Stimulation Petrophysics Consulting, LLC

A Review and Evaluation of EPA's Drilling and Cement Jobs for EPA's MW01 and MW02 Monitoring Wells In the Pavillion Field, Wyoming

April 2012

Prepared for:

Encana Oil & Gas (USA) Inc.
370 17th Street, Suite 1700
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Analysis by:
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The opinions of Stimulation Petrophysics Consulting, LLC (SPCLLC) described herein do not constitute an exhaustive study of all aspects of the subject property. In preparing this report, SPCLLC has based its analysis on the available data, as further described in the body of this report. SPCLLC does not warrant or guaranty the results from actions based on the analysis and opinions provided in this report. Moreover, the analysis and opinions may change as a result of the availability of further and additional data, if such becomes available. This report should not be circulated or quoted for any other purpose without the express written consent of Stimulation Petrophysics Consulting, LLC or except as required by law

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I. Qualifications of Michael J. Mullen

Mike Mullen has been involved with wireline logging and formation evaluation of open hole and cased hole logs for over 35 years. Mike started his career in 1976 after graduating from the University of Missouri – Rolla with a BS degree in Electrical Engineering. He spent two and one half years running hundreds of open hole logs and one year running cased hole logs (including cement bond logs) with Schlumberger in Hobbs, NM. He moved to Farmington, NM in 1980 where he worked as a technical sales engineer. His primary task was insuring that the customer understood the logs they were using to make formation evaluation and cement integrity decisions. He developed course materials and taught numerous schools on formation evaluation using wireline logs, petrophysics and cement sheath evaluation logs for the local oil and gas operators, Bureau of Land Management and New Mexico Oil and Gas Commission regulators. When he joined Halliburton in 1984, he continued working with the oil and gas community in Farmington, NM. During the late 1980's to early 1990's, Mike was involved with many operators in the San Juan Basin who were evaluating the quality of the cement sheath in older wells and mitigating behind casing gas migration. In 1992 Mike relocated to Denver to continue in the technical engineering role with customers in Denver and throughout the Rocky Mountain states. He retired from Halliburton in 2010 and has been working as an independent consultant and formation evaluation specialist globally. Mike is a registered professional engineer in Colorado and New Mexico.

II. Introduction

The conclusions and findings reported in the December 2011 EPA "Draft Report, Investigation of Ground Water Contamination near Pavillion, Wyoming," are primarily based on the water quality testing results from two wells drilled by EPA. During the drilling and grouting of the two wells, EPA MW01 and EPA MW02, there were several instances where the groundwater and adjacent sandstone lenses were contaminated by the drilling mud and grouting practices. This report reviews the daily driller's

commentary during the drilling and grouting of these two wells to point out the serious problems with these drilling mud and grouting practices. It could be very difficult, if not impossible, to rehabilitate these two wells for water quality monitoring purposes.

III. Project Scope and Objective

The objective of this study was to:

> Evaluate the drilling and cementing operations for the EPA wells, MW01 and EPA MW02.

IV. Findings

As explained below in further detail, this review concludes that EPA's monitoring wells MW01 and MW02 were not properly designed, drilled and completed. As a result, cement has come in contact with the water-bearing sands being tested and both wells are contaminated. Neither of these wells, in their current condition, is a reliable water quality monitoring well. Rehabilitating these wells to serve as groundwater monitoring wells to detect constituents to part per billion levels would be difficult, at best. Rehabilitation would require acidification of MW02 to clean cement off the well screen and repeated flushings of both wells with clean water. Even then, because the sandstones being tested have been contaminated with cement and possible other materials, sufficient cleansing may not be achievable.

There are multiple reasons to believe the screen and the screened interval in MW02 are fouled with drilling mud and cement. At least 50 gallons of cement were lost at the screened interval. It also appears that the screen got stuck before it reached the bottom of the wellbore or was not lowered to the bottom of the wellbore. There was 17' of open borehole below the screen. During the cementing of the MW02, the EPA pumped at least "fifteen feet" of cement below the screen. There is no suggestion the screened interval is isolated from this cement operation.

