Wellington KS CO2 EOR Project Monitoring CO2

- August 5, 2016

- Dana G. Wreath
- Vice President Engineering
- Berexco LLC – a private oil and gas company based in Wichita KS

- Operator of Wellington Field in southern KS

DANA G. WREATH

PRESENT POSITION:

Vice President
BEREXCO, LLC
Wichita, Kansas

EDUCATION AND TRAINING:

B.S. - University of Kansas, Petroleum Engineering – 1987
M.S. - University of Texas, Petroleum Engineering – 1989
Many Petroleum Engineering Continuing Education Courses

PROFESSIONAL EXPERIENCE:

2010 - Present	Vice President, BEREXCO, LLC., Wichita, Ks.
1996 - 2010	Division Engineer, BEREXCO, INC., Wichita, Ks.
1992 - 1996	Reservoir Engineer, BEREXCO, INC., Wichita, Ks.
1989 - 1992	Reservoir Engineer, Mobil E&P US, Houston, TX

DOE Funded CO2 Research

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

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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.

WELLINGTON FIELD PILOT DEMONSTRATION

DOE-NETL Contract #FE0006821

KANSAS GEOLOGICAL SURVEY
The University of Kansas

L. Watney (Joint PI), J. Rush (Joint PI), T. Bidgoli, J. Doveton, E. Holubnyak, M. Fazelalavi, R. Miller, D. Newell, J. Hollenbach
(static & dynamic modeling, well test analysis, high-resolution seismic, passive seismic, accelerometers, geomechanical analysis, project management)

Brian Dressel, DOE Project Manager

BEREXCO

Dana Wreath & Adam Beren
(field operator and operations, repeat 3D multicomponent seismic)

BERKELEY LAB
LAWRENCE BERKELEY NATIONAL LABORATORY

Tom Daley, Barry Freifeld *(CASSM, U-Tube, cross well seismic)*

THE LINDE GROUP
Linde

CO_2 supply

Schlumberger

CMG COMPUTER MODELLING GROUP LTD.

IRIS INSTRUMENT CENTER
PASSCAL
Program for Array Seismic Studies of the Continental Lithosphere

seismometers

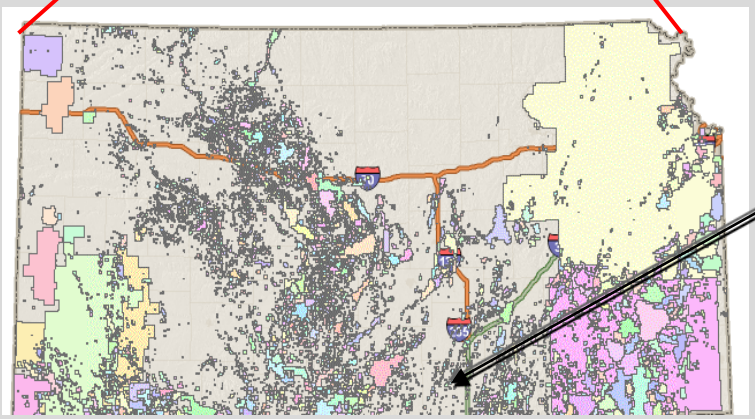
TBirdie Consulting, Inc
4705 McCormick Street • Lawrence • KS 66047 • 785 843 1085 • 785 865 0678 (fax) • tbirdie@sunflower.com

T. Birdie *(Class VI permitting, monitoring, synthesis, reporting, closure)*

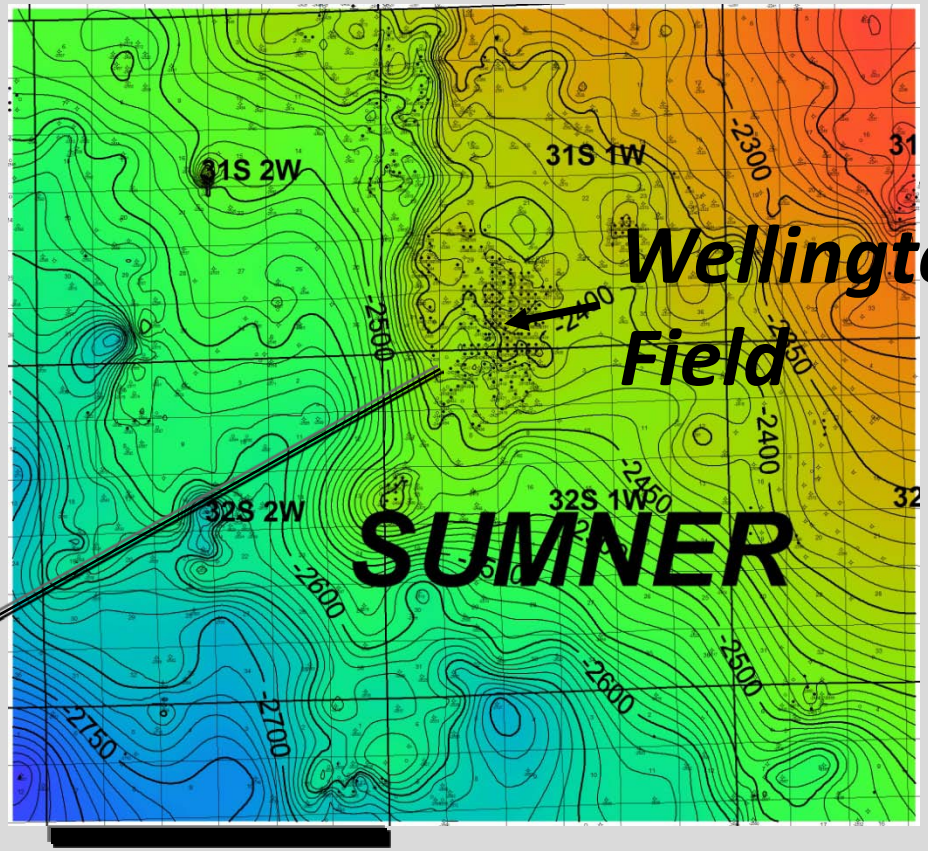
KU THE UNIVERSITY OF KANSAS Department of Geology

Jennifer Roberts, Leigh Stearns (cGPS), Mike Taylor *(InSAR)*, George Tsoflias *(passive and active seismic)*

Wellington Field
Site of Small Scale Field Test



Top Mississippian Structure, 10 ft C.I.



6 mi (10 km)

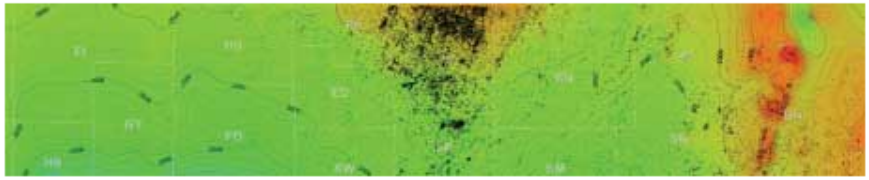
20 Million Barrel Oil Field above Arbuckle Group

KU KANSAS GEOLOGICAL SURVEY
The University of Kansas

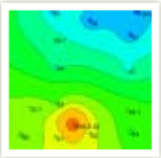
Kansas Geological Survey Website
http://www.kgs.ku.edu/PRS/Ozark/index.html

South-central Kansas CO_2 Project

Kansas Geological Survey

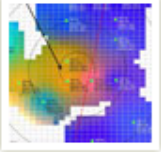


Updates — June 2016



New presentations from Carbon Capture, Utilization & Storage Conference, June 2016.

Updates — May 2016



Eighteenth Quarterly Report for Small Scale Field Test.

Updates — April 2016

New photos from a recent tour of the CO_2 injection site.

New presentations from Nov. 2015 conferences.

New presentation from Kansas NextStep Conference in Hays, April 2016.

About...

South-central Kansas CO_2 Project is a DOE-funded project of the Kansas Geological Survey. More ...

Topics...

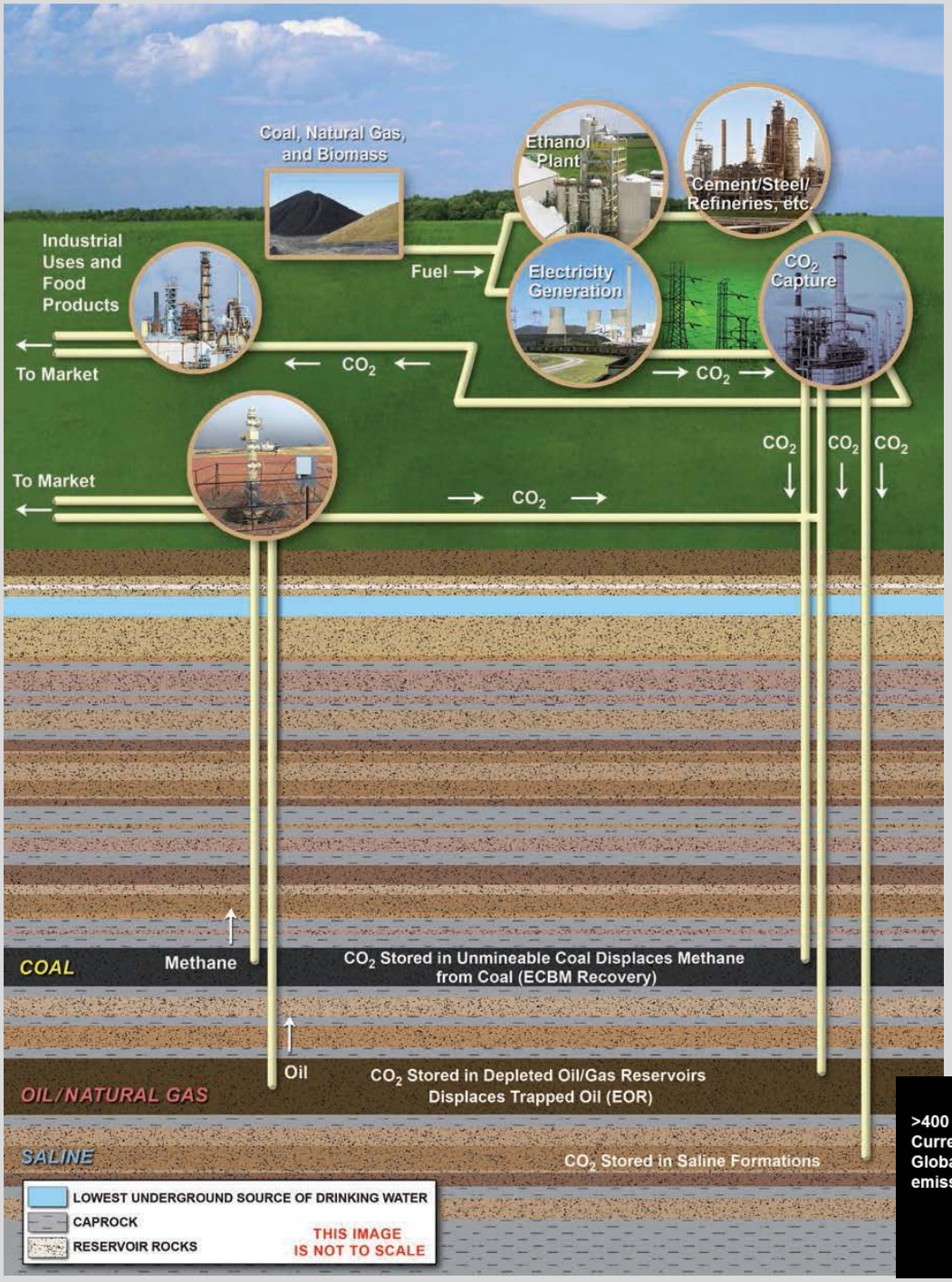
- Home
- Small Scale Field Test
- Presentations
- Reports
- Well Data
- Well 1-32
- Well 2-32
- Well 1-28
- Interactive Map

