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

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

BLM WSD 2024

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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LIST OF ACRONYMS AND ABBREVIATIONS

AF	acre-feet
AFFF	aqueous film-forming foam
APD	Application for Permit to Drill
bbl	barrel(s)
BLM	Bureau of Land Management
B.S.&W.	Basic Sediment and Water
CAS	Chemical Abstracts Service
CFO	Carlsbad Field Office
CFR	Code of Federal Regulations
COA	condition of approval
CWA	Clean Water Act
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
FFO	Farmington Field Office
gpm	gallons per minute
GWPC	Ground Water Protection Council
HPA	high-potential area
HUC	Hydrologic Unit Code
IOGCC	Interstate Oil and Gas Compact Commission
mcf	thousand cubic feet
mg/L	milligrams per liter
MOU	memorandum of understanding
N/A	not applicable
NEPA	National Environmental Policy Act of 1969
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMISC	New Mexico Interstate Stream Commission
NMOCD	New Mexico Oil Conservation Division
NMOSE	New Mexico Office of the State Engineer
NMSO	New Mexico State Office
NMSWP	New Mexico State Water Plan
NMWQCC	New Mexico Water Quality Control Commission

PDO	Pecos District Office
PET	petroleum engineering technician
PFAS	per- and polyfluoroalkyl substances
ppm	parts per million
RFD	reasonably foreseeable development
RFFA	reasonably foreseeable future action
RFO	Roswell Field Office
RMP	resource management plan
RPFO	Rio Puerco Field Office
TDS	total dissolved solids
USGS	U.S. Geological Survey
WIPP	Waste Isolation Pilot Plant
WU	combined water use

CHAPTER 1. INTRODUCTION

1.1 PURPOSE AND SCOPE

The intent of this Water Support 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 NEPA analysis related to federal oil and gas leasing and development under the jurisdiction of the Bureau of Land Management (BLM) New Mexico State Office (NMSO). This includes federally managed oil and gas within the Pecos District Office (PDO) area, the Farmington Field Office (FFO) area, and the Rio Puerco Field Office (RPFO) area.

The content of this report is focused on existing water uses and projections of future water use based on past use, as well as planned use. The report also provides information regarding existing water quality and potential causes of water contamination related to oil and gas leasing and development.

This document does not include analysis of the following data types and sources:

- Surface water quality impacts from leasing and development: Surface water that is used in oil and gas production comes from a previously approved water source. Surface water quality impacts are analyzed at the leasing stage with consideration of the site-specific conditions and stipulations that are applied to protect them. Surface water quality impacts are again analyzed during site-specific development when specific facility placement details are known.
- Surface water quality assessment information: In the State of New Mexico, the New Mexico Environment Department (NMED) administers Clean Water Act (CWA) Sections 303(d), 305(b), and 314 related to surface water quality assessment and reporting. The NMED defines surface water quality beneficial uses and water quality criteria to evaluate if these uses are being attained. The BLM does not have responsibility to make use attainment evaluations based on water chemistry data.
- Water quality information for other areas mandated by the NMSO: The NMSO also manages federal oil and gas leasing and development within the Oklahoma Field Office area (which includes Texas, Oklahoma, and Kansas). Due to the scattered nature of leases, the lack of defined focal areas where leasing regularly occurs (such as the three field offices described in this report), and the number of counties within each state for which data would need to be compiled (254 counties in Texas, 77 in Oklahoma, and 105 in Kansas), the BLM determined that water quality and quantity information for the Oklahoma Field Office area will be gathered and evaluated in the BLM's Oklahoma Field Office's Water Support Document for oil and gas development in report. The NMSO also manages federal oil and gas leasing and development for other field offices and districts within New Mexico; however, these are not areas in which leasing and subsequent development typically occur.
- Water uses related to oil and gas development beyond hydraulic fracturing: Although this Water Support Document focuses on water usage during the hydraulic fracturing process, water is also used for drilling fluid preparation, completion fluids, rig washing, coolant for internal combustion engines, dust suppression on roads/well pads, and equipment testing. The majority of water use is associated with stimulation activities (including hydraulic fracturing), and data are currently unavailable for the previously mentioned uses. Operators will provide information regarding estimated water use at the project specific NEPA level.
- Environmental impacts of hydraulic fracturing: While the environmental impacts of hydraulic fracturing are relevant to the focus of this report, the fate and transport of chemicals used during hydraulic fracturing are complicated and have been the subject of human health and

environmental concerns as oil and gas development continues throughout the United States. As such, the complexity of this subject would require substantial discussion that exceeds the scope of this report. Readers interested in understanding the environmental impacts of hydraulic fracturing should review the comprehensive U.S. Environmental Protection Agency (EPA) report *Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States (Final Report)* (EPA 2016). In summary, this report presents scientific evidence that drinking water resources can be impacted by hydraulic fracturing under six 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, the 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 water and groundwater resources in New Mexico.

1.2 REPORT ORGANIZATION

Chapter 2 contains a summary of water use data for the state of New Mexico, including water use by industry or use category as well as water use by oil and gas wells. Chapter 2 also summarizes the most frequently disclosed chemical constituents used in hydraulic fracturing operations in the state of New Mexico, as well as general information related to drought and water availability and per- and polyfluoroalkyl substances (PFAS). Chapter 3 summarizes water quantity and quality data for the PDO area, which comprises the Carlsbad Field Office (CFO) and the Roswell Field Office (RFO). Chapters 4 and 5 summarize water quantity and quality data for the FFO area and the RPFO area, respectively. Chapter 6 contains the references pertinent to the analysis. This report is organized so that authors and data analysts may use field office chapters as standalone reports when evaluating impacts to water resources associated with proposed future federal oil and gas leasing and development.

1.3 DATA SOURCES

This section describes the primary data sources that are used throughout this report to evaluate impacts to water resources from oil and gas leasing and development activities in New Mexico.

1.3.1 State and County Water Use by Category

Since 1950, the U.S. Geological Survey (USGS) has published a comprehensive report every 5 years that compiles water use data across the United States. The most recent report (Dieter et al. 2018) is the fourteenth circular report published as part of the National Water Census and contains the average daily withdrawals for all 50 states by source (groundwater and surface water), quality (fresh and saline), and category (public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric power). Domestic water use includes self-supplied water and deliveries from the public supply; industrial and thermoelectric power are both self-supplied. Saline water is defined in Dieter et al. (2018:4) as “water containing dissolved solids of 1,000 milligrams per liter or more.”

In 2023, the USGS made an update to water usage estimates for the Dieter et al. 2018 water use analysis for the United States. Updates were made to water use estimate categories of public supply water, thermoelectric power, and irrigation water use. The update in 2023 was a reanalysis of water usage for years 2000 to 2020, providing 5 additional years (years 2016 to 2020) to the original 2018 USGS water use data set. The updated water use estimates are delineated at the Hydrologic Unit Code (HUC)-12 boundary level rather than by county as found in the original 2018 USGS report. Due to this variance in reporting between years, and since all categories were not updated in 2024, analysis for the updated years of data has not been included in this Water Support Document. It is expected that new data for all water use categories will be released in 2025 (self-supplied industrial, domestic, mining, livestock, and aquaculture). The updated USGS Water Use data will be incorporated into the next update of the New Mexico Water Support Document and all analysis will be completed at the HUC-12 level. See Appendix A for details regarding how USGS water use data are obtained, organized, and analyzed for use in this report.

1.3.2 FracFocus Data

FracFocus is a national hydraulic fracturing chemical registry managed by the Ground Water Protection Council (GWPC) and Interstate Oil and Gas Compact Commission (IOGCC) (FracFocus 2024a). FracFocus was initially created to provide a place for publicly available information regarding chemicals used during hydraulic fracturing. Currently, 28 states require oil and gas operators to disclose information to FracFocus for any hydraulically fractured well (FracFocus 2024b). In the state of New Mexico, New Mexico Administrative Code (NMAC) 19.15.16.19 states that "for a hydraulically fractured well, the operator shall complete and file with the FracFocus chemical disclosure registry a completed hydraulic fracturing disclosure within 45 days after completion, recompletion or other hydraulic fracturing treatment of the well. See Appendix A for details regarding how FracFocus data were obtained, organized, and analyzed for use in this report.

1.3.3 Spill Data

NMOCD regulates oil and gas activity in New Mexico and enforces its rules and the state's oil and gas statutes. NMOCD manages data and information related to oil and gas development, including well production, abandoned wells, and oil and gas spills.

In each field office or district section of this report, 2023 spill data from the NMOCD database (NMOCD 2024a) are used to evaluate potential impacts to surface water quality from oil and gas development. Spills associated with oil and gas development may reach surface water directly during a spill event. Spills may also reach surface waters indirectly when a rain event moves contaminants into nearby surface waterbodies through surface water flow or even subsurface groundwater flow into springs that discharge into a surface waterbody. In the NMOCD database, many attributes of spill incidents are tracked, including the location, spill material, volume, and amount recovered, and information on whether the spill reached a watercourse. Spill data from 2022 onward is markedly higher than in previous years due to more stringent spill reporting requirements for natural gas liquids in New Mexico.

To update the spill data in the Water Support Document, data for the previous year are downloaded in January of the publication year. For example, this 2024 Water Support Document discusses calendar year 2023 spill data downloaded from the NMOCD database in January (or later) 2024. Appendix A contains specific details on how NMOCD spill data are obtained, organized, and analyzed for use in this report.

1.4 UPDATING THE REPORT

As new data become available throughout the state of New Mexico, it will be necessary to update water use (water use by category data from the USGS, the New Mexico Office of the State Engineer [NMOSE], and FracFocus) and water quality (data from the NMOCD database) information included in this report. The water use by category data from the USGS and NMOSE are updated every 5 years. As updated water use data are released, they will be included in the annual water support document report updates. At the time of drafting this 2024 report, new USGS data were only available for three water use categories (thermoelectric, irrigation, and public supply) out of eight total water use categories. See 1.3.1 for the rationale as to why this data was not incorporated into this report. It is anticipated that updated water use data for all categories from the USGS for the years 2000 through 2020 will be included in the 2025 Water Support Document.

The FracFocus registry is updated throughout each year, and updates may include changes to well data for previous years. To maintain consistency in data included in annual Water Support Document updates, FracFocus data is pulled on January 1 every year. For example, the 2024 Water Support Document includes all data from January 1, 2014, through December 31, 2023. The data utilized for this report was pulled from the FracFocus database on January 1, 2024. Historic data from FracFocus (from years 2014 to 2023) was then recalculated using the new dataset. Thus, the FracFocus data presented in this Water Support Document for the years 2014–2023 may differ slightly from previous years' Water Support Documents due to updates to historical FracFocus data made throughout 2023.

CHAPTER 2. STATE OF NEW MEXICO

This chapter contains an analysis and summary of the available water use and water quality data for the state of New Mexico that support the evaluation of water resource impacts from oil and gas leasing and development (as described in Chapter 1). Water use estimates for all categories of consumptive water use (e.g., public drinking water supply, irrigation, thermoelectric power) are presented in Section 2.1. Additionally, Section 2.1 contains the summarized FracFocus water use data so that water use from hydraulic fracturing can be compared with statewide water use. Section 2.2 contains a summary of the chemicals used in hydraulic fracturing that are disclosed to FracFocus.

Oil and gas leasing and development in New Mexico occurs mostly in the San Juan Basin and the Permian Basin. New Mexico ranks third in the United States in the production of oil (World Population Review 2022). In 2023, the state of New Mexico produced 664,810,087 barrels of oil (NMOCD 2024b).

The BLM field offices that intersect these oil-producing areas of the San Juan Basin are the FFO and RPFO (Figure 2-1). The San Juan Basin, a circular geologic formation that covers northwestern New Mexico and southwestern Colorado, is the second-largest gas-producing basin in the nation and supports about 21,000 active oil and gas wells (NMOCD 2021). In 2023, 10,535,416 barrels of oil were produced from the San Juan Basin (NMOCD 2024b). Most of the hydrocarbons that have formed in the San Juan Basin are a result of stratigraphic traps within the geologic structure (BLM 2003a).

The Permian Basin, a sedimentary rock formation spanning from west Texas into New Mexico, has been a producing oil and natural gas field since the early 1900s.The Permian Basin is the largest oil-producing region in the United States, accounting for over 39% of total United States oil production (U.S. Energy Information Administration 2020). Of the approximately 20 million acres in the total PDO planning area boundary, about 2.4 million acres have already been leased for oil and gas development (Haque 2024).

The Las Cruces Field Office (Permian Basin) and Taos Field Office (San Juan Basin) were omitted from this report due to their small areas of overlap with the basins and the paucity of oil and gas leasing within those areas.

2.1 WATER QUANTITY

In 2015, the combined fresh and saline water withdrawals for all water use categories across the state of New Mexico totaled 3,249,667 acre-feet (AF) (Table 2-1) (Dieter et al. 2018). Irrigation withdrawals accounted for the greatest water use within the state of New Mexico at 82% (2,660,424 AF) in 2015. Public water supply and mining accounted for 9% and 5% of total water use (293,467 and 163,901 AF), respectively. While total water withdrawals within the state were equally split between surface water and groundwater; thermoelectric power and irrigation sectors used proportionally more surface water than groundwater (82% and 56%, respectively) and the remaining sectors primarily consumed groundwater. It is important to consider the impacts of groundwater well pumping on surface water availability, especially since New Mexico uses surface water for over half of its water use needs (Dieter et al. 2018). Groundwater pumping impacts the storage capacity of an aquifer, which can alter groundwater discharge zones that are connected to the aquifer from which water is being withdrawn (Barlow and Leake 2012). Altering aquifer storage capacity via groundwater pumping has the potential to change the local hydraulic gradient, which can impact connected discharge zones that feed surface water systems (Barlow and Leake 2012).

Total annual water use associated with the hydraulic fracturing of oil and gas wells throughout New Mexico increased in all but 2 years from years 2014–2023 (all but 2020 and 2023), and totals ranged from 3,898 AF in 2014 to 90,200 AF in 2023. In the same time frame (2014–2023), average water use per well increased from 6.0 AF in 2014 to 52.6 AF in 2023 (Table 2-2) (FracFocus 2024a). The 10-year average (2014–2023) water use was 33.6 AF per well. Water use for federal wells (as a percentage of water use for all wells) varies and ranged from a low of 12.7% in 2016 to a high of 52.0% in 2021. From 2014 through 2023, cumulative water use within New Mexico totaled 378,271 AF, with federal wells comprising 39.0% (149,298 AF). From 2014 through 2023, 8,964 total wells (includes all ownership/management jurisdictions) were reported to FracFocus, with an average of 896 wells per year between years 2014 and 2023 (FracFocus 2024a).

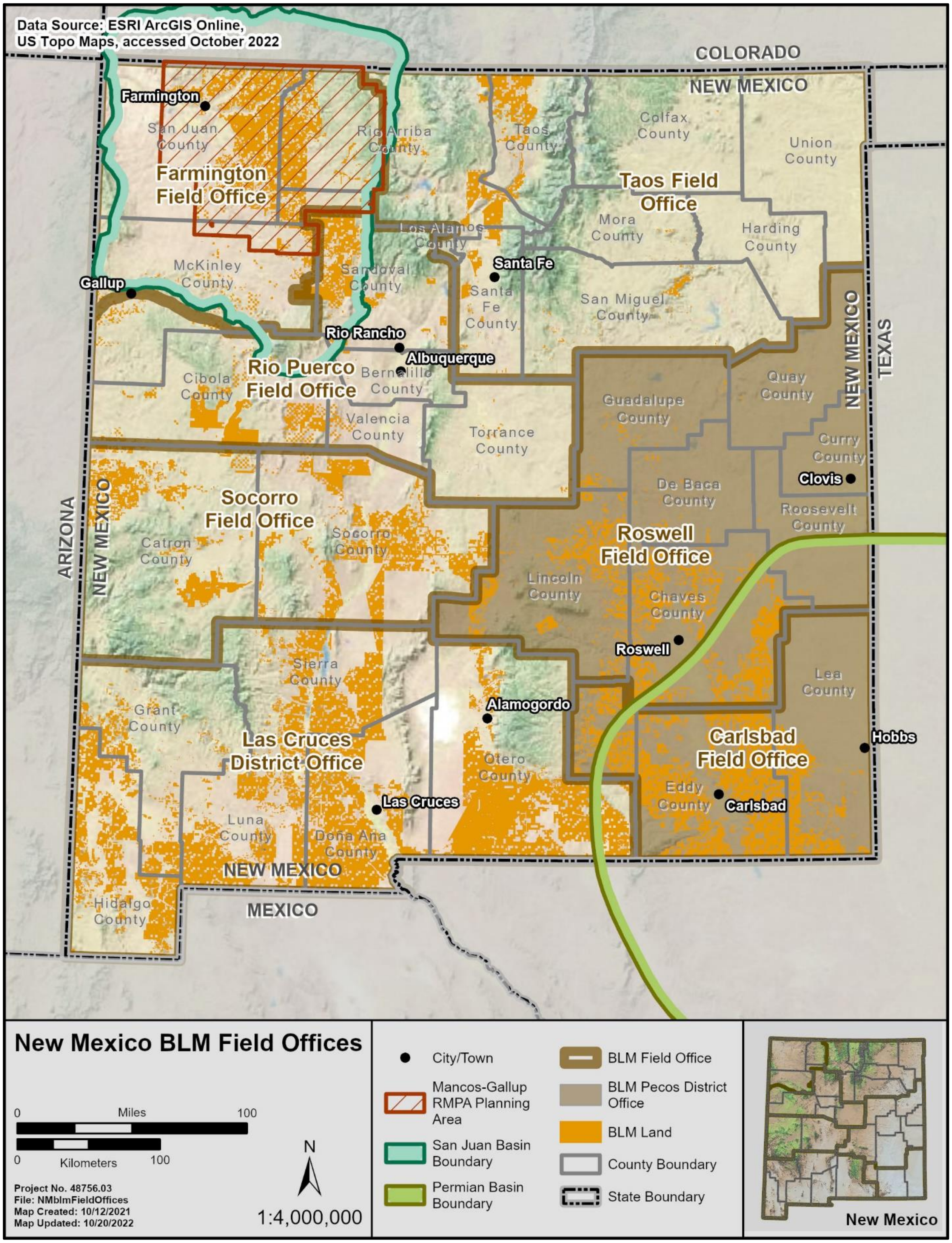

Figure 2-1. New Mexico BLM field offices and basin boundaries.

Table 2-1. State of New Mexico Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)†
	Fresh	Saline*	Total	Total Use (%)†	Fresh	Saline*	Total	Total Use (%)†	Fresh	Total Use (%)	Saline*	Total Use (%)†		
Aquaculture	6,109	0	6,109	<1%	20,929	0	20,929	1%	27,039	1%	0	0%	27,039	1%
Domestic	0	–	0	0%	27,621	–	27,621	1%	27,621	1%	–	–	27,621	1%
Industrial	0	0	0	0%	3,811	0	3,811	<1%	3,811	<1%	0	0%	3,811	<1%
Irrigation	1,485,112	–	1,485,112	46%	1,175,312	–	1,175,312	36%	2,660,424	82%	–	–	2,660,424	82%
Livestock	2,522	–	2,522	0%	33,372	–	33,372	1%	35,894	1%	–	–	35,894	1%
Mining	19,550	0	19,550	1%	44,111	100,240	144,351	4%	63,662	2%	100,240	3%	163,901	5%
Public Water Supply	87,752	0	87,752	3%	205,715	0.00	205,715	6%	293,467	9%	0	0%	293,467	9%
Thermoelectric Power	30,637	0	30,637	1%	6,872	0	6,872	<1%	37,509	1%	0	0%	37,509	1%
Total	**1,631,683**	**0**	**1,631,683**	**50%**	**1,517,744**	**100,240**	**1,617,984**	**50%**	**3,149,427**	**97%**	**100,240**	**3%**	**3,249,667**	**100%**

Source: Dieter et al. (2018)

Note: Values may not sum to totals because of independent rounding (Dieter et al. 2018). Water use data are in acre-feet/year unless otherwise indicated.

* Saline water withdrawals are not reported for domestic, irrigation, or livestock water use (Dieter et al. 2018).

† Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 3,249,667 acre-feet.

Table 2-2. Water Use by Oil and Gas Wells for Hydraulic Fracturing in New Mexico from 2014 through 2023

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 No. of Wells	Produced Water
2014	1,432	2,466	3,898	36.7	1,432	3,898	6.0	651	86,287
2015	1,873	4,334	6,207	30.2	3,305	10,105	10.8	574	87,520
2016	874	5,993	6,867	12.7	4,179	16,972	20.4	337	82,752
2017	3,301	11,047	14,348	23.0	7,480	31,320	24.6	583	86,335
2018	9,171	22,707	31,878	28.8	16,651	63,198	29.0	1,099	101,537
2019	10,380	32,037	42,417	24.5	27,031	105,615	38.4	1,106	127,442
2020	15,944	24,897	40,842	39.0	42,975	146,457	50.9	803	132,192

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 No. of Wells	Produced Water
2021	34,203	31,562	65,765	52.0	77,178	212,222	50.5	1,301	157,050
2022	39,104	51,096	90,200	43.4	116,282	302,422	52.5	1,719	201,360
2023	33,016	42,834	75,850	43.5	149,298	378,272	52.6	1442	223,787
Total	**149,298**	**228,294**	**378,271**	**39.0**	**–**	**–**	**51.9**[†]	**8,964**	**1,286,262**

Source: FracFocus (2024a). Data only for those wells that reported water usage to FracFocus are presented; produced water data are from NMOCD (2024b).

Note: All water use data are presented in acre-feet. Produced water is not considered a type of water use, but is produced as a byproduct of hydraulic fracturing and comes from naturally occurring water that exists in a formation that is being targeted for mineral extraction.

* Includes both federal and non-federal wells.

[†] 3-year average (2021–2023).

2.2 WATER QUALITY

The chemical composition of water used during the hydraulic fracturing process varies due to differences in fracturing techniques used by oil and gas companies. 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. The most disclosed chemical used in New Mexico wells from 2014 through 2023 was water, with 24,097 disclosures (Table 2-3). Other frequent disclosures were methanol (n = 7,523) and hydrochloric acid (n = 6,046). There were 45,446 records of non-disclosed chemicals entered in the FracFocus database (FracFocus 2024a). Ingredient names and Chemical Abstracts Service (CAS) numbers are not standardized in FracFocus, leading to widespread differences and discrepancies in CAS numbers, number of disclosures, and ingredient names. For this reason, the values and ingredients presented in Table 2-3 are for general information only. Appendix A contains information on how FracFocus data are analyzed and summarized.

2.2.1 Spills

Oil and gas development spills have the potential to impact surface water directly by falling into a waterbody or indirectly by surface runoff, soil contamination, and ensuing transport during rainfall, or migration into groundwater and subsequent discharge from a spring into surface water. According to NMAC 19.15.29.10, major releases must be reported to NMOCD within 24 hours of the discovery of the release. A major release is defined in NMAC 19.15.29.7 as an unauthorized release of a volume, excluding gases, of 25 barrels or more. A major release also includes any unauthorized release that results in a fire; may reach a watercourse; may endanger public health, property, or the environment; or may be detrimental to fresh water. Minor releases (less than 25 barrels and greater than five barrels) must be reported to NMOCD within 15 days (NMAC 19.15.29.10). All major and minor release reports (spills) are archived in the NMOCD spills database.

Spill data from NMOCD were retrieved from the NMOCD database and further reviewed and summarized (NMOCD 2024a) (see Appendix A). In 2024, there was a total of 1,105 liquid spills across the state associated with federal and non-federal oil and gas wells and facilities (Table 2-4) (NMOCD 2024a). The average percentage of the liquid spill volume that was lost (volume lost divided by volume released) varies by spill type, but the average spill volume for liquids that was lost (not recovered) was 47% (NMOCD 2024a). Gaseous spills (including flared natural gas, vented natural gas, and carbon dioxide) had a 100% spill loss. Complete spill loss for gaseous spills is expected to occur due to the ignition process of flaring excess natural gas liquids.

The BLM works with NMOCD to remediate spills associated with federal oil and gas wells on BLM-managed lands or on private or state surface. Title 19, Chapter 15 of the NMAC pertains to oil and gas releases. According to 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 NMOCD or with an abatement plan submitted in accordance with NMAC 19.15.30. The remaining contaminants from unrecovered spills are remediated in accordance with federal and state standards. Such remediation consists of removing contaminated soil and replacing it with uncontaminated soil and performing corresponding chemical testing.

Table 2-3. Most Frequently Disclosed Ingredients Reported to FracFocus within New Mexico from 2014 through 2023

Ingredient Name±	CAS Registry Number	Number of Disclosures	Percentage of Hydraulic Fracturing Jobs*	Percentage of Total Number of FracFocus Disclosures†
Not Disclosed	N/A	45,446	N/A	15.00%
Water	7732-18-5	24,097	30.10	7.95%
Methanol	14808-60-7	7,523	0.01	2.48%
Hydrochloric Acid	64742-47-8	6,046	0.18	2.00%
Glutaraldehyde	67-56-1	4,127	0.01	1.36%
Crystalline silica, Quartz	7647-01-0	3,539	11.67	1.17%
Ammonium Chloride	111-30-8	3,256	0.00	1.07%
Ethanol	68424-85-1	3,182	0.00	1.05%
Sodium Chloride	68551-12-2	3,068	0.05	1.01%
Acetic Acid	78330-21-9	2,946	0.05	0.97%
Crystalline Silica	12125-02-9	2,786	12.47	0.92%
Distillates (Petroleum), Hydrotreated Light	7647-14-5	2,730	0.03	0.90%
Ethylene Glycol	67-63-0	2,631	0.05	0.87%
Proprietary	64-17-5	2,631	0.01	0.87%
Propargyl Alcohol	64-19-7	2,579	0.00	0.85%
Crystalline Silica, Quartz	Proprietary	2,323	11.48	0.77%
Aluminum Oxide	107-21-1	2,233	0.10	0.74%
Sodium Hydroxide	7727-54-0	2,160	0.01	0.71%
Guar Gum	107-19-7	2,158	0.11	0.71%
Alcohols, C12-16, Ethoxylated	1310-73-2	1,957	0.00	0.65%
Ammonium Persulfate	9000-30-0	1,952	0.01	0.64%
Sodium Perborate Tetrahydrate	7173-51-5	1,741	0.02	0.57%
Ethoxylated Alcohols	Proprietary	1,718	0.01	0.57%
Isopropanol	77-92-9	1,707	0.01	0.56%
Citric Acid	1344-28-1	1,666	0.00	0.55%

Source: FracFocus (2024a)

Note: Ingredient names and CAS numbers are not standardized in FracFocus, leading to widespread differences and discrepancies in CAS numbers, number of disclosures, and ingredient names. For this reason, the values and ingredients presented in this table are for general information only.

* The amount of the ingredient in the total hydraulic fracturing volume by percent mass (definition from FracFocus [2024a] data dictionary).

† The total number of FracFocus ingredient disclosures in the state of New Mexico is 236,076.

± FracFocus lists certain chemicals as proprietary and no additional information is available regarding ingredient contents.

Table 2-4. Summary of 2023 Spills in the State of New Mexico

Material	Spill Count	Volume Spilled	Volume Lost	Units	Average Spill Volume	Mean Percent Lost (%)	Waterways Affected	Groundwater Affected
Produced Water	673	81,500	37,553	bbl	121	46	2	0

Material	Spill Count	Volume Spilled	Volume Lost	Units	Average Spill Volume	Mean Percent Lost (%)	Waterways Affected	Groundwater Affected
Crude Oil	297	7,114	2,739	bbl	24	39	1	0
Condensate	98	1,730	1,366	bbl	18	79	7	0
Other (Specify)	20	4,675	3,558	bbl	234	76	0	2
Drilling Mud/Fluid	6	828	154	bbl	138	19	0	0
Natural Gas Liquids	4	63	38	bbl	16	60	0	0
Diesel	1	9	7	bbl	9	78	0	0
Glycol	2	9	2	bbl	5	22	0	0
Unknown	3	49	49	bbl	16	100	0	0
Brine Water	1	27	7	bbl	27	26	0	0
Total Liquid Spills	**1,105**	**96,004**	**45,453**	**bbl**	**87**	100	**10**	**2**
Natural Gas Flared	49,706	19,607,467	19,607,467	mcf	394	100	1	4
Natural Gas Vented	1,513	449,745	449,745	mcf	297	100	3	0
Carbon Dioxide	143	28,008	28,008	mcf	196	100	0	0
Hydrogen Sulfide	1	250	250		250	100		
Total Gaseous Spills	**51,363**	**20,085,470**	**20,085,470**	**mcf**	**391**	46	**4**	**4**

Source: NMOCD (2024b)

Units: bbl = barrels; mcf = thousand cubic feet.

Note: FracFocus does not differentiate between natural gas flaring/venting and a normal liquid spill that could occur during the hydraulic fracturing process; therefore, this table reflects two total value rows (one total value for conventional spills and one for natural gas flaring and venting). Natural gases that are vented and flared are done intentionally as part of the hydraulic fracturing process with no expected spill recovery.

2.2.2 Per- and polyfluoroalkyl substances (PFAS)

Per- and polyfluoroalkyl substances (PFAS) is a broad term classification for a large group of human-made chemicals that are found in a wide variety of industrial processes and common household items. They are widely used in disposable food packaging, cookware, outdoor equipment, furniture, and carpet for their hydrophobic and oleophobic properties (Sunderland et al. 2018). PFAS are a main component of aqueous film-forming foam (AFFF), which is used regularly in fire suppression and prevention activities performed at airports and military bases (Sunderland et al. 2018). AFFF is a major source of PFAS groundwater contamination and has been recognized as a nationally significant challenge in the United States (Sunderland et al. 2018).There are approximately 4,700 distinct chemicals that are categorically grouped as PFAS (Cousins et al. 2020). The most common and widely studied PFAS include PFOS (perfluorooctane sulfonate and PFOA (perfluorooctanoic acid) (EPA 2024). PFAS are very persistent in both the environment and the human body due to their inability to readily break down (EPA 2024). PFAS persistence has been linked to bioaccumulation in both the environment and human body, which may lead to adverse effects on human health (EPA 2024).

In the years 2020–2021 the USGS partnered with the NMED to conduct a statewide assessment on PFAS to better understand PFAS contamination throughout the state (USGS 2024). The study analyzed PFAS presence in surface water and groundwater across New Mexico. Due to groundwater usage during the hydraulic fracturing process, only groundwater results will be considered in this section. Of the 117 groundwater sample locations across New Mexico, 27 sample locations (23% of sampling locations) were found to have one or more PFAS above the laboratory detection limit (USGS 2024). There were no PFAS sample locations that had concentrations exceeding the EPA's 70 nanogram/liter recommendation (USGS 2024).