The story at MW01 is simpler, but also a significant cause for concern. Five hundred ninety eight gallons of cement are unaccounted for in the screen interval. One source of high pH in MW01 could be the fact that soda ash was used as a mud additive during the drilling of this well for the purpose of raising the pH. (The Draft EPA Report suggests soda ash was used in both wells.) The cement slurry would also be a source of high pH in both wells.

In addition, neither well was properly designed to isolate the screened interval from cement slurry related impacts to the water bearing zone being tested above and, in the case of MW02, below the screen.

V. Review of the Drilling and Cementing of the EPA MW01 and EPA MW02 Wells

The EPA draft report indicated high pH in the water quality monitoring results for MW01 and MW02. Based on my review of the well completion report for MW01 and MW02, all of the available information points to the source of this contamination as the cementing practices used in the

construction of these wells and the location of the screens within the water bearing zones used for testing.

The screen in EPA MW01 was located near the base of a sand package (with interbedded shales). The volumetric analysis of the annular hole volume (the volume of the space between the casing and the borehole) and the pumped cement volume suggests that enough cement was pumped to fill the annular space back to the surface. However, the actual top of cement was located at 98'. Therefore, at least 598 gallons of cement was lost into the formation somewhere between the original cement top and the top of the cement cap placed on the basket above the screen at 748'. The pressure gradient of the cement column is approximately 0.81 psi/ft. This would be enough to overcome the closure pressure of most of the sands in this wellbore causing cement to break into the sand. The most likely location in the borehole for this cement loss to happen is to go into the sand in which the 20' screen is placed. Cement was also placed in contact with the sand being tested. These cementing operations are problematic for any detailed testing conducted on this water chemistry. Figure MM-1.

The cementing of the MW02 was even more problematic. First, there is no mention of running a cement basket on top of the screen to prevent cement from contaminating the sand targeted for testing. Second, the screen and casing were not lowered all the way to the bottom of the borehole. The open hole logs, which did not reach the bottom of the borehole, indicate the borehole diameter is essentially the same size as the screen. This interval was noted in the driller's log as having swelling problems while drilling the borehole. There was no mention in the driller's log as to why the screen was not run to the bottom of the borehole. Perhaps, the screen became stuck before getting to bottom.

The first attempt of isolation of the cement from the screen was on June 27, 2010 by lowering the Trimie pipe to 960' (the same depth as the top of the screen) and pumping 100# of sand ahead of 50 gallons of cement. Based on the driller's log chronology, this attempt failed, leaving 50 gallons of cement somewhere below the top of the screen. The daily drillers log on June 30, 2010 says that the "Trimie pipe was run to bottom." But, no mention was made of whether this operation took place in the annulus or through the screen. They tried to pump sand to bottom through the Trimie pipe with water but were unsuccessful. They decided to pump 15' of cement with calcium and noted that it was a successful operation. No actual depths were mentioned in the driller's record. It is assumed that cement was placed against the formation being tested to plug off the 17' of borehole below the screen. Figure MM-2. However, in the EPA Draft Report, the wellbore diagram of the MW02 noted mud and cuttings were below the screen, which is contradictory to the driller's log. As in MW01, cement was also placed against the formation being tested and, in this case, below the screened interval as well.

Grouting of the well the second time started on July 1, 2010 by lowering the Trimie pipe to 960' – the top depth of the screen – to begin the grouting operation. It is likely that the cement being pumped in the annulus between the casing and borehole came into contact with the screen as there was nothing to prevent this from happening. During the daily chronology of events, there was no record of a measured cement top after the grouting. Based on the volumetric analysis of the cement pumped and the annular volume between the casing and the borehole, there was not sufficient cement pumped to completely fill the annular space. Furthermore, the cement contamination of the screen can also be inferred based on the very low flow rates from this well and the details of wellsite activity in the daily report. It is notable that this well was repeatedly pumped or bailed dry indicating very little fluid entry

into the wellbore. This further supports the conclusion that the screen in this well has been fouled with cement.

