THE REGULATORY FRAMEWORK SURROUNDING PRODUCED WATER IN NEW MEXICO AND IMPACTS ON POTENTIAL USE

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Abstract

We examined the US Federal and New Mexico (NM) regulatory framework surrounding produced water use both within and outside of the oil and gas industry for Lea and Eddy Counties. Previous studies identified many unanswered questions regarding jurisdiction, ownership, liability, and regulatory requirements. We describe the pertinent regulations in New Mexico within the jurisdiction of the NM Oil Conservation Division (NMOCD), the NM Office of the State Engineer (NMOSE), and the NM Environment Department (NMED). We review case studies from New Mexico, Wyoming, California, and Colorado as illustrations of how produced water has been used beneficially. Finally, we provide hypothetical scenarios in order to assist the analysis of produced water treatment and use processes, and to identify gaps in the regulatory framework. We found that the primary jurisdiction falls under the NMOCD for most uses, both before and after treatment. The NMED is responsible for spills and for permitting for certain uses, for example in agricultural applications. US Environmental Protection Agency permits (NPDES) are needed when water is discharged to navigable waters of the United States. Significantly, the NMOSE does not require a water right when produced water is put to beneficial use in New Mexico, based on 2004 legislation.

Keywords: water rights, NPDES, reuse, treatment, pretreatment, agriculture, irrigation, recharge, discharge, case studies, beneficial use.

Contents

List of Abbreviations and Acronyms

API	American Petroleum Institute
bbl	barrel (=42 US liquid gallons)
BLM	Bureau of Land Management
BPJ	Best Professional Judgment
CBM	Coal Bed Methane
CBNG	Coal Bed Natural Gas
CFR	Code of Federal Regulations
COD	Chemical Oxygen Demand
Colorado SEO	Colorado State Engineers Office
CWA	Clean Water Act (Federal)
DMR	Discharge Monitoring Reports (Federal CWA)
E&P	Exploration and Production (oil and gas industry)
EC	Electrical Conductance
EIB	Environmental Improvement Board (New Mexico)
EMNRD	Energy, Minerals and Natural Resources Department (New Mexico)

EOR	Enhanced Oil Recovery
ESP	Exchangeable Sodium Percentage
MCL	Maximum Contaminant Level
NEPA	National Environmental Policy Act
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMOCD	New Mexico Oil Conservation Division
NMOSE	New Mexico Office of the State Engineer
NMSA	New Mexico Statutory Authority
NMWQA	New Mexico Water Quality Act
NORM/TENORM	Naturally Occurring Radioactive Material/Technologically enhanced NORM
NPDES	National Pollution Discharge Elimination System
O&G	Oil and Gas
OCD	Oil Conservation Division (New Mexico)
Oil and Gas Act	Oil and Gas Act
OTSG	Once-Through Steam Generator
POTW	Privately-Owned Treatment Works (Water treatment)
PSES	Pretreatment Standards for Existing Sources
PSNS	Pretreatment Standards for New Sources
RCRA	Resource Conservation and Recovery Act (Federal)
RO	Reverse Osmosis
SAR	Sodium Adsorption Ratio
SDWA	Safe Drinking Water Act
TAMU	Texas A&M University
TDS	Total Dissolved Solids
Texas CEQ	Texas Commission on Environmental Quality
TSS	Total Suspended Solids
UIC	Underground Injection Control
USEPA	United States Environmental Protection Agency
WDR	Waste Discharge Requirements (California)
WQA	Water Quality Act
WQCC	Water Quality Conservation Commission (New Mexico)

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Introduction

Water brought to the surface as a part of oil and gas extraction is known as co-produced or "produced" water. This water is normally considered a waste product, and most of it is reinjected into deep reservoirs either to dispose of it or to use it in active reservoirs for enhanced oil recovery processes.

Recently, the oil and gas industry began to use produced water for drilling, stimulating, and completing oil and gas wells in both conventional and unconventional (tight shale) formations. Industry is also beginning to use the produced water for hydraulic fracturing ("fracking") operations. This is occurring most frequently in areas where there is limited availability of disposal wells (e.g., Pennsylvania Marcellus Shale region) or where there is limited fresh water availability for drilling (e.g., arid regions such as in the Permian Basin of Texas and New Mexico). Also new to the industry is the application of water treatment technologies to create useable product streams from produced water that would otherwise be disposed. While these treatment methods can be expensive, the relative value of the products is increasing, and treatment costs are being driven down by technological and process innovation. The regulatory framework surrounding these product streams is of interest; because to date produced water is categorized as an oilfield waste material and is regulated as such. Treated product streams, however, may be useful in many applications, and may not retain the characteristics of produced water (e.g., toxic organic compounds, metals, or high levels of salt). Therefore, it is appropriate to define the point at which a product stream derived from produced water is not considered to be a solid waste, or at least, changes its characteristics from a regulatory standpoint.

Wastewater generated from oil and gas extraction comes in large quantities. An estimated volume of 21.2 billion barrels (bbl; 1 bbl = 42 US gallons) of produced water was generated in the United States in 2012 {Veil, 2015 #1142}. The total volume of produced water from New Mexico wells in 2012 was 775,930,303 bbl or 100,012 acre-feet [*Veil*, 2012]. Of this water, 87% of the water was generated from conventional oil production. Conventional gas wells generate 8% of the total, and unconventional gas wells produced the remaining 5% of the water. By comparison, water withdrawals for all purposes (e.g., primarily fresh water) in New Mexico in 2010 totaled 3,815,945 acre-feet; of this, water for agricultural use totaled 3,000,155 acre-feet, and water for public use totaled 317,410 acre-feet [*Longworth*, 2013]. Produced water usually has high levels of total dissolved solids (TDS) and other constituents (organic chemicals, inorganic chemicals, metals and naturally occurring radioactive materials, NORM) that are potentially harmful to human health and the environment when released, and that require treatment prior to many uses.

Recent studies in New Mexico and the U.S. have addressed many questions surrounding treatment, reuse or repurposing of produced water, either within the oil and gas industry, or outside of the industry [*Al-Haddabi and Ahmed*, 2007; *Plumlee et al.*, 2014; *Shaffer et al.*, 2013; *Silva*, 2012; *Sullivan Graham et al.*, 2016]. Veil [2015] and [*Clark and Veil*, 2012] addressed the volumes of produced water extracted, handled, and disposed in each state. The Dagger Draw study by [*McGovern and Smith,* 2003], addressed many issues related to supply, treatment design and costs, and regulations for treatment and use of produced water as a local fresh water supply in the Pecos River region of southeastern New Mexico, which includes the current study area of Lea and Eddy Counties [*McGovern and Smith*, 2003]. This region is severely stressed for fresh water supplies, and in many parts of the region, ground water from the High Plains/Ogallala aquifer is the only source of fresh water. Of many water-stressed regions in New Mexico, this region could clearly benefit from having access to alternative sources of water. The McGovern report summarized a list of questions that remained unanswered at the end of their study. Some of the questions could be answered by government entities (local, state, or possibly federal):

- Who has ownership and jurisdiction before and after treatment?
- Where in the system/process does ownership change?
- Where does the liability end/change hands?
- Who defines specifications for treatment?
- Who has responsibility/jurisdiction for rejected concentrate or other treatment wastes?
- What funds can government provide?

Some of the questions could be answered by non-governmental public or private entities, including market forces:

- Who provides treatment?
- Who pays for treatment?
- Who will define and provide treatment specifications?
- Who will pay for the water as an end user?
- Who provides the management, storage, and conveyance of the treated water?

Obtaining answers to these questions is the focus of this report. We point readers to sections below on Jurisdiction and on New Mexico Regulatory Agencies for a discussion of relevant laws and jurisdictional illustrations; to the section on Federal Regulatory Agencies for a discussion of relevant federal laws including discharge to waters of the United States; and to Example Use Cases under the Discussion Section which are helpful to describe treatment strategies, ownership chains, and points for transfer of liability and regulatory authority. Other chapters in the online report evaluate potential uses; identify potential users of treated produced water, the quality, quantity, and location of produced water in the study area, and treatment methods and costs for those specific treatments. We also discuss gaps that we found related both to regulations and to other issues.

While definitive policy directions cannot be fully answered by scientific research, we point to case studies and opportunities found to address these issues from New Mexico and other states facing similar challenges. We also describe policy gaps that we found, in order to assist agencies dealing with questions about produced water handling and reuse. Funding for future research, and funding for infrastructure and development of water resources including nontraditional saline water resources, remains limited and spread over many different agencies and entities. We hope that the information provided in this document will help promote funding for nontraditional water uses.

Finally, we note the complexity surrounding produced water regulations and rules. This report is intended as a brief overview of pertinent factors. It is not a definitive policy statement and should not be relied upon for legal decision making. It is intended as preliminary guidance for readers with interest in the topic. Those who wish to know more, or who have specific legal and regulatory needs, should consult with the appropriate regulatory agencies such as the United States Environmental Protection Agency (USEPA) and the New Mexico state agencies listed below.

Source of Produced Water

The flowchart below gives an overview of a treatment process for crude oil from wells and is typical of systems found in Lea and Eddy counties in the Permian Basin of New Mexico. The separation process employs the use of gravity and density differences of the various liquids (produced oil, produced water and gas). A series of separation tanks are used in the treatment/separation process. The heavier liquid, produced water, settles in the bottom of the tank, the produced oil floats on the water and the gas occupies the open space in the separation tank/separator. The water that is separated from this process, i.e. produced water, has the potential to address various water needs and challenges in the study area if treated in an efficient and economical way.

Typical crude oil treatment system (separation, heating, dehydration, stabilization, storage, metering, pumping)

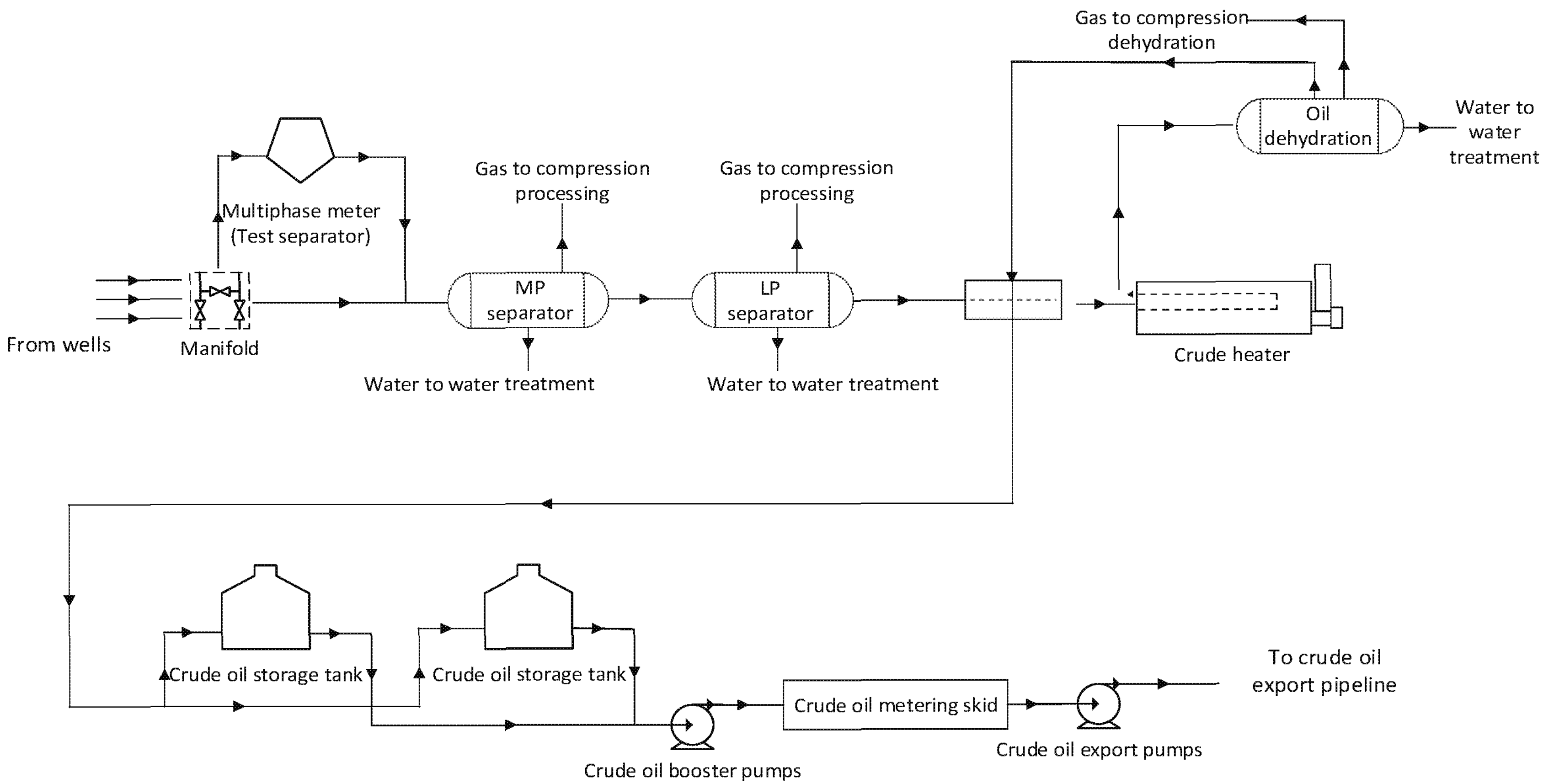


Figure 1. Example of a Crude Oil Treatment Process (Schlumberger, 2016). Note: MP=multiphase; LP=liquid phase. Well sources are oil production wells. Water is produced water in this example.

Potential Beneficial Uses of Produced Water

The ability to use produced water for beneficial uses will depend upon quantity, quality, location, and sustainable yields; no less important will be the economics of treatment, transport, supply, and demand. At this time, desalination remains an expensive option for brackish- and saline-quality waters. Table 1 shows typical ranges of water salinity, or total dissolved solids (TDS) as defined by the USGS, along with typical ranges of produced water salinity from this report in the Permian Basin (USGS, 2016). The additional costs of desalination and waste disposal above and beyond the costs of supplying fresh surface and ground water require favorable market conditions and a strong need for supplemental water resources. Infrastructure costs, financing, and planning also can become prohibitive. A clear regulatory and legal framework supports the opportunity costs of treatment and use/reuse.