CO_2-EOR Technology & Carbon Management Research in Kansas

- Utilize oil and gas field Infrastructure
- Utilize comparable approaches to characterization and simulation of oil and reservoirs
- Evaluated sites for commercial scale carbon storage sites in aquifers beneath existing oil fields
- Conduct small scale CO2-EOR injection at Wellington Field, Sumner County Kansas
- KU & partners have performed extensive research on:
  - -monitoring
  - -verification
  - -accounting of the CO_2 over the long term

Geologic Carbon Utilization & Storage

The 2015 United States Carbon Utilization and Storage Atlas – Fourth Edition (Atlas IV)
DOE-NETL



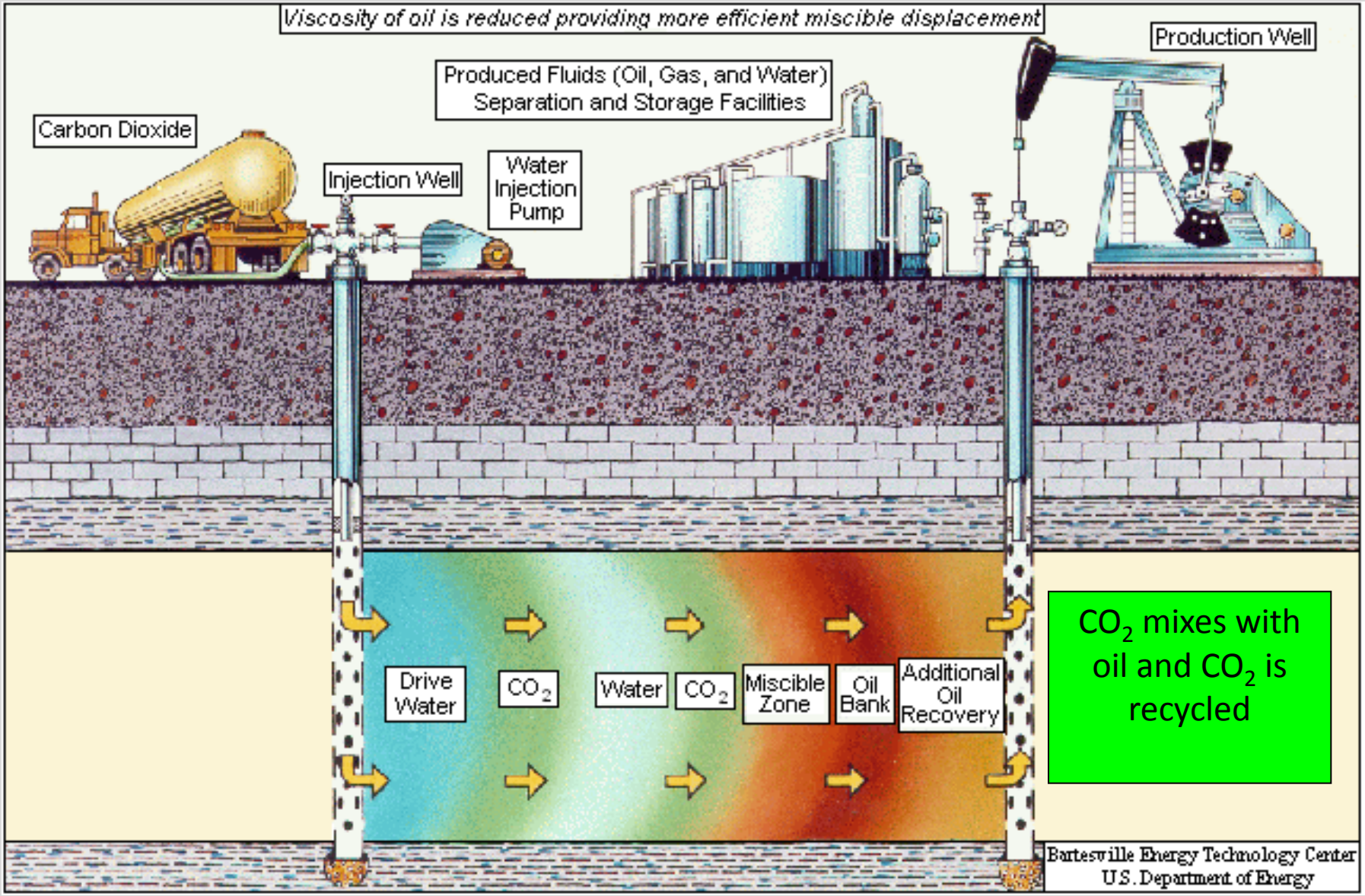
>400 yrs Current Global emissions

Formation Type	10^9 Metric Tons	%
Saline Aquifers	3,297 – 12,618	91.8 – 97.5
Unmineable Coal Seams	157 – 178	4.4 – 1.4
Mature Oil & Gas Reservoirs	138	3.8 – 1.1
Total Capacity	3,592 – 12,934	100.0

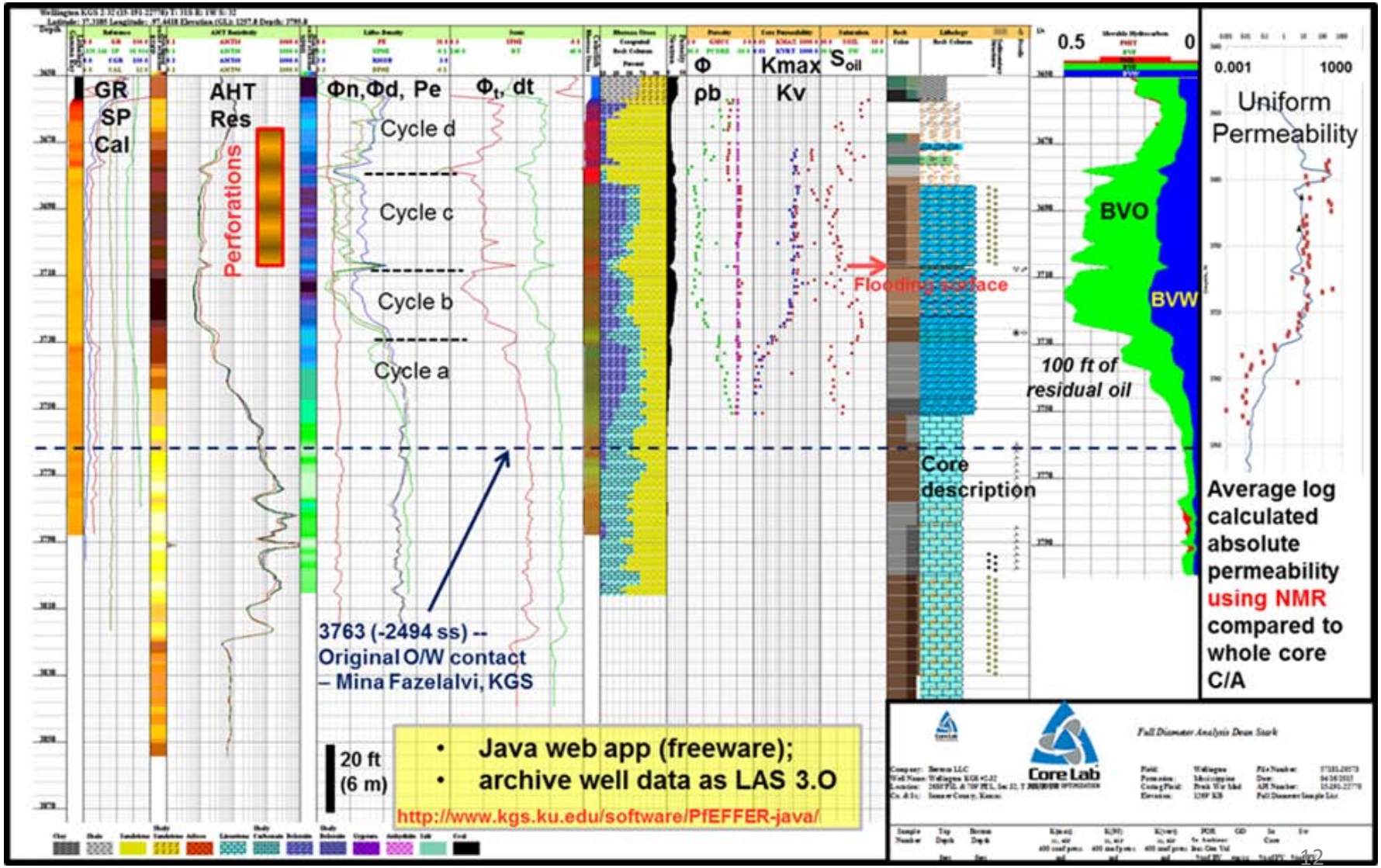
Wellington Project Current Status

- CO2 EOR Project is the first phase at 3600' depth, then deep saline injection to follow (USEPA Class 6) at 5100' depth.
- CO2 EOR injection began Jan 2016 and was completed June 22, 2016.
- EOR recovery, monitoring and CO2 mass balance measurement currently ongoing.
- USEPA Class 6 Injection Permit pending for saline injection phase. Timing?