Additional chronological detail from the drill log daily reports, discussed below, supports this analysis.

VI. Summary Chronology of Drilling and Cementing the EPA MW01 and EPA MW02 Wells

I have read through the daily reports concerning the drilling and cementing of the two EPA wells. Both wells were called MW01 which caused a bit of confusion initially. So in this section, I'll refer to the well names by the EPA name and the landowner name.

1. Drilling and Cementing of the EPA MW01 (Randall)

The EPA MW01 (Randall) was drilled to a total depth of 990'. The base of a sand package (with interbedded shales) was at 800' which was the target for the testing. The portion of the borehole below this sand was filled with cement to 979' in two attempts (Figure MM-1). The 20' of 8.5" screen, grout basket and 4" casing were lowered to a depth of 785'. The Trimie pipe was lowered to 761' (4' above the grout basket) where "1 drum" of cement was pumped. The cement was tagged at 748' and the casing annulus was cemented (grouted) with 14 yards (378 cu ft) of cement. The annular volume from the basket to the surface is 350 cu ft. The top of cement was tagged at 98' and filled to the surface with 1.5 yards of cement. Volumetric analysis of the cement column from 98' – 748' was 298 cu ft. Since 378 cu ft of cement was pumped, 598 gallons of cement was missing. The most likely sand that would have taken the cement would be the sand at the bottom of the cement column which would have had to hold the most pressure. This is the sand where the screen is set (Figure MM-1).

Concerning the drilling fluids, in EPA MW01 (Randall) soda ash was used in the drilling mud. Soda ash is used for raising the pH to balance the alkalinity in the mud system. The amount of mud that was invaded into the formation is unknown because the drilling was only conducted during the day and mud levels were not reported on the daily reports.

The chronology of the cementing (grouting) events for the EPA MW01 (Randall) is tabulated below.

8/02/10	Trip in to 990' and pump cement to fill rathole
8/03/10	Found cement top at 831'
8/04/10	Trip in to 831', Pumped 16 sacks cement
8/05/10	Found TOC at 797'. Trip in with screen, grout basket and 4" casing to 785'. Trip in with Trimie pipe to 761', pump "1 drum" of cement ~4 sacks? Estimated fill of 10.2' above the basket (765')
8/06/10	Trip in to find TOC at 748'. Grout hole with 14 yards (378 cu ft) cement. Annular hole volume from surface to 748' is 350 cu ft.
8/11/10	Run in hole to 785' and jet hole

8/12/10	TOC tagged at 98' in annulus. Actual fill volume was 298 cu ft. Lost 80 cu. ft. (598 gallons of) cement into formation most likely in the sand being tested. 1.5 yards of cement was pumped to top off to fill to surface.
8/13/10	Blow out total of 7,369 gallons of water throughout the day
8/14/10	High methane on LEL monitor ~30% leave well open over weekend to reduce methane presence
8/16/10	Methane on LEL was at 35%
8/18/10	Pressure well to 50 psi with nitrogen. Blow back well with spikes of 40% methane on LEL meter
8/25/10	Blow down methane to safe level. Run pump in hole to 763.3'
8/26/10	Pump test 1491 gallons