Table 1. Ranges of salinity for various water types.

Water Type	Total Dissolved Solids (TDS) in milligrams/Liter	Comment
Fresh	Less than 1,000	Typical fresh range for drinking or agricultural use.
Brackish	1,000 to 10,000	As defined by USGS* to include slightly to moderately saline water. Typically not suitable for drinking but lower levels (<3,000 mg/L) may be suitable for stock watering or some agricultural purposes.
Saline	10,000 to 35,000	Seawater is ~35,000. USGS describes this as highly saline.
Brine	35,000 to 200,000	
Fully salt saturated	>250,000	Found in some oil and gas produced waters or in deep saline reservoirs
Oil and gas co-produced waters	~500 to over 200,000	Derived from oil and gas production
Permian basin produced waters	30,000 to over 200,000	Typical Permian Basin ranges from this study (Sabie et al. 2016)

*https://water.usgs.gov/edu/saline.html

Treatment Processes

Most treatment processes typically employed on produced water are separations processes, and result in multiple product streams. Some of these streams are useable (e.g., purified water), and some may remain waste (reject) streams (e.g., salt concentrate) that require appropriate disposal. Research in recent years has focused on reducing energy and costs and increasing efficiency of separations to maximize recovery of desirable products and minimize the volume of wastes. An undesirable effect of this trend is that waste stream toxicity may increase with increased concentration factors, complicating disposal. One example of this is the case where radioactive isotopes in produced water are concentrated during treatment and the resulting solid waste must be sent to a disposal facility approved for radioactive waste. Nonetheless, minimizing waste volumes is a positive goal in most cases, in order to reduce waste transport or disposal costs. The objective remains to create a stream of fresh water, or saline water that has a specific use, while minimizing wastes, preventing environmental degradation, and reducing treatment costs.

Finished Water Products

There are several types of finished water products that can be derived from produced water. Some produced waters are low in salinity, either naturally in a few cases, or via treatments; some waters are treated minimally, e.g. by filtration or microbicidal treatments; and some may be extensively treated to remove high levels of salts and other constituents. These products include, but are not limited to, waters that can be used within the oil and gas industry:

- Untreated produced water for direct reuse in drilling and completions, or in enhanced oil recovery (EOR)
- Filtered produced water for use as hydraulic fracturing fluid
- "Clean Brine"-produced water that has been more extensively filtered and pretreated for removal of specific mineral components and microbes, for hydraulic fracturing fluid, other drilling and completion uses, and potentially for industrial uses.

These products also may include water used outside of oil and gas, such as:

- Saline water for solution mining of potash and other minerals (>30,000 mg/L TDS)
- Saline water or brine for road deicing applications or for dust suppression.
- Water for agricultural use in stock watering and irrigation (~1,000 mg/L and usually less than 3,000 mg/L total dissolved solids).
- Fresh water (<1,000 mg/L total dissolved solids)-a quality that can be used for industry, irrigation, biofuel systems, dilution, and possibly land application (e.g., dust control).
- Potable fresh water (<500 mg/L total dissolved solids, meeting Drinking Water quality standards) (USEPA, 2016)

Waste Products

Waste products arise from separations processes including filtration, sedimentation, and mechanical filtration methods. Wastes from produced water treatment remain under New Mexico Oil Conservation Division (NMOCD, or OCD) jurisdiction and, thus, permit requirements for transport, handling, and disposal. Most wastes are required to be landfilled (solid wastes), or reinjected (fluid wastes) following OCD permitted methods at permitted locations (see OCD section below). Transport also requires appropriate permits. These products include:

- Solid or semisolid filtrate from produced/hydraulic fracturing fluid separations processes
- Fluid concentrate from desalination or mineral component separations
- Solid salts
- Waste materials resulting from the treatment processes, including spent filters, filter media (filter cartridges, zeolites, walnut shells, activated carbon, e.g.) and other spent/used materials (tanks, pipes, pipe scale) and miscellaneous materials.

Valuable Co-products

Co-products are created as a result of separations processes. They are not classified as wastes, because they have a use or value to another process or industry. They may include:

- Industrial chemicals, including metals such as lithium, as well as iodide, gypsum, magnesium salts, and sulfates
- Brine for industrial use including acid or alkaline chemical production
- Brine or salts for road applications to reduce dust or to mitigate ice and snow

Federal Regulations

We present a brief review of relevant Federal regulations pertinent to produced water and oil and gas wastes. Federal law does not specifically address treatment and beneficial use of produced water, except in the case of uses described by the Clean Water Act (CWA, Subpart E, below).

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) is the public law that creates the framework for the proper management of hazardous and non-hazardous solid wastes. RCRA regulations are intended to prevent environmental contamination arising from industrial processes and are a "cradle-to-grave" regulatory framework for waste materials. The law was passed by Congress giving the Environmental Protection Agency (EPA) the authority to establish and implement the waste management program of RCRA [*McGovern and Smith, 2003*].

Hazardous Waste

Under RCRA, waste is defined as hazardous if it is specifically listed in 40 CFR 261 Subpart D or if it exhibits at least one of the four characteristics defined in 40 CFR Part 261 subpart C:

- **Ignitability (D001)** – Ability to start fires under certain conditions, naturally combustible or have a flash point less than 140 °F (60 °C)
- **Corrosivity (D002)** – Ability to corrode metal containers, usually acids or bases (compounds with very high or very low pH)
- **Reactivity (D003)** – unstable under normal conditions i.e. they can cause explosions, generate toxic fumes, gases or vapors or explosive mixtures when heated, compressed or mixed with water, undergo violent reactions.
- **Toxicity (D004 –D043)** – Ability to cause harm or fatal when ingested or absorbed by the body. [*EPA*]

EPA proposed a hazardous waste management standard that included reduced requirements for several large-volume wastes in December 1978. EPA believed that these large volume wastes were lower in toxicity than other wastes being regulated under RCRA. Drilling wastes, including produced water, are included in this exemption as large-volume wastes. According to the American Petroleum Institute (API), it is estimated that approximately 1.21 barrels of drilling wastes are generated for every foot drilled in the United States (http://www.oilandgasbmps.org/resources/solidwaste.php).

The wastes covered by the proposal originally included gas and oil drill muds and production brines. However, this later expanded to include drilling fluids, produced water, and other wastes associated with the exploration, development and production of crude oil and natural gas. In 1979 and in subsequent determinations, EPA excluded exploration and production wastes from regulation as hazardous wastes under RCRA, subtitle C, pursuant to RCRA section 3001(b)(2) and EPA regulations at 40 CFR Part 261.4(b)(5).

In 1988, EPA issued a regulatory determination stating that regulation of E&P wastes under the RCRA Subtitle C was not warranted, and such wastes would remain exempt under RCRA Subtitle C. This however did not exclude them from regulation under other RCRA statutory authorities (e.g., section 70003 or Subtitle D[1]) or state and federal regulations. The exemption also does not mean these wastes are non-hazardous to humans and the environment if not properly handled.

Waste Exemptions

Only wastes generated from primary field operations were included in the exemptions. Primary field operations in this case refer to activities directly involved in the exploration, development, or production of crude oil and natural gas. Examples include:

- Water separation
- Demulsifying
- Degassing
- Storage at tank batteries associated with specific wells.

Additionally, since natural gas often requires processing to remove water and other impurities prior to entering the sales line, gas plants are considered to be part of the production operations irrespective of their locations. Wastes associated with transport and manufacturing operations are, however, not exempted. To determine if a waste is exempted from the RCRA subtitle C regulations, the answers to the following questions should be YES.

- Has the waste come from down-hole, i.e. was it brought to the surface during oil and gas E&P operations?
- Has the waste otherwise been generated by contact with the oil and gas production stream during the removal of produced water or other contaminant from the product?

Exempt E&P Wastes

Below are lists of some of the wastes exempted under the RCRA regulations. This list is, however, not comprehensive.

- Produced water
- Drilling fluids
- Rigwash
- Produced sand

[1] EPA regulations at 40 CFR 257, Subpart A apply to all solid wastes, including those excluded from regulation under Subtitle C.

- Accumulated materials such as hydrocarbons, solids, sands, and emulsion from production separators, fluid treating vessels, and production impoundments.
- Well completion, treatment, and stimulation fluids.

Produced water must be disposed via any of several approved surface or subsurface methods, including Class II injection wells (see below), evaporation ponds, and sometimes other methods such as crystallization (which produces a solid waste product).

Nonexempt E&P Wastes

Below are lists of some of the wastes not exempted under the RCRA regulations. This list is however not comprehensive.

- Unused fracturing fluids
- Painting wastes
- Gas plant cooling tower cleaning wastes
- Used equipment lubricating oils
- Laboratory and sanitary wastes
- Oil and gas service company wastes such as empty drums, drum rinsate, sandblast media, painting wastes, spent solvents, spilled chemicals and waste acids.

Appendix A shows figures that summarize the rules for classifying wastes mixtures as either exempt or non-exempt and contains additional discussion regarding waste classification steps.

Radioactive Waste

Oil and gas wastes can contain Technologically Enhanced Naturally Occurring Radioactive Material, or TENORM, that forms in pipe scale and drill fluid wastes. Radioactive compounds are also found in produced water, and can accumulate in filtration media or precipitates during handling or treatment processes. These wastes must be disposed in approved landfills as covered in regulations promulgated on a state-by-state basis. In New Mexico, the disposal of radioactive oil and gas waste is regulated by the NMOCD under the Oil and Gas Act rules, 19.15.35 NMAC, and by the EIB and the NMED under the Radiation Protection Act and its rules, NMSA 1978, Section 74-3-1 et seq. and 20.3.14 NMAC ("Naturally Occurring Radioactive Materials (NORM) in the Oil and Gas Industry") (http://164.64.110.239/nmac/parts/title20/20.003.0014.htm).

Solid Waste Disposal

Solid wastes from oil and gas (non-radioactive) are disposed in landfills approved for this disposal process. This includes drill muds and other solid and semi-solid materials that are byproducts of drilling, as well as membranes, filters, and pit liner materials. States have different methods of regulating solid wastes. The NMOCD retains jurisdiction over solid and semisolid wastes produced from drilling operations in New Mexico (OCD, 70-2-12 NMAC).

Clean Water Act and NPDES Permits

Discharges to waters of the United States are regulated by the 1972 Clean Water Act (CWA) (https://www.epa.gov/laws-regulations/summary-clean-water-act). The CWA establishes the basic structure for regulating discharges into the waters of the United States. The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but was significantly reorganized and expanded in 1972. The Act is administered by the USEPA. The CWA made it unlawful to discharge any pollutant from a point source into waters of the United States (for this report, surface water) except as authorized by a National Pollutant Discharge Elimination System (NPDES) permit or by certain other specified statutory provisions, CWA sections 301 and 402 (https://www.epa.gov/npdes). The NPDES program aims to protect and restore the quality of water bodies (e.g., rivers, lakes and coastal waters) through permit requirements to monitor and control pollutants discharged from point sources. EPA's NPDES permit regulations require permittees to report compliance with NPDES permit limits via regular Discharge Monitoring Reports (DMR) submitted to the permitting authority. NPDES permits are needed if produced water is treated and subsequently discharged to surface water. Treated produced water that is used in an application, such as industry or irrigation (not disposed) without discharge to surface water is unlikely to need an NPDES permit, but may be subject to other state and federal permits depending upon the use.

NPDES permits are issued for New Mexico by USEPA Region VI (Dallas, Texas) with assistance from the New Mexico Environment Department (NMED) (https://www.epa.gov/npdes). NPDES permits must include technology-based effluent limitations. For direct dischargers of oil and gas extraction wastewater (produced water) from onshore oil and gas facilities, with the exception of coal bed methane (CBM), 40 CFR Part 435 is the source of technology-based effluent limitations. Direct discharges from oil and gas extraction are also subject to NPDES regulations 40 CFR Parts 122 through 125. Indirect discharges are subject to the General Pretreatment Regulations (40 CFR Part 403) in addition to the requirements of 40 CFR Part 435.

Permits for onshore oil and gas facilities must include the requirements listed in 40 CFR Part 435, including a ban on the discharge of pollutants to surface water. Oil and natural gas operators typically meet the zero-discharge requirement by injecting produced water into underground disposal wells, re-using the produced water for subsequent drilling operations; or sending the produced water to privately owned treatment facilities known as Centralized Waste Treatment facilities, discharges from which are subject to regulation under 40 CFR Part 437. In the event that produced water is "of good enough quality", then there may be an exception to the zero-discharge requirement for specific uses in livestock or wildlife watering. This applies only to onshore facilities located in the continental United States located west of the 98th meridian. Under 40 CFR Part 435, oil and gas operators are subject to a categorical pretreatment standard prohibiting them from sending produced water from unconventional oil and gas operations to Publicly Owned Treatment Operations (POTWs) for treatment and disposal (see discussion below), although no such categorical prohibition yet applies with respect to conventional oil and gas produced water.

Some subparts of the CWA and later amendments are relevant to produced water use and handling, as described in Appendix C. Details about the Clean Water Act as related to oil and gas development can be found here: http://www.oilandgasbmps.org/laws/federal_water_quality_law.htm.

Safe Drinking Water Act and Underground Injection Control Regulations

The Safe Drinking Water Act (SDWA) (42 U.S.C. § 300f et seq.) (2006) is the main federal law that ensures drinking water quality in the U.S. Provisions of the SDWA most pertinent to oil and gas development include the Underground Injection Control (UIC) program to prevent injection of fluids that would endanger underground sources of drinking water (USDWs). This program covers injection of oil and gas wastes to UIC Class II wells. The goal of federal Underground Injection Control regulations is to prevent contamination of USDWs from the placement of fluids underground through injection wells. The underground injection control regulations do this by regulating the construction, operation, and closure of injection wells. Source water protection zones are also a critical part of drinking water protection for municipalities.