2.2.2.1 PFAS Sources in Hydraulic Fracturing

PFAS may be used during the hydraulic fracturing process due to their stability at high temperatures and pressures and may be used in well drilling (in the form of drilling fluids), well completion, and workover operations (Gaines 2022). PFAS can be used as a surfactant to enhance recovery in oil and gas wells (Gaines 2022) to decrease friction during the drilling and hydraulic fracturing process to allow for better drilling efficiency. In addition to drilling efficiency purposes, PFAS are utilized as an effective method to mitigate oil spills in water. PFAS can be injected into contaminated water to promote the formation of a barrier between oil and water. This allows for an increased efficiency of skimming oil spills from water during the remediation process (Gaines 2022).

PFAS utilized in hydraulic fracturing are categorized into four distinct groups in the FracFocus database; perfluoroalkyl alkanes/cycloalkanes, fluoroalkyl alcohol substituted polyethylene glycol, nonionic fluorosurfactants, and polytetrafluoroethylene (Connor et al. 2021). Utilization of PFAS chemicals makes up a minimal amount (less than 1%) of chemical constituents disclosed to FracFocus for hydraulic fracturing in New Mexico (FracFocus 2024a). In 2023, New Mexico had 40 reported ingredient instances of nonionic surfactants and 23 reported ingredient instances of fluoroalkyl alcohol substituted polyethylene glycol used in association with hydraulic fracturing. In total, 63 of the approximately 31,000 ingredient disclosures (0.01%) in 2023 were related to PFAS utilized in hydraulic fracturing processes in New Mexico. The majority of PFAS-contaminated water usage is strictly for well drilling, completion, stimulation, and oil spill mitigation. PFAS use in hydraulic fracturing is likely to occur in areas not associated with New Mexico's drinking water.

2.3 DROUGHT AND WATER AVAILABILITY

To standardize drought reporting across federally managed lands, the BLM requested the use of ClimateEngine.org to calculate and categorize drought impacts across various jurisdictions. ClimateEngine.org integrates multiple drought indices and weights them differently to produce both long- and short-term drought blend summaries. Both the long- and short-term drought blend assessments provide analysis at the same temporal levels (current, 3 month, and 1 year); however, the data indices used are weighted differently to produce a different drought blend (long and short term). ClimateEngine.org evaluates the following indices and spatial data to determine drought severity at the landscape level:

- Palmer-Z Index
- Palmer Drought Severity Index
- Standardized Precipitation Index
- Palmer Hydrological Drought Index
- Soil Moisture from National Oceanic and Atmospheric Administration

The short-term drought blend provides insights into drought impacts over a brief period (days to months), which is useful for assessing effects on agriculture and soil moisture. In contrast, the long-term drought blend assesses impacts related to precipitation over extended periods (months to years) and is more effective for evaluating groundwater levels and overall water availability at a landscape level. The long-term drought blend is used for evaluating drought severity across the field offices within New

Mexico (PDO, FFO, RPFO). The drought blend figures presented below combine the current, 3-month, and 1-year drought summaries to produce each blend figure.

New Mexico–specific drought data were compiled from the NMSO to ensure accurate statewide drought information. Climate Engine data at the highest level of analysis (entirety of the NMSO) include drought information from the entire jurisdiction of the NMSO (Texas, Oklahoma, and Kansas). As a result, statewide drought blend assessments are not available for New Mexico.

2.3.1 State of New Mexico

New Mexico has been subjected to a prolonged period of drought, which puts further strain on sources of water that are accessible via surface water diversion or groundwater pumping. According to the U.S Drought Monitoring tool, approximately 1.7 million residents in New Mexico are living in drought-affected areas as of May 2024 (National Drought Mitigation Center 2024). Since 2023, 78.51% of New Mexico experienced some level of drought severity (D0–D4), leaving most of the state subjected to long-term drought conditions (Table 2-5) (NMOSE 2024). Figure 2-2 displays the change in drought conditions over the past 10 years, reflecting the change in the total drought percent area under each drought condition (D0–D4) (NMOSE 2024).

Table 2-5. Drought Percent Area Across New Mexico

Time Period	D0 (Abnormally Dry)	D1 (Moderate Drought)	D2 (Severe Drought)	D3 (Extreme Drought)	D4 (Exceptional Drought)
1-year average (2023)	21.0	20.6	22.6	12.3	1.9
5-year average (2019–2023)	15.4	17.2	22.7	15.9	9.2
10-year average (2014–2023)	19.2	18.0	19.2	11.8	5.7

Source: NMOSE (2024)

With the unpredictability of monsoonal precipitation due to climate change, it cannot be reliably assumed that aquifers supplying water for hydraulic fracturing will consistently recharge via percolation from precipitation events. Extended drought conditions could result in decreased water availability at identified discharge zones. Consequently, surface water bodies hydrologically connected to these aquifers may experience reduced water levels due to the prolonged drought, impacting surface water availability across regions with significant hydraulic fracturing activity.

Moreover, increased groundwater withdrawals for oil and gas extraction for reasonably foreseeable development in New Mexico could result in additional stress to aquifers. Hydrologically connected surface waters may exhibit altered flow regimes due to the increased groundwater extraction. Increased groundwater pumping due to the expansion of hydraulic fracturing, combined with regional drought, may reduce the water available for irrigation. Irrigation water supply is primarily sourced from surface water bodies and springs/seeps, which often depend on stable groundwater levels and climatic conditions for recharge.

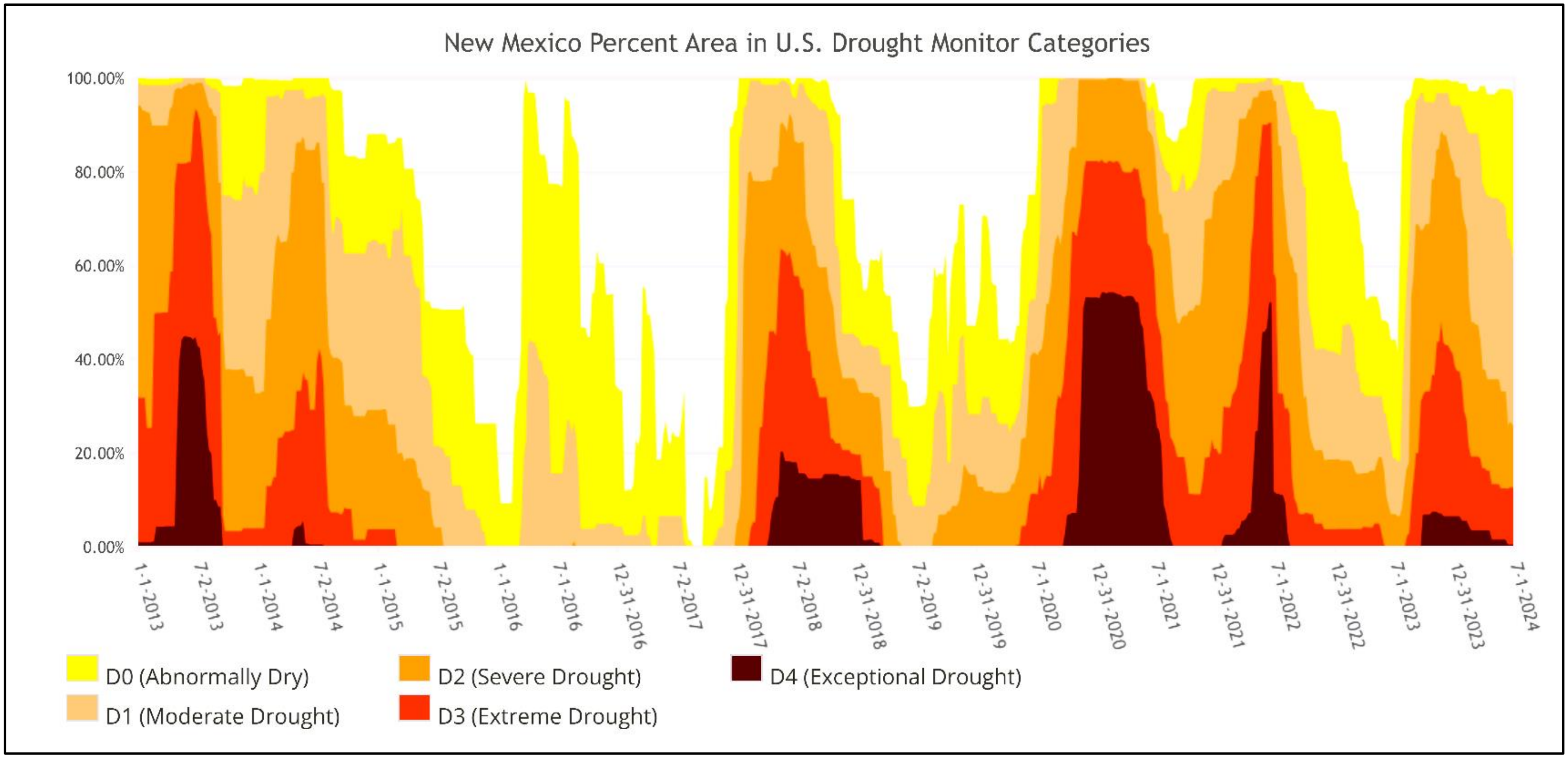

Figure 2-2. Drought conditions in New Mexico from 2013 through 2023.

Source: U.S. Drought Monitor (2024)

Note: D0 = Abnormally Dry, D1 = Moderate Drought, D2 = Severe Drought, D3 = Extreme Drought, D4 = Exceptional Drought.

2.3.2 Pecos District Office

Since 2023, 61.9% of the PDO has faced varying degrees of drought severity (D1–D4) within its jurisdiction. Specifically, 16.2% of the area has encountered severe drought conditions, and 6.8% has experienced extreme drought (Table 2-6). The PDO has reported the highest levels of both severe and extreme drought compared to the FFO and RPFO. These severe and extreme conditions are primarily concentrated in the southern regions of the PDO. Figure 2-3 illustrates both long-term and short-term drought blend scenarios.

Table 2-6. Drought Percent Area Across the Pecos District Office

Term	Time Period	D0 (Abnormally Dry)	D1 (Moderate Drought)	D2 (Severe Drought)	D3 (Extreme Drought)	D4 (Exceptional Drought)
Long Term	Current (07/23/2024)	49.9	39.2	17.1	8.8	0.1
	3 Month (04/24/2024)	68.7	54.5	21.8	9.4	0
	1 Year (07/24/2023)	49.2	38.9	16.2	6.8	0
Short Term	Current (07/23/2024)	16.0	9.6	0.8	0	0
	3 Month (04/24/2024)	57.9	31.6	0	0	0
	1 Year (07/24/2023)	54.3	46.8	22.0	13.1	0

Source: Climateengine.org (2024)

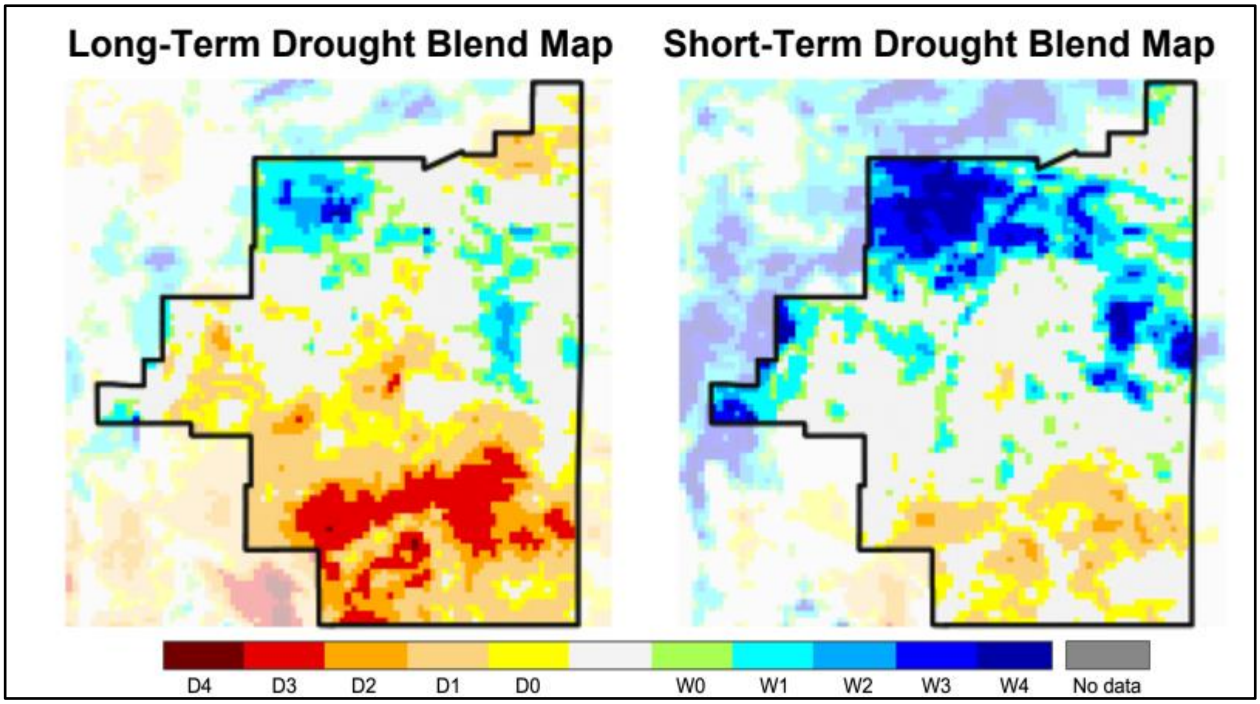

Figure 2-3. Drought blend summaries for the PDO.

Source: Climateengine.org (2024)

Note: D0 = Abnormally dry, D1 = Moderate Drought, D2 = Severe Drought, D3 = Extreme Drought, D4 = Exceptional Drought.

2.3.3 Farmington Field Office

Since 2023, 26.2% of the FFO has encountered various levels of drought severity (D1–D4) (Table 2-7). Specifically, 4.8% of the area has faced severe drought conditions, while 1.9% has experienced extreme drought. Overall, the FFO has predominantly dealt with moderate drought conditions, which are primarily concentrated in the northeastern part of the region. Figure 2-4 provides a summary of the blended drought report.

Table 2-7. Drought Percent Area Across the Farmington Field Office

Term	Time Period	D0 (Abnormally Dry)	D1 (Moderate Drought)	D2 (Severe Drought)	D3 (Extreme Drought)	D4 (Exceptional Drought)
Long Term	Current (07/23/2024)	18.8	7.1	0.5	0.2	0
	3 Month (04/24/2024)	56.2	34.6	2.8	0.5	0.2
	1 Year (07/24/2024)	30.5	19.5	4.8	1.9	0
Short Term	Current (07/23/2024)	0.1	0	0	0	0
	3 Month (04/24/2024)	64.0	30.1	0.9	0.4	0
	1 Year (07/24/2024)	67.8	65.5	32.0	12.0	0

Source: Climateengine.org (2024)

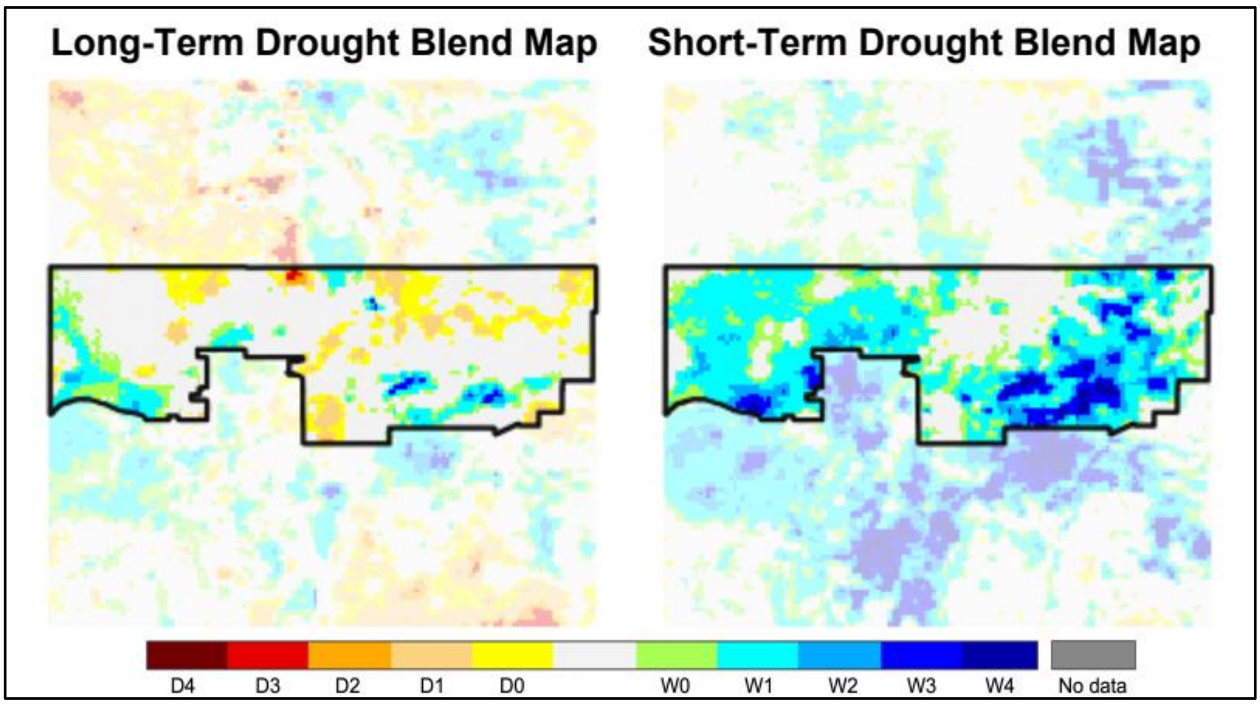

Figure 2-4. Drought blend summaries for the FFO.

Source: Climateengine.org (2024)

Note: D0 = Abnormally Dry, D1 = Moderate Drought, D2 = Severe Drought, D3 = Extreme Drought, D4 = Exceptional Drought.

2.3.4 Rio Puerco Field Office

Since 2023, 31.1% of the RPFO has encountered various levels of long-term drought severity (D1–D4) (Table 2-8). Specifically, 0.1% of the area has faced severe drought conditions, while 4.5% has experienced extreme drought conditions. Overall, the RPFO has predominantly dealt with moderate drought conditions, which are primarily concentrated in the northeastern part of the region. Figure 2-5 provides a visual summary of both the long- and short-term blended drought summaries.

Table 2-8. Drought Percent Area Across the Rio Puerco Field Office

Term	Time Period	D0 (Abnormally Dry)	D1 (Moderate Drought)	D2 (Severe Drought)	D3 (Extreme Drought)	D4 (Exceptional Drought)
Long Term	Current (07/23/2024)	6.8	2.8	0.0	0.0	0.0
	3 Month (04/24/2024)	32.2	17.1	0.8	0.0	0.0
	1 Year (07/24/2024)	39.4	26.2	4.5	0.1	0
Short Term	Current (07/23/2024)	0	0	0	0	0
	3 Month (04/24/2024)	23.0	9.0	0.1	0	0
	1 Year (07/24/2024)	93.1	89.0	71.4	42.0	0.3

Source: Climateengine.org (2024)

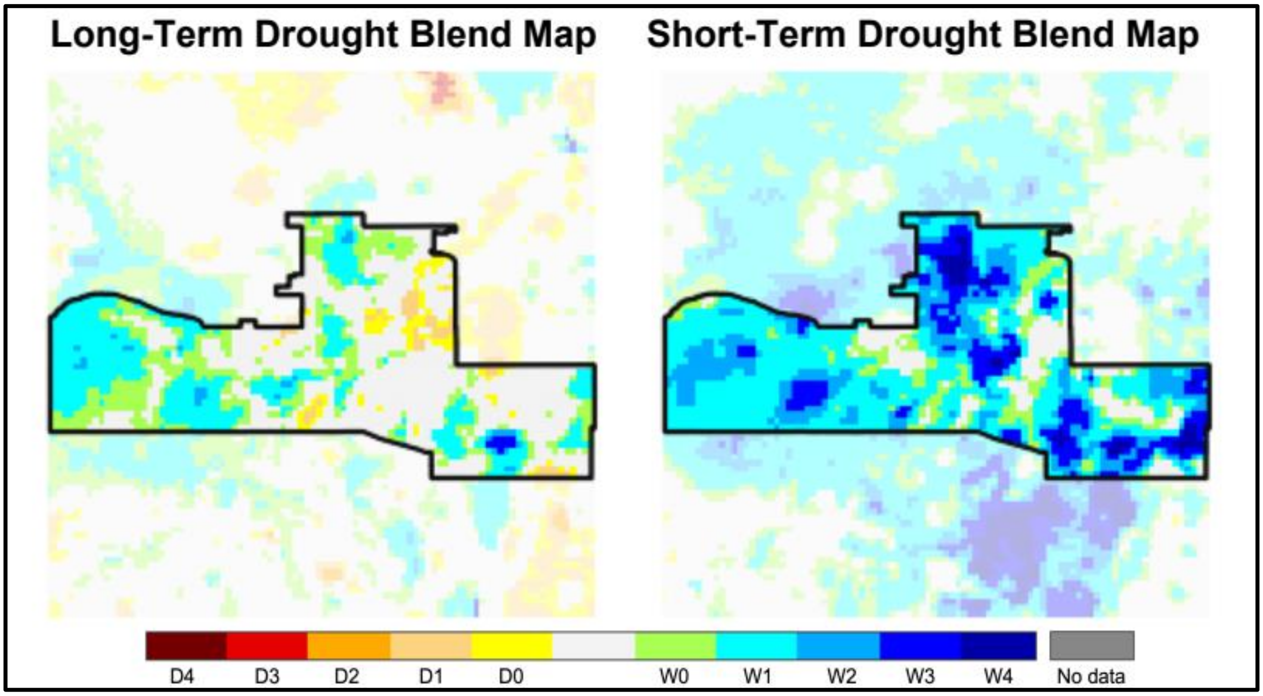

Figure 2-5. Drought blend summaries for the RPFO.

Source: Climateengine.org (2024)

Note: D0 = Abnormally Dry, D1 = Moderate Drought, D2 = Severe Drought, D3 = Extreme Drought, D4 = Exceptional Drought.

2.4 STATE OF NEW MEXICO WATER PLANS

The State of New Mexico's approach to water resources management is guided by a comprehensive strategy outlined in its three-part 2018 New Mexico State Water Plan (NMSWP) and a separate 50-year Water Action Plan, developed in 2021–2022. The 2018 NMSWP is divided into three key components; Part I of the 2018 plan outlines the state's highest priority water issues and the policies, goals, and strategies needed to address these issues and provides details regarding available resources (New Mexico Interstate Stream Commission [NMISC] 2018a). Part I of the 2018 NMSWP also highlights eight of the state's priority policy topics, including water infrastructure, data collection, drought, watershed management, water supply and demand, water conservation, water quality, and water planning (NMISC 2018a). Part II of the 2018 NMSWP integrates water resource data from regional plans completed in 2016–2017. Part II is a technical report that includes information about estimated water availability and associated uses, population projections, and stakeholder developed strategies to address these issues (NMISC 2018b). Part II does not directly address the impacts of climate change; however, prolonged drought estimates were considered (NMISC 2018b). Part III of the 2018 NMSWP details information about New Mexico water law decisions and events, as well as the circumstances that led to the structure of water resource management in New Mexico (NMISC 2018c). In accordance with the State Water Plan Act, the State of New Mexico published a 5-year review of the 2018 NMSWP, evaluating the status of water planning relative to new climate projections and statutory requirements and prioritizing next steps for incorporating modern climate science into the state's water management planning (NMISC 2023). The review details successes and shortcomings of the 2018 plan elements across numerous categories from watershed management to water security and supply and discusses potential impacts of climate change within those categories utilizing information from the 2022 Leap Ahead Report (Dunbar et al. 2022).

The 50-year Water Action Plan, developed by the State of New Mexico in 2021–2022, provides a high-level view of the state's planned approach to water security and water quality management. Divided into 11 priority actions, the plan aims to protect water supply through water conservation, the establishment of new water sources, and watershed protection (NMISC 2022). The state plans to achieve its water conservation goals through public outreach and education, incentive programs to drive the adoption of efficient irrigation technology in agriculture, developing and repairing a robust drinking water system, and prioritizing water infrastructure improvement projects (NMISC 2022). To establish new water sources, the state plans to establish reserve funds to be used to purchase community water supply, implement comprehensive rules for water reuse, and fully implement a reservoir monitoring system to support water supply management decisions (NMISC 2022). Lastly, the plan aims to reach its watershed protection goals through the cleanup of superfund sites in the state, a state surface water discharge permitting program, the overhaul and maintenance of wastewater treatment facilities and implementation of modern stormwater infrastructure, and the acceleration of watershed restoration projects (NMISC 2022).

2.5 INDUCED SEISMICITY

Induced seismicity refers to seismic events that are triggered by human activities rather than natural tectonic forces. A broad range of human activities have been attributed to induced seismicity, including but not limited to underground fluid injection (e.g., for wastewater and hydraulic fracturing) and oil and gas extraction (GWPC 2021). Between 2008 and 2015, seismicity events increased in the mid-continental United States and studies pointed to a connection between increasing seismic events and the widespread disposal of wastewater into deep Class II[1] injection wells (GWPC 2021). Seismic events can occur when specific geologic conditions are present (e.g., sufficient pore pressure build-up near a pre-existing fault of concern) (GWPC 2021; Oklahoma Corporation Commission 2018).

A combination of many factors is necessary to induce felt earthquakes: the injection rate and total volume injected, the presence of faults that are large enough to produce felt earthquakes, stresses that are large enough to produce earthquakes, and the presence of pathways for the fluid pressure to travel from the injection point to faults (Machette et al. 2000; USGS 2021). High injection rates of greater than 300,000 barrels (bbl) per month are much more likely to be associated with earthquakes, and any earthquake within approximately 10 to 30 kilometers (6.2–18.6 miles) of an active injection well could be associated with that well (Oklahoma Corporation Commission 2018, Weingarten et al. 2015). Although hydraulic

[1] Class II wells dispose of fluid produced in conjunction with oil and gas drilling, completion, and production operations (GWPC 2021).

fracturing can also contribute to induced seismicity, seismic events triggered by hydraulic fracturing are relatively uncommon and generally have smaller magnitudes than injection-induced seismicity and are therefore considered to pose less risk (GWPC 2021). Even relatively extreme seismic events associated with hydraulic fracturing have been well below the damage threshold for modern building codes (Petersen et al. 2018; USGS 2021).

The risk for induced seismicity increases with high-volume injections into deep wells carried out through wastewater injections and enhanced oil recovery techniques. A combination of many factors is necessary for injection to induce felt earthquakes: the injection rate and total volume injected, the presence of faults that are large enough to produce felt earthquakes, stresses that are large enough to produce earthquakes, and the presence of pathways for the fluid pressure to travel from the injection point to faults (Machette et al. 2000; USGS 2021). High injection rates of greater than 300,000 barrels per month are much more likely to be associated with earthquakes, and any earthquake within 15 kilometers (9.3 miles) of an active injection well is considered to be associated with that well (Weingarten et al. 2015).

Since 1996 there have been 35 recorded earthquakes related to induced seismicity in New Mexico. Five of the 35 recorded earthquakes had a magnitude greater than 3.5 (NMOCD 2024c). Several areas of heightened induced seismicity have been identified in the state of New Mexico; most areas of concern occur in southeastern New Mexico, and one area occurs in northern New Mexico approximately 16 miles west of Raton and 7 miles north of Cimarron along U.S. Highway 64 (NMOCD 2021, 2024c).

2.5.1 Pecos District Office

The following four areas of concern for induced seismicity are within the Permian Basin (NMOCD 2024c):

- The County Line Seismic Response Area, approximately 35 miles southeast of Carlsbad, New Mexico, on the border of Eddy and Lea Counties, New Mexico, and extending slightly into Texas
- 6 miles northeast of Jal, New Mexico, in Lea County, and extending slightly into Texas
- 12 miles southwest of Lovington, New Mexico, in Lea County
- 9 miles south of Artesia and 10 miles northwest of Carlsbad, New Mexico, in Eddy County (also associated with an area known as the Dagger Draw Field)

In November 2021, NMOCD issued a new seismic response protocol to address seismic activity related to Class II injection wells in the state of New Mexico. The protocol includes requirements that are implemented either through voluntary actions by operators or by orders issued by NMOCD. The protocol directs operators to monitor seismic events and implement reduced injection rates if the seismic event has a magnitude of 2.5 or greater. The magnitude of reductions varies based on the earthquake magnitude and proximity of wells to these events (with 10 miles being the maximum distance for injection reductions to apply) (NMOCD 2021). Since 2021 there have been 21 instances of seismicity greater than magnitude 2.5 (NMOCD 2024c).

2.5.2 Farmington Field Office and Rio Puerco Field Office

Seismically, the San Juan Basin is a relatively quiescent sedimentary basin in the Four Corners region of the United States. Since 1996, only 32 earthquakes of magnitude 2.5 or greater in the basin are reported in the USGS database, including two events estimated to have magnitudes of approximately 5.0. One occurred in 1966, and the other occurred in 1976 (McCormack et al. 2022). In 2018, the San Juan Basin was situated in an area forecast to have less than a 1% annual chance of potentially minor-damage ground shaking (Petersen et al. 2018; USGS 2018). The Galina and Nacimiento faults, which are situated on the eastern boundary of the San Juan Basin, are predominantly normal faults and experience vertical displacement of less than 0.2 millimeter per year (USGS 2021). Since 2021 there were no recorded seismicity events greater than 2.5 in either the FFO or RPFO (NMOCD 2024c).

CHAPTER 3. PECOS DISTRICT OFFICE

The BLM Pecos District, which oversees the CFO and RFO, encompasses over 3.6 million surface acres and over 7.6 million federal mineral acres. The Pecos District includes the New Mexico portion of the Permian Basin, a sedimentary depositional basin (Figure 3-1). The Permian Basin is one of the premier oil and gas producing regions in the United States, and prolific producing horizons occur in the New Mexico portion of the basin in Chaves, Eddy, and Lea Counties. The Permian Basin has been a producing oil and natural gas field since the early 1900s.

The portion of the Pecos District that is underlain by the Permian Basin encompasses Eddy County, Lea County, and the majority of Chaves County (which is analogous to the New Mexico portion of the Permian Basin). Although limited drilling also occurs in Roosevelt County, the overwhelming majority of drilling in the Permian Basin occurs outside of Roosevelt County, and the water use associated with oil and gas wells (per well) in Roosevelt County is much less than the water use in Chaves. Eddy, and Lea Counties. Since the likely water sources used to support future potential development are located in the other three counties, Roosevelt County is not included for analysis in this document. The Pecos District tri-county area contains approximately 3.4 million acres of federal minerals. Some data analyzed (e.g., FracFocus and USGS water use) are available at the county level only; thus, the term “Pecos tri-county area” may be used interchangeably with “Pecos District” (which denotes BLM administrative boundaries) in this report.

