HADAWAY
CONSULTING & ENGINEERING, LLC
Since 1982

To: Panoche Energy Center and the United States Environmental Protection Agency Region 9

Date: 2019-11-07

Subject: Opinion on Drilling Mud Remaining in Plugged and Abandoned Wells.

To Whom it May Concern:

My name is Allen Hadaway. I am a prior owner and current senior consulting engineer at Hadaway Consulting & Engineering, LLC in Canadian, Texas. I am a registered professional engineer in Texas (TX # 61256) and my resume is provided with this statement in Attachment A. I have 37 years of direct experience in the drilling, completion, testing, stimulation, production, and plugging and abandonment operations involving oil and gas production wells and saltwater disposal wells.

As part of my well operations experience, I have been involved as an engineer, engineering manager, and on-site engineering supervisor during approximately 20 re-entries of plugged and abandoned oil and gas wells. The time period elapsed from plugging and abandonment to re-entry of these wells ranges from one year to 30 years. The range of depths of these re-entries is from 3,000 feet to 14,000 feet measured total depth (MDTD). The purpose of these re-entries was for recompletion of the wells for hydrocarbon production and/or conversion to saltwater disposal wells. These re-entry projects were located in the midcontinent region of the United States including the states of Texas and Oklahoma. These wells were all located in areas having consolidated sedimentary bedrock similar to that found in the Central Valley of California. The pre-existing wellbore configurations of these re-entries included surface casings set at a depth ranging from 250 feet to 2,500 feet MDTD. In addition, a subset of these re-entries had intermediate casing set at a depth ranging from 4,500 feet to 12,000 feet MDTD.

All of these well re-entries had water-based drilling mud left in the wellbore when originally plugged and abandoned. The range of drilling mud weights left in these wellbores (when plugged) varied from 9.0 to 14.0 pounds per gallon (PPG). During re-entry none of these wells demonstrated an absence of mud, but might show a modest fall back in the mud depth of approximately zero to 200 feet. The mud remaining in the wellbores was generally observed to be thick and semi-rigid (similar to thick toothpaste) and contained essentially the original mud qualities present when emplaced, but with a much higher mud weight, gel strength, and viscosity due to partial water loss. In general, the typical well re-entry procedure is described below (this is very general procedure):

- MOVE IN AND RIG UP WELL SERVICE UNIT OR DRILLING RIG.
- PICK UP DRILL BIT AND BOTTOMHOLE ASSEMBLY AND DRILL/WASH AND REAM DOWN EACH JOINT OF DRILL PIPE (DUE TO THE THICK/SEMI-RIGID NATURE OF THE MUD IN THE WELLBORE). CIRCULATE AND CONDITION MUD RETURNS WHILE WASHING AND REAMING.
- CLEAN OUT TO CEMENT PLUGS LEFT INSIDE CASING AND TAG CEMENT PLUG. PRESSURE TEST CEMENT PLUG AND CASING. DRILL OUT CEMENT PLUG. CONTINUE TO WASH AND REAM AND CIRCULATE AND CONDITION MUD AND REPEAT PROCEDURE FOR ALL CEMENT PLUGS LEFT INSIDE CASING.

- ONCE OUT OF CASING AND INTO OPEN-HOLE SECTION, WASH AND REAM AND CIRCULATE EACH JOINT OF DRILL PIPE AND CIRCULATE AND CONDITION MUD RETURNS. WASH AND REAM AND CIRCULATE TO MDTD. CIRCULATE AND CONDITION MUD AND PREP FOR ADDITIONAL ACTIVITIES INCLUDING OPEN-HOLE LOGS, ADDITIONAL TESTING, AND/OR RUNNING AND CEMENTING PRODUCTION CASING/LINER.

During the re-entry process, the drilling and/or plugging mud that was in the wellbore is circulated out of the hole into the mud pits and reused in the re-entry process. This is because the mud that is circulated out of the wellbore still retains the primary fluid properties to be considered a viable drilling mud. These primary fluid properties consist of: 1) mud weight, 2) viscosity, and 3) gel strength. Based on my experience, the mud circulated out of the wellbore most commonly needs to be treated with fresh water in order to reduce the viscosity and mud weight. Generally, lignite and/or a deflocculant such as Desco (thinners to reduce the gel strengths), water loss control additive (such as Drispac), and pH elevators (typically sodium hydroxide) are used to treat the returned mud. Overall, the most common treatment of this mud circulated out of the wellbore is the addition of fresh water and lignite to reduce the viscosity and gel strength that have increased significantly due to the passage of time, partial water loss, and exposure to increased temperature.