States often establish their own UIC programs, which are reviewed and approved by the EPA under the SDWA. The New Mexico program for Class II wells, which is administered by the NMOCD, was approved by the EPA effective March 7, 1982 (40 CFR 147.1600). The State authority for the Class II program is found in the Oil and Gas Act, NMSA 1978, Section 70-2-12(B) and the regulations of the OCD (19.15.26 NMAC). Class II wells are designated specifically for oil and gas waste disposal. These wells have specific construction requirements and are used for 1) enhanced recovery, 2) disposal, or 3) hydrocarbon storage (< https://www.epa.gov/uic/class-ii-oil-and-gas-related-injection-wells>). The New Mexico program for Class I, III, IV and V wells, which is administered by the NMED and NMOCD, was approved by the EPA effective August 10, 1983 (40 CFR 147.1601). The State authority for the Class I, III, IV and V well program is found in the Water Quality Act, NMSA 1978, Section 74-6-4, and the regulations of the Water Quality Control Commission, 20.6.2 NMAC (http://164.64.110.239/nmac/parts/title20/20.006.0002.htm).

Oil and Gas Effluent Guidelines and Standards

Under the Oil and Gas Extraction Category, the EPA promulgated the Oil and Gas (O&G) Effluent Guidelines and Standards (40 CFR Part 435) in 1979, and amended the regulations in 1993, 1996 and 2001. The regulations cover wastewater discharges from field exploration, drilling, production, well treatment and well completions activities on land, in coastal areas and offshore. The Oil and Gas Regulations apply to both conventional and unconventional oil and gas extraction, excluding coalbed methane.

These regulations apply to facilities organized into five subcategories namely:

a) Offshore
b) Onshore
c) Coastal
d) Agricultural and Wildlife Water Use
e) Stripper Wells

Additionally, oil pollution prevention is covered by 40 CFR part 112, to prevent oil discharge into navigable waters of the U.S. or nearby areas. 40 CFR parts 435.30-435.32 prohibits discharge of water pollutants associated with oil and gas operations. More information can be found here: http://www.oilandgasbmps.org/laws/federal_water_quality_law.htm.

Unconventional Extraction in the Oil and Gas Industry

Unconventional oil and gas (UOG) traditionally refers to oil and natural gas produced by a well drilled into a shale and/or tight formation (including, but not limited to, shale gas, shale oil, tight gas, tight oil) fracturing impermeable formations to create channels for the flow of the hydrocarbons. Natural gas can include "natural gas liquids," components that are liquid at ambient temperature and pressure.

Produced water from UOG extraction is frequently disposed by underground injection into Class II disposal wells where available. In areas with limited injection wells and/or few opportunities for reuse or recycling, operators turned to public and private wastewater treatment facilities to manage their wastewaters. Negative consequences can occur because wastewaters from UOG extraction are not typical influents for a POTW. Some UOG extraction constituents [*McGovern and Smith, 2003*; EPA, Natural Gas Extraction-Hydraulic Fracturing]:

- can be discharged, untreated, from the POTW to the receiving stream.
- can disrupt the operation of the POTW (for example, by inhibiting biological treatment).
- can accumulate in biosolids (also called sewage sludge), limiting their use and disposal options due to higher concentrations of metals and NORM.
- can facilitate the formation of harmful disinfection by-products.

Because of these potential disruptions to POTWs, EPA in 2016 (June 13, 2016) enacted a zero-discharge pretreatment standard for unconventional oil and gas discharges to POTWs (https://www.epa.gov/sites/production/files/2016-06/documents/uog-final-rule_fact-sheet_06-14-2016.pdf). However, there is currently no categorical pretreatment standard that applies with respect to conventional oil and gas wastewater discharges to POTWs. UOG extraction operators can also continue to send their wastewater to privately-owned centralized waste treatment facilities, which can treat and discharge the wastewater subject to regulation under 40 CFR Part 437.

Coalbed Methane Extraction

Coalbed Methane (CBM) is a form of unconventional natural gas extracted from coal beds. During the extraction of the CBM, groundwater (produced water or CBM wastewater) is pumped out of the formation to depressure the coal seam (also called dewatering) thereby allowing the methane molecules to desorb from the coal. The gas flows from the seam up to the surface via a gas well, and is compressed and piped to market. Discharges from CBM extraction from onshore oil and gas facilities are not subject to effluent limitations guidelines and standards under the Oil and Gas Extraction Category 40 CFR Part 435. Nonetheless, NPDES permits for the CBM discharges are currently developed according to the best professional judgment (BPJ) of the permit authority based on the factors specified in 40 CFR 125.(c)(2). The BPJ-based requirements that have been applied to the management of coalbed methane wastewater vary from state to state. These BPJ-based requirements for CBM have included limitations on some conventional pollutants prior to discharge, to prohibition of direct discharges to waters of the US. While coalbed methane extraction is common in the northwest corner of New Mexico, in the San Juan Basin region, this type of extraction is not done in southeastern New Mexico.

EPA published a report based on its detailed study of the CBM extraction industry in 2010 (U.S. EPA 2010). From this report, EPA commenced a rulemaking to develop controls for pollutant discharges from the CBM industry. Data were collected and analyzed after the commencement of the CBM rulemaking. EPA concluded that though effective technologies exist, have been demonstrated, and may be affordable for some sites, these technologies are not economically achievable for the CBM extraction industry as a whole. Thus, the Agency is not developing national effluent limitations guidelines for these operations at this time.

New Mexico State Regulations

There are three agencies within the State of New Mexico that are responsible for regulations that apply either to produced water (New Mexico Oil Conservation Division or New Mexico Environment Department), or to deep nonpotable waters that might be used in oil and gas operations, among other uses (New Mexico Office of the State Engineer).

New Mexico Oil Conservation Division

The Oil Conservation Division (OCD) is the part of the New Mexico Energy, Minerals and Natural Resources Department (EMNRD) that regulates oil and gas activity in New Mexico (http://www.emnrd.state.nm.us/OCD/). The agency collects and disseminates well production data; issues permits for new wells; enforces OCD rules and the state's oil and gas statutes; makes certain that abandoned wells are properly plugged; and ensures that land used in oil and gas operations is restored responsibly. OCD also regulates the use and disposition of produced water from oil and gas operations. Under the Oil and Gas Act, NMOCD is the primary regulatory body for the use and disposal of produced water. NMOCD has the authority to "regulate the disposition of water produced or used in connection with the drilling for or the producing of oil and gas or both and to direct surface or subsurface disposal of the water…" (NMSA 1978, Section 70-2-12(B)(15)). This includes disposal (surface and subsurface methods) and "disposition by use". The Oil Conservation Commission has enacted regulations that deal with specific processes or facilities associated with produced water. These include rules governing injection including disposal wells and enhanced recovery wells, 19.15.26 NMAC, rules governing pits, closed loop systems, below grade tanks and sumps, 19.15.17 NMAC, rules governing recycling facilities, 19.15.34 NMAC, and rules governing surface waste management facilities, 19.15.36 NMAC.

The New Mexico Oil and Gas Act defines "produced water" as water that is "an incidental byproduct from drilling for or the production of oil and gas" (70-2-33(K) NMSA 1978). The Oil and Gas Act (70-2-12.1 NMSA 1978) assigns the authority for produced water to OCD. Specifically, no permit from the state engineer for disposition of produced water in accordance with Section 70-2-12 NMSA 1978 is required.

Recent changes to OCD regulations addressed the potential for reuse of produced water within NMOCD jurisdiction. Rules were promulgated to direct "transportation, disposal, recycling, re-use, or the direct surface or subsurface disposition by use" of produced water (19.15.34.2 NMAC). The rule also applies to uses of produced water "in road construction or maintenance, or other construction; in the generation of electricity or in other industrial processes". The rule also applies to the transportation of drilling fluids and liquid oil field waste. In addition, these rules allow OCD to set test requirements for treated water for other uses (19.15.34.8 A2 NMAC). In 2013, the NMOCD Director issued a notice regarding permits for reuse of produced water (posted 9/9/2013; http://www.emnrd.state.nm.us/OCD/announcements.html), stating that:

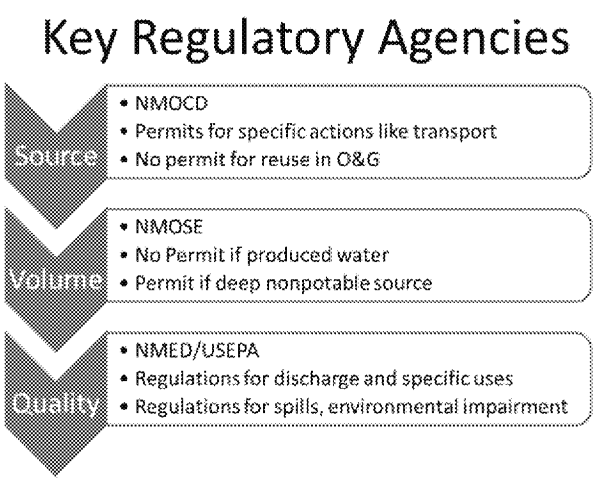
> " No OCD permit or authorization is required for the re-use of produced water, drilling fluids or other oil field liquids as a drilling or completion fluid or other type of oil field fluid, including makeup water, fracturing fluid or drilling mud, at a permitted drilling, production or plugging operation. However, the re-use of produced water is NOT permitted for any use which involves contact with fresh water zones. No permit is required for the delivery of produced water to permitted salt-water disposal facilities,

secondary recovery, pressure maintenance or EOR projects, surface waste management facilities, or to well sites for use in drilling, completion, or plugging operations. Produced water must be stored and re-used in a manner that protects fresh water, public health, and the environment. Produced water, brine makeup water, or frac flowback water can be stored in permanent pits or in temporary multi-well fluid management pits when used only on wells identified in the multi-well fluid management pit permit."

This notice clarifies the use of permits in handling of produced water for reuse under the jurisdiction of NMOCD. NMOCD encourages use and reuse of produced water in order to conserve fresh water resources in New Mexico.

In addition to upstream water production, OCD administers and enforces regulations pertaining to surface and ground water discharges at oil and gas production sites and oil refineries, natural gas processing plants, geothermal installations, carbon dioxide facilities, natural gas transmission lines, and discharges associated with activities of the oil field service industry pursuant to the Oil and Gas Act and the Water Quality Act. The Water Quality Act requires the WQCC to assign responsibility for administering it's regulations to "constituent agencies". Section 74-6-4(F); See Section 74-6-2(K) NMSA 1978 (listing the 8 constituent agencies). A "Delegation of Responsibilities" Memo from the Water Quality Control Commission (http://www.emnrd.state.nm.us/OCD/tab2att2.html) assigns responsibilities to 2 constituent agencies (NMED and NMOCD) and defines NMOCD's jurisdiction and related enforcement of regulations regarding discharges from refinery activities.

Brines are a special case of water administered by OCD (i.e., not fresh, produced, or deep nonpotable waters), including brine manufacturing operations, discharges to ground or surface water at brine manufacturing operations, and including all brine production wells, holding ponds and tanks, transportation and disposal (via UIC Class II injection wells) of the brine. Interestingly, brine may be a viable co-product of desalination treatment and could be regulated by OCD under this framework (Source: 6/13/89, Commission minutes).



The OCD also regulates surface waste management facilities used for oil and gas wastes. NMAC regulation 19.15.36 NMAC - Surface Waste Management Facilities-regulates disposal of oil field wastes and construction, operation and closure of surface waste management facilities. Only exempt or non-hazardous wastes may be disposed.

Pits, closed-loop systems, and below-grade tanks and sumps used in connection with oil and gas operations are regulated by OCD for the protection of fresh water, public health, and the environment. This includes pits containing "low-chloride fluids"-water-based fluids containing less than 15,000 mg/L chlorides; and pits containing fluids that are not low-chloride fluids (separate provisions)(19.15.17 NMAC).

New Mexico Office of the State Engineer

The Office of the State Engineer in New Mexico (NMOSE) administers the state's water resources and has authority over the supervision, measurement, appropriation, and distribution of both surface and ground water in New Mexico (http://www.ose.state.nm.us/OSE/index.php). New Mexico's water resources are administered under the Prior Appropriation Doctrine (N.M. Const. art. 16 § 2), where the user who first places water to beneficial use becomes the senior water right owner to those who subsequently place water to beneficial use from the same source. In times of a shortage, such as a drought, a senior water right owner has priority over junior water right owners.

The NMOSE implements state statutes governing the appropriation of underground water (NMSA 1978, Section 72-12-1 through 72-12-28). However, permitting authority over the disposition of water produced or used in connection with the drilling or production of oil and gas is assigned to OCD under NMSA 1978, Section 70-2-12(B)(15). The New Mexico State Legislature's passage of NMSA 1978, Section 70-2-12.1 in 2004, states that no permit from NMOSE is required for the disposition of produced water. This action by the Legislature clarified that no water right is acquired through the disposition by use of produced water at any time, regardless of the type of use or whether the produced water is treated.

A former oil and gas well may be utilized for the diversion of water, assuming the well owner follows the applicable Sections of NMSA 1978, Section 72-12-1 through 72-12-28. Specifically, if the well owner desires to utilize the former oil and gas well to appropriate any unappropriated fresh water, they must file an application with the NMOSE, pursuant to NMSA 1978, Section 72-12-1 through 72-12-3, and comply with any additional requirements Sections 72-12-4 through 72-12-24. If the well owner seeks to utilize a former oil and gas well to appropriate nonpotable water from a deep saline aquifer, they must file, with the NMOSE, a Notice of Intent ("NOI") to drill or recomplete the well, pursuant to NM SA 1978, Section 72-12-26, and follow any additional requirements under NMSA 1978, Section 72-12-25 through 72-12-28.

Water appropriated from deep saline aquifers may be used in oil and gas drilling and for other uses. Deep saline aquifers containing nonpotable water, for purposes of Section 72-12-25, are aquifers the top of which is at a depth of 2,500 feet or more below ground surface and contain nonpotable water (defined as >1,000 mg/L total dissolved solids). NMOSE may also require additional pertinent data to be filed with respect to each well for appropriations from deep saline aquifers pursuant to NMSA 1978, Section 72-12-27.