This chapter presents information on existing and projected water quantity and water quality data for the Pecos District, as summarized from information from the following sources:

- *Reasonable Foreseeable Development (RFD) Scenario for the BLM New Mexico Pecos District* (Engler and Cather 2012) and *Update to the Reasonable Foreseeable Development for the BLM Pecos District, SENM* (Engler and Cather 2014)
- *Reasonably Foreseeable Development (RFD) Scenario for Oil and Gas Activities, Carlsbad Field Office, Eddy County, Southeastern New Mexico* (Engler 2023)
- Data compiled from the USGS report *Estimated Use of Water in the United States in 2015* (Dieter et al. 2018)
- FracFocus, a national hydraulic fracturing chemical registry managed by the GWPC and IOGCC (FracFocus 2024a)
- Draft Resource Management Plan and Environmental Impact Statement Carlsbad Field Office, Pecos District, New Mexico (BLM 2018)
- Sandia National Laboratories report *Water Resource Assessment in the New Mexico Permian Basin* (Lowry et al. 2018)
- Addendum to Water Resource Assessment in the New Mexico Permian Basin (Reardon et al. 2021)
- Spill data from the NMOCD database (NMOCD 2024a)
- Water use estimates from the USGS report *Estimates of Water Use Associated with Continuous Oil and Gas Development in the Permian Basin, Texas and New Mexico, 2010-19* (Valder et al. 2021)
- Data to Estimate Water Use Associated with Oil and Gas Development within the Bureau of Land Management Carlsbad Field Office area, New Mexico (Gonzalez-Salvat et al. 2023)
- Geodatabase of oil and gas pads and roads within the Bureau of Land Management's Carlsbad Field Office area, New Mexico (Villarreal et al. 2023)

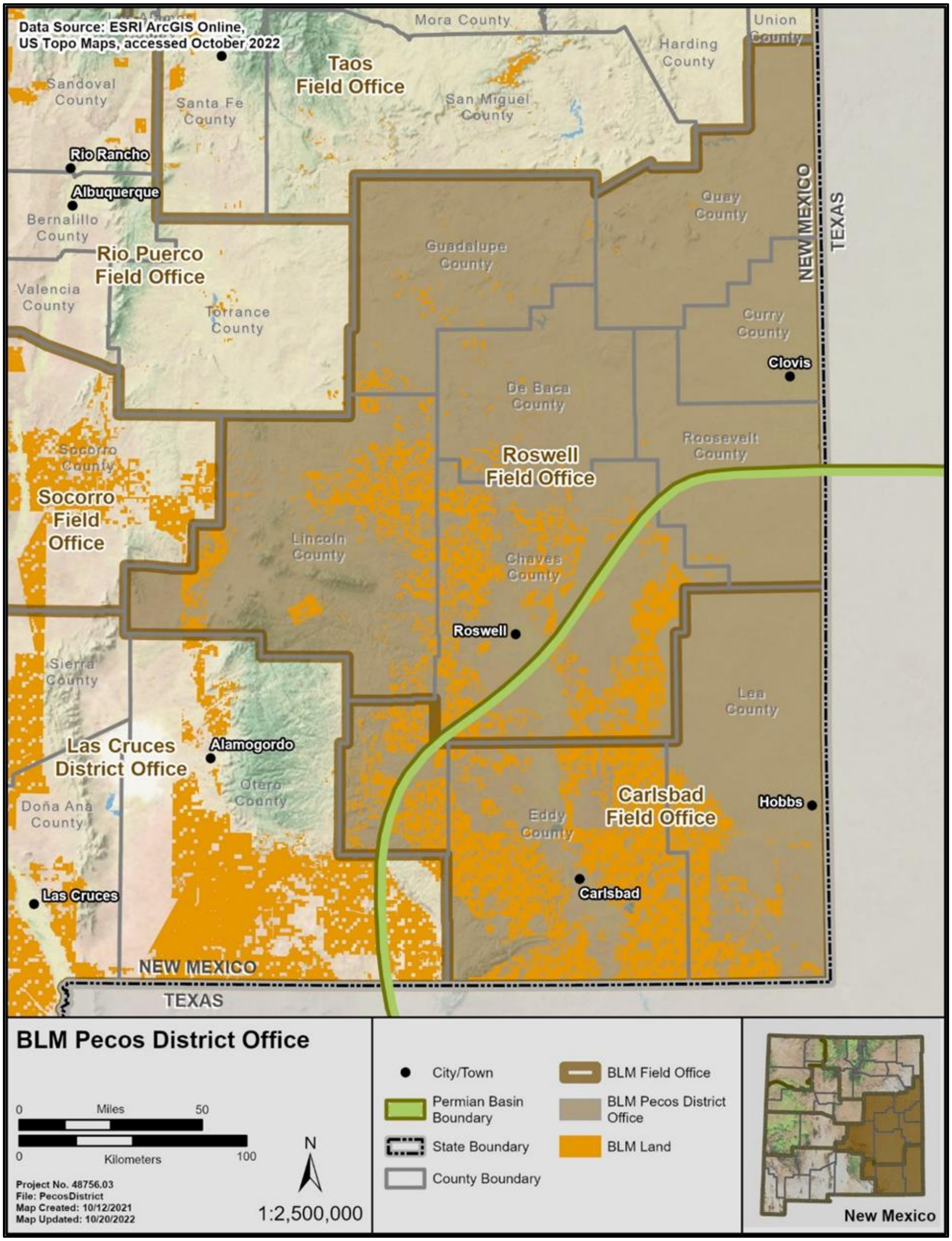

Figure 3-1. Map of BLM PDO boundaries.

3.1 WATER QUANTITY

3.1.1 Existing Surface Water and Groundwater Use

For the Pecos tri-county area, Dieter et al. (2018) list total water withdrawals across eight water use categories: aquaculture, domestic, industrial, irrigation, livestock, mining, public water supply, and thermoelectric power. Water usage data for Lea, Eddy, and Chaves Counties are presented in Table 3-1., Table 3-2, and Table 3-3, respectively. Total water usage in the Pecos tri-county area in 2015 was 619,375 AF (Table 3-4; Figure 3-2). Irrigation and mining activities consumed the greatest amount of water, accounting for 75% (466,784 AF) and 15% (94,758 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, 17% of withdrawals were from saline sources.

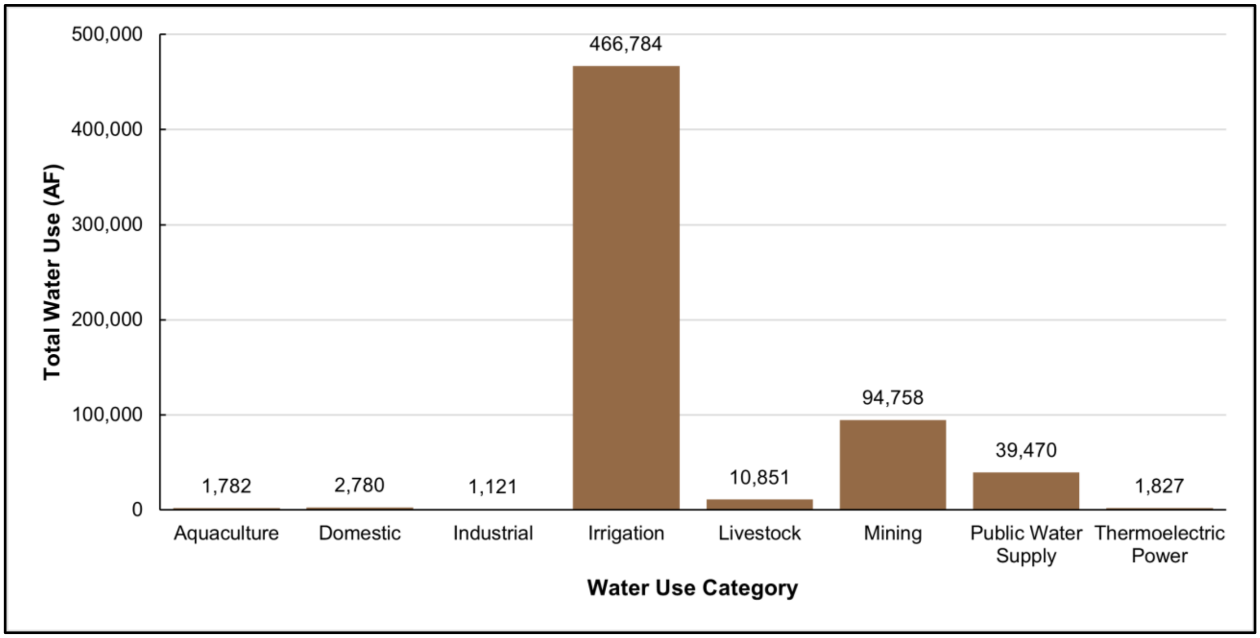

Figure 3-2. Pecos tri-county area (Chaves, Eddy, and Lea Counties) water use by category in 2015 (Dieter et al. 2018).

Table 3-1. Lea County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)†
	Fresh	Saline*	Total	Total Use (%)†	Fresh	Saline*	Total	Total Use (%)†	Fresh	Total Use (%)	Saline*	Total Use (%)†		
Aquaculture	0	0	0	0	0	0	0	0%	0	0%	–	0%	0	0%
Domestic	0	–	0	0	1,513	–	1,513	<1%	1,513	<1%	–	0%	1,513	<1%
Industrial	0	0	0	0	78	0	78	<1%	78	<1%	0	0%	78	<1%
Irrigation	0	–	0	0	166,099	–	166,099	63%	166,099	63%	–	0%	166,099	63%
Livestock	56	–	56	<1%	2,870	–	2,870	1%	2,926	1%	–	0%	2,926	1%
Mining	0	0	0	0	325	81,642	81,968	31%	325	<1%	81,642	31%	81,968	31%
Public Water Supply	0	0	0	0	11,423	0	11,423	4%	11,423	4%	0	0%	11,423	4%
Thermoelectric Power	0	0	0	0	1,827	0	1,827	<1%	1,827	<1%	0	0%	1,827	<1%
County Totals	**56**	**0**	**56**	**<1%**	**184,135**	**81,642**	**265,778**	**100%**	**184,192**	69%	**81,642**	**31%**	**265,834**	**100%**

Source: Dieter et al. (2018)

Note: Values may not sum to totals because of independent rounding (Dieter et al. 2018). Water use data are in acre-feet/year unless otherwise indicated.

* Saline water withdrawals are not reported for domestic, irrigation, or livestock water use (Dieter et al. 2018).

† Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 265,834 acre-feet.

Table 3-2. Eddy County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)†
	Fresh	Saline*	Total	Total Use (%)†	Fresh	Saline*	Total	Total Use (%)†	Fresh	Total Use (%)	Saline*	Total Use (%)†		
Aquaculture	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Domestic	0	–	0	0%	258	–	258	<1%	258	<1%	–	0%	258	<1%
Industrial	0	0	0	0%	1,043	0	1,043	<1%	1,043	<1%	0	0%	1,043	<1%
Irrigation	64,054	–	64,054	35%	89,994	–	89,994	49%	154,048	84%	–	0%	154,048	84%
Livestock	34	–	34	<1%	1,289	–	1,289	<1%	1,323	<1%	–	0%	1,323	<1%
Mining	0	0	0	0%	975	10,145	11,120	6%	975	<1%	10,145	6%	11,120	6%
Public Water Supply	0	0	0	0%	15,077	0	15,077	8%	15,077	8%	0	0%	15,077	8%

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)†
	Fresh	Saline*	Total	Total Use (%)†	Fresh	Saline*	Total	Total Use (%)†	Fresh	Total Use (%)	Saline*	Total Use (%)†		
Thermoelectric Power	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
County Totals	**64,088**	**0**	**64,088**	**35%**	**108,636**	**10,145**	**118,781**	**65%**	**172,724**	**95%**	**10,145**	**6%**	**182,869**	**100%**

Source: Dieter et al. (2018)

Note: Values may not sum to totals because of independent rounding (Dieter et al. 2018). Water use data are in acre-feet/year unless otherwise indicated.

* Saline water withdrawals are not reported for domestic, irrigation, or livestock water use (Dieter et al. 2018).

† Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 182,869 acre-feet.

Table 3-3. Chaves County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)†
	Fresh	Saline*	Total	Total Use (%)†	Fresh	Saline*	Total	Total Use (%)†	Fresh	Total Use (%)	Saline*	Total Use (%)†		
Aquaculture	0	0	0	0%	1,782	0	1,782	1%	1,782	1%	0	0%	1,782	1%
Domestic	0	–	0	0%	1,009	–	1,009	<1%	1,009	<1%	–	0%	1,009	<1%
Industrial	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Irrigation	9,854	–	9,854	6%	136,784	–	136,784	80%	146,638	86%	–	0%	146,638	86%
Livestock	224	–	224	<1%	6,378	–	6,378	4%	6,603	4%	–	0%	6,603	4%
Mining	0	0	0	0%	78	1,592	1,670	<1%	78	<1%	1,592	<1%	1,670	<1%
Public Water Supply	0	0	0	0%	12,970	0	12,970	8%	12,970	8%	0	0%	12,970	8%
Thermoelectric Power	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
County Totals	**10,078**	**0**	**10,078**	**6%**	**159,003**	**1,592**	**160,594**	**94%**	**169,080**	**99%**	**1,592**	**<1%**	**170,672**	**100%**

Source: Dieter et al. (2018)

Note: Values may not sum to totals because of independent rounding (Dieter et al. 2018). Water use data are in acre-feet/year unless otherwise indicated.

* Saline water withdrawals are not reported for domestic, irrigation, or livestock water use (Dieter et al. 2018).

† Total use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 170,672 acre-feet.

Table 3-4. Pecos Tri-county Area (Chaves, Eddy, and Lea Counties) Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)†
	Fresh	Saline*	Total	Total Use (%)†	Fresh	Saline*	Total	Total Use (%)†	Fresh	Total Use (%)	Saline*	Total Use (%)†		
Aquaculture	0	0	0	0%	1,782	0	1,782	<1%	1,782	<1%	0	0%	1,782	<1%
Domestic	0	–	0	0%	2,780	–	2,780	<1%	2,780	<1%	–	0%	2,780	<1%
Industrial	0	0	0	0%	1,121	0	1,121	<1%	1,121	<1%	0	0%	1,121	<1%
Irrigation	73,908	–	73,908	12%	392,877	–	392,877	63%	466,784	75%	–	0%	466,784	75%
Livestock	314	–	314	<1%	10,537	–	10,537	2%	10,851	2%	–	0%	10,851	2%
Mining	0	0	0	0%	1,379	93,379	94,758	15%	1,379	<1%	93,379	15%	94,758	15%
Public Water Supply	0	0	0	0%	39,470	0	39,470	6%	39,470	6%	0	0%	39,470	6%
Thermoelectric Power	0	0	0	0%	1,827	0	1,827	<1%	1,827	<1%	0	0%	1,827	<1%
County Totals	**74,222**	**0**	**74,222**	**12%**	**451,774**	**93,379**	**545,154**	**88%**	**525,996**	**85%**	**93,379**	**15%**	**619,375**	**100%**

Source: Dieter et al. (2018)

Note: Values may not sum to totals because of independent rounding (Dieter et al. 2018). Water use data are in acre-feet/year unless otherwise indicated.

* Saline water withdrawals are not reported for domestic, irrigation, or livestock water use (Dieter et al. 2018).

† Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 619,375 acre-feet.

3.1.2 Water Use Trends and Planned Actions

3.1.2.1 Past and Present Actions

The Pecos tri-county area total water usage in 2015 was 619,375 AF (see Table 3-4) and accounted for approximately 19% of total state withdrawals (Dieter et al. 2018). See Table 2-1 for statewide water use data. Water use in 2015 associated with mining, which includes oil and gas development, in the Pecos tri-county area was 94,758 AF (see Table 3-4) and represented approximately 57% of statewide mining water use (163,901 AF) and 15% of the Pecos District total water use (619,375 AF). Within the Pecos tri-county area, the largest amount of water is used for irrigation (see Figure 3-2), which represents 75% of all water use within the Pecos tri-county area (619,375 AF) and 14% of all water use within the state (3,249,667 AF).

Data from FracFocus were evaluated to provide objective information on the amount of water used by hydraulic fracturing activities in the Pecos tri-county area. Annual water use associated with direct hydraulic fracturing in federal wells has generally increased over time, ranging between 1,268 AF in 2014 and 32,304 AF in 2023 (5) (FracFocus 2024a). In 2023, federal oil and gas water usage accounted for 43% of all oil and gas water usage (32,304 AF) in the Pecos tri-county area (Table 3-5). Non-federal oil and gas hydraulic fracturing used 42,591 AF of water, with a total combined usage between federal and non-federal wells of 74,895 AF in 2023. A full summary of water usage aggregated from FracFocus for the Pecos tri-county area can be found in Table 3-5.

In 2023, 1,341 wells used an estimated 74,895 AF, for an average of 55.9 AF per well (FracFocus 2024a) (see Table 3-5). The average total annual water use for all wells over the last 10 years was 37,335 AF/year.

Water use for hydraulic fracturing of all wells within the Pecos tri-county area increased from 3,581 to 74,895 AF from 2014 to 2023 (see Table 3-5), corresponding with an increase in average water use per well from 7.0 to 55.9 AF (FracFocus 2024a). At the time of this report, data were not available to distinguish between the type of well stimulation techniques (e.g., nitrogen, recompletion, or slickwater). Additionally, there are very few well recompletions, with the majority of new wells being slickwater completions (Murray 2021). An increase in the amount of water used per well may be associated with changes in production stimulation techniques.

Combined water use is the amount of water cumulatively used each year by hydraulic fracturing and consists of the water use for any given year plus the water use for each previous year since 2014. See Appendix A for details on the combined water usage calculations.

The combined water use estimates for federal and total (both federal and non-federal) water use associated with hydraulic fracturing in the Pecos tri-county area are shown in Table 3-5.

Table 3-5. Water Use by Oil and Gas Wells for Hydraulic Fracturing in the New Mexico Portion of the Permian Basin (Chaves, Eddy, and Lea Counties) for 2014 through 2023

Year	Federal Water Use	Non-Federal Water Use	Total Water Use	Federal Water Use (%)	Federal Combined Water Use	Total Combined Water Use	Total Average Water Use Per Well	Total Well Count	Produced Water
2014	1,268	2,313	3,581	35	1,268	3,581	7.0	509	80,475
2015	1,790	4,101	5,891	30	3,058	9,472	12.2	481	82,120

Year	Federal Water Use	Non-Federal Water Use	Total Water Use	Federal Water Use (%)	Federal Combined Water Use	Total Combined Water Use	Total Average Water Use Per Well	Total Well Count	Produced Water
2016	790	5,949	6,739	12	3,848	16,211	22.6	298	77,963
2017	3,072	10,997	14,069	22	6,920	30,280	27.0	521	81,795
2018	8,792	22,303	31,095	28	15,712	61,375	32.4	960	97,997
2019	10,293	31,968	42,261	24	26,005	103,636	41.8	1,012	122,089
2020	15,893	24,897	40,790	39	41,898	144,426	51.4	794	127,515
2021	33,652	31,402	65,054	52	75,550	209,480	51.8	1,255	153,625
2022	37,932	50,942	88,974	43	113,482	298,454	55.7	1,596	197,326
2023	32,304	42,591	74,895	43	145,786	373,349	55.9	1,341	220,043
Total	**145,786**	**227,463**	**373,249**	**39**	**145,786**	**–**	**–**	**8,767**	**1,240,948**

Source: FracFocus (2024a). Data are presented only for those wells reporting water usage to FracFocus. Produced water data are from NMOCD (2024b).

Note: Water use data are in acre-feet/year unless otherwise indicated. See Appendix A for data methodology. Produced water is naturally occurring water that exists in a formation that is being targeted for mineral extraction and is produced as a byproduct.

A water use study (hereinafter referred to as the Valder report) released by the USGS in 2021 (Valder et al. 2021) confirms the upward trend of water usage for oil and gas between the years 2010 and 2019 in the Permian Basin. This report modeled both direct and indirect water use for oil and gas development and operations across the Permian Basin between 2010 and 2019 (Valder et al. 2021). The Valder report characterized the mean water usage across the Permian Basin for total water usage and mean water usage per hydraulic fracturing well for both New Mexico and Texas oil and gas operations. The results modeled in this report were compared with other literature used to project water usage across the Permian Basin, further solidifying the increasing water usage trend across the Permian Basin. Hydraulic fracturing has shown an increase in water usage between the years 2010 and 2019. The average water use has steadily increased from 2010–2019 with the amount of water usage for oil and gas tripling between 2016 and 2019. From years 2010–2019, the Valder study shows a mean water usage of 15,449 AF for direct water use per year across all well sites across the Permian Basin.

The Valder et al. (2021) study estimates water usage associated with oil and gas development in the Permian Basin from years 2010–2019. The mean direct water use for oil and gas hydraulic fracturing, in AF as reported in the Valder report (Valder et al. 2021) varied greatly between the counties located in the Permian Basin. Between years 2010 and 2019, three counties, Chaves, Eddy, and Lea, in the Permian Basin registered more than 15,406 AF of direct water usage for oil and gas development (Valder et al. 2021). Lea County used 7,920 AF/year, Eddy County used 7,456 AF/year, and Chaves County used substantially less water with only 30.7 AF/year for direct oil and gas development (Valder et al. 2021). Across the New Mexico portion of the Permian Basin (Chaves Eddy, and Lea Counties). When compared to county-wide mining data provided by Dieter et al. (2018), direct hydraulic fracturing uses 16.2% of total water use associated with mining in the Pecos District.

3.1.2.2 Water Use Associated with Reasonably Foreseeable Oil and Gas Development

The 2012 RFD scenario for the Pecos District was developed as a reasonable estimate of development associated with oil and gas production in the New Mexico portion of the Permian Basin from 2015 to 2035 and updated in 2014 to provide better estimates based on new data. Planning factor assumptions used in the 2014 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). The revised reasonably foreseeable development (RFD) scenario for the Pecos District in 2014 (Engler and Cather 2014) projects approximately 800 new oil and gas wells per year (40% federal and 60% non-federal) over a 20-year period (2015–2035), for a total of 16,000 new wells. The 2014 revised RFD estimate of an average water use per well of 7.3 AF was based on a study of the Bone Spring Formation, where the majority of wells completed are horizontal, using data from 2013 (Engler and Cather 2014). The 2014 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. Since the initial revision to the RFD in 2014, there has been significant activity and development of slickwater wells throughout the area of the Pecos District underlain by the Permian Basin. During preparation of the draft CFO resource management plan (RMP)/environmental impact statement (EIS) (BLM 2018), 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 16,000 new wells projected in the revised 2018 estimates. This increased the estimated water use to a cumulative total of 24,960 AF of water in any given year across the CFO (Figure 3-3).

The new 2023 CFO RFD (Engler 2023) contains revised estimates for several plays in the Permian Basin, especially the Bone Spring and Leonard plays, and the projected oil and gas development activity for the next 20 years (2023–2043). The 2023 RFD included time frame, estimated well count, average water use, and proportion of horizontal and vertical wells across all plays in Eddy and Lea Counties. These planning factors are used to estimate water usage within the region for the duration of the RFD. The 2023 RFD estimates water usage in only Eddy and Lea Counties within the CFO; Chaves County has minimal oil and gas potential and therefore is not considered by the 2023 RFD. The 2023 CFO RFD projects a short-term increase in well development that tapers down across the duration of the 2023 RFD. The initial increase in well development in the beginning years is tied to the price of projected oil and gas commodities across the United States.

The total (federal and non-federal) cumulative projected well count of 19,600 wells (90% are expected to be horizontal wells) is a 20% increase compared with the 16,000 total wells predicted in the 2014 RFD. Of these 19,600 wells, at least 12,500 wells in CFO planning area alone would be federal (Engler 2023). Total well development per year on both federal and non-federal land is expected to be 1,208 new wells (770 federal) in the beginning of the forecast period (2023–2025) and is expected to decline to approximately 769 wells (490 federal) at the end of the 20-year 2023 RFD scenario, for an approximate average of 1,012 new wells per year. The 2023 RFD average total wells per year across all lands of 1,012 wells is 20.9% higher than the 800 total wells per year that was forecasted in the revised 2014 RFD (see Table 3-6).

The CFO planning area encompasses Lea and Eddy Counties and portions of Chaves County. The CFO RFD does not account for future well development in the RFO portion of the PDO planning area (which encompasses portions of Chaves and Roosevelt Counties); therefore, well projections for the RFO planning area were extracted from the PDO RFD (Engler and Cather 2012, 2014). The PDO RFD projects that 800 oil and gas wells would be completed within the PDO each year for the 20-year scenario (2015–2035), for a total of approximately 16,000 new wells (federal and non-federal), most of which are expected to be horizontally drilled. Based on the review of cumulative production volumes through 2010 (see Summary Table 1 [page 49] in Engler and Cather [2012]), most of the production has occurred in Eddy and Lea Counties, and development in Chaves and Roosevelt Counties represents approximately 4% of the cumulative production volumes for the PDO planning area. Assuming that this proportion of development in Chaves and Roosevelt Counties relative to the larger PDO planning area would remain relatively stable into the future, the number of projected wells from the PDO RFD that are likely to occur within Chaves and Roosevelt Counties would be approximately 640. When combined, the total number of projected wells for the PDO planning area is 20,240 (including 19,600 wells in CFO and 640 wells in

RFO). PDO RFD projections over a 20-year time period show well development with an average of 1,012 wells per year (of which at least 625 would be federal).

Water use is expected to follow well completion trends projected by the 2023 CFO RFD, which will potentially see an increase in total water usage for the first 2 years before tapering down from 2025 through 2043. Development of the RFD scenario is estimated to require approximately 60 AF per well (Engler 2023). Development of the 20,240 federal and non-federal wells projected in the RFDs would require 1,214,400 AF of water over the 20-year development period, or 60,720 AF of water in any given year. Of the 20,240 predicted wells, approximately 12,500 in the CFO planning area alone are expected to be on federally managed lands over the duration of the 20-year planning estimate. With consideration of the revised water use estimates (60 AF/well), development of the 12,500 BLM surface wells projected in the CFO RFD would require 750,000 AF of water, or 37,500 AF of water in any given year.

Since the release of the 2023 CFO RFD, the average water use per well within the Permian Basin has increased substantially (FracFocus 2024a). Based on the analysis presented in the CFO's 2023 RFD (Engler 2023), there has been an increasing trend in water use for well completions since 2011, which is largely due to increasing lateral lengths (approximately 1.5 to 2 miles) of horizontal wells. Using the most recent data, the RFD estimates average water use at 60 AF per well. This value is consistent with the increasing trend seen in the FracFocus data and is considered a reasonable estimate of water use associated with future oil and gas development in the PDO.

Table 3-6. Planning Factors Used to Estimate Water Use Associated with the RFD in the Pecos District

Factor	2014 PDO RFD (Engler and Cather 2012, 2014)	Revised Estimate (2018)	2023 RFD
Time Frame	2015–2035	No change	2023–2043
Number of Wells	16,000 (approximately 800 per year)**	No change	20,240 (approximately 1,012 per year)**
Average Water Use, Horizontal Well	7.3 AF	31.2 AF*	60 AF
Average Water Use, Vertical Well	N/A	1.53 AF† and assumed 100% horizontal wells for the RFD	60 AF‡
Number of Wells Needed for Resource Development in Emerging Plays§	Four wells per section per play (horizontal wells)	No change	11 wells per section per play (horizontal wells)
Percentage of Horizontal Wells in Bone Spring Formation	82% horizontal	No change	90% horizontal
Percentage of Horizontal Wells in Leonard Formation	14% horizontal	No change	N/A

Note: N/A = not applicable.

* The water use estimate of 31.2 AF per well reflects water use per well as reported to FracFocus data at the time the CFO draft RMP/EIS was released (BLM 2018).

** Of the 16,000 wells projected in the PDO RFD (Engler and Cather 2012, 2014), 4% (or approximately 640) are likely to occur within the RFO portion of the PDO. Therefore, 2023 RFD projections for PDO (20,240 wells total) include19,600 wells for the CFO (as projected in the 2023 CFO RFD [Engler 2023]) and an additional 640 wells for the RFO (as projected in the PDO RFD [Engler and Cather 2012, 2014]).

† BLM calculation developed during preparation of the CFO draft RMP/EIS (BLM 2018).

‡The 2023 RFD (Engler 2023) does not provide a separate water use estimate for vertical wells; only one average water use estimate is provided for all wells, which reflects an increasing trend in horizontal wells for the CFO.

§ Resource development in emerging plays refers to the development of unconventional resource regions within the Woodford shale in southeastern New Mexico (Engler and Cather 2012).

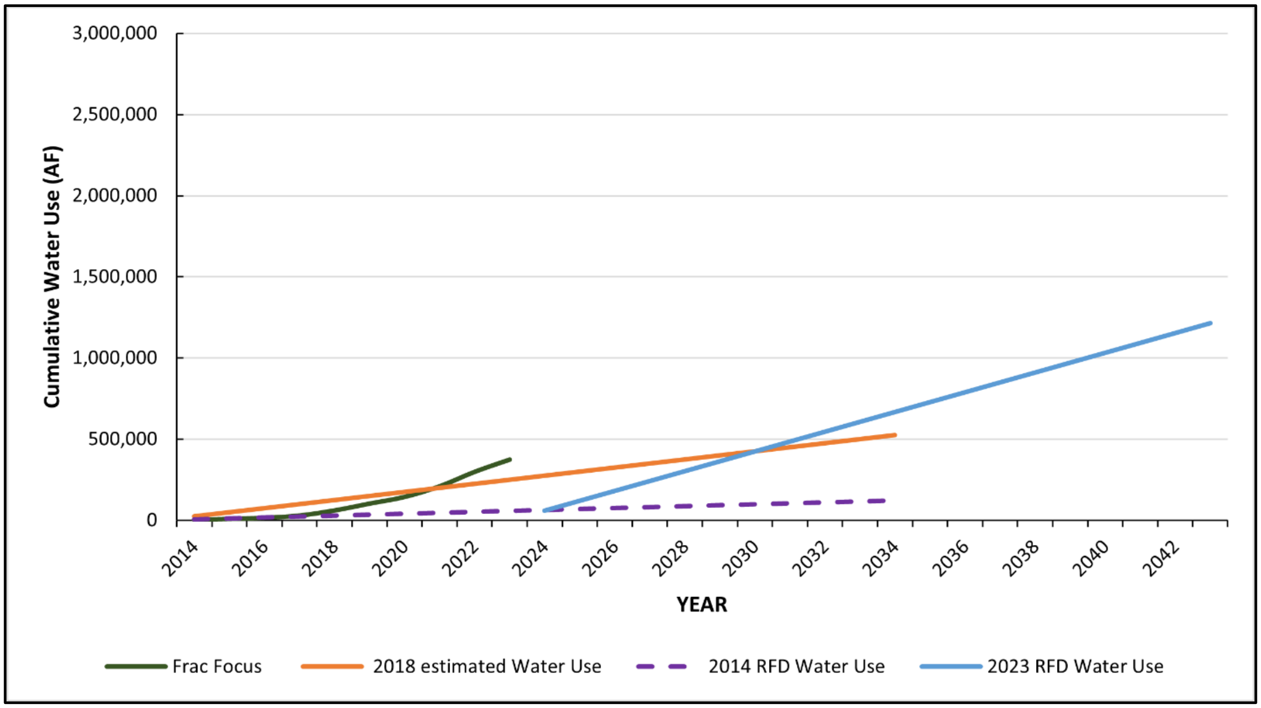

Figure 3-3. Cumulative water use associated with reasonably foreseeable oil and gas development in the New Mexico portion of the Permian Basin (Chaves, Eddy, and Lea Counties) from 2014 through 2022 with projections through 2043.

