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

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

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U.S. Department of the Interior
Bureau of Land Management:
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LIST OF ACRONYMS AND ABBREVIATIONS

AF	acre-feet
APD	Application for Permit to Drill
bbl	barrel
BLM	Bureau of Land Management
CAS	Chemical Abstracts Service
CFO	Carlsbad Field Office
C.F.R.	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
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
NMOCD	New Mexico Oil Conservation Division
NMOSE	New Mexico Office of the State Engineer
NMSO	New Mexico State Office
NMWQCC	New Mexico Water Quality Control Commission
PDO	Pecos District Office
PET	petroleum engineer technician
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
SDS	safety data sheet
TDS	total dissolved solids
USGS	U.S. Geological Survey
WIPP	Waste Isolation Pond 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), the Farmington Field Office (FFO), and the Rio Puerco Field Office (RPFO).

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 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 (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 will be gathered and evaluated on an as-needed basis during the leasing NEPA process. 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 occurs.
- 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. Chapter 3 summarizes water quantity and quality data for the PDO, 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 and the RPFO, 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.”

An updated report is expected in 2023 for water use across the United States from 2018 to 2022. This updated report was not available at the time of drafting this document. 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 2022a). FracFocus was initially created to provide a place for publicly available information regarding chemicals used during hydraulic fracturing. Currently, 27 states require oil and gas operators to disclose information to FracFocus for any hydraulically fractured well (FracFocus 2022b). 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, 2021 spill data from the NMOCD database (NMOCD 2022a) 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.

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 2022 Water Support Document discusses calendar year 2021 spill data downloaded from the NMOCD database in January (or later) 2022. 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 report updates. At the time of drafting this 2022 report, new USGS data were not available. It is anticipated that water use by category data from the USGS for the years of 2018 through 2022 will be included in the 2023 Water Support Document.

New data are input into the FracFocus registry throughout the year. The 2022 Water Support Document considers FracFocus data from 2014 through 2021. To maintain consistency in data included in annual Water Support Document updates, FracFocus data will be pulled on January 1 every year. For example, the 2022 Water Support Document includes all data from January 1, 2014, through December 31, 2021.

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, etc.) 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. The BLM field offices that intersect these oil-producing areas are the FFO and RPFO, which intersect the San Juan Basin, and the PDO, which intersects the Permian Basin (Figure 2-1).

New Mexico ranks third in the United States in the production of oil (World Population Review 2022). In 2021, the state of New Mexico produced 451,363,671 barrels of oil (NMOCD 2022b). 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. Of the approximately 20 million acres in the total PDO planning area boundary, about 2.3 million acres have already been leased for oil and gas development (Purcell 2020). The RFO, CFO, and the Las Cruces District Office overlap the Permian Basin (see 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 2021, 7,905,903 barrels of oil were produced from the San Juan Basin (NMOCD 2022b). 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 FFO, RPFO, and the Taos Field Office overlap the San Juan Basin (see Figure 2-1).

The Las Cruces Field Office and Taos Field Office 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.

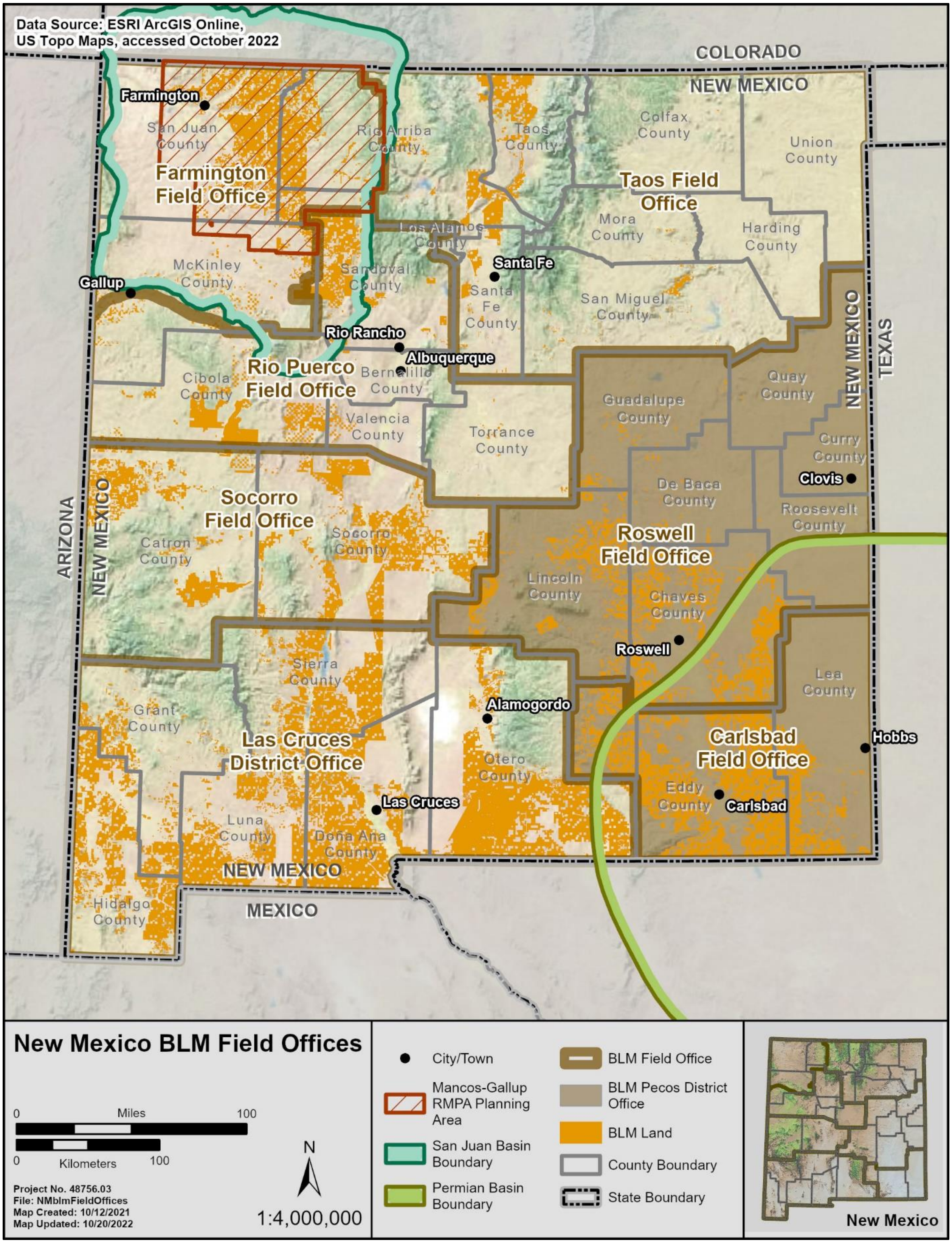


Figure 2-1. New Mexico BLM field offices and basin boundaries.

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. Water withdrawals within the state were equally split between surface water and groundwater. Thermoelectric power and irrigation used proportionally more surface water than groundwater (82% and 56%, respectively), whereas the remaining sectors primarily consumed groundwater.

Total annual water use by oil and gas wells throughout New Mexico increased in all but 2 years, and totals ranged from 3,939 AF in 2014 to 49,349 AF in 2021. In the same time frame (2014–2021), average water use per well increased from 6.0 AF in 2014 to 51.0 AF in 2021 (Table 2-2) (FracFocus 2022a). The 8-year average (2014–2021) water use was 29.0 AF per well. Water use for federal wells (as a percentage of water use for all wells) varies and ranged from a low of 12.8% in 2016 to a high of 48.1% in 2015. From 2014 through 2021, cumulative water use within New Mexico totaled 579,023 AF, with federal wells comprising 11.6% (67,094 AF). From 2014 through 2021, 6,033 total wells (includes all ownership/management jurisdictions) were reported to FracFocus, with an average of 754 wells per year (FracFocus 2022a).

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 2021 was water, with 17,353 disclosures (Table 2-3). Other frequent disclosures were crystalline silica, quartz (n = 6,532) and methanol (n = 6,301). There were 21,909 records of non-disclosed chemicals entered in the FracFocus database (FracFocus 2022a). 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.

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 2022a) (see Appendix A). In 2021, there were a total of 15,196 spills across the state associated with federal and non-federal oil and gas wells and facilities (Table 2-4) (NMOCD 2022a). The average percentage of the spill volume that was lost (volume lost divided by volume released) varies by spill type, but the average spill volume that was lost (not recovered) for all state spill types was 69% (NMOCD 2022a).

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 2-1. 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	56%	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).

Table 2-2. Water Use by Oil and Gas Wells for Hydraulic Fracturing in New Mexico from 2014 through 2021

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	1,433	2,507	3,939	36.4	1,433	3,939	6.0	657	115,050
2015	4,041	4,357	8,398	48.1	5,474	12,338	14.6	575	116,696
2016	874	5,975	6,849	12.8	6,348	19,186	20.4	335	110,337
2017	3,341	11,030	14,370	23.2	9,689	33,557	24.7	582	114,487
2018	9,171	22,336	31,508	29.1	18,860	65,065	28.9	1,090	135,347
2019	10,415	31,443	41,858	24.9	29,275	106,923	38.5	1,088	159,539
2020	13,105	24,306	37,410	35.0	42,379	144,333	50.7	738	171,355
2021	24,714	24,635	49,349	50.1	67,094	193,682	51.0	968	204,093

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
Total	**67,094**	**126,589**	**193,681**	**32.5%**	**-**	**-**	**32.0†**	**6,033**	**1,126,904**

Source: FracFocus (2022a). Data only for those wells that reported water usage to FracFocus are presented; produced water data are from NMOCD (2022b).

Note: All water use data are presented in acre-feet. Produced water is naturally occurring water that exists in a formation that is being targeted for mineral extraction and is produced as a byproduct.

* Includes both federal and non-federal wells.

† 8-year average (2014–2021).

Table 2-3. Most Frequently Disclosed Constituents Reported to FracFocus within New Mexico from 2014 through 2021

Ingredient Name	CAS Registry Number	Number of Disclosures	Percentage of Hydraulic Fracturing Job*	Percentage of Total Number of FracFocus Disclosures†
Not disclosed	NA	21,909	2%	10%
Water	7732-18-5	17,353	38%	8%
Crystalline silica, quartz	14808-60-7	6,532	6%	3%
Methanol	67-56-1	6,301	<1%	3%
Distillates (petroleum), hydrotreated light	64742-47-8	5,572	<1%	3%
Hydrochloric acid	7647-01-0	5,027	1%	2%
Isopropanol	67-63-0	3,025	<1%	1%
Glutaraldehyde	111-30-8	2,954	<1%	1%
Sodium chloride	7647-14-5	2,794	<1%	1%
Alcohols, C12-16, ethoxylated	68551-12-2	2,659	<1%	1%
Ammonium chloride	12125-02-9	2,597	<1%	1%
Ethylene glycol	107-21-1	2,429	<1%	1%
Crystalline silica	14808-60-7	2,286	7%	1%
Guar gum	9000-30-0	2,137	<1%	1%
Sodium hydroxide	1310-73-2	2,050	<1%	1%
Propargyl alcohol	107-19-7	1,948	<1%	1%
Acetic acid	64-19-7	1,928	<1%	1%
Ammonium persulfate	7727-54-0	1,923	<1%	1%

Ingredient Name	CAS Registry Number	Number of Disclosures	Percentage of Hydraulic Fracturing Job*	Percentage of Total Number of FracFocus Disclosures†
Ethanol	64-17-5	1,807	<1%	1%
Proprietary	Proprietary	1,795	<1%	1%
Citric acid	77-92-9	1,493	<1%	1%
Sodium perborate tetrahydrate	10486-00-7	1,194	<1%	1%
Quaternary amine	Confidential	1,162	<1%	1%
Ethoxylated alcohols	Proprietary	1,157	<1%	1%
Cinnamaldehyde	104-55-2	1,062	<1%	0%

Source: FracFocus (2022a)

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 [2022a] data dictionary).