A useful summary of groundwater rights information can be found in [*Adams et al. 2004*]; a discussion of water rights in New Mexico also can be found in Ortega Klett [2002]; and in DeMouche et al, [2010]. Figure 2 provides a general breakdown of agencies, code references, and waters covered under different jurisdictions. However, the Statutes listed above offer the most up-to-date information on current rules regarding produced water.

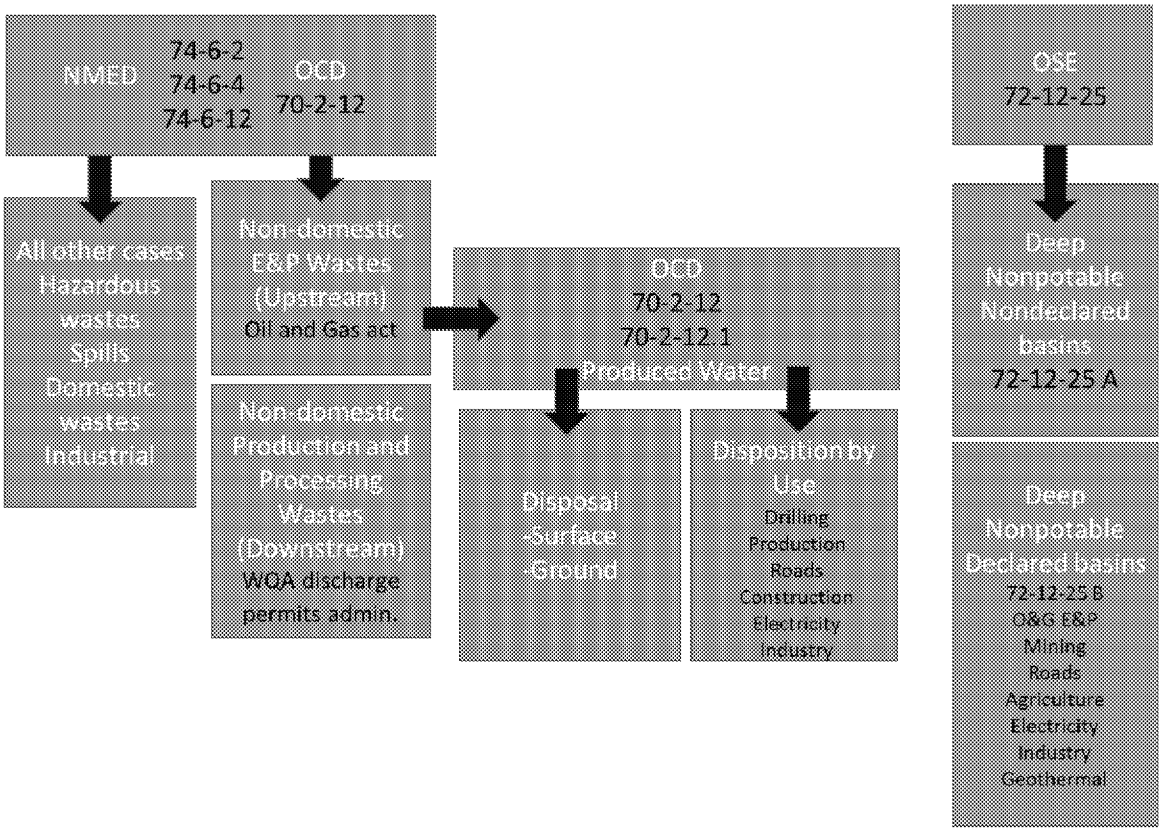


Figure 2. Schematic of jurisdiction and rules applicable to nonpotable waters, produced waters, and all other water cases. Numbers refer to NMAC sections.

New Mexico Environment Department

The New Mexico Environment Department is the environmental agency for the state of New Mexico which is tasked with the responsibilities of protecting the environment. This includes cleanups, permits, and licenses pertinent to air, water, wastes, health and safety, and environmental cleanups. The NMED has water quality programs and regulatory information on drinking water, ground water, surface water, wastewater, water and wastewater infrastructure and cleanups and monitoring for water resource protection. The NMED Drinking Water program is responsible for overseeing water infrastructure and water quality issues throughout the state (https://www.env.nm.gov/water/).

Drinking Water

The Safe Drinking Water Act (SDWA) is the primary law governing public water systems, however, the NMED (Drinking Water Program) has primacy for the SDWA, i.e. it has the authority to implement and enforce the SDWA regulations. The SDWA regulates over 90 separate contaminants and sets the Maximum Contaminant Level (MCL) for each. The contaminants include microorganisms, disinfectants, disinfection byproducts, inorganic chemicals, organic chemicals and radionuclides. Appendix A (Table A-2) shows the MCLs for the listed contaminants.

The basic authority for water quality management in New Mexico is provided through the State Water Quality Act which establishes the Water Quality Control Commission (WQCC). The WQCC is the state water pollution control agency for purposes of the Federal Clean Water and portions of the Safe Drinking

Water Acts. The Environmental Improvement Board (EIB) is responsible for rules relating to water supply and capacity development.

Ground Water

The New Mexico Water Quality Act and the WQCC mandate the NMED to prevent waste pollution in the state at sites which pose a significant risk to human health and the environment. The NMED also monitors and issues Ground Water Discharge Permits through 20.6.2 NMAC. Table 1, below, shows the ground water standards for human health, domestic water supply and irrigation use.

Table 1. Ground water standards for New Mexico (20.6.2 NMAC).

A. Human Health Standards			
Contaminant	**mg/L**	**Contaminant**	**mg/L**
Arsenic (As)	0.1	1,2-dichloroethane (EDC)	0.01
Barium (Ba)	1.0	1,1-dichloroethylene (1,1DCE)	0.005
Cadmium (Cd)	0.01	1,1,2,2-tetrachloroethylene (PCE)	0.02
Chromium (Cr)	0.05	1,1,2-trichloroethylene (TCE)	0.1
Cyanide (CN)	0.2	ethylbenzene	0.75
Fluoride (F)	1.6	total xylenes	0.62
Lead (Pb)	0.05	methylene chloride	0.1
Total Mercury (Hg)	0.002	chloroform	0.1
Nitrate (NO_3 as N)	10.0	1,1-dichloroethane	0.025
Selenium (Se)	0.05	ethylene dibromide (EDB)	0.0001
Silver (Ag)	0.05	1,1,1-trichloroethane	0.06
Uranium (U)	0.03	1,1,2-trichloroethane	0.01
Radioactivity[1]	30	1,1,2,2-tetrachloroethane	0.01
Benzene	0.01	vinyl chloride	0.001
Polychlorinated biphenyls (PCB's)	0.001	PAHs:	0.03
Toluene	0.75	Benzo-a-pyrene	0.0007
Carbon Tetrachloride	0.01		
B. Standards for Domestic Water Supply		**C. Standards for irrigation use**	
Chloride (Cl)	250.0	Aluminum (Al)	5.0
Copper (Cu)	1.0	Boron (B)	0.75
Iron (Fe)	1.0	Cobalt (Co)	0.05
Manganese (Mn)	0.2	Molybdenum (Mo)	1.0
Phenols	0.005	Nickel (Ni)	0.2
Sulfate (SO_4)	600.0		
Total Dissolved Solids (TDS)	1,000.0		
Zinc (Zn)	10.0		
pH	6 to 9		
[1] pCi/L			

Surface Water

The NMED is responsible for the monitoring and assessment of all surface waters, overseeing discharges to surface water (through the NPDES, assisting EPA in this role), developing water quality standards, and protecting the New Mexico watersheds (https://www.env.nm.gov/water/).

Wastewater

The NMED regulates municipal and industrial operations discharging water to surface water by assisting the EPA in implementing the NPDES permitting program. The NMED also issues permits to regulate groundwater discharges. It also issues permits or registrations for septic systems through the NMED Liquid Waste Program.

Water and Wastewater Infrastructure

Through the Drinking Water Bureau and the Construction Programs Bureau, the NMED works with communities to develop, track and inspect the infrastructure needed to manage water and wastewater. The Operator Certification Program certifies wastewater operators, as well.

Cleanups and Monitoring for Water Resource Protection

The NMED, through the following bureaus (The Ground Water Quality Bureau, the Surface Water Quality Bureau, the Hazardous Waste Bureau and Petroleum Storage Tank Bureau) works in conjunction with the Department of Energy (DOE) Oversight Bureau in developing rigorous monitoring and assessment programs to protect the quality of our surface and ground water sources from existing or potential contaminants. Pretreatment of produced water is likely to be needed prior to any use outside of the oil and gas industry in order to prevent releases of potential contaminants. Treatment levels will vary depending upon the initial quality of the water and the potential use. The potential use is most likely to define any type of regulation, or quality criteria that may be relevant. For example, use in agriculture may require that specific constituents fall within crop tolerance ranges, and soil quality regulations will also apply.

In summary, NMED regulates areas where spills of produced water or hazardous wastes may occur, and also regulates discharges from users or industries where produced water could be used in processes with emissions or otherwise discharged to the environment (e.g., agriculture, streamflow, groundwater recharge). Users need to be aware of process limits and regulations and consult with NMED for appropriate permits for the process being considered.

Case Study Examples of Regulatory Framework Leading to Beneficial Uses

Case studies that include the use and reuse of produced water in New Mexico and other states are described below. Where possible, the pertinent regulatory framework or permit structure is described. If ownership information is available, it is included.

New Mexico-Farmington Pilot Treatment Study

In this study, produced water from a Coal Bed Natural Gas (CBNG) well (~10,000 mg/L TDS) (also known as Coal Bed Methane or CBM) was treated and used for improvement of rangeland in a multi-month experimental study. The produced water was first pretreated to remove coal fines and dissolved organics using sand filter media, modified zeolite test media (surfactant-modified zeolite or SMZ), and an Advanced BioSystems filtration unit (for COD)[*Atkinson*, 2005]. This was followed by reverse osmosis (RO) to remove the salts from the produced water. Table 2 below shows the results from this study.

Table 2. Results from Farmington Pilot treatment study. Note: Values are in mg/L.

Feed			Bio Unit Product				RO Unit			
COD	Salinity	TSS	COD	Corrected COD	Salinity	TSS	COD	Salinity	TSS	TDS
730 - 1130	10,000 -16,000	38-112	120-440	12-44	9,000-14,000	24-58	ND	ND	ND	84 - 119

About 90% of the COD value was a result of the salt content and the remaining carbon was too low for microbial use. The corrected values were 12 – 44 mg/L. The study was able to produce water that met the New Mexico groundwater standards (NMAC 20.6.2.2101). Treated water was discharged to the land surface plots. The research evaluated the differences in rangeland plant growth and plant diversity between plots irrigated with different irrigation water sources (desalinated water, mixed water, and non-desalinated produced water).

The New Mexico Oil Conservation Division and the US Bureau of Land Management provided consultation and guidance on regulatory and permitting issues. ConocoPhillips also provide the site for the study as well as key personnel on the project. The Navajo Agricultural Products Industry, Agriculture and Testing Research Laboratory and the Assaigai Analytical Laboratories also provided personnel, testing and analytical services of the produced and purified water. Research was conducted by Sandia National Laboratories, Los Alamos National Laboratories, and ConocoPhilips.

This test showed that there are technologies available that can treat produced water to regulatory standards for land application. Permitting for the treatment and land application was provided by the New Mexico Oil Conservation Division and the Bureau of Land Management. The site was handled as a short-term research test case for the purpose of the permits. A copy of the permit letter from NMOCD is included in Appendix B. Waste concentrate from the reverse osmosis unit was stored in a tank and was disposed via a Class II injection well after the test.

The Bureau of Land Management follows federal law and case precedent regarding oil and gas operations. In Center for Biological Diversity v. Bureau of Land Management, the U.S. District Court for the Northern District of California ruled that BLM must look at impacts from hydraulic fracturing in issuing oil and gas leases. Other operations require impact analyses under National Environmental Policy Act (NEPA)(http://elr.info/litigation/43/20076/center-biological-diversity-v-bureau-land-management). Presumably if the above-described testers had requested a permanent or longer-term permit, then NEPA analysis would have been necessary.

New Mexico-Pecos River Recharge and HB 388

In 2002, the New Mexico House passed House Bill 388, providing for an income tax or corporate tax credit for investments in treating produced water (https://www.nmlegis.gov/sessions/02%20Regular/bills/house/hb0388.HTML; Appendix D). The bill was designed to promote the treatment of produced water and subsequent discharge into the Pecos River system, to meet Pecos River Compact delivery obligations. The legislation covered some very important aspects of jurisdiction, ownership, and water quality criteria for produced water use outside of the oil and gas industry. The bill expired in 2006, with no entities ever taking advantage of the relatively substantial ($1,000/acre-foot) tax credit.

Specifically, the bill required that discharges be in compliance with the New Mexico Water Quality Act, New Mexico water quality control commission regulations, and the Federal CWA. The water was made available only for appropriation to meet the terms of the Pecos River Compact (addressing Interstate Stream Commission rules) and also required that the water must be "produced from oil and gas drilling from a depth of three thousand feet or more below the surface"; this language means that a water right would not be assigned by the OSE. Today, brackish water rules state that the water must be extracted from a reservoir whose top is greater than 2,500 feet below ground surface-a construct designed to protect fresh water resources from brackish water extraction. Finally, a provision of the rule specifically addressed transfer of title of the water from the operator/provider to the interstate stream commission, "which shall indemnify the operator from future liability"-clearly addressing the issue of ownership and liability for the produced water.

Wyoming

There are a number of instances where produced water from coalbed methane has been used for crop production and livestock watering in the state of Wyoming. For example, in the Pinedale Anticline of southwest Wyoming, produced water is treated so that 75% is delivered to industry and 25% is discharged to a local river after further treatment to drinking water standards (http://www.highsierrawater.com/pinedale-anticline/)). Limitations on disposal volumes are the prime reason for reuse [*Brockmann*, 2009]. We also discuss a project managed by Fidelity and Williams [*Guerra et al.*, 2011], below.

