U.S. Department of the Interior
Bureau of Land Management

# BLM Water Support Document for Oil and Gas Development in New Mexico

## BLM WSD 2020

**Prepared by:**
Jason R. Burgess-Conforti, Ph.D.
Physical Scientist

**U.S. Department of the Interior**
**Bureau of Land Management:**
New Mexico State Office
301 Dinosaur Trail
Santa Fe, New Mexico 87508
505-954-2000

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# CHAPTER 1. INTRODUCTION

## 1.1. Purpose of the Report

The intent of this document is to collect and present the data and information needed for water resources analysis to be incorporated by reference into National Environmental Policy Act (NEPA) documents, most specifically the proposed NEPA analysis related to federal oil and gas development under the jurisdiction of the Bureau of Land Management (BLM) New Mexico State Office. This includes federally managed oil and gas within the Pecos District, Farmington Field Office (FO), and Rio Puerco FO but does not include the Oklahoma FO due to differences in data availability and the resources needed to thoroughly analyze water quality throughout Oklahoma, Texas, and Kansas.

## 1.2. Report Organization

Chapter 2 is a brief summary of data available for the state of New Mexico. Chapter 3 summarizes water quantity and quality data for the Pecos District, which comprises the Carlsbad and Roswell FOs and the Hobbs Field Station. Chapters 4 and 5 summarize water quantity and quality data for the Farmington FO and the Rio Puerco FO, respectively. Chapter 6 summarizes how to use this report to inform analyses of water use at the oil and gas lease sale and project-specific level. Each chapter contains the references that are pertinent to the analysis.

Although this report focuses on water usage during the hydraulic fracturing process, water is also used for drilling fluid preparation, make-up water for completion fluids, rig wash water, coolant for internal combustion engines, dust suppression on roads/well pads, and equipment testing. Water use associated with stimulation activities (including hydraulic fracturing) comprises most of the water use, and water use data are currently unavailable for the previously mentioned uses. Analyses of surface water quality data are not provided in this document due to the lack of publicly available data throughout the state of New Mexico.

## 1.3. Updating of the Report

The BLM will update this report with new data as it becomes available. All FracFocus data on water use in this report was analyzed from 2014 to 2019 and will be updated annually. As these data are released the BLM will review them to consider if the cumulative analysis of water use requires updating. The State of New Mexico Office of the State Engineer (NMOSE) and U.S. Geological Survey (USGS) data, “Water Use by Category,” are updated every five years. The spill data reporting will be updated annually.

## 1.4. Notes on Data Sources/Information Used for this Report

### 1.4.1. Surface Water Quality

Surface water quality data from 2010 to 2019 were retrieved from STORET and NWIS for analysis in this report. However, the severe lack of publicly available surface water quality data within New Mexico impeded any beneficial use of these data. There were not enough spatially or temporally diverse data available for analyses that would provide additional information beneficial for evaluating oil and gas development. As such, there are no surface water quality data analyses included in this report.

### 1.4.2. Environmental Impacts of Hydraulic Fracturing on Surface and/or Ground Water Quality

The fate and transport of chemicals used during hydraulic fracturing is complicated and has been the subject of health concerns as oil and gas development continues throughout the United States. While the environmental impacts of hydraulic fracturing are relevant to the focus of this report, the complexity of this subject would require substantial discussion which would exceed the scope of this report.

Readers interested in understanding the environmental impacts of hydraulic fracturing should review the comprehensive EPA report “Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States” (EPA, 2016). In summary, this report presents scientific evidence that drinking water resources can be impacted by hydraulic fracturing under six differing conditions 1) water withdrawals during periods of low water availability; 2) spills of hydraulic fracturing fluids/chemicals and/or produced water; 3) release of hydraulic fracturing fluids from wells with inadequate casing; 4) direct injection of hydraulic fracturing fluids into groundwater; 5) discharge of insufficiently treated wastewater to surface water; and 6) contamination of groundwater from unlined storage/disposal pits. The BLM, New Mexico Environment Department (NMED), and the New Mexico Oil Conservation Division (NMOCD) have put in place numerous requirements for oil and gas producers to prevent the contamination of surface and groundwater resources in New Mexico.

# CHAPTER 2. STATE OF NEW MEXICO

In 2015, withdrawals for all water use categories across the State of New Mexico totaled 3,249,667 acre-feet (AF; Dieter et al., 2017; Table 2-1). Irrigation consumed the greatest amount of water within the state of New Mexico accounting for 82% (2,660,424 AF) of water use in 2015. Public water supply (9%) and mining (5%) consumed 293,467 and 163,901 AF, respectively. Water withdrawals within the state were split 50/50 between surface water and groundwater. Proportionally, thermoelectric power (82%) and irrigation (56%) used the greatest amount of surface water whereas the remaining sectors primarily consumed groundwater.

Annual water use by oil and gas wells throughout New Mexico increased more than eight fold, from 4,060 to 34,992 AF, between 2014 and 2019, with a corresponding increase in average water use from 6.0 to 36.8 AF/well (FracFocus, (2020); Table 2-2). The six-year average (2014-2019) water use is 23.6 AF/well. The proportion of federal to non-federal wells varies within a year and ranged from 13.4% to 47.7%. From 2014 to 2019, cumulative water use within New Mexico totaled 100,721 AF with federal wells comprising 26.8% (27,086 AF). From 2014 to 2019, 4,264 total wells (includes all ownership/management jurisdictions) were reported as completed with an average of 710 wells/year.

The chemical composition of water used during the hydraulic fracturing process varies due to differences in fracturing techniques used by oil and gas companies. The most commonly disclosed chemical used in Permian Basin from 2014 to 2019 wells was ethanol with 11,822 disclosures (Table 2-3). Other frequent disclosures include 1,2-propylene glycol (n=11,088), water (n=7,129), quartz-alpha (n=5,625), and methanol (n=3,457). There are 6,384 records of non-disclosed chemicals which includes chemicals listed as proprietary, confidential, and trade secrets. A typical oil/gas well uses approximately 20 to 25 unique chemicals during the hydraulic fracturing process but in some cases more than 60 distinct chemicals can be used.

**Table 2-1. State of New Mexico water use by category in 2015. Data obtained from Dieter et al., (2017); updated with additional information provided to the BLM from the NMOSE regarding water use of the Navajo Power Plant (BLM 2019).**

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Public Water Supply | 87,752[a] | - | 87,752 | 30% | 205,715 | - | 205,715 | 70% | 293,467 | 100% | - | - | 293,467 | 9% |
| Industrial | - | - | - | 0% | 3,811 | - | 3,811 | 100% | 3,811 | 100% | - | - | 3,811 | 0% |
| Irrigation | 1,485,112 | - | 1,485,112 | 56% | 1,175,312 | - | 1,175,312 | 44% | 2,660,424 | 100% | - | - | 2,660,424 | 82% |
| Livestock | 2,522 | - | 2,522 | 7% | 33,372 | - | 33,372 | 93% | 35,894 | 100% | - | - | 35,894 | 1% |
| Aquaculture | 6,109 | - | 6,109 | 23% | 20,929 | - | 20,929 | 77% | 27,039 | 100% | - | - | 27,039 | 1% |
| Mining | 19,550 | - | 19,550 | 12% | 44,111 | 100,240 | 144,351 | 88% | 63,662 | 39.0% | 100,240 | 61.00% | 163,901 | 5% |
| Thermoelectric | 30,637 | - | 30,637 | 82% | 6,872 | - | 6,872 | 18% | 37,509 | 100% | - | - | 37,509 | 1% |
| Domestic | - | - | - | 0% | 27,621 | - | 27,621 | 100% | 27,621 | 100% | - | - | 27,621 | 1% |
| **Totals** | **1,631,683** | **-** | **1,631,683** | **50%** | **1,517,744** | **100,240** | **1,617,984** | **50%** | **3,149,427** | **97%** | **100,240** | **3%** | **3,249,667** | **100%** |

[a] All water use data are presented in acre-feet/yr

**Table 2-2. Water use by oil and gas wells in New Mexico from 2014-2019 (FracFocus, 2020). Data are only presented for wells which report water use data.**

| Year | Federal Water Use | Non-Federal Water Use | Total Water Use | Federal Water Use (%) | Federal Cumulative Water Use | Total Cumulative Water Use | Average Water Use per Well | Total # of Wells | Produced Water |
|---|---|---|---|---|---|---|---|---|---|
| 2014 | 1,468[a] | 2,592 | 4,060 | 36.2 | 1,468 | 4,060 | 6.0 | 681 | 115,050 |
| 2015 | 4,083 | 4,475 | 8,558 | 47.7 | 5,551 | 12,618 | 14.4 | 596 | 116,696 |
| 2016 | 920 | 5,958 | 6,878 | 13.4 | 6,471 | 19,496 | 20.3 | 339 | 110,337 |
| 2017 | 3,385 | 11,128 | 14,513 | 23.3 | 9,856 | 34,009 | 24.5 | 593 | 114,487 |
| 2018 | 9,292 | 22,429 | 31,721 | 29.3 | 19,148 | 65,729 | 28.5 | 1,114 | 135,347 |
| 2019 | 7,939 | 27,055 | 34,994 | 22.7 | 27,086 | 100,723 | 36.8 | 950 | 159,539 |
| Totals | 27,086 | 73,635 | 100,723 | - | - | - | 23.6 | 4,264 | 751,455 |

[a]All water use data are presented in acre-feet

**Table 2-3. Twenty-five most frequently disclosed constituents in horizontal wells within New Mexico from 2014 to 2019. Data were obtained from FracFocus (2020) and are only presented for wells which disclose chemical data.**

| EPA Chemical Name | CAS Registry Number[1] | Number of Disclosures[2] | Median (mg/L) | Sum (Gg) |
|---|---|---|---|---|
| Ethanol | 64-17-5 | 11,822 | 20.0 | 567 |
| 1,2-Propylene glycol | 57-55-6 | 11,088 | 25.3 | 568 |
| Water | 7732-18-5 | 7,129 | 3,963 | 104,986 |
| Not-Disclosed | - | 6,384 | 27.5 | 640 |
| Quartz-alpha (SiO2) | 14808-60-7 | 5,625 | 80,246 | 17,907 |
| Methanol | 67-56-1 | 3,457 | 33.5 | 6.7 |
| Distillates, petroleum, hydrotreated light | 64742-47-8 | 2,838 | 264.0 | 41.2 |
| Hydrochloric acid | 7647-01-0 | 2,518 | 1,121 | 119 |
| Sodium chloride | 7647-14-5 | 1,798 | 51.5 | 34.6 |
| Guar gum | 9000-30-0 | 1,608 | 1,526 | 30.7 |
| Diammonium peroxydisulfate | 7727-54-0 | 1,451 | 35.6 | 1.3 |
| Ethylene glycol | 107-21-1 | 1,430 | 66.5 | 2.7 |
| Isopropanol | 67-63-0 | 1,409 | 5.0 | 1.6 |
| Propargyl alcohol | 107-19-7 | 1,254 | 0.9 | 0.1 |
| Glutaraldehyde | 111-30-8 | 1,237 | 59.1 | 4.5 |
| Sodium hydroxide | 1310-73-2 | 1,159 | 11.6 | 1.0 |
| Acetic acid | 64-19-7 | 994 | 29.1 | 39.9 |
| C12-16-Alkylbenzyldimethylammonium chlorides | 68424-85-1 | 940 | 12.5 | 0.9 |
| Solvent naphtha, petroleum, heavy arom. | 64742-94-5 | 858 | 10.1 | 0.3 |
| Citric acid | 77-92-9 | 839 | 21.4 | 0.9 |
| Sodium perborate tetrahydrate | 10486-00-7 | 832 | 74.2 | 2.4 |
| Glycerol | 56-81-5 | 822 | 109.3 | 0.7 |
| Alcohols, C12-16, ethoxylated | 68551-12-2 | 786 | 25.4 | 1.2 |
| Ammonium chloride | 12125-02-9 | 780 | 24.2 | 1.1 |
| Thiourea, polymer with formaldehyde and 1-phenylethanone | 68527-49-1 | 775 | 3.3 | 0.1 |

[1] 351 CAS registry errors

[2] 105,611 disclosures

# CHAPTER 3. PECOS DISTRICT

The BLM Pecos District Office, which oversees the Carlsbad and Roswell FOs and the Hobbs Field Station, encompasses over 9.3 million surface acres. Some data analyzed (e.g., FracFocus and USGS water use) are only available at the county level, as such, the term Pecos tri-county area may be used interchangeably with Pecos District (which denotes BLM administrative boundaries). The Pecos tri-county area encompasses Eddy, Lea, and the majority of Chaves Counties which includes approximately 4.3 million acres of federal mineral estate. The Permian Basin has been a producing oil and natural gas field since the early 1900s. New Mexico ranks fifth in the United States in the production of oil (Statista 2019). In 2019, it produced 329,439,684 barrels (bbl) of oil (NMOCD 2020a). Most of the Permian Basin that is open to oil and gas leasing is already leased for fluid mineral development.

This chapter presents information on existing and projected water quantity and water quality data for the Pecos District as summarized from information gathered from the following sources: 1) the Reasonable Foreseeable Development (RFD) Scenario for the BLM New Mexico Pecos District (Engler and Cather 2012; 2014), 2) data compiled from the 2015 USGS report, Estimated Use of Water in the United States in 2015 (Dieter et al., 2017), 3) FracFocus, a national hydraulic fracturing chemical registry managed by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission (FracFocus 2020), and 4) surface water quality obtained from the USGS National Water Information System (NWIS) and EPA STORET databases.

## 3.1. Water Quantity

### 3.1.1. Existing Surface and Groundwater Water Use

The 2015 USGS Report, Estimated Use of Water in the United States in 2015 (Dieter et al., 2017), lists total water withdrawals across eight water use categories: aquaculture, domestic, industrial, irrigation, livestock, mining, public water supply, and thermoelectric power. Total water usage in 2015 was 265,834, 183,910, and 170,672 AF for Lea, Eddy, and Chaves Counties, respectively (Table 3-1, Table 3-2, and Table 3-3). Total water use in the Pecos District Tri-County Area (analogous to the NM portion of the Permian Basin) was 620,416 AF (Table 3-4; Figure 3-1). Irrigation and mining activities consumed the greatest amount of water accounting for 75% (466,784 AF) and 15% (95,800 AF), respectively, of all water use within the Pecos Tri-County Area. Approximately 88% of all water used within this region originated from groundwater. Of that total, 99% of withdrawals were from saline sources. Most (87%) of mining-related water use occurred in Lea County, where mining comprised 31% of the total county withdrawals.

## Table 3-1. Lea County water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 11,423 | 0 | 11,423 | 4% | 11,423 | 4% | 0 | 0% | 11,423 | 4% |
| Domestic | 0 | 0 | 0 | 0% | 78 | 0 | 78 | 0% | 78 | 0% | 0 | 0% | 78 | 0% |
| Industrial | 0 | 0 | 0 | 0% | 166,099 | 0 | 166,099 | 62% | 166,099 | 62% | 0 | 0% | 166,099 | 62% |
| Irrigation | 56 | 0 | 56 | 0% | 2,870 | 0 | 2,870 | 1% | 2,926 | 1% | 0 | 0% | 2,926 | 1% |
| Livestock | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Mining | 0 | 0 | 0 | 0% | 325 | 81,642 | 81,967 | 31% | 325 | 0% | 81,642 | 31% | 81,967 | 31% |
| Public Water Supply | 0 | 0 | 0 | 0% | 1,827 | 0 | 1,827 | 1% | 1,827 | 1% | 0 | 0% | 1,827 | 1% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 1,513 | 0 | 1,513 | 1% | 1,513 | 1% | 0 | 0% | 1,513 | 1% |
| **County Totals** | **56** | **0** | **56** | **0.02%** | **184,135** | **81,642** | **265,777** | **99.98%** | **184,191** | **69.29%** | **81,642** | **30.71%** | **265,833** | **100%** |

[a] Water use data are presented in AF/yr.

## Table 3-2. Eddy County water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 15,077 | 0 | 15,077 | 8% | 15,077 | 8% | 0 | 0% | 15,077 | 8% |
| Domestic | 0 | 0 | 0 | 0% | 1,043 | 0 | 1,043 | 1% | 1,043 | 1% | 0 | 0% | 1,043 | 1% |
| Industrial | 64,054 | 0 | 64,054 | 35% | 89,994 | 0 | 89,994 | 49% | 154,048 | 84% | 0 | 0% | 154,048 | 84% |
| Irrigation | 34 | 0 | 34 | 0% | 1,289 | 0 | 1,289 | 1% | 1,323 | 1% | 0 | 0% | 1,323 | 1% |
| Livestock | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Mining | 0 | 0 | 0 | 0% | 1,169 | 10,993 | 12,162 | 7% | 1,169 | 1% | 10,993 | 6% | 12,162 | 7% |
| Public Water Supply | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 258 | 0 | 258 | 0% | 258 | 0% | 0 | 0% | 258 | 0% |
| **County Totals** | **64,088** | **0** | **64,088** | **34.85%** | **108,830** | **10,993** | **119,823** | **65.15%** | **172,918** | **94.02%** | **10,993** | **5.98%** | **183,911** | **100%** |

[a] Water use data are presented in AF/yr.

## Table 3-3. Chavez County water use by Category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 12,970 | 0 | 12,970 | 8% | 12,970 | 8% | 0 | 0% | 12,970 | 8% |
| Domestic | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Industrial | 9,854 | 0 | 9,854 | 6% | 136,784 | 0 | 136,784 | 80% | 146,638 | 86% | 0 | 0% | 146,638 | 86% |
| Irrigation | 224 | 0 | 224 | 0% | 6,378 | 0 | 6,378 | 4% | 6,602 | 4% | 0 | 0% | 6,602 | 4% |
| Livestock | 0 | 0 | 0 | 0% | 1,782 | 0 | 1,782 | 1% | 1,782 | 1% | 0 | 0% | 1,782 | 1% |
| Mining | 0 | 0 | 0 | 0% | 78 | 1,592 | 1,670 | 1% | 78 | 0% | 1,592 | 1% | 1,670 | 1% |
| Public Water Supply | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 1,009 | 0 | 1,009 | 1% | 1,009 | 1% | 0 | 0% | 1,009 | 1% |
| **County Totals** | **10,078** | **0** | **10,078** | **5.90%** | **159,001** | **1,592** | **160,593** | **94.10%** | **169,079** | **99.07%** | **1,592** | **0.93%** | **170,671** | **100%** |

[a]Water use data are presented in AF/yr.

## Table 3-4. Pecos District Tri-County Area (Chaves, Eddy, and Lea Counties) water use by Category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 39,470 | 0 | 39,470 | 6% | 39,470 | 6% | 0 | 0% | 39,470 | 6% |
| Domestic | 0 | 0 | 0 | 0% | 1,121 | 0 | 1,121 | 0% | 1,121 | 0% | 0 | 0% | 1,121 | 0% |
| Industrial | 73,908 | 0 | 73,908 | 12% | 392,877 | 0 | 392,877 | 63% | 466,785 | 75% | 0 | 0% | 466,785 | 75% |
| Irrigation | 314 | 0 | 314 | 0% | 10,537 | 0 | 10,537 | 2% | 10,851 | 2% | 0 | 0% | 10,851 | 2% |
| Livestock | 0 | 0 | 0 | 0% | 1,782 | 0 | 1,782 | 0% | 1,782 | 0% | 0 | 0% | 1,782 | 0% |
| Mining | 0 | 0 | 0 | 0% | 1,573 | 94,227 | 95,800 | 15% | 1,573 | 0% | 94,227 | 15% | 95,800 | 15% |
| Public Water Supply | 0 | 0 | 0 | 0% | 1,827 | 0 | 1,827 | 0% | 1,827 | 0% | 0 | 0% | 1,827 | 0% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 2,780 | 0 | 2,780 | 0% | 2,780 | 0% | 0 | 0% | 2,780 | 0% |
| **County Totals** | **74,222** | **0** | **74,222** | **11.96%** | **451,967** | **94,227** | **546,194** | **88.04%** | **526,189** | **84.81%** | **94,227** | **15.19%** | **620,416** | **100%** |

[a]Water use data are presented in AF/yr.