† The total number of FracFocus ingredient disclosures in the state of New Mexico is 213,424.

Table 2-4. Summary of 2021 Spills in the State of New Mexico

Material Type	Spill Count	Volume Spilled	Volume Lost	Units	Average Spill Volume	Percent Lost	Waterway Affected	Groundwater Affected
Brine water	3	62	28	bbl	21	68%	0	0
Condensate	43	557	422	bbl	13	92%	1	0
Crude oil	235	13,264	5,119	bbl	56	62%	0	0
Diesel	1	20	20	Bbl	20	100%	0	0
Gelled brine (frac fluid)	2	40	29	bbl	20	65%	0	0
Lube oil	2	55	13	bbl	28	40%	0	0
Other (specify)	19	4,573	4,293	bbl	241	46%	0	0
Produced water	509	71,767	31,208	bbl	141	60%	4	0
Sulfuric acid	3	202	45	bbl	67	23%	0	0
Total	**817**	**90,540**	**41,177**		**67**	62%	**5**	**0**
Natural gas (methane)	204	119,489	119,489	mcf	586	100%	2	0

Material Type	Spill Count	Volume Spilled	Volume Lost	Units	Average Spill Volume	Percent Lost	Waterway Affected	Groundwater Affected
Natural gas liquids*	14,175	7,020,532	7,020,532	mcf	669	100%	1	6
Total	**14,379**	**7,140,021**	**7,140,021**	**mcf**	**627**	**100%**	**3**	**6**
Total spill count	**15,196**			mcf	**Average percent lost**	**69%**	**8**	**6**

Source: NMOCD (2022b)

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

Note: No spills were reported in Bernalillo, Cibola, Torrance, Valencia, or Santa Fe Counties in 2021. No spills of chemicals, drilling mud/fluid or glycol were reported during 2021.

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

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.

Some data analyzed (e.g., FracFocus and USGS water use) are available at the county level only; as such, the term *Pecos tri-county area* may be used interchangeably with Pecos District (which denotes BLM administrative boundaries) in this report. The portion of the Pecos District that is underlaid by the Permian Basin encompasses Eddy, Lea, 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 Eddy, Lea, and Chaves counties. Since the likely location of water sources used to support future potential development are located in the other three counties, Roosevelt County is not included in this document. The Pecos District tri-county area contains approximately 3.4 million acres of federal minerals. In this report, water use for all of Chaves County will be reported.

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 B.L.M. 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).[1]
- 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 2022a)
- 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 2022a)

[1] A new RFD is in development for the Pecos District. The Final RFD is scheduled for June 30, 2023, and the finalized Final RFD (after BLM review) is scheduled for August 1, 2023.

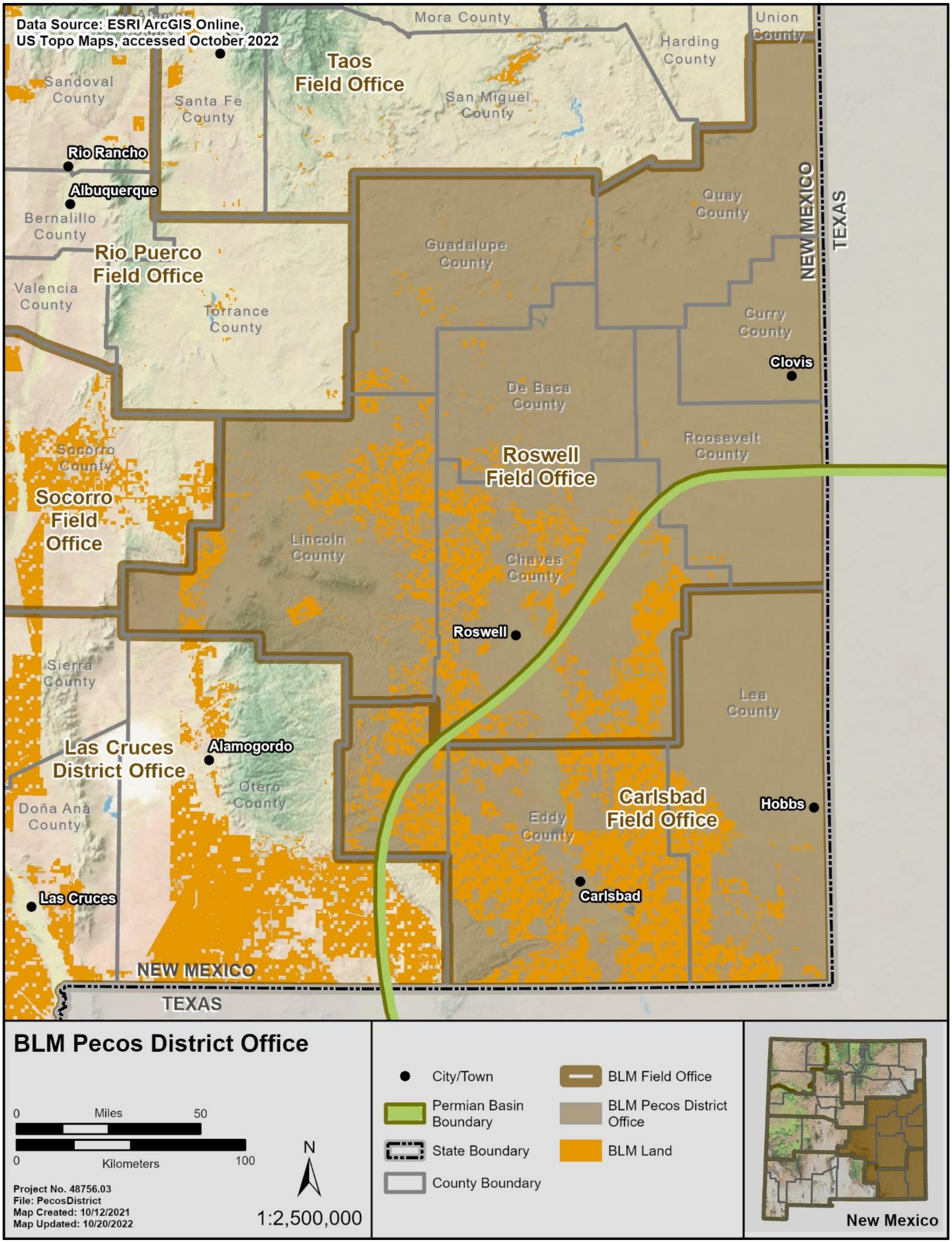


Figure 3-1. Map of BLM PDO boundaries.

3.1 WATER QUANTITY

3.1.1 Existing Surface and Groundwater Use

In 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 Tables 3-1, 3-2, and 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.

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).

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).

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%	1009	<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%	12970	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).

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	-	313.88	<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	**74,221**	**0**	**74,221**	**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).

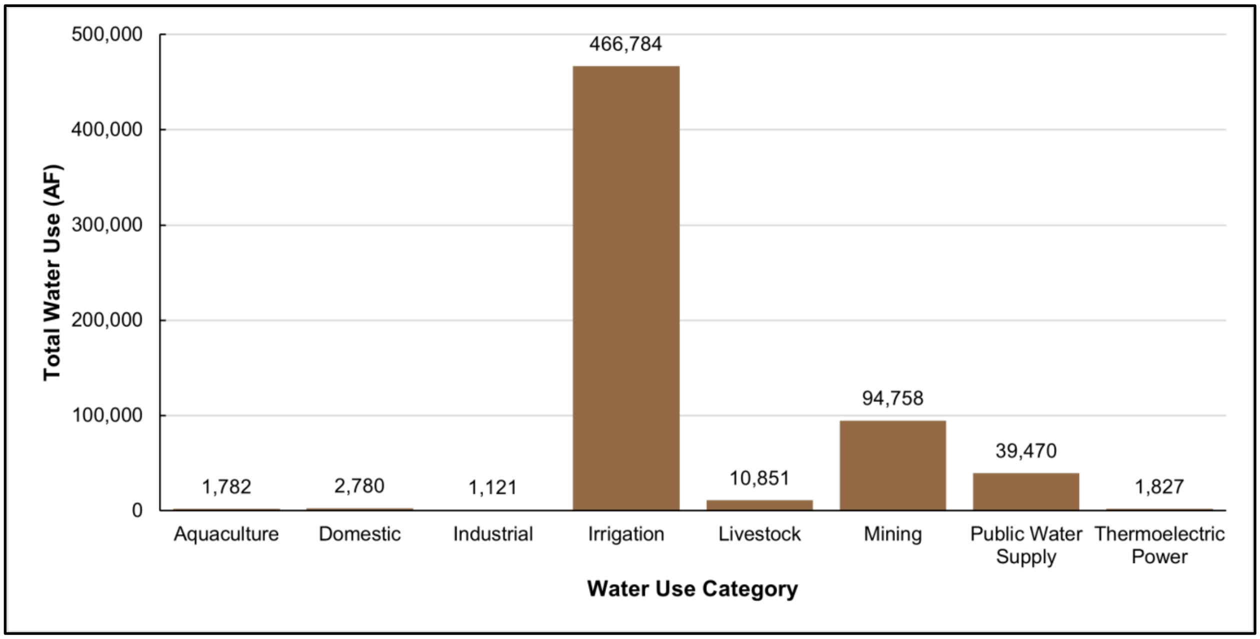


Figure 3-2. Pecos tri-county area (Chaves, Eddy, and Lea Counties) water use by category in 2015 (Dieter et al. 2018).

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). 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 hydraulic fracturing in federal wells has generally increased over time, ranging between 1,433 AF in 2014 and 24,714 AF in 2021 (Table 3-5) (FracFocus 2022a). Water use for hydraulic fracturing of all wells within the Pecos tri-county area increased from 3,939 to 49,349 AF from 2014 to 2021 (see Table 3-5), corresponding with an increase in average water use per well from 6.0 to 51.0 AF. At the time of this report, data were not available to distinguish between the type of well (e.g., nitrogen, recompletion, or slickwater). Additionally, distinguishing between completion types in the PDO is not necessary because of the relatively low number of recompletions, with the majority of new wells being slickwater completions (Murray 2021). An increase in the amount of water used per well is 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.
For example, the combined water use in 2021 would be generated using the following formula:

2021 Combined Water Use (WU) = 2021 WU + 2020 WU + 2019 WU + 2018 WU + 2017 WU + 2016 WU + 2015 WU + 2014 WU

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 2021

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	Total Well Count	Produced Water
2014	1,268	2,355	3,623	35%	1,268	3,623	6.0	515	107,301
2015	3,958	4,101	8,060	49%	5,226	11,682	14.6	482	109,495
2016	790	5,949	6,739	12%	6,016	18,421	20.4	297	103,951
2017	3,112	10,980	14,092	22%	9,128	32,513	24.7	520	108,911
2018	8,792	22,055	30,847	29%	17,920	63,360	28.9	953	130,771
2019	10,328	31,375	41,703	25%	28,249	105,063	38.5	994	152,731
2020	13,054	24,306	37,359	35%	41,302	142,423	50.7	729	165,191
2021	24,163	24,515	48,678	50%	65,465	191,101	51.0	923	199,615
Total	**65,465**	**125,635**	**191,101**	**32%**			**35.3**	**5,413**	**1,077,966**

Source: FracFocus (2022a). Data are presented only for those wells reporting water usage to FracFocus. Produced water data are from NMOCD (2022b).