Fidelity Exploration and Production conducted a project where produced water from coalbed methane was used for the production of livestock forage [*Harvey et al.*, 2005]. The project by Fidelity was performed in three phases, including laboratory bench-scale testing, large-scale (100 acres) pilot testing, and a full-scale (800 acres) operation [*All Consulting*, 2003].

Permitting body

The permitting of the produced water was issued by Mr. John Wagner of the Wyoming Department of Environmental Quality, Water Quality Division, permit number WY0051772. The permit application included discharge specifications for a Wyoming NPDES (WYPDES) permit, flow rate specifications, landowner information, outfall description and location, and other pertinent information related to the discharge. A key aspect of the permit was the requirement that the discharged effluent be of equal to or better quality than the ambient quality of the perennial class 2 receiving water. The permit is provided in Appendix B.

Laboratory Pilot Testing

The aim of the pilot project was to determine the best method for managing high sodium levels and bicarbonate in the coalbed methane produced water. Controlling the sodium and bicarbonate levels meant reducing the Sodium Adsorption Ratio (SAR) of the soil which leads to a reduced chance of forming sodic soil conditions. The bench-scale test was done using soil columns made from PVC pipes to simulate the irrigation area, and produced water was obtained from the Tongue River Basin. Three treatment strategies were tested in the lab in finding the best method for managing high sodium and bicarbonate levels. They were:

- Application of amendments directly to the soil
- Adding amendments to the produced water
- Blending the produced water with irrigation water from local water source

The produced water used exhibited an initial Electrical Conductivity (EC) of 2.5 and an SAR of 60. The effects of the treatment methods were found by measuring the pH, electrical conductivity (EC) and SAR of the soil in the various columns. Table 3 summarizes the results.

Table 3. Results of soil sampling and analysis from the Fidelity bench-scale managed irrigation tests.

Treatments	Average pH	Average electrical conductivity (dS/m)	Average SAR
Gypsum and sulfur applied to the soil and irrigated with CBNG produced water	7.8	2.9	7.5
Gypsum and sulfuric acid added to the CBNG produced water and irrigated on the soil	7.5	2.8	8.9
Untreated CBNG produced water irrigated on the soil	8.3	1.6	20
Untreated Tongue River water irrigated on the soil	7.7	0.69	0.69
Non-irrigated control where no water or treatments were applied to the soil	7.9	0.41	0.44

Results from the bench-scale test showed that the average soil pH values after treatment were within the typical range of 6.5 – 8.4 for most undisturbed range soils. There was an increase in the soil EC in all the treatments when compared to baseline conditions. Soils treated with amendments recorded an increase in EC. Soil samples from all the treatment methods recorded an average EC of less than 4 dS/m, which is below the range of soil salinity thresholds (4 to 12 dS/m) for western rangeland and forage plant species [*Harvey et al.*, 2005]. Soils watered with produced water without any soil amendments recorded average SAR value of 20, whiles irrigation with produced water on soils treated with amendments showed average SAR of 7.5. In short, the laboratory test confirmed the feasibility of using produced water from coalbed methane extraction, together with agricultural soil amendments (elemental sulfur and gypsum) for irrigation.

Large Scale Pilot Testing

Following the success of the results from the laboratory testing, a large-scale pilot test was carried out on a 100 acre piece of land where sulfur and gypsum were applied to the soil and produced water was applied to the field using center-pivot irrigation method. Results from the large-scale test showed slight change in pH values for pre-irrigation and post irrigation soil samples. It was also reported that there was an increase in average soil EC levels from 0.38 to 2.4dS/m. The reason of using gypsum as soil amendment was to add calcium to the soil to offset the effect of sodium added by the produced water. Again, SAR values in the amended soils increased slightly after irrigation with the produced water.

The large-scale pilot testing showed that the use of elemental sulfur was effective in controlling bicarbonates in the produced water, and also the use of gypsum added calcium to counterbalance the sodium introduced in the soil by the produced water.

Full-Scale Operation

The success in the full-scale test led Fidelity to employ managed irrigation as one of its preferred methods of managing produced water from coalbed methane. Fidelity irrigates over 850 acres of land in its Tongue River project, and produces about 4 tons per acre of alfalfa annually for local ranchers. Fidelity employed an intensive soil-monitoring program which included soil sampling at the beginning and end of every irrigation season to track the soil chemical and physical condition. Soil samples were analyzed in lab to monitor the pH, EC, and exchangeable sodium percentage (ESP). The ESP is a more accurate laboratory method that measures the amount of sodium ions held on the soil exchange sites whiles SAR is a less expensive method to estimate ESP.

A four year study of the management practices from four of Fidelity's managed irrigation areas using the center pivot irrigation method showed the following results (Table 4):

Table 4. Summary of managed irrigation results.

Parameter	Pre-irrigation range	Managed irrigation range
pH	6 – 8.5	7 - 8
EC (dS/m)	1 – 5	4 - 6
ESP (%)	1 - 5	< 10

Colorado

The town of Wellington, and the northern area of Larimer County, Colorado, were running short of drinking water in the early 2000's. The Town contracted with Stewart Environmental Consultants Inc. to construct the first oil production water treatment plant for beneficial use in the U.S. The produced water was treated to meet stream standards in Colorado. The treated water was then used to augment groundwater via a shallow injection well. Treatment methods include ceramic microfiltration, a dissolved air flotation prefilter, and an activated carbon bed polish. System design size was 125 gpm (0.18 mgd) and the system cost ~$2M for construction in 2006. (http://www.stewartenv.com/php_uploads/stewart_lg_20100604154748.pdf).

Jurisdiction for permitting falls under the State Engineer, and the Colorado Energy Office. Wellington, CO. water is recharged via a shallow ground water well to an aquifer that ultimately is a supply for local town after RO treatment [*Bridger*, 1996].

In March, 2008, the Colorado State water court granted two decrees, allowing beneficial use of produced water (for irrigation), and allowing a transfer of water rights used for irrigation to domestic use (http://www.northfortynews.com/Archive/A200804photo_01N-WellingtonWaterWorks.htm). Wellington Water Works and Wellington Operating Co. were the beneficiaries of the decrees.

In Colorado, there is a distinction between tributary and non-tributary ground water. Tributary water is subject to Colorado's priority withdrawal system (Witt, 2015). Recent court cases surrounding the extraction of coal-bed methane (CBM) water led to a Colorado Supreme Court decision declaring that CBM produced water is subject to Colorado water rights administration (Colvin, 2011). The Colorado State Engineers office (SEO) interpreted this ruling to include all produced waters. The Colorado State Legislature subsequently developed House Bill 09-1303 and Senate Bill 10-165, to give the SEO authority to initiate rule-making for Produced Water regulations. By 2009, the SEO had designated several geologic units as nontributary groundwater based on modeling and structural evaluations. At this time, a process, while unique to Colorado, has been defined for identifying and handling of nontributary produced water (Witt, 2015). While court cases led to determination of jurisdiction in Colorado, subsequent legislation was needed to define rulemaking for permitting and use.

Current Colorado rules allow for reuse of produced water among oil and gas producers located within the same geologic basin. This includes roadspreading, enhanced recovery, drilling, well stimulation, well maintenance, pressure control, pump operations, dust control on- or off-site, pipeline and equipment testing, fire suppression, and discharge into state waters (C.R.S. § 37-90-137(7)(a)), (Curtis, 2014). Ownership of the withdrawn water, however, is still unresolved, even though reuse can occur while "mining of minerals" is ongoing (C.R.S. § 37-90-137(7)(a)) (Curtis, 2014).

Texas

Texas recently passed several new rules ("House Rule" or HR) that address produced water use, reuse, handling, and disposal. The intent is clearly to promote the use of produced water as a substitute for fresh water, and to clarify ownership, liability, and jurisdiction.

The Railroad Commission of Texas Oil and Gas Division issued a permit to Energy Water Solutions (May 2013 to October 2015) in pursuant to the Statewide Rule 8 (Texas Administrative Code Title 16 Part 1 Chapter 3 Rule §3.8(d)(7)). The intended purpose of treating the water was for use in a test plot for growing cotton at the Texas A&M Agricultural Research Center in Pecos, TX. Cotton growth tests were conducted by Dr. Katie Lewis of TAMU Agrilife from June 2, 2015 to November 24, 2015 (Lewis, 2016).

Tests were carried out to determine the cotton growth and yield response to irrigating with treated produced water blended with groundwater, and also to determine the effects of treated produced water on the soil chemistry. The cotton plants were planted on June 2, 2015 and harvested on November 2015. The study compared irrigation with 100% groundwater against blended treated produced water (4:1 ratio, groundwater: treated produced water). Table 5 below summarizes the water qualities of the both types of irrigation water.

Table 5. Water sample analyzed quality (as reported by Lewis, 2016).

		Water Source		
Parameters	**Units**	**Groundwater**	**Treated Produced Water**	**Blended**
Sodium (Na)	ppm	999	42	766
Calcium (Ca)	ppm	167	4	127
Magnesium (Mg)	ppm	50	1	40
Carbonate (CO3)	ppm	<1	<1	<1
Bicarbonate (HCO3)	ppm	122	37	122
Chloride (Cl)	ppm	1,900	20	1,450
Conductivity	µS/cm	4,950	150	3,800
pH		7.6	7.8	7.4
Phosphorus (P)	ppm	<0.01	<0.01	<0.01
Potassium (K)	ppm	18	5	14
Nitrate (NO3)	ppm	5	6	4
Sulfate (SO4)	ppm	1,204	31	1,362
Boron	ppm	0.5	4.1	0.8
TDS	ppm	3,218	98	2,470
SAR	ppm	17.4	4.9	15.2

The soil chemistry was also determined prior to the study and post harvesting. Tables 6 and 7 summarize the soil characteristics.

Table 6. Hoban Silty Clay Loam characteristics (Lewis, 2016).

pH	Conductivity mmhos/cm	NO_3-N	P	K	Ca (ppm)	Mg	S	Na	SAR
8.7	1.8	22.1	30	450	17,634	516	482	1,373	16.7

Table 7. Post harvest soil characteristics (Lewis, 2016),

Irrigation source	**Sample depth**	**pH**	**Conductivity (mmhos/cm)**	**NO_3-N**	**P**	**K**	**Ca**	**Mg**	**S**	**Na**	**B**	**Cl**	**SAR**
Blended	0-6"	9.0	1.5	9	35	531	14,915	575	654	1,230	1.6	1,018	13.8
	6-12"	9.1	1.2	12	26	474	16,896	513	476	1,347	1.2	896	17.6
	12-24"	8.8	1.7	19	19	425	24,243	485	528	1,349	1.2	1,256	15.3
Ground-water	0-6"	8.9	2.2	36	35	528	15,054	596	835	1,751	1.6	1,637	17.5
	6-12"	9.0	2.1	18	26	471	16,352	514	503	1,496	1.1	979	17.3
	12-24"	8.8	1.8	26	16	409	25,706	485	504	1,487	1.2	1,609	16.9

The produced water for this research was provided by Anadarko. The treatment of the produced water was done by Energy Water Solutions using a patented technology treatment train. This included several unspecified methods treatment stages including tar and oil removal, volatile organic removal, metal and inorganics removal, suspended solids removal, chlorine removal, and salt removal and water polishing

(Lewis, 2016). The salinity of the treated water, and many other quality parameters (Table 5) were much lower than in native groundwater from the site.

Results from the studies showed that using blended water for irrigation reduced the soil salinity parameters as compared to the using 100% groundwater. Furthermore, the cotton yield or lint quality was not affected by irrigating with treated produced water. Irrigating with groundwater produced a lint yield of 587 lb/acre whiles blended water produced a lint yield of 568 lb/acre.

The precedent for using treated produced water for a non-food crop irrigation test and the results showing a net improvement to soil properties is encouraging. Further testing to quantify long-term effects on the crop and soils is planned (Lewis, 2016). The treatments used, while not specified, appear to be suitable to accommodate the variety of constituents of concern that can be found in produced water. No information was given regarding the cost-effectiveness of the treatment, however.

California-Cawelo Field Example

In recent years, the state of California has experienced serious and widespread drought conditions. The state is one of the leading producers of oil and gas in the United States, and one of the largest producers of agricultural products in the U.S. Produced water has been utilized in California as an additional water source for irrigation and aquifer recharge, as described in the following three studies.

California state laws govern land application of wastes and apply to surface discharges such as to an irrigation canal. Oil producers wanting to discharge produced water into the environment (land or water) must obtain a permit, Waste Discharge Requirement (WDR) from their Regional Water Quality Control Board. The WDR spells out the requirements for water treatment, set limits for the quantity of discharge, and establishes the maximum allowed limit of certain pollutants. The WDR also establishes requirements for monitoring and reporting water quality [*Guerra et al.*, 2011]. Table 8 below shows the WDR for Chevron's delivery of water to the Cawelo Water District.
(http://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/kern/r5-2012-0058.pdf)

Table 8. Discharge limits and sampling required by the water board for Chevron's discharge of water to the Cawelo Water District [19].

Parameter	Maximum allowed under permit	Sample type	Minimum sampling frequency
Flow	33.5 million gpd	Meter	Continuous
Electrical conductivity	940 μmhos/cm	Meter	Continuous
Arsenic	10 μg/l (10 ppb)	Grab	Monthly
Oil and grease	35 mg/l	Grab	Monthly
Boron	1.3 mg/l, annual average	Grab	Monthly
Chloride	200 mg/l (200 ppm)	Grab	Monthly
pH	No limit set by permit	Grab	Monthly
Total suspended solids	No limit set by permit	Grab	Monthly
Sodium	142 mg/l, annual average	Grab	Quarterly
General minerals[1]	No limit set by permit	Grab	Quarterly
Priority pollutants[2]	No limit set by permit	Varies	Every 5 years

1 Standard minerals shall include the following: boron, calcium, iron, magnesium, potassium, sodium, chloride, manganese, and phosphorus; total alkalinity (including alkalinity series); and hardness; as well as verification that the analysis is complete (i.e., cation/anion balance).

