APPENDIX B

Farmington Field Office Slickwater Stimulation Water Use Update

ASSUMPTIONS

This update evaluates the potential water requirements for the development of the Mancos Shale formation and Gallup Sandstone member (Mancos-Gallup development) within the San Juan Basin using the slickwater stimulation technique. Current industry trends in unconventional reservoir development have shifted to drilling of long (1- to 3-mile) horizontal laterals that are stimulated using large volumes of low-viscosity water-based fluids (slickwater stimulation). This development scenario evaluates the projected water demand of Mancos-Gallup development based on current industry expectations of lateral density. No evaluation of other factors (i.e., execution pace, reservoir recovery factor, economic results, alternative completion techniques) are made in this model.

PURPOSE OF THE UPDATE

Fluid mineral development in the San Juan Basin has experienced technological advances with the introduction of slickwater stimulation beginning in 2015. Since the development of the *RFD Scenario for Oil and Gas Activities, Mancos-Gallup RMPA Planning Area* (Mancos-Gallup RFD) (Crocker and Glover 2018), additional information regarding the slickwater stimulation technique has been gathered by the BLM FFO. The 2018 Mancos-Gallup RFD presents the projected fluid mineral development potential for the Mancos-Gallup RMPA planning area, encompassing a total area of 4 million acres. Half of the total planning area (2 million acres) is located within one major horizontal oil and gas play, resulting in fluid mineral interest with "high" and "medium" development potentials (Crocker and Glover 2018).
The purpose of this update is to address the forecasted amount of water from the 2018 Mancos-Gallup RFD that may be used during Mancos-Gallup development utilizing slickwater stimulation in the San Juan Basin.

CONTEXT

The Colorado River Compact (The Compact) of 1922 determined how much water would be delivered downstream for use in the western states listed in The Compact. The remaining water is left to the individual states for allocation. It is the responsibility of NMOSE to allocate remaining useable water within New Mexico and to ensure that all water is used according to state regulations and correctly reported. The authority and regulation of NMOSE applies to water acquired for use in the production and operation of oil and natural gas wells. Water use is published every 5 years in the report titled *Estimated Use of Water in the United States in 2015*, most recently published in 2018 (Dieter et al. 2018).
See Section 4 of the Water Support Document for information on the volume of water that was used specifically for oil and gas wells in the San Juan Basin using information from the USGS water use report (Dieter et al. 2018).

The two general water types that may be used for slickwater stimulation are categorized as potable/fresh and non-potable. Any water that has TDS greater than 1,000 ppm has been defined as "non-potable" by the State of New Mexico (72-12-25 NMSA 1978); the BLM has identified anything less than 10,000 ppm to be protected in the casing rule of the BLM's Onshore Oil and Gas Order #2 (BLM 1988). Non-potable water is outside the appropriative processes and is mainly diverted for mineral exploration purposes. Conversely, any water that has less than 1,000 ppm TDS is potable/fresh. In general, potable water has a water right associated with it and is permitted and regulated by NMOSE and may or may not be adjudicated.

During the process of gathering information regarding slickwater stimulation, the FFO prepared a questionnaire to conduct industry interviews. The questionnaire focused on estimated water use during the

drilling, completion, and operation/production phases of oil and gas wells, with specific focus on water sources and water use associated with slickwater stimulation. The questions were used to help the BLM to determine how saline water is being utilized and to better understand the potential TDS levels within source water for the stimulation fluid. Onshore Oil and Gas Order #1 (BLM 2017) requires operators to identify adequate water sources for stimulation plans as part of their APD.

Based on results of the questionnaire, the FFO concluded that the water used for slickwater stimulation can have high levels of TDS for the technology to be effective. The majority of operators within the San Juan Basin limit their TDS levels to 50,000 ppm for use in a slickwater stimulation operation. The higher allowable TDS levels that are acceptable for slickwater stimulation expand the possible water sources beyond those that are traditionally used (e.g., surface water or groundwater) into non-traditional sources of water (e.g., non-potable groundwater sources).

Recently, the NMOSE received notices of intent to appropriate non-potable water from aquifers at depths 2,500 feet below ground level or greater. NMOSE has approved permits to drill wells within the San Juan Basin to withdraw non-potable connate water (groundwater) from the Entrada Sandstone formation for use as a potential source of water for slickwater stimulation operations. The Entrada Sandstone maximum depth is approximately 9,500 feet below ground level. Water contained in the Entrada Sandstone is highly saline (Kelley et al. 2014). As such, it is considered non-potable and has not been declared as an administrative aquifer by NMOSE. NMOSE is the agency responsible for water withdrawal permitting actions. Its notice of intent process includes a model-based evaluation of the potential effects of proposed withdrawals and the identification of possible requirements for applicants to obtain water rights to offset any depletions identified in NMOSE's analyses prior to applicants commencing diversions.

Other sources of non-potable water that can be utilized in stimulation are flowback fluid and produced water. Flowback fluid is a mixture of chemical proppant, water, and sand that flows back through the wellhead directly after stimulation activities. Generally, 10% to 40% of the initial volume utilized for stimulation activities returns as flowback fluid; of this, 10% to 40% is non-potable water that may be used in future stimulation activities. Produced water is naturally occurring water that exists in the formation that is being targeted for mineral extraction and is produced as a byproduct, thereby becoming produced water. Based on the results of the FFO questionnaire, after the initial flowback recovery of 10% to 40%, the remaining water used for stimulation returns to the surface through production activities at a slower rate of return.

