37900	< 20	< 20	< 20	< 40	1400
< 3	0	< 500	0	< 500	0	< 500	0	11000	11	< 60	0	61100	< 20	< 20	< 20	< 40	832
< 3	0	< 500	0	< 500	0	< 500	0	5210	5.21	121	121	53200	< 20	< 20	< 20	< 40	1100
< 3	0	< 500	0	< 500	0	< 500	0	1000	1	< 60	0	27400	< 20	< 20	< 20	< 40	2560
< 3	0	< 500	0	< 500	0	< 500	0	< 300	0	< 60	0	67300	< 20	< 20	< 20	< 40	1070
< 3	0	< 500	0	< 500	0	< 500	0	3880	3.88	117	117	100000	< 20	< 20	< 20	< 40	750
< 3	0	< 500	0	< 500	0	< 500	0	2290	2.29	< 60	0	73800	< 20	< 20	< 20	< 40	930

Figure 47. Brine analyses from swab and DSTs from Berexco Cutter KGS #1 performed by KSU.

Simulation Studies of Chester/Morrow Oil Fields

All models will be finished in the final two months of the project.

Task 19: Integrate Results with Larger 17+ County Regional Project in South-central Kansas

Deliverables for the Final Report

1. Reservoir geomodel of Wellington Mississippian Chat reservoir and its CO_2-sequestration and CO_2-EOR potential.
2. Reservoir geomodel of Arbuckle Group saline aquifer underlying Wellington field and its CO_2-sequestration potential
3. Regional geomodel of OPAS covering 17+ counties in south central Kansas and its CO_2-sequestration potential

4. Risk assessment studies related to CO_2 sequestration including characterization of leakage pathways, vertical communication within the Arbuckle Group, and well abandonment histories in the 17+ county study area and the Western Annex.
5. Geomodel and simulations of CO_2 sequestration potential of the Arbuckle Group saline aquifer and of CO_2-EOR in a select Chester/Morrow incised valley sandstone oil reservoir in the Western Annex – a new addition of ~5,000 mi^2 to the regional study.
6. Results and interpretation of the seismic surveys, and interpretation of all laboratory analysis performed in the 17+ county study area and the Western Annex.

PRESENTATIONS AND PUBLICATIONS

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 48**).

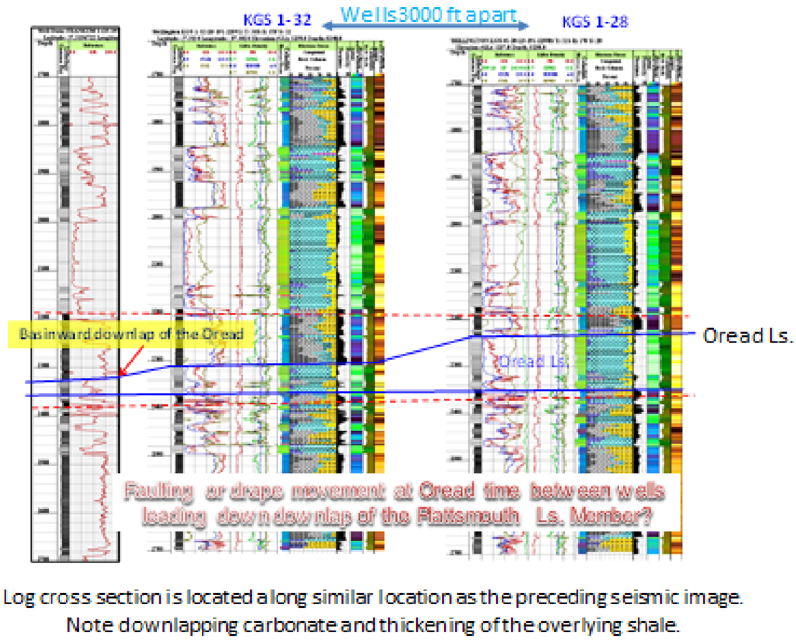


Figure 48. Notable changes in stratigraphy at the Oread Limestone horizon. Paper describes differences between the two wells in the Oread Limestone and overlying Kanwaka Shale.

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

KEY FINDINGS

1. Type logs are being reviewed and improvements are being incorporated into the database.

2. Extensive analysis of flow units was completed including used of independent methods of using petrophysical data to perform the classification. Flow units were correlated regionally and used in the simulations of the 10 regional commercial scale modeling and eventually in the final CO_2 storage assessment.
3. The step-rate test involving Wellington KGS #1-32 and #1-28 was reexamined as the result of continued analysis and refinement of the 3D seismic volume and Petrel geomodel. The permeability field in the vicinity of these wells remains in the 100 md range that is consistent with the drill stem tests, whole core analysis, and estimates from the nuclear magnetic resonance well log. The effective thickness used in this analysis of 30 ft is considered a minimum (assuming the flow unit does not connect with other layers beyond the wellbore) and leads to higher permeability calculations, the computed value of this iteration suggests permeability in the 100 Darcy range in the vicinity of well 1-28 and is attributed to a fracture or fault.