CO_2 Utilization in Enhanced Oil Recovery (EOR)



Mississippian Reservoir



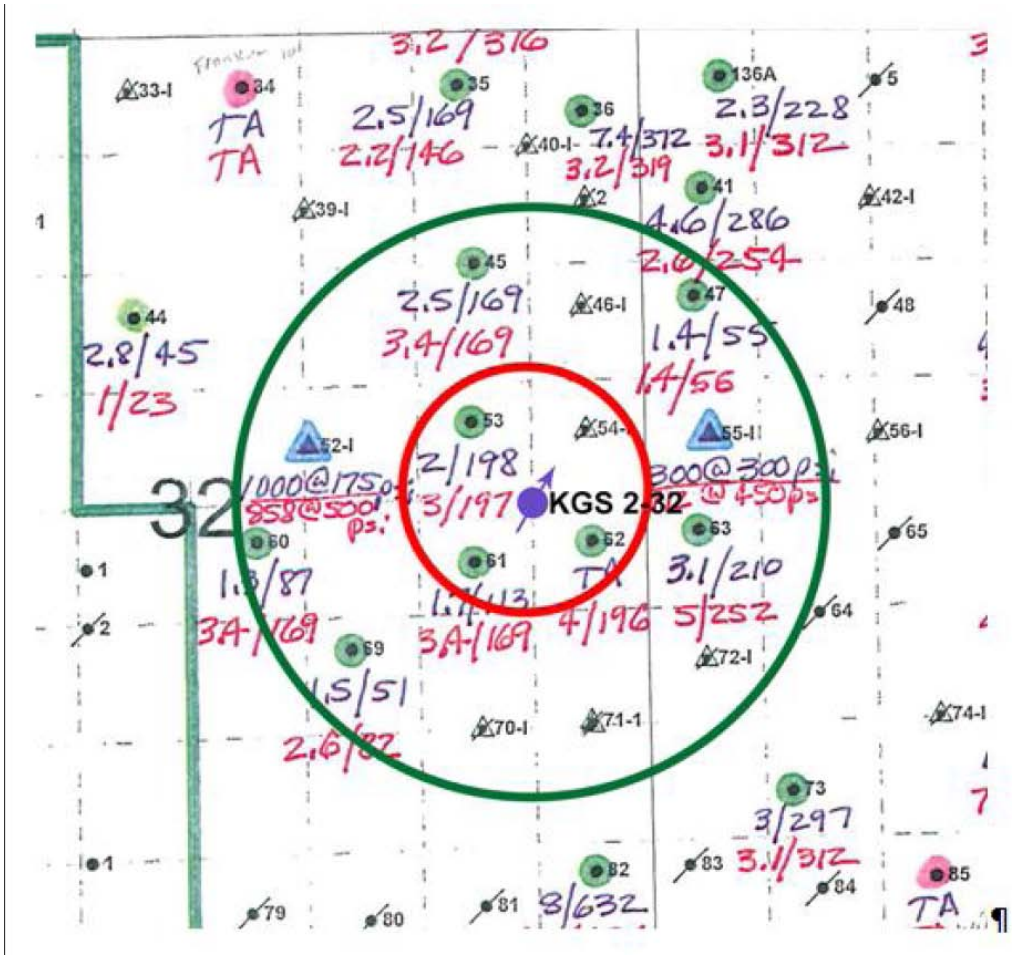
Pilot CO_2-EOR well drilled in 2015 and injection began in January 2016

Mississippian dolomite reservoir in Wellington Field
Sumner County, Kansas

Berexco LLC
Wellington KGS #2-32
2680'FSL & 709'FEL, Sec 32, T 31S, R 1W
Sumner County, Kansas

Drilled in March 2015

Wellington CO2 Project

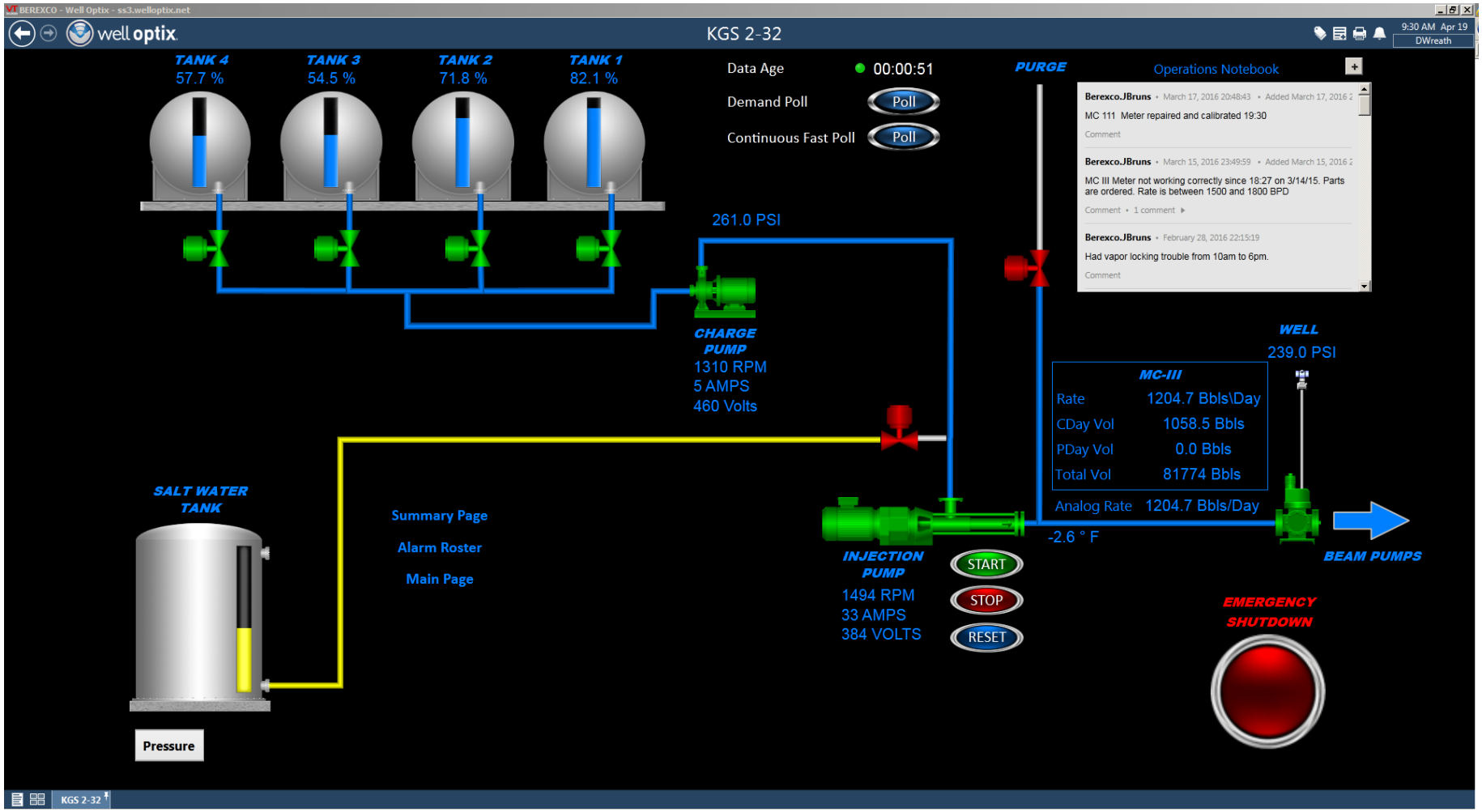


Wellington CO2 Monitoring

- CO2 Flowmeter at injector wellhead.
- Temperature sensor at injector wellhead
- Water Flowmeter at wellhead
- CO2 Flowmeters at producing wells
- CO2 Flowmeter at tank battery

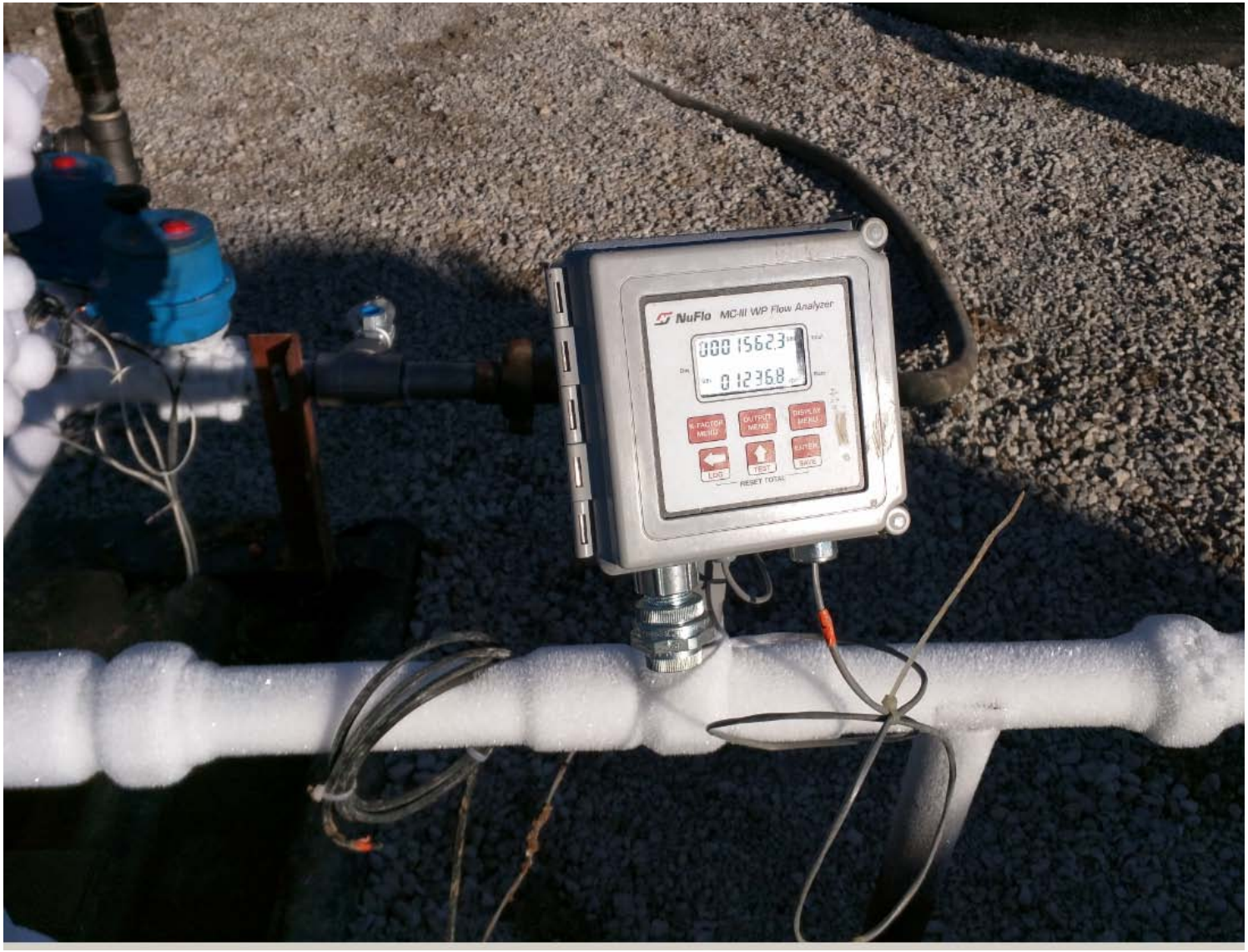
WARNING
Linde

Wellington Automation System



SPOC
SPOC

Liquid CO2 Injection Meter Display



CO2 Properties

Linde LLC Data

CO2 Weight-Volume Equivalents			
Weight	Volume of Liquid @ -14 F		Volume of Gas @ 60 F, 1ATM
Pounds	Gallons	Barrels	Cubic Feet
1	0.114	.0027	8.59
8.80	1	.024	72.7
369.6	42	1	3053.6
2000	227.3	5.41	17190