METHODOLOGY FOR WELL COMPLETION TYPE DETERMINATION

To determine the well completion type, data from FracFocus is obtained for wells in the desired county and during the desired year. The individual well reports provides the well American Petroleum Institute (API) number and water use. If the water quality information includes nitrogen and water use is ~2.5 AF, then it is a nitrogen well (BLM 2021).

To determine if a well is slickwater, BLM Form 3160-4 is downloaded from the NMOCD website using the well API number and the NMOCD Well File Search form (NMOCD 2021). This form has information on if the well is new or recomplete. If the well is new, the water use is greater than 2.5 AF, and the chemical data does not include nitrogen, then the well is slickwater (BLM 2021). The chemical data for slickwater also includes a listing for guar gum.

METHODOLOGY FOR PROJECTED WATER USE

To gain the most current information, a questionnaire was distributed to local operators actively drilling and producing mineral resources in the San Juan Basin to gather information regarding slickwater stimulation and reservoir development.

Horizontal wells are currently stimulated during completion in short sections of laterals called stages. To date, 20 wells have been drilled using long laterals with slickwater stimulation within the FFO. The water volume and stage length were averaged from the 20 wells using the APD and data from FracFocus. The equation for calculating estimated water volume is as follows:

Total water volume = (stage water volume/stage length) × (number of stages/lateral length)

The total miles of lateral estimated to develop the Mancos Shale formation and Gallup Sandstone member are based on the 2,300 horizontal wells projected in the 2018 Mancos-Gallup RFD. On average, the wells would be stimulated in 2-mile laterals, which equates to approximately 4,600 miles, all of which are projected to be slickwater stimulated. For the 20 completed wells, the FFO calculated the average stage length to be 200 feet and the average water used per stage to stimulate the formation to be 1 AF (Table B-1).

According to the 20 APDs, the average lateral well bore is 1.5 miles in length for a horizontal well. The estimated water use is approximately 41 AF for slickwater stimulation. Advances in horizontal drilling and completion techniques in the San Juan Basin in the past 4 to 5 years have resulted in the ability to drill and complete horizontal laterals up to 3 miles in length (according to operator input). Horizontal well bores are stimulated in intervals; each interval is called a stage.

Refer to Table B-2 for the number of stages dependent on the length of the well bore and Table B-3 for the average water use of 1- to 3-mile laterals per completion.

Table B-1. Water use averages from 20 slickwater APDs from the FFO using FracFocus data.

Well Name/Operator	Water Usage Per Stage (gallons)	Stage Length (feet)
NEBU604_3H(BP)	517,171.19	201
NEBU602COM1H(BP)	444,653.34	149.6
NEBU604COM2H(BP)	535,124.92	200
NEBU604COM1H(BP)	526,524.65	200
NEBU605COM2H(BP)	551,075.29	205
NEBU605COM1H(BP)	427,903	165
SEscavdaUnit353H(Enduring)	160,437.94	176.64
EscavadaUnit302H(Enduring)	162,902.25	179.5
NEscavadaUnit316H(Enduring)	143,312.48	177.28
NEscavadaUnit330H(Enduring)	429,107.70	482.85
NEscavadaUnit317H(Enduring)	150,050.52	180
NEscavadaUnit318H(Enduring)	152,921.60	180
NEscavadaUnit331H(Enduring)	143,150.40	175.48
NEscavadaUnit315H(Enduring)	145,898.40	179.4
ROSAUnit641H(WPX)	468,363.91	207.3

Well Name/Operator	Water Usage Per Stage (gallons)	Stage Length (feet)
ROSAUnit643H(WPX)	338,364.25	202.3
ROSAUnit640H(WPX)	389,188.64	200.3
ROSAUnit642H(WPX)	330,273.30	212.7
PallucheHZMC1H(Hilcorp)	207,003.06	201.25
SanJuan29-6UnitCom601_1H(Hilcorp)	458,228.90	194.9
Average	**334,082.79**	**203.525**

Table B-2. Projected water use of slickwater wells in the New Mexico portion of the San Juan Basin (San Juan, Rio Arriba, and Sandoval Counties) by lateral length.

Lateral Length (feet)	Lateral Length (miles)	Number of Stages	Water Used (gallons)	Water Used (AF)
5,280	1.0	25.94	8,667,029.18	26.60
7,920	1.5	38.91	13,000,543.76	39.90
10,560	2.0	51.89	17,334,058	53.20
13,200	2.5	64.86	21,667,572.94	66.50
15,840	3.0	77.83	26,001,087.53	79.79

Table B-3. Average volume of water required to complete 1- to 3-mile laterals using slickwater stimulation in the Mancos Shale formation and Gallup Sandstone member.

Lateral Length (miles)	Number of Stages	Volume (AF)
1.0	26	27
1.5	39	40
2.0	52	53
2.5	65	67
3.0	78	80

CONCLUSIONS

The amount of water that would be required to completely develop 4,600 miles of horizontal wells in the Mancos Shale formation and Gallup Sandstone member via slickwater stimulation is estimated to be approximately 125,000 AF. The 2018 RFD estimates 2,300 horizontal wells may be developed between 2018 and 2037. Based on operator input, the horizontal lengths would range from 1 to 3 miles. Current technology allows operators to utilize water with TDS of 50,000 ppm, well above the NMOSE potable water threshold of 1,000 ppm. This allows for the use of currently non-traditional potable water sources, including the connate water within the Entrada Sandstone and recycled flowback water and produced water for use in slickwater stimulation activities.

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