2 Priority pollutants include several dozen inorganic and organic compounds, pesticides, and dioxin congeners

California-San Ardo Field Example

The San Ardo project in the Monterey region takes produced water of relatively low salinity (~6,000 mg/L TDS) and treats it to recharge the local ground-water basin via a wetlands discharge, as well as for the production of Once-Through Steam Generator (OTSG) make-up water for heavy oil production. The project is contracted to Veolia Water Solutions and Technologies by Chevron, and is permitted by the California Regional Water Quality Control Board (Central Coast Office) with a "Waste Discharge Requirements" order (WDR). The WDR order includes a California NPDES permit for this use. These orders normally include background information, prohibitions, discharge specifications, monitoring and reporting provisions, and sample frequency and volume reporting requirements (http://www.waterboards.ca.gov/centralcoast/board_info/agendas/2005/july/item20/item20_attach1_wdr.pdf).

For the San Ardo project, the produced water is treated using oil removal/sorption, softening, filtration and reverse osmosis (RO) to achieve the desired water quality. Table 9, below, shows a summary of the produced water qualities at different treatment stages.

Table 9. Results of treatment of produced water [Heberger et al 2015].

Constituent	Produced Water	Double Pass RO Permeate	Final Treated Effluent	Effluent Specifications
TDS (ppm)	6,500	76	120	510
Sodium (ppm)	2,300	43	43	85.0
Chloride (ppm)	3,400	Non-Detect	11	127.5
Sulfate (ppm)	133	Non-Detect	120	127.5
Nitrate (ppm)	10.0	Non-Detect	Non-Detect	4.25
Boron (ppm)	26.0	0.24	0.24	0.64
pH (S.U)	7.5	10.7	7.0	6.5 – 8.4

California-Kern River Field Example

Produced water from the Kern River Field has been used for many years in agricultural irrigation. The water is extracted with heavy oil production from a shallow formation (1,500-2,000 ft below ground surface). Treatment and handling steps are described in the WDR order as follows:

a. Primary and secondary surge tanks used for initial oil/water separation;
b. Additional oil recovery using flotation clarifiers ("Wemcos") to separate emulsified oil droplets from the water;
c. Walnut shell filtration for further reduction of remaining oil in the water through a filtering process;
d. Reclaiming water for steam injection;
e. Blending produced water with available surface water supplies and groundwater to achieve specified discharge limits for beneficial reuse through crop irrigation and groundwater recharge;
f. Management of produced water to maximize reuse;
g. Diversion of local surface water flood flows to the storage basins whenever available to further improve percolation water quality; and
h. Monitoring of discharges to and from the storage reservoir and discharges to the storage Basins, the overall groundwater quality of the District, and groundwater quality near the storage basins.

(http://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/kern/r5-2015-0127.pdf)

No desalination is needed because of the low total dissolved solids content. The water is blended with other fresh water sources (surface and ground water) before use in irrigation. It is regarded as a valuable resource during times of drought. Predominant crops irrigated include permanent tree fruits and nuts, and vine crops. This use is regulated by the California Regional Water Quality Control Board (Central Valley Office) with the objectives of providing water for beneficial use while not degrading ground water in the district. The WDR for this operation includes a California NPDES permit. Characteristics of the water monitored include flow rate in million gallons per day, electrical conductivity in μmhos/cm, oil and grease (mg/L), arsenic (μg/L), boron (mg/L), chloride (mg/L), and sodium (mg/L). Best management practices and monitoring limits for the operation are specified in detail in the WDR order.

Recent concerns in the news media about the use of produced water in agriculture has prompted the Board to set up a Food Safety Panel consisting of academics, regulators, and consulting scientists to review the practices used for treatment and the use of produced water in agriculture. The Panel is expected to recommend studies to fill data gaps, and possibly new sampling and testing requirements. (http://www.waterboards.ca.gov/centralvalley/water_issues/oil_fields/food_safety/index.shtml)

California-Additional Information

California has witnessed a number of projects in which treated produced water has been used for irrigation and other uses. Table 10, below, shows a summary of these projects. These projects can serve as a guideline for New Mexico to follow in addressing issues regarding agricultural use of produced water. All were permitted by the state, and many include blending with other (fresh) sources of water. In addition, another company in California, Water Planet, is currently carrying out pilots test to treat produced water from oilfields by utilizing an integrated mechanical and membrane filtration system. The process uses ceramic membranes to filter the water followed by reverse osmosis [*Hazmat*, 2016]. The purpose of this pilot study is to test treated produced water from oilfield operations as irrigation water for crops.

Table 10. Projects where produced water has been used for crop irrigation in California. (Heberger & Donnelly, 2015) Note: Blank spaces indicate unknown data.

Date permitted	County	Oil field	Operator	Permitted volume (acre-feet per year)	Water Treatment	Blending	Application	Crops irrigated	User
	Tulare	Deer Creek			Mechanical separation with addition of coagulants	No	Irrigation	Alfalfa	Private land
	Tulare	Deer Creek			Mechanical separation with addition of coagulants	No	Irrigation	Alfalfa	Private land
	Kern	Jasmin			Mechanical separation with addition of coagulants	Blended with canal water some of the time	Irrigation	Citrus	Jasmin Ranchos Mutual Water Company
	Kern	Mount Poso					Irrigation		Cawelo Water District
2012	Kern	Kern River	Chevron	37,500	Mechanical separation, sedimentation, air flotation, and air filtration (walnut hull filters)	Treated wastewater, imported surface water, groundwater	Irrigation groundwater recharge	99% permanent crops (citrus, almonds, pistachios, apples, peaches, plums, and vineyards); 1% (alfalfa, potatoes, corn, grains, vegetables, melons)	
2012	Kern	Kern River	California Resources Corporation	16,600		Treated wastewater, imported surface water, groundwater	Irrigation, groundwater recharge	Same as above	Cawelo Water District
2011	Kern	Kern Front	Hathaway LLC	70	No treatment requirements	7% wastewater; 93% groundwater	Irrigation; during non irrigation season, disposed of via underground injection	Citrus	Concordia Ranch
2015	Kern	Kern Front	California Resources Corporation	21,200	Gas separation, free-water knock-out tanks, air flotation, and skimming	Produced water, surface water, and groundwater blended in the Lerdo Canal	Irrigation, groundwater recharge in the Rosedale Basin	80% permanent crops of nuts, vineyards, and fruits	North Kern Water Storage District

2014	San Luis Obispo	Arroyo Grande	Freeport-McMoran Price Canyon	940	Mechanical, Chemical, reverse osmosis	Yes (indirect reuse)	Discharged to Pismo Creek to improve habitat and water quality in the creek is recharging groundwater and reused indirectly by downstream irrigators with wells.	Vineyards, row crops	Private land

Discussion

These case studies illustrate potential pathways to answer some of the questions posed by the Dagger Draw study (McGovern and Smith, 2003). In addition, the methods used in each study are helpful to understand what types of analyses, treatment methods, collaborations, and approaches are useful. The use of test case permits is one option (New Mexico/BLM and Texas) that allows agencies to gather data from the studies without a long-term commitment. In all cases, extensive analytical information for the produced water treatment and use, for surface discharges, and for soil applications was obtained.

Jurisdiction

Jurisdiction is important because it dictates which authority, regulations, rules, and permits apply to any given stage of storage, transport, treatment, or use of produced water. Understanding jurisdiction is key for creating policy incentives at the state and federal level that encourage treatment and use of produced water. Jurisdiction for the case studies primarily fell under State agencies, as follows:

- New Mexico Oil Conservation Division; US Bureau of Land Management (Federal), and the New Mexico Environment Department
- New Mexico Interstate Stream Commission, New Mexico Environment Department and New Mexico Water Quality Control Commission
- Wyoming Department of Environmental Quality, Water Quality Division.
- Colorado Office of the State Engineer, and the Colorado Energy Office
- The Railroad Commission of Texas (regulates oil and gas operations) and MOUs with the Texas Commission on Environmental Quality (Texas CEQ).
- California Regional Water Quality Control Boards (various regions)
- California also has primacy for NPDES permits in California.

We do not know if this is a complete picture of the jurisdictions, only what was reported. The case studies also do not completely describe the conditions where jurisdictional transfer might occur between agencies either before, during, or after the presented use.

In New Mexico, there are several statutory provisions that describe the jurisdictional framework for produced water. These include:

- 70-2-12.1 Disposition of produced water; no permit required
    - This rule indicates that no permit is needed from the state engineer for disposition of produced water as long as OCD rules are followed (e.g., UIC Class II injection as opposed to illegal surface discharge).
    - This requirement is administered and enforced by NM OCD.
- 70-2-12 Enumeration of Powers
    - This rule authorizes OCD to regulate the "disposition" of produced water. This includes surface or subsurface disposal, and also a process known as "disposition by use", where the water is used in drilling or production of oil and gas; but also can be used in road construction or maintenance, other construction, in electricity generation, and in other

industrial processes, as long as the environment is protected and fresh water supplies are not contaminated (applies to both surface and ground water).
    - This requirement is administered and enforced by NM OCD.
- 72-12-25 Declaration of basin; nonpotable deep aquifers
    - This rule is sometimes known as the Brackish Water rule.
    - The rule places deep aquifers with an aquifer formation top greater than 2,500 feet below ground surface, AND ALSO having a total dissolved solids content greater than 1,000 mg/L, under the administration of the state engineer.
    - A notice of intent to drill must be files with the state engineer, and in declared basins, metering and additional quality analysis may be required by the engineer's office.
    - If the formation is in a declared underground basin, then uses of this water specifically for oil and gas exploration and production, prospecting, mining road construction, agriculture, generation of electricity, geothermal use, or industrial processes remain under the jurisdiction of the state engineer.
    - In declared basins, impairment and subsequent dispute of existing water rights also is covered by the jurisdiction of the state engineer, under a process similar to that of other water rights.
    - This requirement is administered and enforced by the NM State Engineer.
- Water Quality Authority division between NMED and OCD
    - 74-6-12 Limitations
        - This rule describes the limitations of the Water Quality Act. In this case, there are provisions that confer jurisdiction to OCD to prevent or abate water pollution (70-2-2 and 70-2-12).
    - The OCD is authorized to make and enforce rules, regulations, and orders to protect public health and the environment in regulating the disposition of wastes generated from exploration, development, production and storage of oil or gas, and;
    - The OCD also is authorized to do the same for disposition of wastes resulting from oil and gas service industries, transport, and "downstream" treatment or refining.
    - 74-6-4 Duties and powers of commission
        - This rule assigns responsibilities for administration to different agencies to prevent duplication of effort with regard to water classifications and water contaminants.
    - 74-6-2, Definitions
        - Matches responsibilities with agencies such as NMED, the state engineer, OCD, the parks division of EMNRD, the NM department of agriculture, and others.

Produced water that is treated and used outside of the oil and gas industry would need to follow NM Environment Department/state water quality control commission/CWA rules or permit requirements that apply to the industry or process that uses the water. For example, if an industry chose to use the water in a process, then a discharge permit relevant to the process could be required by NMED.

Ownership of Produced Water

No definitive statute assigning ownership of produced water was found in our literature search or in discussions with OCD legal advisors. Because there is no water right associated with produced water, then the water exists outside of OSE jurisdiction and is not part of the "waters of the State". Whosoever "possesses" the produced water at any given time can bear liability for any environmental degradation that may occur because of spills, based on NMSA 1978 70-2-12 (B)(15) ("disposition of water"). At this time actual "ownership" appears to be a function of possession and can be based on contractual agreements between the oil and gas operator, the mineral rights owner, and any subcontractors for transportation, storage, treatment, and use or disposal (evaporation or injection). Because produced water has been considered a waste, there has been no desire to "own" it. However, if there is potential value in the mineral constituents (dissolved solids) of the water, or in the water itself, then there may be more interest in owning the water outright.

Example Use Cases

Figures 3-5 illustrates a hypothetical set of scenarios where produced water is generated by an oil and gas operator, transported, treated, and reused within the oil and gas industry (Figure 3), or transported, treated, and used outside of the industry (Figures 4 and 5). We show the potential ownership of the water at each stage, the jurisdictional agency for New Mexico, the holder of liability at each stage, and permitting needs. These use cases are for illustration only and do not constitute a final determination of jurisdiction, ownership, or liability. We present these in order to evaluate the potential use of oil and gas produced water not as a waste product, but as a resource, and to evaluate where gaps may exist in the regulatory framework. A key concept is the function of ownership by possession. At this time, ownership is not expressly defined in regulation. Therefore, ownership is a function of possession, and transfers are accomplished by contractual agreements. Environmental liability transfers are accomplished contractually with transfer from the oil and gas producer to either the treatment/transport entity, and ultimately to the final user or disposal entity. In the former case, the treatment/transport entity may be contracted by the oil and gas company. In the latter case, the treatment/transport entity is either contracted by the oil and gas producer, the transport agent, or by the final user/purchaser. The treatment/transport company may also be completely independent, contractually.

In Figure 3, the use of the water remains entirely within the oil and gas industry. This is the simplest case for jurisdiction, because the jurisdiction lies entirely with the OCD. This includes production, transfers, treatment (or, case-by-case uses) and reuse. Waste materials are disposed under existing regulations and permits; transportation is by permit. Liability is held by the producer, the transporting agent, or the treatment company. If the treatment system is defined as a commercial recycling system, then specific rules apply to that entity for permitting and reporting. Changes in possession or liability may be specified by contract between entities. This exemplifies the use of produced water as a privately-owned (possessed) material or product, not as a "water of the state".