Note: RFD water use planning factors of 7.3 AF/well and 5,840 AF/year come from the 2014 RFD (Engler and Cather 2014). Planning factors estimates of 31.2 AF/well and 24,960 AF/year are taken from the updated 2018 estimates. The 2018 water use planning factors are based on analysis of FracFocus data at the time the CFO draft RMP/EIS (BLM 2018) was released in 2018. The FracFocus data presented are actual total cumulative water use estimates between 2014 and 2024 (FracFocus 2024a). RFD water use planning factors of 60 AF/well and 58,800 AF/year come from the 2023 RFD.

Since 2014 there is a total of 8,767 wells with an average increase of 877 wells per year. The total cumulative water use from 2014 to 2023 across all well types is approximately 373,349 AF with an average water use per well of 42.6 AF since 2014. The water use reported to FracFocus over the previous 10 years (FracFocus 2024a) indicates that the revised planning factors associated with the 2023 RFD (60 AF per well and 145,004 AF/year) are currently much more than the projected water use trends outlined in the 2023 RFD (see Figure 3-3).

3.1.2.3 Other Development

The BLM has not identified any additional reasonably foreseeable future actions (RFFAs) that would substantially contribute to water use impacts within the Pecos District beyond existing water use trends (BLM 2018). Some water use would be required during construction and operation of transmission lines and pipelines as part of RFD in the area; however, water use varies greatly by project, and these uses are not quantified in this analysis.

3.1.2.4 Water Use Associated with Planned Actions

The total water use associated with development of all RFFAs in the Pecos tri-county area is the same as the total water use estimate associated with reasonably foreseeable oil and gas development. This is because 1) no RFFAs related to mining apart from oil and gas development would contribute significantly to water use impacts from planned actions within the Pecos District (BLM 2018); and 2) water use estimates for other development such as construction and development of transmission lines and pipelines vary greatly by project, and specific water use estimates for these projects are not included in this analysis.

Development of all RFFAs within the RFD scenario using the revised water use planning factors in Table 3-6 would require approximately 37,500 AF of water in any given year. This is about 6% of Pecos tri-county area 2015 total water withdrawals (619,375 AF), which already include past and present actions. Irrigation would remain by far the largest water use (currently 75% of all water use within the Pecos District and 82% of all water use within the state).

3.1.3 Potential Sources of Water for Project Development

The Pecos District contains a variety of surface waters, including springs, seeps, lakes, playas, rivers, and ephemeral drainages (Table 3-7; Figure 3-4), that interact with the groundwater system as locations of recharge or discharge. Waters from spring developments, reservoirs or streams, and stream diversions within the Pecos tri-county area are used primarily for irrigation, livestock, and wildlife. Surface water is not used for domestic water supply in the Pecos tri-county area (Dieter et al. 2018). Diversions on BLM-managed land support crop irrigation and stock water needs on private lands.

Because approximately 88% of all water use and 100% of all mining water use (including oil and gas) in the Pecos District is currently from groundwater, it is reasonable to assume that water used for development of the RFD would 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 NMOCD as well as NMOSE. 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 the Pecos Tri-county Area (Chaves, Eddy, and Lea Counties)

Aquifer Name	Description
Pecos Valley Alluvium	Surficial deposits along the Pecos River. Recharged by precipitation and hydrologically losing sections of the Pecos River and its tributaries. Hydraulically connected with the Pecos River. Typical total dissolved solids (TDS) range of <200 to 10,000 milligrams per liter (mg/L).
Dockum Formation (includes Dewey Lake and Santa Rosa)	Redbed sandstones. Inconsistent water source. Recharge occurs closer to the surface from precipitation. Typical TDS range of <5,000 to >10,000 mg/L.
Rustler Formation (includes Culebra and Magenta)	Dolomite, fractured and dissolution zones. Local recharge is driven by precipitation. Typical TDS ranges from <1,000 to 4,600 mg/L.
Capitan Reef	Limestone, Karstic formation. Low salinity west of the Pecos River, brackish toward 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.

Note: Data are adapted from Lowry et al. (2018).

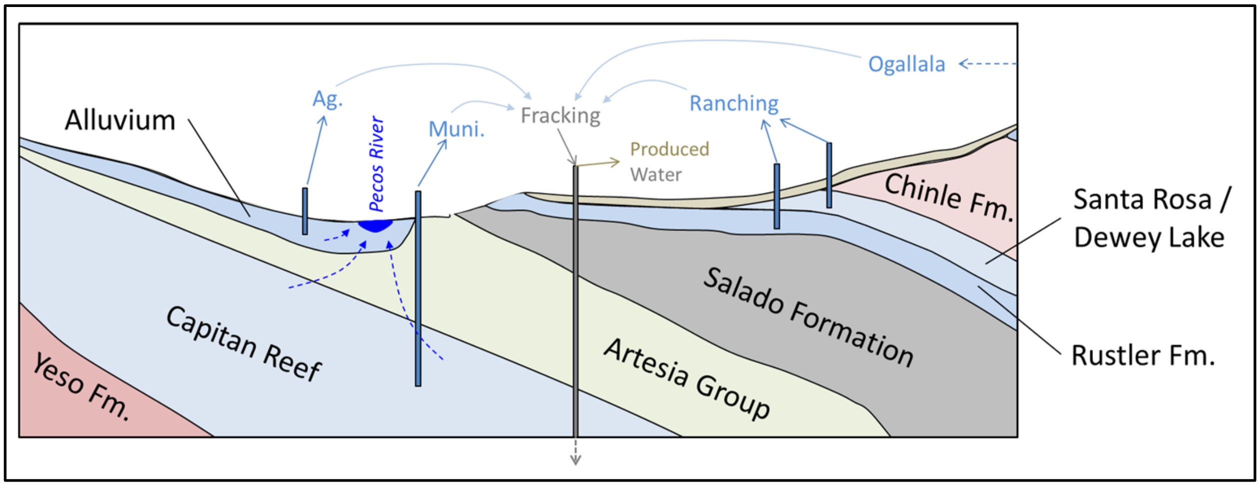

Figure 3-4. Idealized geologic cross section of potential water sources in the Pecos District (Summers 1972).

The Water Resource Assessment in the New Mexico Permian Basin (Lowry et al. 2018) is a study conducted by Sandia National Laboratories of four high-potential areas (HPAs) for oil and gas development within Eddy and Lea Counties. The HPAs were associated with the BLM-managed mineral estate in the Alto Platform, Bone Spring, and Delaware Mountain Group plays.

The study established a water level and chemistry baseline and developed a modeling tool to aid the BLM in understanding the regional water supply dynamics under different management, policy, and growth scenarios, as well as to preemptively identify risks to water sustainability. Addendum to Water Resource Assessment in the New Mexico Permian Basin (Reardon et al. 2021) expands upon the 2018 report, discussing water level and quality in the HPAs.

Most of the water wells that were sampled in each HPA appeared to have a mixture 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 aquifers (the Dewey Lake/Santa Rosa Formation) 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/Santa Rosa Formation and the Rustler Formation. For the South HPA (located near Malaga and Loving), the main water sources are the Dewey Lake/Santa Rosa Formation. 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 throughout the study using continuous and manual water level measurements (Reardon et al. 2021). Water levels in the two sampling water wells located in the North HPA (the Rustler Formation) fluctuated slightly over the monitoring period and had an overall decreasing trend. Based on available data, it is unclear if the drop in water level was a result of well operation or natural fluctuation in groundwater level. Water levels from five additional wells in the Center North HPA were also examined as part of the study. Additionally, three wells completed in the Rustler Formation showed variable water level fluctuations. One showed low water level changes suggestive of barometric effects and seasonal change; the second well showed water levels typical of nearby pumping; and a third well showed an overall decrease in water level due to unknown causes (Reardon et al. 2021). Two wells completed in the Dewey Lake/Santa Rosa Formation show increasing water levels due to recharge of the aquifer.

Of the 13 wells monitored in the South HPA:

- Eight are completed in the Rustler Formation, and three wells were monitored continuously as part of the study. Two wells have monitoring data indicating a steady declining trend due to livestock watering and prospecting of a natural resource. One well exhibited erratic water levels consistent with pumping cycles associated with small community water supply wells.
- Four wells are completed in the Dewey Lake/Santa Rosa Formation, and three are within 0.5 mile of one another. All three wells show the same general declining trend indicative of pumping in 2017 followed by recovery. The wells are listed for commercial use, and reports of nearby pumping in 2017 explain the general overall decrease. The fourth well is permitted for livestock watering, and water levels show decreasing trends consistent with pumping, although pumping ceased at this well in 2018 and water levels are rebounding.
- The final well in the South HPA is drilled to an unknown formation, although based on water levels, it is assumed to be completed in the Dewey Lake/Santa Rosa Formation. It is located in close proximity to the three wells listed for commercial use in the Dewey Lake/Santa Rosa Formation and exhibits the same general pattern in water levels over the same monitoring period.
- The Capitan Reef aquifer is one of the primary sources of water used to enhance oil recovery in Eddy County and is also a primary source of domestic water supply in that county. Four wells drilled in the Capitan Reef aquifer were monitored. Two wells show a steady decline, with daily fluctuations indicative of nearby pumping. Two wells on the east side of the Capitan Reef aquifer show steadily increasing water levels and recovery, which could be due to natural recharge that could potentially be enhanced by injection wells.

3.1.4 Water Use Mitigation Measures

Public concern about water use from hydraulic fracturing is especially high in semiarid regions. Overall, there have been calls to increase the use of alternative water sources such as brackish water or to recycle 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 for oil and gas extraction when possible rather than rely on freshwater sources. 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 (Kondash et al. 2018). Water returning to the surface is highly saline, difficult to treat, and often disposed of through deep injection wells (Kondash et al. 2018). Since the 2014 RFD, the Pecos District Office has seen an increase in the use of slickwater wells for oil and gas development. It is reasonable to assume with the increase in slickwater well construction that highly saline return water from the hydraulic fracturing process can be reused via water recycling methods. The NMED signed a memorandum of understanding (MOU) with New Mexico State University in September of 2019 to develop new technologies for treating produced water to inform future policies for produced water reuse (NMED 2019).

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 that 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 200 to 10,000 mg/L depending on aquifer material (Table 3-8).

Table 3-8. Typical TDS Ranges for the Primary Aquifers of the Pecos District

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

Note: Data are adapted from Lowry et al. (2018).

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

Water quality data collected at wells in the HPAs in 2018 (Lowry et al. 2018) and 2020 (Reardon et al. 2021) were also compared with 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 (NMAC 20.6.2.3103). All wells in the Center North and South HPAs reported exceedances of sulfate in 2020. Most wells in the Center North and South HPAs reported exceedances of TDS and chloride. One well in the South HPA reported an exceedance of fluoride. Two wells in the South HPA reported exceedances of the NMWQCC pH standards. Table 3-9 lists the sampled water quality parameters by HPA compared with the NMWQCC standards for drinking water (Lowry et al. 2018; Reardon et al. 2021).

Table 3-9. Sampled Water Quality Parameters Compared with NMWQCC Drinking Water Standards

Parameter	NMWQCC Standard	North HPA*	Central North HPA*	South HPA and WIPP*	Capitan Reef†
pH (pH units)	6–9	7.64	7.51–7.61	7.25–**9.29**	8.08–8.86

Parameter	NMWQCC Standard	North HPA*	Central North HPA*	South HPA and WIPP*	Capitan Reef†
Specific Conductance (μmhos/cm)	–	1,000	7,700–95,000	860–21,000	2,770–174,500
TDS	1,000	773	**3,800–51,800**	395–**11,100**	1,951–141,875
Calcium (Ca^{2+})	–	130	580–680	3–970	1.4–5,902
Magnesium (Mg^{2+})	–	45	95–1,700	5–360	82.26–1,420
Sodium (Na^{+})	–	21	440–14,000	110–2,000	225–46,700
Potassium (K^{+})	–	1.6	26–550	4–28	6.58–3,352
Chloride (Cl^{-})	250	18	**820–28,000**	32–**3,800**	388.80–82,602.1
Alkalinity ($CaCO_3$)	–	166.7	93–200	146–292	18.53–250.10
Bicarbonate (HCO_3^{-})	–	166.7	93–200	146–247	18.74–249.27
Carbonate (CO_3^{2-})	–	<2.0	<2.0	7–110	0–0.83
Sulfate (SO_4^{2-})	600	360	**8,800-16,000**	**900–2,800**	0–1,975.67
Fluoride (F^{-})	1.6	0.67	0–1.5	<1**–2**	0.09–0.52
Nitrate/Nitrite (NO_3/$NO_{2)}$)	10	<RL	<RL	1.8–8.2	0.05–7.60
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	0–1,400	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 (Sr^{2+})	–	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	–

Sources: Lowry et al. (2018); Reardon et al. (2021)

Note: Units are mg/L unless otherwise noted.

Mmhos/cm = millimhos per centimeter; a unit of measure for electrical conductivity.

RL = reporting limit.

Bold = exceeds NMWQCC standard for groundwater <10,000 mg/L.

-- = not applicable or not detected

* Values from 2020 samples, Reardon et al. (2021:Table 3). Range not reported for North HPA values because only one well was sampled.

† Values from Lowry et al. (2018:Table 16) because updated water quality values were not available in Reardon et al. (2021).

At the time of drafting this Water Support Document, Sandia National Laboratories released a water resource assessment of the Permian Basin for 2023 (Kirkes et al. 2024). The 2024 Sandia report provides an in-depth look at water quality, geochemistry, and water level changes in the Permian Basin. In addition to reanalyzing water quality data (see Table 3-9), the 2024 Sandia report added new monitoring wells to each HPA. The 2024 Sandia report will be used in the next New Mexico Water Support Document to provide updated water quality and geochemical characteristics for the PDO. Additionally, the CFO plans to conduct a hydrology study on the Black River. This study is projected to start in October 2024 and be completed in approximately 2 years. The study will focus on sampling the Black River and shallow groundwater. If available, preliminary data from the Black River study will be included in the 2025 draft of this Water Support Document.

3.2.2 Surface Water

In the state of New Mexico, the NMED administers CWA Sections 303(d), 305(b), and 314 related to surface water quality assessment and reporting. The NMED defines surface water quality beneficial uses and water quality standards to evaluate if these uses are being attained. Water quality standards are composed of designated uses for surface waters of the state and associated water quality criteria to protect those uses. The NMED prepares a report every 2 years (the Integrated Report), where waterbodies not attaining their designated beneficial uses are reported. The Integrated Report also contains information on surface water quality and water pollution control programs in the state of New Mexico (NMED 2021). The BLM does not have authority to make use attainment evaluations based on water chemistry data.

Designated uses in the Pecos District consist of industrial water supply, irrigation storage, livestock watering, recreation, warm water fishery, and wildlife habitat. Water quality in streams flowing on BLM-managed lands is influenced by both natural water quality with regard to salinity content and the intensity of human and industrial activities 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 activities. 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 streambanks and riverbanks.

The major perennial waterbody in the Pecos District is the Pecos River, which is segmented into smaller reaches for assessment purposes in the Integrated Report. The most common pollutants listed across segments of the Pecos River in the Pecos District are *Escherichia coli* (*E. coli*), dichlorodiphenyltrichloroethane (DDT), and polychlorinated biphenyls (PCBs), the latter in fish consumption advisories (NMED 2021). Other impairments in the region include nutrients and dissolved oxygen (NMED 2021).

3.2.3 Potential Sources of Surface Water or Groundwater Contamination

3.2.3.1 Spills

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

Spill data were retrieved from the NMOCD spills database and further reviewed and summarized (see Appendix A) (NMOCD 2024a). In 2023, a total of 1,003 liquid spills were associated with federal and non-federal oil and gas wells and facilities in the Pecos tri-county area (Table 3-10) (NMOCD 2024a). Produced water and crude oil made up 63% and 28% of total liquid spills, respectively. The large increase in natural gaseous liquid spills in the years 2021 and 2022 is attributed to NMOCD’s new natural gas waste rules, NMAC 19.15.27 and 19.15.28, requiring more stringent recording of spills—which resulted in a much greater number of spills being recorded than in previous years. Operators can retroactively add spill data based on updated spill recording laws and regulations, which is reflected in

Table 3-10. The percent loss varies by spill type, but the average lost volume of spilled liquids was 47%. Gaseous spills are not recoverable due to their rapid dispersion into the atmosphere or potential for ignition. Consequently, no gaseous spills were recovered in 2023. In 2023, two produced water spills were reported as having affected a surface waterway and two spills with unspecified material types (Other) were reported to have affected groundwater. Additionally, four natural gas liquid spills were reported as having affected groundwater in Chaves, Eddy, and Lea Counties (NMOCD 2024a). Table 3-11 provides total spill counts since 2014.

The BLM works with NMOCD to remediate spills associated with federal oil and gas wells on BLM-managed lands or private or state surface. Title 19, Chapter 15 of the NMAC pertains to oil and gas releases. According to NMAC 19.15.29.11, the responsible person shall complete NMOCD-approved corrective action for releases that endanger public health or the environment in accordance with a remediation plan submitted to and approved by NMOCD or with an abatement plan submitted in accordance with NMAC 19.15.30. The remaining contaminants 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 performing corresponding chemical testing.

The most commonly disclosed chemical used in wells in the New Mexico portion of the Permian Basin from 2014 through 2023 was water, with 23,231 disclosures (Table 3-12). Other frequent disclosures include crystalline silica quartz (n = 7,696), and hydrochloric acid (n = 6,051). There were 40,714 records of non-disclosed chemicals, including chemicals listed as proprietary, confidential, and trade secrets.

Table 3-10. Summary of 2023 Spills from All Wells in the New Mexico Portion of the Permian Basin (Chaves, Eddy, and Lea Counties)

Material Type*	Spill Count	Volume Spilled	Volume Lost	Unit	Average Volume Spilled	Percent Lost (%)	Waterways Affected	Groundwater Affected
Produced Water	629	78,992	36,194	bbl	126	46	2	0
Crude Oil	282	6,406	2,314	bbl	23	36	0	0
Condensate	58	1,361	1,000	bbl	23	73	0	0
Other (Specify)	20	4,675	3,558	bbl	234	76	0	2
Drilling Mud/Fluid	1	1.2	1.2	bbl	1.2	100	0	0
Natural Gas Liquids	3	62	37	bbl	21	60	0	0
Diesel	1	9	7	bbl	9	78	0	0
Glycol	1	1	1	bbl	1	100	0	0
Unknown	2	20	20	bbl	10	100	0	0
Brine Water	1	27	7	bbl	27	26	0	0
Total liquid spills	**1,003**	**92,381**	**43,292**	**bbl**	**61.1**	47	**2**	**2**
Natural Gas Flared	49,282	19,378,182	19,378,182	mcf	393	100	0	4
Natural Gas Vented	1,443	409,538	409,538	mcf	284	100	0	0
Carbon Dioxide	140	27,720	27,720	mcf	198	100	0	0
Hydrogen Sulfide	1	250	250	mcf	250	100	0	0
Total Gaseous Spills	***50,866***	***19,815,690***	***19,815,690***	mcf	***281***	100	***0***	***4***

Source: NMOCD (2024a)
Units: bbl = barrels; mcf = thousand cubic feet.
Note: FracFocus does not differentiate between natural gas flaring/venting and a normal liquid spill that could occur during the hydraulic fracturing process; therefore, this table reflects two total value rows (one total value for conventional spills and one for natural gas flaring and venting). Natural gases that are vented and flared are done so intentionally as part of the hydraulic fracturing process with no expected spill recovery.
* No spills of gelled brine (frac fluid) or sulfuric acid were documented in 2023.

Table 3-11. Summary of Spills from All Wells in the New Mexico Portion of the Permian Basin (Chaves, Eddy, and Lea Counties) between 2014 and 2023

Material Type	Spill Count									
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Produced Water	574	551	464	489	545	627	497	468	616	629
Crude Oil	305	398	329	323	377	347	254	212	338	282
Condensate	7	23	16	11	13	11	15	21	60	58
Other (Specify)	11	6	11	8	25	25	17	28	47	20
Drilling Mud/Fluid	6	3	1	4	5	2	0	0	5	6
Natural Gas Liquids	8	10	14	9	6	7	5	13	12	3
Diesel	1	1	0	1	3	0	0	1	3	1
Hydrogen Sulfide	0	0	0	0	0	0	0	0	0	1
Glycol	0	0	0	0	0	0	0	0	1	1
Unknown	1	2	0	0	0	0	0	0	2	2
Brine Water	3	3	6	3	3	4	3	3	5	1
Chemical (Specify)	0	1	1	1	5	3	0	0	2	0
Acid	3	2	0	0	1	2	0	3	1	0
Lube Oil	1	0	0	0	0	0	0	2	1	0
Gelled Brine (Frac Fluid)	3	2	0	0	0	2	0	2	0	0
Sulfuric Acid	0	0	0	0	1	0	0	0	0	0
B.S. & W.	0	0	1	2	3	0	0	0	0	0
Gasoline	4	1	0	0	0	0	0	0	0	0
Total Liquid Spills	**923**	**1,003**	**843**	**851**	**987**	**1,030**	**791**	**753**	**1,093**	**1,004**
Natural Gas Flared	1	0	0	0	0	0	9	13,914	36,661	49,282
Natural Gas Vented	0	0	0	0	0	0	2	699	1,471	1,443
Carbon Dioxide	0	0	0	0	0	0	0	0	0	140
Methane	98	233	260	49	153	171	210	190	0	0
Hydrogen Sulfide	0	0	0	0	0	0	0	0	0	1
Total Gaseous Spills	**99**	**233**	**260**	**49**	**153**	**171**	**221**	**14,803**	**38,132**	**50,866**

Source: NMOCD (2024b)

Note: bbl = barrels; mcf = thousand cubic feet.

* Natural gas liquids material types include natural gas flared, natural gas liquids, and natural gas vented material.

† On May 25, 2021, NMOCD's new natural gas waste rules, NMAC 19.15.27 and 19.15.28, went into effect. These new rules resulted in a higher reporting number for natural gas liquid spills compared with previous years (Center for Western Priorities 2022).

Table 3-12. Most Frequently Disclosed Ingredients in Wells within the New Mexico Portion of the Permian Basin (Chaves, Eddy, and Lea Counties) from 2014 through 2023

Ingredient Name±	CAS Registry Number	Number of Disclosures	Percentage of Hydraulic Fracturing Job*	Percentage of Total Number of FracFocus Disclosures†
Not Disclosed	Listed Below	40,708	ND	15%
Water	1310-58-3	22,130	34%	8%

Ingredient Name±	CAS Registry Number	Number of Disclosures	Percentage of Hydraulic Fracturing Job*	Percentage of Total Number of FracFocus Disclosures†
Methanol	67-56-1	6,571	<1%	2%
Hydrochloric Acid	10486-00-7	5,629	<1%	2%
Glutaraldehyde	Proprietary	4,003	<1%	1%
Ammonium Chloride	121285-02-9	3,246	<1%	1%
Crystalline Silica, Quartz	14808-60-7	2,892	9%	1%
Acetic Acid	64-19-7	2,823	<1%	1%
Crystalline Silica, Quartz	14808-60-7	2,775	12%	1%
Ethanol	67-56-1	2,631	<1%	1%
Distillates (Petroleum), Hydrotreated Light	6742-47-8	2,625	<1%	1%
Proprietary	7732-18-5	2,620	<1%	1%
Sodium Chloride	7447-40-7	2,399	1%	1%
Ethylene Glycol	111-76-2	2,351	<1%	1%
Aluminum oxide	1302-76-7	2,228	<1%	1%
Propargyl Alcohol	108-19-7	2,194	<1%	1%
Crystalline Silica Quartz	Proprietary	2,029	10%	1%
Sodium Hydroxide	7647-14-5	1,922	<1%	1%
Alcohols, C12-16, Ethoxylated	68551-12-2	1,885	<1%	1%
Ammonium persulfate	7727 - 54 - 0	1,755	<1%	1%
Quar Qum	Proprietary	1,743	<1%	1%
Ethoxylated Alcohols	68002-97-1	1,594	<1%	1%
Citric Acid	77-92-9	1,586	<1%	1%
Surfactant	24938-91-8	1,557	<1%	1%
Sodium Perborate Tetrahydrate	7775-27-1	1,545	<1%	1%
Ethoxylated Alcohol	68131-39-5	1,502	<1%	1%
Isopropanol	Proprietary	1,425	<1%	1%
Iron Oxide	1309-37-1	1,353	<1%	1%
Cinnamaldehyde	77-92-9	1,341	<1%	0%
Polylactide resin	Proprietary	1,331	<1%	0%
Titanium Oxide	108-88-3	1,312	<1%	0%
2-Butoxyethanol	9005-67-8	1,188	<1%	0%
Mineral Oil	64742-47-8	1,148	<1%	0%
Distillates, Petroleum, Hydrotreated Light	6742-47-8	1,069	<1%	0%
Amino phosphonate Salt	Proprietary	1,017	<1%	0%

Source: FracFocus (2024a)

Note: Ingredient names and CAS numbers are not standardized in FracFocus, leading to widespread differences and discrepancies in CAS numbers, number of disclosures, and ingredient names. For this reason, the number of disclosures and ingredients presented in this table are to be used for general information only.

* The amount of the ingredient in the total hydraulic fracturing volume by percent mass (definition from FracFocus [2024a] data dictionary).

† The total number of FracFocus ingredient disclosures in the Pecos tri-county area is 211,492.

± FracFocus lists certain chemicals as proprietary and no additional information is available regarding ingredient contents.

3.2.3.2 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 highly concentrated chemicals reaching groundwater resources. If contamination of usable water aquifers (TDS 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 NMOCD have casing, cementing, and inspection requirements in place to limit the potential for groundwater reservoirs and shallow aquifers to be impacted by hydraulic fracturing 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) § 3162. In addition, these regulations require oil and gas development to comply with directives in the Onshore Oil and Gas Orders and the orders of the Authorized Officer. The regulations at 43 CFR § 3162.3-3 and 43 CFR § 3170 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 (NMAC 19.15.16). Complying with the aforementioned regulations requires producers and regulators to verify the integrity of casing and cementing jobs. Casing specifications are designed and submitted to the BLM in a drilling plan as a component of an Application for Permit to Drill (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. The aforementioned regulations and review practices surrounding proper casing and cementing procedures isolate 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. These may include requirements for closed loop drilling systems, spill prevention plans, leak detection plans, and appropriate equipment (leak detection and automatic shutoff system) in sensitive groundwater recharge areas. Casing and cementing operations are witnessed by certified BLM petroleum engineering technicians (PETs). At the end of the well's economic life, the operator is required to submit a plugging plan to the BLM for approval. A BLM petroleum engineer will review the plan prior to commencement of plugging operations. The BLM PETs witness plugging operations to ensure the planned procedures are properly followed. The BLM's review, approval, and inspections ensure the permanent isolation of usable groundwater from hydrocarbon-bearing zones.

In summary, the BLM, NMED, and NMOCD have put in place numerous requirements for oil and gas producers 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. These include BLM regulations covered under 43 CFR § 3160; 43 CFR § 3162.3-3; 43 CFR § 3162.3-5; 43 CFR § 3170; Notice to Lessees and Operators of Onshore Federal and Indian Oil and Gas Leases (NTL)-3A; NMOCD regulations under NMAC 19.15.26; and the state's primacy agreement under the Safe Drinking Water Act (42 United States Code 300f et seq.). With these requirements in place, including the use of casing and cementing measures, contamination of groundwater resources from development of the lease parcels is highly unlikely. In addition, the BLM has authority under standard terms and conditions to require additional measures to protect water quality if site-specific circumstances require them. Site-specific mitigation tools would be developed as appropriate for the individual circumstances, including groundwater-quality monitoring studies. The regulations at 43 CFR § 3162.5-2(d) give the BLM the authority to require an operator to monitor water resources to ensure that the isolation procedures utilized to protect water and other resources are effective.

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CHAPTER 4. FARMINGTON FIELD OFFICE

The FFO encompasses over 1.4 million acres of public lands and over 2.4 million acres of federal minerals within McKinley, Rio Arriba, Sandoval, and San Juan Counties. Portions of the FFO are within the San Juan Basin, an oil and gas basin in northwestern New Mexico and southwestern Colorado (BLM 2003a).

The Mancos-Gallup planning area was the analysis area used by the FFO to develop the Mancos-Gallup RFD scenario (2018 RFD) (Crocker and Glover 2018), which examines past, present, and reasonably foreseeable oil and gas development in support of the FFO's Mancos-Gallup draft RMPA/EIS (BLM 2020). Although the BLM and Bureau of Indian Affairs announced the termination of the RMPA/EIS development process on July 12, 2024 (*Federal Register* 89:57165), the FFO is still in the process of updating its RFD, with completion expected in May 2025. The Mancos-Gallup planning area comprises those portions of the New Mexico portion of the San Juan Basin that overlay the Mancos/Gallup formations in portions of McKinley, Rio Arriba, Sandoval, and San Juan Counties (Figure 4-1).
The Mancos-Gallup planning area comprises 4.2 million acres of all mineral ownership types; federal oil and gas in the area covers 2.1 million acres (BLM 2003a; 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 (allotted and tribal) covers 1.4 million acres. Most of the oil and gas development within the FFO area occurs within the Mancos-Gallup planning area.