2. Drilling and Cementing of the EPA MW02 (Locker)

The EPA MW02 (Locker) well was drilled to a total depth of 997'. When logged, the logging company tagged the total depth of the well at 980'. The drilling records show this was a tight spot when tripping pipe out to log the well. Twenty feet of 8" screen and 4" casing was then run to a depth of 980', 17' from the bottom of the borehole (Figure MM-3). It should be noted that a grout basket was not reported as being run on the casing string. The open hole log indicated the depth range where the screen was located had a caliper reading of 8.25" – 8.5". This is a very tight tolerance for this size of equipment. No comments were noted in the daily report why the screen was not run to the total depth. The first attempt to grout the well was to run the Trimie pipe to 960', the top of the screen, and pump 100# of sand (1 cu ft) and 50 gallons of cement. If this grouting was successful, the top of the cement would have been at 920' basically grouting in the Trimie pipe. The Trimie pipe was pulled free using the blocks on the rig twice before it was pulled out of the annulus. The Trimie pipe was run to "bottom" of the hole. No mention was made whether this was inside the casing below the screen, or in the casing annulus. I'm assuming that the 15' of grout was pumped below the screen in the open hole below the screen. Since no volumes of cement pumped were mentioned, it's not possible to calculate the cement fill and there was no mention of tagging the cement pumped below the screen. The question of over displacement would also be a concern given the pumping volume measurements on a water well drilling rig.

Next in the chronology, the Trimie pipe was run to 960' again, the top of the screen. If the first attempt of protecting the grout from entering the screen had succeeded, the Trimie pipe would not have been able to get that deep. The cementing was conducted in 14 cycles of 15 sacks of cement. The first cycle of grouting most likely grouted the screen and contaminated the zone being tested with cement. The total volume of cement pumped was 247 cu ft. The annular volume between the casing and the borehole between the surface and 960' is 440 cu ft. There is no mention of tagging the top of cement after the grouting in the drilling chronology. It is doubtful the casing annulus is completely filled with cement. After the cementing, the well was swabbed and blew dry with no immediate water entry.

Over the next 10 days, it was reported that the rig crew bailed approximately 103 gallons of water out of the well. This all points to the screen being damaged with cement or swelling formation fines.

The chronology of the cementing (grouting) events for the EPA MW02 (Locker) is tabulated below.

6/27/10	Run 20' screen and 4" csg to 980' Run Trimie pipe to 960' Pump 100# sand and 50 gal cement (This should have filled annulus to 920' if it was successful. There is 17' of hole below the screen. It is doubtful this was successful as they ran Trimie pipe to 960' on 7/1/10)
6/28/10	Trimie pipe is stuck – pull free with rig
6/29/10	Trimie pipe stuck again – pull free with rig Trip Trimie pipe in hole (no mention of in annulus or in casing)
6/30/10	Tripping Trimie pipe to "bottom" Depth not reported Attempt to pump sand – unsuccessful Pump 15' grout seal Two options 1) Grout was pumped below the screen in the borehole and into the formation being tested making the test results questionable and possibly over displacing cement into the screen. 2) 15' of grout was pumped in the annulus above the screen. Option 2 is not likely given the report log on 7/1/10.
7/01/10	Ran Trimie pipe in annulus to 960' Pumped 14 cycles of 15 sacks of cement total of 247 cu ft Annular fill volume between casing and borehole 2.18 ft /cu ft Estimated TOC at 419' if the cement was uniformly filling the annulus
7/16/10	Trip in to 980' swab and blew well dry. No water entry.
7/17/10	Trip out of hole. Fluid level at 886'
7/20/10	Methane check 110 ppm static water at 771.2. Bail water to 821.4'. Water inflow 0.6" in 3 minutes
7/21/10	Bailed 64 runs static water level at 970'
7/22/10	2,000 ppm methane on well opening static water level at 938'. Swabbed screen and gained 5' of water. Bailed well dry
7/23/10	Bailed well dry
7/24/10	Static water level at 928'
7/26/10	Bailed 103 gal
7/27/10	Well opened having high methane reading LEL at 10% (50,000 ppm)
9/09/10	Fill well with water and run pump
9/11/10	Lower pump to 975'. Recovered 34' of water overnight. Added 200 gal water and pumped down to 944' and take water samples.