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.

* 8-year average (2014–2021).

3.1.2.2 Water Use Associated with Reasonably Foreseeable Oil and Gas Development

The reasonably foreseeable development (RFD) scenario for the Pecos District (Engler and Cather 2012) projects approximately 800 new oil and gas wells per year (40% federal and 60% non-federal) over a 20-year period, for a total of 16,000 new wells. The 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. The RFD is a comprehensive study of all existing plays and an analysis of recent activity, historical production, emerging plays for future potential, and completion trends. Since the initial RFD was released in 2012, there has been significant activity and development throughout the area of the Pecos District underlain by the Permian Basin. An update to the RFD (Engler and Cather 2014) includes revised estimates for several plays in the Permian Basin, especially the Bone Spring and Leonard/Yeso plays.

Planning factor assumptions used in the RFD include time frame, estimated well count, average water use, and proportion of horizontal wells drilled in the Bone Spring and Leonard Formations (Table 3-6). These planning factors are used to estimate water usage within the region for the duration of the RFD.

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

Factor	RFD Assumed Values (Engler and Cather 2012, 2014)	Revised Estimate	Rationale for Change
Time frame	2015–2035	No change	N/A
Number of wells	16,000 (approximately 800 per year)	No change	N/A

Factor	RFD Assumed Values (Engler and Cather 2012, 2014)	Revised Estimate	Rationale for Change
Average water use, horizontal well	7.3 AF	31.2 AF*	Reflects actual water use reported in FracFocus*
Average water use, vertical well	NA	1.53 AF† and assumed 100% horizontal wells for the RFD	Reflects actual water use reported in FracFocus*
Number of wells needed for resource development in emerging plays‡	4 wells per section per play (horizontal wells)	No change	N/A
Percentage of horizontal wells in Bone Spring Formation	82% horizontal	Assumed 100% horizontal wells for the RFD	Reflects actual water use reported in FracFocus‡
Percentage of horizontal wells in Leonard Formation	14% horizontal	Assumed 100% horizontal wells for the RFD	Reflects actual water use reported in FracFocus‡

Note: N/A=not applicable.

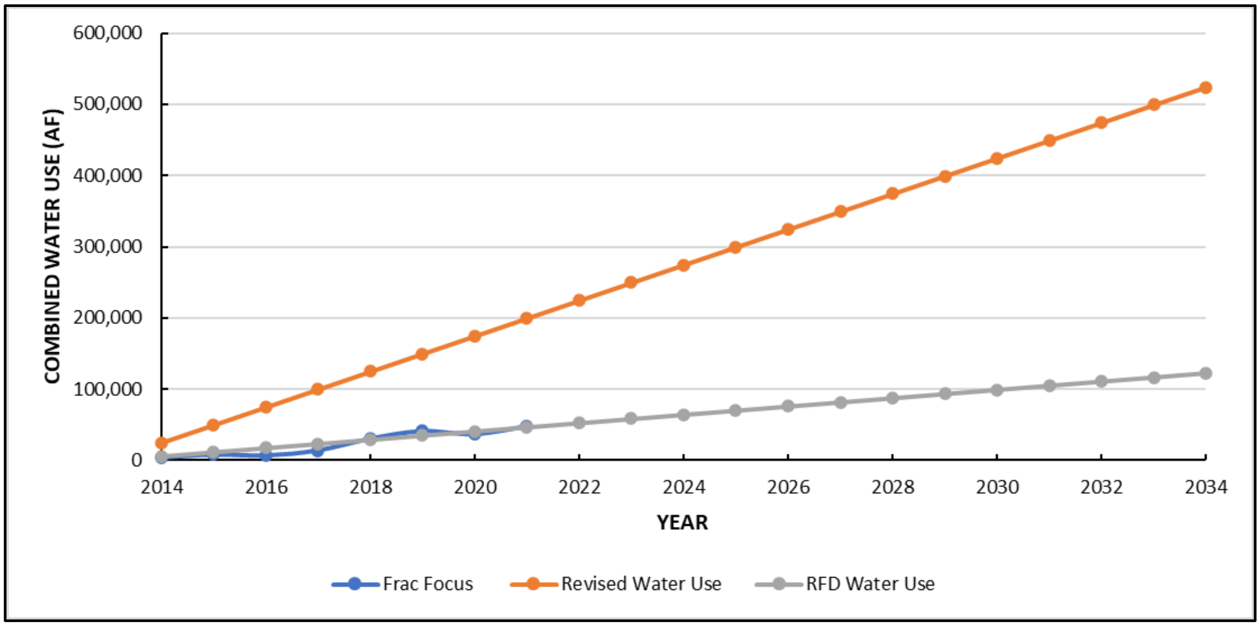
* The water use estimate of 31.2 AF per well reflects water use per well as reported to FracFocus data at the time the CFO draft RMP/EIS was released (BLM 2018).

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

‡ 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).

The RFD estimate of an average water use per well of 7.3 AF was based on a study of the Bone Spring Formation using data from 2013 (Engler and Cather 2014), where the majority of wells are horizontal. Assuming an average water use of 7.3 AF per well (assuming all horizontal wells) and 800 wells per year, the RFD estimated a total water use of 116,800 AF and an annual water use of 5,840 AF/year. Since that time, the average water use per well within the Permian Basin (see Table 3-5) has increased substantially (FracFocus 2022a). In 2018, 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 the 16,000 wells projected in the RFD. This increased the estimated water use to 499,200 AF, or 24,960 AF of water in any given year (Figure 3-3).

In 2021, 968 wells used an estimated 49,349 AF, for an average of 51.0 AF per well (FracFocus 2022a) (see Table 3-5). With an average annual water use rate of 29.3 AF per well and an average development rate of 754 wells per year since 2014, the average annual water use for the last 8 years was 22,122 AF/year. The water use reported to FracFocus over the previous 8 years (FracFocus 2022a) indicates that the revised planning factors associated with the RFD (31.2 AF per well and 24,960 AF/year) are within a reasonable range of current water use trends (see Figure 3-3).



Note: RFD water use planning factors of 7.3 AF/well and 5,840 AF/year come from the RFD (Engler and Cather 2012, 2014). Revised water use planning factors are 31.2 AF/well and 24,960 AF/year. Revised 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 water use estimates between 2014 and 2021 (FracFocus 2022a).

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 2021 with projections through 2034.

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) there are no RFFAs related to mining apart from oil and gas development that would contribute 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 24,960 AF of water in any given year. This is about 4% 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).

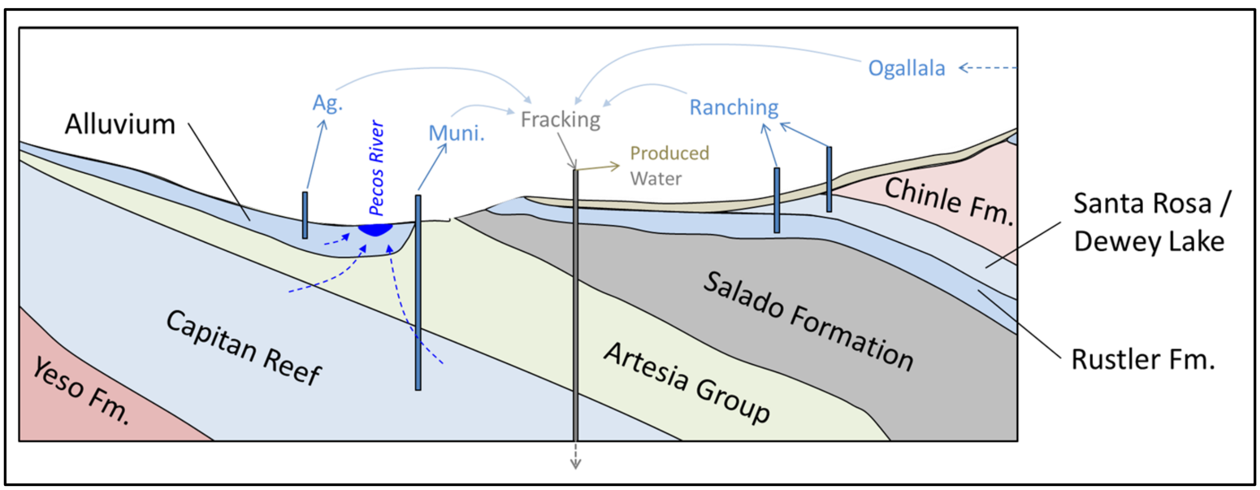


Figure 3-4. Idealized geologic cross section of potential water sources in the Pecos District (Summers 1972).

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.

A model has been developed as part of the Sandia National Laboratories study (Lowry et al. 2018) to simulate water availability over a range of different future scenarios, including drilling activity and water demand relative to areas that are most vulnerable, and to estimate the risk to water sustainability. The recently completed model may potentially allow the BLM to examine the balances between water demand and water availability to predict and track risks to each aquifer and to calculate well drawdown. While the model has been recently completed, it is still undergoing review by the BLM for accuracy, reliability, and useability in evaluating water supply and demand related to oil and gas development in the Pecos District. This model is not yet being used in the WSD for water use simulations.

3.1.3.1 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). 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 (New Mexico Environmental Department 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 Pond 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 pH NMWQCC 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
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	**16,000–8,800**	**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

Parameter	NMWQCC Standard	North HPA*	Central North HPA*	South HPA and WIPP*	Capitan Reef†
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: μmhos/cm = millimhos per centimeter; this is a unit of measure for electrical conductivity. -- = not applicable or not detected. RL = reporting limit. Units are mg/L unless otherwise noted. **Bold** = exceeds NMWQCC standard for groundwater <10,000 mg/L.

* 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)

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 2022a). In 2021, a total of 14,924 spills were associated with federal and non-federal oil and gas wells and facilities in the Pecos tri-county area (Table 3-10) (NMOCD 2022a). The percent loss (volume lost divided by volume released) varies by spill type, but the average loss for all 2021 records in the Pecos tri-county area was 67%. In 2021, two produced water spills and one natural gas liquid spill were reported as having affected a surface waterway and six natural gas liquid spills were reported as having affected groundwater in Eddy, Lea, and Chaves Counties (NMOCD 2022a). Additionally, 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 2021 was water, with 15,952 disclosures (Table 3-12). Other frequent disclosures include methanol (n = 5,607), crystalline silica, quartz (n = 5,509), and petroleum distillates (n = 5,268). There were 18,383 records of non-disclosed chemicals, including chemicals listed as proprietary, confidential, and trade secrets.