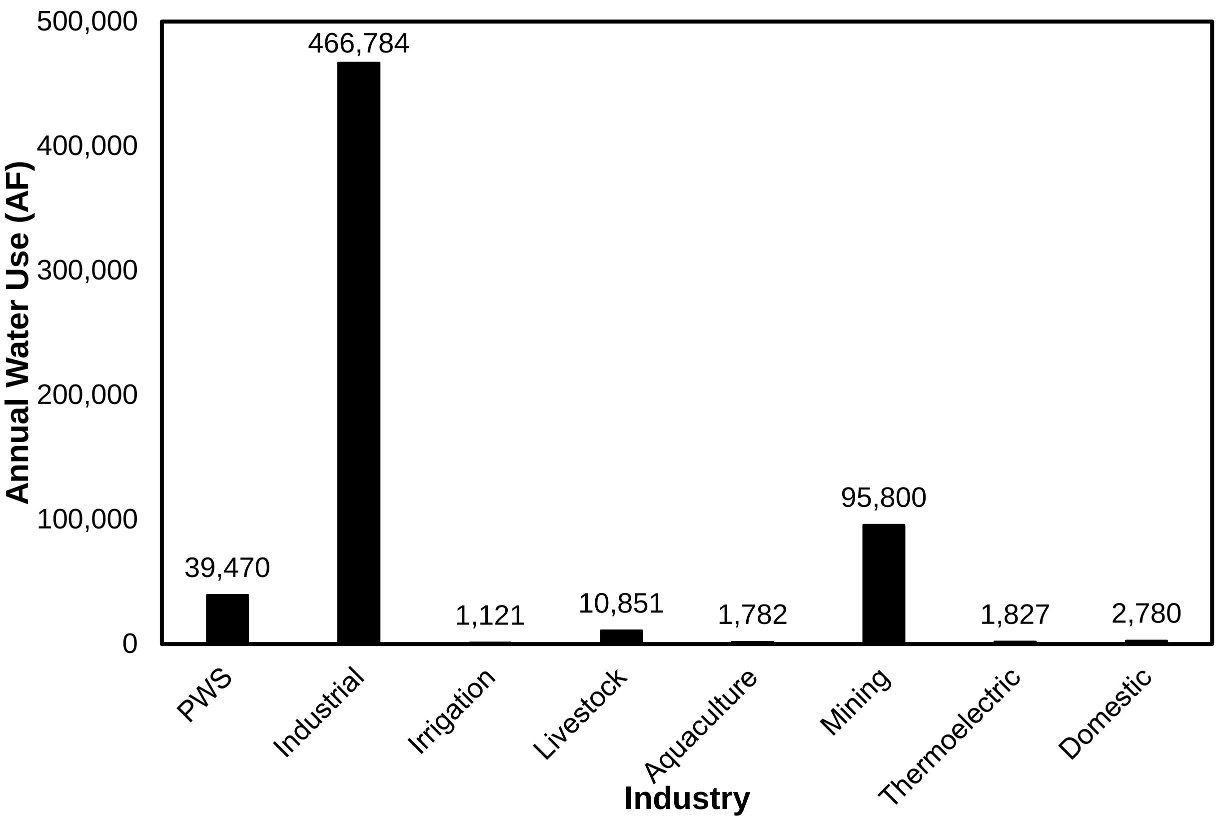

**Figure 3-1. Pecos District Tri-County Area (Chaves, Eddy, and Lea Counties) water use by category in 2015 (Dieter et al., 2017).**

### 3.1.2. Cumulative Water Use Estimates

#### Past and Present Actions

Pecos District total water usage in 2015 (620,416 AF) accounted for about 19% of the total state withdrawals. Mining (95,800 AF; which includes oil and gas development) comprises approximately 15% of Pecos District water withdrawals. Water use in 2015 associated with oil and gas development in the Pecos tri-county area (8,215 AF Table 3-5) comprised approximately 5% of the statewide mining water use (163,901 AF), 8.6% of the Pecos District Tri-County Area mining water use (95,800 AF), and 1.3% of Pecos District total water usage. The largest use of water within the tri-county area and the state is irrigation, comprising 75% of all water use within the Pecos tri-county area and 82% of all water use within the state.

Recently, however, in association with changes in production stimulation techniques, water use per horizontal well has been increasing. The BLM conducted studies using 2014–2019 data from FracFocus, a national hydraulic fracturing chemical registry managed by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission, to provide objective information on hydraulic fracturing. Water use for hydraulic fracturing in federal wells ranged from 1,303 to 8,913 AF in 2014 and 2018, respectively (FracFocus (2020), Table 3-5). Cumulative water use of federal wells for hydraulic fracturing within the Pecos Tri-County Area increased from 1,303 to 26,052 AF from 2014 to 2019 (Table 3-5). Cumulative water use for hydraulic fracturing of all wells within the Pecos Tri-County Area has increased from 3,741 to 98,852 AF from 2014 to 2019 (Table 3-5) corresponding with an increase in average water use from 7.0 to 40.9 AF/well. Although the average water use per well for hydraulic fracturing increased to 40.9 AF, the 6-year average is 26.8 AF/well. The proportion of federal wells within a year ranged from 12.3 to 48.6% for 2017 and 2015, respectively, with a 6-year (2014-2019) total of 26.3%.

**Table 3-5. Water Use by oil and gas wells for hydraulic fracturing in the NM portion of the Permian basin (Chaves, Eddy, and Lea Counties) from 2014-2019 (FracFocus, 2020). Data are only presented for wells which reported water usage to FracFocus. Produced water data was obtained from the New Mexico Oil Conservation Division (2020).**

| Year | Federal Water Use | Non-Federal Water Use | Total Water Use | Federal Water Use (%) | Federal Cumulative Water Use | Total Cumulative Water Use | Average Water Use | Well Count | Produced Water |
|---|---|---|---|---|---|---|---|---|---|
| 2014 | 1,303[a] | 2,438 | 3,741 | 34.9 | 1,303 | 3,741 | 7.0 | 537 | 107,301 |
| 2015 | 3,996 | 4,219 | 8,215 | 48.6 | 5,299 | 11,956 | 16.4 | 502 | 109,495 |
| 2016 | 836 | 5,932 | 6,768 | 12.3 | 6,135 | 18,724 | 22.6 | 300 | 103,951 |
| 2017 | 3,157 | 11,078 | 14,235 | 22.2 | 9,292 | 32,959 | 26.8 | 531 | 108,911 |
| 2018 | 8,913 | 22,147 | 31,060 | 28.7 | 18,205 | 64,019 | 32.0 | 972 | 130,771 |
| 2019 | 7,847 | 26,986 | 34,833 | 22.5 | 26,052 | 98,852 | 40.9 | 852 | 152,731 |
| **Total** | 26,052 | 72,800 | 98,852 | 26.3 | - |  | 26.8[b] | 3694 | 713,160 |

[a] Water use data are presented in acre-feet.

[b] Six-year average (2014 to 2019)

### 3.1.3. Water Use Associated with Reasonably Foreseeable Oil and Gas Development

The Reasonable Foreseeable Development (RFD) Scenario for the Pecos District projects approximately 800 new oil and gas wells per year (40% federal and 60% non-federal) over a 20-

year period for a total of 16,000 new wells (Engler and Cather 2012 and 2014).The scenario for the BLM New Mexico Pecos District was developed as a reasonable estimate of development associated with oil and gas production in southeast New Mexico for the next 20 (2015 to 2035) years in the New Mexico portion of the Permian Basin. The RFD is a comprehensive study of all existing plays and an analysis of recent activity, historical production, emerging plays for future potential, and completion trends. Planning factor assumptions used in the RFD include time frame, estimated well count, average water use, and proportion of horizontal wells drilled in the Bone Spring and Leonard Formations (Table 3-6). These planning factors are used for the estimation of water usage within the region for the duration of the RFD.

**Table 3-6. Planning Factors used in the Pecos District reasonable foreseeable development for prediction of water use.**

| Factor | RFD Assumed Values |
|---|---|
| Time Frame | 2015–2035 |
| Number of wells | 16,000 (approximately 800 per year) |
| Average Water Use, Horizontal Well | 7.3 AF (2.4 million gallons) |
| Average Water Use, Vertical Well | 1.53 AF (500,000 gal) |
| Number of Wells Needed for Reservoir Development | 4 wells per section per play (horizontal wells) |
| Percentage of horizontal wells in Bone Spring Formation | 84% horizontal |
| Percentage of horizontal wells in Leonard Formation | 14% horizontal |

The RFD estimate of an average water use per well of 7.3 AF was based on a study of the Bone Springs formation using data from 2013. Assuming the average water use is 7.3 AF/well and 800 wells per year, the RFD estimated an annual water use of 5,840 AF/yr. Since that time, there has been a substantial increase in the average water usage per well within the Permian Basin (Table 3-5). In 2018, during preparation of the Carlsbad Proposed RMP/Final EIS, the BLM updated estimated cumulative water use assuming an average of 31.2 AF per well (based on FracFocus data available at the time of the update) and development of the 16,000 wells projected in the RFD. This increased the estimated water use to 499,200 AF, or 24,960 AF of water in any given year (Figure 3-2). In 2019, 852 wells used an estimated 34,833 AF with an average of 40.9 AF/well (Table 3-5). With an average annual water use rate of 26.8 AF/well and development rate of 614 wells/yr since 2014, the average annual water use for the last 6 years was 16,475 AF/yr. The water use over the previous six years indicates that the RFD estimated water use of 31.2 AF/well and 24,960 AF/yr is within a reasonable range of current water use trends.

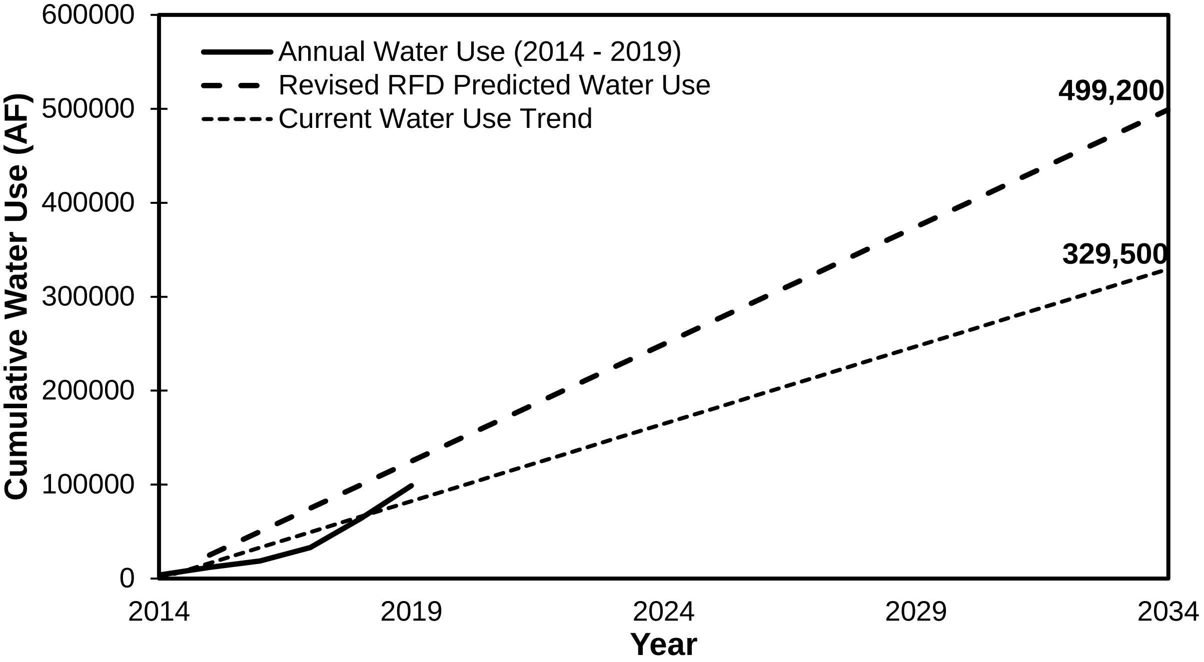

**Figure 3-2. Cumulative water use in the New Mexico Permian Basin (Chaves, Eddy, and Lea Counties) from 2014 to 2019 with projection to 2034. The revised Carlsbad RFD predicted usage of 31.2 AF/well or 24,960 AF/yr over a 20-year period. Current water use trend was derived from the average water use from 2014 to 2019 (26.8 AF/well or 16,474 AF/yr) projected to 2034. Cumulative water use data were collected from FracFocus (2020).**

#### Other Development

There are no anticipated mining reasonable foreseeable future actions (RFFAs) that would contribute to cumulative water withdrawals within the Pecos District (BLM 2019b). Some water use would be required during construction and operation of transmission lines and pipelines as part of reasonably foreseeable development in the area; however, these uses are not quantified in this analysis because water use is anticipated to be minimal.

#### Cumulative Impacts

Development of all RFFAs within the revised RFD scenario would require approximately 24,960 AF of water in any given year. This is about 4% of Pecos District 2015 total water withdrawals (620,416 AF, which already includes past and present actions). Irrigation would remain by far the largest water use within the county (currently 75% of all water use within the Pecos District and 82% of all water use within the state).

### 3.1.4. Potential Sources of Water for Project Development

The Pecos District contains a variety of surface waters, from springs and seeps to lakes, playas, rivers, and ephemeral drainages and draws (Table 3-7; Figure 3-3) which contribute to groundwater recharge. Waters from spring developments, reservoirs or streams, and stream diversions within the planning area are used primarily for irrigation, livestock, and wildlife. No surface waters used for domestic purposes originate on BLM-managed land. Diversions on BLM-managed lands support private land crop irrigation and stock water needs.

Because approximately 88% of all water use and 100% of all mineral water use in the Pecos District is currently from groundwater, it is reasonable to assume that water used for development of the RFD would likely be groundwater. Water used for oil and gas drilling and completion would be purchased legally from those who hold water rights in or around the Permian Basin. The transaction would be handled by the New Mexico Oil Conservation Division, as well as the New Mexico Office of the State Engineer. Potential sources of groundwater for use in oil and gas development in the Pecos District are outlined in Table 3-7.

**Table 3-7. Potential sources of groundwater in Pecos Tri-County District Area (Chaves, Eddy, and Lea Counties). Adopted from Lowry et al., (2018).**

| Aquifer Name | Description |
|---|---|
| Pecos Valley Alluvium | Surficial deposits along the Pecos River. No known recharge areas. Typical total dissolved solids (TDS) of <200 to 10,000 mg/L. |
| Dewey Lake and Santa Rosa | Redbed sandstones. Inconsistent water source. Recharge occurs closer to the surface from precipitation. Typical TDS of <5,000 to >10,000 mg/L |
| Rustler Formation (Culebra and Magenta) | Dolomite, fractured and dissolution zones. Local recharge is driven by precipitation. Typical TDS of <1,000 to 4,600 mg/L |
| Capitan Reef | Limestone, Karstic formation. Low salinity west of the Pecos, brackish towards the east. TDS ranges from 300 to >5,000 mg/L. Recharge in the west occurs mainly in the vicinity of the Guadalupe Mountains. Recharge in the east occurs in the vicinity of the Glass Mountains (in Texas). The New Mexico portion of the eastern part of the Capitan Reef is recharging at a high rate. |

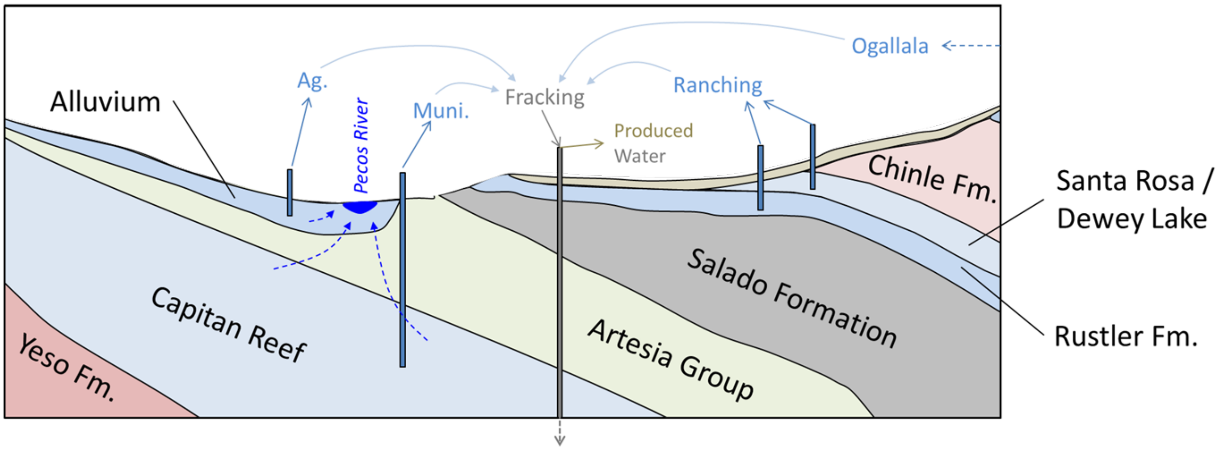

**Figure 3-3. Idealized geologic cross-section of potential water sources in Pecos District (Summers 1972).**

A study conducted by Sandia National Laboratory (Lowry et al., 2018) was completed in portions of Eddy and Lea counties that were identified as having of high potential for oil and gas development in the RFD. The study was undertaken to establish a water-level and chemistry baseline and to develop a modeling tool to aid the BLM in understanding the regional water supply dynamics under different management, policy, and growth scenarios and to pre-emptively identify risks to water sustainability.

Four high potential areas (HPAs) were studied. The HPAs were associated with the extent of BLM-managed lands in the Alto Platform, Bone Spring, and Delaware Mountain Group plays.

Most of the water wells that were sampled in each HPA appeared to have a mix of source waters and establishing definitive signatures for each aquifer was not possible. However, evidence shows that the main water source for water wells in the North HPA (which includes Loco Hills and areas along the Pecos River) are from the Dewey Lake and Santa Rosa aquifer or another perched source in the host Dockum Formation. For the Center North HPA (which encompasses a region known as Burton Flats), the main sources are from the Dewey Lake and Santa Rosa aquifer and the Rustler Formation. For the South HPA (located near Malaga and Loving), the main water sources are the Dewey Lake and Santa Rosa aquifer. The east HPA, which primarily represents the Ogallala aquifer, was excluded from the study because only a small percentage of the land is managed by the BLM (Lowry et al., 2018). The study also sampled wells that access water from the Capitan Reef, located near the community of Carlsbad.

Select wells were monitored using continuous and manual water level measurements throughout the study:

- Water levels in the two sampling water wells located in the North HPA fluctuated only slightly (>1 pounds per square inch [psi]) and carried no obvious trend, indicating a high likelihood that the water level variations are naturally occurring through seasonal and barometric pressure fluctuations.
- Of the two monitoring wells located in the Center North HPA, one showed only low water level changes suggestive of barometric effects and seasonal change; the other well

displayed a sharp water level increase. The cause of this change is conjectured to be from active drilling, pumping, or injecting near the well.

- Of the 16 wells monitoring the South HPA:
  - 2 wells showed minimal water level change with a slight increasing trend over time, indicating that the aquifer is not being locally impacted by pumping or aquifer development.
  - 2 wells showed pressure variations that are typical of nearby pumping. One well is located near a known oil supply well which is the likely driver to the drawdown and recovery response; the other is located near a municipal water supply well and its erratic response is indicative of pumping cycles associated with a small community water supply.
  - 5 wells displayed water level changes that are typical for aquifers affected by seasonal variations in pressure and barometric effects.
  - 3 wells showed minor water level changes likely due to activity in adjacent wells. The origin of the aquifer activity affecting each well are unknown, but likely due to oilfield drilling activities.
  - 1 well had substantial changes in water level as a result of nearby pumping tests conducted as part of monitoring of the Waste Isolation Pilot Plant.
  - 3 wells displayed water level changes due to high production pumping by a local ranch.
- Of the five wells monitoring the Capitan Reef, two wells recorded pressure decreases. The source of the pressure change is undetermined; however, it is likely these wells are influenced by precipitation given their shallow depth and the karstic nature of the formation, as well as from localized municipal pumping by the City of Carlsbad. The remaining 3 wells recorded water levels increasing at a relatively constant rate. This suggests that the aquifer in the eastern part of the Capitan is experiencing recharge.