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Randall MW-1 (EPA MW01)

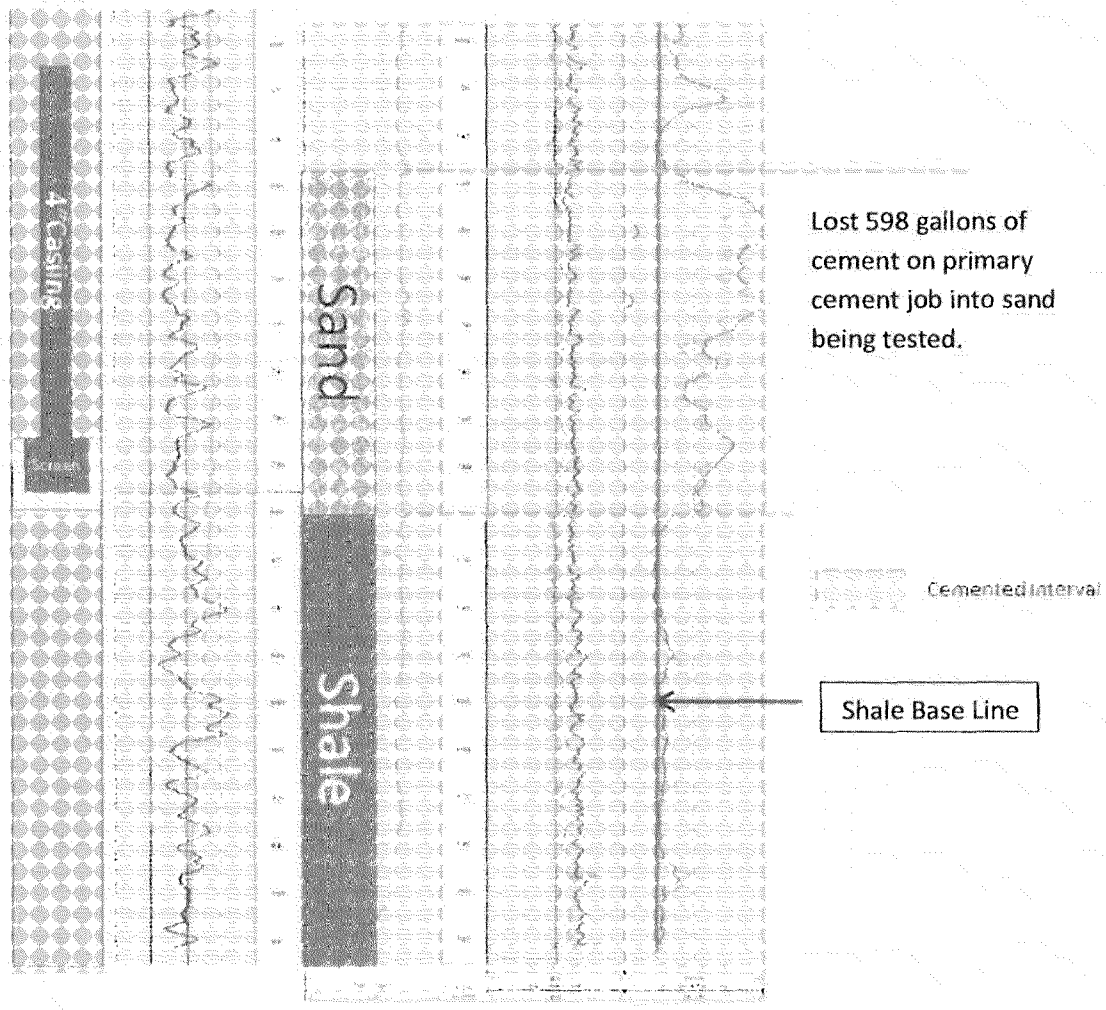
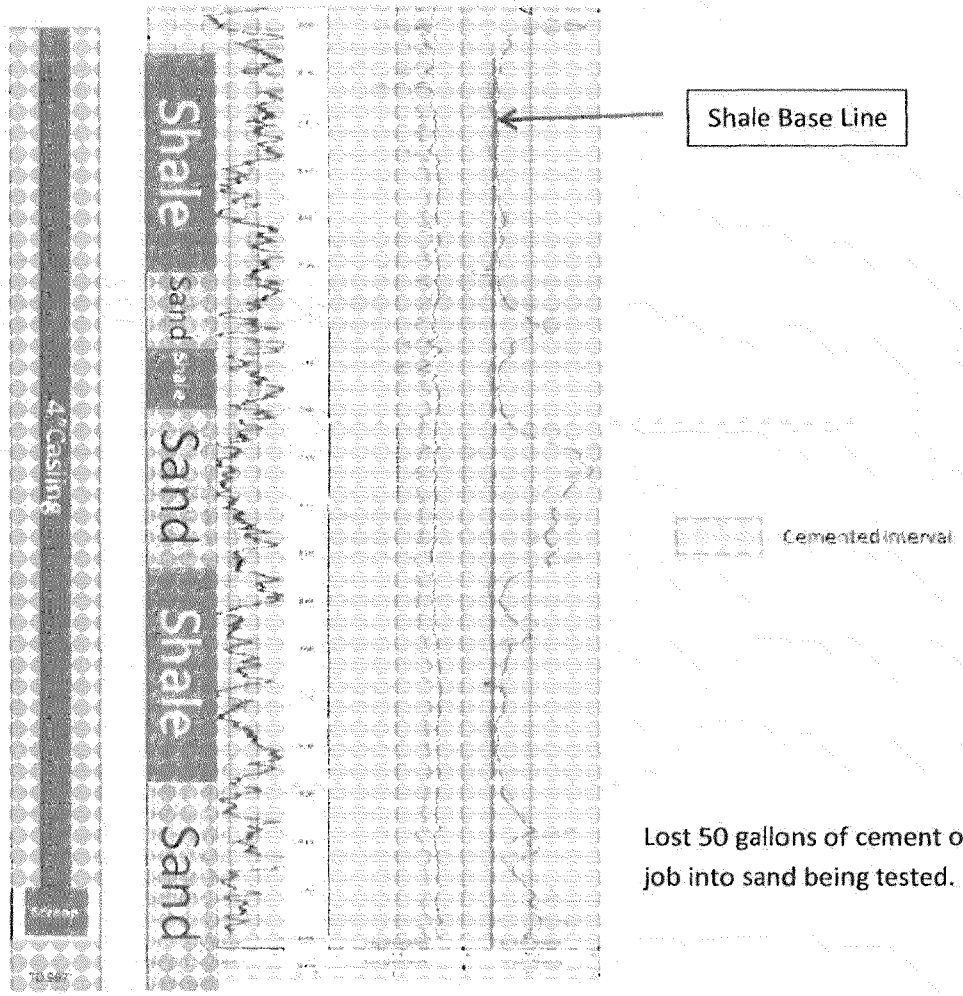