CO2 Injection

5/23/16	1269 BBL CO2 injected at 174# TP. Current rate 1327 BPD. E. Nelson 26 BO.
5/24/16	1081 BBL CO2 injected. Had to switch to water while repairing CO2 pump. E. Nelson 23 BO.
5/25/16	Injected 886 BBL water @ 0# TP. Current rate 1213 BPD. Switched back to CO2. E. Nelson 28 BO.
5/26/16	1668 BBL CO2 injected @ 173# TP. Current rate 1230 BPD. E. Nelson 22 BO.
5/27/16	1383 BBL CO2 injected @ 163# TP. Current rate 1367 BPD. E. Nelson 45 BO.
5/28/16	1515 BBL CO2 injected @ 175# TP. Current rate 1499 BPD. E. Nelson 43 BO.
5/29/16	1331 BBL CO2 injected @ 160# TP. Current rate 1412 BPD. E. Nelson 37 BO.
5/30/16	1502 BBL CO2 injected @ 166# TP. Current rate 1588 BPD. E. Nelson 27 BO.
5/31/16	1480 BBL CO2 injected @ 154# TP. Current rate 1428 BPD. E. Nelson 28 BO.
6/1/16	1472 BBL CO2 injected @ 180# TP. Current rate 1453 BPD. E. Nelson 28 BO.
6/2/16	1758 BBL CO2 injected @ 180# TP. Current rate 1543 BPD. E. Nelson 28 BO.
6/3/16	1186 BBL CO2 injected @ 160# TP. Current rate 1373 BPD. E. Nelson 4 BO- cleaned stock tank.
6/4/16	1236 BBL CO2 injected @ 171# TP. Current rate 1473 BPD. E. Nelson 33 BO.
6/5/16	1433 BBL CO2 injected @ 152# TP. Current rate 1322 BPD. E. Nelson 35 BO.
6/6/16	1727 BBL CO2 injected @ 184# TP. Current rate 1575 BPD. E. Nelson 32 BO.
6/7/16	1176 BBL CO2 injected @ 200# TP. Current rate 1405 BPD. E. Nelson 33 BO.
6/8/16	1514 BBL CO2 injected @ 177# TP. Current rate 1508 BPD. E. Nelson 45 BO.
6/9/16	1514 BBL CO2 injected @ 178# TP. Current rate 1453 BPD. E. Nelson 42 BO.

Lessons Learned Measuring Liquid CO2 Injection Volume

- Temperature Matters!!
- Daily volume of liquid CO2 trucked in averaged 900 bbl, but wellhead flowmeter was reading 1400 bbl per day.
- CO2 density at -14F is different than -5F.
- Berexco installed temperature sensors tied to SPOC controller to record temp continuously.
- Reccomendation: Measure gas volume at low pressure in gas phase. Its more reliable.

CO2 Produced Gas Measurement

- Cameron MC-III EXP Flow Measurement
- Installed at wellhead vent, or 2 phase separator at well.
- Separators needed to stop liquids flowing up annulus making a mess as gas volumes increase.
- CO2 Content Sensors for low volume gas venting.

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NUFLO Gas Turbine Meters

Overview Specifications

Overview

NUFLO GT gas turbine flowmeters feature a transducer that utilizes a lightweight, low-inertia rotor to sense gas velocity. It offers an output frequency that has a linear relationship to gas velocity over a wide flow range.

The meter tracks the flow rate continuously, offers little resistance to flow, and has a unique cartridge design that allows removal of all internal parts as one assembly. The meter also exhibits little sensitivity to gas density above two atmospheres pressure. The low inertia of the rotor and vee bearings allows overranging of the meter to twice its rated capacity without damage for intermittent flow variations.