A model is being developed as part of the Sandia study to simulate water availability over a range of different future scenarios, including drilling activity and water demand relative to areas that are most vulnerable and to estimate the risk to water sustainability. The model is still under development, but when completed, it may allow BLM to look at the balances between water demand and water availability to predict and track both risks to each aquifer as well as calculate well drawdown. The intent is to screen future water extraction that may be unsustainable. The CFO and RPFO will have the capacity to apply this model during future NEPA actions.

### Water Use Mitigation Measures

Public concern about water use from hydraulic fracturing is especially high in semiarid regions, where water withdrawals for hydraulic fracturing can account for a significant portion of consumptive water use within a given region. Overall, there have been calls to increase the use of alternative water sources such as brackish water or recycling produced water, minimizing the strain on local freshwater resources (Kondash et al., 2018). The BLM encourages the use of recycled water in hydraulic fracturing techniques, and in 2019, the State of New Mexico passed the Produced Water Act, which encourages oil and gas producers to reuse produced water when possible, rather than relying on fresh water sources for oil and gas extraction. Recent studies indicate that the water used for hydraulic fracturing may be retained within the shale formation, with only a small fraction of the fresh water injected into the ground returning as flowback water; water returning to the surface is highly saline, is difficult to treat, and is often disposed through deep-injection wells (Kondash et al., 2018). NMED recently signed a memorandum of understanding with New Mexico State University to develop new technologies for treating produced water to inform future policies for produced water reuse.

## 3.2. Water Quality

### 3.2.1. Groundwater

Groundwater quality in Eddy and Lea Counties and in the Lower Pecos Valley varies considerably depending on the aquifer and location (Lowry et al., 2018). In general, groundwater on the west side of the Pecos River is fresher than east of the Pecos River. East of the Pecos River, salinity is higher and can reach concentrations of 35,000 milligrams per Liter (mg/L). Shallow groundwater quality can be very good in the alluvial aquifers, but of poor quality in deeper geologic formations due to the presence of salt, gypsum, and other evaporite deposits. Groundwater tends to be mineralized or 'hard' west of the Ogallala aquifer (Lowry et al., 2018). Total dissolved solids (TDS) typically range from less than 200 to more than 10,000 mg/L depending on aquifer material (Table 3-8).

**Table 3-8. Typical TDS ranges found in the main aquifers of the Pecos District area (Lowry et al., 2018).**

| Aquifers | Aquifer Material | Typical TDS Range (mg/L) |
|---|---|---|
| Pecos | Alluvium | <200 to 10,000 |
| Rustler (includes Culebra and Magenta) | Carbonates and Evaporites | <1,000 to 4,600 |
| Dockum (includes Dewey Lake and Santa Rosa) | Sandstone and Conglomerates | <5,000 to >10,000 |
| Capitan Reef | Dolomite and Limestone | 300 to >5,000 |

Overall,30 wells in the South HPA, 11 wells in the Center North HPA, and 19 wells in the North HPA were selected for water quality analysis. The predominant water types for each of the HPAs and the Capitan Reef are listed below:

1. North – calcium and magnesium dominant
2. Center-North – sodium and calcium dominant
3. South – sodium and calcium dominant
4. Waste Isolation Pilot Plant (WIPP) – sodium and chloride dominant
5. Capitan Reef – sodium dominant

The samples were also compared to the New Mexico Water Quality Control Commission (NMWQCC) human health, domestic water supply, and irrigation use standards for groundwater with a TDS concentration of 10,000 mg/L or less (20.6.2.3103 NMAC). Table 3-9 presents a listing of the sampled water quality parameters by HPA against the NMWQCC standards for drinking water.

**Table 3-9. Sampled water quality parameters against NMWQCC drinking water standards (Lowry et al., 2018).**

| Parameter | NMWQCC Standard | North HPA | Central North HPA | South HPA and WIPP | Capitan Reef |
|---|---|---|---|---|---|
| pH (pH units) | 6 to 9 | 7.07 - 7.97 | 7.53 - 7.97 | 6.18 - 8.59 | 8.08 - 8.86 |
| Specific Conductance (µmhos/cm) | -- | 1000 - 3905 | 1300 - 83000 | 600 - 270000 | 2770 - 174500 |
| Total Dissolved Solids (TDS) | 1000 | 331 - 3550 | 869 - 43000 | 322 - 330000 | 1951 - 141875 |
| Calcium (Ca2+) | -- | 0.73 - 590 | 2.6 - 920 | 0.7 - 1900 | 1.4 - 5902 |
| Magnesium (Mg2+) | -- | 23 - 200 | 44 - 1492 | 2.10 - 10000 | 82.26 - 1420 |
| Sodium (Na+) | -- | 18 - 262 | 92.58 - 12000 | 26 - 95000 | 225 - 46700 |
| Potassium (K+) | -- | 0 - 30 | 4 - 1136 | 0 - 21000 | 6.58 - 3352 |
| Chloride (Cl-) | 250 | 16 - 1000 | 97 - 21000 | 11 - 190000 | 388.80 - 82602.1 |
| Alkalinity (CaCO3) | -- | 139 - 312 | 19.9 - 181.2 | 23 - 297.10 | 18.53 - 250.10 |
| Bicarbonate (HCO3-) | -- | 139 - 312 | 19.8 - 181.2 | 39.72 - 297.10 | 18.74 - 249.27 |
| Carbonate (CO3-) | -- | 0 - <2 | 0 - <2 | 0 - 16.08 | 0 - 0.83 |
| Sulfate (SO42-) | 600 | 0 - 1900 | 306.71 - 6400 | 0 - 15000 | 0 - 1975.67 |
| Fluoride (F-) | 1.6 | 0 - 1.3 | 0.82 - 2.60 | 0.00 - 3.63 | 0.09 - 0.52 |
| Nitrite (NO2) | 10 | 0 - 6.27 | 0 - 8.8 | 0.00 - 20.08 | 0.05 - 7.60 |
| Nitrate (NO3) | 10 | 0 - 10 | 2.6 - 8.8 | 0 - 19 | 0.04 - 7.60 |
| Silver (Ag) | 0.05 | -- | -- | -- | 0 |
| Aluminum (Al) | 5 | -- | 0.18 | 0 – 4.06 | -- |
| Arsenic (As) | 0.1 | 0.02 – 0.06 | 0.03 - 0.32 | 0 – 0.29 | 0.10 |
| Barium (Ba) | 1 | 0.01 – 0.13 | 0.01 - 0.03 | 0- 0.1 | 0.02 - 0.25 |
| Bromide (Br) | -- | 0 - 7.8 | 0.28 - 12.00 | 0 - 1400 | 0.3 - 12.73 |
| Cadmium (Cd) | 0.01 | -- | -- | -- | -- |
| Copper (Cu) | 1 | 0.02 | 0.03 | 0.06 - 0.37 | -- |
| Iron (Fe) | 1 | 3.34 | 0.04 | 0.01 - 1.62 | 3.41 |
| Lithium (Li) | -- | 0.14 - 1.70 | 0.140 - 1.695 | 0.05 - 0.85 | 0.04 - 4.49 |
| Manganese (Mn) | 0.2 | 0 - 0.06 | 0 - 0.20 | 0 - 0.06 | 0 - 7.61 |
| Nickel (Ni) | 0.2 | -- | 0 - 0.02 | 0 - 0.01 | 0.01 |
| Lead (Pb) | 0.05 | 0.04 | -- | 0.02 - 0.06 | -- |
| Silicon (Si) | -- | 2.67 - 18.38 | 1.9 - 23.4 | 4.91 - 47.0 | 0 - 7.10 |
| Strontium (Sr2+) | -- | 0.63 - 8.47 | 2.73 - 13.75 | 0.05 - 32.0 | 2.52 - 104.8 |
| Vanadium (V) | -- | -- | 0.01 - 0.03 | 0 - 0.1 | -- |

Units are milligrams per liter (mg/L) unless otherwise noted.
“—" = not applicable or not detected.
Values rounded to two decimal places.

### 3.2.2. Surface Water

Stream and river conditions vary widely, from completely undisturbed river and vegetative communities in the mountainous highlands, to deep, erodible soil banks at lower elevations where livestock, recreationists, and other public users have access to stream and riverbanks.

Water quality in streams flowing on BLM-managed land is influenced by both natural water quality with regard to salinity content and the intensity of human and industrial activity in the watershed. For example, water quality may be vastly different in a remote mountain spring creek than in waters with natural brine discharge, or where there are human impacts due to urban, farming, ranching, or industrial activity.

Further chemistry samples of surface water in the region are needed to establish a baseline chemistry data for the waters. Variances in baseline chemistry can indicate water quality changes attributable to changes in land use. The most common pollutants for waters in the region are sediment and mercury. Beneficial uses listed for these waters are industrial water supply, irrigation storage, livestock watering, recreation, warm water fishery, and wildlife habitat. The dominant legislation affecting national water quality and BLM compliance with New Mexico water quality requirements is the Clean Water Act (CWA) or Federal Water Pollution Control Act.

### 3.2.3. Potential Sources of Surface Water or Groundwater Contamination

#### Spills

Spills associated with oil and gas development may reach surface water directly during the spill event. Spills may also reach surface waters indirectly, when the spill has occurred, and a rain event moves contaminants into nearby surface water bodies through surface water flow or even subsurface groundwater flow into springs that discharge into a surface water body.
In 2019, there were a total (federal and non-federal) of 1,208 spills in the Permian Basin ( Table 3-10). The rate of recovery varies by spill type but the average recovery rate for all spill types was 44.59%. No spills occurring in the Eddy, Lea, and Chaves Counties were reported as having affected surface or groundwater.

**Table 3-10. Summary of 2019 spills from all wells in the New Mexico Portion of the Permian Basin (Eddy, Lea, and Chaves Counties; NMOCD, 2020).**

| Material Type | Count of Spills | Volume Spilled | Volume Lost | Units | %Lost |
|---|---|---|---|---|---|
| Acid | 2 | 37 | 32 | Barrels | 86.49 |
| Basic sediment and water (BS&W) | 1 | 52 | 0 | Barrels | 0.00 |
| Brine Water | 4 | 44 | 19 | Barrels | 43.18 |
| Chemical | 5 | 66 | 3 | Barrels | 4.55 |
| Condensate | 14 | 511 | 237 | Barrels | 46.38 |
| Crude Oil | 362 | 11,697 | 4,985 | Barrels | 42.62 |
| Drilling Mud/Fluid | 2 | 39 | 1 | Barrels | 2.56 |
| Gelled Brine (Frac Fluid) | 3 | 98 | 81 | Barrels | 82.65 |
| Other (Specify) | 23 | 2,743 | 2,555 | Barrels | 93.15 |
| Produced Water | 633 | 74,889 | 32,294 | Barrels | 43.12 |
| Unknown | 3 | 0 | 0 | Barrels | - |
| **Total** | **1,052** | **90,176** | **40,207** | | **44.59** |
| | | | | | |
| Natural Gas (Methane) | 150 | 624,972 | 624,972 | MCF | 100.00 |
| Natural Gas Liquids | 6 | 26,868 | 26,868 | MCF | 100.00 |
| **Total Number of Spills** | **1,208** | | | | |

The BLM works with the NMOCD to remediate spills on BLM lands. Per NMAC 19.15.29.11, the responsible person shall complete division-approved corrective action for releases that endanger public health or the environment in accordance with a remediation plan submitted to and approved by the division or with an abatement plan submitted in accordance with 19.15.30 NMAC. The remaining contaminates from unrecovered spills are remediated in accordance with federal and state standards. Some remediation consists of removing contaminated soil and replacement with uncontaminated soil and corresponding chemical testing.

The chemical composition of water used during the hydraulic fracturing process varies due to differences in fracturing techniques used by oil and gas companies. The most commonly disclosed chemical used in wells in the New Mexico portion of the Permian Basin from 2014-2019 was Ethanol with 9,109 disclosures (Table 3-11). Other frequent disclosures include 1,2-

propylene glycol (n=8,712), water (n=5,993), quartz-alpha (n=4,662), and methanol (n=2,872). There were 4,373 records of non-disclosed chemicals which includes chemicals listed as proprietary, confidential, and trade secrets. A typical oil/gas well uses approximately 20 to 25 unique chemicals during the hydraulic fracturing process but in some cases more than 60 distinct chemicals can be used.

**Table 3-11. Twenty-five most frequently disclosed chemicals in horizontal wells within the New Mexico Permian Basin (Chaves, Eddy, and Lea Counties) from 2014 to 2019. Data obtained from FracFocus (2020) and only presented for wells which reported chemical data.**

| EPA Chemical Name | CAS Registry Number[1] | Number of Disclosures[2] | Median (mg/L) | Sum (Gg) |
|---|---|---|---|---|
| Ethanol | 64-17-5 | 9,109 | 14.1 | 564.3 |
| 1,2-Propylene glycol | 57-55-6 | 8,712 | 18.0 | 564.5 |
| Water | 7732-18-5 | 5,993 | 2371.9 | 102,747 |
| Quartz-alpha (SiO2) | 14808-60-7 | 4,662 | 72873 | 17,149 |
| Not-disclosed | - | 4,373 | 19.7 | 587.3 |
| Methanol | 67-56-1 | 2,872 | 22.6 | 6.4 |
| Distillates, petroleum, hydrotreated light | 64742-47-8 | 2,576 | 247.7 | 40.3 |
| Hydrochloric acid | 7647-01-0 | 2,184 | 957.4 | 117.1 |
| Diammonium peroxydisulfate | 7727-54-0 | 1,261 | 34.6 | 1.2 |
| Guar gum | 9000-30-0 | 1,241 | 1251 | 28.4 |
| Ethylene glycol | 107-21-1 | 1,214 | 81.1 | 2.7 |
| Sodium chloride | 7647-14-5 | 1,202 | 37.3 | 33.9 |
| Glutaraldehyde | 111-30-8 | 1,148 | 56.0 | 4.5 |
| Isopropanol | 67-63-0 | 1,140 | 1.5 | 1.3 |
| Propargyl alcohol | 107-19-7 | 1,066 | 0.8 | 0.1 |
| Acetic acid | 64-19-7 | 977 | 28.9 | 39.9 |
| Sodium hydroxide | 1310-73-2 | 959 | 29.3 | 0.9 |
| C12-16-Alkylbenzyldimethylammonium chlorides | 68424-85-1 | 865 | 12.5 | 0.8 |
| Citric acid | 77-92-9 | 772 | 21.0 | 0.9 |
| Ammonium chloride | 12125-02-9 | 765 | 24.2 | 1.1 |
| Potassium hydroxide | 1310-58-3 | 687 | 56.9 | 0.9 |
| Sodium perborate tetrahydrate | 10486-00-7 | 681 | 60.8 | 2.3 |
| Alcohols, C12-16, ethoxylated | 68551-12-2 | 666 | 25.3 | 1.2 |
| Sorbitan, mono-(9Z)-9-octadecenoate | 1338-43-8 | 661 | 13.1 | 0.7 |
| Thiourea, polymer w/ formaldehyde & 1-phenylethanone | 68527-49-1 | 591 | 2.7 | 0.1 |

[1] 340 CAS registry number errors
[2] 83352 Total Disclosures

## Drilling and Completion Activities

When wells are drilled, they most likely pass through usable groundwater aquifers currently or potentially supplying stock, residential, and/or irrigation water. If proper cementing and casing programs are not followed, there may be a loss of well integrity, surface spills, or loss of fluids in the drilling and completion process that could result in large volumes of high concentrations of chemicals reaching groundwater resources. If contamination of usable water aquifers (total dissolved solids less than 10,000 parts per million [ppm]) from any source occurs, changes in groundwater quality could impact springs and water wells that are sourced from the affected aquifers.

The BLM and the New Mexico Oil Conservation Division (NMOCD) have casing, cementing, and inspection requirements in place to limit the potential for groundwater reservoirs and shallow aquifers to be impacted by fracking or the migration of hydrocarbons during oil and gas drilling and production activities. The BLM requires operators to comply with the regulations at 43 Code of Federal Regulations (CFR) 3160. These regulations require oil and gas development to comply with directives in the Onshore Orders and the orders of the Authorized Officer. Onshore Order No. 2 and the regulations at 43 CFR 3162.3-3 provide regulatory requirements for hydraulic fracturing, including casing specifications, monitoring and recording, and management of recovered fluids. The State of New Mexico also has regulations for drilling, casing and cementing, completion, and plugging to protect freshwater zones (19.15.16 New Mexico Administrative Code). Complying with the aforementioned regulations requires producers and regulators to verify the integrity of casing and cement jobs. Casing specifications are designed and submitted to the BLM together with an APD. The BLM petroleum engineer independently reviews the drilling plan, and based on site-specific geologic and hydrologic information, ensures that proper drilling, casing, and cementing procedures are incorporated in the plan to protect usable groundwater. This isolates usable water zones from drilling, completion/hydraulic fracturing fluids, and fluids from other mineral bearing zones, including hydrocarbon bearing zones. Conditions of Approval (COAs) may be attached to the APD, if necessary, to ensure groundwater protection. Casing and cementing operations are witnessed by certified BLM Petroleum Engineering Technicians. At the end of the well’s economic life, the operator must submit a plugging plan, which is reviewed by the BLM petroleum engineer prior to well plugging. This review ensures permanent isolation of usable groundwater from hydrocarbon bearing zones. BLM inspectors ensure planned procedures are properly followed in the field.

The requirements listed above are in place so that drilling fluids, hydraulic fracturing fluids, and produced water and hydrocarbons remain within the well bore and do not enter groundwater or any other formations. This makes contamination of groundwater resources highly unlikely. Since the advent of hydraulic fracturing, more than 1 million hydraulic fracturing treatments have been conducted nation-wide, with perhaps only one documented case of direct groundwater pollution resulting from injection of hydraulic fracturing chemicals used for shale gas extraction (Gallegos and Varela 2015). There have not been any documented past instances of groundwater contamination attributed to well drilling in the Pecos District. This is an indication of how effective the use of casing and cement is at preventing leaks and contamination.

# CHAPTER 4. FARMINGTON FIELD OFFICE

The analysis area for the cumulative impacts scenario is the “Mancos-Gallup planning area” which was used to develop the Mancos-Gallup RFD Scenario (Crocker and Glover 2018). The Mancos-Gallup planning area includes 4.2 million total acres of all mineral ownership types in portions of San Juan, Rio Arriba, Sandoval, and McKinley Counties (Crocker and Glover 2018). Federal oil and gas minerals in the area cover 2.1 million acres, primarily in the Farmington FO but also in a small area of the Rio Puerco Field Office (in northwestern Sandoval County, where most of the previous oil and gas development has taken place) (BLM 2003, 2012; Crocker and Glover 2018). Of the federal minerals, 1.8 million acres (85%) are leased and 300,000 acres (15%) are currently unleased. Native American–owned oil and gas minerals (allotted and tribal) cover 1.4 million acres. The Farmington FO is also a part of the New Mexico portion of the San Juan Basin, an oil and gas basin that is in the northwestern portion of New Mexico and the southwestern portion of Colorado (BLM 2003). Data presented for the San Juan Basin include San Juan, Rio Arriba, and Sandoval Counties.

Chapter 4 outlines existing and projected (reasonably foreseeable) water quantity and water quality for the Farmington FO based on information gathered from the following sources: 1) the Farmington Resource Management Plan and Final Environmental Impact Statement (BLM 2003), 2) the Reasonable Foreseeable Development Scenario for Oil and Gas Activities, Mancos-Gallup RMPA Planning Area, Farmington Field Office, northwestern New Mexico (“2018 RFD”, Crocker and Glover 2018), 3) data compiled from a 2015 USGS report, Estimated Use of Water in the United States in 2015 (Dieter et. al. 2017), and 4) FracFocus, a national hydraulic fracturing chemical registry managed by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission (FracFocus 2020).