During the re-entry process I have observed that the deeper we go into the wellbore the properties of the mud in the wellbore change in the following manner: 1) mud weight has increased (due to partial solids settling), 2) viscosity has increased (presumably due to loss of water in the mud due to hydrostatic pressure and temperature increasing with depth), and 3) gel strength has increased (also presumably due to loss of water due to hydrostatic pressure and temperature increasing with depth). It should be noted that although gravity settling and stratification of the mud column may occur, the overall weight of the hydrostatic column is unchanged as it will be heavier on the bottom and lighter on the top instead of uniform throughout.

During any drilling operation, the viscosity and gel strengths of the drilling mud are regularly tested and gel strengths are reported in units of pounds per 100 feet^2 of borehole surface area. Gel strengths are most commonly measured for 10-second and 10-minute intervals (less common is the 30-minute test) utilizing a rotating viscometer (Fann V-G Meter). Based on my experience and from reviewing mud reports generated on many projects, the results of these gel strength tests for water-based drilling mud encountered during a typical drilling operation are as follows: 10-second gel strength is from 2 to 8 pounds per 100 feet^2 and for the 10-minute test is 12 to 20 pounds per 100 feet^2. This follows the convention for water-based drilling fluid, as it is known in the industry that the gel strength of the mud increases with time.

My experience with the approximately 20 re-entry projects that I have performed indicates that the viscosity and gel strength have increased significantly with the passage of time under wellbore conditions. As such, based on my experience and first-hand observations as described above, it is my opinion that the gel strengths of drilling and/or plugging mud returned from the wellbore during a re-entry have increased by at least a factor of 10 times from the 10-minute testing interval results mentioned above. The returned mud is thick, viscous, and often semi-rigid and retains its fluid properties necessary for continued use but must be thinned and conditioned. It is also my opinion that the basic mud properties including mud weight, viscosity, and gel strength of the drilling mud left in the hole at the time of drilling and/or plugging and abandonment offer more than an adequate seal to prevent entry of fluids into the plugged well bore. This is due to the inherent nature and performance characteristics of the mud combined with the borehole mud cake that is produced by design on the surface of the borehole during the drilling process. Additonally, I have never re-entered a well where the mud has disappeared or fallen back more than 200 feet. Mud is always present in the borehole with minimal fall-back, and over time the

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mud properties of weight, viscosity, and gel strength only increase due to the static nature of the wellbore and exposure to subsurface pressure and temperature conditions.

2015/11/07

STATE OF TEXAS
ALLEN C. HADAWAY
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Hadaway Consulting & Engineering, LLC

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Since 1982

Attachment A

Allen C. Hadaway, P.E. Résumé

HADAWAY ENGINEERING, INC.

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ALLEN C. HADAWAY, P.E.

Allen C. Hadaway, P. E. is a Registered Professional Engineer in Texas (# 61256) and has 37 years of experience in oil and gas well operations.

- ***HADAWAY ENGINEERING, INC., HADAWAY CONSULTING AND ENGINEERING, LLC, AND DRILLING, COMPLETION, AND PRODUCTION ENGINEERING CONSULTANT: 01-1990 TO PRESENT.***

  During this time period I have acted as Operations Manager for clients in the following service areas:

  - **Engineering**
  - **Administration**
  - **Personnel Management**
  - **Accounting**
  - **Regulatory**

  In addition, I have been directly responsible for all the operations, engineering design, work plan implementation, and supervision of field personnel for:

  - **Well Drilling, completion, workover, and recompletion (including directional, vertical, SWD and horizontal wells).**
  - **Drilling, completion, and production of over 1,800 horizontal wells (sweet and sour) in three different basins, and in 17 different productive formations. The depths of these horizontal wells range from 1,800' TVD and 3,800' MD to 12,000' TVD and 22,000' MD.**
  - **Drilling, completion and production of over 800 vertical oil and gas wells (sweet and sour). The depths of these wells range from 900' to 24,600' with a shut-in pressure of 10 PSIG to 12,000 PSIG.**
  - **Drilling, completion, and facilities design of lease and commercial Class II SWD wells with injection rates of 50,000 BPD.**

- **Drilling, completion, workover, and facilities design of commercial Class II disposal wells at petrochemical plants.**
- **Designed and implemented production enhancement methods such as coiled tubing gas lift, conventional gas lift, downward injection electrical submersible pump, and many others.**
- **Designed and implemented and installed gas-gathering systems with a capacity of 50,000 MCFPD.**
- **Designed and implemented oil and water gathering systems with a capacity of 50 MBPD.**

I have also been hired as an expert witness in the oil and gas industry and researched and submitted testimony in numerous cases for my clients. I have evaluated, purchased, and sold producing oil and gas properties for my clients. I have personally been involved in the design and implementation and on-site supervision of multiple well control projects in the Texas Panhandle and Western Oklahoma area.