This chapter presents information on existing and projected water quantity and water quality data for the FFO as summarized from information gathered from the following sources:

- 2003 Farmington Resource Management Plan with Record of Decision (BLM 2003a)
- 2018 RFD (Crocker and Glover 2018)
- Data compiled from the USGS report *Estimated Use of Water in the United States in 2015* (Dieter et al. 2018)
- FracFocus, a national hydraulic fracturing chemical registry managed by the GWPC and IOGCC (FracFocus 2024a)
- Spill data and recompletion activities from the NMOCD database (NMOCD 2024a)

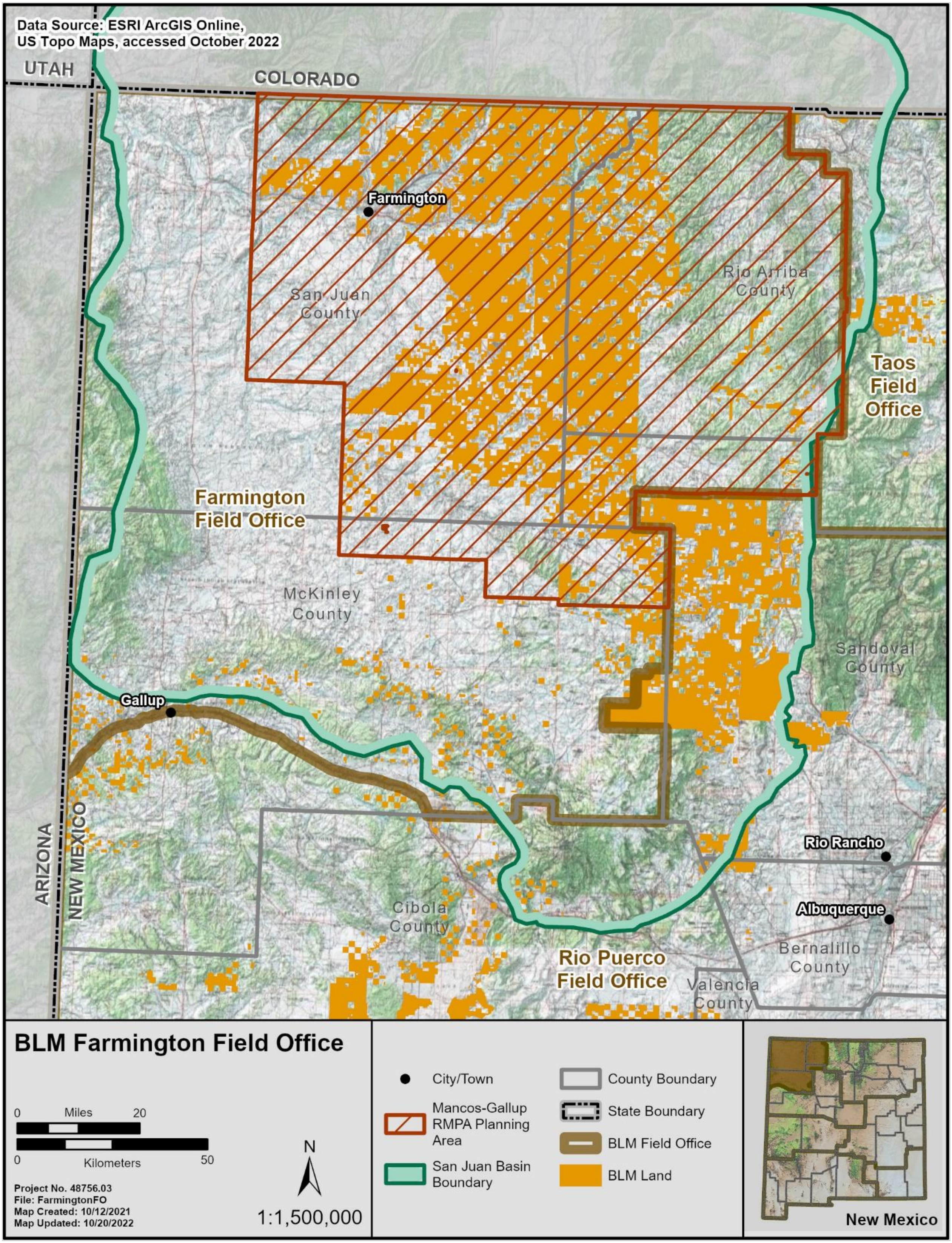

Figure 4-1. BLM FFO and Mancos-Gallup planning area boundaries.

4.1 WATER QUANTITY

4.1.1 Existing Surface Water and Groundwater Use

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

Dieter et al. (2018) list total water withdrawals across eight water use categories: aquaculture, domestic, industrial, irrigation, livestock, mining (which includes oil and gas development), public water supply, and thermoelectric power (Table 4-1 through Table 4-4; Figure 4-2). Water use totals for each of these industries are summarized by surface water and groundwater, which are further divided into fresh water and saline water for each category. Total water usage is 13,217 AF, 118,120 AF, 71,576 AF, and 283,748 AF for McKinley, Rio Arriba, Sandoval, and San Juan Counties, respectively (see Table 4-1–Table 4-4), for a combined total of 486,660 AF (Table 4-5). This is 14.7% of total water usage within the state of New Mexico in 2015 (see Table 2-1). The largest use of water within the FFO area was irrigation, comprising 79.07% (384,817 AF) of total water use.

Water use associated with mining (11,658 AF) comprises 2% of total water use within the FFO area; over half of all mining-related water use in the FFO area occurred in San Juan County (6,356 AF, or 55% of the total mining water use in the FFO area). Water use for mining is sourced from both surface water and groundwater (23% and 77%, respectively) and includes both fresh water and saline water (55% and 45%, respectively). Fresh water is sourced from both surface water and groundwater (43% and 57%, respectively); all reported saline water use is from groundwater.

Table 4-1. McKinley County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)†
	Fresh	Saline*	Total	Total Use (%)†	Fresh	Saline*	Total	Total Use (%)†	Fresh	Total Use (%)†	Saline*	Total Use (%)†		
Aquaculture	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Domestic	0	–	0	0%	3,195	–	3,195	24%	3,195	24%	–	0%	3,195	24%
Industrial	0	0	0	0%	34	0	34	<1%	34	<1%	0	0%	34	<1%
Irrigation	1,099	–	1,099	8%	0	–	0	0%	1,099	8%	–	0%	1,099	8%
Livestock	101	–	101	<1%	370	–	370	3%	471	4%	–	0%	471	4%
Mining	0	0	0	0%	1,625	684	2,309	17%	1,625	12%	684	5%	2,309	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	**1,199**	**0**	**1,199**	**9%**	**11,333**	**684**	**12,017**	**91%**	**12,533**	**95%**	**684**	**5%**	**13,217**	**100%**

Source: Dieter et al. (2018)

Note: Values may not sum to totals because of independent rounding (Dieter et al. 2018). Water use data are in acre-feet/year unless otherwise indicated.

* Saline water withdrawals are not reported for domestic, irrigation, or livestock water use (Dieter et al. 2018).

† Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 13,217 acre-feet.

Table 4-2. Rio Arriba County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)†
	Fresh	Saline*	Total	Total Use (%)†	Fresh	Saline*	Total	Total Use (%)†	Fresh	Total Use (%)†	Saline*	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%	1,345	–	1,345	1%	1,345	1%	–	0%	1,345	1%
Industrial	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Irrigation	107,874	–	107,874	91%	1,256	–	1,256	1%	109,129	92%	–	0%	109,129	92%
Livestock	168	–	168	<1%	191	–	191	<1%	359	<1%	–	0%	359	<1%
Mining	0	0	0	0%	437	1,244	1,682	1%	437	<1%	1,244	1%	1,682	1%
Public Water Supply	381	0	381	<1%	1,670	0	1,670	1%	2,051	2%	0	0%	2,051	2%

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)†
	Fresh	Saline*	Total	Total Use (%)†	Fresh	Saline*	Total	Total Use (%)†	Fresh	Total Use (%)†	Saline*	Total Use (%)†		
Thermoelectric Power	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
County Totals	**108,423**	**0**	**108,423**	**92%**	**8,452**	**1,244**	**9,697**	**8%**	**116,875**	**99%**	**1,244**	**1%**	**118,120**	**100%**

Source: Dieter et al. (2018)

Note: Values may not sum to totals because of independent rounding (Dieter et al. 2018). Water use data are in acre-feet/year unless otherwise indicated.

* Saline water withdrawals are not reported for domestic, irrigation, or livestock water use (Dieter et al. 2018).

† Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 118,120 acre-feet.

Table 4-3. Sandoval County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)†
	Fresh	Saline*	Total	Total Use (%)†	Fresh	Saline*	Total	Total Use (%)†	Fresh	Total Use (%)	Saline*	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%	3,128	–	3,128	4%	3,128	4%	–	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	–	48,326	68%	2,320	–	2,320	3%	50,647	71%	–	0%	50,647	71%
Livestock	101	–	101	<1%	123	–	123	<1%	224	<1%	–	0%	224	<1%
Mining	0	0	0	0%	1,065	247	1,312	2%	1,065	1%	247	<1%	1,312	2%
Public Water Supply	135	0	135	<1%	12,466	0	12,466	17%	12,600	18%	0	0%	12,600	18%
Thermoelectric Power	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
County Totals	**48,562**	**0**	**48,562**	**68%**	**22,768**	**247**	**23,014**	**32%**	**71,329**	**100%**	**247**	**<1%**	**71,576**	**100%**

Source: Dieter et al. (2018).

Note: Values may not sum to totals because of independent rounding (Dieter et al. 2018). Water use data are in acre-feet/year unless otherwise indicated.

* Saline water withdrawals are not reported for domestic, irrigation, or livestock water use (Dieter et al. 2018).

† Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 71,576 acre-feet.

Table 4-4. San Juan County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)†
	Fresh	Saline*	Total	Total Use (%)†	Fresh	Saline*	Total	Total Use (%)†	Fresh	Total Use (%)†	Saline*	Total Use (%)†		
Aquaculture	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Domestic	0	–	0	0%	1,312	–	1,312	<1%	1,312	<1%	–	0%	1,312	<1%
Industrial	0	0	0	0%	22	0	22	<1%	22	<1%	0	0%	22	<1%
Irrigation	223,942	–	223,942	79%	0	–	0	0%	223,942	79%	–	0%	223,942	79%
Livestock	67	–	67	<1%	303	–	303	<1%	370	<1%	–	0%	370	<1%
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	**278,468**	**0**	**278,468**	**98%**	**2,197**	**3,083**	**5,280**	**2%**	**280,665**	**99%**	**3,083**	**1%**	**283,748**	**100%**

Source: Dieter et al. (2019).

Note: Values may not sum to totals because of independent rounding (Dieter et al. 2018).

* Saline water withdrawals are not reported for domestic, irrigation, or livestock water use (Dieter et al. 2018).

† Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 283,748 acre-feet.

Table 4-5. Water Use by Category in 2015 within the FFO Area (McKinley, Rio Arriba, Sandoval, and San Juan Counties)

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)†
	Fresh	Saline*	Total	Total Use (%)†	Fresh	Saline*	Total	Total Use (%)†	Fresh	Total Use (%)†	Saline*	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%	8,979	–	8,979	2%	8,979	2%	–	0%	8,979	2%
Industrial	0	0	0	0%	2,634	0	2,634	<1%	2,634	<1%	0	0%	2,634	<1%
Irrigation	381,241	–	381,241	78%	3,576	–	3,576	<1%	384,817	79%	–	0%	384,817	79%
Livestock	437	–	437	<1%	986	–	986	<1%	1,424	<1%	–	0%	1,424	<1%
Mining	2,724	0	2,724	<1%	3,677	5,257	8,934	2%	6,401	1%	5,257	1%	11,658	2%
Public Water Supply	21,613	0	21,613	4%	17,958	0	17,958	4%	39,571	8%	0	0%	39,571	8%

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)†
	Fresh	Saline*	Total	Total Use (%)†	Fresh	Saline*	Total	Total Use (%)†	Fresh	Total Use (%)†	Saline*	Total Use (%)†		
Thermoelectric Power	30,637	0	30,637	6%	2,298	0	2,298	<1%	32,935	7%	0	0%	32,935	7%
Basin Totals	**436,652**	**0**	**436,652**	**90%**	**44,750**	**5,257**	**50,008**	**9%**	**481,402**	**99%**	**5,257**	**1%**	**486,660**	**100%**

Source: Dieter et al. (2018).

Note: Values may not sum to totals because of independent rounding (Dieter et al. 2018). Water use data are in acre-feet/year unless otherwise indicated.

* Saline water withdrawals are not reported for domestic, irrigation, or livestock water use (Dieter et al. 2018).

† Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 486,660 acre-feet.

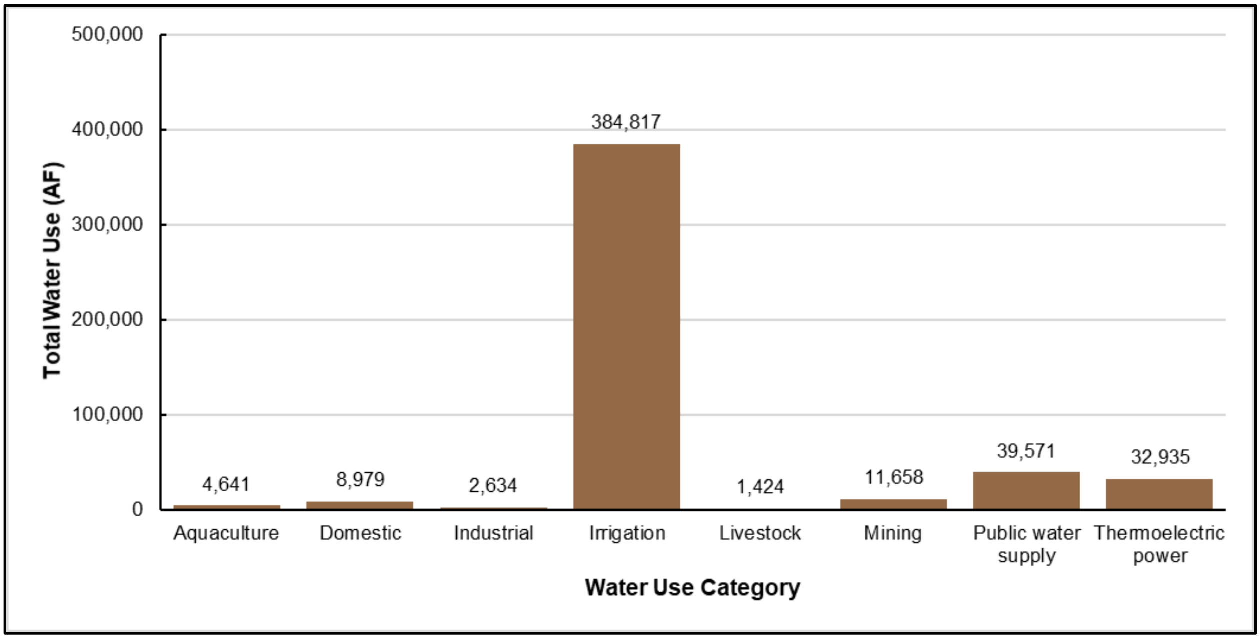

Figure 4-2. FFO (McKinley, Rio Arriba, Sandoval, and San Juan Counties) water use by category in 2015 (Dieter et al. 2018).

4.1.2 Water Use Trends and Planned Actions

4.1.2.1 Past and Present Actions

As noted previously, total water usage in the four FFO counties in 2015 was approximately 486,660 AF and accounted for approximately 15% (3,249,667 AF) (see Table 2-1) of the total state water withdrawals (Dieter et al. 2018). The largest use of water within the FFO area is irrigation, comprising 79% of all water use within the FFO area and 14% of all irrigation-related use within the state. Mining (which includes oil and gas development) comprised 2% of the total water withdrawals within the FFO area and 7% of all mining-related water use in the state.

Data from FracFocus were evaluated to provide objective information on the amount of water used in hydraulic fracturing (see Appendix A). Operators are required by the State of New Mexico to disclose chemistry and water use information to FracFocus. Annual water use in oil and gas wells within the four FFO counties has varied over the past 7 years. The number of wells completed decreased from 123 in 2022 to 101 in 2023, and the total water use for all wells decreased from 1,326 AF in 2022 to 955 AF in 2023. Average water use per well decreased from 15 AF in 2021 to 10 AF in 2023 (Table 4-6) (FracFocus 2024a). Wells on federal land consumed 711 AF of water in 2023, 75% of the 2023 total water usage.

Combined water use (federal and total) is the amount of water cumulatively used each year by hydraulic fracturing and includes the water use for any given year plus the water use for each previous year since 2014. See Appendix A for details on how cumulative totals were calculated.

The combined water use estimates for federal and total (both federal and non-federal) water use associated with hydraulic fracturing in the FFO are shown in Table 4-6. With consideration of all water use by oil and gas wells for hydraulic fracturing from 2014 to 2023, the combined federal water use and total combined water use was 3,507.8 AF and 4,833.3 AF, respectively. The 10-year total combined water use is approximately 4,833.3 AF and the average AF per well in 2023 was approximately 9.5 AF. However, based on the most recent 3 years of data (2021–2023), the 3-year average is 11.7 AF per well.

This is due to the higher volume of wells, the likelihood that horizontal wells are being drilled to longer lengths in the intervening time, the continued use of hydraulic fracturing technologies in well drilling and completion, and operators transitioning from nitrogen fracturing methods to water-intensive slickwater fracturing. While slickwater fracturing is a more water-intensive process, most operators are targeting non-potable water sources for fracturing operations, though exact sources cannot be determined as FracFocus does not distinguish between water types used.

Given the increasing trend in water use seen in the FracFocus data (see Table 4-6) the 3-year average of 11.7 AF per well is considered to be a reasonable estimate of water use associated with future oil and gas development in the FFO.

Table 4-6. Water Use by Oil and Gas Wells for Hydraulic Fracturing in the FFO (McKinley, Rio Arriba, Sandoval, and San Juan Counties) from 2014 through 2023

Year	Federal Water Use	Non-Federal Water Use	Total Water Use	Federal Water Use (%)	Federal Combined Water Use	Total Combined Water Use	Average Water Use/Well	Well Count	Produced Water
2014	165	151	316	52	165	316	2.4	130	4,284
2015	83	230	313	27	248	629	3.6	88	3,955
2016	85	26	110	77	332	740	2.9	38	3,374
2017	228	50	278	82	561	1,018	4.5	62	3,184
2018	375	281	657	57	936	1,675	4.8	136	2,287
2019	87	69	156	56	1,023	1,830	1.7	89	3,792
2020	51	0	51	100	1,074	1,881	5.7	9	3,480
2021	551	120	671	82	1,625	2,552	14.9	45	2,184
2022	1,172	154	1,326	88	2,797	3,879	10.8	123	2,871
2023	712	243	955	75	3,508	4,833	9.5	101	2,473
Total	3,508	1,325	4,833	73			5.9* (11.7)	821	31,884

Source: FracFocus (2024a)

Note: Data are presented only for those wells reporting water usage to FracFocus. See Appendix A for data analysis methodology. Produced water data are from NMOCD (2024b). Produced water is naturally occurring water that exists in a formation that is being targeted for mineral extraction and is produced as a byproduct. Water use data are in acre-feet unless otherwise indicated.

*10-year average (2014–2023). The second number found within the total average water use per well is a 3-year average value (10.5 AF/well)

While the FracFocus database is an excellent tool for identifying well completions, FracFocus does not currently differentiate between wells that are new completions or recompletions of previously drilled wells. This data reporting discrepancy can skew water use statistics, as recompletions typically use less water than new completions. The FracFocus database alone does not provide all the required data on well completion method (vertical, slickwater, nitrogen) and requires additional data sources to accurately capture water use associated with each well completion method. Water use can vary depending on the well completion method, so additional well information was compiled from BLM records and available data from NMOCD and aggregated with FracFocus data to provide a more detailed analysis of water use by well type (new completion versus recompletion and completion method) (Table 4-7). From 2014 to 2023, recompletions of previously existing wells used an average of 0.3 AF/well for a total of 109.3 AF of total water use over 9 years, while completions of vertical wells used an average of 0.3 AF/well but accounted for 10.1 AF of total water use. Water use associated with new completions of nitrogen and slickwater wells used an average of 4.0 and 40.5 AF/well, respectively. Total water volume used for nitrogen wells from 2014 through 2023 equaled 1,327.8 AF, whereas slickwater wells utilized 3,404.2 AF of water over the same period. The total new well counts for 2014 through 2023 (excluding recompletion wells) equals 452, with 28 new wells developed in 2023. The average volume of water used per new well completed in 2023 (excluding recompletions) was 32.5 AF. Despite accounting for only 18.6% of well completions from 2014 through 2023, slickwater well development was responsible for approximately 70% of water used in well development during this time period, including water used in recompletions. Figure 4-3 indicates the proportion of wells by completion type.

Table 4-7. Water Use Statistics by Well Type for the FFO from 2014 through 2023

Year	Well Type	Count	Average Water Use per Well (AF)	Total Water Use (AF)
2014	Nitrogen	105	2.9	301.3
	Recompletion	22	0.7	15.6
	Slickwater	0	–	–
	Vertical	4	0.4	1.7
	Total	**131**	**2.4**	**318.6**
2015	Nitrogen	65	3.3	213.3
	Recompletion	7	0.3	2.1
	Slickwater	3	40.4	121.3
	Vertical	15	0.4	5.8
	Total	**90**	**3.8**	**342.5**
2016	Nitrogen	16	5.1	81.5
	Recompletion	23	0.2	5.9
	Slickwater	1	23.3	23.3
	Vertical	0	–	–
	Total	**40**	**2.7**	**110.7**
2017	Nitrogen	40	4.8	186.9
	Recompletion	11	0.3	3.4
	Slickwater	1	87.3	87.3
	Vertical	11	0.1	1.0
	Total	**63**	**4.4**	**278.6**
2018	Nitrogen	19	4.6	88.3
	Recompletion	107	0.2	25
	Slickwater	14	38.9	544.5
	Vertical	2	0.1	0.2
	Total	**142**	**4.6**	**658.0**
2019	Nitrogen	17	5.6	94.4
	Recompletion	74	0.2	17.2
	Slickwater	1	49.2	49.2
	Vertical	0	–	–
	Total	**92**	**1.7**	**160.8**
2020	Nitrogen	9	5.7	51.0
	Total	**9**	**5.7**	**51.0**

Year	Well Type	Count	Average Water Use per Well (AF)	Total Water Use (AF)
2021	Nitrogen	15	5.2	78.2
	Recompletion	16	0.3	4.5
	Slickwater	14	42.1	588.4
	Total	**45**	**14.9**	**671.1**
2022	Nitrogen	34	5.2	177
	Recompletion	53	0.2	12.8
	Slickwater	31	35.5	1,135.8
	Vertical	7	0.2	1.4
	Total	**125**	**10.3**	**1,327**
2023	Nitrogen	9	6.2	55.9
	Recompletion	78	0.3	22.8
	Slickwater	19	45.0	854.4
	Total	**106**	**17.2**	**933.1**
2014–2023	Nitrogen	329	4.0	1,327.8
	Recompletion	391	0.3	109.3
	Slickwater	84	40.5	3,404.20
	Vertical	39	0.3	10.1
	Total	**843**	**5.8**	**4,851.4**
	Total (without recompletions)	**452**	**10.5**	**4,742.10**

Note: Well data was sourced from FracFocus (2024a) and aggregated with additional data from BLM records.

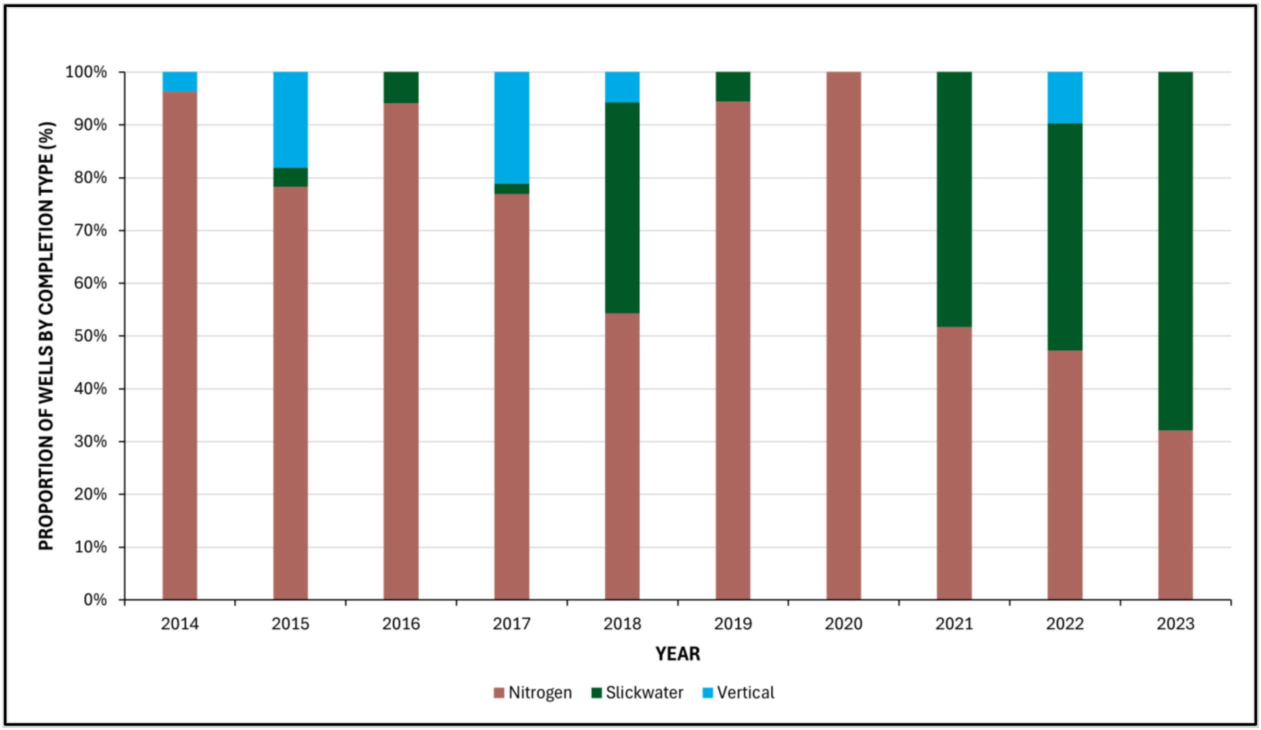

Figure 4-3. Proportion of oil and gas well stimulation techniques in the FFO from 2014 through 2023 (FracFocus 2024a).

Note: Well data sourced from FracFocus (2024a) and aggregated with additional data from BLM records. Recompletion wells were not included in this chart as they are not a stimulation technology. The new well total for 2023, without recompletion wells, equals 28 wells. Associated percentages are based on this total

4.1.2.2 Water Use Per Well Comparisons

As previously discussed, actual water use quantities reported from 2014 through 2023 for the FFO vary from an average of 5.8 AF per well (see Table 4-6) to 10.97 AF per well (see Table 4-7), depending on the data source used. For the FFO specifically, a summary of the average water use per well across data sources is summarized in Table 4-8. The 10.6 AF/well 3-year average per well is considered a reasonable estimate of water use associated with future oil and gas development in the FFO. This value is also the most conservative approach for assessing impacts from water use.

Table 4-8. Water Use per Well Comparisons

Data Source	Water User (AF/well)	Notes
FracFocus 10-year average	5.8	Average water use per well between 2014 and 2023.
FracFocus 3-year average	10.6	Average water use per well between 2021 and 2023.
FracFocus data with corrected stimulation techniques (without recompletions)	10.5	Average water use per new well between 2014 and 2023.

4.1.2.3 Water Use Scenarios Associated with Reasonably Foreseeable Oil and Gas Development

4.1.2.3.1 2018 RFD WATER USE PROJECTIONS

The 2018 RFD (Crocker and Glover 2018) was used to forecast the potential quantity of oil and gas wells in the Mancos-Gallup planning area, which includes most of the FFO 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 reuse or recycling of hydraulic fracturing fluid.

The 2018 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 20 years (2018–2037). According to the 2018 RFD, 3,200 wells are expected to be drilled in the Mancos-Gallup planning area between 2018 and 2037, based on projections from existing 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.

The 2018 RFD projected water use for vertical wells is 0.537 AF per 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 would require on average approximately 3.13 AF of water per well (Table 4-9).

4.1.2.3.2 2018 REVISED RFD WATER USE PROJECTIONS

In 2018, the BLM reviewed the initial 2018 RFD water use projections against 2018 FracFocus data and found that the 2018 RFD per-well water estimates were lower than actual water use quantities based on current FracFocus data. Therefore, the BLM revised the estimated per-well water use to an average of 4.84 AF per horizontal well (BLM 2019; see Table 4-9). This revised water use number assumes well development technologies stay relatively similar to what was described in the RFD.

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 and is based on historic oil and gas development in the area and county water use data. Drilling and completion of the 3,200 wells estimated to occur in the Mancos-Gallup planning area would require approximately 7,683 AF using the water use estimates contained in the 2018 RFD. Using the BLM's revised water use estimates (4.84 AF per horizontal well; see Table 4-9), 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. Projected annual water use would be approximately 0.12% of the 2015 total water use in the four counties comprising the FFO (486,660 AF).

Table 4-9. Projected Water Use in the New Mexico Portion of the San Juan Basin (FFO)

Factor	Water Use in RFD (Crocker and Glover 2018)	2018 Revised RFD Water Use	Rationale for Change
Average water use per horizontal well during a hydraulic fracturing operation	3.13 AF*	4.84 AF†	Reflects actual use as reported in FracFocus (2018)
Average water use per vertical well during a hydraulic fracturing operation	0.537 AF	0.537 AF	No change

Factor	Water Use in RFD (Crocker and Glover 2018)	2018 Revised RFD Water Use	Rationale for Change
Total Water Use (2018–2037)‡	**7,683 AF†**	**11,615 AF†**	–

* Derived from Crocker and Glover (2018).

† Source: BLM (2019)

‡ Total water use = (2,300 horizontal wells × horizontal well water use estimate) + (900 vertical wells × vertical well water use estimate).

4.1.2.3.3 WATER USE PROJECTIONS BY STIMULATION TECHNOLOGY

As discussed in Section 4.1.2.1, water use associated with horizontal well completions varies by method of stimulation. This section provides RFD water use projections based on stimulation technology. In all scenarios, development of vertical wells is assumed to require 0.537 AF. Development of all 900 vertical wells in the 2018 RFD would require 483 AF, or approximately 24 AF/year.

Nitrogen Stimulation Water Use Projections

In 2020, the FFO began assessing water use trends associated with nitrogen stimulation. Nitrogen stimulation, in which gaseous nitrogen is used in place of water to fracture oil and gas formations, is a common stimulation technique in the FFO. There are three predominant methods of nitrogen stimulation: nitrogen foam, energized nitrogen, and pure nitrogen. 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 yields. The proportion of nitrogen-stimulated wells within a year has ranged from 32% to 100% (see Figure 4-3).