## 4.1. Water Quantity

### 4.1.1. Existing Surface and Groundwater Water Use

**Farmington Field Office (San Juan, Rio Arriba, and McKinley Counties)**

Dieter et. al. (2017), lists total water withdrawals for the counties comprising the Farmington FO across eight water use categories: aquaculture, domestic, industrial, irrigation, livestock, mining, public water supply, and thermoelectric power. Water use totals (in acre feet per year [AF/yr]) for each of these industries are summarized by surface water and groundwater, which is further divided into fresh water and saline water use for each category. Public water supply (29%) and domestic water use (24%) were the greatest consumers of water in McKinley County. Mining in McKinley County (17%) consumed a greater proportion of water than in the other three counties which all consumed less than 3% of their respective water supplies. The San Juan Basin consumed approximately 15% (486,660 AF) of the water used within New Mexico.

## Table 4-1. Rio Arriba County water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 3,554 | 0 | 3,554 | 3% | 3,554 | 3% | 0 | 0% | 3,554 | 3% |
| Domestic | 0 | 0 | 0 | 0% | 1,345 | 0 | 1,345 | 1% | 1,345 | 1% | 0 | 0% | 1,345 | 1% |
| Industrial | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Irrigation | 107,874 | 0 | 107,874 | 91% | 1,256 | 0 | 1,256 | 1% | 109,130 | 92% | 0 | 0% | 109,130 | 92% |
| Livestock | 168 | 0 | 168 | 0% | 191 | 0 | 191 | 0% | 359 | 0% | 0 | 0% | 359 | 0% |
| Mining | 0 | 0 | 0 | 0% | 437 | 1,244 | 1,681 | 1% | 437 | 0% | 1,244 | 1% | 1,681 | 1% |
| Public Water Supply | 381 | 0 | 381 | 0% | 1,670 | 0 | 1,670 | 1% | 2,051 | 2% | 0 | 0% | 2,051 | 2% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| **County Totals** | **108,423** | **0** | **108,423** | **91.79%** | **8,453** | **1,244** | **9,697** | **8.21%** | **116,876** | **98.95%** | **1,244** | **1.05%** | **118,120** | **100%** |

[a] Water use data are presented in acre-feet.

## Table 4-2. San Juan County water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Domestic | 0 | 0 | 0 | 0% | 1,312 | 0 | 1,312 | 0% | 1,312 | 0% | 0 | 0% | 1,312 | 0% |
| Industrial | 0 | 0 | 0 | 0% | 22 | 0 | 22 | 0% | 22 | 0% | 0 | 0% | 22 | 0% |
| Irrigation | 223,942 | 0 | 223,942 | 79% | 0 | 0 | 0 | 0% | 223,942 | 79% | 0 | 0% | 223,942 | 79% |
| Livestock | 67 | 0 | 67 | 0% | 303 | 0 | 303 | 0% | 370 | 0% | 0 | 0% | 370 | 0% |
| Mining | 2,724 | 0 | 2,724 | 1% | 549 | 3,083 | 3,632 | 1% | 3,273 | 1% | 3,083 | 1% | 6,356 | 2% |
| Public Water Supply | 21,097 | 0 | 21,097 | 7% | 11 | 0 | 11 | 0% | 21,108 | 7% | 0 | 0% | 21,108 | 7% |
| Thermoelectric Power | 30,637 | 0 | 30,637 | 11% | 0 | 0 | 0 | 0% | 30,637 | 11% | 0 | 0% | 30,637 | 11% |
| **County Totals** | **278,467** | **0** | **278,467** | **98.14%** | **2,197** | **3,083** | **5,280** | **1.86%** | **280,664** | **98.91%** | **3,083** | **1.09%** | **283,747** | **100%** |

[a] Water use data are presented in acre-feet.

## Table 4-3. Sandoval County water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 1,087 | 0 | 1,087 | 1% | 1,087 | 1% | 0 | 0% | 1,087 | 1% |
| Domestic | 0 | 0 | 0 | 0% | 3,128 | 0 | 3,128 | 3% | 3,128 | 3% | 0 | 0% | 3,128 | 3% |
| Industrial | 0 | 0 | 0 | 0% | 2,578 | 0 | 2,578 | 3% | 2,578 | 3% | 0 | 0% | 2,578 | 3% |
| Irrigation | 48,326 | 0 | 48,326 | 52% | 23,201 | 0 | 23,201 | 25% | 71,527 | 77% | 0 | 0% | 71,527 | 77% |
| Livestock | 101 | 0 | 101 | 0% | 123 | 0 | 123 | 0% | 224 | 0% | 0 | 0% | 224 | 0% |
| Mining | 0 | 0 | 0 | 0% | 1,065 | 247 | 1,312 | 1% | 1,065 | 1% | 247 | 0% | 1,312 | 1% |
| Public Water Supply | 135 | 0 | 135 | 0% | 12,466 | 0 | 12,466 | 13% | 12,601 | 14% | 0 | 0% | 12,601 | 14% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| **County Totals** | **48,562** | **0** | **48,562** | **52.52%** | **43,648** | **247** | **43,895** | **47.48%** | **92,210** | **99.73%** | **247** | **0.27%** | **92,457** | **100%** |

[a] Water use data are presented in acre-feet.

## Table 4-4. McKinley County water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Domestic | 0 | 0 | 0 | 0% | 3,195 | 0 | 3,195 | 24% | 3,195 | 24% | 0 | 0% | 3,195 | 24% |
| Industrial | 0 | 0 | 0 | 0% | 34 | 0 | 34 | 0% | 34 | 0% | 0 | 0% | 34 | 0% |
| Irrigation | 1,099 | 0 | 1,099 | 8% | 0 | 0 | 0 | 0% | 1,099 | 8% | 0 | 0% | 1,099 | 8% |
| Livestock | 101 | 0 | 101 | 1% | 370 | 0 | 370 | 3% | 471 | 4% | 0 | 0% | 471 | 4% |
| Mining | 0 | 0 | 0 | 0% | 1,626 | 684 | 2,310 | 17% | 1,626 | 12% | 684 | 5% | 2,310 | 17% |
| Public Water Supply | 0 | 0 | 0 | 0% | 3,811 | 0 | 3,811 | 29% | 3,811 | 29% | 0 | 0% | 3,811 | 29% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 2,298 | 0 | 2,298 | 17% | 2,298 | 17% | 0 | 0% | 2,298 | 17% |
| **County Totals** | **1,200** | **0** | **1,200** | **9.08%** | **11,334** | **684** | **12,018** | **90.92%** | **12,534** | **94.83%** | **684** | **5.17%** | **13,218** | **100%** |

[a] Water use data are presented in acre-feet.

**Table 4-5. Water use by category in 2015 (Dieter et al., 2017) within the Farmington Field Office (San Juan, Rio Arriba, McKinley, and Sandoval Counties).**

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 4,641 | 0 | 4,641 | 1% | 4,641 | 1% | 0 | 0% | 4,641 | 1% |
| Domestic | 0 | 0 | 0 | 0% | 8,979 | 0 | 8,979 | 1% | 8,979 | 1% | 0 | 0% | 8,979 | 1% |
| Industrial | 0 | 0 | 0 | 0% | 2,634 | 0 | 2,634 | 0% | 2,634 | 0% | 0 | 0% | 2,634 | 0% |
| Irrigation | 381,241 | 0 | 381,241 | 56% | 3,576 | 0 | 3,576 | 1% | 384,817 | 56% | 0 | 0% | 384,817 | 56% |
| Livestock | 437 | 0 | 437 | 0% | 987 | 0 | 987 | 0% | 1,424 | 0% | 0 | 0% | 1,424 | 0% |
| Mining | 2,724 | 0 | 2,724 | 0% | 3,677 | 5,258 | 8,935 | 1% | 6,401 | 1% | 5,258 | 1% | 11,659 | 2% |
| Public Water Supply | 216,123 | 0 | 216,123 | 32% | 17,958 | 0 | 17,958 | 3% | 234,081 | 34% | 0 | 0% | 234,081 | 34% |
| Thermoelectric Power | 30,637 | 0 | 30,637 | 4% | 2,298 | 0 | 2,298 | 0% | 32,935 | 5% | 0 | 0% | 32,935 | 5% |
| **Basin Totals** | **631,162** | **0** | **631,162** | **92.66%** | **44,750** | **5,258** | **50,008** | **7.34%** | **675,912** | **99.23%** | **5,258** | **0.77%** | **681,170** | **100%** |

[a]Water use data are presented in acre-feet.

### 4.1.2. Cumulative Water Use Estimates

#### Past and Present Actions

As noted previously, total water use in the counties comprising the New Mexico portion of the San Juan Basin (486,660 AF) accounted for 15% of total state withdrawals (3,249,667 AF) in 2015 (Dieter et al., 2017). Mining (which includes oil and gas development) comprised about 2% of San Juan Basin total water withdrawals. The largest user of water in the New Mexico portion of the San Juan Basin is irrigation (comprising 79% of all withdrawals in the New Mexico portion of the San Juan Basin).

Water use in oil and gas wells within the New Mexico portion of the San Juan Basin has varied over the last 6 years but it decreased from 658 in 2018 to 161 AF in 2019, with a corresponding decrease in average water use from 4.7 to 1.8 AF/well (Table 4-6). Wells on federal lands consumed 92 AF in 2019, 57.1% of the 2019 total water usage. Cumulative federal water use and total cumulative water use increased in 2019 to 1,033, and 1,869 AF, respectively. The number of wells completed decreased from 141 in 2018 to 92 in 2019. The 6-year average water use is 311.5 AF/year and 3.36 AF/well. Twenty slickwater wells have been installed since 2014 with an average lateral well bore of 1.5 miles and an average water use of 41 AF/well.

**Table 4-6. Water Use (in AF) by oil and gas wells for hydraulic fracturing in the NM portion of the San Juan Basin (San Juan, Rio Arriba, and Sandoval Counties) from 2014-2019 (FracFocus, 2020). Data only presented for wells which reported water usage to FracFocus. Produced water data obtained from the New Mexico Oil Conservation Division (2020).**

| Year | Federal Water Use | Non-Federal Water Use | Total Water Use | Federal Water Use (%) | Federal Cumulative Water Use | Total Cumulative Water Use | Average Water Use | Well Count | Produced Water |
|---|---|---|---|---|---|---|---|---|---|
| 2014 | 165 | 154 | 319 | 51.7 | 165 | 319 | 2.4 | 132 | 5,406 |
| 2015 | 87 | 255 | 342 | 25.4 | 252 | 661 | 3.8 | 90 | 5,040 |
| 2016 | 85 | 26 | 111 | 76.6 | 337 | 772 | 2.9 | 39 | 4,233 |
| 2017 | 228 | 50 | 278 | 82.0 | 565 | 1,050 | 4.5 | 62 | 3,554 |
| 2018 | 376 | 282 | 658 | 57.1 | 941 | 1,708 | 4.7 | 141 | 2,681 |
| 2019 | 92 | 69 | 161 | 57.1 | 1,033 | 1,869 | 1.8 | 92 | 4,391 |
| **Total** | 1033 | 836 | 1,869 | - | - | - | 3.36[1] | 556 | 25,305 |

### 4.1.3. Water Use Associated with Reasonably Foreseeable Oil and Gas Development

The 2018 RFD (Crocker and Glover 2018) was used to forecast the potential quantity of oil and gas wells in the Mancos-Gallup Resource Management Plan Amendment (RMPA) Planning Area, which includes most of the Farmington FO and is where most potential oil and gas development is projected to occur. The RFD was also used to forecast estimates of the quantity of water that would be required for hydraulic fracturing of the forecasted wells. These water use estimates assume that 100% of wells will be hydraulically fractured, and do not account for re-use or recycling of hydraulic fracturing fluid.

The RFD is a reasonable estimate of the development (federal and non-federal) and consumptive water use associated with hydrocarbon production in the New Mexico portion of the San Juan Basin for the 20 years (2018–2037). According to the 2018 RFD, 3,200 wells are expected to be drilled in the planning area between 2018 and 2037 based on actualized data.

Water use associated with hydraulic fracturing is dependent on many factors, including (but not limited to) the drilling method (horizontal or vertical) and the geologic formation at the well site. Of the 3,200 wells projected to be drilled between 2018 and 2037, 2,300 are expected to be horizontal and 900 are expected to be vertical.

On average, the water use for vertical wells in the New Mexico portion of the San Juan Basin is 0.537 AF/well (Crocker and Glover 2018). Horizontal wells require more water than vertical wells. The 2018 RFD reported that horizontal wells in the San Juan Basin require on average approximately 3.13 AF of water per well (Table 4-7). More recent information on horizontal well development in the San Juan Basin has indicated water use is slightly higher. Because of this uncertainty, the BLM analyzes data from FracFocus, a national hydraulic fracturing chemical registry managed by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission, to provide objective information on hydraulic fracturing. Operators are required by the State of New Mexico to disclose chemistry and water use information on FracFocus. Analysis of 2018 FracFocus data for the New Mexico portion of the San Juan Basin (which includes 142 records) resulted in a value of 4.8 AF of water per horizontal well completion. Average water use decreased in 2019 to 1.8 AF/well bringing the 6-year average to 3.36 AF/well. Despite the 6-year average being lower than the revised water use estimates, an assumed water use of 4.8 AF/well provides a good upper limit on the estimated water use over the next 20 years.

**Table 4-7. Projected water use in New Mexico portion of San Juan Basin (Farmington Field Office)**

| Factor | Water Use in RFD (Crocker and Glover 2018) | Revised Water Use | Rationale for Change |
|---|---|---|---|
| Average Water Use per Horizontal Well during a hydraulic fracturing operation | 3.13 AF | 4.84 AF[1] | Reflects actual use as reported in FracFocus |
| Average Water Use per Vertical Well during a hydraulic fracturing operation | 0.537 AF | 0.537 AF[2] | No change |
| **Total Water Use (2018-2037)** | **7,683 AF[3]** | **11,615 AF[3]** | |

[1] Source: Derived from Crocker and Glover 2018.
[2] Source: FracFocus, 2018
[3] Source: BLM 2019b
[4] Total water use = (2,300 horizontal wells[1] * horizontal well water use estimate) + (900 vertical wells[1] * vertical well water use estimate)
Note: AF is acre-feet.

Water used for hydraulic fracturing of the estimated 3,200 wells in the 2018 RFD (Crocker and Glover 2018) is assumed to come primarily from fresh groundwater sources based on historic oil and gas development in the area and from county water use data. Drilling and completion of the 3,200 wells estimated to occur in the planning area would require approximately 7,683 AF using the water use estimates contained in the Crocker and Glover RFD scenario. Using the BLM's revised water use estimates (4.84 AF per horizontal well), development of the 3,200 wells in the 2018 RFD would require 11,615 AF of water, or 580 AF of water in any given year. The estimated amount of water needed to develop the RFD in any given year (580 AF) is approximately 0.12% of the 2015 water use in the San Juan Basin.

### 4.1.4. Water Use Associated with Slickwater Stimulation

Beginning in 2015, the Farmington FO began receiving APDs that included new technologies that utilize greater quantities of water during the stimulation of the well under development, such as slickwater fracturing. If operators implement the slickwater technology more frequently than occurred in 2018 and prior years, it is expected that total water use volumes on a per well basis would trend upward. Current technology allows operators to utilize water with TDS of 50,000 ppm for use in slickwater stimulation activities, well above the NMOSE potable water threshold of 1,000 ppm. This allows for the use of currently non-traditional water sources, including the connate water, recycled flowback water, and produced water. Appendix C contains additional background information on slickwater fracturing in the Farmington FO as well as information regarding the methodology for capturing information and calculating water use by stage.

To date, 20 wells have been drilled using long laterals with slickwater stimulation within the Farmington FO. Horizontal well bores are stimulated in intervals, each interval is called a stage. For the 20 completed wells, the Farmington FO calculated the average stage length to be 200 feet and the average water used per stage to stimulate the formation to be 334,000 gallons (~ 1 acre-foot). The equation for calculating estimated water volume is indicated below:
Total water volume = (stage water volume/stage length) x (number of stages/lateral length)
According to data from FracFocus, the average water use associated with slickwater stimulation of the 20 wells was 41 AF. Using this information, and an average lateral well bore of 1.5 miles (as obtained from the corresponding completion reports), the BLM has calculated an average of 27 AF per lateral mile. Table 3-9 provides a summary of average number of stages dependent on length of well bore and the average water use to complete 1- to 3-mile laterals.

**Table 4-8. Average volume of water required to complete 1 to 3-mile laterals using slickwater stimulation in the Mancos Shale and Gallup Sandstone formations.**

| Miles | Number of Stages | Acre Feet |
|---|---|---|
| 1 | 26 | 27 |
| 1.5 | 39 | 40 |
| 2 | 52 | 53 |
| 2.5 | 65 | 67 |
| 3 | 78 | 80 |

If 100% of the wells developed in the future used slickwater stimulation, the amount of water that would be required to completely develop 4,600 miles of horizontal wells (2300 wells with a 2 mile lateral) in the Mancos Shale and Gallup Sandstone formations is estimated to be approximately 125,000 AF, or 6,250 AF in any given year (assuming 53 AF/well). Currently, only 3% of wells within the San Juan Basin use slickwater stimulation. Water use in the San Juan Basin in 2018 and 2019 was 658 and 161 AF, respectively, which is 89.5% and 97.4% less than the predicted 6,250 AF/year.

### 4.1.5. Water Use Associated with Nitrogen Stimulation

Nitrogen stimulation is a common technique in the San Juan Basin where gaseous nitrogen is used in place of water to fracture oil and gas formations. There are three predominant methods of nitrogen stimulation: nitrogen foam, energized nitrogen, and pure nitrogen stimulation. The three techniques vary in the amount of nitrogen and water used as well as the partnering chemicals. The advantage to using nitrogen in place of water is the reduced quantity of water needed to achieve the same oil and gas yield. The proportion of nitrogen-stimulated wells within a year has ranged from 76.6% to 97.8% (Figure 4-1). Over the last 6 years (2014 - 2019), approximately 85% of the completed wells within the San Juan Basin have used nitrogen stimulation. The average water use of a nitrogen stimulated well is 1.9 AF/well compared to the 2.7 and 41.3 AF/well, respectively, used in conventional water and slickwater wells (Table 4-9).