Figure MM-1. Location of the screen and cemented casing in the EPA MW01. Cement slurry was placed in contact with the water-being sand being tested.

LOCKER MW-2 (EPA MW02)



Lost 50 gallons of cement on primary cement job into sand being tested.

Figure MM-2. Location of the screen and cemented casing in the EPA MW02. The screen is fouled and the water-bearing sands are in contact with the cement slurry.

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EPAPAV0002560

Stimulation Petrophysics Consulting, LLC

Attachment MM-1

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Professional Experience

Mike is the president and founder of Stimulation Petrophysics Consulting, LLC. He has over 36 years of oil field wireline logging and formation evaluation experience. Starting in West Texas, his career path led him to New Mexico where he began working with tight gas sands and shale reservoirs. While in Farmington, NM, he witnessed the birth of the coalbed methane play and developed methods to evaluate coalbed methane potential using wireline logs. Building on this experience, he also developed methods to evaluate shale reservoirs using wireline logs. Since one key technology in all unconventional reservoirs is hydraulic fracture stimulation treatment, he worked on methods to improve the estimation of the mechanical rock properties used in hydraulic fracture stimulation models and drilling design models.

During his 25 year career with Halliburton, he integrated these techniques for the analysis of conventional and unconventional reservoirs with a specific focus toward reservoir characterization and mechanical rock properties used in the stimulation treatment design from wireline logging measurements into a single petrophysical model.