Under a nitrogen stimulation scenario, a fixed scenario developed in the 2021 Water Support Document, the average water use of a new nitrogen-stimulated well is 3.80 AF per well. If all 2,300 horizontal wells in the 2018 RFD used nitrogen stimulation technologies, development according to the 2018 RFD scenario would require 9,223 AF of water, or 461 AF of water in any given year (this includes 483 AF for the 900 vertical wells projected in the 2018 RFD). Projected annual water use would be approximately 0.09% of the 2015 total water use in the four FFO counties (486,660 AF). Current data on water use for nitrogen-stimulated wells indicate an increase in the use of nitrogen stimulation technology. The current average water use of a new nitrogen-stimulated well is 4.04 AF, representing an increase of 0.24 AF from the average developed in the 2021 Water Support Document.

Slickwater Stimulation Water Use Projections

In 2015, the FFO began receiving APDs proposing slickwater hydraulic fracturing. Slickwater hydraulic fracturing utilizes greater quantities of water during the stimulation process than nitrogen or standard water hydraulic fracturing. Appendix B contains additional background information on slickwater fracturing in the FFO, as well as the methodology for capturing information and calculating water use by stage, the average number of stages per wells, and other information used to project water use associated with slickwater well development. In particular, Appendix B explains how the BLM used a lateral well bore of 1.5 miles to determine an average of 27 AF per lateral mile for slickwater completions.

If operators implement slickwater technology more frequently than in 2018 and prior years, it is expected that total water use volumes on a per-well basis will trend upward. If 100% of the 2,300 horizonal wells projected in the 2018 RFD were to use slickwater fracturing, development of the horizontal well portion of the RFD scenario would require 125,000 AF (see Appendix B) and development of the full 2018 RFD scenario would require approximately 125,483 AF of water (total), or 6,275 AF of water in any given year. Projected annual water use of 6,275 AF would be approximately 1.3% of the 2015 total water use in the four FFO counties (486,660 AF). However, water utilized in slickwater fracturing can have TDS of

50,000 ppm, well above the NMOSE potable water threshold. This allows for the use of non-traditional water sources, including connate water, recycled flowback water, and produced water (see Appendix B). During 2014–2023, 18.58% of wells within the FFO area were developed using slickwater fracturing. The use of non-traditional water sources has increased over time (see Table 4-7).

4.1.2.4 Water Use Forecasts Comparisons

A good strategy for projecting water use over an extended period is the utilization of scenarios with varying conditions. This section provides a comparison of water use associated with four water use scenarios (three defined above [RFD, nitrogen, and slickwater] and a fourth scenario developed as part of the 2021 Water Support Document):

1. 2018 RFD revised water use projections scenario: This scenario predicts an annual use of 580 AF/year, which would result in a 20-year cumulative water use of 11,615 AF by 2037.
2. Nitrogen scenario: This assumes that all 2,300 horizontal wells predicted in the 2018 RFD will use nitrogen stimulation (3.8 AF per horizontal well), which would result in a 20-year cumulative water use of 9,223 AF by 2037 (including 483 AF for the 900 vertical wells projected in the 2018 RFD).
3. Slickwater scenario: This scenario assumes that all 2,300 horizontal wells predicted in the RFD would use slickwater stimulation, with an average lateral length of approximately 2 miles, which would result in a 20-year cumulative water use of 125,483 AF by 2037 (including 483 AF for the 900 vertical wells projected in the 2018 RFD).
4. A fourth scenario assumes a consistent 3% increase in the proportion of slickwater wells and a corresponding decrease in nitrogen-stimulated wells from 2020 through 2037 (Table 4-10). An annual increase of 3% was used for this scenario based on the percentage of wells within the FFO area in 2020 using slickwater fracturing (3%). Under this scenario, vertical well development is assumed to stay constant. Well count by completion method and estimated water use for this scenario is detailed by year in Table 4-10. The values are based on an average water use of 3.8 and 41.3 AF per well for the nitrogen and slickwater scenarios, respectively, and 0.537 AF per well for vertical wells. This scenario would result in an 18-year (2020–2037) cumulative horizontal well water use of 29,822 AF.

Table 4-10. Estimated Well Counts and Associated Water Use for the 3% Annual Slickwater Increase Scenario

Year	Estimated Number of Wells			Estimated Water Use (AF) by Well Type			Annual Water Use (AF)	Cumulative Water Use (AF)
	Slickwater	Nitrogen	Vertical	Slickwater	Nitrogen	Vertical		
2020	3	112	45	124	376	24	524	524
2021	7	108	45	289	49	24	363	887
2022	10	105	45	413	357	24	794	1,681
2023	14	101	45	578	350	24	952	2,633
2024	17	98	45	702	342	24	1,068	3,702
2025	21	94	45	867	331	24	1,222	4,924
2026	24	91	45	991	323	24	1,338	6,262
2027	28	87	45	1,156	315	24	1,496	7,758

Year	Estimated Number of Wells			Estimated Water Use (AF) by Well Type			Annual Water Use (AF)	Cumulative Water Use (AF)
	Slickwater	Nitrogen	Vertical	Slickwater	Nitrogen	Vertical		
2028	31	84	45	1,280	308	24	1,612	9,370
2029	35	80	45	1,446	296	24	1,766	11,136
2030	38	77	45	1,569	289	24	1,882	13,019
2031	41	74	45	1,693	281	24	1,999	15,017
2032	45	70	45	1,859	266	24	2,149	17,166
2033	48	67	45	1,982	255	24	2,261	19,427
2034	52	63	45	2,148	239	24	2,411	21,838
2035	55	60	45	2,272	228	24	2,524	24,362
2036	59	56	45	2,437	213	24	2,674	27,036
2037	62	53	45	2,561	201	24	2,786	29,822

Note: Estimated well counts were calculated assuming 115 horizontal well completions per year (from the 2018 RFD) rounded to the whole number, a 3% annual increase in the number of slickwater wells developed per year, and a corresponding decrease in nitrogen well stimulation methods. An assumed water use of 41.3 and 3.8 AF/well was used for slickwater- and nitrogen-stimulated wells, respectively.

Figure 4-4 presents combined water use estimates for these four well development scenarios and also presents actual combined water use based on FracFocus 2014–2023 water use as presented in Table 4-6.

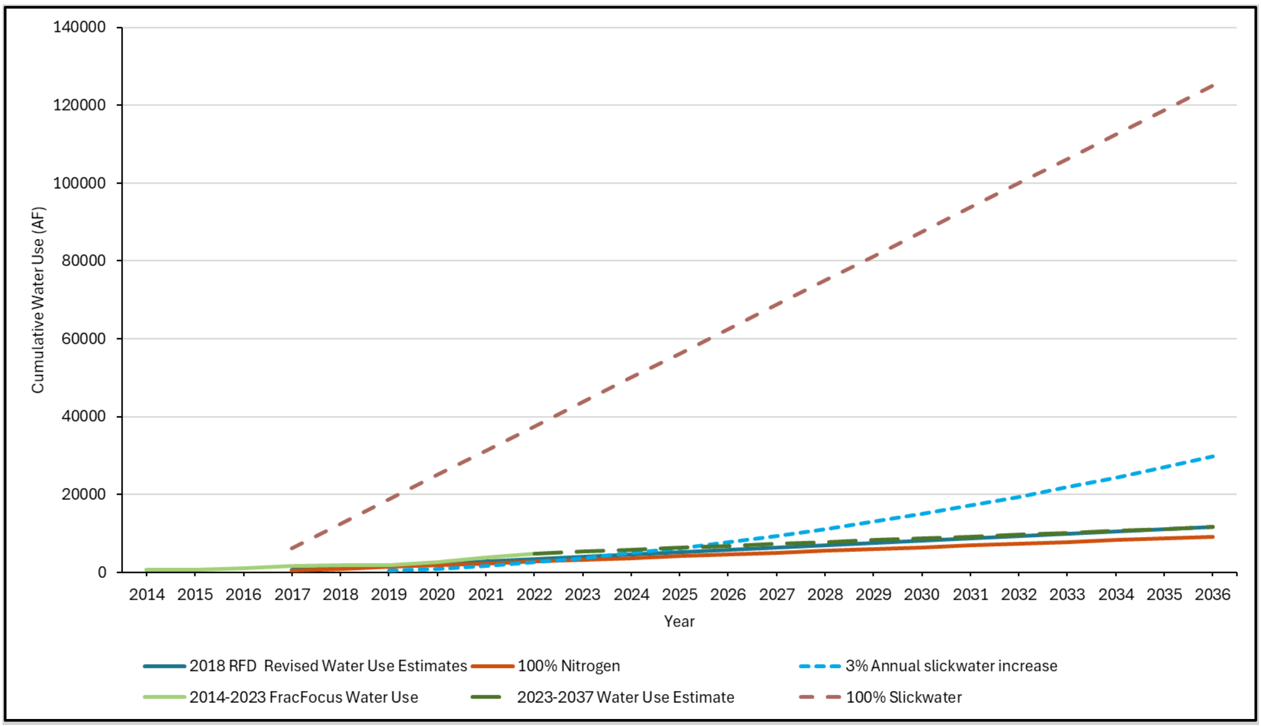

Figure 4-4. Cumulative water use estimates for four well development scenarios and 2014–2023 FracFocus water use within the New Mexico portion of the San Juan Basin (McKinley, Rio Arriba, Sandoval, and San Juan Counties) based on a predicted 2,300 horizontal and 900 vertical wells.

Current FracFocus water use trends over the past 10 years (5.8 AF per well and 485 AF/year) indicate that cumulative water use by 2037 will be approximately 11,649 AF. Without recompletions, the average water use per well was 10.5 AF over the past 10 years. The following observations can be made from review of Table 4-6, Table 4-7, and Figure 4-4:

- Current new well completion water use trends lie slightly above both the nitrogen and revised 2018 RFD scenarios.
- The slickwater scenario predicts that, starting in 2019, all wells within the San Juan Basin will use slickwater stimulation, whereas FFO data indicate that in 2019, one well was completed using slickwater stimulation, no wells in 2020 used slickwater stimulation, 31 wells completed in 2022 used slickwater stimulation, and 19 of the 106[2] wells completed in 2023 used slickwater stimulation (see Table 4-7).
- The slickwater scenario estimates a 2019 water use of 6,142 AF, whereas annual water use for well completion reported to FracFocus in the FFO in 2019 and 2022 was 161 AF and 933 AF, respectively, which is 97.4% and 84.8% less, respectively, than the slickwater scenario predicted annual use of 6,142 AF/year. If recompletion wells are not included in these totals, the annual water use for well completion reported to FracFocus in the FFO in 2019 and 2023 was 143.2 AF and 910.3 AF, or 97.7% and 85.2% less, respectively, than the slickwater scenario predicted annual use of 6,142 AF/year.
- However, of the 92 wells completed in 2019, 17 (18.5%) used nitrogen stimulation, and nine of the total wells (8.5%) completed in 2023 used nitrogen stimulation. Of the total wells completed within the San Juan Basin, there is a growing trend of increased slickwater stimulation use as compared with nitrogen stimulation.
- The number of slickwater wells that have been developed since 2020 has exceeded the projected increase envisioned in the 3% Annual Slickwater Increase Scenario. If this trend continues, it is anticipated that actual combined water use will exceed the water use presented in the 3% Annual Slickwater Increase Scenario.

4.1.3 Potential Sources of Water for Project Development

Because approximately 77% of all water used in mining activities, which include oil and gas development, in the counties that comprise the FFO is currently from groundwater (see Section 4.1.1 and Table 4-5), 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 FFO. Water yields in these areas vary, but most aquifers yield less than 20 gallons per minute (gpm) (BLM 2003b). Aquifers that are known to yield sufficient quantities of water are usually found within sandstone units of Jurassic, Cretaceous, and Tertiary age (BLM 2003b). Aquifers that have the potential to yield 100 gpm include the San Andres Glorieta system, the Entrada Sandstone, the Morrison Formation, the Gallup Sandstone, the Ojo Alamo Sandstone, the Nacimiento Formation, and the San Jose Formation, all of which are within the greater Uinta-Animas aquifer (BLM 2003b). However, water used in hydraulic fracturing may also originate from regulated and controlled surface water sources. Principal surface water drainages in the analysis area are the San Juan River (which is impounded at Navajo Dam), the Animas River, and the La Plata River (Dieter et al. 2018).

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

[2] This total includes recompletion wells. The addition of these wells combines new and old wells, resulting in a higher total; without the addition of recompletion wells, the total is 28 wells.

stimulation are categorized as potable/fresh and non-potable. Any water that has TDS greater than 1,000 ppm has been defined as non-potable by the State of New Mexico (72-12-25 New Mexico Statutes Annotated 1978). The BLM has identified anything less than 10,000 ppm to be protected in the casing rule of the BLM's 43 CFR § 3170. Non-potable water is outside the appropriative processes and is mainly diverted for mineral exploration purposes. The higher allowable TDS levels that are acceptable for slickwater stimulation expand the possible water sources beyond those that are traditionally used (e.g., surface water or groundwater) into non-traditional sources of water (e.g., non-potable groundwater sources). Recently, 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 has also been used for nitrogen simulations (see Appendix B for more information). Water contained in the Entrada Sandstone is highly saline (Kelley et al. 2014). As such, it is considered non-potable and has not been declared an administrative aquifer by NMOSE. The associated rock types and the sources of recharge for four aquifers found in the FFO area are identified in Table 4-11.

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 wellhead directly after stimulation activities. Generally, 10% to 40% of the initial volume utilized for stimulation activities returns as flowback fluid; of this flowback fluid, 10% to 40% is non-potable water that may be used in future stimulation activities. Produced water is the outcome of a process involving naturally occurring water that exists in a formation. It is targeted for mineral extraction and is produced as a byproduct, thereby becoming produced water.

Water used for oil and gas drilling and completion would generally be obtained through the following methods:

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

In addition to utilizing surface water or groundwater, operators may also bring water to a well site via truck from any number of sources. The transaction would be handled by NMOCD as well as NMOSE. All water use would be evaluated at the APD stage in site-specific NEPA analysis and subject to standard lease terms and conditions; all water used for well development and operations would be from an approved source.

Table 4-11. Potential Sources of Groundwater in the FFO

Aquifer Name	Description	Sources of Recharge
Mesa Verde	Sandstone, coal, siltstone, and shale of the Mesa Verde Group	Upland areas, mainly in areas of the Zuni Uplift, the 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

Aquifer Name	Description	Sources of Recharge
Entrada Sandstone	Sandstone; eolian sand dunes	Through surface exposures on the margins of the basin in the foothills of the Laramide uplifts

Source: BLM (2003b); Kelley et al. (2014)

4.1.4 Water Use Mitigations

Public concern about water use from hydraulic fracturing is especially high in semiarid regions. 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 rely on freshwater 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, difficult to treat, and often disposed through deep injection wells (Kondash et al. 2018). The NMED recently signed an MOU 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 nitrogen or slickwater fracturing can be accomplished using non-traditional water sources, including the connate water within the Entrada Sandstone. NMOSE is the agency responsible for water withdrawal permitting actions. Its notice of intent process includes a model-based evaluation of the potential effects of proposed withdrawals and the identification of possible requirements for applicants to obtain water rights to offset any depletions identified in NMOSE’s analyses prior to applicants commencing diversions.

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 4-5 is an illustrated geologic cross section showing the distribution of saline aquifers within the San Juan Basin.

TDS concentration is a measure of all dissolved matter in a sample of water and is the primary indicator of groundwater quality, as higher TDS concentrations typically render water less suitable for drinking or agricultural purposes such as 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 geologic formation where the water resides. Fresh water (TDS <1,000 mg/L) is typically found at depths less than 2,500 feet below the ground surface, although exceptions to this generalization occur in deeper layers such as the Gallup Sandstone and Morrison Formation. Saline and brackish water is dominant in the center of the San Juan Basin at greater depths (Kelley et al. 2014).

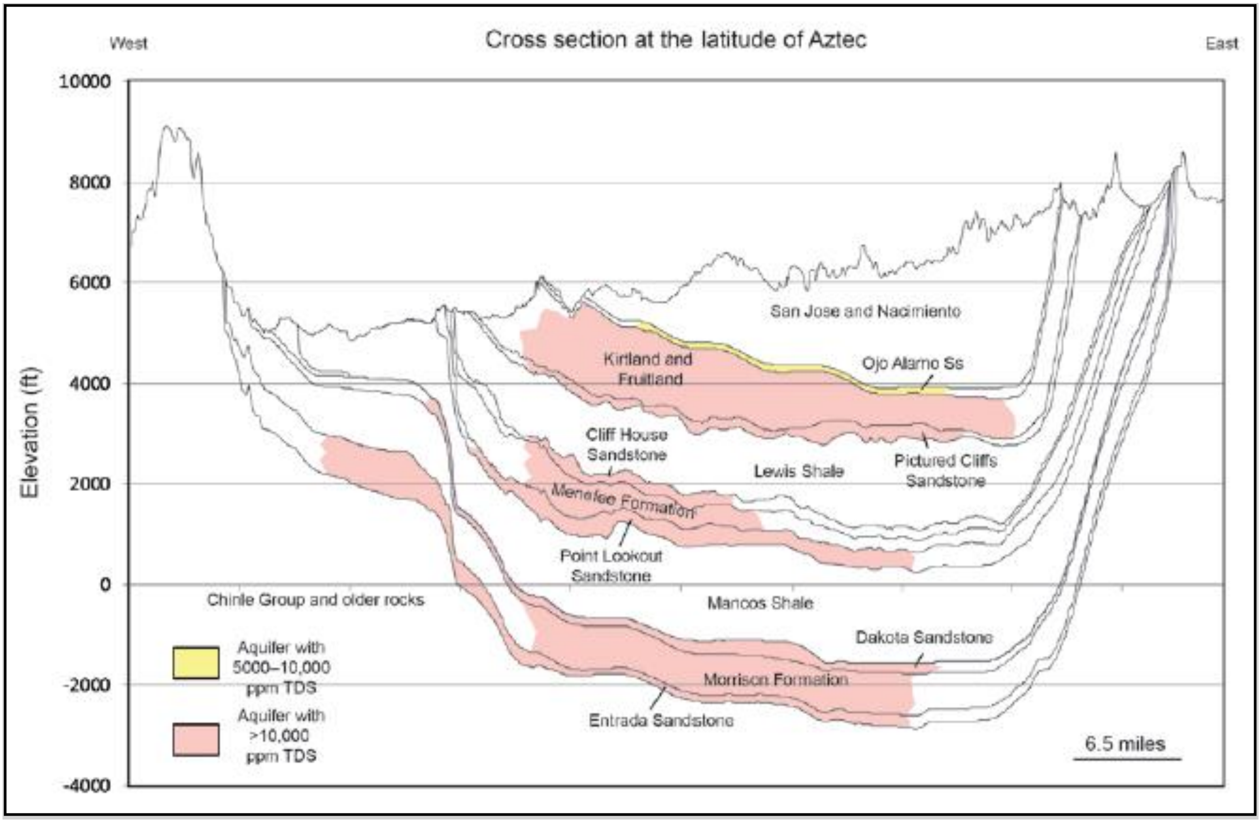

Figure 4-5. Geologic cross section showing the distribution of saline aquifers in the San Juan Basin (Kelley et al. 2014).

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 streambanks and riverbanks.

Water quality in streams flowing on BLM-managed lands is influenced by both natural water quality with regard to salinity content and the intensity of human and industrial activities 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 activities.

Additional chemistry samples of surface water in the region are needed to establish a baseline 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 CWA.

4.2.3 Potential Sources of Surface Water or Groundwater Contamination

4.2.3.1 Spills

Spills associated with oil and gas development may reach surface water directly. Spills may also reach surface waters indirectly, after a spill has occurred and a rain event moves contaminants into nearby surface waterbodies through surface water flow or subsurface groundwater flow into springs that discharge into a surface waterbody.

The San Juan Basin has been a producing oil and natural gas field since the early to middle 1900s. In 2023, oil and gas development in the counties within the San Juan Basin resulted in 10,535,416 bbl of oil (NMOCD 2024b). There were 90 liquid and 383 gaseous spills in the New Mexico portion of the San Juan Basin in 2023 (Table 4-12). Additionally, Table 4-13 provides a more in-depth view of both liquid and gaseous spills in 2023.

Table 4-12. Summary of Spills by Year in the FFO (McKinley, Rio Arriba, Sandoval, and San Juan Counties)

Material Type	Spill Count									
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Chemical (Specify)	2	0	0	1	0	0	0	0	0	0
Condensate	20	24	12	8	20	18	15	22	33	40
Crude Oil	23	8	9	7	11	20	9	14	11	12
Drilling Mud/Fluid	0	3	0	0	0	0	0	0	0	0
Glycol	0	0	0	0	0	2	0	0	0	1
Lube Oil	2	0	2	1	1	0	2	0	0	0
Motor Oil	0	0	0	0	1	0	0	0	0	0
Other (Specify)	11	6	1	3	10	9	3	3	3	0
Produced Water	71	34	48	34	31	45	35	28	32	35
Unknown	0	0	0	0	0	0	0	1	1	1
Natural Gas Liquids	12	16	4	2	6	5	0	0	0	1
Total Liquid Spills	**141**	**91**	**76**	**56**	**80**	**99**	**64**	**68**	**80**	**90**
Natural Gas (Methane)	104	70	34	27	20	24	21	12	0	0
Natural Gas Flared	0	0	0	0	0	0	0	132	775	314
Natural Gas Vented	0	0	0	0	0	0	0	30	89	69
Total Gaseous Spills	**104**	**70**	**34**	**27**	**20**	**24**	**21**	**174**	**864**	**383**

Source: NMOCD (2024b)

Unit: bbl = barrels; mcf = thousand cubic feet.

Note: FracFocus does not differentiate between natural gas flaring/venting and a normal liquid spill that could occur during the hydraulic fracturing process; therefore, this table reflects two total value rows (one total value for conventional spills and one for natural gas flaring and venting). Natural gases that are vented and flared are done so intentionally as part of the hydraulic fracturing process with no expected spill recovery.

Table 4-13. Summary of 2023 Spills in the FFO (McKinley, Rio Arriba, Sandoval, and San Juan Counties)

Material Type*	Spill Count	Volume Spilled	Volume Lost	Units	Average Volume Spilled	Percent Lost	Waterways Affected	Groundwater Affected
Condensate	40	369	366	bbl	9	100	7	0
Crude Oil	12	691	411	bbl	58	79	1	0
Glycol	1	8	1	bbl	8	11	0	0
Produced Water	35	1,692	1,224	bbl	48	77	0	0
Unknown	1	29	29	bbl	29	100	0	0
Natural Gas Liquids	1	1	1	bbl	1	100	0	0
Total Liquid Spills	**90**	**2,790**	**2,032**	**bbl**	**31**	**73**	**8**	**0**
Natural Gas Flared	314	180,959	180,959	mcf	576	100	1	0
Natural Gas Vented	69	39,737	39,737	mcf	576	100	3	0
Total Gaseous Spills	**383**	**220,696**	**220,696**	**mcf**	**576**	**100**	**4**	**0**

Source: NMOCD (2024b)

Units: bbl = barrels; mcf = thousand cubic feet.

Note: FracFocus does not differentiate between natural gas flaring/venting and a normal liquid spill that could occur during the hydraulic fracturing process; therefore, this table reflects two total value rows (one total value for conventional spills and one for natural gas flaring and venting). Natural gases that are vented and flared are done so intentionally as part of the hydraulic fracturing process with no expected spill recovery.

* No spills of brine water, chemicals, drilling mud/fluid, gelled brine (frac fluid), lube oil, sulfuric acid, or natural gas (methane) were reported in 2022.

In 2023, ability for spill recovery varied by spill type, but in general, for liquid spills about 73% of all spills were lost. Gaseous spills had a 100% spills lost rate in 2023 (due to the ignition process of flared and vented natural gas compounds). Of the spills in 2023, 12 incidents were reported as having affected surface waterways. The BLM works with NMOCD to remediate spills on associated federal oil and gas wells, including spills from federal wells drilled on private or state surface. According to NMAC 19.15.29.11, the responsible person shall complete NMOCD-approved corrective action for releases that endanger public health or the environment in accordance with a remediation plan submitted to and approved by NMOCD or with an abatement plan submitted in accordance with NMAC 19.15.30. The remaining contaminants 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 performing 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 common ingredient disclosed in FracFocus for wells within the FFO area was water, with 24,097 disclosures (Table 4-14). Other frequent disclosures included crystalline methanol (n = 7,523), hydrochloric acid (n = 6,046), and glutaraldehyde (n = 4,127). There were 45,446 records of non-disclosed chemicals, including chemicals listed as proprietary, confidential, and trade secrets.

Table 4-14. Most Frequently Disclosed Ingredients in Wells within the San Juan Basin (McKinley, Rio Arriba, Sandoval, and San Juan Counties) from 2014 through 2023

Ingredient Name±	CAS Registry Number	Number of Disclosures*	Percentage of Hydraulic Fracturing Job†	Percentage of Total Number of FracFocus Disclosures*
Not Disclosed	N/A	45,446	N/A	15%

Ingredient Name±	CAS Registry Number	Number of Disclosures*	Percentage of Hydraulic Fracturing Job†	Percentage of Total Number of FracFocus Disclosures*
Water	1310-58-3	24,097	20.97	8%
Methanol	67-56-1	7,523	<1%	2%
Hydrochloric Acid	10486-00-7	6,046	<1%	2%
Glutaraldehyde	Proprietary	4,127	<1%	1%
Crystalline Silica, Quartz	14808-60-7	3,539	12.19	1%
Ammonium Chloride	121285-02-9	3,256	<1%	1%
Ethanol	67-56-1	3,182	<1%	1%
Sodium Chloride	7447-40-7	3,068	<1%	1%
Acetic Acid	64-19-7	2,946	<1%	1%
Crystalline Silica	14808-60-7	2,786	6.46	1%
Distillates (Petroleum), Hydrotreated Light	6742-47-8	2,730	<1%	1%
Ethylene Glycol	111-76-2	2,631	<1%	1%
Proprietary	7732-18-5	2,631	<1%	1%
Propargyl Alcohol	108-19-7	2,579	<1%	1%
Crystalline Silica (Quartz)	Proprietary	2,323	13.44	1%
Aluminum oxide	1302-76-7	2,233	<1%	1%
Sodium Hydroxide	7647-14-5	2,160	<1%	1%
Quar Gum	Proprietary	2,158	<1%	1%

Source: FracFocus (2024a)

Note: Ingredient names and CAS numbers are not standardized in FracFocus, leading to widespread differences and discrepancies in CAS numbers, number of disclosures, and ingredient names. For this reason, the number of disclosures and ingredients presented in this table are to be used for general information only.

* The total number of FracFocus ingredient disclosures in the FFO area is 302,988.

† The amount of the ingredient in the total hydraulic fracturing volume by percent mass (definition from FracFocus [2024a] data dictionary).

± FracFocus lists certain chemicals as proprietary and no additional information is available regarding ingredient contents.

4.2.3.2 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 (TDS less than 10,000 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 NMOCD have casing, cementing, and inspection requirements in place to limit the potential for groundwater reservoirs and shallow aquifers to be impacted by hydraulic fracturing or the migration of hydrocarbons during oil and gas drilling and production activities. The BLM requires operators to comply with the regulations at 43 CFR § 3160. In addition, these regulations require oil and gas development to comply with directives in the Onshore Oil and Gas Orders and the orders of the Authorized Officer. Regulatory requirements for hydraulic fracturing, including casing specifications, monitoring and recording, and management of recovered fluids are located in 43 CFR § 3170 and 43 CFR § 3162.3-3. The State of New Mexico also has regulations for drilling, casing and cementing, completion, and plugging to protect freshwater zones (NMAC 19.15.16). Complying with the aforementioned regulations requires producers and regulators to verify the integrity of casing and cementing jobs. Casing specifications are designed and submitted to the BLM in a drilling plan as a component of 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. The aforementioned regulations and review practices surrounding proper casing and cementing procedures isolate usable water zones from drilling, completion/hydraulic fracturing fluids, and fluids from other mineral-bearing zones, including hydrocarbon-bearing zones. COAs may be attached to the APD, if necessary, to ensure groundwater protection. These may include requirements for closed loop drilling systems, spill prevention plans, leak detection plans, and appropriate equipment (leak detection and automatic shutoff system) in sensitive groundwater recharge areas. Casing and cementing operations are witnessed by certified BLM PETs. At the end of the well's economic life, the operator is required to submit a plugging plan to the BLM for approval. A BLM petroleum engineer will review the plan prior to commencement of the plugging operations. The BLM PETs witness plugging operations to ensure the planned procedures are properly followed. The BLM's review, approval, and inspections ensure the permanent isolation of usable groundwater from hydrocarbon-bearing zones.

In summary, the BLM, the NMED, and NMOCD have put in place numerous requirements for oil and gas producers 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. These include BLM regulations covered under 43 CFR § 3160; 43 CFR § 3170; 43 CFR § 3162.3-3; 43 CFR § 3162.3-5; Notice to Lessees and Operators of Onshore Federal and Indian Oil and Gas Leases (NTL)-3A; NMOCD regulations under NMAC 19.15.26; and the state's primacy agreement under the Safe Drinking Water Act. With these requirements in place, including the use of casing and cementing measures, contamination of groundwater resources from development of the lease parcels is highly unlikely. In addition, the BLM has authority under standard terms and conditions to require additional measures to protect water quality if site-specific circumstances require them. Site-specific mitigation tools would be developed as appropriate for the individual circumstances, including groundwater-quality monitoring studies. The regulations at 43 CFR § 3162.5-2(d) give the BLM the authority to require an operator to monitor water resources to ensure that the isolation procedures utilized to protect water and other resources are effective.

CHAPTER 5. RIO PUERCO FIELD OFFICE

The RPFO area 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 (Figure 5-1). To date, most of the drilling in the RPFO area has occurred in the northeastern corner of Sandoval County, which is in the San Juan Basin (FracFocus 2024a). Additionally, the 2019 RFD predicts that future oil and gas development will occur in the San Juan Basin (Crocker et al. 2019).