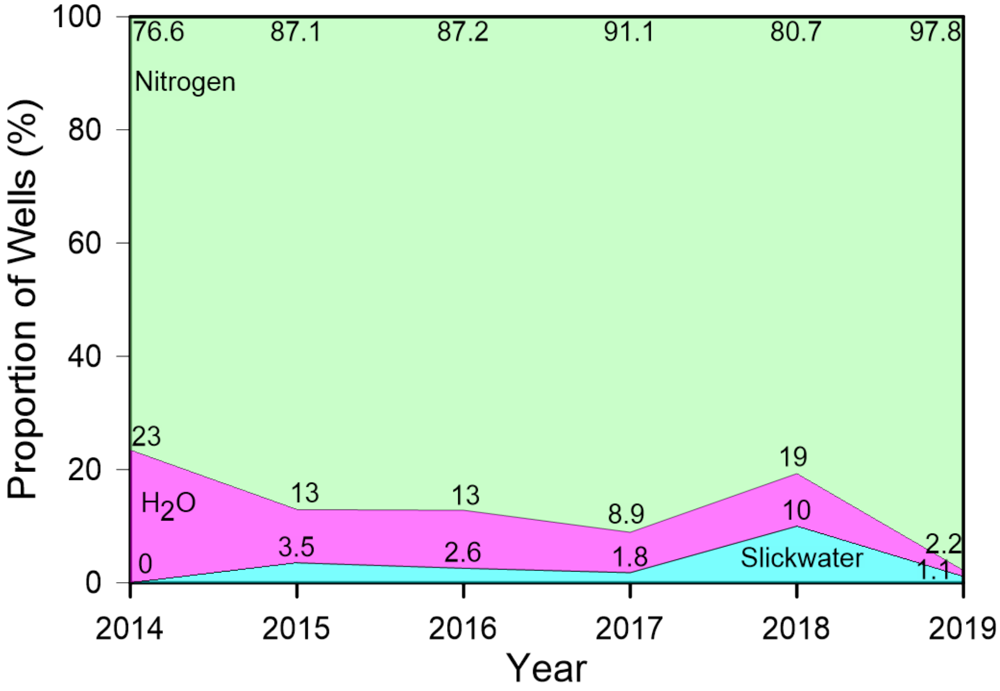

**Figure 4-1. Proportion of oil and gas well stimulation techniques in the Farmington FO from 2014 to 2019 (FracFocus, 2020).**

**Table 4-9. Descriptive statistics of water use of oil and gas wells for three stimulation technologies from 2014 to 2019 within the Farmington FO. Wells hydraulically fractured with water were identified as wells which did not use nitrogen or slickwater stimulation. Data are only presented for wells which reported chemical compositions to FracFocus (2020).**

| | | Water Use (AF/well) | | | |
|---|---|---|---|---|---|
| Well Type | Number of Wells in SJ Basin | Min. | Max. | Median | Mean |
| Nitrogen | 461 | 0.005 | 13.1 | 0.3 | 1.9 |
| Water | 60 | 0.01 | 11.5 | 3.0 | 2.7 |
| Slickwater | 20 | 13.2 | 94.7 | 25.1 | 41.3 |

### 4.1.6. Cumulative Water Use Forecasts

Water use varies greatly year to year. A good strategy for projecting water use over an extended period is the utilization of scenarios with varying conditions. As previously mentioned, the 6-year average of nitrogen stimulated wells within the San Juan Basin is approximately 85%. The first scenario assumes all 2,300 horizontal wells predicted in the revised RFD will use nitrogen stimulation (1.9 AF/horizontal well) which would result in a 20-year cumulative water use of 4,853 AF and a total cumulative use of 6,237 by 2038 (Figure 4-2). The revised RFD scenario (2018 to 2037) predicts an annual use of 580 AF/year which would result in a 20-year cumulative water use of 11,615 AF and a total cumulative use of 12,665 AF by 2037. The 3% annual slickwater increase scenario predicts a consistent 3% increase in the proportion of slickwater wells and a corresponding decrease in water and nitrogen stimulated wells from 2020 to 2037 and is detailed further in (Table 4-10). This scenario assumes an average water use of 1.9, 2.7, and 41.3 AF/well for nitrogen, water, and slickwater stimulated wells, respectively. This scenario would result in an 18-year (2020 to 2037) cumulative water use of 27,229 AF and a total cumulative use of 29,098 AF. The final scenario predicts that all 2,300 wells predicted in the RFD would use slickwater stimulation with an average lateral length of 2 miles (51.3 AF/well) which would result in a 20-year cumulative water use of 124,998 AF and a total cumulative use of 125,565 AF by 2037.

**Table 4-10. Estimated well counts and associated water use of the 3% annual slickwater increase scenario. Estimated well counts were calculated assuming 115 well completions per year (from the RFD) rounded to the whole number, a 3% annual increase in the number of slickwater wells developed per year, and corresponding decrease in other well stimulation methods. An assumed water use of 41.3, 1.9, and 2.7 AF/well was used for the slickwater, nitrogen, and water stimulated wells, respectively.**

| | Estimated # of Wells | | | Estimated Water Use (AF) | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Slickwater | N | Water | Slickwater | N | Water | Total | Cumulative |
| 2020 | 3 | 99 | 13 | 124 | 187 | 35 | 346 | 346 |
| 2021 | 7 | 97 | 12 | 289 | 183 | 33 | 505 | 851 |
| 2022 | 10 | 94 | 10 | 413 | 178 | 27 | 618 | 1,469 |
| 2023 | 14 | 92 | 9 | 578 | 174 | 24 | 777 | 2,246 |
| 2024 | 17 | 90 | 8 | 702 | 170 | 22 | 894 | 3,140 |
| 2025 | 21 | 87 | 7 | 867 | 164 | 19 | 1,051 | 4,191 |
| 2026 | 24 | 85 | 6 | 991 | 161 | 16 | 1,168 | 5,359 |
| 2027 | 28 | 83 | 5 | 1,156 | 157 | 14 | 1,327 | 6,686 |
| 2028 | 31 | 81 | 3 | 1,280 | 153 | 8 | 1,442 | 8,127 |
| 2029 | 35 | 78 | 2 | 1,446 | 147 | 5 | 1,598 | 9,726 |
| 2030 | 38 | 76 | 1 | 1,569 | 144 | 3 | 1,716 | 11,441 |
| 2031 | 41 | 74 | 0 | 1,693 | 140 | 0 | 1,833 | 13,274 |
| 2032 | 45 | 70 | 0 | 1,859 | 132 | 0 | 1,991 | 15,265 |
| 2033 | 48 | 67 | 0 | 1,982 | 127 | 0 | 2,109 | 17,374 |
| 2034 | 52 | 63 | 0 | 2,148 | 119 | 0 | 2,267 | 19,641 |
| 2035 | 55 | 60 | 0 | 2,272 | 113 | 0 | 2,385 | 22,026 |
| 2036 | 59 | 56 | 0 | 2,437 | 106 | 0 | 2,543 | 24,568 |
| 2037 | 62 | 53 | 0 | 2,561 | 100 | 0 | 2,661 | 27,229 |

Of the four scenarios presented, current water use trends over the past 6 years (3.36 AF/well; 300 AF/year) indicate that cumulative water use by 2037 will be approximately 7,300 AF, placing it between the nitrogen and revised RFD scenarios. The slickwater scenario predicts that starting in 2019, all wells within the San Juan Basin would use slickwater stimulation whereas only one well has been completed. The slickwater scenario estimates a 2019 water use of 6,250 AF whereas a water use of only 161 AF was reported to FracFocus. Of the 92 wells completed in 2019, 90 (97.8%) used nitrogen stimulation. Therefore, it is a more likely scenario that all wells completed within the San Juan Basin would use nitrogen stimulation as opposed to slickwater stimulation.

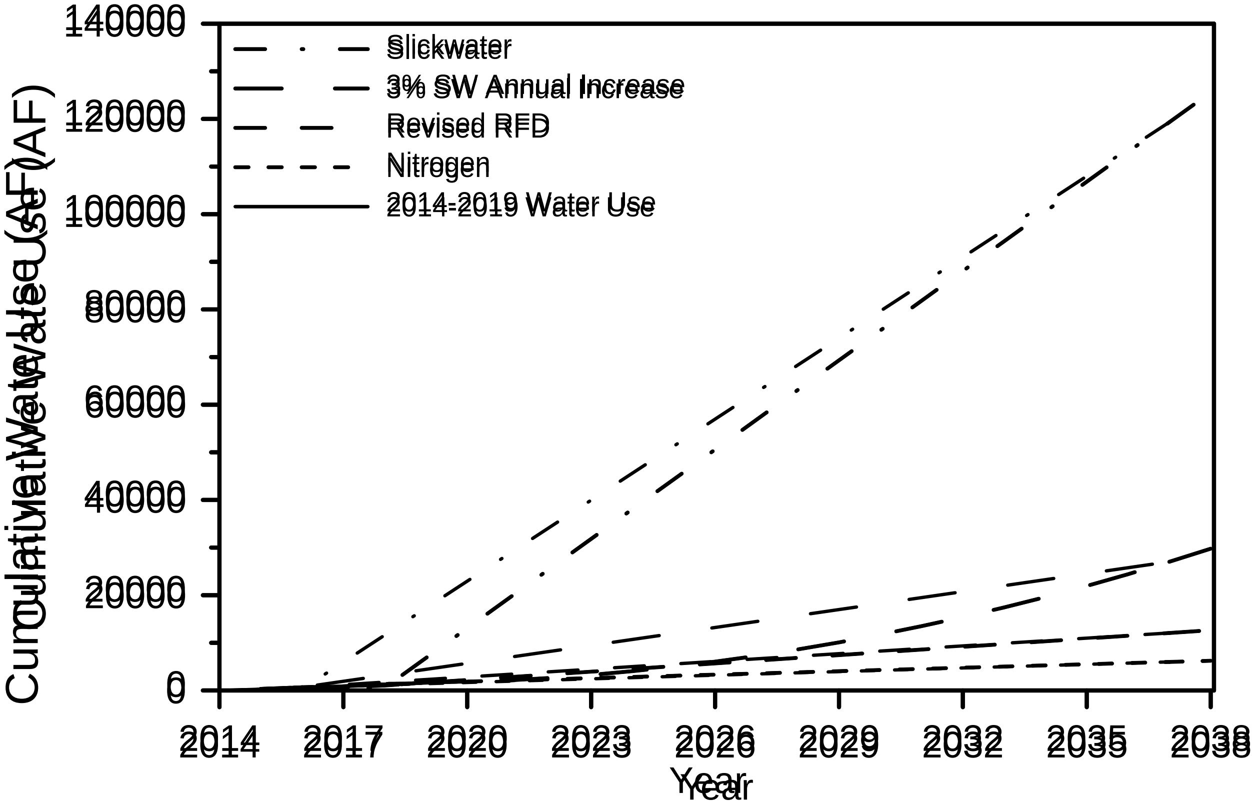

**Figure 4-2. Cumulative water use estimates for four well development scenarios within the New Mexico portion of the San Juan Basin (San Juan, Rio Arriba, and Sandoval Counties). Scenarios are based on a predicted 2,300 horizontal and 900 vertical wells.**

### 4.1.7. Potential Sources of Water for Project Development

Because most water used in mining activities (which encompasses oil and gas development) in the counties that comprise the Farmington FO is currently from groundwater, it is reasonable to project that a large portion of the water used for hydraulic fracturing under the 2018 RFD scenario would be groundwater. Groundwater is a more readily available source of water than surface water due to the ephemeral nature of many surface water features in the San Juan Basin. Generally, sources of groundwater can be found in nearly every area of the Farmington FO. Water yields in these areas vary, but most aquifers yield less than 20 gallons per minute (gpm) (BLM 2003). Aquifers that are known to yield sufficient quantities of water are usually found within the sandstone units of Jurassic, Cretaceous, and Tertiary age (BLM 2003). Aquifers that have the potential to yield 100 gpm include the Ojo Alamo Sandstone, the Nacimiento Formation, and the San Jose Formation, all of which are within the greater Uinta-Animas aquifer (BLM 2003).

San Juan Basin oil and gas operators have included plans to use multiple hydraulic fracturing methods including slickwater fracturing technology. The two general water types that may be used for slickwater stimulation are categorized as “potable/fresh” and “non-potable”. Any water that has Total Dissolved Solids (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 Order #2 (BLM 1988). Non-potable water is outside the appropriative processes and is mainly diverted for mineral exploration purpose. 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 or ground water) into non-traditional sources of water (e.g. non-potable groundwater sources). Recently, the 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 (see Appendix C for more information). Water contained in the Entrada formation is highly saline (Kelley et al., 2014). As such, it is considered non-potable and has not been declared as an administrative aquifer by the NMOSE. Table 4-11 identifies four aquifers found within the Farmington FO, their associated rock types, and sources of recharge.

Other sources of non-potable water that can be utilized in stimulation are “flowback fluid” and “produced water.” Flowback fluid is a mixture of water and small amounts of chemicals and other proppants that flow back through the well head directly after stimulation activities. Generally, 10-40% of the initial volume utilized for stimulation activities returns as flowback fluid, of this 10-40% 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, therefore becoming “produced water.” Based on operator input, after the initial flowback recovery of 10-40%, remaining water used for stimulation does return to the surface through production activities at a slower rate of return. Water used for oil and gas drilling and completion would generally be obtained through the following methods:

- leasing a valid water right through a NMOSE permit.
- buying/leasing water from a legal water provider (or, up to 3 AF, a private well owner).
- purchasing water from a non-potable reclaimed water supplier.

It is speculative to predict the actual source of water that would be used for development of the RFD (or the development of any specific lease sales). In addition to utilizing surface or groundwater, operators may also bring water to a well site via truck from any number of sources. The transaction would be handled by the New Mexico Oil Conservation Division, as well as the New Mexico Office of the State Engineer. All water uses would be evaluated at the APD stage in site-specific NEPA analysis and subject to standard lease terms and conditions; however, it is important to note that sources of water for lease development are also not always known at the APD stage.

**Table 4-11. Potential sources of groundwater in Farmington Field Office (BLM, 2003; Kelley et al., 2014).**

| Aquifer Name | Description | Sources of Recharge |
|---|---|---|
| Mesaverde | Sandstone, coal, siltstone and shale of the Mesaverde Group | Upland areas, mainly in areas of the Zuni Uplift, Chuska Mountains, and northern Sandoval County |
| Rio Grande | Unconsolidated sand and gravel basin-fill | Precipitation and snowmelt from the mountains and valleys that surround the basin. Most precipitation is lost to evaporation and transpiration, and very little percolates to a sufficient depth to recharge the aquifer. |
| Uinta-Animas | Lower tertiary rocks; permeable, coarse, arkosic sandstone interlayered with mudstone; permeable conglomerate and medium to very coarse sandstone interlayered with relatively impermeable shale and mudstone | In higher elevations that encircle the San Juan Basin |
| Entrada Sandstone | Sandstone; eolian sand dunes | Through surface exposures on the margins of the basin in the foothills of the Laramide uplifts. |

### 4.1.8. Water Use Mitigations

Public concern about water use from hydraulic fracturing is especially high in semiarid regions, where water withdrawals for hydraulic fracturing can account for a significant portion of consumptive water use within a given region. Overall, there have been calls to increase the use of alternative water sources such as brackish water or recycling produced water, minimizing the strain on local freshwater resources (Kondash et al., 2018). The BLM encourages the use of recycled water in hydraulic fracturing techniques, and in 2019, the State of New Mexico passed the Produced Water Act, which encourages oil and gas producers to reuse produced water when possible, rather than relying on fresh water sources for oil and gas extraction. Recent studies indicate that the water used for hydraulic fracturing may be retained within the shale formation, with only a small fraction of the fresh water injected into the ground returning as flowback water; water returning to the surface is highly saline, is difficult to treat, and is often disposed through deep-injection wells (Kondash et al., 2018). NMED recently signed a memorandum of understanding with New Mexico State University to develop new technologies for treating produced water to inform future policies for produced water reuse.

As noted above, water-intensive stimulation methods such as slickwater fracturing can be accomplished using non-traditional water sources, including the connate water within the Entrada Formation. NMOSE is the agency responsible for water withdrawal permitting actions. Their NOI 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.

## 4.2. Water Quality

### 4.2.1. Groundwater

Results of the hydrologic assessment of oil and gas development of the Mancos Shale in the San Juan Basin (Kelley et al., 2014) indicate that groundwater quality in the San Juan Basin is variable (ranging from fresh to brackish) due to the complex stratigraphy and varying rock formations within the Basin. Brackish and saline water is typically found in the center of the Basin, and fresh groundwater is typically found along the Basin margins. Deep saline water can migrate upward along cracks and fissures. Fresh water along the Basin margins at depths greater than 3,500 feet indicate fast recharge rates influenced by geologic structures (Kelley et al., 2014).

The geologic formation where groundwater resides also influences groundwater salinity. Figure 4.3 is an illustrated geologic cross section showing the distribution of saline aquifers within the San Juan Basin.

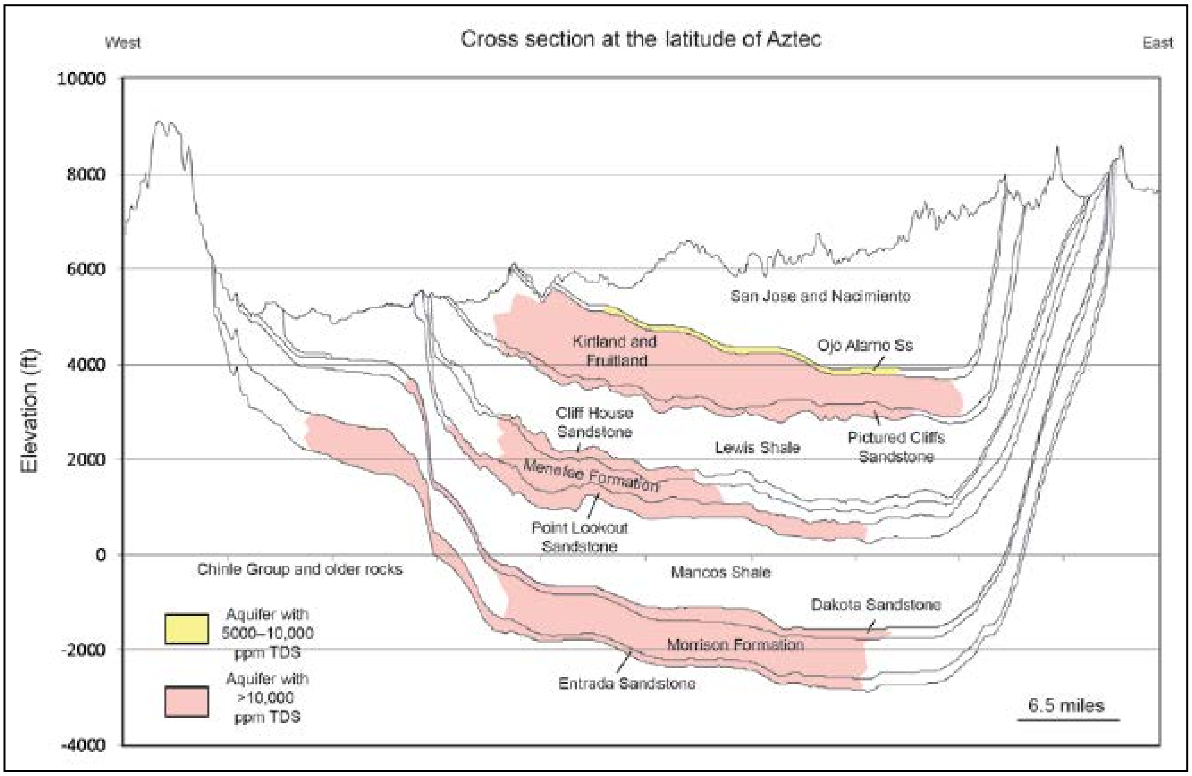

**Figure 4.3. Geologic cross section showing the distribution of saline aquifers in the San Juan Basin (Kelley et al., 2014).**

Total dissolved solids (TDS) concentration is a measure of all the dissolved matter in a sample of water. TDS is the primary indicator of groundwater quality as higher TDS concentrations typically make water less suitable for drinking or for agricultural purposes like irrigation. In groundwater, TDS is influenced by the dissolution of natural materials such as rock, soil, and organic material. Anthropogenic activities also contribute to TDS concentrations in shallow unconfined aquifers.

TDS concentration in the San Juan Basin is dependent on the stratigraphic location and the geologic formation where the water resides. Fresh water (TDS < 1,000 milligrams per liter [mg/l]) is typically found at depths <2,500 feet (ft) below the ground surface, although exceptions to this generalization occur in deeper layers like the Gallup Sandstone and Morrison Formation. Saline and brackish water is dominant in the center of the Basin at deeper depths (Kelley et al., 2014).

### 4.2.2. Surface Water

Stream and river conditions vary widely, from completely undisturbed river and vegetative communities in the mountainous highlands, to deep, erodible soil banks at lower elevations where livestock, recreationists, and other public users have access to stream and riverbanks. Water quality in streams flowing on BLM-managed land is influenced by both natural water quality with regard to salinity content and the intensity of human and industrial activity in the watershed. For example, water quality may be vastly different in a remote mountain spring creek than in waters with natural brine discharge, or where there are human impacts due to urban, farming, ranching, or industrial activity.

Further chemistry samples of surface water in the region are needed to establish a baseline chemistry data for the waters. Variances in baseline chemistry can indicate water quality changes attributable to changes in land use. The most common pollutants for waters in the region are sediment and mercury. Beneficial uses listed for these waters are industrial water supply, irrigation storage, livestock watering, recreation, warm water fishery, and wildlife habitat. The dominant legislation affecting national water quality and BLM compliance with New Mexico water quality requirements is the Clean Water Act (CWA) or Federal Water Pollution Control Act.

### 4.2.3. Potential Sources of Surface Water or Groundwater Contamination

#### Spills

Spills associated with oil and gas development may reach surface water directly during the spill event. Spills may also reach surface waters indirectly, when the spill has occurred and a rain event moves contaminants into nearby surface water bodies through surface water flow or even subsurface groundwater flow into springs that discharge into a surface water body.