Table 3-10. Summary of 2021 Spills from all Wells in the New Mexico Portion of the Permian Basin (Eddy, Lea, and Chaves Counties)

Material Type*	Spill Count	Total Volume Spilled	Volume Lost	Unit	Average Spill Volume	Percentage Lost	Waterways Affected	Groundwater Affected
Brine water	3	62	28	bbl	21	68%	0	0
Condensate	21	358	233	bbl	17	87%	0	0
Crude oil	217	12,840	4,857	bbl	59	61%	0	0
Diesel	1	20	20	bbl	20	100%	0	0
Gelled brine (frac fluid)	2	40	29	bbl	20	65%	0	0
Lube oil	2	55	13	bbl	28	40%	0	0
Other (specify)	16	2,916	2,636	bbl	182	36%	0	0
Produced water	474	67,752	27,571	bbl	143	58%	2	0
Sulfuric acid	3	202	45	bbl	67	23%	0	0
Total	***739***	***84,245***	***35,432***	*bbl*	***62***	***60%***	***2***	***0***
Natural gas (methane)	191	112,871	112,871	mcf	591	100%	0	0
Natural gas liquids[†]	13,994	6,810,569	6,810,569	mcf	657	100%	1	6
Total	***14,185***	***6,923,440***	***6,923,440***	***mcf***	***624***	***100%***	***1***	***6***
Total Spills	**14,924**				**Average Percent Lost**	**67%**	3	6

Source: NMOCD (2022b)

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

* No spills of chemicals, drilling mud/fluid, or glycol were documented in 2021.

[†] Natural gas liquids material types include natural gas flared, natural gas liquids, and natural gas vented materials.

Table 3-11. Summary of Spills from all Wells in the New Mexico Portion of the Permian Basin (Eddy, Lea, and Chaves Counties) between 2019 and 2021

Material Type	Spill Count							
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Acid	3	2	0	0	1	2	0	0
Basic sediment and water (BS&W)	0	0	1	2	4	1	0	0

Material Type	Spill Count							
	2014	2015	2016	2017	2018	2019	2020	2021
Brine water	3	3	6	3	3	4	3	3
Chemical	0	1	1	1	6	5	0	0
Condensate	6	20	16	11	13	14	17	21
Crude oil	296	403	330	328	382	362	339	217
Drilling mud/fluid	6	3	1	4	5	2	1	0
Diesel	1	1	0	1	3	0	0	1
Gelled brine (frac fluid)	3	2	0	0	0	3	3	2
Lube oil	1	0	0	1	0	0	0	2
Other (specify)	10	5	9	8	24	23	21	16
Produced water	576	555	464	488	546	633	663	474
Sulfuric acid	0	0	0	0	1	0	1	3
Unknown	1	1	0	0	0	3	0	0
Total	***906***	***996***	***828***	***842***	***988***	***1,052***	***1,048***	***739***
Natural gas (methane)	1	9	7	0	5	150	202	191
Natural gas liquids*	8	10	14	9	2	6	1	13,994[†]
Total	***9***	***19***	***21***	***9***	***7***	***156***	***203***	***14,185***
Total Spills	**915**	**1,015**	**849**	**851**	**995**	**1,208**	**1,251**	**14,924**

Source: NMOCD (2022b)

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, the 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 Chemicals in Horizontal Wells within the New Mexico Portion of the Permian Basin (Chaves, Eddy, and Lea Counties) from 2014 through 2021

Ingredient Name	CAS Registry Number	Number of Disclosures	Percentage of Hydraulic Fracturing Job*	Percentage of Total Number of FracFocus Disclosures[†]
Not disclosed	NA	18,383	4%	10%
Water	7732-18-5	15,952	40%	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	5,607	1%	3%
Crystalline silica, quartz	14808-60-7	5,509	5%	3%
Distillates (petroleum), hydrotreated light	64742-47-8	5,268	<1%	3%
Hydrochloric acid	7647-01-0	4,654	2%	2%
Glutaraldehyde	111-30-8	2,852	<1%	2%
Isopropanol	67-63-0	2,702	<1%	1%
Ammonium chloride	12125-02-9	2,583	<1%	1%
Alcohols, C12-16, ethoxylated	68551-12-2	2,521	<1%	1%
Crystalline silica	14808-60-7	2,259	6%	1%
Ethylene glycol	107-21-1	2,178	<1%	1%
Sodium chloride	7647-14-5	2,156	<1%	1%
Ethoxylated alcohols	Proprietary	2,031	<1%	1%
Acetic acid	64-19-7	1,911	<1%	1%
Sodium hydroxide	1310-73-2	1,836	<1%	1%
Proprietary	Proprietary	1,793	<1%	1%
Propargyl alcohol	107-19-7	1,753	<1%	1%
Guar gum	9000-30-0	1,744	<1%	1%
Ammonium persulfate	7727-54-0	1,705	<1%	1%
Citric acid	77-92-9	1,415	<1%	1%
Ethanol	64-17-5	1,331	<1%	1%
Cinnamaldehyde	104-55-2	1,050	<1%	1%
Sodium perborate tetrahydrate	10486-00-7	1,023	<1%	1%
2-butoxyethanol	111-76-2	961	<1%	1%

Source: FracFocus (2022a)

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 [2022a] data dictionary).

† The total number of FracFocus ingredient disclosures in the Pecos tri-county area is 187,763.

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 (C.F.R.) 43 C.F.R. § 3162 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. Onshore Order No. 2 and the regulations at 43 C.F.R. § 3162.3-3 provide regulatory requirements for hydraulic fracturing, including casing specifications, monitoring and recording, and management of recovered fluids. The State of New Mexico also has regulations for drilling, casing and cementing, completion, and plugging to protect freshwater zones (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 C.F.R. § 3160; 43 C.F.R. § 3162.3-3; 43 C.F.R. § 3162.3-5; Onshore Orders Nos. 1, 2, and 7; 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 Water Drinking 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 C.F.R. § 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 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 RMP/EIS (BLM 2021). 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 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:

- 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 2022a)
- Spill data from the NMOCD database (NMOCD 2022a)

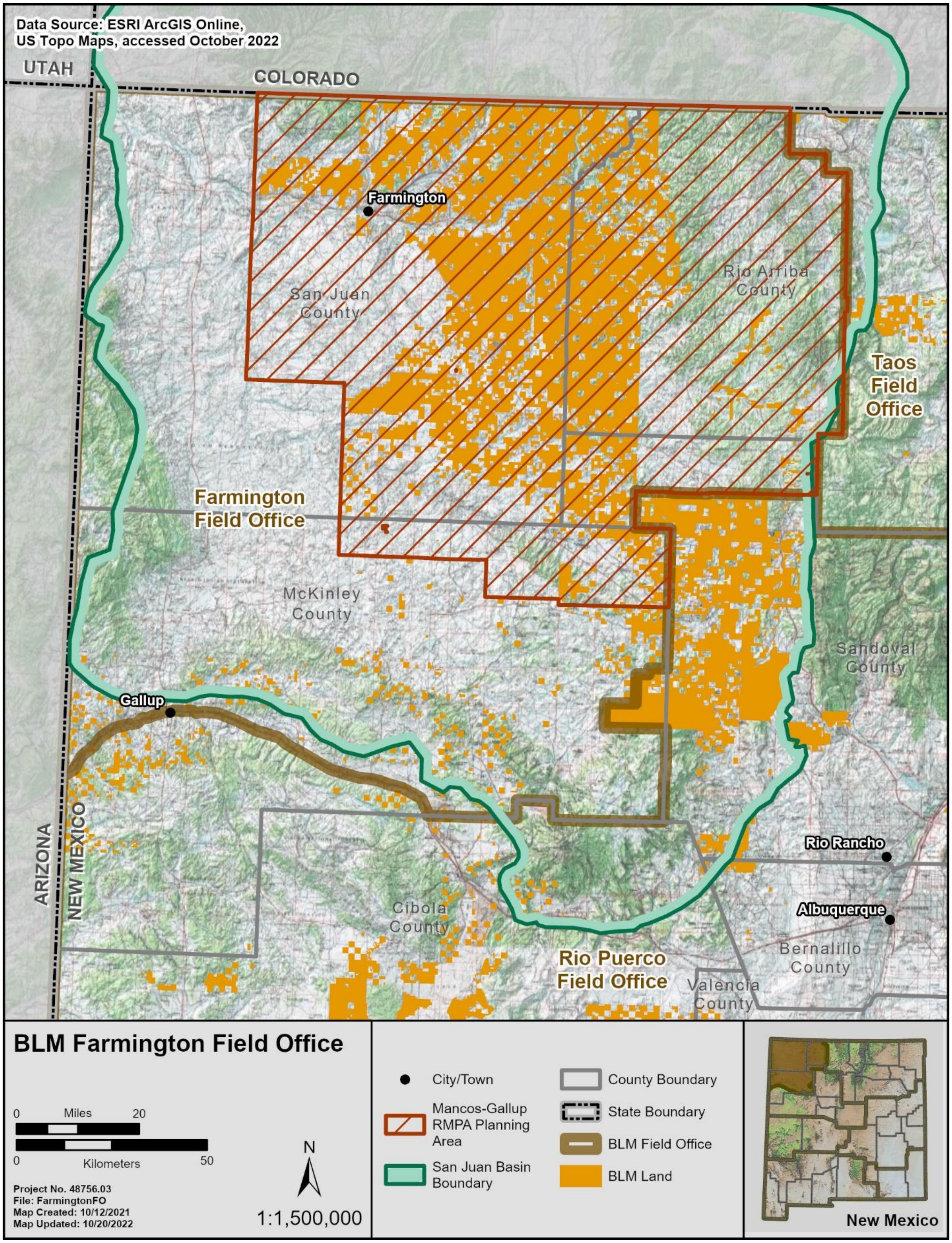


Figure 4-1. BLM FFO and Mancos-Gallup planning area boundaries.

4.1 WATER QUANTITY

4.1.1 Existing Surface and Groundwater Use

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

Dieter et al. (2018) lists 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–Table 4-4). 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. The largest use of water within the FFO was irrigation, comprising 79.07% (384,817 AF) of total water use.

Water use associated with mining (11,658 AF) comprises 2.4% of total water use within the FFO; over half of all mining-related water use in the FFO occurred in San Juan County (6,356 AF, or 54.52% of the total mining water use in the FFO). 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).

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).

Table 4-3. 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).

Table 4-4. 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).

Table 4-5. Water Use by Category in 2015 within the FFO (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%
Thermoelectric Power	30,637	0	30,637	6%	2,298	0	2,298	<1%	32,935	7%	0	0%	32,935	7%

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 (%)		
Basin Totals	**436,652**	**0**	**436,652**	**90%**	**44,750**	**5,257**	**50,008**	**10%**	**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).