Chapter 5 outlines existing and projected (reasonably foreseeable) water quantity and water quality for the RPFO area. The analysis is based on information gathered from the following sources:

- the RFD for the RPFO (Crocker et al. 2019)
- 2015 consumptive water use data from the USGS report *Estimated Use of Water in the United States in 2015* (Dieter et al. 2018)
- FracFocus, a national hydraulic fracturing chemical registry managed by the GWPC and IOGCC (FracFocus 2024a)
- Spill data from the NMOCD database (NMOCD 2024a)
- Personal communication with the BLM on well completion type data

5.1 WATER QUANTITY

5.1.1 Existing Surface Water and Groundwater Use

The water use of counties within RPFO area varies greatly and is dependent on the predominant industry within a given 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; Figure 5-2). Bernalillo County (which contains Albuquerque) consumed 155,382 AF of water in 2015, with public water supply (69%; 106,820 AF) and irrigation (30%; 46,544 AF) representing 99% of water use (Table 5-2). Irrigation used the greatest proportion of water in Sandoval (71%; 50,647 AF), Valencia (93%; 146,246), Torrance (94%; 45,849 AF), Santa Fe (62%; 24,314 AF), and Cibola (50%; 5,448 AF) Counties (Table 5-3 through Table 5-7). Water use associated with mining (which includes oil and gas development), ranged from 112 to 2,309 AF (in Torrance and McKinley Counties, respectively). The proportion of surface water and groundwater use varied by county and was also industry-specific. Water use for all RPFO counties totaled 495,874 AF (Table 5-8), with surface water and groundwater comprising 60% and 40%, respectively. Mining activities consumed 5,953 AF, which made up 1% of water use in 2015 (see Figure 5-2). Irrigation, at 320,146 AF (65% of all water use), was the sector that consumed the greatest amount of water within RPFO area (see Figure 5-2). Irrigation water usage made up 14% of all water use within the state (3,249,667 AF).

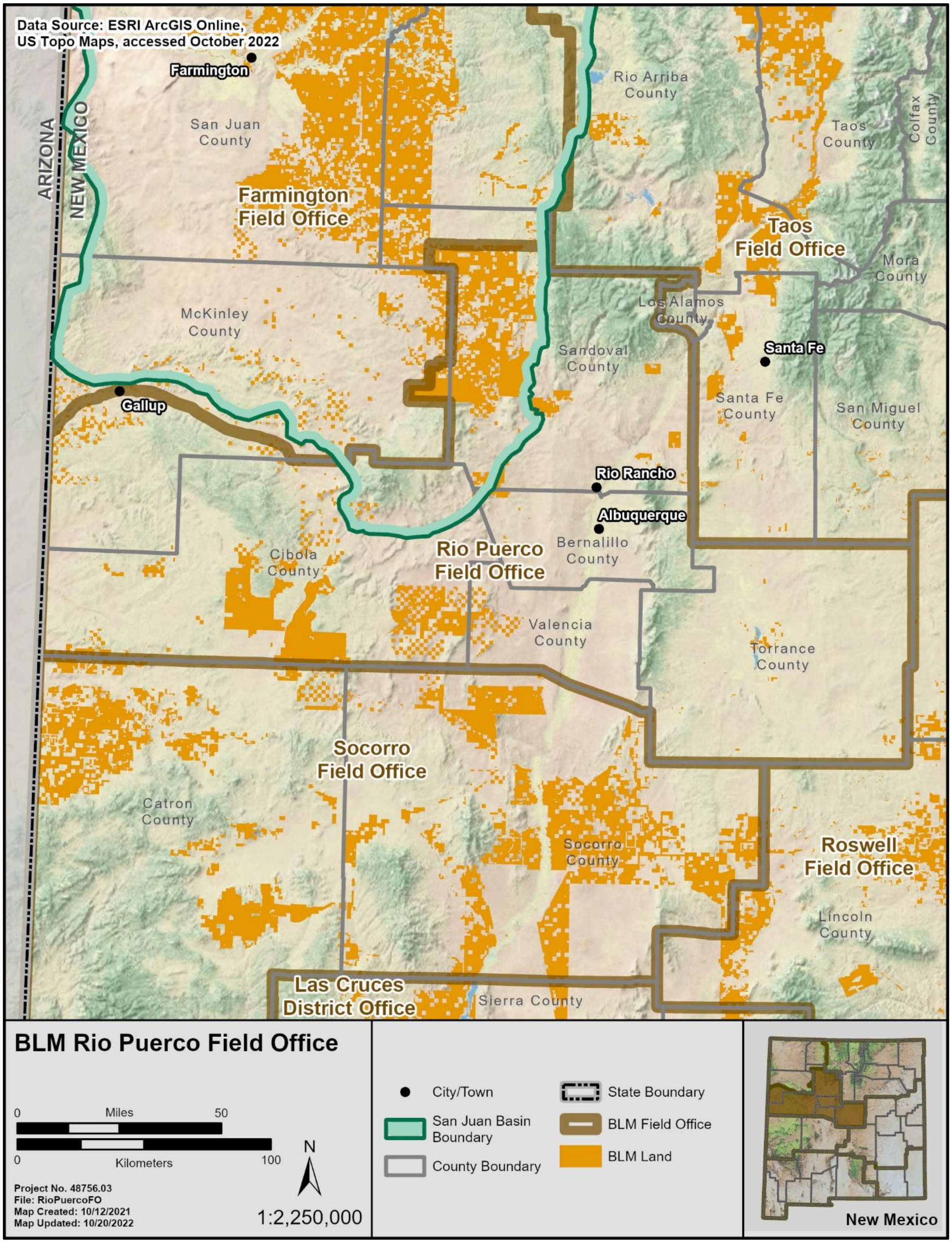

Figure 5-1. Map of BLM RPFO boundaries.

Table 5-1. McKinley County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)*
	Fresh	Saline	Total	Total Use (%)*	Fresh	Saline	Total	Total Use (%)*	Fresh	Total Use (%)*	Saline	Total Use (%)*		
Aquaculture	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Domestic	0	–	0	0%	3,195	–	3,195	24%	3,195	24%	–	0%	3,195	24%
Industrial	0	0	0	0%	34	0	34	<1%	34	<1%	0	0%	34	<1%
Irrigation	1,099	–	1,099	8%	0	–	0	0%	1,099	8%	–	0%	1,099	8%
Livestock	101	–	101	<1%	370	–	370	3%	471	4%	–	0%	471	4%
Mining	0	0	0	0%	1,625	684	2,309	17%	1,625	12%	684	5%	2,309	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	**1,199**	**0**	**1,199**	**9%**	**11,333**	**684**	**12,017**	**91%**	**12,533**	**95%**	**684**	**5%**	**13,217**	**100%**

Source: Dieter et al. (2018)

Note: Water use data are presented in acre-feet unless otherwise indicated.

* Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 13,217 acre-feet.

Table 5-2. Bernalillo County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)*
	Fresh	Saline	Total	Total Use (%)*	Fresh	Saline	Total	Total Use (%)*	Fresh	Total Use (%)*	Saline	Total Use (%)*		
Aquaculture	0	0	0	0%	22	0	22	<1%	22	<1%	0	0%	22	<1%
Domestic	0	–	0	0%	1,312	–	1,312	<1%	1,312	<1%	–	0%	1,312	<1%
Industrial	0	0	0	0%	56	0	56	<1%	56	<1%	0	0%	56	<1%
Irrigation	38,843	–	38,843	25%	7,701	–	7,701	5%	46,544	30%	–	0%	46,544	30%
Livestock	11	–	11	<1%	191	–	191	<1%	202	<1%	–	0%	202	<1%
Mining	0	0	0	0%	135	0	135	<1%	135	<1%	0	0%	135	<1%
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%	291	0	291	<1%	291	<1%	0	0%	291	<1%

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)*
	Fresh	Saline	Total	Total Use (%)*	Fresh	Saline	Total	Total Use (%)*	Fresh	Total Use (%)*	Saline	Total Use (%)*		
County Totals	**91,597**	**0**	**91,597**	**59%**	**63,785**	**0**	**63,785**	**41%**	**155,382**	**100%**	**0**	**0%**	**155,382**	**100%**

Source: Dieter et al. (2018)

Note: Water use data are presented in acre-feet unless otherwise indicated.

* Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 155,382 acre-feet.

Table 5-3. Sandoval County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)*
	Fresh	Saline	Total	Total Use (%)*	Fresh	Saline	Total	Total Use (%)*	Fresh	Total Use (%)*	Saline	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%	3,128	–	3,128	4%	3,128	4%	–	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	–	48,326	68%	2,320	–	2,320	3%	50,647	71%	–	0%	50,647	71%
Livestock	101	–	101	<1%	123	–	123	<1%	224	<1%	–	0%	224	<1%
Mining	0	0	0	0%	1,065	247	1,312	2%	1,065	1%	247	<1%	1,312	2%
Public Water Supply	135	0	135	<1%	12,466	0	12,466	17%	12,600	18%	0	0%	12,600	18%
Thermoelectric Power	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
County Totals	**48,562**	**0**	**48,562**	**68%**	**22,768**	**247**	**23,014**	**32%**	**71,329**	**100%**	**247**	**<1%**	**71,576**	**100%**

Source: Dieter et al. (2018)

Note: Water use data are presented in acre-feet unless otherwise indicated.

* Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 71,576 acre-feet.

Table 5-4. Valencia County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)*
	Fresh	Saline	Total	Total Use (%)*	Fresh	Saline	Total	Total Use (%)*	Fresh	Total Use (%)*	Saline	Total Use (%)*		
Aquaculture	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Domestic	0	–	0	0%	3,554	–	3,554	2%	3,554	2%	–	0%	3,554	2%
Industrial	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Irrigation	136,157	–	136,157	87%	10,089	–	10,089	6%	146,246	93%	–	0%	146,246	93%
Livestock	34	–	34	<1%	986	–	986	<1%	1,020	<1%	–	0%	1,020	<1%
Mining	0	0	0	0%	437	0	437	<1%	437	<1%	0	0%	437	<1%
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	**136,190**	**0**	**136,190**	**87%**	**20,604**	**0**	**20,604**	**13%**	**156,794**	**100%**	**0**	**0%**	**156,794**	**100%**

Source: Dieter et al. (2018)

Note: Water use data are presented in acre-feet unless otherwise indicated.

* Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 156,794 acre-feet.

Table 5-5. Torrance County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)*
	Fresh	Saline	Total	Total Use (%)*	Fresh	Saline	Total	Total Use (%)*	Fresh	Total Use (%)*	Saline	Total Use (%)*		
Aquaculture	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Domestic	0	–	0	0%	437	–	437	<1%	437	<1%	–	0%	437	<1%
Industrial	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Irrigation	0	–	0	<1%	45,849	–	45,849	94%	45,849	94%	–	0%	45,849	94%
Livestock	45	–	45	0%	605	–	605	1%	650	1%	–	0%	650	1%
Mining	0	0	0	0%	112	0	112	<1%	112	<1%	0	0%	112	<1%
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	<1%	0	0	0	0%	0	0%	0	0%	0	0%

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)*
	Fresh	Saline	Total	Total Use (%)*	Fresh	Saline	Total	Total Use (%)*	Fresh	Total Use (%)*	Saline	Total Use (%)*		
County Totals	**45**	**0**	**45**	**<1%**	**48,976**	**0**	**48,976**	**100%**	**49,021**	**100%**	**0**	**0%**	**49,021**	**100%**

Source: Dieter et al. (2018)

Note: Water use data are presented in acre-feet unless otherwise indicated.

* Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 49,021 acre-feet.

Table 5-6. Santa Fe County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)*
	Fresh	Saline	Total	Total Use (%)*	Fresh	Saline	Total	Total Use (%)*	Fresh	Total Use (%)*	Saline	Total Use (%)*		
Aquaculture	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Domestic	0	–	0	0%	2,522	–	2,522	6%	2,522	100%	–	0%	2,522	6%
Industrial	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Irrigation	11,378	–	11,378	29%	12,936	–	12,936	33%	24,314	100%	–	0%	24,314	62%
Livestock	56	–	56	<1%	67	–	67	<1%	123	100%	–	0%	123	<1%
Mining	0	0	0	0%	224	0	224	<1%	224	100%	0	0%	224	<1%
Public Water Supply	4,663	0	4,663	12%	7,186	0	7,186	18%	11,849	100%	0	0%	11,849	30%
Thermoelectric Power	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
County Totals	**16,098**	**0**	**16,098**	**41%**	**22,936**	**0**	**22,936**	**59%**	**39,033**	**100%**	**0**	**0%**	**39,033**	**100%**

Source: Dieter et al. (2018)

Note: Water use data are presented in acre-feet unless otherwise indicated.

* Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 39,033 acre-feet.

Table 5-7. Cibola County Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)*
	Fresh	Saline	Total	Total Use (%)*	Fresh	Saline	Total	Total Use (%)*	Fresh	Total Use (%)*	Saline	Total Use (%)*		
Aquaculture	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Domestic	0	–	0	0%	1,143	–	1,143	100%	1,143	11%	–	0%	1,143	11%
Industrial	0	0	0	0%	0	0	0	0%	0	0%	0	0%	0	0%
Irrigation	1,592	–	1,592	15%	3,856	–	3,856	71%	5,448	50%	–	0%	5,448	50%
Livestock	34	–	34	<1%	135	–	135	80%	168	2%	–	0%	168	2%
Mining	0	0	0	0%	67	1,356	1,424	100%	67	<1%	1,356	13%	1,424	13%
Public Water Supply	0	0	0	0%	2,668	0	2,668	100%	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	**1,625**	**0**	**1,625**	**15%**	**7,869**	**1,356**	**9,226**	**85%**	**9,495**	**88%**	**1,356**	**13%**	**10,851**	**100%**

Source: Dieter et al. (2018)

Note: Water use data are presented in acre-feet unless otherwise indicated.

* Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 10,851 acre-feet.

Table 5-8. RPFO Counties Water Use by Category in 2015

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)*
	Fresh	Saline	Total	Total Use (%)*	Fresh	Saline	Total	Total Use (%)*	Fresh	Total Use (%)*	Saline	Total Use (%)*		
Aquaculture	0	0	0	0%	1,110	0	1,110	<1%	1,110	<1%	0	0%	1,110	<1%
Domestic	0	–	0	0%	15,290	–	15,290	3%	15,290	3%	–	0%	15,290	3%
Industrial	0	0	0	0%	2,668	0	2,668	<1%	2,668	<1%	0	0%	2,668	<1%
Irrigation	237,394	–	237,394	48%	82,752	–	82,752	17%	320,146	65%	–	0%	320,146	65%
Livestock	381	–	381	<1%	2,477	–	2,477	<1%	2,859	<1%	–	0%	2,859	<1%
Mining	0	0	0	0%	3,666	2,287	5,953	1%	3,666	<1%	2,287	<1%	5,953	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%

Category	Surface Water				Groundwater				Total Withdrawals				Total	Total Use (%)*
	Fresh	Saline	Total	Total Use (%)*	Fresh	Saline	Total	Total Use (%)*	Fresh	Total Use (%)*	Saline	Total Use (%)*		
County Totals	**295,316**	**0**	**295,316**	**60%**	**198,271**	**2,287**	**200,558**	**40%**	**493,588**	**100%**	**2,287**	**<1%**	**495,874**	**100%**

Source: Dieter et al. (2018)

Note: Water use data are presented in acre-feet unless otherwise indicated.

* Total Use percentages for surface water, groundwater, and overall totals represent the proportion of each water use category out of the total water usage in 2015, which amounted to 495,874 acre-feet.

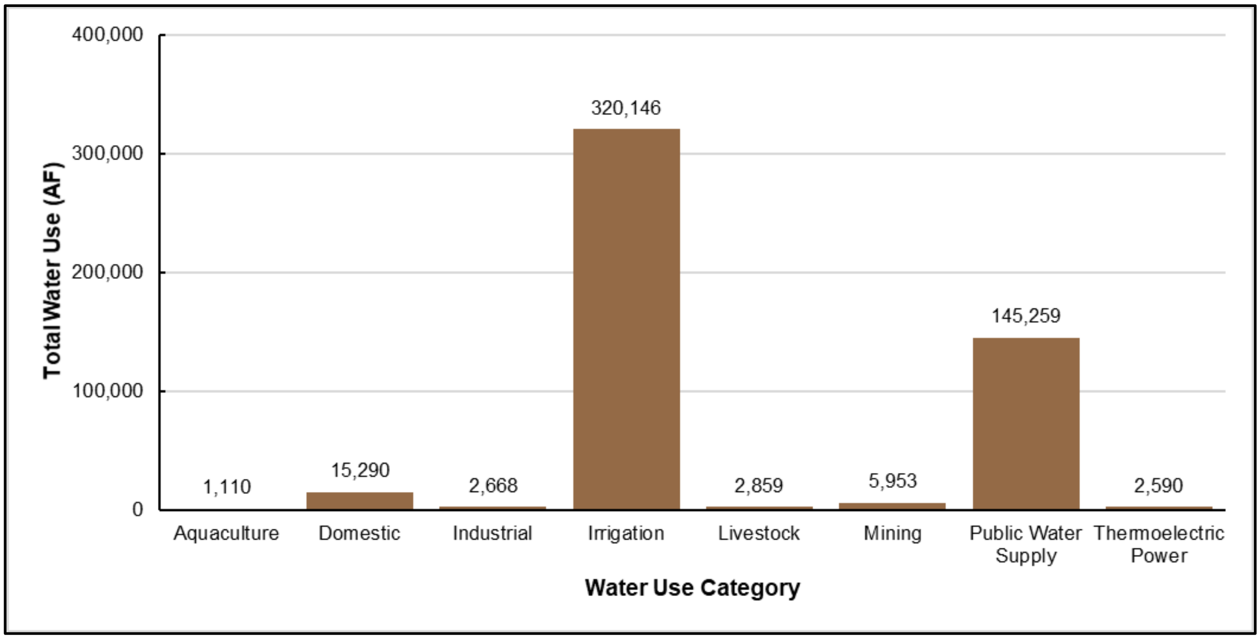

Figure 5-2. RPFO (Bernalillo, Cibola, Torrance, Valencia, Sandoval, McKinley, and Santa Fe Counties) water use by category in 2015 (Dieter et al. 2018).

5.1.2 Water Use Associated with Reasonably Foreseeable Oil and Gas Development

In 2019, a new RFD was published (Crocker et al. 2019) that updates the estimates for the number of oil and gas wells that could reasonably occur within the boundaries of the RPFO. Although the RPFO area encompasses several counties, the only county with consistent oil and gas well development is Sandoval County, with 12 wells. As such, oil and gas development scenarios and discussion in this chapter assume that all development will occur in the portion of Sandoval County within the RPFO area.

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

The 2019 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 reuse or recycling of hydraulic fracturing fluid. These are conservative water use estimates, as the 2019 RFD suggests that most wells would be vertical wells, which typically require less water to drill than horizontal wells. The quantity of water used during hydraulic fracturing is expected to increase from 8.34 to 22.49 AF/year from 2020 to 2039, with an estimated total water use of 308 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 et al. 2019).

Water used for development of the estimated 200 wells in the 2019 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 (see Table 5-3). Projected well developments within Sandoval County were estimated at 23.4% of the 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 Water Use Trends and Planned Actions

5.1.3.1 Past and Present Actions

Although there are well completions reported in the BLM Automated Fluid Minerals Support System, since 2014 there have been no completed oil and gas wells (federal or non-federal) reported to FracFocus within the administrative boundaries of the RPFO (FracFocus 2024a). Although there has been consistent development within Sandoval County, the completed oil and gas wells reported in FracFocus are within FFO area. As such, there are no data available from FracFocus for water use by oil and gas wells within RPFO boundaries, and statistical analysis and forecasting are not possible.

5.1.3.2 Water Use Associated with Reasonably Foreseeable Oil and Gas Development

The 2019 RFD (Crocker et al. 2019) predicted an initial development of seven 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 AF by 2039, resulting in a 20-year average water use of 15.4 AF/year and a total cumulative water use of 308 AF (Figure 5-3). 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 within the RPFO area. In contrast, no water usage associated with hydraulic fracturing has been reported to FracFocus for the RPFO during the 4 years in which FracFocus reporting overlaps with predictions from the 2019 RFD (see Figure 5-3). Despite this, water usage in neighboring Sandoval County is rapidly increasing due to hydraulic fracturing, indicating that oil and gas development in the RPFO may also increase, as predicted by the 2019 RFD. Consequently, cumulative water usage is likely to increase (see Figure 5-3).

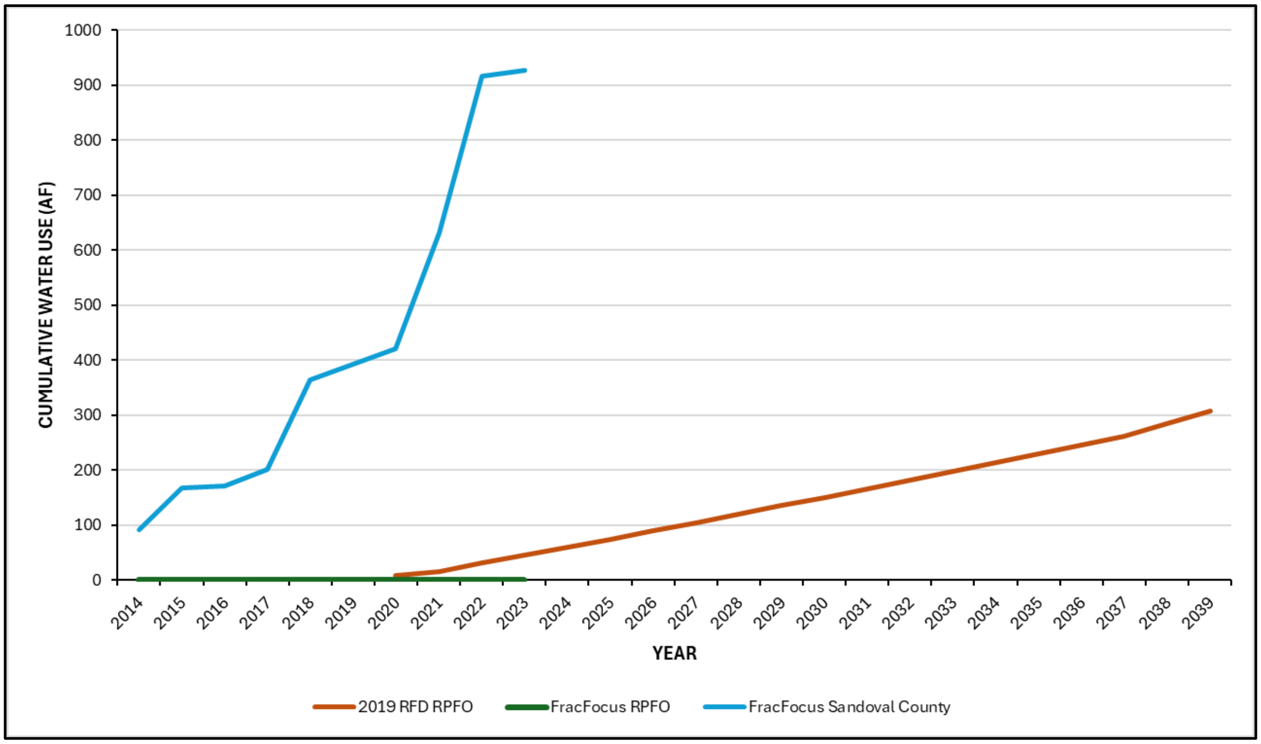

Figure 5-3. Cumulative water use associated with reasonably foreseeable oil and gas development in the RPFO from 2020 through 2039, and FracFocus water reporting for RPFO and Sandoval County from 2014 through 2023.

Water use estimates from the neighboring FFO area may also provide some insight regarding water use by oil and gas wells developed in the RPFO area in the future. From 2014 to 2022, 31 wells (federal and non-federal) in the portion of Sandoval County in the FFO area reported data to FracFocus (Section 4.1.2 discusses the water use associated with reasonably foreseeable oil and gas development in the FFO area). In 2023, no wells were reported to use slickwater stimulation; however three wells were reported to use nitrogen and carbon dioxide as a stimulation technique (Table 5-9). The relative distribution of stimulation technologies within a year varies greatly in the FFO area, which makes it difficult to predict total water usage. As such, the values provided in the 2019 RFD should be used for water use projections.

Table 5-9. Descriptive Statistics of Water Use of Oil and Gas Wells in the FFO Portion of Sandoval County for Two Stimulation Techniques in 2023

Stimulation Technique	Number of Wells
Nitrogen and carbon dioxide	3
Slickwater	0

Source: BLM (2022)

Note: Wells hydraulically fractured with water were identified as wells that did not use nitrogen or slickwater stimulation. Data are only presented for wells that reported chemical compositions to FracFocus (2024a).

5.1.4 Potential Sources of Water for Project Development

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

Because most water used in mining activities in the counties that compose the RPFO is currently from groundwater (see Table 5-8), it is reasonable to assume that a large portion of the water used for hydraulic fracturing under the 2019 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.

Information about the aquifers underlying the RPFO comes primarily from *Hydrologic Assessment of Oil and Gas Development of the Mancos Shale in the San Juan Basin* (Kelley et al. 2014) and *Farmington Proposed Resource Management Plan and Final Environmental Impact Statement* (BLM 2003b).The geologic setting of the region is highly stratified and complex. Geologic processes have created both continuous and discontinuous sandstone aquifers. There are 12 major confined aquifers in the San Juan Basin: San Jose Formation, Nacimiento Formation, 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 gpm (BLM 2003b). Other aquifers in the San Juan Basin are known to yield water at a rate of less than 20 gpm (BLM 2003b). 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, "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."

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 NMOCD and NMOSE. Water used for oil and gas drilling and completion would generally be obtained through the following methods:

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

It is difficult to predict the actual source of water that would be used for development of the RPFO RFD (or the development of any specific lease sales) because in addition to utilizing surface water or groundwater, operators may also bring water to a well site via truck from any number of sources. 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 5-10. General Description of the Major Rock Units in the San Juan Basin

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 Formation	Siltstone, sandstone	N/A
Oldest	Entrada Sandstone	Sandstone	Oil, gas, water

Source: Kelley et al. (2014)

Note: N/A = not applicable.

5.1.5 Water Use Mitigations

Public concern about water use from hydraulic fracturing is especially high in semiarid regions. 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 freshwater 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, difficult to treat, and often disposed through deep injection wells (Kondash et al. 2018). The NMED recently signed an MOU 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, while 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 indicates fast recharge rates influenced by geologic structures (Kelley et al. 2014).

The geologic formation where groundwater resides also influences groundwater salinity. Figure 5-4 (Kelley et al. 2014) is an illustrated geologic cross section showing the distribution of saline aquifers within the San Juan Basin.

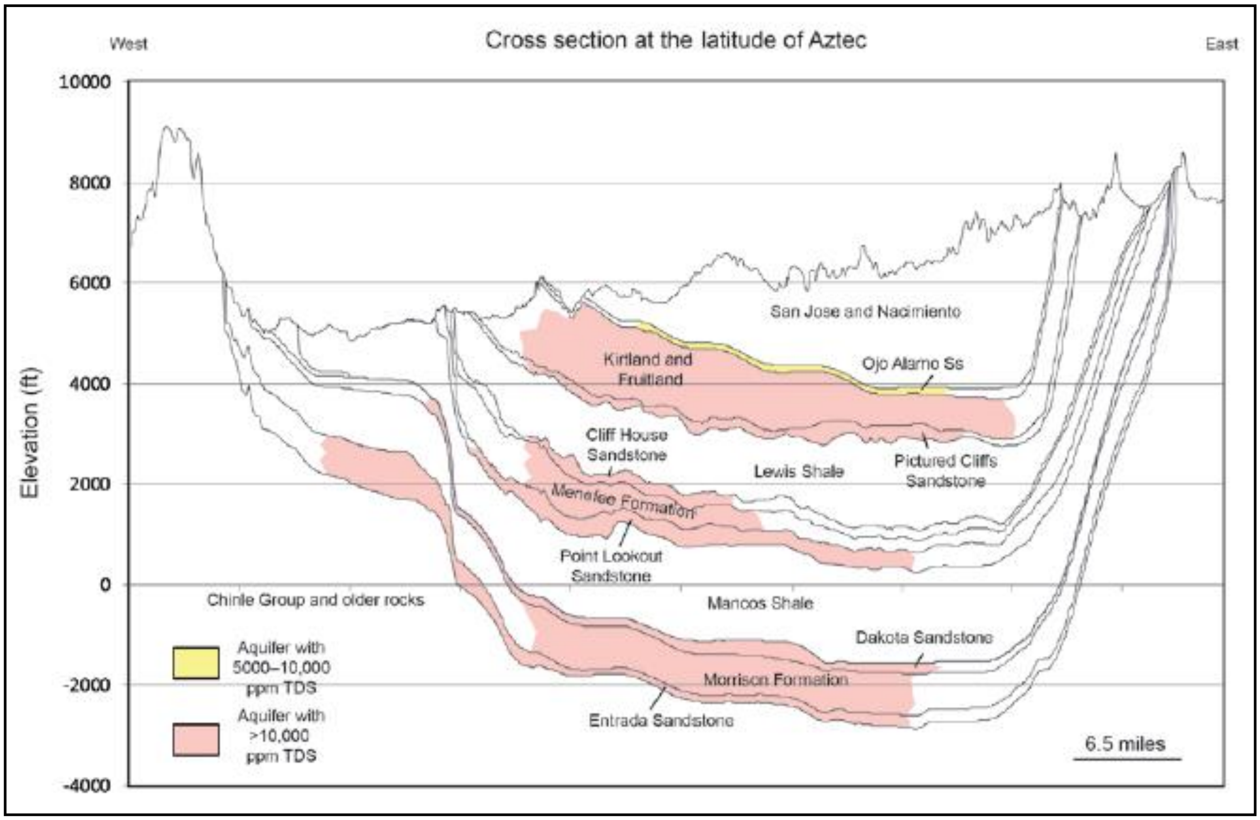

Figure 5-4. Geologic cross section showing the distribution of saline aquifers in the San Juan Basin (Kelley et al. 2014).

TDS concentration is a measure of 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 agricultural purposes such as 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 geologic formation where the water resides. Fresh water (TDS <1,000 mg/L) is typically found at depths less than 2,500 feet below the ground surface, although exceptions to this generalization occur in deeper layers such as the Gallup Sandstone and Morrison Formation. Saline and brackish water is dominant in the center of the basin at greater 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 lands is influenced by both natural water quality with regard to salinity content and the intensity of human and industrial activities 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 activities.

Further chemistry samples of surface water in the region are needed to establish 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 CWA.

5.2.3 Potential Sources of Surface Water or Groundwater Contamination

5.2.3.1 Spills

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

Spill data from NMOCD were retrieved from the spills database and further reviewed and summarized (NMOCD 2024a; see Appendix A).

A total of 121 spills occurred in the Rio Puerco portion of the San Juan Basin in 2023 (NMOCD 2024a) (Table 5-11 and Table 5-12). The percentage of a spill that was not recovered (the amount lost) varied by material that was spilled, but on average, about 100% of the spilled material was lost. Of the spills in 2023, no incidents were reported as having affected surface waterways (see Table 5-12) (NMOCD 2024a). The BLM works with NMOCD to remediate spills on BLM-managed lands. According to NMAC 19.15.29.11, the responsible person shall complete NMOCD-approved corrective action for releases that endanger public health or the environment in accordance with a remediation plan submitted to and approved by NMOCD or with an abatement plan submitted in accordance with NMAC 19.15.30. The remaining contaminants 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 performing corresponding chemical testing. See Table 5-11 for total spill counts from 2014 through 2023 and Table 5-12 for a breakdown of 2023 spills.