   The depth-migrated solution of the 3D seismic suggests a zone of discontinuous seismic reflections in the injection zone in the lower Arbuckle that have minor offset (as noted in previous quarterly report). The juxtaposed strata in the Arbuckle are essentially within the framework of existing flow units so low permeability zones are not faulted out placing lower permeable zones with upper permeable layers. Extensive brine geochemistry and microbiology have previously shown that the tripartite hydrostratigraphic divisions that comprise the Arbuckle are not communicating. In other words, the fault/fracture zone is not permitting vertical fluid exchange, but the step rate tests suggests that the lateral flow along the zone would be greatly enhanced and notably affect the fate of a CO_2 plume. This scenario is being examined as a final modeling exercise in this study.

4. Regional simulations are being completed including an assessment of the fate of commercial scale CO_2 (30 million + tonnes) at 10 sites.

5. Total CO_2 storage potential in southern Kansas will be derived by a mega-scale simulation as outlined in this report. The simulation is incorporating the major factors that can trap CO2 to realistically provide a measure of capacity beyond a volumetric-based storage assessment.

PLANS

1. Complete geomodeling and simulations of commercial scale CO2 injection at the 10 regional sites and the regional CO2 assessment.
2. Complete the updates for the Wellington geomodels simulations.
3. Complete the modeling of the SW Kansas fields.
4. Gather results for write final report.

SPENDING PLAN

Please see next page.

COST PLAN/STATUS

BP3 Starts 8/8/12 Ends 9/30/14

Baseline Reporting Quarter	**7/1/12 - 9/30/12 Q12**	**10/1/12 - 12/31/12 Q13**	**1/1/13 - 3/31/13 Q14**	**4/1/13 - 6/30/13 Q15**	**7/1/13 - 9/30/13 Q16**	**10/1/13 - 12/31/13 Q17**	**1/1/14 - 3/31/14 Q18**	**4/1/14 - 6/30/14 Q19**	**7/1/14 - 9/30/14 Q20**
Baseline Cost Plan (from SF-424A)									
Federal Share	$316,409.00	$316,409.00	$316,409.00	$316,409.00	$0.00	$0.00	$0.00	$0.00	$0.00
Non-Federal Share	$81,854.50	$81,854.50	$81,854.50	$81,854.50	$0.00	$0.00	$0.00	$0.00	$0.00
Total Planned (Federal and Non-Federal)	$398,263.50	$398,263.50	$398,263.50	$398,263.50	$0.00	$0.00	$0.00	$0.00	$0.00
Cumulative Baseline Cost	$11,428,700.50	$11,826,964.00	$12,225,227.50	$12,623,491.00	$12,623,491.00	$12,623,491.00	$12,623,491.00	$12,623,491.00	$12,623,491.00
Actual Incurred Costs									
Federal Share	$1,282,545.00	$1,314,156.54	$395,319.33	$299,454.96	$465,714.15	$190,945.64	$234,848.28	$214,216.79	
Non-Federal Share	$221,053.41	$121,637.40	-$65,989.76	$23,362.67	$34,263.50	$915,863.95	$32,999.36	$15,523.55	
Total Incurred Costs-Quarterly (Federal and Non-Federal)	$1,503,598.41	$1,435,793.94	$329,329.57	$322,817.63	$499,977.65	$1,106,809.59	$267,847.64	$229,740.34	
Cumulative Incurred Costs	$7,735,945.41	$9,171,739.35	$9,501,068.92	$9,823,886.55	$10,323,864.20	$11,430,673.79	$11,698,521.43	$11,928,261.77	
Variance									
Federal Share	-$966,136.00	-$997,747.54	-$78,910.33	$16,954.04	-$465,714.15	-$190,945.64	-$234,848.28	-$214,216.79	
Non-Federal Share	-$139,198.91	-$39,782.90	$147,844.26	$58,491.83	-$34,263.50	-$915,863.95	-$32,999.36	-$15,523.55	
Total Variance-Quarterly Federal and Non-Federal)	-$1,105,334.91	-$1,037,530.44	$68,933.93	$75,445.87	-$499,977.65	-$1,106,809.59	-$267,847.64	-$229,740.34	
Cumulative Variance	**$3,648,775.05**	**$2,611,244.61**	**$2,680,178.54**	**$2,755,624.41**	**$2,255,646.76**	**$1,148,837.17**	**$880,989.53**	**$651,249.19**	