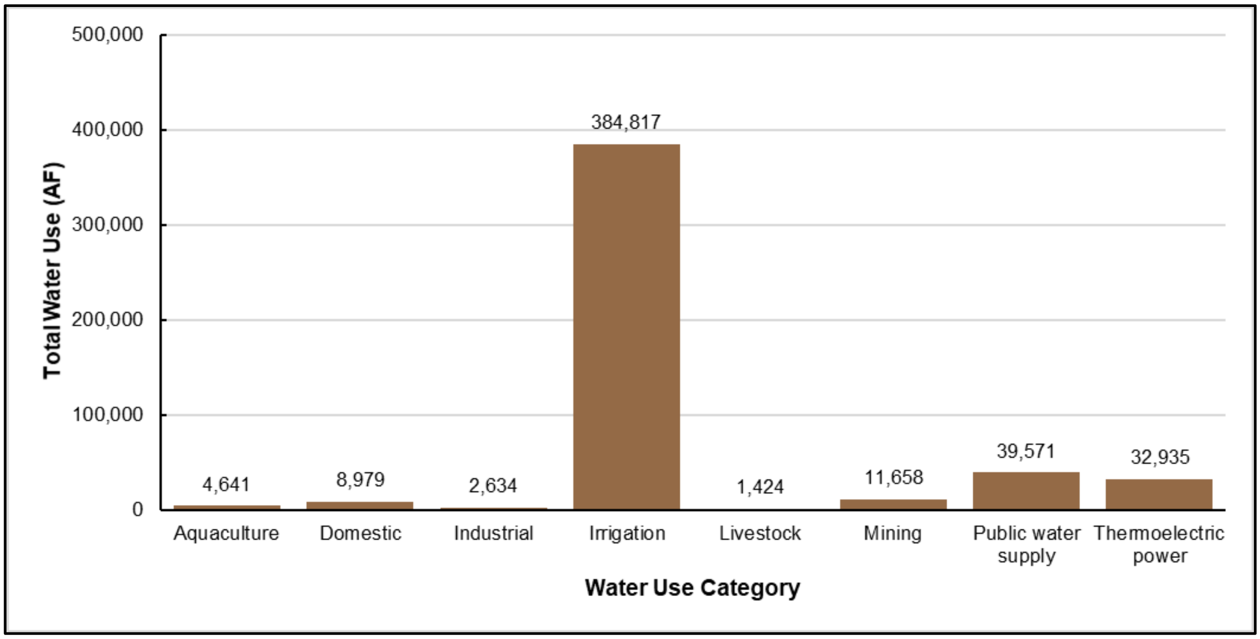


Figure 4-2. FFO (McKinley, Rio Arriba, Sandoval, and San Juan Counties) water use by category in 2015 (Dieter et al. 2018).

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 486,660 AF and accounted for approximately 15% (3,249,667 AF) of the total state water withdrawals (Dieter et al. 2018). The largest use of water within the FFO is irrigation, comprising 79% of all water use within the FFO and 14% of all irrigation-related use within the state. Mining (which includes oil and gas development) comprised 2.4% of the total water withdrawals within the FFO 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 last 7 years. The total water use for all wells increased from 51 AF in 2020 to 671 AF in 2021. Average water use per well increased from 5.7 AF in 2020 to 14.9 AF in 2021 (Table 4-6) (FracFocus 2022a). Wells on federal land consumed 551 AF of water in 2021, 82% of the 2021 total water usage. The number of wells completed increased from nine in 2020 to 45 in 2021.

Combined water use 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.
For example, the combined water use in 2021 would be generated using the following formula:

2021 Combined Water Use (WU) = 2021 WU + 2020 WU + 2019 WU + 2018 WU + 2017 WU + 2016 WU + 2015 WU + 2014 WU

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 2021, the combined federal water use and total combined water use increased to 1,625 AF and 2,577 AF, respectively. The 8-year average water use was 322 AF/year and 5.1 AF per well.

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 2021

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	5,406
2015	83	255	338	25	248	654	3.8	89	5,040
2016	85	26	110	77	332	764	2.9	38	4,233
2017	228	50	278	82	561	1,043	4.5	62	3,554
2018	375	281	657	57	936	1,700	4.8	136	2,681
2019	87	69	156	56	1,023	1,855	1.7	89	4,391
2020	51	0	51	100	1,074	1,906	5.7	9	4,435
2021	551	120	671	82	1,625	2,577	14.9	45	2,822
Total	**1,625**	**952**	**2,577**				**5.1***	**598**	**35,562**

Source: FracFocus (2022a).

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 (2022b). 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.

* 8-year average (2014–2021).

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 discrepancy can skew water use statistics, as recompletions typically use less water than new completions. Additional well information was compiled from BLM records, available from NMOCD, and aggregated with the 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 2021, recompletions of previously existing wells (vertical) used an average of 0.58 AF/well and completions of vertical wells used an average of 0.3 AF/well. Water use associated with new completions of nitrogen and slickwater wells used an average of 9.01 and 83.3 AF/well, respectively. 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 2021

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**

Year	Well Type	Count	Average Water Use per Well (AF)	Total Water Use (AF)
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**	**109.4**
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**	**278.7**
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**	**657.8**
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**	**160.9**
2020	Nitrogen	9	5.7	51.0
	Total	**9**	**5.7**	**51.0**
2021	Nitrogen	15	5.21	78.2
	Recompletion	16	0.3	4.5
	Slickwater	14	42.1	588.4
	Total	**45**	**14.9**	**671.1**
2014–2021	Nitrogen	286	3.82	1,095
	Recompletion	260	0.58	73.2
	Slickwater	34	83.3	1414
	Vertical	32	0.3	8.70
	Total	**612**	**4.23**	**2,590**

Note: Well data sourced from FracFocus (2022a) and aggregated with additional data from BLM records (BLM 2021). The well total without recompletion wells equals 352 wells and a total water use average of 7.15 AF. Additionally, the total average for nitrogen and slickwater wells is 7.84.

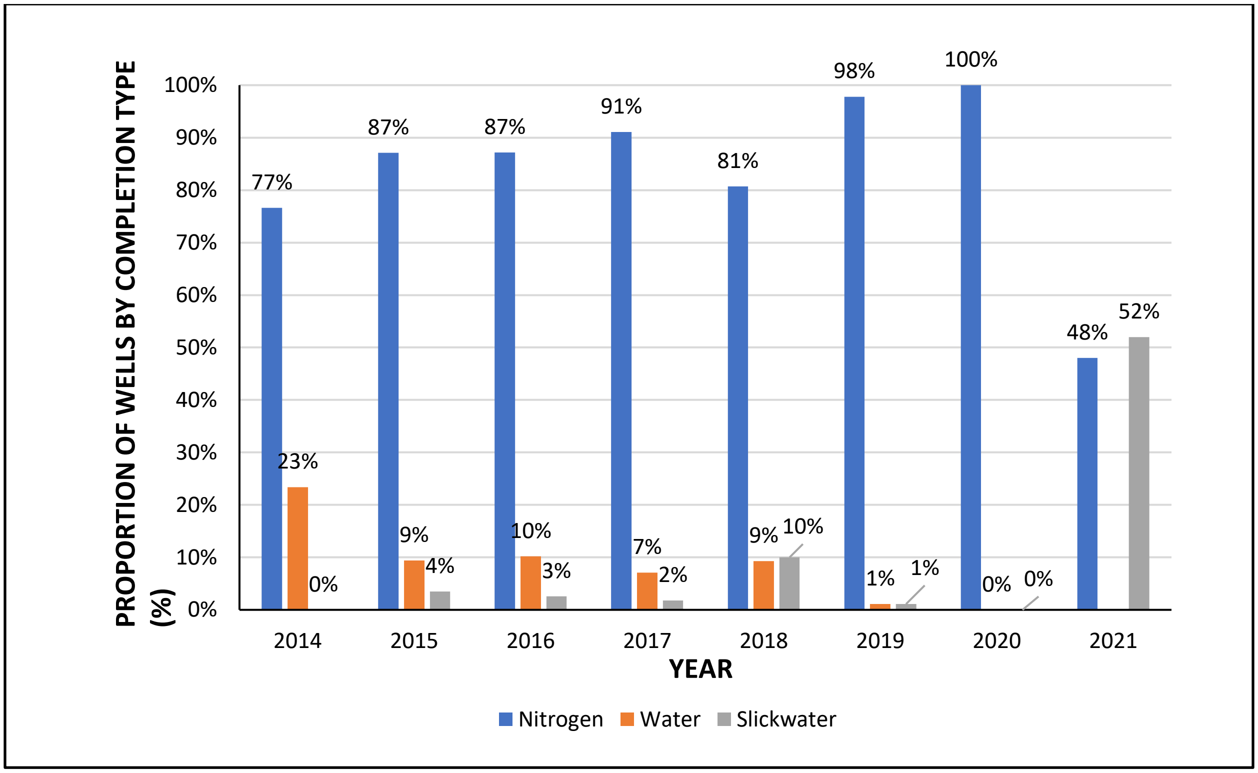


Figure 4-3. Proportion of oil and gas well stimulation techniques in the FFO from 2014 through 2021 (FracFocus 2022a).

Note: Well data sourced from FracFocus (2022a) and aggregated with additional data from BLM records (BLM 2021). The well total for 2021 without recompletion wells equals 29 wells. Associated percentages are based on this total.

4.1.2.2 Water Use Associated with Reasonably Foreseeable Oil and Gas Development

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

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 4-8).

As previously discussed, actual water use quantities reported from 2014 through 2021 vary from an average of 5.1 AF per well (see Table 4-6) to 4.23 AF per well (see Table 4-7), depending on the data sources being reviewed. Because the 2018 RFD per-well water estimates are lower than actual water use quantities, an assumed water use of 5.1 AF per well provides a good upper limit on the estimated water use over the next 20 years (see Table 4-8).

Table 4-8. Projected Water Use in the New Mexico Portion of the San Juan Basin (FFO)

Factor	Water Use in RFD (Crocker and Glover 2018)	Revised Water Use	Rationale for Change
Average water use per horizontal well during a hydraulic fracturing operation	3.13 AF*	5.1 AF†	Reflects actual use as reported in FracFocus in 2018
Average water use per vertical well during a hydraulic fracturing operation	0.537 AF	0.537 AF	No change
Total Water Use (2018–2037)‡	**7,683 AF§**	**11,615 AF§**	

* Derived from Crocker and Glover (2018).

† Source: FracFocus (2022a)

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

§ Source: BLM (2020)

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 (5.1 AF per horizontal well; see Table 4-8), 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).

4.1.2.2.2 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

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 76.6% to 100% (see Figure 4-4).

The average water use of a new nitrogen-stimulated well is 3.82 AF per well (see Table 4-7). If all 2,300 horizontal wells in the 2018 RFD used nitrogen-stimulated technologies, development of the 2018 RFD scenario would require 9,223 AF of water, or 461 AF of water in any given year. Projected annual water use would be approximately 0.09% of the 2015 total water use in the four FFO counties (486,660 AF).

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). As of 2022, 5.55% of wells within the FFO administrative boundaries use slickwater fracturing, an increase of approximately 1.5% in 2021.

4.1.2.3 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 the three water use scenarios described above.

- 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.
- Nitrogen scenario: This assumes 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.
- Slickwater scenario: This scenario assumes that all 2,300 wells predicted in the RFD would use slickwater stimulation, with an average lateral length of 2 miles, which would result in a 20-year cumulative water use of 125,483 AF by 2037.

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. An annual increase of 3% was used for this scenario based on the percentage of wells within the FFO administrative boundaries in 2020 using slickwater fracturing (3%). 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 4-9.
The values are based on an average water use of 3.82 and 41 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 4-9. 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

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		
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
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 four well development scenarios 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. Figure 4-4 estimates combined water use based on actual water use provided to FracFocus from 2014 through 2021.