Mike directed the development of the software model used by Halliburton throughout the world to evaluate Tight Sands, Shale Gas, Shale Oil and Coalbed Methane. He was also a leader of a multi-disciplinary team to identify completion and stimulation "best practices" by conducting studies integrating petrophysics, stimulation techniques and production. Mike has been involved with over 20 technical papers on formation evaluation and one text book on coalbed methane.

Mike holds a Bachelor of Science degree in Electrical Engineering from the University of Missouri – Rolla, 1976, and is a registered professional petroleum engineer in New Mexico and Colorado, USA.

Stimulation Petrophysics Consulting, LLC June 2010 - Present
President and Founder

- Offers Petrophysical Consulting Services including wireline job planning, digital data preparation, data QC, formation evaluation, reservoir characterization, resource assessment for conventional and unconventional reservoirs, mechanical rock property and rock strength evaluation for stimulation design and drilling applications, digital log analysis project maintenance, customized petrophysical model creation from core data and final reporting. Provides workshop training on basic log analysis, unconventional reservoir analysis and Geographix Prizm modeling

- Presented and taught Shale Evaluation Workshop at the AAPG, April 2011

- Presented and taught a customized in-house Unconventional Reservoir Analysis Workshop, October 2011

Realm Energy International June 2010-November 2011
Chief Operating Officer

- Performed the duties of a Chief Operating Officer of a public company (investor relations, meeting with government officials and potential JV partners)
- Led an integrated team of geoscientists to explore for shale gas and shale oil in France, Poland, Germany and Spain. Realm acquired 5.5 million acres of prospective shale acreage before being acquired by San Leon Energy

Halliburton January 2003-June 2010
Technical Professional Manager

- Led a team of professionals in multi disciplinary hydraulic fracture optimization studies to identify key technologies or practices that improve well production and improve the assets net present value
- Authored Halliburton's ShaleLOG evaluation model used worldwide with commercial value in excess of $1MM/year revenue
- Involved with completion optimization studies for emerging plays in tight gas and unconventional reservoirs throughout the Rockies, Europe, South America, Saudi Arabia and Australia

Principle Technical Professional January 1995- December 2003

- Developed the StimLOG evaluation model used worldwide to evaluate wells for stimulation and production modeling
- Petrophysist member of the initial Sigma Evaluation group within Halliburton to integrate log analysis, stimulation modeling and reservoir simulation as a systematic approach to benchmark and demonstrate the effectiveness of applying new technology or completion practices to overcome reservoir challenges
- Founding member of the North America Shale team within Halliburton

Senior Sales Engineer – Denver April 1992-December 1995

- Worked with major accounts on logging and perforating recommendations and operational logistics throughout the Rocky Mountain states

Senior Field Sales Engineer September 1984-April 1992

- Directed sales and oversaw operations in the Farmington, NM area for logging and perforating
- Successfully re-introduced logging operations in Vernal, Utah
- Taught numerous OH and CH logging schools
- Initiated CBM log analysis model in Halliburton

Schlumberger
Field Engineer – Sales Engineer June 1976-July 1984

- Logging Engineer in Hobbs, NM working SE New Mexico and Permian Basin
- Division Staff Engineer – Midland, Texas overseeing introduction and training of the digital logging units
- Sales Engineer – Farmington, NM and Denver, CO

Stimulation Petrophysics Consulting, LLC

Education

University of Missouri – Rolla (1972-1976) BS Electrical Engineering

Professional Affiliations, Certifications and Associations

Member SPE – 26 years
SPWLA – 25 years
AAPG – 3 years
Registered Professional Engineer New Mexico (10699) and Colorado (39264)

Personal Information

I reside in Centennial, Colorado with my wife, Nadine, whom I have been married to for 29 years. We have three grown children with careers in the software industry and in the Aerospace industry. I enjoy cycling, playing bluegrass banjo, wood turning and water gardening.

Attachment MM-2

Technical Accomplishments

Papers/Articles Written

Coalbed Methane

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