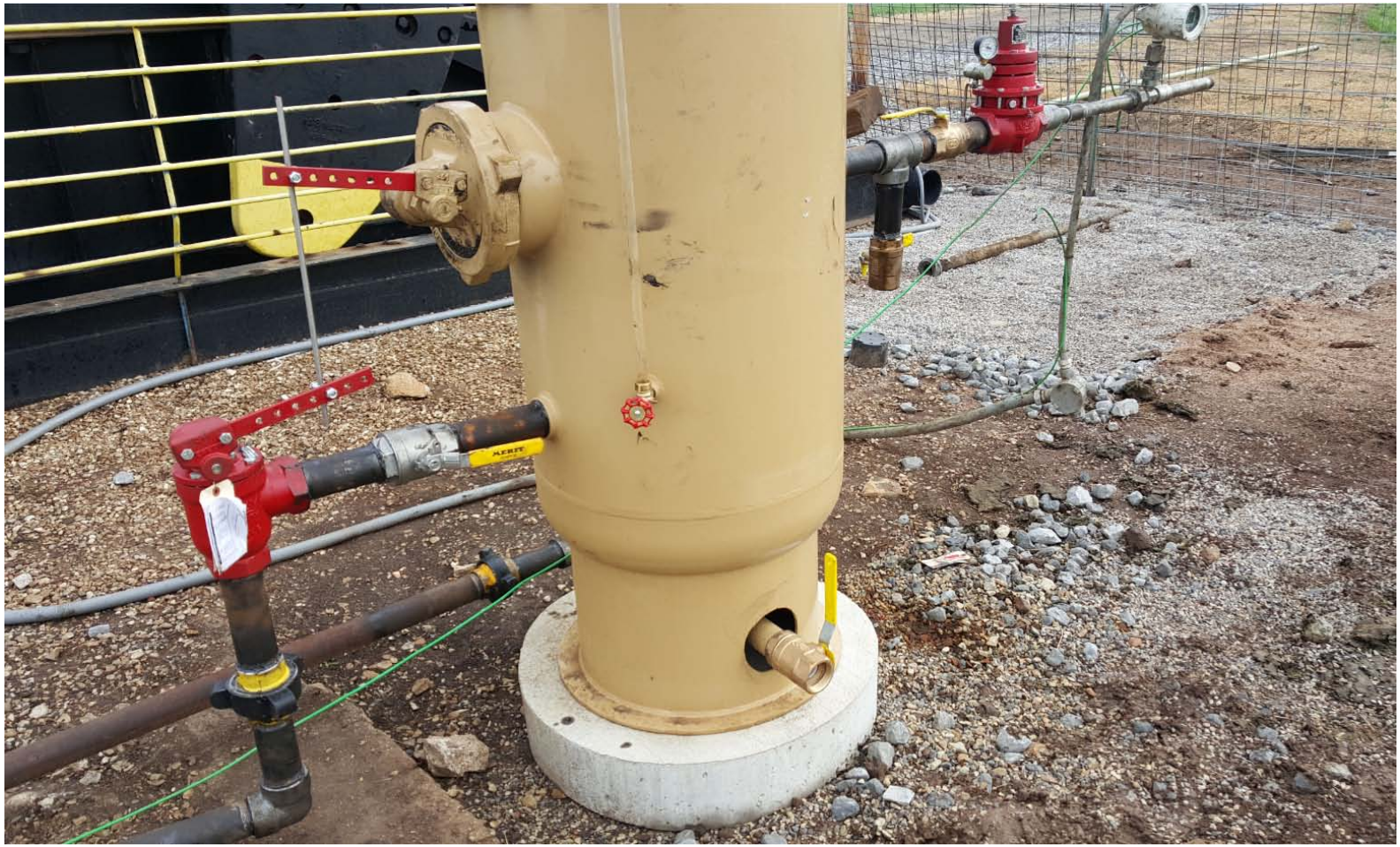
NUFLO™

MC-III™ EXP Flow Analyzer

User Manual

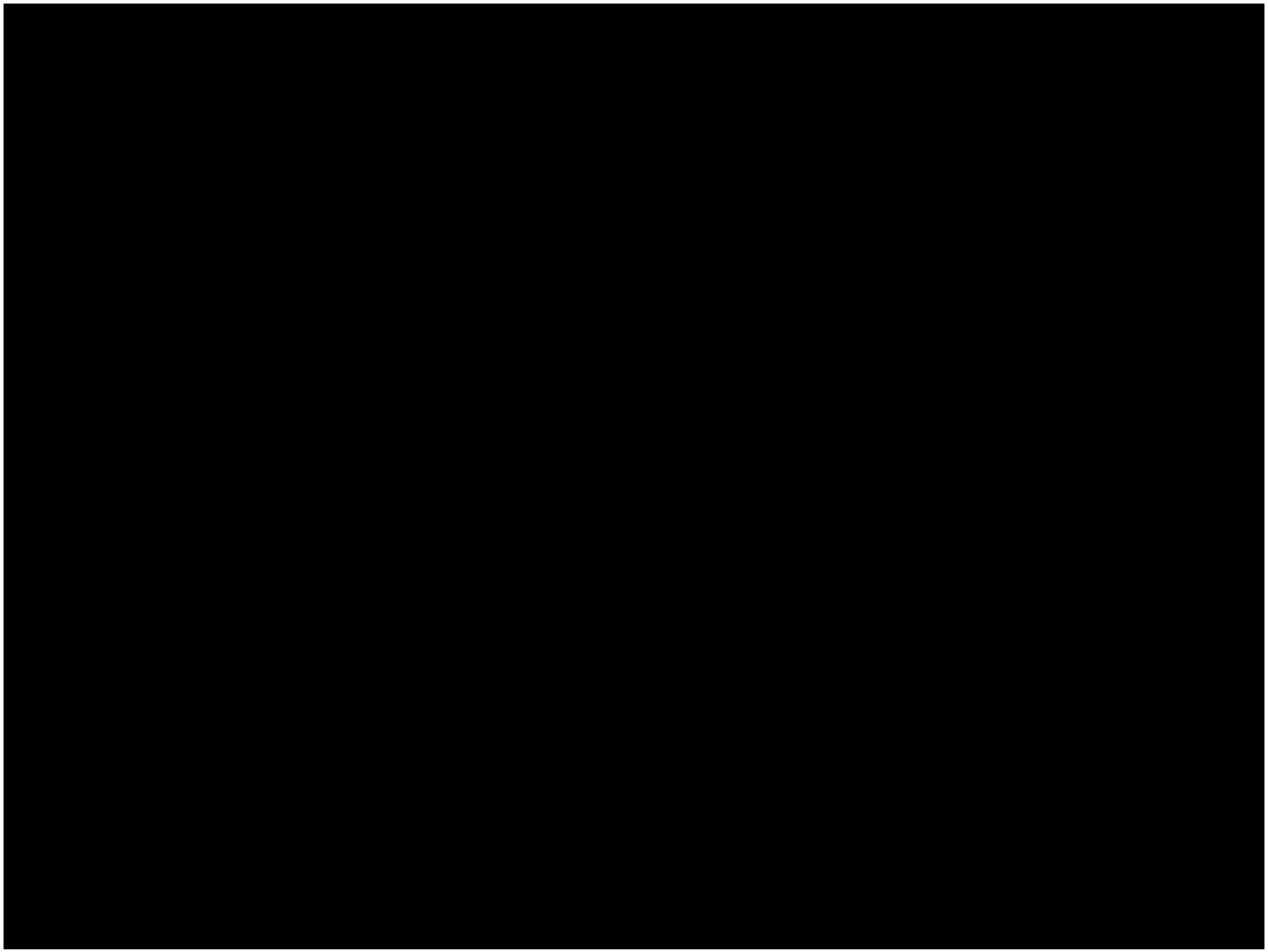
Wellington Oil Well Configuration

2 Phase Separator



CO2 Vent Measurement

CO2 Content Sensor



CO2 Monitoring Data at Oil Wells

A1 'KGS MCF/D and % CO2 venting

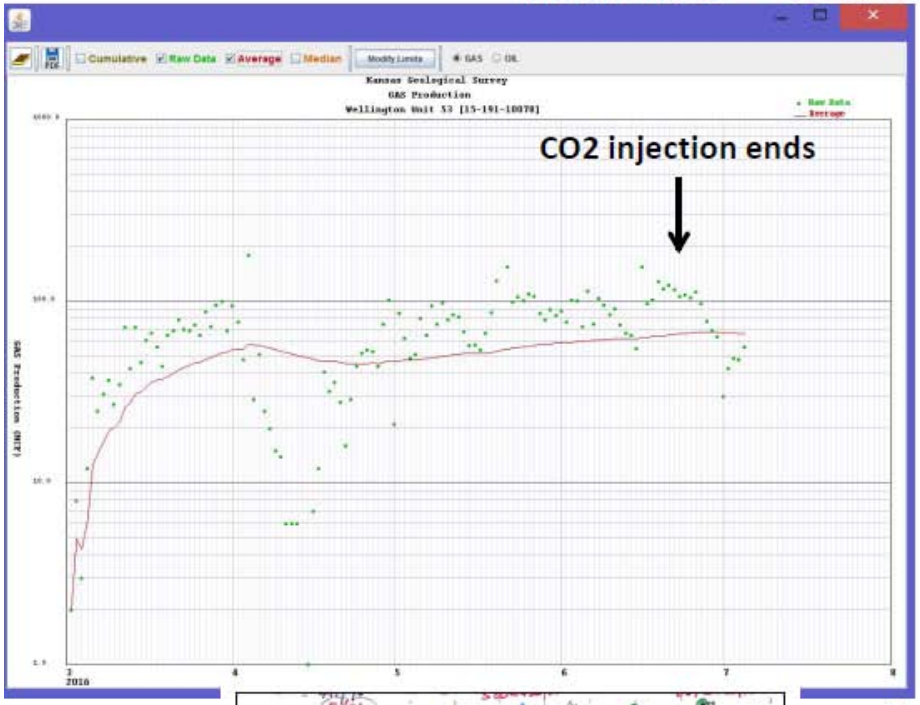
	A	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	C
1	KGS MCF/D and % CO2 venting												
2	Well	% CO2	Date	MCF	% CO2	Date	MCF	% CO2	Date	MCF	% CO2	Date	MCF
3	Red Circle												
4	53	100	25-Jul	8764	100	26-Jul	8809	100	27-Jul	8871	100		
5	61	100	25-Jul	12187	100	26-Jul	12212	100	27-Jul	12251	100		
6	62	100	25-Jul	5001	100	26-Jul	5001	100	27-Jul	5001	100		
7	Green Circle												
8	45	2.2	25-Jul	0	2.2	26-Jul	0	2.2	27-Jul	0	2.2		
9	47												
10	60	100	25-Jul	6239	100	26-Jul	6312	100	27-Jul	6419	100		
11	63	100	25-Jul	3021	100	26-Jul	3021	100	27-Jul	3021	100		
12	69												
13	Orange Circle												
14	35												
15	36												
16	41												
17	44												
18	73												
19	82												
20	136A												
21													
22	Other												
23	6												
24	E Nelson TB	100	25-Jul	6545	100	26-Jul	6562	100	27-Jul	6574	100		
25													
26													
27													
28													
29	**TOTAL**			**41757**			**41917**			**42137**			
30													
31													
32													

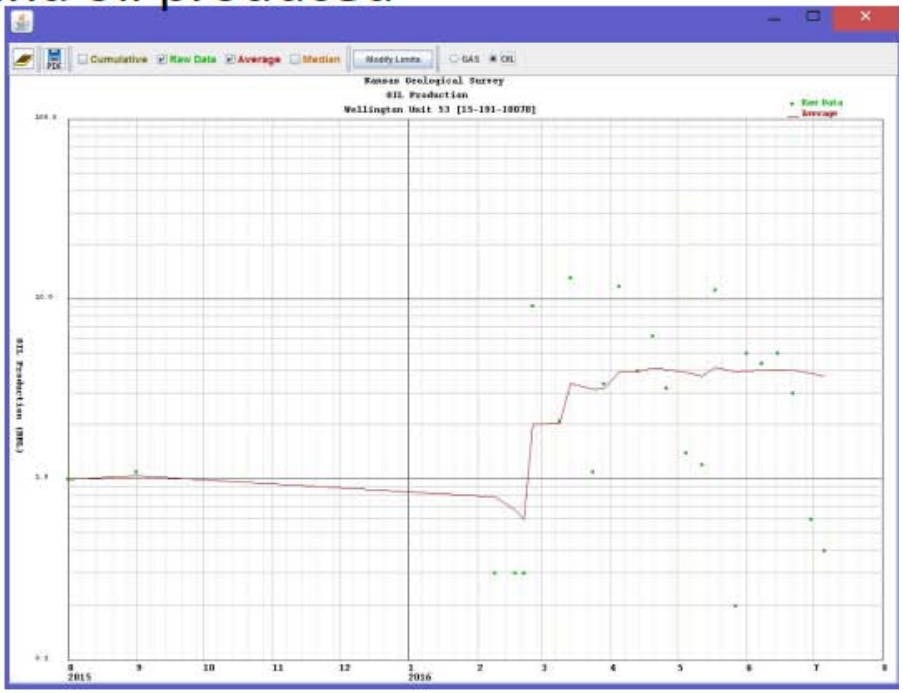
Producing Well Test Data

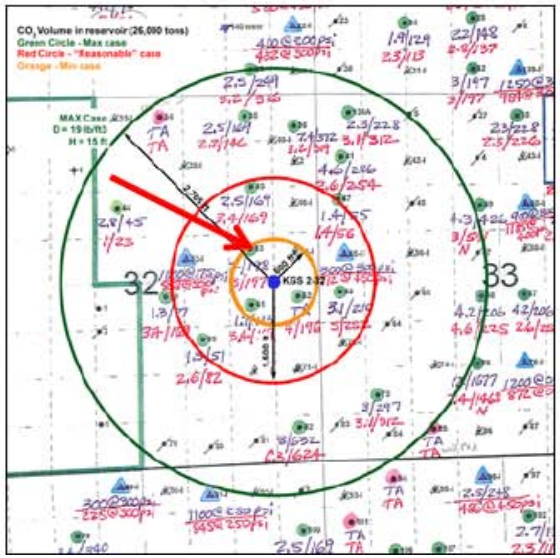
	A	B	C	D	E	F	G
1	Well Number	53					
2	Date	Total Fluid	Oil Cut	BOPD	Fluid Level	Jts in Well	Estimated BHP
12	22-Feb	123.25	0.3	0.3	29	116	1352
13	26-Feb	114.6	8.0	9.2	18	116	1522
14	29-Feb		11.0		56	116	932
15	2-Mar				47	116	1072
16	5-Mar				29	116	1352
17	9-Mar	143	1.5	2.1	49	116	1041
18	14-Mar	171	7.7	13.2	68	116	746
19	22-Mar	158	2.0	3.2	37	116	1227
20	24-Mar	114	1	1.1	49	116	1041
21	29-Mar	172	2.0	3.4	20	116	1491
22	5-Apr	79	15.0	11.9	40	116	1181
23	13-Apr	200.5	2.0	4.0	93	116	357
24	20-Apr	210	3.0	6.3	23	116	1445
25	26-Apr	158	2.0	3.2	61	116	854
26	5-May	143	1.0	1.4	26	116	1398
27	12-May	158	0.8	1.2	16	116	1554
28	18-May	125	9.0	11.3	38	116	1212
29	27-May	45	0.5	0.2	22	116	1460
30	1-Jun	143	3.5	5.0			
31	8-Jun	145	3.0	4.4			
32	15-Jun	143	3.5	5.0			
33	22-Jun	201	1.5	3.0			
34	30-Jun	115	0.5	0.6	27	116	1383
35	6-Jul	172	0.3	0.4	29	116	1352
36	20-Jul	229	3.0	6.9	19	116	1507
37							
38							

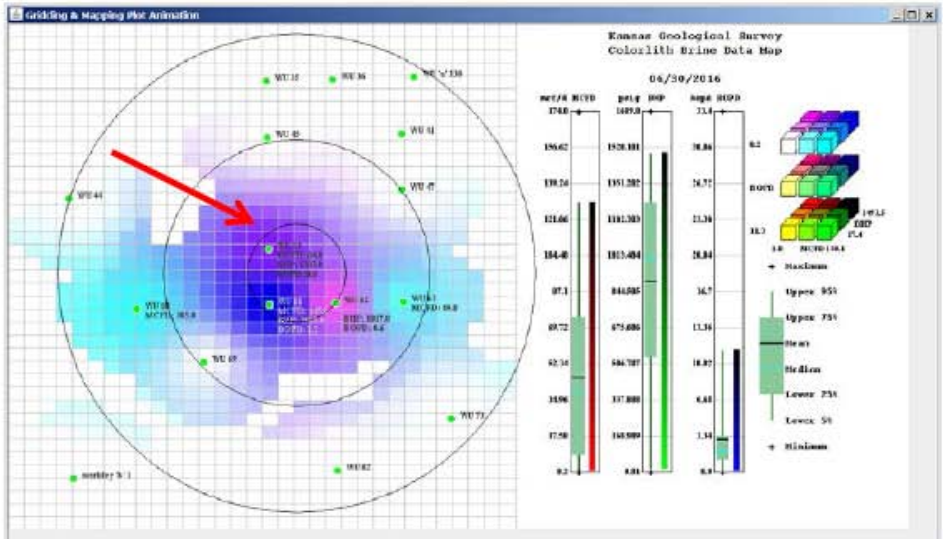
http://www.kgs.ku.edu/PRS/Ozark/Summary/CO2_II.html