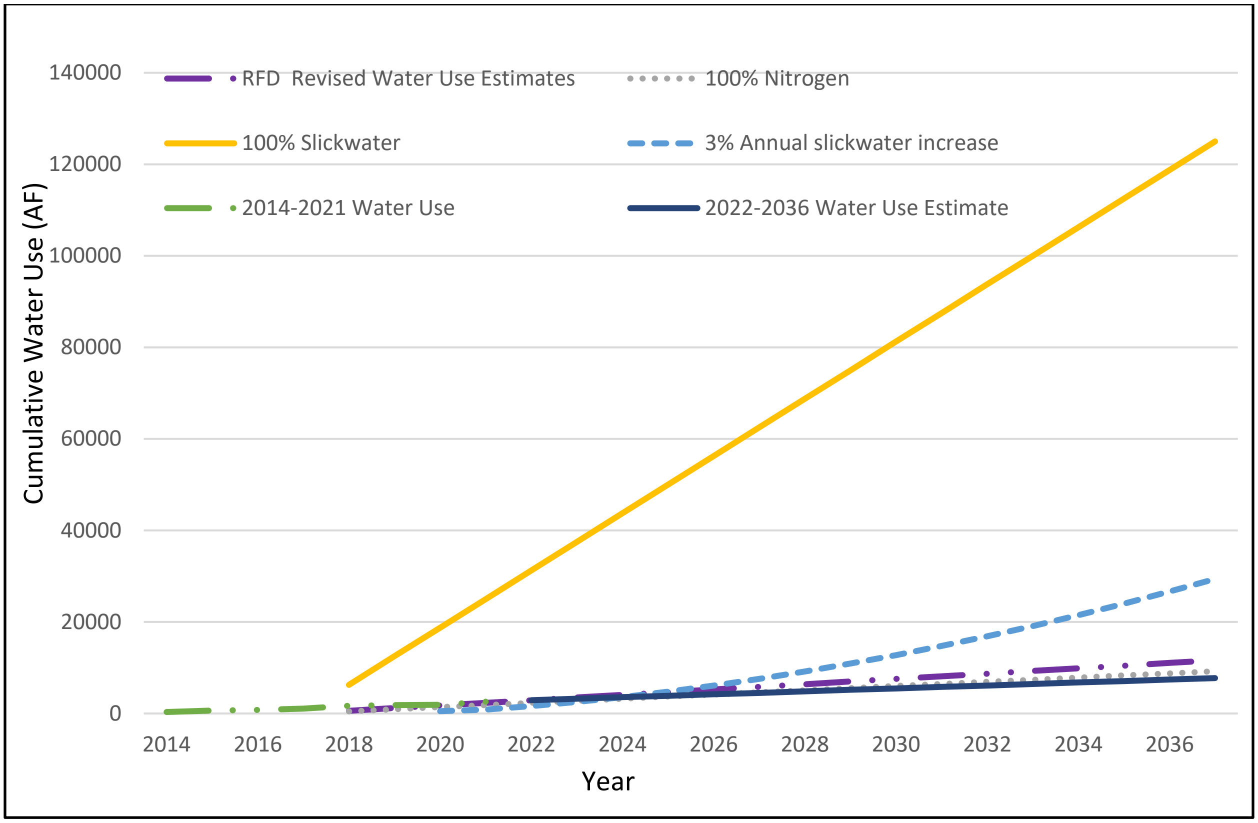


Figure 4-4. Cumulative water use estimates for four well development scenarios within the New Mexico portion of the San Juan Basin (McKinley, Rio Arriba, Sandoval, and San Juan Counties) based on a predicted 2,300 horizontal and 900 vertical wells.

Current water use trends over the past 8 years (4.23 AF per well and 322 AF/year) indicate that cumulative water use by 2037 will be approximately 7,407 AF. Without recompletions, the average water use per well was 7.36 AF over the past 8 years. Current new well completion water use trends fall below 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, and 14 of the 45[2]wells completed in 2021 used slickwater stimulation (see Table 4-7). The slickwater scenario estimates a 2019 water use of 6,142 AF, whereas total water use for well completion reported to FracFocus in the FFO in 2019 and 2021 was 161 and 671.1 AF, respectively, which is 97.4% and 89.1% less, respectively, than the predicted 6,142 AF/year. If recompletion wells are not included in these totals, the total water use for well completion reported to FracFocus in the FFO in 2019 and 2021 was 144 AF and 666.6 AF, or 97.7% and 89.15% less, respectively, than the predicted 6,142 AF/year. Of the 92 wells completed in 2019, 90 (97.8%) used nitrogen stimulation, and 15 of the total wells (33.33%) completed in 2021 used nitrogen stimulation. Therefore, it is a more likely scenario that, of the total wells completed within the San Juan Basin, a slightly greater percentage will use nitrogen stimulation as opposed to slickwater stimulation.

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 3.1.1 and Table 4-5), it

[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 29 wells.

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.

San Juan Basin oil and gas operators have included plans to use multiple hydraulic fracturing methods, including slickwater fracturing technology. The two general water types that may be used for slickwater stimulation are categorized as potable/fresh and nonpotable. Any water that has TDS greater than 1,000 ppm has been defined as nonpotable 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 Onshore Order No. 2 (BLM 1988). Nonpotable 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., nonpotable groundwater sources). Recently, NMOSE has approved permits to drill wells within the San Juan Basin to withdraw nonpotable 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 nonpotable and has not been declared an administrative aquifer by NMOSE. Table 4-10 identifies four aquifers found within the FFO, their associated rock types, and sources of recharge.

Other sources of nonpotable 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 nonpotable 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. Based on operator input, 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.

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 nonpotable 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 4-10. Potential Sources of Groundwater in the FFO

Aquifer Name	Description	Sources of Recharge
Mesaverde	Sandstone, coal, siltstone and shale of the Mesaverde Group	Upland areas, mainly in areas of the Zuni Uplift, 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
Entrada Sandstone	Sandstone; eolian sand dunes	Through surface exposures on the margins of the basin in the foothills of the Laramide uplifts

Source: BLM (2003); 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.

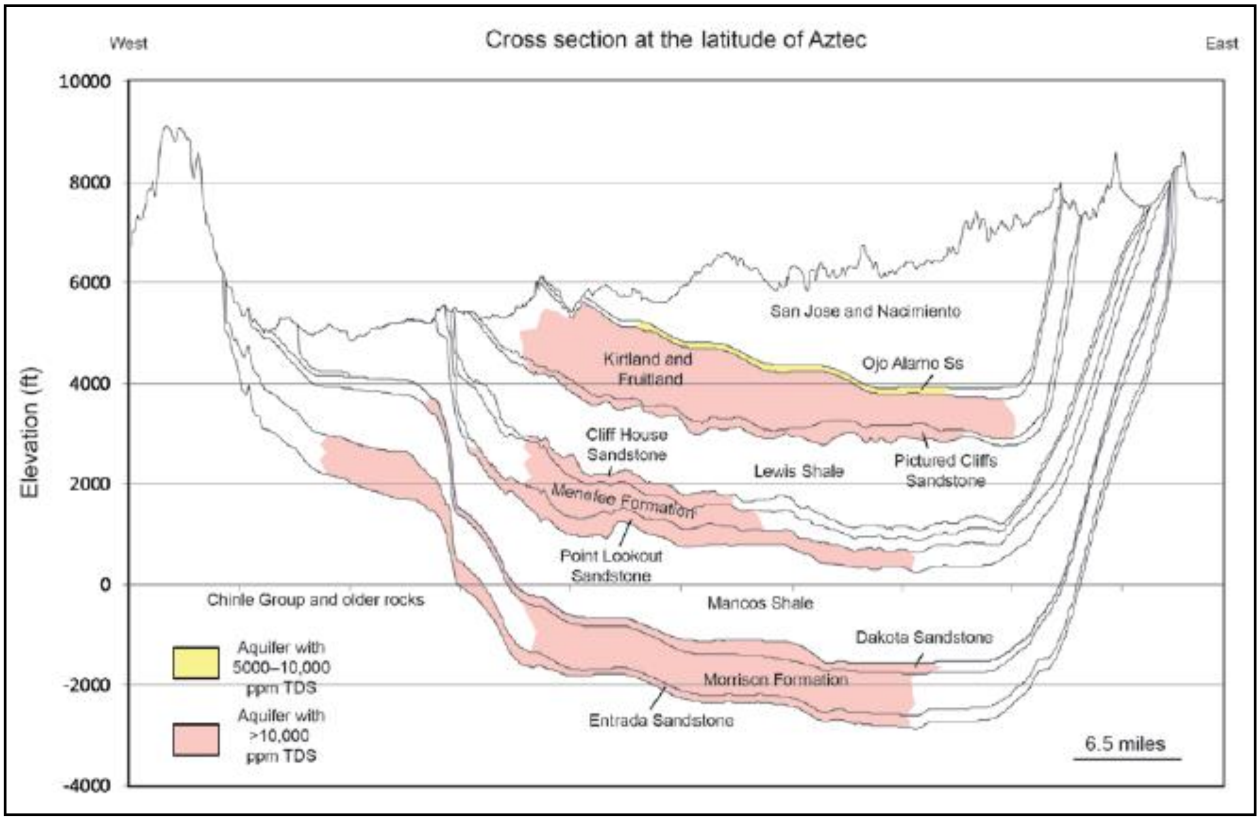


Figure 4-5. Geologic cross section showing the distribution of saline aquifers in the San Juan Basin (Kelley et al. 2014).

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 deeper depths (Kelley et al. 2014).

4.2.2 Surface Water

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

Water quality in streams flowing on BLM-managed 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 2020, oil and gas development resulted in 8,014,296 bbl of oil (NMOCD 2021b). There were a total of 241 spills in the New Mexico portion of the San Juan Basin in 2021 (Table 4-11). Additionally, Table 4-12 provides total spill counts since 2014.

In 2021, ability for spill recovery varied by spill type, but in general, about 91% of all spills were lost. Of the spills in 2021, five 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 chemical disclosed in FracFocus for wells within the FFO was water, with 1,294 disclosures (Table 4-13). Other frequent disclosures included Crystalline Silica quartz (n = 1,011), sodium chloride (n = 6,257), and methanol (n = 680). There were 3,273 records of non-disclosed chemicals, including chemicals listed as proprietary, confidential, and trade secrets. Five records had CAS registry number errors and were unidentifiable.

Table 4-11. 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
Condensate	20	24	12	8	20	24	17	22
Crude oil	23	8	9	7	11	21	13	14
Lube oil	2	0	2	1	1	0	2	0
Glycol	0	0	0	0	0	2	0	0
Other (specify)	11	6	1	3	10	30	3	3
Produced water	71	34	48	34	31	59	40	28
Total	***127***	***72***	***72***	***53***	***73***	***136***	***75***	***67***

Material Type	Spill Count							
	2014	2015	2016	2017	2018	2019	2020	2021
Natural gas (methane)	2	11	1	0	0	39	21	12
Natural gas liquids†	12	16	4	2	5	19	0	162
Total	***14***	***27***	***5***	***2***	***5***	***58***	***21***	***174***
Total Spills	**141**	**99**	**77**	**55**	**78**	**194**	**96**	**241**

Source: NMOCD (2022b)

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

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

Table 4-12. Summary of 2021 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	Waterway Affected	Groundwater Affected
Condensate	22	199	189	bbl	9	97%	1	0
Crude oil	14	410	158	bbl	29	70%	0	0
Other (specify)	3	1,657	1,657	bbl	552	100%	0	0
Produced water	28	3,825	3,476	bbl	137	85%	2	0
Total	**67**	**6,091**	**5,480**	**bbl**	**182**	**88%**	**3**	**0**
Natural gas (methane)	12	6,549	6,549	mcf	546	100%	2	0
Natural gas liquids†	162	198,859	198,859	mcf	1086	100%		
Total	**174**	**205,408**	**205,408**	**mcf**	**816**	**100%**	**2**	**0**
Total Spill Count	**241**				**Average Percent Lost**	**91%**	**5**	**0**

Source: NMOCD (2022b)

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

* No spills of brine water, chemicals, drilling mud/fluid, gelled brine (frac fluid), glycol, lube oil, sulfuric acid, or natural gas liquids were reported in 2021.