The San Juan Basin has been a producing oil and natural gas field since the early to middle 1900s. According to available GIS data, approximately 37,300 wells (federal and non-federal) have been drilled within the boundary of the Farmington FO (BLM 2018). In 2017 oil and gas development resulted in 5,979,536 barrels (bbls) of crude oil; 464,709,385 thousand cubic feet (mcf) of natural gas; and 17,068,297 bbls of produced water. As shown in Table 4-12, there were a total of 159 spills in the New Mexico portion of the San Juan Basin in 2019.

In 2019, the rate of recovery varied by spill type but, in general, about 76% of all spills were not recovered. Of the spills this year, zero incidents were reported as having affected surface waterways or groundwater. The BLM works with the NMOCD to remediate spills on public BLM lands. Per NMAC 19.15.29.11, the responsible person shall complete division-approved corrective action for releases that endanger public health or the environment in accordance with a remediation plan submitted to and approved by the division or with an abatement plan submitted in accordance with 19.15.30 NMAC. The remaining contaminates from unrecovered spills are remediated in accordance with federal and state standards. Some remediation consists of removing contaminated soil and replacing it with uncontaminated soil and corresponding chemical testing.

**Table 4-12. Summary of 2019 Spills in New Mexico portion of the San Juan Basin (San Juan, Rio Arriba, and Sandoval Counties; NMOCD, 2020).**

| Material Type | Spill Count | Volume Spilled | Volume Lost | Units | %Lost |
|---|---|---|---|---|---|
| Condensate | 22 | 650 | 650 | Barrels | 100 |
| Crude Oil | 14 | 510 | 242 | Barrels | 47.45 |
| Glycol | 2 | 15 | 15 | Barrels | 100 |
| Other | 19 | 294 | 154 | Barrels | 52.38 |
| Produced Water | 48 | 1,791 | 1,424 | Barrels | 79.51 |
| **Total** | 105 | 3,260 | 2,485 | | 76.23 |
| | | | | | |
| Natural Gas (Methane) | 35 | 12,678 | 12,678 | MCF | 100 |
| Natural Gas Liquids | 19 | 36 | 36 | MCF | 100 |
| **Total Number of Spills** | **159** | | | | |

The chemical composition of water used during the hydraulic fracturing process varies due to differences in fracturing techniques used by oil and gas companies. The most commonly disclosed chemical used in San Juan Basin wells was ethanol with 2,662 disclosures (Table 4-13). Other frequent disclosures included 1,2-propylene glycol (n=2,332), water (n=1,058), and quartz-alpha (n=933). There were 2,010 records of non-disclosed chemicals which includes chemicals listed as proprietary, confidential, and trade secrets. There 7 records with CAS registry number errors and were unidentifiable.

**Table 4-13. Twenty-five most frequently disclosed chemicals in horizontal wells within the San Juan Basin (San Juan, Rio Arriba, and Sandoval Counties) from 2014 to 2019. Data were obtained from FracFocus (2020) and are only presented for wells which reported chemical data.**

| EPA Chemical Name | CAS Registry Number[1] | Number of Disclosures[2] | Median (mg/L) | Sum (Mg) |
|---|---|---|---|---|
| Ethanol | 64-17-5 | 2,662 | 66.8 | 2,282 |
| 1,2-Propylene glycol | 57-55-6 | 2,332 | 67.4 | 2,060 |
| Not-Disclosed | - | 2,010 | 47.2 | 52,991 |
| Water | 7732-18-5 | 1,058 | 2,862 | 221,865 |
| Quartz-alpha (SiO2) | 14808-60-7 | 933 | 246,388 | 755,554 |
| Sodium chloride | 7647-14-5 | 589 | 641.5 | 649.9 |
| Methanol | 67-56-1 | 570 | 119.7 | 294.9 |
| Nitrogen | 7727-37-9 | 463 | 322,504 | 514,283 |
| Solvent naphtha, petroleum, heavy arom. | 64742-94-5 | 411 | 120.9 | 146.7 |
| Naphthalene | 91-20-3 | 409 | 6.6 | 20.2 |
| Guar gum | 9000-30-0 | 360 | 2,314 | 2,335 |
| Glycerol | 56-81-5 | 353 | 168.7 | 95.9 |
| Hydrochloric acid | 7647-01-0 | 329 | 3,907 | 1,578 |
| Tergitol | 127087-87-0 | 311 | 18.7 | 19.9 |
| 1,2,4-Trimethylbenzene | 95-63-6 | 310 | 3.8 | 4.1 |
| Isopropanol | 67-63-0 | 248 | 570.7 | 349.8 |
| Distillates, petroleum, hydrotreated light | 64742-47-8 | 246 | 855.1 | 908.2 |
| Hemicellulase | 9012-54-8 | 243 | 19.9 | 12.9 |
| Formaldehyde | 50-00-0 | 241 | 3.5 | 10.4 |
| Ethylene glycol | 107-21-1 | 208 | 45.9 | 32.0 |
| Sodium hydroxide | 1310-73-2 | 193 | 5.9 | 3.2 |
| Sodium hypochlorite | 7681-52-9 | 193 | 76.4 | 47.7 |
| Propargyl alcohol | 107-19-7 | 187 | 2.6 | 0.4 |
| Lactose | 63-42-3 | 184 | 85.5 | 34.0 |
| Thiourea, polymer with formaldehyde and 1-phenylethanone | 68527-49-1 | 184 | 5.6 | 0.9 |

[1] 7 CAS Errors

[2] 20,685 Disclosures

### Drilling and Completion Activities

When wells are drilled, they most likely pass through usable groundwater aquifers currently or potentially supplying stock, residential, and/or irrigation water. If proper cementing and casing programs are not followed, there may be a loss of well integrity, surface spills, or loss of fluids in the drilling and completion process that could result in large volumes of high concentrations of chemicals reaching groundwater resources. If contamination of usable water aquifers (total dissolved solids less than 10,000 parts per million [ppm]) from any source occurs, changes in groundwater quality could impact springs and water wells that are sourced from the affected aquifers.

The BLM and State of New Mexico Oil Conservation Division (NMOCD) have casing, cementing, and inspection requirements in place to limit the potential for groundwater reservoirs and shallow aquifers to be impacted by fracking or the migration of hydrocarbons during oil and gas drilling and production activities. The BLM requires operators to comply with the regulations at 43 Code of Federal Regulations (CFR) 3160. These regulations require oil and gas development to comply with directives in the Onshore Orders and the orders of the Authorized Officer. Onshore Order No. 2 and the regulations at 43 CFR 3162.3-3 provide regulatory requirements for hydraulic fracturing, including casing specifications, monitoring and recording, and management of recovered fluids. The State of New Mexico also has regulations for drilling, casing and cementing, completion, and plugging to protect freshwater zones (19.15.16 New Mexico Administrative Code). Complying with the aforementioned regulations requires producers and regulators to verify the integrity of casing and cement jobs. Casing specifications are designed and submitted to the BLM together with an APD. The BLM petroleum engineer independently reviews the drilling plan, and based on site-specific geologic and hydrologic information, ensures that proper drilling, casing and cementing procedures are incorporated in the plan to protect usable groundwater. This isolates usable water zones from drilling, completion/hydraulic fracturing fluids, and fluids from other mineral bearing zones, including hydrocarbon bearing zones. Conditions of Approval (COAs) are attached to the APD to ensure groundwater protection. Casing and cementing operations are witnessed by certified BLM Petroleum Engineering Technicians. At the end of the well’s economic life, the operator must submit a plugging plan, which is reviewed by the BLM petroleum engineer prior to well plugging. This review ensures permanent isolation of usable groundwater from hydrocarbon bearing zones. BLM inspectors ensure planned procedures are properly followed in the field.

The requirements listed above are in place so that drilling fluids, hydraulic fracturing fluids, and produced water and hydrocarbons remain within the well bore and do not enter groundwater or any other formations. This makes contamination of groundwater resources highly unlikely. Since the advent of hydraulic fracturing, more than 1 million hydraulic fracturing treatments have been conducted nation-wide, with perhaps only one documented case of direct groundwater pollution resulting from injection of hydraulic fracturing chemicals used for shale gas extraction (Gallegos and Varela 2015).

# CHAPTER 5. RIO PUERCO FIELD OFFICE

The Rio Puerco Field Office (FO) is approximately 8,620,838 acres and includes all of Bernalillo, Cibola, Torrance, and Valencia Counties, most of Sandoval County, and small parts of McKinley and Santa Fe Counties. Some of the land managed by the Rio Puerco FO within Sandoval County is within the San Juan Basin. To date, most of the drilling in the Rio Puerco FO has occurred in the portion of Sandoval County that is within the San Juan Basin.

Chapter 4 outlines existing and projected (reasonably foreseeable) water quantity and water quality for the Rio Puerco FO. The analysis is based on information gathered from the following sources: 1) the newly revised RFD for the RPFO (Crocker et al., 2019), 2) 2015 consumptive water use data from a USGS report, Estimated Use of Water in the United States in 2015 (Dieter et. al. 2017), and 3) FracFocus, a national hydraulic fracturing chemical registry managed by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission (FracFocus 2020).

## 5.1. Water Quantity

### 5.1.1. Existing Surface and Groundwater Use

The water use of counties within the RPFO boundaries varies greatly and is dependent on the predominant industry within that county. In 2015, public water supply and domestic water use comprised the greatest proportion of water use in McKinley County (53%; 7,006 AF;Table 5-1). Bernalillo County (which contains Albuquerque) consumed 155,388 AF of water in 2015 with public water supply (69%; 106,820 AF) and irrigation (30%; 46,544 AF) comprising 99% of water use (Table 5-1). Irrigation used the greatest proportion of water in Sandoval (79%; 50,647 AF), Valencia (93%; 146,246), Torrance (94%; 45,849), Santa Fe (62%; 24,315 AF) and Cibola (50%; 5,448 AF) counties (Table 5-2,Table 5-3, Table 5-4,Table 5-5, and Table 5-6). Water use associated with mining (which includes oil and gas development), ranged from 112 to 2,309 AF (Torrance and McKinley Counties, respectively). The proportion of surface and groundwater use varied by county and was also industry specific. Total water use for all RPFO counties totaled 495,881 AF with surface water and groundwater comprising 60% and 40%, respectively. Mining activities consumed 5,953 AF which comprised 1% of water usage in 2015. Irrigation, which consumed 320,148 AF (65% of all water usage), was the sector that consumed the greatest amount of water within the RPFO boundaries.

## Table 5-1. McKinley County water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Domestic | 0 | 0 | 0 | 0% | 3,195 | 0 | 3,195 | 24% | 3,195 | 24% | 0 | 0% | 3,195 | 24% |
| Industrial | 0 | 0 | 0 | 0% | 34 | 0 | 34 | 0% | 34 | 0% | 0 | 0% | 34 | 0% |
| Irrigation | 1,099 | 0 | 1,099 | 8% | 0 | 0 | 0 | 0% | 1,099 | 8% | 0 | 0% | 1,099 | 8% |
| Livestock | 101 | 0 | 101 | 1% | 370 | 0 | 370 | 3% | 471 | 4% | 0 | 0% | 471 | 4% |
| Mining | 0 | 0 | 0 | 0% | 1,626 | 684 | 2,310 | 17% | 1,626 | 12% | 684 | 5% | 2,310 | 17% |
| Public Water Supply | 0 | 0 | 0 | 0% | 3,811 | 0 | 3,811 | 29% | 3,811 | 29% | 0 | 0% | 3,811 | 29% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 2,298 | 0 | 2,298 | 17% | 2,298 | 17% | 0 | 0% | 2,298 | 17% |
| **County Totals** | **1,200** | **0** | **1,200** | **9.08%** | **11,334** | **684** | **12,018** | **90.92%** | **12,534** | **94.83%** | **684** | **5.17%** | **13,218** | **100%** |

[a]Water use data are presented in acre-feet.

## Table 5-2. Bernalillo County water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 22 | 0 | 22 | 0% | 22 | 0% | 0 | 0% | 22 | 0% |
| Domestic | 0 | 0 | 0 | 0% | 1,312 | 0 | 1,312 | 1% | 1,312 | 1% | 0 | 0% | 1,312 | 1% |
| Industrial | 0 | 0 | 0 | 0% | 56 | 0 | 56 | 0% | 56 | 0% | 0 | 0% | 56 | 0% |
| Irrigation | 38,843 | 0 | 38,843 | 25% | 7,701 | 0 | 7,701 | 5% | 46,544 | 30% | 0 | 0% | 46,544 | 30% |
| Livestock | 11 | 0 | 11 | 0% | 191 | 0 | 191 | 0% | 202 | 0% | 0 | 0% | 202 | 0% |
| Mining | 0 | 0 | 0 | 0% | 135 | 0 | 135 | 0% | 135 | 0% | 0 | 0% | 135 | 0% |
| Public Water Supply | 52,743 | 0 | 52,743 | 34% | 54,077 | 0 | 54,077 | 35% | 106,820 | 69% | 0 | 0% | 106,820 | 69% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 292 | 0 | 292 | 0% | 292 | 0% | 0 | 0% | 292 | 0% |
| **County Totals** | **91,597** | **0** | **91,597** | **58.95%** | **63,786** | **0** | **63,786** | **41.05%** | **155,383** | **100.00%** | **0** | **0.00%** | **155,383** | **100%** |

[a]Water use data are presented in acre-feet.

## Table 5-3. Sandoval County water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 1,087 | 0 | 1,087 | 2% | 1,087 | 2% | 0 | 0% | 1,087 | 2% |
| Domestic | 0 | 0 | 0 | 0% | 3,128 | 0 | 3,128 | 4% | 3,128 | 4% | 0 | 0% | 3,128 | 4% |
| Industrial | 0 | 0 | 0 | 0% | 2,578 | 0 | 2,578 | 4% | 2,578 | 4% | 0 | 0% | 2,578 | 4% |
| Irrigation | 48,326 | 0 | 48,326 | 68% | 2,321 | 0 | 2,321 | 3% | 50,647 | 71% | 0 | 0% | 50,647 | 71% |
| Livestock | 101 | 0 | 101 | 0% | 123 | 0 | 123 | 0% | 224 | 0% | 0 | 0% | 224 | 0% |
| Mining | 0 | 0 | 0 | 0% | 1,065 | 247 | 1,312 | 2% | 1,065 | 1% | 247 | 0% | 1,312 | 2% |
| Public Water Supply | 135 | 0 | 135 | 0% | 12,466 | 0 | 12,466 | 17% | 12,601 | 18% | 0 | 0% | 12,601 | 18% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| **County Totals** | **48,562** | **0** | **48,562** | **67.85%** | **22,768** | **247** | **23,015** | **32.15%** | **71,330** | **99.65%** | **247** | **0.35%** | **71,577** | **100%** |

[a] Water use data are presented in acre-feet.

## Table 5-4. Valencia County water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Domestic | 0 | 0 | 0 | 0% | 3,554 | 0 | 3,554 | 2% | 3,554 | 2% | 0 | 0% | 3,554 | 2% |
| Industrial | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Irrigation | 136,157 | 0 | 136,157 | 87% | 10,089 | 0 | 10,089 | 6% | 146,246 | 93% | 0 | 0% | 146,246 | 93% |
| Livestock | 34 | 0 | 34 | 0% | 987 | 0 | 987 | 1% | 1,021 | 1% | 0 | 0% | 1,021 | 1% |
| Mining | 0 | 0 | 0 | 0% | 437 | 0 | 437 | 0% | 437 | 0% | 0 | 0% | 437 | 0% |
| Public Water Supply | 0 | 0 | 0 | 0% | 5,538 | 0 | 5,538 | 4% | 5,538 | 4% | 0 | 0% | 5,538 | 4% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| **County Totals** | **136,191** | **0** | **136,191** | **86.86%** | **20,605** | **0** | **20,605** | **13.14%** | **156,796** | **100.00%** | **0** | **0.00%** | **156,796** | **100%** |

[a] Water use data are presented in acre-feet.

## Table 5-5. Torrance County water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Domestic | 0 | 0 | 0 | 0% | 437 | 0 | 437 | 1% | 437 | 1% | 0 | 0% | 437 | 1% |
| Industrial | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Irrigation | 0 | 0 | 0 | 0% | 45,849 | 0 | 45,849 | 94% | 45,849 | 94% | 0 | 0% | 45,849 | 94% |
| Livestock | 45 | 0 | 45 | 0% | 605 | 0 | 605 | 1% | 650 | 1% | 0 | 0% | 650 | 1% |
| Mining | 0 | 0 | 0 | 0% | 112 | 0 | 112 | 0% | 112 | 0% | 0 | 0% | 112 | 0% |
| Public Water Supply | 0 | 0 | 0 | 0% | 1,973 | 0 | 1,973 | 4% | 1,973 | 4% | 0 | 0% | 1,973 | 4% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| **County Totals** | **45** | **0** | **45** | **0.09%** | **48,976** | **0** | **48,976** | **99.91%** | **49,021** | **100.00%** | **0** | **0.00%** | **49,021** | **100%** |

[a] Water use data are presented in acre-feet.

## Table 5-6. Santa Fe County water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Domestic | 0 | 0 | 0 | 0% | 2,522 | 0 | 2,522 | 6% | 2,522 | 6% | 0 | 0% | 2,522 | 6% |
| Industrial | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Irrigation | 11,378 | 0 | 11,378 | 29% | 12,936 | 0 | 12,936 | 33% | 24,314 | 62% | 0 | 0% | 24,314 | 62% |
| Livestock | 56 | 0 | 56 | 0% | 67 | 0 | 67 | 0% | 123 | 0% | 0 | 0% | 123 | 0% |
| Mining | 0 | 0 | 0 | 0% | 224 | 0 | 224 | 1% | 224 | 1% | 0 | 0% | 224 | 1% |
| Public Water Supply | 4,663 | 0 | 4,663 | 12% | 7,185 | 0 | 7,185 | 18% | 11,848 | 30% | 0 | 0% | 11,848 | 30% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| **County Totals** | **16,097** | **0** | **16,097** | **41.24%** | **22,934** | **0** | **22,934** | **58.76%** | **39,031** | **100.00%** | **0** | **0.00%** | **39,031** | **100%** |

[a] Water use data are presented in acre-feet.

## Table 5-7. Cibola County water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Domestic | 0 | 0 | 0 | 0% | 1,143 | 0 | 1,143 | 11% | 1,143 | 11% | 0 | 0% | 1,143 | 11% |
| Industrial | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| Irrigation | 1,592 | 0 | 1,592 | 15% | 3,856 | 0 | 3,856 | 36% | 5,448 | 50% | 0 | 0% | 5,448 | 50% |
| Livestock | 34 | 0 | 34 | 0% | 135 | 0 | 135 | 1% | 169 | 2% | 0 | 0% | 169 | 2% |
| Mining | 0 | 0 | 0 | 0% | 67 | 1,356 | 1,424 | 13% | 67 | 1% | 1,356 | 12% | 1,424 | 13% |
| Public Water Supply | 0 | 0 | 0 | 0% | 2,668 | 0 | 2,668 | 25% | 2,668 | 25% | 0 | 0% | 2,668 | 25% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 0 | 0 | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| **County Totals** | **1,626** | **0** | **1,626** | **14.98%** | **7,869** | **1,356** | **9,226** | **85.02%** | **9,495** | **87.50%** | **1,356** | **12.50%** | **10,852** | **100%** |

[a]Water use data are presented in acre-feet.