Well #53 – CO2 and oil produced



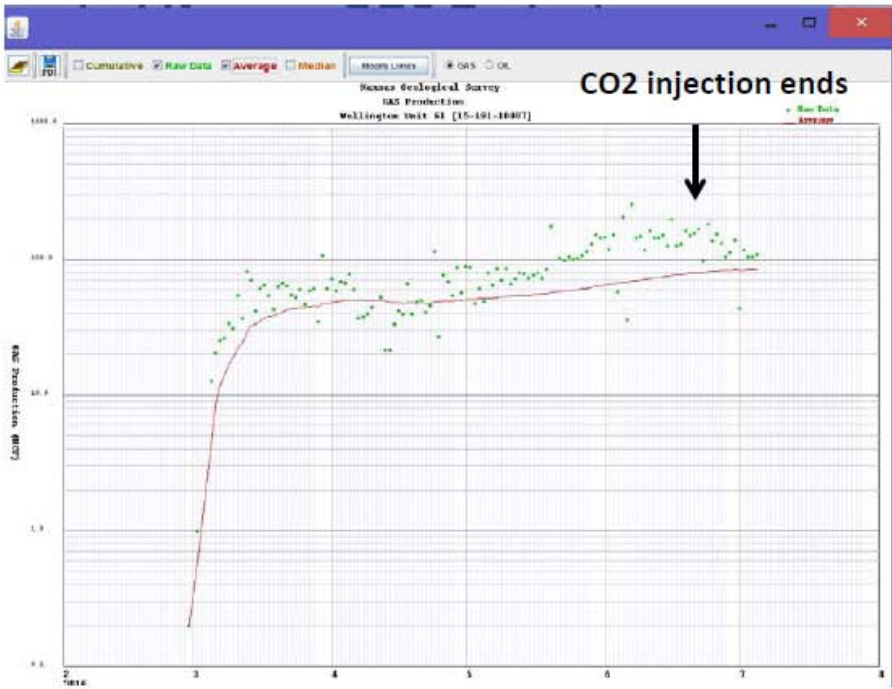


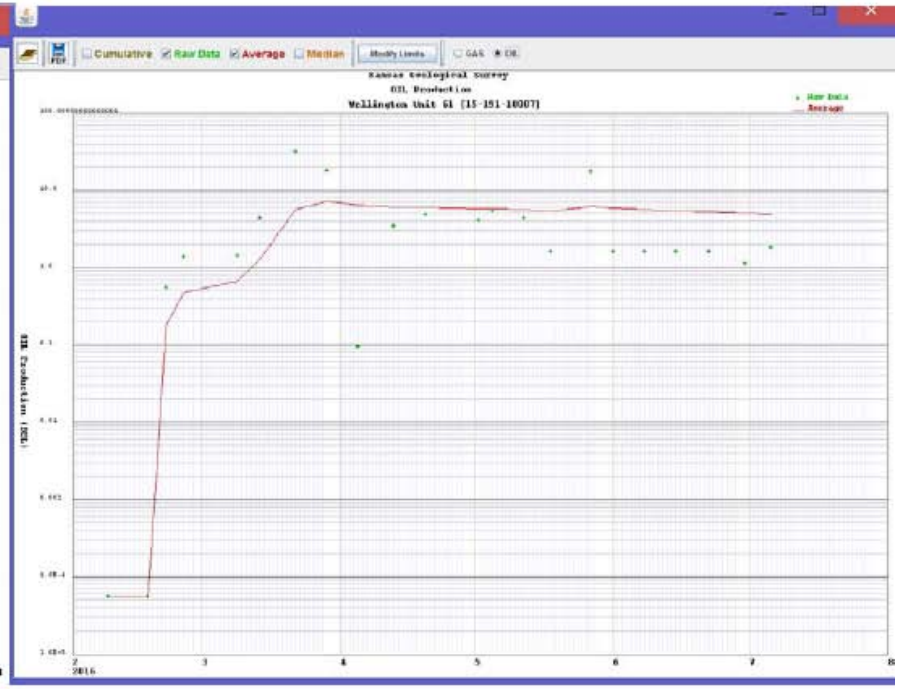




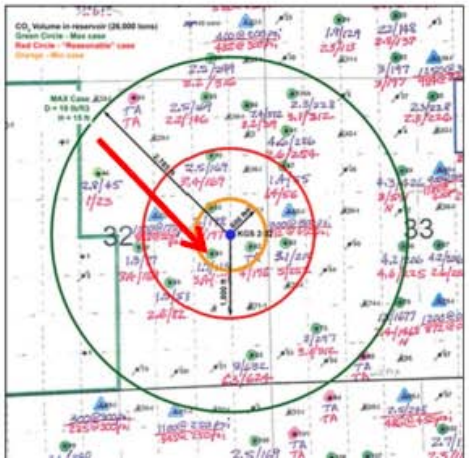
http://www.kgs.ku.edu/PRS/Ozark/Summary/CO2_II.html

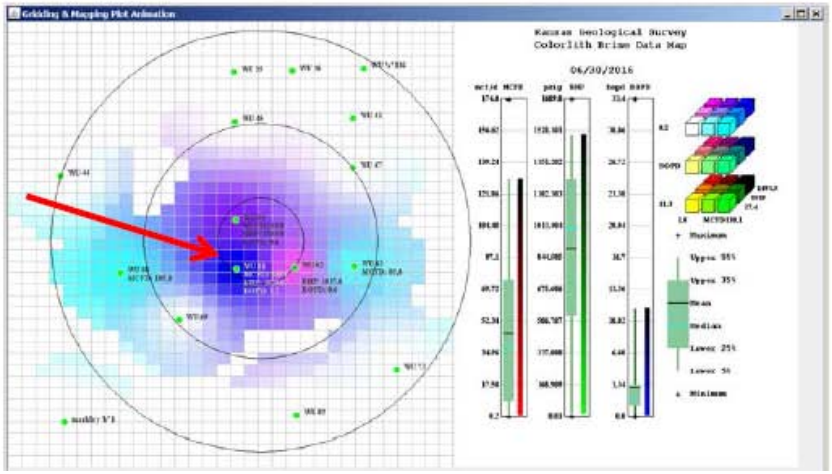
Well #61 – CO2 and oil produced





- Very steady CO2 produced after breakthrough with slow, recent increase in CO2
- CO2 production did not drop off midway as result of pause of the CO2
- Good, consistent oil recovery





CO2 Measurement at Tank Battery

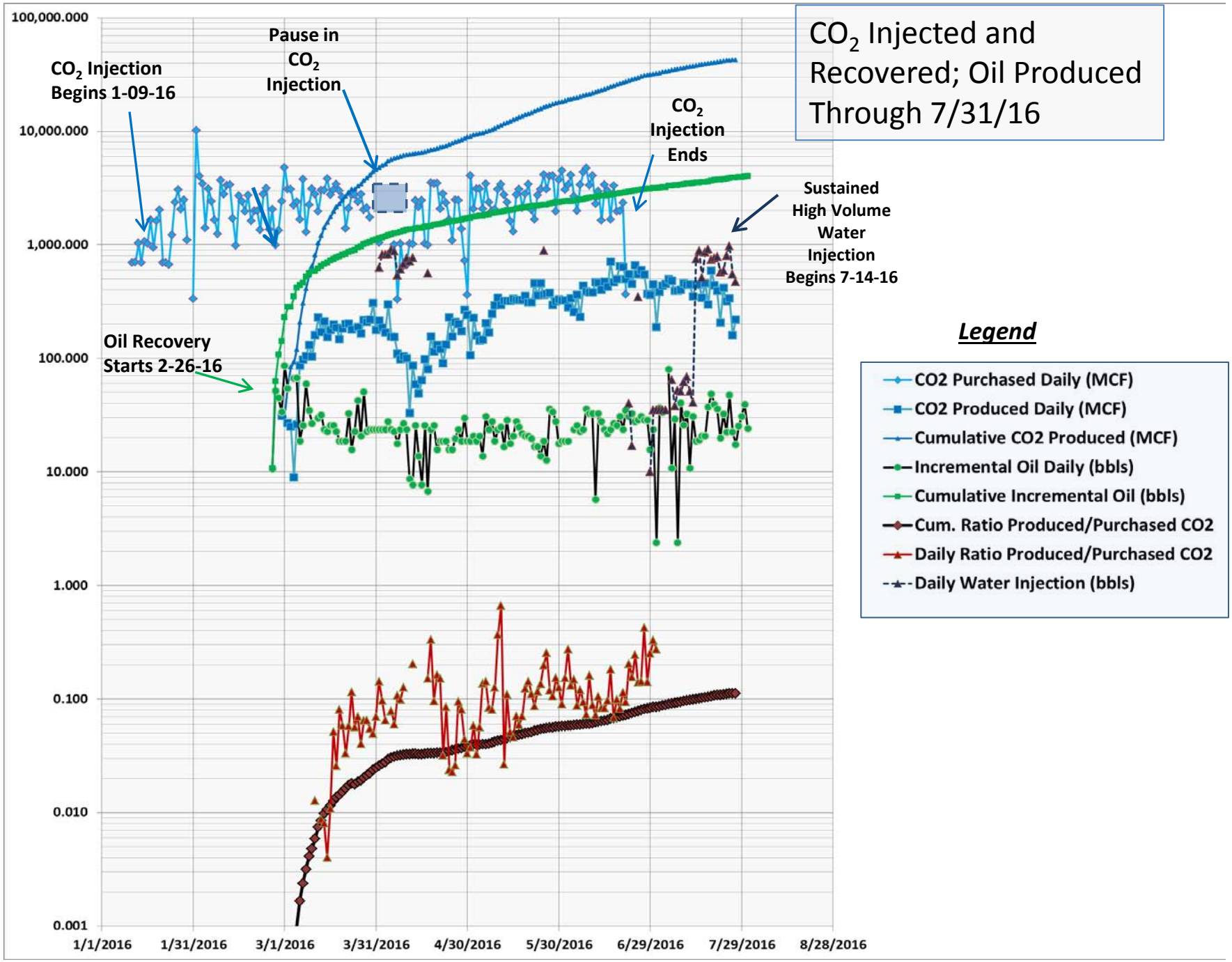
CO2 Meter at Tank Battery

CO2 Measurement, Verification and Accounting

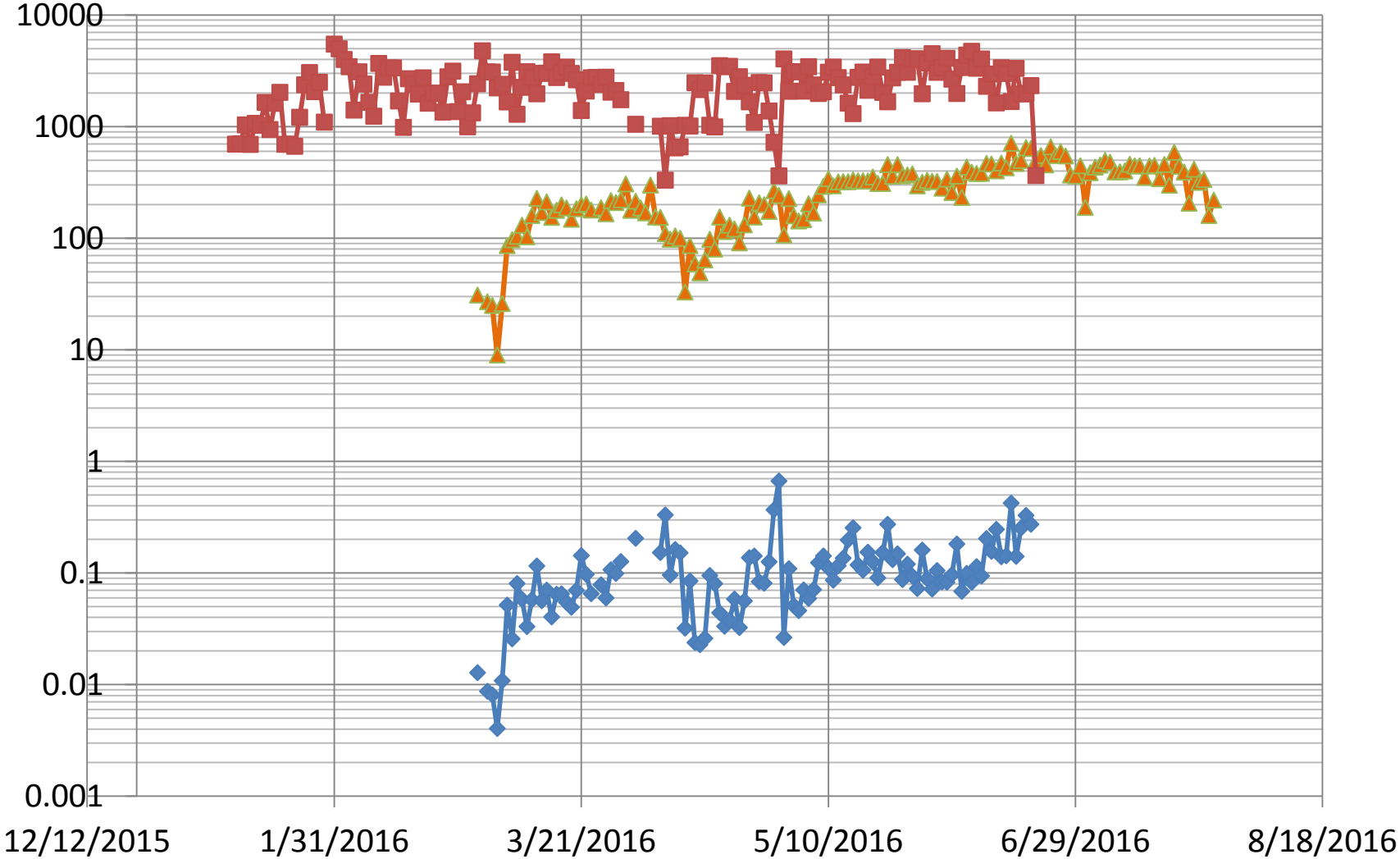
- Accurately measure ALL CO2 injected – volume or mass.
- Must know relationship between volume and mass if using liquid CO2!
- Accurately measure ALL CO2 at producing wells and tank batteries. Any place CO2 leaves the reservoir.
- Choose injection site carefully to avoid underground leakage.