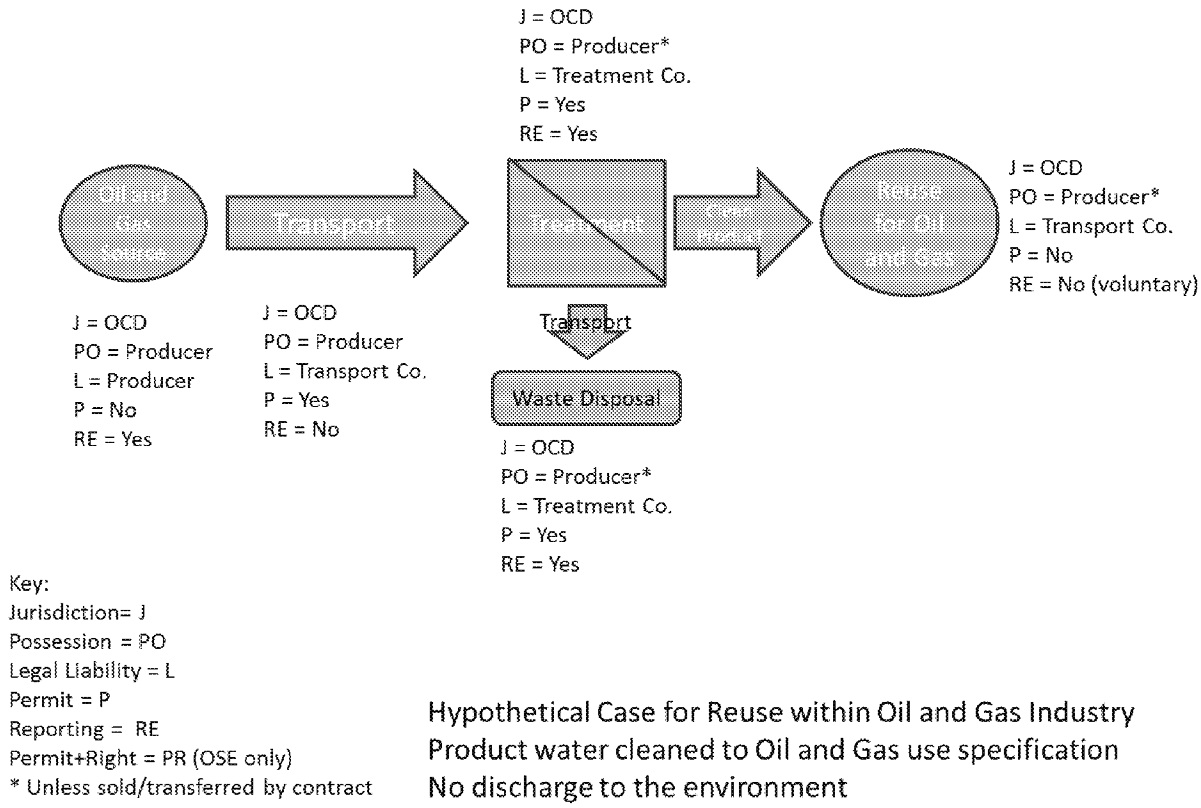


Figure 3. Hypothetical Case for Reuse within the Oil and Gas Industry

In Figure 4, a scenario is shown where the water is produced within the oil and gas industry, then treated and sold/transferred outside of the oil and gas industry to a fully consumptive use. One example of this might be a sale/transfer of treated water to an electric power company for consumptive cooling. As shown here, the jurisdiction lies with OCD until after treatment. Waste materials are disposed under existing OCD regulations and permits; transportation is by OCD permit. Liability is held by the producer, the transporting agent, or the treatment company. The oil and gas industry has well-developed methods for disposal, the wastes are mostly RCRA-exempt, and there is precedent for this pathway in New Mexico law and in multistate oil and gas operations. pPossession of the water begins with the producer. After treatment, the water could be sold or transferred to a non-oil-and-gas entity as a disposition-by-use (public or private). At this point, NMED and the USEPA may elect to have jurisdiction over quality issues at this stage depending upon the use. In addition, the purchaser/user will likely have quality requirements for their specific process/use. Changes in ownership or liability should be specified by contract between entities because produced water is viewed by NMOSE as a private commodity-there is no water right associated with further use. Most importantly, after treatment in this scenario, the receiving entity would use the water entirely within a closed–loop system, and/or the water would be totally consumed. In this situation, no NPDES permit is required by EPA. The use of this water could replace existing fresh water withdrawals, conserving natural fresh ground or surface waters for other uses or later use. For land applications, if no surface water body is encountered, then NMED would consider this to be land application and would apply those pertinent regulations in a Ground Water Discharge Permit. All of these scenarios must be evaluated on a case-by-case basis by the agencies involved.

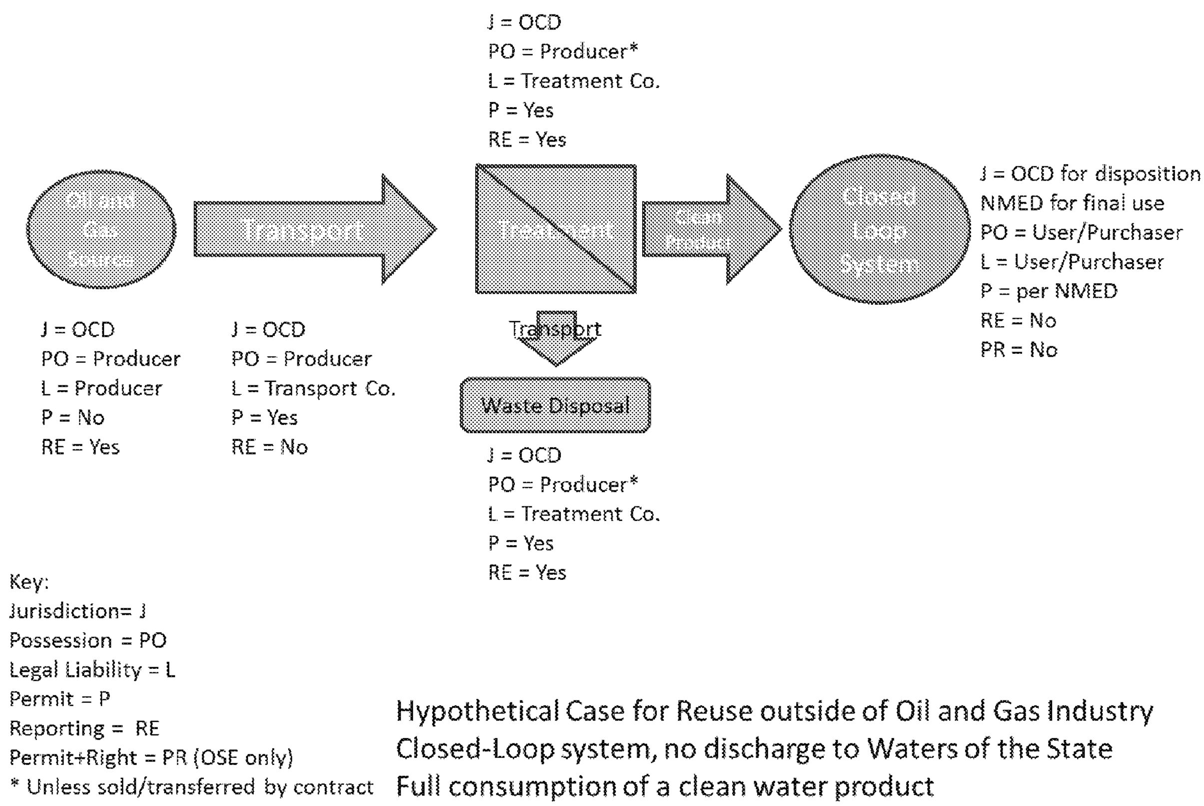


Figure 4. Hypothetical Case for Reuse outside of Oil and Gas Industry; Closed-Loop system, no discharge to Waters of the State; Full consumption of clean water product

In Figure 5, we illustrate a hypothetical case where the treated water is utilized in an open system, or is deliberately discharged to righted waters of the state. This was the scenario described in the Pecos River case study (described above), where treated produced water was intended to supplement the Pecos Compact requirements. Legislation was written to support this kind of use (Appendix D). In the legislation, jurisdiction, legal liability, and ownership were clearly established. The tax credit was designed to reduce economic barriers to the treatment. Many barriers to produced water beneficial use were reduced by this legislation; however, they were not sufficient at the time to accomplish this goal.

Because this legislation has expired, there is no current precedent for this kind of use. Additional legislation to renew the prospects for this pathway may be helpful. Alternately, the agencies involved may be able to develop a system of memoranda of understanding, regulations or rulemaking, and permits that could support this kind of use. Because no water right is attached to the use of produced water, the two agencies involved are OCD and NMED.

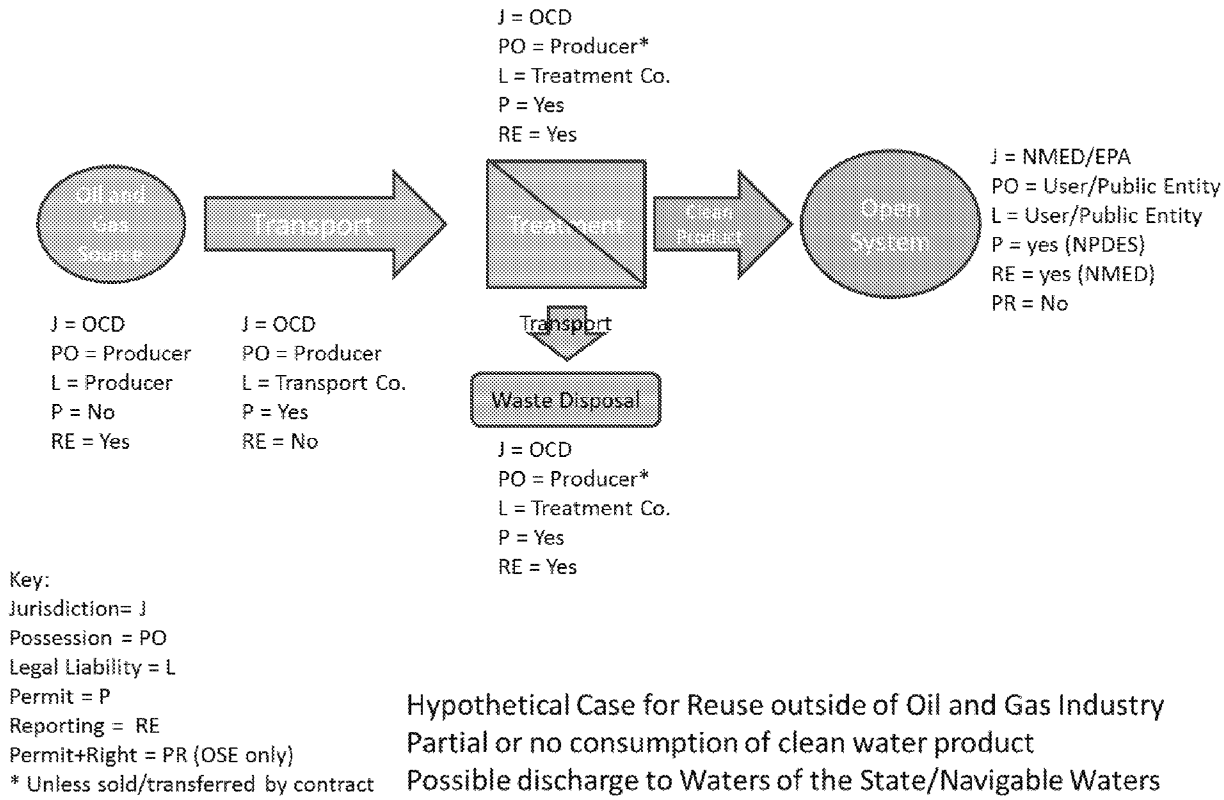


Figure 5. Hypothetical Case for Reuse outside of Oil and Gas Industry; Partial or no consumption of clean water product; Intentional discharge to Waters of the State/Navigable Waters

Further, we considered the questions (from the beginning of this report):

- Who defines specifications for treatment? Specifications for use?
- Who provides treatment?
- Who pays for treatment?

The regulations under the CWA or the New Mexico WQA provide treatment specifications for waters that would be released to the environment, such as to the Pecos River (CWA) or to an agricultural irrigation plot (NMWQA). NPDES/CWA (EPA) permitting would likely be needed if the discharge is to a surface water body; NMED would permit discharge or recharge to an underground aquifer; use of a Class I or other class of injection well is permitted via the EPA UIC program. End users of water that is treated for an industrial purpose, such as cooling, would need to provide their own process specifications. More stringent requirements are expected for more sensitive or higher-quality receiving waters. Many different companies are capable of treating water to high quality standards. Examples of localities where water desalination is being done or will be done include El Paso, Texas (brackish ground water) and Alamogordo, New Mexico (brackish ground water). The costs of planning, financing, and implementation can be found in references including [*Hazmat*, 2016; *Gorder*, 2009; and *Guerra et al*, 2011]. Produced water treatment is covered in Dahm and Chapman [2009].

- Who provides the management, storage, and conveyance of the treated water?
- Who will pay for the water as an end user?

Provision of and payment for treatment depends upon market conditions, and also upon the degree of perceived or measured water scarcity in a region. The study area (this report) relies upon the High Plains/Ogallala aquifer for drinking water and irrigation. Increased demands in drought years can have severe impacts on this resource, as is evident in declining well water levels. Surface water sources are unavailable in Lea County, and fully allocated elsewhere. The costs of treatment are addressed in other chapters of this report. The willingness of a client to pay for treatment will depend upon how critical their need is for fresh water and upon their financial resources. In municipalities, the water costs are usually born by the taxpayers and by ratepayers on public water systems.

- What funds can government provide?

The government can sometimes fund tax credits, grants for planning and construction, and research funding. The Federal government provided significant funding for the KBH plant in El Paso, for example, via congressional appropriations. In New Mexico, there are state water grant programs for studies. Public-private partnerships (PPPs) can be formed between a municipal entity and a private company, such as water treatment companies or engineering firms.

Gap Identification

Gaps in regulation or unclear regulatory guidance were found in the following points of the use cases:

- In the transfer between OCD and NMED jurisdiction (what is the specific point of transfer?)
- In the definition of produced water as a "waste" under OCD versus as a "product" or as "water" outside of OCD.
- In the possesion and legal liability train between production/transport to treatment, and transfer of treated water to use outside of the oil and gas domain
- In the definition of ownership, versus possession, at any point in the handling process.
- In the use of treated produced water as a supplement to surface or ground water supplies via mixing with "righted" water.
- In the regulation of constituents of concern that might exist in produced water that are not explicitly identified in current water quality or land discharge regulations (note these rules are being updated at the time of this report).