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

Table 4-13. Most Frequently Disclosed Chemicals in Horizontal Wells within the San Juan Basin (McKinley, Rio Arriba, Sandoval, and San Juan Counties) from 2014 through 2021

Ingredient Name	CAS Registry Number	Number of Disclosures*	Percentage of Hydraulic Fracturing Job†	Percentage of Total Number of FracFocus Disclosures*
Not disclosed	NA	3,273	<1%	13%
Water	7732-18-5	1,294	35	5%
Crystalline silica, quartz	14808-60-7	1,011	11	4%
Methanol	67-56-1	680	<1%	3%
Sodium chloride	7647-14-5	625	<1%	3%
Quaternary amine	Confidential	551	<1%	2%

Ingredient Name	CAS Registry Number	Number of Disclosures*	Percentage of Hydraulic Fracturing Job[†]	Percentage of Total Number of FracFocus Disclosures[*]
Ethanol	64-17-5	464	<1%	2%
Amine salts	Confidential	463	<1%	2%
Nitrogen	7727-37-9	457	24	2%
Naphthalene	91-20-3	428	<1%	2%
Heavy aromatic petroleum naphtha	64742-94-5	415	<1%	2%
SDS[‡] and non-SDS ingredients listed below	NA	407	2%	2%
Guar gum	9000-30-0	380	<1%	2%
Hydrochloric acid	7647-01-0	368	<1%	1%
Glycerin	56-81-5	365	<1%	1%
Inner salt of alkyl amines	Confidential	360	<1%	1%
1,2,4 Trimethylbenzene	95-63-6	328	<1%	1%
Poly(oxy-1,2-ethanediyl), alpha-(4-nonylphenyl)-omega-hydroxy-, branched	127087-87-0	328	<1%	1%
Isopropanol	67-63-0	296	<1%	1%
Distillates (petroleum), hydrotreated light	64742-47-8	290	<1%	1%
Hydroxyalkylammonium chloride	Proprietary	277	<1%	1%
Formaldehyde	50-00-0	253	<1%	1%
Hemicellulase enzyme	9012-54-8	244	<1%	1%
Ethylene glycol	107-21-1	241	<1%	1%
Oxylated phenolic resin	Proprietary	228	<1%	1%

Source: FracFocus (2022a)

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 Pecos tri-county area is 24,941.

† The amount of the ingredient in the total hydraulic fracturing volume by percent mass (definition from FracFocus [2022a] data dictionary).

‡ SDS = safety data sheet

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 C.F.R. § 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.

Onshore Order No. 2 and the regulations at 43 C.F.R. § 3162.3-3 provide regulatory requirements for hydraulic fracturing, including casing specifications, monitoring and recording, and management of recovered fluids. The State of New Mexico also has regulations for drilling, casing and cementing, completion, and plugging to protect freshwater zones (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 C.F.R. § 3160; Onshore Orders Nos. 1, 2, and 7; 43 C.F.R. § 3162.3-3; 43 C.F.R. § 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 Water Drinking 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 C.F.R. § 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 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 has occurred in the northeastern corner of Sandoval County, which is in the San Juan Basin (FracFocus 2022a). Additionally, the 2019 RFD predicts 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. 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 2022a)
- Spill data from the NMOCD database (NMOCD 2022a)

5.1 WATER QUANTITY

5.1.1 Existing Surface and Groundwater Use

The water use of counties within RPFO boundaries varies greatly and is dependent on the predominant industry within that county. In 2015, public water supply and domestic water use comprised the greatest proportion of water use in McKinley County (53%; 7,006 AF) (Table 5-1). Bernalillo County (which contains Albuquerque) consumed 155,382 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 (Tables 5-3 through 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. Irrigation, at 320,146 AF (65% of all water use), was the sector that consumed the greatest amount of water within RPFO boundaries. Irrigation water usage made up 14% of all water use within the state (3,249,667 AF).

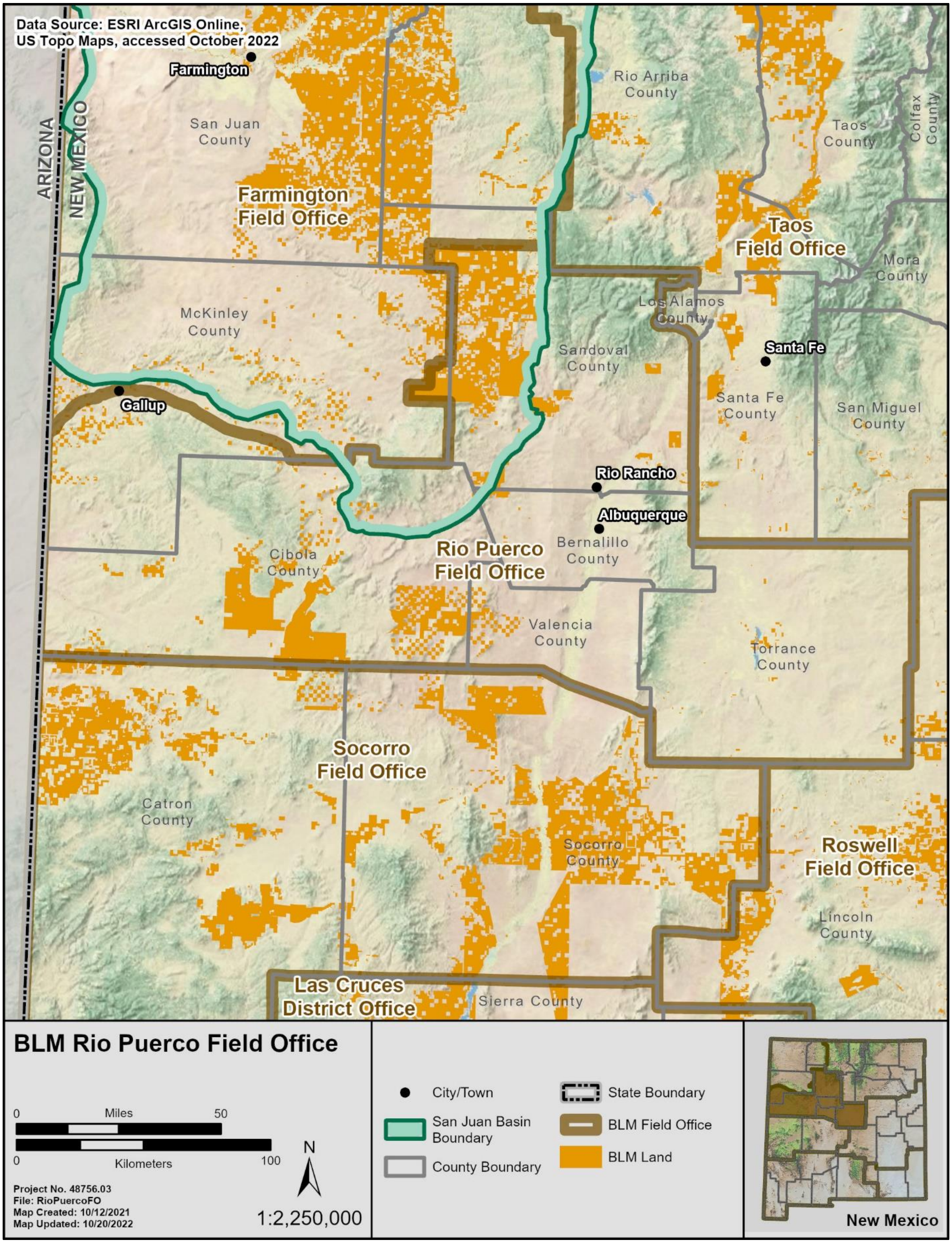


Figure 5-1. Map of BLM RPFO boundaries.

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.

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%

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%	291	0	291	<1%	291	<1%	0	0%	291	<1%
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.

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**	**246.62**	**23,014**	**32%**	**71,329**	**100%**	**246.6**	**<1%**	**71,576**	**100%**

Source: Dieter et al. (2018)

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

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.

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%

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.

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.

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%

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 (%)		
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.

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%
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.

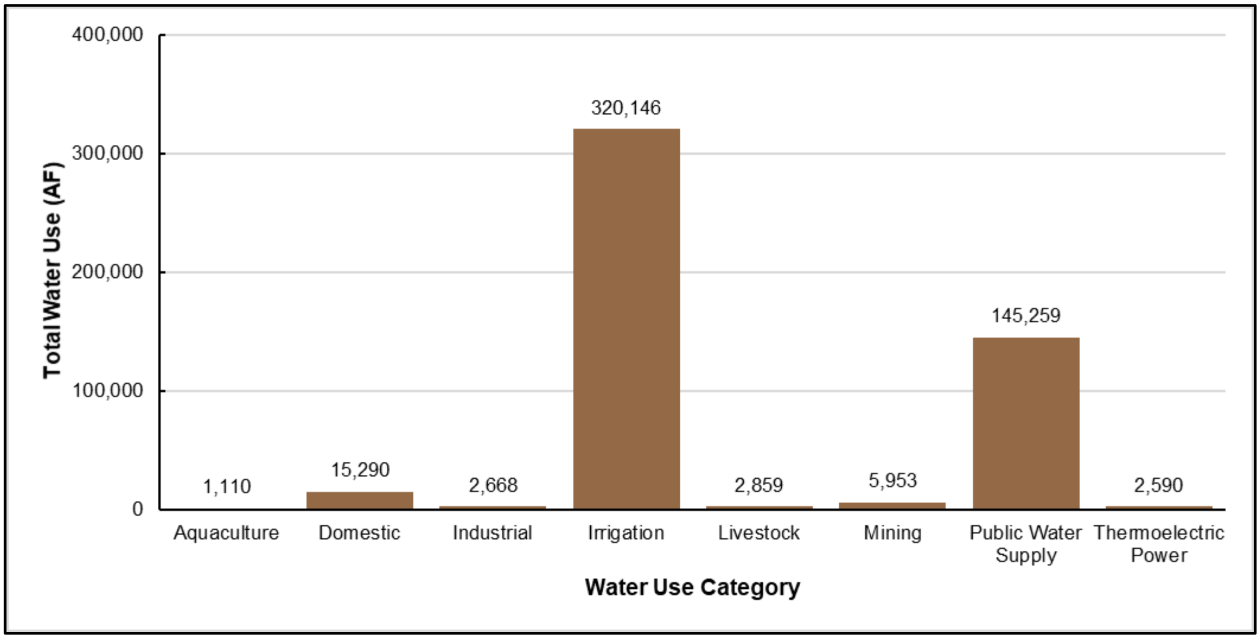


Figure 5-2. RPFO (Bernalillo, Cibola, Torrance, Valencia, Sandoval, McKinley, and Santa Fe Counties) water use by category in 2015 (Dieter et al. 2018).

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 encompasses several counties, the only county with consistent oil and gas well development is Sandoval County, with 71 wells. As such, oil and gas development scenarios and discussion in this chapter assumes that all development will occur in the portion of Sandoval County within the RPFO.