## Table 5-8. Rio Puerco Field Office Counties water use by category in 2015 (Dieter et al., 2017).

| Category | Surface Water | | | | Groundwater | | | | Total Withdrawals | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh | Saline | Total | Total Use (%) | Fresh | Saline | Total | Total Use (%) | Fresh | Total Use (%) | Saline | Total Use (%) | Total | Total Use (%) |
| Aquaculture | 0 | 0 | 0 | 0% | 1,109 | 0 | 1,109 | 0% | 1,109 | 0% | 0 | 0% | 1,109 | 0% |
| Domestic | 0 | 0 | 0 | 0% | 15,291 | 0 | 15,291 | 3% | 15,291 | 3% | 0 | 0% | 15,291 | 3% |
| Industrial | 0 | 0 | 0 | 0% | 2,668 | 0 | 2,668 | 1% | 2,668 | 1% | 0 | 0% | 2,668 | 1% |
| Irrigation | 237,395 | 0 | 237,395 | 48% | 82,752 | 0 | 82,752 | 17% | 320,147 | 65% | 0 | 0% | 320,147 | 65% |
| Livestock | 382 | 0 | 382 | 0% | 2,478 | 0 | 2,478 | 0% | 2,860 | 1% | 0 | 0% | 2,860 | 1% |
| Mining | 0 | 0 | 0 | 0% | 3,666 | 2,287 | 5,954 | 1% | 3,666 | 1% | 2,287 | 0% | 5,954 | 1% |
| Public Water Supply | 57,541 | 0 | 57,541 | 12% | 87,718 | 0 | 87,718 | 18% | 145,259 | 29% | 0 | 0% | 145,259 | 29% |
| Thermoelectric Power | 0 | 0 | 0 | 0% | 2,590 | 0 | 2,590 | 1% | 2,590 | 1% | 0 | 0% | 2,590 | 1% |
| **County Totals** | **295,318** | **0** | **295,318** | **59.55%** | **198,272** | **2,287** | **200,559** | **40.45%** | **493,590** | **99.54%** | **2,287** | **0.46%** | **495,877** | **100%** |

[a]Water use data are presented in acre-feet.

### 5.1.2. Water Use Associated with Reasonably Foreseeable Oil and Gas Development

In 2019, a new RFD was published which updates the estimates for the number of oil and gas wells that could reasonably occur within the boundaries of the RPFO. Although the RPFO encompasses several counties, the only county with consistent oil and gas well development is Sandoval County. As such, oil and gas development scenarios and discussion in this chapter assumes that all development will occur within the portion of Sandoval County within the planning area of the RPFO.

The 2019 RFD forecasted development of 200 oil and gas wells (federal and non-federal) over a 20-year period from 2020 to 2039 (Table 5-8). Of the 200 projected wells, 160 wells are expected to be vertical and 40 wells are expected to be horizontal. Annual well counts are expected to increase from 7 to 13 per year from 2020 to 2039.

The RPFO RFD was also used to forecast estimates of the quantity of water that would be required for hydraulic fracturing of the forecasted wells. These water use estimates assume that 100% of wells will be hydraulically fractured, and do not account for re-use or recycling of hydraulic fracturing fluid. The quantity of water used during hydraulic fracturing is expected to increase from 8.34 to 22.49 AF per year from 2020 to 2039 with an estimated total water use of 307.4 AF over the 20-year period. The water use projections assume that one vertical well will require 0.32 AF and one horizontal well with a 1-mile lateral will require 6.44 AF) (Crocker and Glover, 2019).

**Table 5-9. Annual projections for oil and gas well development and water use for federal and non-federal well development within the RPFO from 2020 to 2039.**

| | Number of Wells to be Developed | | | | | | Water Use for Hydraulic Fracturing (AF) | |
|---|---|---|---|---|---|---|---|---|
| | Total | | Horizontal | | Vertical | | | |
| Year | Non-Federal | Federal | Non-Federal | Federal | Non-Federal | Federal | Non-Federal | Federal |
| 2020 | 2 | 5 | 0 | 1 | 2 | 4 | 0.63 | 7.71 |
| 2021 | 2 | 5 | 0 | 1 | 2 | 4 | 0.63 | 7.71 |
| 2022 | 2 | 5 | 1 | 1 | 1 | 4 | 6.76 | 7.71 |
| 2023 | 3 | 5 | 1 | 1 | 2 | 4 | 6.76 | 7.71 |
| 2024 | 3 | 5 | 1 | 1 | 2 | 4 | 6.76 | 7.71 |
| 2025 | 3 | 5 | 1 | 1 | 2 | 4 | 6.76 | 7.71 |
| 2026 | 3 | 6 | 1 | 1 | 2 | 5 | 7.07 | 8.03 |
| 2027 | 3 | 6 | 1 | 1 | 2 | 5 | 7.07 | 8.03 |
| 2028 | 4 | 6 | 1 | 1 | 3 | 5 | 7.39 | 8.03 |
| 2029 | 4 | 6 | 1 | 1 | 3 | 5 | 7.39 | 8.03 |
| 2030 | 4 | 6 | 1 | 1 | 3 | 5 | 7.39 | 8.03 |
| 2031 | 4 | 7 | 0 | 2 | 4 | 5 | 1.26 | 14.47 |
| 2032 | 4 | 7 | 0 | 2 | 4 | 5 | 1.26 | 14.47 |
| 2033 | 4 | 7 | 0 | 2 | 4 | 5 | 1.26 | 14.47 |
| 2034 | 4 | 8 | 0 | 2 | 4 | 6 | 1.26 | 14.79 |
| 2035 | 4 | 8 | 0 | 2 | 4 | 6 | 1.26 | 14.79 |
| 2036 | 4 | 8 | 0 | 2 | 4 | 6 | 1.26 | 14.79 |
| 2037 | 4 | 8 | 0 | 2 | 4 | 6 | 1.26 | 14.79 |
| 2038 | 5 | 8 | 1 | 2 | 4 | 6 | 7.7 | 14.79 |
| 2039 | 5 | 8 | 1 | 2 | 4 | 6 | 7.7 | 14.79 |
| Total | 71 | 129 | 11 | 29 | 60 | 100 | 88.83 | 218.56 |

Water used for development of the estimated 200 wells in the RFD scenario is assumed to come primarily from groundwater sources based on previous oil and gas development in the area and USGS county water use data. The projected well developments within Sandoval County is an estimated 23.4% of water used in mining and 0.43% of the total water consumption in 2015. Due to the split of Sandoval County between the FFO and RPFO and the lack of historical water use data, it is difficult to accurately predict the water use of oil and gas development throughout the county over the next 20 years.

### 5.1.3. Cumulative Water Use Estimates

#### Past and Present Actions

Unlike the Carlsbad and Farmington Field Offices, oil and gas development within the RPFO has been minimal. Since 2014 there have been no completed oil and gas wells (federal and non-federal) within the administrative boundaries of the RPFO reported to FracFocus. Although there has been consistent development within Sandoval County, the completed oil and gas wells are within the Farmington Field Office boundaries. As such, there are no data available for water use by oil and gas wells within the RPFO boundaries and statistical analysis and forecasting is not possible.

#### 5.1.4. Cumulative Water Use Forecasts

The RPFO RFD predicts an initial development of 7 wells and a water use of 8.34 AF in 2020 which is predicted to increase to 13 wells and a water use of 22.49 by 2039, resulting in a 20-yr average water use of 15.4 AF/yr and a total water use of 307.39 AF (Figure 5-1). The projected well developments would be an estimated 23.4% of water used in mining and 0.43% of the total water consumption in 2015.

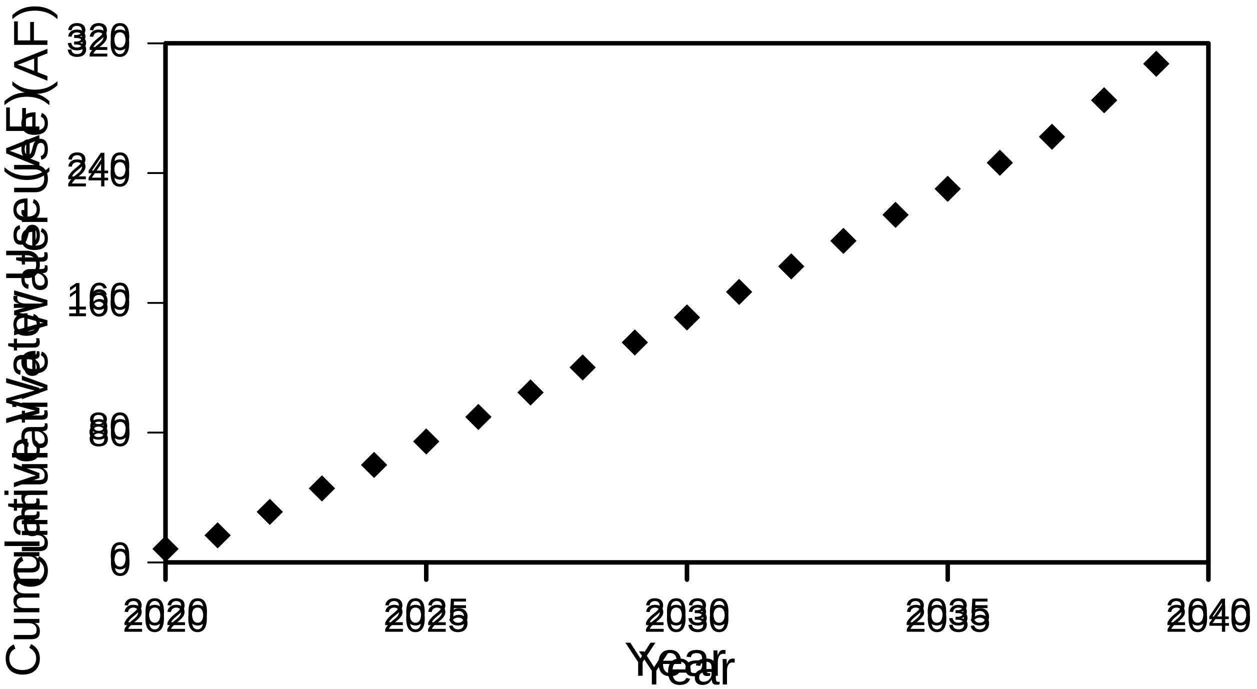

**Figure 5-1. Cumulative water use projections for oil and gas wells within the Rio Puerco Field Office from 2020 to 2039.**

Water use estimates from the neighboring FFO may also provide some insight on water use by oil and gas wells developed in RPFO in the future. From 2014 to 2019, 71 wells in Sandoval County reported data to FracFocus. Average water use varied by stimulation technique and averaged 3.8, 3.9, and 19.2 AF/well for nitrogen, water, and slickwater stimulation techniques, respectively (Table 5-9). The distribution of stimulation technologies within a year varies greatly which makes it difficult to predict total water usage. As such, the values provided in the RPFO RFD should be used for water use projections.

**Table 5-10. Descriptive statistics of water use of oil and gas wells for three stimulation technologies from 2014 to 2019 within Sandoval County. Wells hydraulically fractured with water were identified as wells which did not use nitrogen or slickwater stimulation. Data are only presented for wells which reported chemical compositions to FracFocus (2020).**

| | | Water Use (AF/well) | | | |
|---|---|---|---|---|---|
| Stimulation Technique | Number of Wells | Minimum | Maximum | Median | Mean |
| Nitrogen | 54 | 0.1 | 13.1 | 3.3 | 3.8 |
| Slickwater | 8 | 13.2 | 25.3 | 19.5 | 19.2 |
| Water | 9 | 2.6 | 5.3 | 4.0 | 3.9 |

### 5.1.5. Potential Sources of Water for Project Development

Water used for oil and gas drilling and completion would be purchased legally from those who hold water rights in or around the San Juan Basin. The transaction would be handled by the New Mexico Oil Conservation Division, as well as the New Mexico Office of the State Engineer. All water uses would be evaluated at the APD stage in site-specific NEPA analysis and subject to standard lease terms and conditions; however, it is important to note that sources of water for lease development are also not always known at the APD stage.

It is speculative to predict the actual source of water that would be used for development of the RFD (or the development of any specific lease sales). In addition to utilizing surface or groundwater, operators may also bring water to a well site via truck from any number of sources. Because most water used in mining activities in the counties that comprise the Rio Puerco FO is currently from groundwater, it is reasonable to assume that a large portion of the water used for hydraulic fracturing under the RFD scenario would likely be groundwater. Groundwater is a more readily available source of water than surface water due to the ephemeral nature of many surface water features in the San Juan Basin. Therefore, surface waters are discussed only briefly in this chapter.

The Rio Puerco FO contains many types of surface water bodies including springs, seeps, lakes, rivers, streams, and ephemeral drainages and draws. Waters from spring developments, reservoirs, streams, and stream diversions within the planning area are used primarily for irrigation, livestock, and wildlife. Diversions on BLM-managed lands support private land crop irrigation and stock water needs.

Information about the aquifers underlying the Rio Puerco FO comes primarily from the hydrologic assessment of oil and gas development in the San Juan Basin (Kelley et al., 2014), the Mancos-Gallup Resource Management Plan Amendment and EIS (BLM 2015), and from the Mancos-Gallup Resource Management Plan Amendment and Environmental Impact Statement (BLM 2015).

The geologic setting of the region is highly stratified and complex. Geologic processes have created both continuous and discontinuous sandstone aquifers. There are ten major confined aquifers in the San Juan Basin: Morrison Formation, Ojo Alamo Sandstone, Pictured Cliffs Sandstone, Cliff House Sandstone, Menefee Formation, Kirtland Shale/Fruitland Formation, Point Lookout Sandstone, Gallup Sandstone, Dakota Sandstone, and Entrada Sandstone”

(Kelley et al., 2014). “Most of the groundwater in the San Juan Basin is developed in Cenozoic to Mesozoic sandstones that are separated by low-permeability shale to mudstone intervals” (Kelley et al., 2014). Table 5-10 lists the general description of the major formations in the San Juan Basin.

Cenozoic (younger) aquifers in the San Juan Basin, such as the Ojo Alamo Sandstone, the Nacimiento Formation, and the San Juan Formation, have potential to produce water at a rate of 100 gallons per minute (gpm) (BLM 2015). Other aquifers in the San Juan Basin are known to yield water at a rate of less than 20 gal/min (BLM 2015). According to Kelley et al., (2014:55), “Of the aquifers investigated in this study, the “true” Gallup Sandstone contains the least amount of water and the San Jose/Nacimiento aquifer contains the most.”

In the southern portion of the San Juan Basin, water for hydraulic fracturing of oil wells comes from sources that tap the Nacimiento Formation and the Ojo Alamo Sandstone. Kelley et al., (2014) state that, “Water level monitoring by the U.S. Geological Survey during the 1980s reveals that long term use of a well drilled into these aquifers will cause water levels to drop, potentially affecting neighboring wells.”

**Table 5-11. General description of the major rock units in the San Juan Basin (Kelley et al., 2014)**

| **Youngest** | **Formation** | **Rock Type (major rock listed first)** | **Resource** |
|---|---|---|---|
| Cenozoic | San Jose Formation | Sandstone and shale | Water, gas |
| | Nacimiento Formation | Shale and sandstone | Water, gas |
| | Ojo Alamo Sandstone | Sandstone and shale | Water, gas |
| Cretaceous | Kirtland Shale | Interbedded shale, sandstone | Water, oil, gas |
| | Fruitland Shale | Interbedded shale, sandstone and coal | Coal, coalbed, methane |
| | Pictured Cliffs Sandstone | Sandstone | Oil, gas |
| | Lewis Shale | Shale, thin limestones | Gas |
| | Cliff House Sandstone | Sandstone | Oil, gas |
| | Menefee Formation | Interbedded shale, sandstone and coal | Coal, coalbed, methane, gas |
| | Point Lookout Sandstone | Sandstone | Oil, gas, water |
| | Crevasse Canyon Formation | Interbedded shale, sandstone and coal | Coal |
| | Gallup Sandstone | Sandstone, and a few shales and coals | Oil, gas, water |
| | Mancos Shale | Shale, thin sandstones | Oil, gas |
| | Dakota Sandstone | Sandstone, shale and coals | Oil, gas, water |
| Jurassic | Morrison Formation | Mudstones, sandstone | Uranium, oil, gas, water |
| | Wanakah/Summerville/Cow Springs/Bluff | Siltsone, sandstone | N/A |
| **Oldest** | Entrada Sandstone | Sandstone | Oil, gas, water |

### 5.1.6. Water Use Mitigations

Public concern about water use from hydraulic fracturing is especially high in semiarid regions, where water withdrawals for hydraulic fracturing can account for a significant portion of consumptive water use within a given region. Overall, there have been calls to increase the use of alternative water sources such as brackish water or recycling produced water, minimizing the strain on local freshwater resources (Kondash et al., 2018). The BLM encourages the use of recycled water in hydraulic fracturing techniques, and in 2019, the State of New Mexico passed the Produced Water Act, which encourages oil and gas producers to reuse produced water when possible, rather than relying on fresh water sources for oil and gas extraction. Recent studies indicate that the water used for hydraulic fracturing may be retained within the shale formation, with only a small fraction of the fresh water injected into the ground returning as flowback water; water returning to the surface is highly saline, is difficult to treat, and is often disposed through deep-injection wells (Kondash et al., 2018). NMED recently signed a memorandum of understanding with New Mexico State University to develop new technologies for treating produced water to inform future policies for produced water reuse.

## 5.2. Water Quality

### 5.2.1. Groundwater

Results of the hydrologic assessment of oil and gas development of the Mancos Shale in the San Juan Basin (Kelley et al., 2014) indicate that groundwater quality in the San Juan Basin is variable (ranging from fresh to brackish) due to the complex stratigraphy and varying rock formations within the Basin. Brackish and saline water is typically found in the center of the Basin, and fresh groundwater is typically found along the Basin margins. Deep saline water can migrate upward along cracks and fissures. Fresh water along the Basin margins at depths greater than 3,500 feet indicate fast recharge rates influenced by geologic structures (Kelley et al., 2015).

The geologic formation where groundwater resides also influences groundwater salinity. Figure 4-1 (Kelley et al., 2014) is an illustrated geologic cross section showing the distribution of saline aquifers within the San Juan Basin.

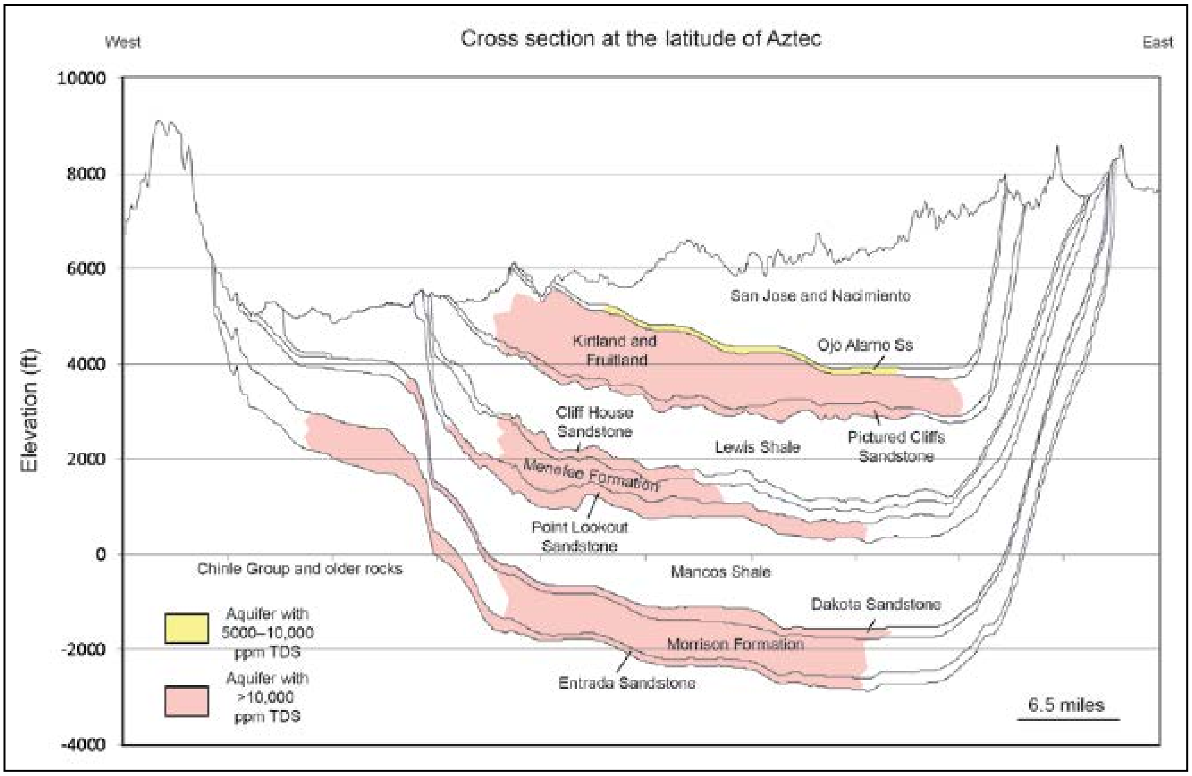

**Figure 5-2. Geologic cross section showing the distribution of saline aquifers in the San Juan Basin**.

Total dissolved solids (TDS) concentration is a measure of all the dissolved matter in a sample of water. TDS is the primary indicator of groundwater quality as higher TDS concentrations typically make water less suitable for drinking or for agricultural purposes like irrigation. In groundwater, TDS is influenced by the dissolution of natural materials such as rock, soil, and organic material. Anthropogenic activities also contribute to TDS concentrations in shallow unconfined aquifers.