I have experience with many types of oil/gas industry software such as, evaluation software, pressure transient analysis software, fracture stimulation software, nodal analysis software, and production enhancement software. I consider myself very proficient at learning any type of software application and using that software in my engineering designs.

- ***C.W. KELLEY JR. INC. PETROLEUM CONSULTANTS - DRILLING, COMPLETION AND PRODUCTION ENGINEER: 03-1985 TO 01-1990.***

During this time period my responsibilities included designing and preparing AFEs, workover procedures, drilling procedures, and completion procedures for oil and gas wells with a depth of 900′ to 24,600′. I was also responsible for the on-site supervision during the drilling, completion, and production of these wells.

- ***MESA PETROLEUM COMPANY - DRILLING, COMPLETION, AND PRODUCTION ENGINEER: 07-1982 TO 03-1985***

My job description, duties and responsibilities included all the engineering design involved in the drilling and completion of oil and gas wells from a depth of 900′ to 24,600′. These wells were in the mid-continent area of the USA. I was also required to be on the location during critical operations such as running and cementing production casing, perforating and fracture stimulations, and emergency conditions such as well blowouts. I was

involved in the design and implementation of a blowout control and subsequent kill of a blowout event with a 19,000' well in Beckham County Oklahoma.

- ***BS IN PETROLEUM ENGINEERING FROM THE UNIVERSITY OF OKLAHOMA WITH A MINOR IN MATHEMATICS: GRADUATION 05-1982.***

- ***UNIVERSITY OF OKLAHOMA - TEACHING ASSISTANT: 08-1981 TO 12-1981***

  Teaching assistant, lab assistant, and teaching aide to Dr. Ronald Evans for sophomore petroleum engineering courses.

- ***AMOCO PRODUCTION COMPANY - ASSISTANT DRILLING ENGINEER: 05-1981 TO 08-1981***

  Summer employment as an assistant drilling engineer. Area of responsibility was the Rocky Mountains division mainly around Evanston, Wyoming. Duties of responsibilities included designing casing strings, mud systems, and hydrogen sulfide contingency plans on 13,500' oil and gas wells.

- ***R AND H DRILLING CO. - DRILLER: 05-1978 TO 09-1978***

  Summer employment as a driller on a small double drilling rig in Oklahoma. The drilling rig had a maximum depth capacity of 5,000'.

- ***DIAMOND M DRILLING CO. – OFFSHORE DERRICKMAN: 09-1977 TO 01-1978***

  Employment as a derrickman on rig #33, which was an inland barge rig. The drilling rig had a depth capacity of 25,000'. Area of employment was in the inland waters of south Louisiana.

- ***ZAPATA OFFSHORE – OFFSHORE FLOOR HAND AND ROUGHNECK: 05-1977 TO 09-1977***

  Summer employment as a floor hand and roughneck on the ZAPATA Yorktown, which was a semi-submergible drilling rig with a depth capacity of 25,000'. Area of employment was off the coast of Louisiana.

- ***BAKER AND TAYLOR DRILLING CO. - FLOOR HAND AND ROUGHNECK: 05-1976 TO 08-1976***

  Summer employment as a floor hand and roughneck on rig #3. The depth rating on rig #3 was 18,000'. Area of employment was Hemphill and Wheeler Counties near Canadian, Texas.

- ***CANADIAN ROUSTABOUTS - ROUSTABOUT: 05-1975 TO 08-1975***

  Summer employment as a roustabout, performing maintenance on producing wells in the Canadian, Texas area.

INDUSTRY SCHOOLS ATTENDED:

1. **Prentice and Records drilling school in Lafayette, Louisiana.**
2. **Current certification in blowout prevention at the blowout school at the University of Oklahoma.**
3. **Numerous service company seminars on mud systems, drill stem testing, open hole logging, log analysis, cementing, stimulation, reservoir analysis, and pressure transient analysis.**
4. **Numerous computer software education schools such as power tools, FEKETE software, and many others.**

REFERENCES:

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