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 (Table 5-9). 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 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).

Table 5-9. Annual Projections for Oil and Gas Well Development and Water Use for Federal and Non-Federal Well Development within the RPFO from 2020 to 2039

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

Water used for development of the estimated 200 wells in the 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

5.1.3.1.1 PAST AND PRESENT ACTIONS

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 2022a). Although there has been consistent development within Sandoval County, the completed oil and gas wells are within FFO boundaries. As such, there are no data available for water use by oil and gas wells within RPFO boundaries, and statistical analysis and forecasting is not possible.

5.1.4 Water Use Associated with Reasonably Foreseeable Oil and Gas Development

The 2019 RFD (Crocker et al. 2019) predicts 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.

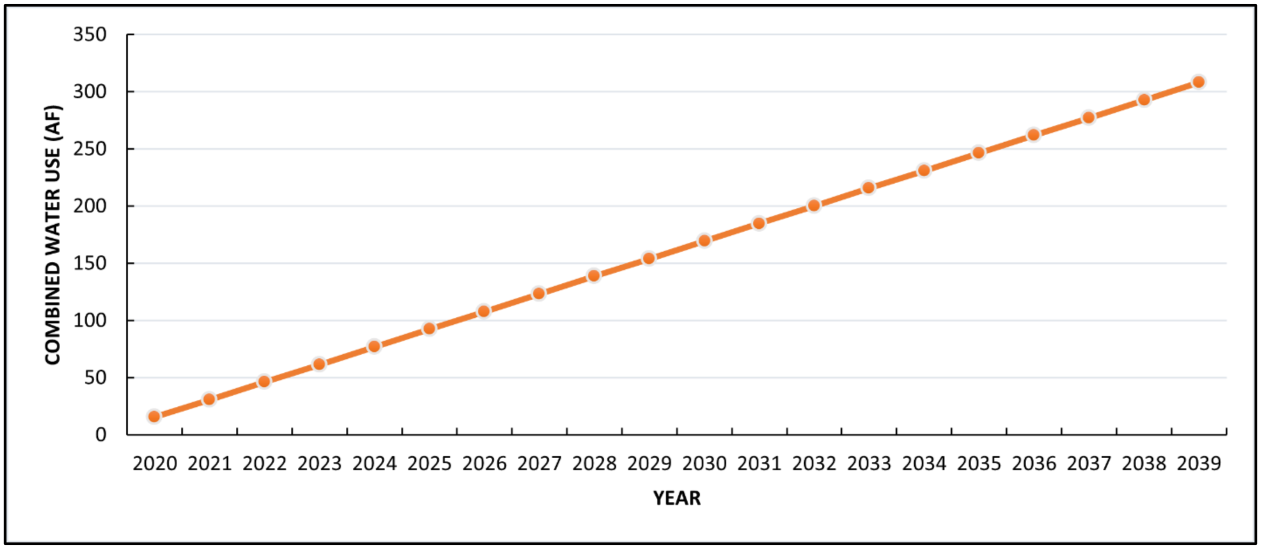


Figure 5-3. Water use associated with reasonably foreseeable oil and gas development in the RPFO from 2020 through 2039.

Water use estimates from the neighboring FFO may also provide some insight regarding water use by oil and gas wells developed in the RPFO in the future. From 2014 to 2019, 71 wells in the portion of Sandoval County in the FFO reported data to FracFocus (Section 4.1.2 discusses the water use associated with reasonably foreseeable oil and gas development in the FFO). Average water use varied by well stimulation technique and averaged 3.8, 3.9, and 19.5 AF per well for nitrogen, water, and slickwater stimulation techniques, respectively (Table 5-10). The distribution of stimulation technologies within a year varies greatly in the FFO, 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 5-10. Descriptive Statistics of Water Use of Oil and Gas Wells in the FFO Portion of Sandoval County for Three Stimulation Technologies from 2014 to 2019

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

Stimulation Technique	Number of Wells	Water Use (AF/well)			
		Minimum	Maximum	Median	Mean
Water	9	2.6	5.3	4.0	3.9

Source: BLM (2021)

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 (2022a).

5.1.5 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 2003).

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 5-11 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 2003). Other aquifers in the San Juan Basin are known to yield water at a rate of less than 20 gpm (BLM 2003). 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 a 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 nonpotable 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 5-11. 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	Siltstone, sandstone	N/A
Oldest	Entrada Sandstone	Sandstone	Oil, gas, water

Source: Kelley et al. (2014)

Note: N/A=not applicable.

5.1.6 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 indicate 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.

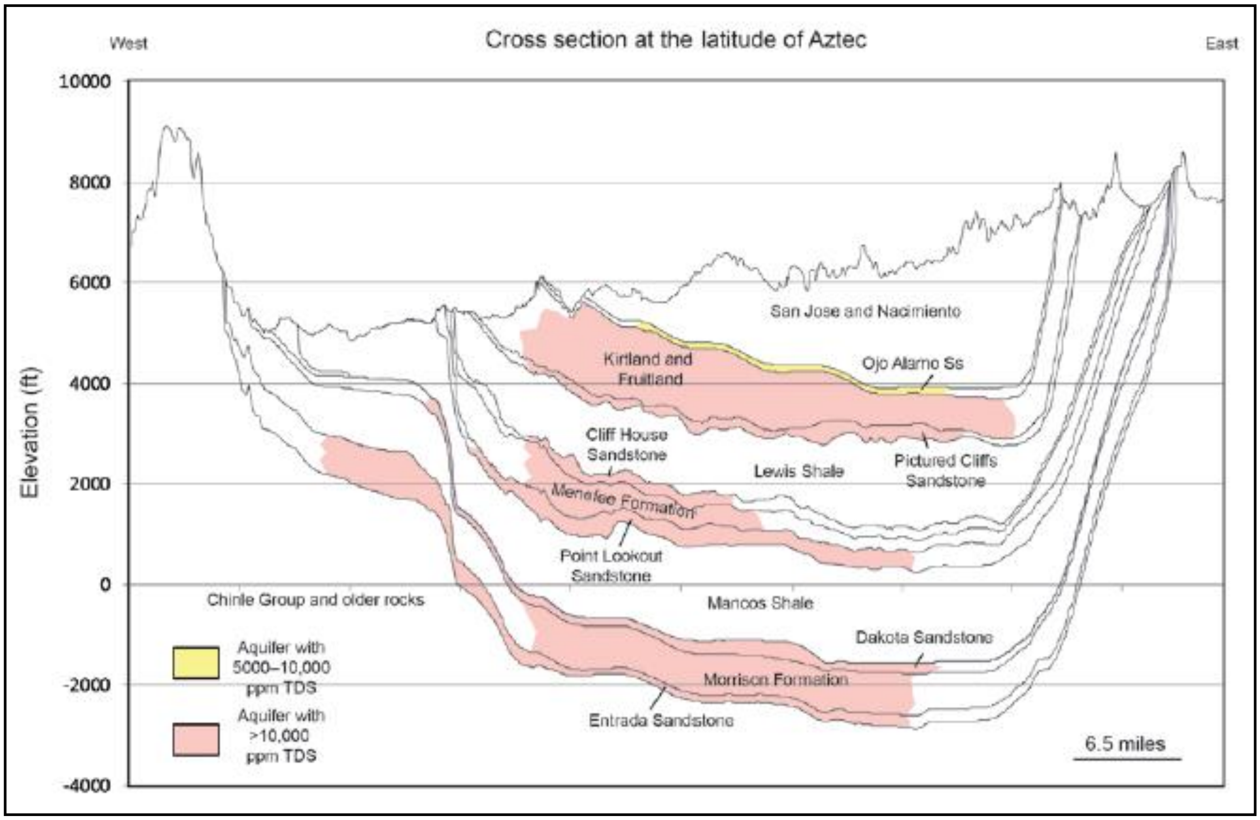


Figure 5-4. Geologic cross section showing the distribution of saline aquifers in the San Juan Basin (Kelley et al. 2014).

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 deeper depths (Kelley et al. 2014).

5.2.2 Surface Water

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

Water quality in streams flowing on BLM-managed 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 a baseline chemistry data for the waters. Variances in baseline chemistry can indicate water quality changes attributable to changes in land use. The most common pollutants for waters in the region are sediment and mercury. Beneficial uses listed for these waters are industrial water supply, irrigation storage, livestock watering, recreation, warm water fishery, and wildlife habitat. The dominant legislation affecting national water quality and BLM compliance with New Mexico water quality requirements is the 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 2022a; see Appendix A).

A total of 55 spills occurred in the New Mexico portion of the RPFO in 2021 (NMOCD 2022a) (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 81% of the spilled material was lost. Of the spills in 2021, no incidents were reported as having affected surface waterways (NMOCD 2022a). 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 5-13 for total spill counts from 2014 through 2021.

Table 5-12. Summary of 2021 Spills in the New Mexico portion of the RPFO (Sandoval County)

Material Type*	Spill Count	Volume Spilled	Volume Lost	Units	Average Spill Volume	Percent Lost	Waterway Affected	Groundwater Affected
Crude oil	4	31	11	bbl	8	62%	0	0
Produced water	2	19	19	bbl	10	100%	0	0

Material Type*	Spill Count	Volume Spilled	Volume Lost	Units	Average Spill Volume	Percent Lost	Waterway Affected	Groundwater Affected
Total	**6**	**50**	**30**	**bbl**	**9**	**81%**	**0**	**0**
Natural gas liquid	55	68,826	68,826	mcf	1251	100%	--	--
Total	**55**	**68,826**	**68,826**	**mcf**	**1251**	**100%**	**0**	**0**
Total Spill Count	**61**				**Average Percent Lost**	**87%**	0	0

Source: NMOCD (2022b)

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

Note: No spills were reported in Bernalillo, Cibola, McKinley, Torrance, Valencia, or Santa Fe Counties in 2021.

* 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 2021.

Table 5-13. Summary of Spills by Year in the New Mexico portion of the RPFO (Sandoval County)

Material Type†	Spill Count							
	2014	2015	2016	2017	2018	2019	2020	2021
Chemical	1	0	0	0	0	0	0	0
Crude oil	3	1	1	0	2	5	3	4
Other (Specify)	4	1	0	0	0	1	0	0
Produced water	1	2	0	1	2	3	1	2
Total	**9**	**4**	**1**	**1**	**4**	**9**	**4**	**6**
Natural gas liquid	0	0	0	0	0	0	8	55
Total	**0**	**0**	**0**	**0**	**0**	**0**	**8**	**55**
Total Spill Count	**9**	**4**	**1**	**1**	**4**	**9**	**12**	**61**

Note: No spills were reported in Bernalillo, Cibola, McKinley, Torrance, Valencia, or Santa Fe Counties in 2021.

* 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 2020 or 2021.

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 C.F.R. § 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. Onshore Order No. 2 and the regulations at 43 C.F.R. § 3162.3-3 provide regulatory requirements for hydraulic fracturing, including casing specifications, monitoring and recording, and management of recovered fluids. The State of New Mexico also has regulations for drilling, casing and cementing, completion, and plugging to protect freshwater zones (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 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 C.F.R. § 3160; Onshore Orders Nos. 1, 2, and 7; 43 C.F.R. § 3162.3-3; 43 C.F.R. § 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 Water Drinking 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 C.F.R. § 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 6. LITERATURE CITED

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