TDS concentration in the San Juan Basin is dependent on the stratigraphic location and the geologic formation where the water resides. Fresh water (TDS < 1,000 milligrams per liter [mg/l]) is typically found at depths <2,500 feet (ft) below the ground surface, although exceptions to this generalization occur in deeper layers like the Gallup Sandstone and Morrison Formation. Saline and brackish water is dominant in the center of the Basin at deeper depths (Kelley et al., 2014).

### 5.2.2. Surface Water

Stream and river conditions vary widely, from completely undisturbed river and vegetative communities in the mountainous highlands, to deep, erodible soil banks at lower elevations where livestock, recreationists, and other public users have access to stream and riverbanks. Water quality in streams flowing on BLM-managed land is influenced by both natural water quality with regard to salinity content and the intensity of human and industrial activity in the watershed. For example, water quality may be vastly different in a remote mountain spring creek than in waters with natural brine discharge, or where there are human impacts due to urban, farming, ranching, or industrial activity.

Further chemistry samples of surface water in the region are needed to establish a baseline chemistry data for the waters. Variances in baseline chemistry can indicate water quality changes attributable to changes in land use. The most common pollutants for waters in the region are sediment and mercury. Beneficial uses listed for these waters are industrial water supply, irrigation storage, livestock watering, recreation, warm water fishery, and wildlife habitat. The dominant legislation affecting national water quality and BLM compliance with New Mexico water quality requirements is the Clean Water Act (CWA) or Federal Water Pollution Control Act.

### 5.2.3. Potential Sources of Surface Water or Groundwater Contamination

#### Spills

When wells are drilled, they most likely pass through usable groundwater aquifers currently or potentially supplying stock, residential, and/or irrigation water. If proper cementing and casing programs are not followed, there may be a loss of well integrity, surface spills, or loss of fluids in the drilling and completion process that could result in large volumes of high concentrations of chemicals reaching groundwater resources. If contamination of usable water aquifers (total dissolved solids less than 10,000 parts per million [ppm]) from any source occurs, changes in groundwater quality could impact springs and water wells that are sourced from the affected aquifers.

The BLM and State of New Mexico Oil Conservation Division (NMOCD) have casing, cementing, and inspection requirements in place to limit the potential for groundwater reservoirs and shallow aquifers to be impacted by fracking or the migration of hydrocarbons during oil and gas drilling and production activities. The BLM requires operators to comply with the regulations at 43 Code of Federal Regulations (CFR) 3160. These regulations require oil and gas development to comply with directives in the Onshore Orders and the orders of the Authorized Officer. Onshore Order No. 2 and the regulations at 43 CFR 3162.3-3 provide regulatory requirements for hydraulic fracturing, including casing specifications, monitoring and recording, and management of recovered fluids. The State of New Mexico also has regulations for drilling, casing and cementing, completion, and plugging to protect freshwater zones (19.15.16 New Mexico Administrative Code). Complying with the aforementioned regulations requires producers and regulators to verify the integrity of casing and cement jobs. Casing specifications are designed and submitted to the BLM together with an APD. The BLM petroleum engineer independently reviews the drilling plan, and based on site-specific geologic and hydrologic information, ensures that proper drilling, casing and cementing procedures are incorporated in the plan to protect usable groundwater. This isolates usable water zones from drilling, completion/hydraulic fracturing fluids, and fluids from other mineral bearing zones, including hydrocarbon bearing zones. Conditions of Approval (COAs) may be attached to the APD, if necessary, to ensure groundwater protection. Casing and cementing operations are witnessed by certified BLM Petroleum Engineering Technicians. At the end of the well's economic life, the operator must submit a plugging plan, which is reviewed by the BLM petroleum engineer prior to well plugging. This review ensures permanent isolation of usable groundwater from hydrocarbon bearing zones. BLM inspectors ensure planned procedures are properly followed in the field.

The requirements listed above are in place so that drilling fluids, hydraulic fracturing fluids, and produced water and hydrocarbons remain within the well bore and do not enter groundwater or any other formations. This makes contamination of groundwater resources highly unlikely. Since the advent of hydraulic fracturing, more than 1 million hydraulic fracturing treatments have been conducted, with perhaps only one documented case of direct groundwater pollution resulting from injection of hydraulic fracturing chemicals used for shale gas extraction (Gallegos and Varela 2015).

# CHAPTER 6. ADDITIONAL REPORT RESOURCES

## 6.1. How to Use this Report to Analyze Water Use Associated with Well or Lease Development

A water use analysis for well or lease development estimates the projected water use associated with a proposed action. These data are then compared to existing water use in the county or counties in which water is assumed to come from and the USGS to understand water use impacts. This report provides existing water use for all counties within PDO, FFO, and RPFO, but the actual counties used in the analysis may vary depending on the location of the proposed action. For the Pecos District, recent lease sale analyses have considered a three-county area (Chavez, Eddy and. Lea counties). For the Farmington FO, recent lease sale analyses have considered Rio Arriba County, San Juan Basin, and Sandoval County. For the Rio Puerco FO, recent lease sale analyses have considered Sandoval County or the San Juan Basin.

Two scenarios are examined for the water use analysis. The first, a maximum development scenario, examines the impacts if all wells were developed in a single year. This is a scenario that may not occur in all instances but provides an analysis of the largest possible impact to water quantity. The second, an RFD scenario, considers water use if the wells were to be developed over a 20-year period. This analysis is consistent with the Engler and Cather 2012, 2014 RFD, and Crocker and Glover 2018, which assumes that reasonably foreseeable future development would not all happen in the same year but would be spread over the next 20 years.

### Maximum Development Scenario Calculations

Under the maximum development scenario, the calculation of water use for well development associated with a proposed action is based on the number of wells and projected water use per well (which may vary by well type). The resulting water use (calculated as AF) is then compared to the existing water use in the chosen county or counties, and to the State of New Mexico to understand how water use would increase. Key reporting metrics for the maximum development scenario analysis are as follows:

1. percent contribution to total water use in the chosen county or counties (delineated in the formulas below as COUNTY/IES. This is calculated as follows:

   **[(proposed action AF + total COUNTY/IES water AF) / total COUNTY/IES water AF]= x 100**

2. percent contribution to groundwater use in the Pecos District. This is calculated as follows:

   **[(proposed action AF + total COUNTY/IES groundwater AF) / total COUNTY/IES groundwater AF] x 100**

3. percent contribution to total “Mining” water use in the Pecos District. This is calculated as follows:

   **[(proposed action AF + total COUNTY/IES mining AF) / total COUNTY/IES mining AF] x 100**[*]

4. percent contribution to Pecos District oil and gas water use. This is calculated as follows:

   **[(proposed action AF + COUNTY/IES O&G AF) / COUNTY/IES AF] x 100**

5. percent contribution to statewide oil and gas water use. This is calculated as follows:

   **[(proposed action AF + statewide oil and gas AF) / statewide O&G AF] x 100**

6. percent contribution of increased Pecos District oil and gas development water use (revised as per above) to the total Pecos Mining water use. This is calculated as follows:

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[*] This calculation could be further refined to be county-specific depending on the location and size of the proposed action. Note also that O&G [first time that O&G has been used as an abbreviation, suggest not using it] comprises a small element of Mining; see the additional calculations below to further put the impact into context.

**(new total COUNTY/IES AF as calculated above / COUNTY/IES Mining AF) x 100**

7. percent contribution of increased statewide oil and gas development water use (revised as per above) to the total statewide mining water use. This is calculated as follows:
   **(new total statewide O&G AF as calculated above / Statewide mining AF) x 100**

### RFD Scenario Calculations

Under the RFD scenario, the calculation of water use for any given year is made by taking the total water use associated with the proposed action (as calculated under the maximum development scenario) and dividing by 20 (life of the RFD). Key reporting metrics for the RFD scenario analysis are as follows:

8. percent contribution to Pecos District oil and gas water use

[(per year proposed action AF + COUNTY/IES O&G AF) / COUNTY/IES O&G AF] x 100

9. percent contribution to statewide oil and gas water use

[(per year proposed action AF + statewide O&G AF) / statewide O&G AF] x 100

10. percent contribution of increased Pecos District oil and gas development water use (revised as per above) to the total Pecos Mining water use

[new total COUNTY/IES O&G AF calculated as above / COUNTY/IES mining use] x 100

11. percent contribution of increased statewide oil and gas development water use (revised as per above) to the total statewide mining water use

[new total statewide O&G AF calculated as above / statewide mining use] x 100

The following example analyzes water use in the Pecos District associated with the maximum development scenario and RFD Scenario for a proposed action of 30 horizontal wells, reporting the 10 metrics listed above.

EXAMPLE WATER USE ANALYSIS

**Proposed action:** 30 horizontal wells

**Analysis area:** Chavez, Lea and Eddy Counties

**Maximum development scenario:** Proposed action would require 810 AF of groundwater total

**RFD Scenario:** Proposed action would require 40.5 AF of groundwater in any given year

Reported Metrics:

If all wells were developed in a single year (a maximum development scenario), there would be:

Metric #1: an increase of 0.13% over 2015 Pecos District total water use

Metric #2: an increase of 0.15% over 2015 Pecos District total groundwater use

Metric #3: an increase of 0.9% over 2015 Mining water use for Pecos District

Metric #4: an increase of 20% over 2015 Pecos District oil and gas water use

Metric #5: an increase of 20% over 2015 statewide oil and gas water use

Metric #6: an increase in the percentage contribution of Pecos District water use associated with oil and gas development to total 2015 Pecos District mining water use, from 4.2% to 5.1%

Metric #7: an increase in the percentage contribution of statewide water use associated with oil and gas development to total 2015 statewide mining water use, from 2.4% to 2.9%

If all wells were developed over a period of 20 years (the RFD scenario), then for any given year, there would be:
Metric #8: an increase of 1% over 2015 Pecos District oil and gas water use
Metric: #9: an increase of 1% over 2015 statewide oil and gas water use
Metric #10: an increase in the percentage contribution of Pecos County water use associated with oil and gas development to total 2015 Pecos District mining water use, from 4.2% to increase to 4.3%
Metric #11: an increase of in the percentage contribution of statewide water use associated with oil and gas development to total 2015 statewide mining water use, from 2.4% to increase to 2.5%

## 6.2. FracFocus Data Analysis Methodology

### Water Use Analysis

1.) Data were downloaded from FracFocus on 1/25/2020 for calendar years 2014-2019 for Permian Basin (Chaves, Eddy, and Lea counties) and San Juan Basin (San Juan, Rio Arriba, and Sandoval counties).
2.) Duplicate entries for each well were removed (due to one record for each chemical species)
3.) Entries with no water use reported were also removed
4.) Summary statistics and cumulative analyses were performed on the processed data

### Chemical Concentration Analysis

1) Data were downloaded from FracFocus on 1/25/2020 for calendar years 2014-2019 for Permian Basin (Chaves, Eddy, and Lea counties) and San Juan Basin (San Juan, Rio Arriba, and Sandoval counties).
2) Entries with no reported ingredient concentration or water use were removed
3) Chemical ingredients were identified by matching CAS registry numbers (CASRN) with the EPA Chemistry Dashboard database (https://comptox.epa.gov/dashboard/dsstoxdb/batch_search)
4) Units were converted from gallons to acre-feet and pounds to milligrams (and scaled accordingly to corresponding SI units [e.g., kilograms, megagrams, gigagrams])

## 6.3. Spill Data Analysis Methodology

**Assumptions:**

- Reject duplicate spills records
- Reject spills where the spill volume was 0 barrels
- Retain the methane spills when looking at number of unique incidents (spills count), but not include them in the volume spilled because the units are MCF (not barrels).
- Reject records where the spill type was natural gas liquid or methane but was reported in barrels (bad data)

**Methodology:**

Working entirely from the spills (1) tab of the San Juan Basin spills spreadsheet (starting with 1607 records):

1. Cleared all filters
2. Created a primary key for the data to identify and remove duplicates. *Primary key=Incident Number_Spilled Material*. In San Juan Basin, there were 3 duplicated spills. Removed one of each duplicated record from analysis. (***1604 records remain***)
3. Filtered on column W (County) to McKinley, Rio Arriba, San Juan, and Sandoval (***227 records remain***)
4. Removed spills where the volume spilled was 0 barrels (assumed to be bad data) Filtered on column P (Volume Spilled) to all values EXCEPT 0 (***111 records remain***)
5. Converted the one volume that was reported as GALLONS to BARRELS (***111 records remain***)
6. Rejected data where 'Spilled material' = Natural Gas (Methane) and Natural Gas Liquid, AND, 'Unit of Volume= BBL' (***106 records remain***)
7. Used Pivot Table tool to aggregate and summarize the data.

Working entirely from the spills (1) tab of the Permian Basin spills spreadsheet (starting with 1607 records):

1. Cleared all filters
2. Filtered on County column for Lea and Eddy counties (***1355 records remain***)
3. Created a primary key for the data to identify and remove duplicates. *Primary key=Incident Number_Spilled Material*. In Permian Basin, there were 14 duplicated spills. Removed one of each duplicated record from analysis. (***1341 records remain***)
4. Removed spills where the volume spilled was 0 barrels (assumed to be bad data). Filtered on 'Volume Spilled' to all values EXCEPT 0 (***1270 records remain***)
5. Converted the 8 volumes that was reported as GALLONS to BARRELS (***1270 records remain***)
6. Rejected data where 'Spilled material' = Natural Gas (Methane) and Natural Gas Liquid, AND, 'Unit of Volume= BBL' (9 records) (***1261 records remain***)
7. Entered 'BBL' as unit for spill with no units (Incident Number= nOY1812332827, Material spilled=Crude Oil) (***1261 records remain***)

On both sets of records

1. Using DATA worksheet, filtered on column AI (groundwater affected). (***0 records remain***)
2. Using DATA worksheet, filtered on column AH (waterway affected). (12 ***records remain***)
3. Removed spills where the volume spilled was 0 barrels (assumed to be bad data) (***9 records remain, all in San Juan Basin***)
4. Reviewed and summarized data (counties, volume of pill, cause and source)

## 6.4. Farmington Field Office Slickwater Stimulation Water Use Update

### 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 Reasonable Foreseeable Development Scenario for Oil and Gas Activities, Mancos-Gallup RMPA Planning Area (Crocker and Glover 2018) additional information regarding the slickwater stimulation technique has been gathered by the BLM Farmington FO. 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 potential (Crocker and Glover 2018). The purpose of this update is to address the forecasted amount of water from the 2018 Mancos-Gallup RFD, which may be used during development of the Mancos Shale formation and Gallup Sandstone member utilizing slickwater stimulation in the San Juan Basin.

### Assumptions and Methodology

This update evaluates the potential water requirements for the development of the Mancos Shale and Gallup Sandstone 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.

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 Farmington FO. 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) x (number of stages/lateral length)**

The total miles of lateral estimated to develop the Mancos Shale and Gallup Sandstone formations 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 Farmington FO calculated the average stage length to be 200 feet and the average water used per stage to stimulate the formation to be 1 AF. From the Farmington FO projected water use calculations, the Mancos Shale and Gallup Sandstone development within the high and medium potential areas would require approximately 125,000 AF for the full development scenario using only slickwater stimulation techniques (Table 1).

### 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 the New Mexico Office of the State Engineer (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 the NMOSE applies to water acquired for use in production and operation of oil and natural gas wells. Water use is published every five years in the report titled “New Mexico Water Use By Categories”, most recently published in 2015. See Chapter 3 of the Water Support document for information on the volume of water that was used specifically for hydraulic stimulation of oil and gas wells in the San Juan Basin using information from the NMOSE 2015 report.

The two general water types that may be used for slickwater stimulation are categorized as “potable/fresh” and “non-potable”. Any water that has Total Dissolved Solids (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 Order #2 (BLM 1988). Non-potable water is outside the appropriative processes and is mainly diverted for mineral exploration purpose. Conversely, any water that is 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 the NMOSE and may or may not be adjudicated.

During the process of gathering information regarding slickwater stimulation, the Farmington FO put together a questionnaire to conduct industry interviews. The questionnaire focused on estimated water use during drilling, completion, 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 determine how saline water is being utilized and to better understand the potential TDS levels within source water for the stimulation fluid. Onshore Order #1 (BLM 2017) requires operators to identify adequate water sources for stimulation plans as part of their APD.

Based on operator input 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 or ground water) into non-traditional sources of water (e.g. non-potable groundwater sources).

Recently, the NMOSE has received Notices of Intent (NOI) to Appropriate non-potable water from aquifers at depths 2,500 feet below ground level (BGL) or greater. The 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 formation maximum depth is approximately 9,500 feet BGL. Water contained in the Entrada formation is highly saline (Kelley et al., 2014). As such, it is considered non-potable and has not been declared as an administrative aquifer by the NMOSE. NMOSE is the agency responsible for water withdrawal permitting actions. Their NOI 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 well head directly after stimulation activities. Generally, 10-40% of the initial volume utilized for stimulation activities returns as flowback fluid, of this 10-40% 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, therefore becoming “produced water.” Based on operator input, after the initial flowback recovery of 10-40%, remaining water used for stimulation does return to the surface through production activities at a slower rate of return.

## Projected Water Use

To gain the most current information, outreach was conducted with local operators actively drilling and producing mineral resources in the San Juan Basin to gather information regarding slickwater stimulation and reservoir development. According to the 20 APDs the average lateral well bore is one and a half miles (1.5) in length for a horizontal well (see Attachment 1). The estimated water use is approximately 41 acre-feet (AF) for slickwater stimulation. Advances in horizontal drilling and completion techniques in the San Juan Basin in the past four to five years have resulted in the ability to drill and complete horizontal laterals up to three miles in length (according to operator input). Horizontal well bores are stimulated in intervals, each interval is called a stage. Refer to Table 6.1 for number of stages dependent on length of well bore as well as the average water use of one to three-mile laterals per completion.

**Table 6-1. Water use averages from 20 slickwater APDs from the Farmington Field Office using FracFocus data.**

| Well Name/Operator | Water Usage Per Stage (gal) | Stage Length (ft) |
|---|---|---|
| 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 |
| 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 6-2.** **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 (Ft) | Lateral Length (Miles) | Number of Stages | Water Used (Gal) | Water Used (AF) |
|---|---|---|---|---|
| 5,280 | 1 | 25.94 | 8,667,029.18 | 26.60 |
| 7,920 | 1.5 | 38.91 | 13,000,543.76 | 39.90 |
| 10,560 | 2 | 51.89 | 17,334,058 | 53.20 |
| 13,200 | 2.5 | 64.86 | 21,667,572.94 | 66.50 |
| 15,840 | 3 | 77.83 | 26,001,087.53 | 79.79 |

**Table 6-3.** **Average volume of water required to complete 1 to 3-mile laterals utilizing slickwater stimulation in the Mancos Shale and Gallup Sandstone formations.**

| Miles | Number of Stages | Acre-Feet |
|---|---|---|
| 1 | 26 | 27 |
| 1.5 | 39 | 40 |
| 2 | 52 | 53 |
| 2.5 | 65 | 67 |
| 3 | 78 | 80 |

## Conclusions

The amount of water that would be required to completely develop 4,600 miles of horizontal wells in the Mancos Shale and Gallup Sandstone formations via slickwater stimulation is estimated to be approximately 125,000 af. The 2018 RFD estimates 2,300 horizontal wells that may be developed between 2018 and 2037, based on operator input the horizontal lengths would range from one to three 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 formation and recycled flowback water and produced water for use in slickwater stimulation activities.

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