Wellington Results

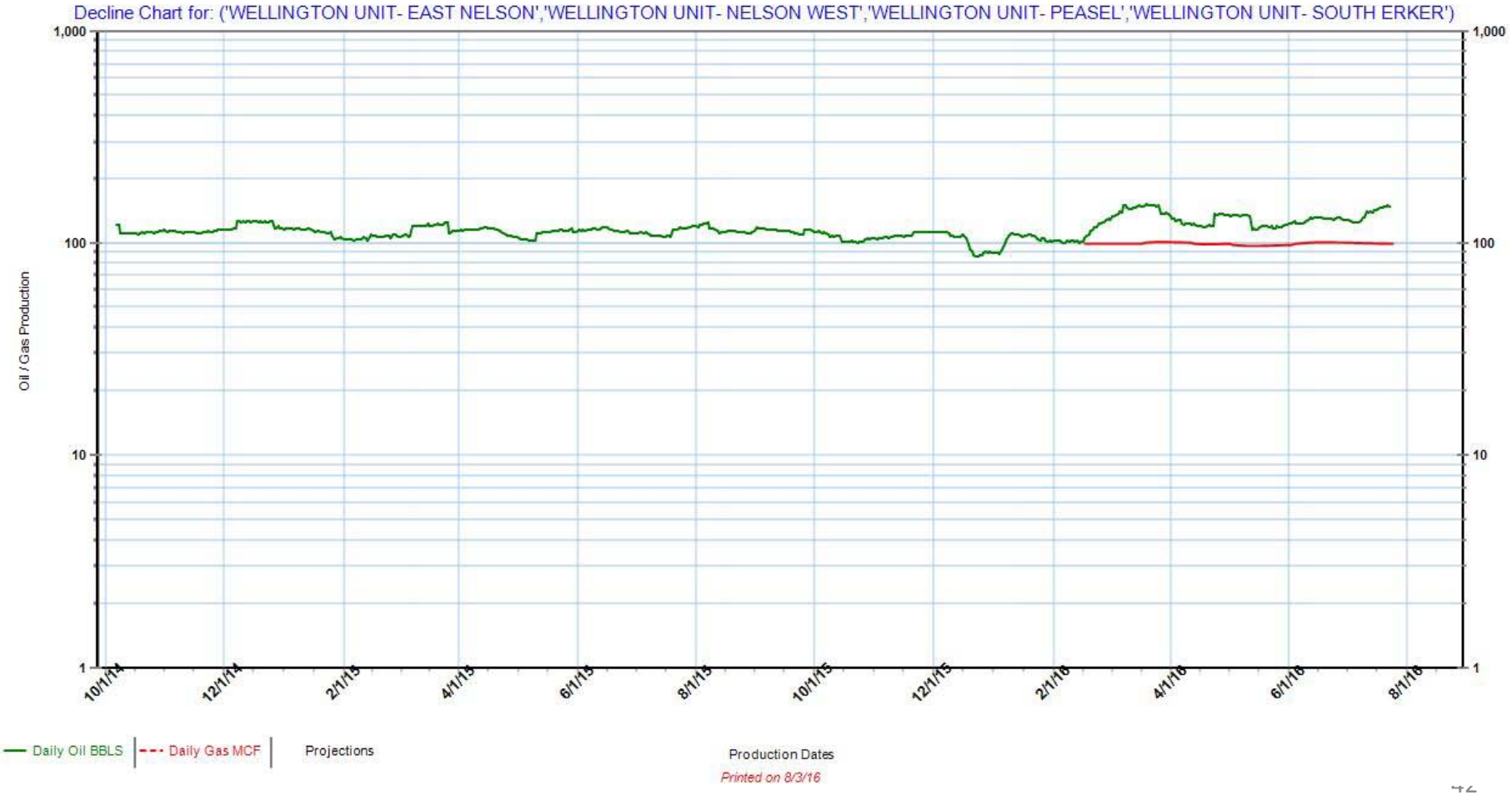
- CO_2 Accounting
- Total 374,461 MCF Injected (21,784 US tons)
- Required 1,101 Truckloads, each about 20 US tons.
- Incremental Oil Production about 4,200 bbls to date.
- Approximately 11% of CO_2 injected has been produced (vented)


CO_2 Injected and Recovered; Oil Produced Through 7/31/16
CO_2 Injection Begins 1-09-16
Pause in CO_2 Injection
CO_2 Injection Ends
Sustained High Volume Water Injection Begins 7-14-16
Oil Recovery Starts 2-26-16
Legend
CO2 Purchased Daily (MCF)
CO2 Produced Daily (MCF)
Cumulative CO2 Produced (MCF)
Incremental Oil Daily (bbls)
Cumulative Incremental Oil (bbls)
Cum. Ratio Produced/Purchased CO2
Daily Ratio Produced/Purchased CO2
Daily Water Injection (bbls)
100,000.000
10,000.000
1,000.000
100.000
10.000
1.000
0.100
0.010
0.001
1/1/2016
1/31/2016
3/1/2016
3/31/2016
4/30/2016
5/30/2016
6/29/2016
7/29/2016
8/28/2016

Daily Purchased MCF CO_2 (red)-- MCF CO_2 recovered (gold) ---- Daily Ratio recovered vs purchased CO_2 (blue)



Wellington Unit Oil Production



Summary and Future Work

- No substantial deviations due to unforeseen circumstances (carbonate fracturing, temperature, pressure, etc.)
- Successful oil recovery
- Low CO_2 losses due to venting or reservoir properties
- Manage CO_2 plume and finalize CO_2 injection
- 2D seismic to confirm CO_2 plume

Phase 2 CO2 Disposal

- Phase 2: Deep CO2 Disposal in Arbuckle Formation at 5100’ depth.
- Phase 2 goals: demonstrate CO2 can be safely disposed (sequestered) in the Arbuckle Formation.
- Phase 2 will start in 2017 (?) but waiting on disposal permit from USEPA. Getting close.
- Previously Berexco drilled two deep wells to the basement to characterize the Arbuckle reservoir, one of which will be the CO2 disposal well.

Conclusions

- Measure CO2 accurately in and out.
- Use good measurement equipment.
- Maintain good records.

- Thanks and Credits to DOE/NETL, Kansas Geological Survey, Berexco LLC.

KGS 2-32 Drilling Phase

3/20/15	Spud well 7:00 am, 3/20/2015. TD 17-1/2" conductor hole @ 140' KB, 3/20/2015. Survey 1° @ 140'. Ran 3 jts 13-3/8" 48# conductor casing- set @ 137' KB. Cemented with 145 sx Class A cement with 1/4# flakes and 3% CC. Finished cementing 1:15 pm, 3/20/2015. Cement circulated to surface.
3/21/15	Drilling @ 465'. TD 12-1/4" surface hole @ 650' KB, 3/21/15. Survey 1° @ 650'. Ran open hole logs in surface hole- LTD @ 653' KB. Log showed base of conductor @ 142' KB. Ran 15 jts 8-5/8" 24# surface casing. Set @ 647' KB. Cemented with 175 sx 60/40 POZ 6% gel 1/4# flakes 3% CC tailed with 150 sx Class A with 1/4# flakes and 3% CC. Plug landed 8:15 pm, 3/21/15. Cement circulated to surface.
3/22/15	Drilling out of surface casing.
3/23/15	Drilling @ 1470'. Survey 3/4° @ 1164'.
3/24/15	Drilling @ 2325'. Surveys 1/2° @ 1670, 3/4° @ 2179'.
3/25/15	Drilling @ 3135'. Surveys 3/4° @ 2624', 1/4° @ 3134'. Displaced mud system at 2815'.
3/26/15	Conditioning hole for coring. Reached core point @ 3654' KB 6:15 am, 3/26/2015. Survey 1/2° @ 3654'. TIH w/ coring tools. Cored from 3654' to 3669' and core barrel jammed. TOH w/ Core #1. Recovered 15' of core. TIH and resumed coring- core barrel jammed @ 3691'. TOH w/ Core #2. Recovered 22' of core.
3/27/15	Coring @ 3691'. Cored to 3751'. Recovered 60' of core. Ran DST #1: DST #1, 3671'-3751', Mississippi Times: 30-60-60-120 IFP: 51-235# FFP: 231-392# ISIP: 955# FSIP: 959# Recovery: 300' VSOSMW (Tr O, 95% W), 120' VSOSWM (Tr O, 35% W), 120' M; Chlorides 95,000 ppm
3/28/15	Drilling @ 3765'. TD well @ 3860' 2:00 pm, 3/28/15. Survey 1/4° @ 3860'.
3/29/15	Running open hole logs- LTD @ 3860' KB. Lay down drill pipe and drill collars. Ran 95 jts 5-1/2" 15.5# casing. Tag TD @ 3860' KB and set casing @ 3858' KB. Circulated halfway into hole and on bottom. DV @ 2515' KB. Baskets @ 3732', 3608', on jt below DV tool and at 1000'. Ran centralizers every other collar up to 3000' and on joints above and below DV tool.
3/30/15	Cemented bottom stage with 95 sx A-Con w/ 1/4# flakes and 2% CC mixed at 2.01 cu ft/sx tailed with 195 sx AA-2 thixotropic cement with 5% Calseal, 1% C-44 Gas Blok CO_2 resistant additive, 10% salt, 1/4# defoamer, 1/4# flakes 1/2% fluid loss, 0.3% CFR-2, and 6# gilsonite. Plug landed 2:10 am, 3/30/15. Opened DV tool and circulated 4 hours. Saw cement from bottom stage circulate to surface. Cemented top stage with 465 sx A-Con w/ 1/4# flakes 2% CC at 2.01 cu ft/sx and 50 sx AA-2. Plug landed 7:20 am, 3/30/15. Cement circulated to surface. Plugged mouse and rat holes with 50 sx A-Con. Rig released 3/30/15
3/31/15	Waiting on completion.