Table 5-11. Summary of Spills by Year in the Rio Puerco Portion of the San Juan Basin (Sandoval County)

Material Type†	Spill Count									
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Chemical (Specify)	1	0	0	0	0	0	0	0	0	0
Crude Oil	3	1	1	0	2	5	1	4	1	1
Other (Specify)	4	1	0	1	0	1	0	0	0	0
Produced Water	1	2	0	1	2	3	1	2	1	0
Natural Gas (Methane)	3	0	0	0	0	0	0	0	0	0
Natural Gas Flared	0	0	0	0	0	0	0	54	129	120
Natural Gas Vented	0	0	0	0	0	0	0	1	1	0
Total Gaseous Spill Count	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**55**	**130**	**120**
Total Liquid Spills	**9**	**5**	**1**	**2**	**4**	**9**	**2**	**6**	**2**	**1**

Note: No spills were reported in Bernalillo, Cibola, McKinley, Torrance, Valencia, or Santa Fe Counties in 2023.

Table 5-12. Summary of 2023 Spills in the Rio Puerco Portion of the San Juan Basin (Sandoval County)

Material Type*	Spill Count	Volume Spilled	Volume Lost	Units	Average Spill Volume	Percent Lost	Waterway Affected	Groundwater Affected
Crude Oil	1	19	19	bbl	19	100	0	0
Natural Gas Flared	120	106,316	106,316	mcf	886	100	0	0
Total Gaseous Spills	**120**	**106,316**	**106,316**	**mcf**	**886**	**100**	**0**	**0**
Total Liquid Spills	**1**	**19**	**19**	**bbl**	**19**	**100**	**0**	**0**

Source: NMOCD (2024b)

Note: bbl = barrels; mcf = thousand cubic feet.

Note: No spills were reported in Bernalillo, Cibola, McKinley, Torrance, Valencia, or Santa Fe Counties in 2023.

* No spills of brine water, condensate, chemicals, drilling mud/fluid, gelled brine (hydraulic fracturing fluid), other, glycol, sulfuric acid, lube oil, or natural gas (methane) were reported in 2023.

5.2.3.2 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 (TDS <10,000 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 NMOCD have casing, cementing, and inspection requirements in place to limit the potential for groundwater reservoirs and shallow aquifers to be impacted by hydraulic fracturing or the migration of hydrocarbons during oil and gas drilling and production activities. The BLM requires operators to comply with the regulations at 43 CFR § 3160. In addition, these regulations require oil and gas development to comply with directives in the Onshore Oil and Gas Orders and the orders of the Authorized Officer. The regulations at 43 CFR § 3162.3-3 and 43 CFR § 3170 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 (NMAC 19.15.16). Complying with the aforementioned regulations requires producers and regulators to verify the integrity of casing and cementing jobs. Casing specifications are designed and submitted to the BLM in a drilling plan as a component of 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 into the plan to protect usable groundwater. The aforementioned regulations and review practices surrounding proper casing and cementing procedures isolate usable water zones from drilling, completion/hydraulic fracturing fluids, and fluids from other mineral-bearing zones, including hydrocarbon-bearing zones. COAs may be attached to the APD, if necessary, to ensure groundwater protection. These may include requirements for closed loop drilling systems, spill prevention plans, leak detection plans, and appropriate equipment (leak detection and automatic shutoff system) in sensitive groundwater recharge areas. Casing and cementing operations are witnessed by certified BLM PETs. At the end of the well's economic life, the operator is required to submit a plugging plan to the BLM for approval. A BLM petroleum engineer will review the plan prior to commencement of plugging operations. The BLM PETs witness plugging operations to ensure the planned procedures are properly followed. The BLM's review, approval, and inspections ensure the permanent isolation of usable groundwater from hydrocarbon-bearing zones.

In summary, the BLM, the NMED, and NMOCD have put in place numerous requirements for oil and gas producers 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. These include BLM regulations covered under 43 CFR § 3160; 43 CFR § 3170; 43 CFR § 3162.3-3; 43 CFR § 3162.3-5; Notice to Lessees and Operators of Onshore Federal and Indian Oil and Gas Leases (NTL)-3A; NMOCD regulations under NMAC 19.15.26; and the state's primacy agreement under the Safe Drinking Water Act. With these requirements in place, including the use of casing and cementing measures, contamination of groundwater resources from development of the lease parcels is highly unlikely.
In addition, the BLM has authority under standard terms and conditions to require additional measures to protect water quality if site-specific circumstances require them. Site-specific mitigation tools would be developed as appropriate for the individual circumstances, including groundwater-quality monitoring studies. The regulations at 43 CFR § 3162.5-2(d) give the BLM the authority to require an operator to monitor water resources to ensure that the isolation procedures utilized to protect water and other resources are effective.

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APPENDIX A

Data Processing Information
(information on FracFocus, USGS, and spill data)

PURPOSE AND SCOPE

This appendix is intended to provide instructions and a description for processing the data included in the Water Support Document. For each dataset described in this appendix, various data processing applications may be used to process the data, depending on user preference (e.g., Excel or R statistical software [R]). Additionally, there are multiple approaches within each application to generate the same information (e.g., in Excel, the use of pivot tables, copying data into new tabs to use the Remove Duplicates button, or using filters; in R, various functions to aggregate and summarize data). Therefore, this appendix provides the basic methodology for data analysis and processing, so that the process can be replicated accurately by others or updated in subsequent years, as needed, due to changes in technologies, the inclusion of other operators' data, or other factors. In the Water Support Document, some counties span multiple field offices. In that instance, it is possible that a county can be associated with multiple field offices. Data for the county will be reported in full for each field office that it overlaps.

DATA SOURCES

Several sources of data were reviewed, compiled, and analyzed where appropriate to address all relevant topics of the Water Support Document. Table A-1 provides a summary of data sources and the context in which they are presented in the Water Support Document. Data for the sources listed in Table A-1—FracFocus, U.S. Geological Survey (USGS), and State of New Mexico Oil Conservation Division—are downloaded and analyzed per the methodologies described in the following sections. Other sources of data include state and federal agency reports that are reviewed and summarized to meet the informational requirements of the Water Support Document. Table A-1 provides an overview of major data sources used in the Water Support Document; however, the data sources listed are not comprehensive, and the final Water Support Document provides a comprehensive list of references that includes additional literature sources not listed in this table.

Table A-1. Data Sources by Water Support Document Topic

Water Support Document Topic	Data Source
Statewide water quantity data associated with oil and gas development	USGS Estimated Use of Water in the United States in 2015 (Dieter et al. 2018)
Summary of water use per well associated with oil and gas development	FracFocus (2024)
State of New Mexico spills	State of New Mexico Oil Conservation Division Permitting Spill Search (New Mexico Oil Conservation Division [NMOCD] 2021)

For data sources where data is downloaded and analyzed, all data are read, cleaned, summarized, and aggregated in R. R serves as a powerful tool for data manipulation, cleaning, summarization, aggregation, and visualization. Within R, data scientists can use a variety of functions and techniques tailored to specific needs to process raw data efficiently and accurately. In addition to its manipulation and analytical capabilities, R enables data scientists to perform detailed data quality checks, ensuring accuracy and reliability throughout the analysis process. The approach outlined herein represents the general approach to data processing and analysis. All code is on file with BLM and contains more specific, annotated data processing steps in addition to what is described in this appendix.

FRACFOCUS DATA PROCESSING INSTRUCTIONS

The FracFocus database serves as the national registry for hydraulic fracturing chemicals and water used in hydraulic fracturing across the United States. When FracFocus was initiated in 2011, many companies voluntarily disclosed hydraulic fracturing chemicals; however, some states later permitted disclosure to FracFocus to fulfill mandatory reporting requirements. As of August 2021, FracFocus emerged as the exclusive national regulatory reporting system used across many states. Housing a repository of data with more than 184,000 disclosures and exceeding 5 million chemical records sourced from over 1,600 registered companies, FracFocus stands as the best available resource for hydraulic fracturing data (FracFocus 2024).

Data Acquisition and Preparation

FracFocus data require substantial cleaning, processing, and data checks prior to reporting. After the dataset is read into R, the data are checked, reorganized, and summarized to develop summary reports for the Water Support Document. A master dataset is created that includes each state and the counties therein. The master dataset includes all the original data columns from the FracFocus registry and additional columns are created for easy downstream grouping and summarizing (e.g., unit conversions).

The following data checks are intended to evaluate and validate the consistency, completeness, and uniqueness of FracFocus data. In this process, records that do not meet the following data quality criteria are flagged and rejected from analysis. Flagged records are not deleted but are flagged in a new column in the data and are not included in further data aggregation. The following steps are taken to acquire, clean, organize, and generate the master dataset:

1. Download FracFocus data from https://fracfocus.org/data-download.
    a. The 2024 Water Support Document will consider FracFocus data from 2014 to 2023.
    b. The file named readme.txt in the data download packet is the FracFocus data dictionary and should be retained with the original downloads.
    c. FracFocus data are divided into registries (Registry 1 through Registry 13) to reduce file size. Each registry can be read into R simultaneously as a CSV file.
2. Filter all data to isolate data for desired years (e.g., 2014–2023) and states using column heading JobStartDate, which is the “date on which the hydraulic fracturing job was initiated” (FracFocus 2024) and state (e.g., New Mexico).
3. Screen the data and perform quality control.
    a. Create a new column—Job—containing the well name and the start date. For the purpose of this analysis, a drilling activity (a job) is defined as the job start date (“JobStartDate”) and the well name (“WellName”).
    b. Code will be applied to create three additional columns: Month, Day, and Year, each containing the corresponding parts of the date. For example, **"2024-04-11"** will be recoded as 2024, April, and 11 within three separate columns for each state.
        i. The same well may have multiple job start dates within the same year; however, these are not necessarily duplicate entries. The “Job” column will contain a hyper-unique ID based on the well, American Petroleum Institute (API) number, month, day, year, and time that can be used to determine if there is a duplicate entry for any given job within a year. If so, duplicate entries will be assessed and the entry with the average reported water usage will be recorded for the summary. Otherwise, all other jobs using the same well within the same year

represent unique jobs within the same well, and their water volumes are counted separately.

c. Check the API well identification numbers. API numbers are assumed to be a unique identifier in the data, and there should be a 1:1 relationship between API number and well name. Differing well names having the same API number should be flagged and rejected from the final summary, as this indicates a non-unique API number (e.g., a 1:2 relationship). Similarly, if the same well name is given two different API numbers, these records should be flagged and rejected from the analysis.

d. Check well designations for accuracy. Federal well designations should be mutually exclusive. A well can either be federal or non-federal but not both. Wells that are given both designations will be reclassified as non-federal wells.

e. Check total base water volume data for accuracy. Any row where TotalBaseWaterVolume = 0 gallons should be flagged and rejected from analysis based on the assumption that all drilling activities require water. Therefore, if a well reports 0 gallons of water use, it is likely erroneous data and should be rejected from analysis.

    i. For each job (note that a job is the well name and job start date) in the FracFocus data, there are several rows to document the various ingredients and chemicals used in the drilling activity, and the total base water volume is duplicated in each row for the specific ingredient. Therefore, the duplicate entries for total base water volume will be averaged across each job in R to generate one volume per job.

Unit Conversions

Water use in FracFocus is reported in gallons and water use in the Water Support Document is reported in AF. The following conversion factors can be used to convert from gallons to AF and vice-versa:

1 AF = 325,851 gallons
1 gallon = 3.0689 x 10^{-6} AF

Data Aggregation

To present the summarized information in tables summarizing water use by oil and gas wells for hydraulic fracturing in New Mexico from 2014 through 2023, FracFocus data are processed and aggregated by various factors such as year and water use by both federal and non-federal wells. The following instructions describe the general process by which the summarized totals are obtained.

Data aggregation and table construction will be conducted using the dplyr package in R, which easily summarizes data based on defined grouping schemes (e.g., mean county water usage by year). Data tables will be built in R and used to populate tables within the Water Support Document. The following data summaries will be conducted at the state and regional level and will only include water usage associated with hydraulic fracturing jobs:

1. **Federal Water Use**: The sum of the total base water volumes for each federal job in AF.
2. **Non-Federal Water**: The sum of the total base water volumes for each non-federal job in AF.
3. **Total Water Use**: The accumulating sum of base water volumes for federal, tribal, and non-federal jobs from 2014 to 2023 in AF.
4. **Federal Water Use (%)**: The percentage of federal water use out of the total water use.

5. **Federal Combined Water Use:** For any given year in the FracFocus data, the federal cumulative water use is that year's federal water use plus the sum of all previously reported federal water use estimates.
    a. For example: $2020_{FCWU} = 2020_{FWU} + 2019_{FWU} + 2018_{FWU} + 2017_{FWU} + 2016_{FWU} + 2015_{FWU} + 2014_{FWU}$
    b. FCWU = federal cumulative water use
    c. FWU = federal water use
6. **Total Combined Water Use**: The year's total water use plus the sum of all previously reported total water use estimates.
7. **Average Water Use Per Well**: The average water use for federal, tribal, and non-federal wells.
8. **Total Well Count**: The total number of federal, tribal, and non-federal wells in a given year.

U.S. GEOLOGICAL SURVEY DATA PROCESSING INSTRUCTIONS

The following processes are intended to guide obtaining data from the USGS 2015 data file to include in the state and field office water use tables throughout the Water Support Document.

Data Acquisition and Preparation

Download *Estimated Use of Water in the United States County-Level Data for 2015* (Dieter et al. 2018) from https://www.sciencebase.gov/catalog/item/get/5af3311be4b0da30c1b245d8; file name usco2015v2.0.xlsx All Data XLSX.

Data Aggregation

To present the summarized water use data in tables throughout the Water Support Document, USGS data are processed and aggregated by state and county. The instructions below describe the process by which the summarized totals are obtained.

State of New Mexico Water Use: For each county in the USGS data, there are many columns to document the various types of water usage. The total water use is listed per county in each state, so the total water use per category for the state must be manually generated. Follow the steps listed below to generate totals for the state of New Mexico.

1. Isolate data for the state of New Mexico using the column titled STATE, copy the data to a new tab, and generate state grand total values (in AF). The grand total values should be a sum of all county values for each water use.
    a. Columns selected for values can include all columns.
    b. Retain the Excel data dictionary with the original data using the DataDictionary tab in the downloaded data file.
2. Once the grand totals are calculated, copy and paste data into a new tab as values, making sure to transpose the data.
    a. It is helpful to set up a definition lookup table for the abbreviated column names by using the translations found in the DataDictionary tab in the original data during this step.

3. Filter all data so the column tag can be filtered to fill out data tables later.

County Water Use: Similar to state water use, county water use is generated for each county in each field office. The following steps are used to prepare the data for the County Water Use data table entry.

1. Isolate data by filtering the original data by STATE = NM. For each county, use the column titled COUNTY to filter data further.
2. Create a new row to generate totals per field office and use the =sum Excel formula to sum each county value per water use.

Unit Conversions

Water use in the USGS data is reported in million gallons per day (MGD), and water use in the Water Support Document is reported in AF. The following conversion factors can be used to convert gallons to AF and vice-versa.

$$\text{Grand total in AF per year} = (\text{Grand Total [MGD]} \times 1.121) \times 1{,}000$$

Data Tables

To present the summarized information in Table 2-1, State of New Mexico Water Use by Category in 2015, in the Water Support Document and individual county water use data included in each field office chapter, USGS data are processed and aggregated. The following instructions describe the process by which the summarized total water use values are obtained. These instructions provide specific column names in the USGS data to guide data entry.

State of New Mexico Water Use: State water use for each water use category is included in the USGS data. Each entry in Table 2-1 in the Water Support Document corresponds with a specific column header in the USGS data. For each category and water use (surface water, groundwater, and total withdrawals), refer to Figure A-1 when pulling data from the USGS data. Text in Figure A-1 and associated data dictionary terms in Table A-2 refer to the specific column tag that should be used for each data entry.

County Water Use: Similar to state water use, county water use is generated for each county in each field office. Using the specific county data of interest and Figure A-1, data can be entered into tables in each field office section of the Water Support Document.

Total Water Use Percentage: The total water use percentage is generated individually by dividing the total water use of a specific category in either surface water, groundwater, or total withdrawals by the total water use for the state, county, or field office of interest. See Figure A-1 and Table A-2 for guidance.

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	AQ-WSWFr	AQ-WSWSa	AQ-WSWTo	AQ-WSWTo / TO-Wtotl	AQ-WGWFr	AQ-WGWSa	AQ-WGWTo	AQ-WGWTo / TO-Wtotl	AQ-WFrTo	AQ-WFrTo / TO-Wtotl	AQ-WSaTo	AQ-WSaTo / TO-Wtotl	AQ-Wtotl	AQ-Wtotl / TO-Wtotl
Domestic	DO-WSWFr	---	DO-WSWFr	DO-WSWFr / TO-Wtotl	DO-WGWFr	---	DO-WGWFr	DO-WGWFr / TO-Wtotl	DO-WFrTo	DO-WFrTo / TO-Wtotl	--	DO-WFrTo / TO-Wtotl	DO-WFrTo	DO-WFrTo / TO-Wtotl
Industrial	IN-WSWFr	IN-WSWSa	IN-WSWTo	IN-WSWTo / TO-Wtotl	IN-WGWFr	IN-WGWSa	IN-WGWTo	IN-WGWTo / TO-Wtotl	IN-WFrTo	IN-WFrTo / TO-Wtotl	IN-WSaTo	IN-WSaTo / TO-Wtotl	IN-Wtotl	IN-Wtotl / TO-Wtotl
Irrigation	IR-WSWFr	---	IR-WSWFr	IR-WSWFr / TO-Wtotl	IR-WGWFr	---	IR-WGWFr	IR-WGWFr / TO-Wtotl	IR-WFrTo	IR-WFrTo / TO-Wtotl	--	IR-WFrTo / TO-Wtotl	IR-WFrTo	IR-WFrTo / TO-Wtotl
Livestock	LI-WSWFr	----	LI-WSWFr	LI-WSWFr / TO-Wtotl	LI-WGWFr	---	LI-WGWFr	LI-WGWFr / TO-Wtotl	LI-WFrTo	LI-WFrTo / TO-Wtotl	--	LI-WFrTo / TO-Wtotl	LI-WFrTo	LI-WFrTo / TO-Wtotl
Mining	MI-WSWFr	MI-WSWSa	MI-WSWTo	MI-WSWTo / TO-Wtotl	MI-WGWFr	MI-WGWSa	MI-WGWTo	MI-WGWTo / TO-Wtotl	MI-WFrTo	MI-WFrTo / TO-Wtotl	MI-WSaTo	MI-WSaTo / TO-Wtotl	MI-Wtotl	MI-Wtotl / TO-Wtotl
Public Water Supply	PS-WSWFr	PS-WSWSa	PS-WSWTo	PS-WSWTo / TO-Wtotl	PS-WGWFr	PS-WGWSa	PS-WGWTo	PS-WGWTo / TO-Wtotl	PS-WFrTo	PS-WFrTo / TO-Wtotl	PS-WSaTo	PS-WSaTo / TO-Wtotl	PS-Wtotl	PS-Wtotl / TO-Wtotl
Thermoelectric	PT-WSWFr	PT-WSWSa	PT-WSWTo	PT-WSWTo / TO-Wtotl	PT-WGWFr	PT-WGWSa	PT-WGWTo	PT-WGWTo / TO-Wtotl	PT-WFrTo	PT-WFrTo / TO-Wtotl	PT-WSaTo	PT-WSaTo / TO-Wtotl	PT-Wtotl	PT-Wtotl / TO-Wtotl
Totals	**TO-WSWFr**	**TO-WSWSa**	**TO-WSWTo**	**TO-WSWTo / TO-Wtotl**	**TO-WGWFr**	**TO-WGWSa**	**TO-WGWTo**	**TO-WGWTo / TO-Wtotl**	**TO-WFrTo**	**TO-WFrTo / TO-Wtotl**	**TO-WSaTo**	**TO-WSaTo / TO-Wtotl**	**TO-Wtotl**	**TO-Wtotl / TO-Wtotl**

Figure A-1. Abbreviated column names for water use tables.

Source: FracFocus (2024)

Table A-2. Data Dictionary Terms and Associated Abbreviated Column Names for Water Use Data (Dieter et al. 2018)

Dictionary Term	Abbreviated Column Name
Aquaculture, groundwater withdrawals, saline	AQ-WGWSa
Aquaculture, groundwater withdrawals, total	AQ-WGWTo
Aquaculture, surface-water withdrawals, fresh	AQ-WSWFr
Aquaculture, surface-water withdrawals, saline	AQ-WSWSa
Aquaculture, surface-water withdrawals, total	AQ-WSWTo
Aquaculture, total withdrawals, saline	AQ-WSaTo
Aquaculture, total withdrawals, total (fresh+saline)	AQ-Wtotl
Aquaculture, total withdrawals, fresh	AQ-WFrTo
Domestic, self-supplied groundwater withdrawals, fresh	DO-WGWFr
Domestic, self-supplied surface-water withdrawals, fresh	DO-WSWFr
Domestic, total self-supplied withdrawals, fresh	DO-WFrTo
Industrial, self-supplied groundwater withdrawals, fresh	IN-WGWFr
Industrial, self-supplied groundwater withdrawals, saline	IN-WGWSa
Industrial, self-supplied groundwater withdrawals, total	IN-WGWTo
Industrial, self-supplied surface-water withdrawals, fresh	IN-WSWFr
Industrial, self-supplied surface-water withdrawals, saline	IN-WSWSa
Industrial, self-supplied surface-water withdrawals, total	IN-WSWTo
Industrial, self-supplied total withdrawals, saline	IN-WSaTo
Industrial, self-supplied total withdrawals, total (fresh+saline)	IN-Wtotl
Irrigation, groundwater withdrawals, fresh	IR-WGWFr
Irrigation, surface-water withdrawals, fresh	IR-WSWFr
Irrigation, total withdrawals, fresh	IR-WFrTo
Livestock, groundwater withdrawals, fresh	LI-WGWFr
Livestock, surface-water withdrawals, fresh	LI-WSWFr
Livestock, total withdrawals, fresh	LI-WFrTo
Mining, groundwater withdrawals, fresh	MI-WGWFr
Mining, groundwater withdrawals, saline	MI-WGWSa
Mining, groundwater withdrawals, total	MI-WGWTo
Mining, surface-water withdrawals, fresh	MI-WSWFr
Mining, surface-water withdrawals, saline	MI-WSWSa
Mining, surface-water withdrawals, total	MI-WSWTo
Mining, total withdrawals, fresh	MI-WFrTo
Mining, total withdrawals, saline	MI-WSaTo
Mining, total withdrawals, total (fresh+saline)	MI-Wtotl
Public Supply, groundwater withdrawals, fresh	PS-WGWFr
Public Supply, groundwater withdrawals, saline	PS-WGWSa
Public Supply, groundwater withdrawals, total	PS-WGWTo

Dictionary Term	Abbreviated Column Name
Public Supply, surface-water withdrawals, fresh	PS-WSWFr
Public Supply, surface-water withdrawals, saline	PS-WSWSa
Public Supply, surface-water withdrawals, total	PS-WSWTo
Public Supply, total withdrawals, fresh	PS-WFrTo
Public Supply, total withdrawals, saline	PS-WSaTo
Public Supply, total withdrawals, total (fresh+saline)	PS-Wtotl
Thermoelectric, groundwater withdrawals, fresh	PT-WGWFr
Thermoelectric, groundwater withdrawals, saline	PT-WGWSa
Thermoelectric, groundwater withdrawals, total	PT-WGWTo
Thermoelectric, surface-water withdrawals, fresh	PT-WSWFr
Thermoelectric, surface-water withdrawals, saline	PT-WSWSa
Thermoelectric, surface-water withdrawals, total	PT-WSWTo
Thermoelectric, total withdrawals, saline	PT-WSaTo
Thermoelectric, total withdrawals, total (fresh+saline)	PT-Wtotl
Thermoelectric, total withdrawals, fresh	PT-WFrTo
Total groundwater withdrawals, fresh	TO-WGWFr
Total groundwater withdrawals, saline	TO-WGWSa
Total groundwater withdrawals, total (fresh+saline)	TO-WGWTo
Total surface-water withdrawals, fresh	TO-WSWFr
Total surface-water withdrawals, saline	TO-WSWSa
Total surface-water withdrawals, total (fresh+saline)	TO-WSWTo
Total withdrawals, fresh,	TO-WFrTo
Total withdrawals, saline	TO-WSaTo
Total withdrawals, total (fresh+saline)	TO-Wtotl

SPILL DATA ANALYSIS METHODOLOGY

Spill data are available for download from the NMOCD spills database (NMOCD 2021). The entire spills database contains records with incident dates ranging from 1900 to 2024 (at the time this update to the report was written). For each update to this report, spill data are analyzed for the year of the report revision. For example, the 2020 Water Support Document summarized records in the spills database with incident dates in the year 2020. Spill data for New Mexico include the quantity of each reported spill, the amount recovered, impacts to surface water, and impacts to groundwater.

A spills data dictionary from NMOCD is not available to accompany the data. Therefore, several assumptions and definitions were made about the data that are summarized below. These data checks are intended to evaluate and validate the consistency, completeness, and uniqueness of spill data. In this process, records that do not meet the data quality criteria are flagged and rejected from analysis. Flagged records are not deleted but are marked as ‘Flagged’ in a new column in the data and are not included in further data aggregation.

Data Acquisition and Preparation

After each state dataset is read into R, a master dataset is created that includes relevant data for this analysis. The master dataset includes the following information:

- County
- Date of incident
- Spill material
- Quantity of spill
- Quantity of spill recovered
- Percentage of spill recovered
- Waterway or groundwater affected

To create this dataset, the following step is taken:

1. The columns above will be extracted or calculated when applicable from the New Mexico state dataset in R and stored in a new data frame.
    a. This step will remove all additional column data not relevant to this report.

The above step will yield a dataset that will be easy to use and filter according to the county of interest. However, data entries will still need to be checked for quality, and spill entries with no defined quantity will need to be quantified accordingly. These data checks are intended to evaluate and validate the consistency, completeness, and uniqueness of spill data. In this process, records that do not meet the data quality criteria are flagged and are rejected from analysis. Flagged records are not deleted but are reclassified in a new column to ensure that quantitative data are not lost; however, data limitations and mistakes are accounted for in each entry. For example, if a spill type is not clear, the entry would be reclassified as “Spill Type: Unknown.” To further clean and process the master spill dataset, the following steps will be taken for each of the data columns defined above.

1. *Date of Incident* will be split into month, day, and year. Code will be applied to create three additional columns (i.e., Month, Day, and Year) that will each contain the corresponding parts of the date. For example, **"2024-04-11"** will be recoded as 2024, April, and 11.
    a. Data structure will be checked, and problematic date entries will be corrected, if possible; otherwise, data will be mutated and defined as “Unknown Date.”
2. *Type of Spill* will be factored to ensure that all entries are consistent. Ambiguous entries will be corrected (e.g., misspelling) if possible; otherwise, ambiguous or undefined data entries will be mutated and defined as “Other.” Spill type data will include multiple levels based on the types of spills reported (e.g., gasoline, pipeline, crude oil, water, natural gas, other).
3. *Quantity of Spill* will require numeric data quality checks.
    a. New Mexico spill data generally include sufficient numeric data on spill quantity and quantity recovered. However, occasional spill entries are not defined, or are classified as “0.” Often, these entries coincide with small-scale spills. For this analysis, “0” or missing entries are removed from the analysis.
4. *Quantity of Spill Recovered* will be denoted as a percentage of the original volume of oil spilled.
5. *Waterway or Groundwater Affected* is reported as unknown, surface water, non-surface water, or groundwater.

Unit Conversions

Spills within the New Mexico dataset may be reported differently. All oil spills are reported in barrels (bbl) or gallons, and all gaseous spills are reported in thousands of cubic feet (mcf). In R, code is applied to universalize spill reporting and ensure all spill types are reported correctly and consistently. Values will be converted accordingly, and units will be updated.

Conversion examples:

- Gallons to barrels: $bbl = gallons \times 0.023810$
- Barrels to thousands of cubic feet: $MCF = Bbl / 5.615$

Data Screening and Quality Control

- For the purpose of this report, a *spill* is defined as the loss of a measurable volume of a material on the same day.
- The incident number is not unique, and for any one incident number, there may be many spill materials.
- Incidents where the volume released is 0 are flagged and rejected from further analysis because these records are not in alignment with the definition of a spill, where a measurable volume of material has been released.
- Incidents where the unit of volume is not volumetric (e.g., pounds) are flagged and rejected from analysis.
- Records where the spill material type is natural gas (methane) or natural gas liquids should be reported in mcf and not bbl. Records where spilled material is natural gas (methane) and natural gas liquids and the unit of volume is bbl will be rejected from analysis. Records where the material is natural gas flared or vented are not counted in the spills summary on the assumption that these are lost to the air.

Data Aggregation

Once the data have been cleaned and a master dataset has been generated that consists of spills at the county levels, data will be filtered and grouped by field office. Data aggregation and table construction will be conducted using the dplyr package in R, which easily summarizes data based on defined grouping schemes (e.g., mean spill quantity by year). State and regional data will be grouped by the date of spill and type of spill, and summary tables will be generated to report the quantity of spill, quantity of spill recovered, and percentage of spill recovered. The tables include a column that specifies whether a waterway was affected by the spill.

Spill Count: Spill count is the number of spill records within a field office for a particular material.

Volume Spilled: Volume released is a sum of the volume released for all spills of a particular material within a field office. The data should be filtered to remove the flagged data.

Volume Lost: Volume lost is a sum of the volume lost for all spills of a particular material within a field office. The data should be filtered to remove the flagged data.

Average Spill Volume: Average volume spilled is an average of the volume released for all spills or all types of material within a field office. Data should be filtered to not include flagged data.

Percentage Lost: Percentage lost is the percentage of the volume spilled that was also lost. An average of percentage lost for all material spilled in a field office can be used to calculate the average percent of volume lost in spills across the entire field office for all spills.

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APPENDIX B

Farmington Field Office Slickwater Stimulation Water Use Update

ASSUMPTIONS

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

PURPOSE OF THE UPDATE

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

CONTEXT

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

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

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

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

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

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

METHODOLOGY FOR WELL COMPLETION TYPE DETERMINATION

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

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

METHODOLOGY FOR PROJECTED WATER USE

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

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

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

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

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

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

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

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

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

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

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

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

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

CONCLUSIONS

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

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