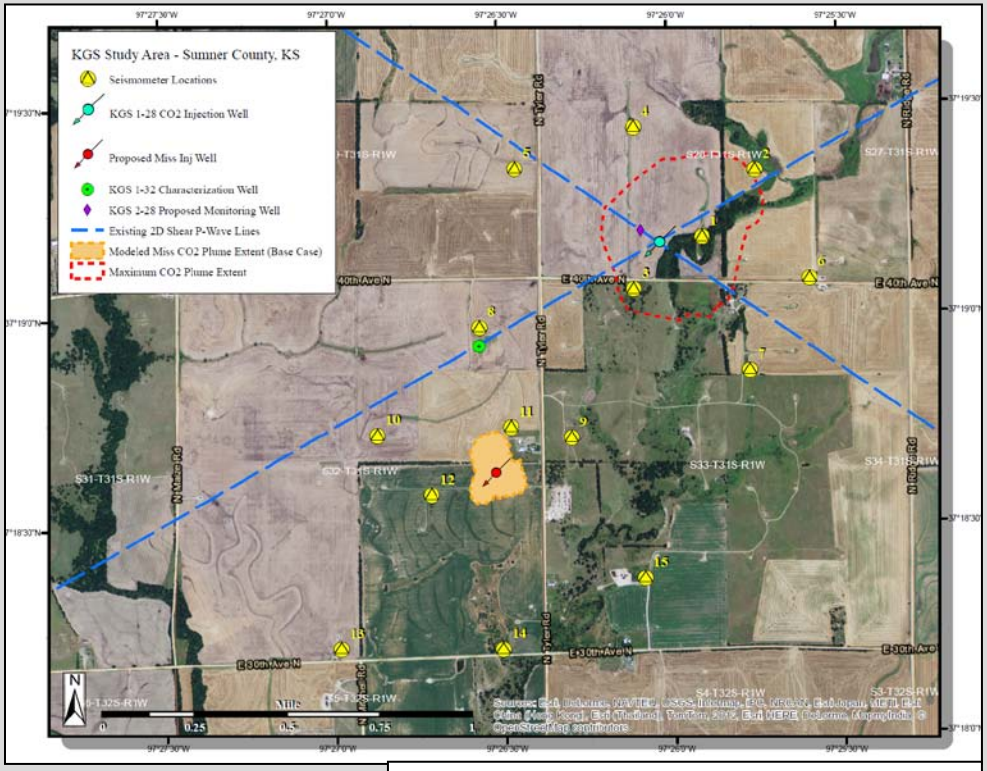
KGS 2-32 Completion

4/22/15	MIRU BX Rig #13. TIH w/ 4-7/8" bit, 3- 3-1/8" drill collars and 2-7/8" workstring. Tag DV @ 2515' KB. Drill out DV tool. Tag PBTD @ 3820' KB. Circulated hole clean with fresh water. SOH w/ tubing, drill collars and bit. Shut down.
4/23/15	FOH w/ tubing and bit. Ran CBL- PBTD @ 3815' KB. Good bond from TD to surface. Pressured casing to 2500#- held. TIH w/ 4-7/8" bit, 5-1/2" casing scraper and 2-7/8" workstring to 3780' KB. Shut down.
4/24/15	Swab casing fluid level down to 3150' from surface. TOH w/ bit, scraper and tubing. Perforate Mississippi Chert from 3664'-3706' KB, 4 SPF. Shut down.
4/25-26/15	Shut down.
4/27/15	Ran 5-1/2" X 2-7/8" Arrowset PKR. Set @ 3638' KB. Ran swab- fluid level 1800' from surface, 100' free oil on top. Recovered 10.8 BW on swab down. Had 700' fill up after 1 hour. Acidized Mississippi perfs with 2500 gallons 10% NEFE-HCl and 250 ball sealers. Treated 3 BPM @ 1300# initially, increased to 5.7 BPM @ 700# towards end. ISIP 50#, 30 seconds to vacuum. TLTR 90 BTF. Ran swab- fluid level 1100' from surface. Recovered 44.7 BW on swab down. Next hour recovered 20.8 BTF with trace oil. Shut down.
4/28/15	Ran swab- fluid level 2000' from surface, 50' oil on top. Swabbed 26.7 BTF. Release PKR and run across perfs to remove any remaining ball sealers. Reset PKR @ 3638' KB. Ran swab. Recovered 16.8 BTF on swab down.
	1st Hour — 19.1 BTF, fluid level 2800' from surface
	2nd Hour — 23.4 BTF
	3rd Hour — 16.7 BTF
	4th Hour — 13.4 BTF
	5th Hour — 13.4 BTF
	6th Hour — 20 BTF. Fluid level stayed 2800' from surface. Caught fluid samples.
	Shut down.
4/29/15	Ran swab- fluid level 2000' from surface, 75' free oil on top. Injected 2 BPM for 10 minutes- took fluid on vacuum. Injected 4 BPM for 10 minutes- stabilized pressure 150#. TOH w/ tubing and PKR. RDMO BX Rig #13.

KGS 2-32 Start of Injection

6/8/15	MIRU Contract WS Rig. TIH w/ nickel coated Arrowset-1X PKR with Viton rubber and 1.875" stainless steel profile nipple for X-style blanking plugs, nickel coated on-off tool and 110 jts TK-70XT coated tubing. Pump packer fluid and set PKR @ 3636' KB. Annulus held 150#. RDMO Contract WS Rig. Will MIT well 6/10/15.
6/10/15	MIT well to 350#- held. Witnessed by Jonathan Hill of KCC District #2 office.
6/23/15	Permit for carbon dioxide injection approved by KCC.
7/7/15	Installed 2" 2250# fiberglass water injection line from Wellington Unit #52I injection well to Wellington KGS #2-32 well.
7/27/15	Waiting on high pressure stainless steel fittings to finish hooking up wellhead.
8/3/15	Finished hooking up wellhead and began injecting water. Instantaneous rate 300 BWIPD @ 0# tubing pressure. Backed rate off to 115 BWIPD.
8/27/15	Injecting 115 BWPD on vacuum.
9/22/15	Injecting 111 BWPD on vacuum.
10/1/15	Shut in Wellington Unit producing wells #53, #61 and #62 to raise reservoir pressure around KGS #2-32. Injecting 115 BWPD on vacuum.
10/5/15	Injecting 115 BWPD average on vacuum. BHP on offset wells: #53 at 1066 psi, #61 at 732 psi, #62 at 961 psi.
10/12/15	Injecting 115 BWPD average on vacuum. BHP on offset wells: #53 at 1222 psi, #61 at 910 psi, #62 at 1100 psi.
10/19/15	Injecting 115 BWPD average on vacuum. BHP on offset wells: #53 at 1254 psi, #61 at 1007 psi, #62 at 1163 psi.
10/26/15	Injecting 115 BWPD average on vacuum. BHP on offset wells: #53 at 1301 psi, #61 at 1072 psi, #62 at 1209 psi.
11/1/15	Increased injection to 250 BWPD- well still on vacuum.
11/2/15	BHP on offset wells: #53 at 1316 psi, #61 at 1120 psi, #62 at 1240 psi.
11/23/15	Finishing pad for injection skid and working on electric hookup.
12/1/15	Injecting 250 BWPD on a vacuum. #53 at 1394 psi, #61 at 1234 psi, #62 at 1333 psi.
12/8/15	Injecting 250 BWPD on a vacuum. #53 at 1394 psi, #61 at 1250 psi, #62 at 1348 psi.
12/18/15	Increase injection to 500 bwpd. Move in first CO2 storage tank.
12/23/15	Move in one transport truckload of CO2. Hook up truck to suction side of Berexco CO2 injection pump. Pump 17 US tons of CO2 down the KGS 2-32 CO2 injection well using the CO2 injection pump over 2.5 hours total. Starting pressure 500 psi, final injection pressure 300 psi. Resume water injection. Total CO2 pumped down well 34,135 lbs. Max rate 1750 bbl per day rate at 300 psi, which is approx 310 tons per day. Resume injection at 500 bwpd. Cumulative water injection to date: 21,894 bbl water.
12/24/15	500 bwipd
12/29/15	Begin filling CO2 storage tanks. Four 70 ton storage tanks on location.

18 seismic seismometer array operating at Wellington Field to monitor CO_2 pilot tests



G. Tsoflias
Alex Nolte
KU Geology
J. Hollenbach &
J. Victorine, KGS

IRIS Seismometer Installation

Housing setup for Sercel (Mark Products) L-22D-3D sensors, ~5 ft below surface to minimize surface noise; installed below frost line in bedrock

Shelby Peterie, KGS Exploration Services, checking installation in July 2014

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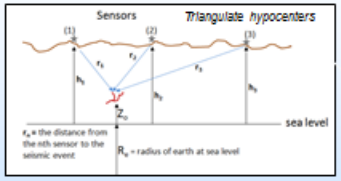
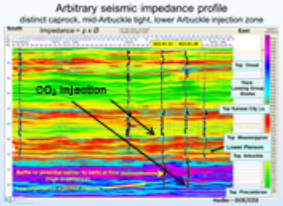
R. Miller and S. Peterie, KGS

Resolution of Hypocenters from IRIS Seismometer Array at Wellington

Refining location of operational seismicity -- Initially for the CO2-EOR injection to evaluate feasibility of methodology



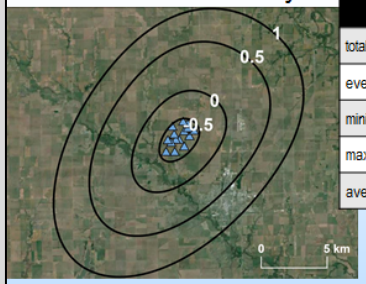
Mississippian and Arbuckle injection zones have good impedance



Adapting Java toolset to manage, interpret, and display solutions on project maps (Victorine, KGS)
→ *Time, location (x,y,z) of event from seismometers*

KGS #1-32 --Synthetic seismogram integrated with well logs and stratigraphy – Java app. (Victorine, KGS)

Network Sensitivity



- Minimum magnitude versus distance from the network
- Operational seismicity from active waterflood being recorded in Wellington Field
- Research underway to improve location of hypocenters of events

Local Activity

Events detected at ≥7 stations†	
total events	53
events/day	4
minimum magnitude	-0.3
maximum magnitude	1.4
average magnitude	0.6

- Earthworm software for automated detection of earthquakes.
- Reporting 2.5+ magnitude per USGS convention.

†initial recording over one weeks time

R. Miller and S. Peterie, KGS