Some resolution of these gaps can be found in the case studies, particularly in the Colorado, Texas and New Mexico (Pecos) examples. Permits can be constructed (e.g. in Texas, New Mexico, California) to allow for specific uses in open (land application) systems, particularly where direct mixing with surface water or ground water is unlikely (arid region, deep water table). Contracts can also be devised to direct ownership of produced water as a privately owned product. The use of produced water for agricultural purposes has raised a great deal of interest, both for irrigation purposes and stock watering. The California examples show ways in which these uses can be accomplished. Framing the liability for these uses would be of great interest to landowners, farmers, and ranchers.

Additional data gaps to consider prior to identifying appropriate treatment(s) and reuse of produced water in New Mexico may include: 1) lack of a comprehensive understanding of produced water chemistry which has implications for the treatment and development of use-appropriate water quality thresholds, particularly for those produced water constituents that currently do not have analytical methods or standards, and 2) potential longer-term human health implications related to the consumption of crops irrigated with produced water and/or consumption of livestock raised on crops irrigated with produced water, and the potential degradation of water bodies receiving treated produced water.

Produced water chemistry and use-specific treatment and standards

As indicated by Sullivan Graham and Sarpong, produced water contains a combination of constituents naturally occurring in formation water as well as chemical additives used by operators for drilling, stimulation/hydraulic fracturing, production, and well maintenance operations at each well site. However, not all chemical additives (specifically post-stimulation maintenance chemicals) require disclosure, making it difficult to fully characterize or understand the complexity of the produced water's chemistry. Many naturally occurring constituents and chemical additives present do not have well established water quality thresholds, and have demonstrated toxic, carcinogenic and/or endocrine disrupting effects (e.g., polycyclic aromatic hydrocarbons, monoaromatic compounds (i.e., BTEX), phenols and alkylphenols and their derivatives, biocides, radioactive materials, etc.), even when present at very low concentrations. Establishing appropriate water quality thresholds and treatment methods for specific uses requires comprehensive knowledge of the composition of the water, as well as the concentration of each contaminant present. The difficulty in characterizing produced water chemistry is related in part to limitations in disclosure of chemical additives contained in the water, lack of an understanding of transformation products resulting from exposure to down-hole temperatures, pressures and co-contaminants, and a lack of technologies and methods readily available to identify all contaminants. Advances in instrumentation for identifying and quantifying micro-pollutants in produced water are underway, but chemical standards do not yet exist for many of the components present in produced water.

Long-term implications for human health and the environment

While existing technologies are capable of treating produced water to drinking water standards, research involving the efficacy of existing treatment technologies has yet to demonstrate effective removal of all known toxins from produced water (e.g., Bellona et al., 2011, Drewes et al., 2013, Priac et al., 2014). Additionally, the additive toxicity potential resulting from the interaction of groups of compounds remaining post-treatment, even in small concentrations, is not well enough understood to assess potential long-term impacts (e.g., Erickson et al., 1999, Staal et al., 2007).

Conclusions and Recommendations

We reviewed Federal and State regulations pertinent to produced water use and the use of treated produced water outside of the oil and gas industry. We analyzed several case studies and developed hypothetical use cases in order to illustrate possible use scenarios relative to jurisdiction, liability, ownership, and permitting. These scenarios led us to identify specific gaps in the regulatory system that are creating perceived barriers to the potential beneficial use of produced water.

This report provides information that we hope will simplify the understanding of the produced water regulatory framework. Our aim is to improve the potential for uses of alternative water resources in New Mexico, without compromising the environment or other water resources. We hope to reduce some of the many barriers to supplementing our limited fresh water supplies with alternative water sources. Utilization of test cases and temporary permits, to facilitate research and data gathering, are proposed here to help inform agencies and regulators of key problems or benefits. Continued strong public interest in utilizing alternative water resources is a motivation for continued examination of regulatory pathways to beneficial uses.

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Appendices

Appendix A-Detailed Information on RCRA Oil and Gas Waste Exemptions and Rules

The most preferred method of preventing pollution is to avoid the generation of waste. Operators must be aware of state and federal regulations governing the management and disposal of hazardous and non-hazardous wastes.

Waste from Exploration, Development, or Production

These are wastes intrinsically derived from primary field operations associated with the exploration, development and production of the oil and gas. These operations are in basically three stages and each stage produces different kinds of wastes.

Well Drilling and Completions Stage

Wastes Produced includes:

- Drilling Fluids (drilling mud)
- Drill Cuttings
- Completion fluids

Wells Stimulation Stage (Hydraulic Fracturing)

Wastes Produced includes:

- Fracturing fluid returns
- Proppant returns
- Produced Water

Well Production Stage

Wastes Produced includes:

- Produced Water

Uniquely Associated Wastes

These include a wide range of small volume of waste streams that are associated with the exploration and production of oil and gas. They come in different categories. The table below shows the various categories and examples:

Table A-1: Associated Wastes Categories and examples

Categories	Examples
Completion fluids	All fluids from initial well completion activities, including any initial acid stimulation or hydraulic fracturing
Workover/Stimulation fluids	All fluids from subsequent workover and stimulation operations.

Dehydration/Sweetening Wastes	Includes glycol-based compounds, glycol filters, molecular sieves, amines, amine filter, precipitated amine sludge, iron sponge, scrubber liquids and sludge, backwash, filter media and other wastes associated with the dehydration and sweetening of natural gas.
Tanks Bottoms/Oily Sludge Bottoms	Tank sediment and water, produced sand and other tank bottoms.

Waste Mixtures

This is basically the mixing of two or more wastes of different classes. It is explained further in the next section.

Hazardous Wastes

As stated above in the report, these are wastes that either (1) exhibit at least one of the following properties: Ignitability, Corrosivity, Reactivity and Toxicity or (2) are specifically "listed" as hazardous wastes by regulation. A complete list of these "listed" hazardous wastes and their respective hazardous waste numbers can be obtained from **40 CFR Part 261, Subpart D.**

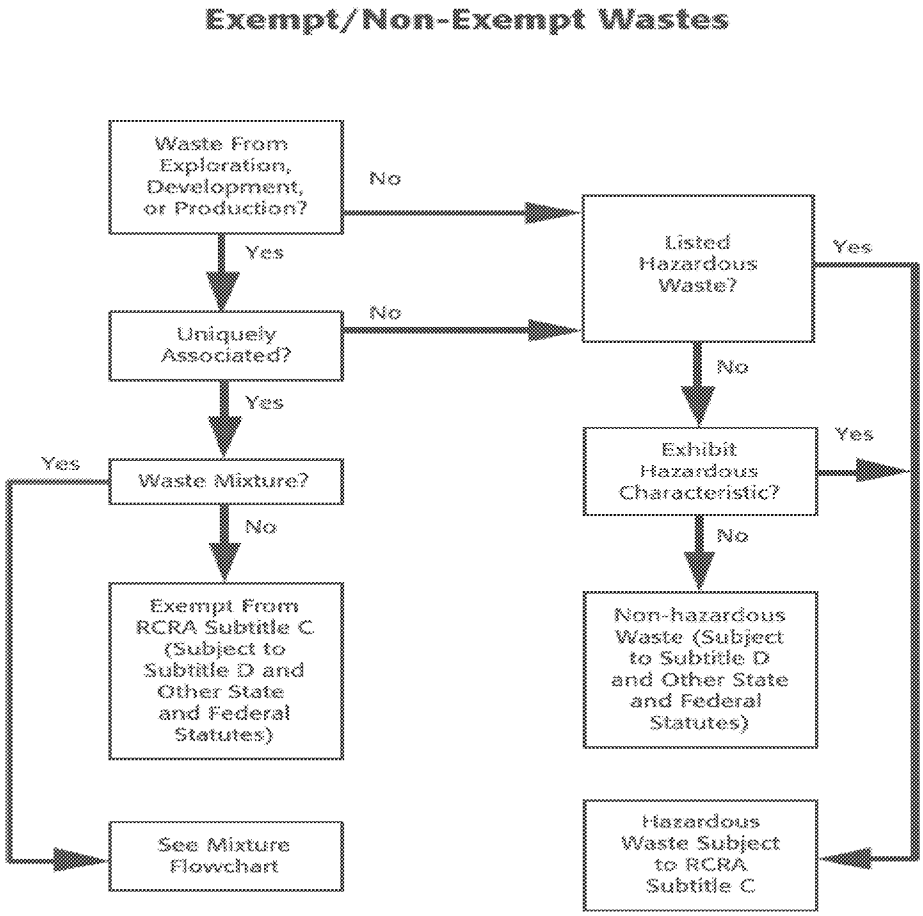
Hazardous Wastes Subject to RCRA Subtitle C

These are wastes that fall under the EPA's federal program of managing hazardous wastes from the creation to the disposal of the waste, i.e. throughout the lifecycle of the waste.

Waste Mixture Classification

Whether a waste mixture is exempt from regulation under subtitle C can be determined based on the characteristics of the resulting mixture.

- A mixture of an exempt waste with another exempt waste remains exempt from regulation under subtitle C.
- Mixing a solid (i.e., non-hazardous waste) with an exempt waste results in a waste mixture that is exempt from regulation under subtitle C.
- If a "characteristic" waste is mixed with an exempt (non-hazardous) waste, and the resulting mixture exhibits any of the hazardous characteristics associated with the non-exempt characteristic hazardous waste, the mixture is a non –exempt hazardous waste. However, if the resulting waste mixture does not exhibit any of the hazardous characteristics associated with the hazardous waste, then the mixture is an exempt waste.
  Note: the mixture of these two wastes is considered to be a "treatment" of a hazardous waste to remove the hazardous characteristics and generally requires a permit.
- A mixture of a listed hazardous waste with an exempt waste results in a non- exempt waste irrespective of the percentage of the listed hazardous waste in the mixture.


Exempt/Non-Exempt Wastes
Waste From Exploration, Development, or Production?
No
Yes
Listed Hazardous Waste?
Yes
Uniquely Associated?
No
Yes
No
Exhibit Hazardous Characteristic?
Yes
Waste Mixture?
Yes
No
No
Exempt From RCRA Subtitle C (Subject to Subtitle D and Other State and Federal Statutes)
Non-hazardous Waste (Subject to Subtitle D and Other State and Federal Statutes)
See Mixture Flowchart
Hazardous Waste Subject to RCRA Subtitle C

Possible Waste Mixtures and Their Exempt and Non-Exempt Status

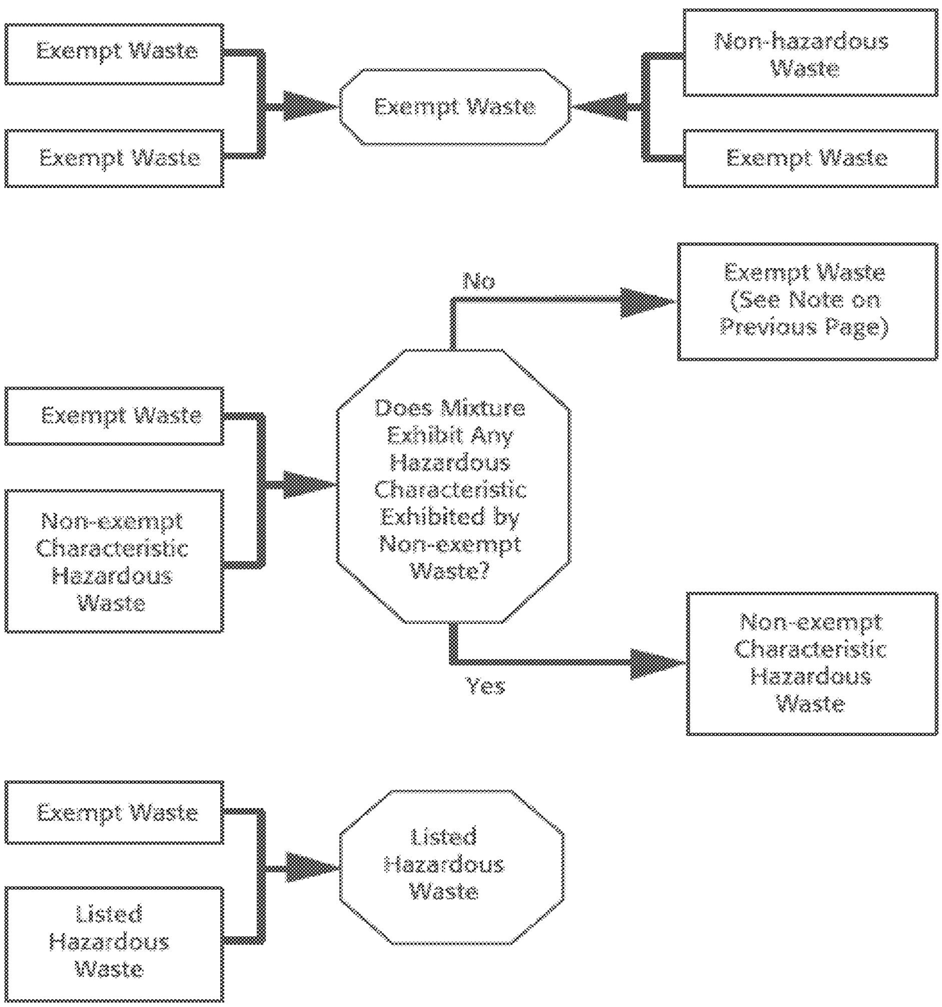


Table A-2 (Appendix A). EPA National Primary Drinking Water Standards (MCL for various drinking water contaminants) [*Dahm and Chapman*, 2014].

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Acrylamide	TT8	Nervous system or blood problems;	Added to water during sewage/wastewater increased risk of cancer treatment	zero
OC	Alachlor	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops	zero
R	Alpha particles	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation	zero
IOC	Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	0.006
IOC	Arsenic	0.010 as of 1/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes	0
IOC	Asbestos (fibers >10 micrometers)	7 million fibers per Liter (MFL)	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits	7 MFL
OC	Atrazine	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops	0.003
IOC	Barium	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	2
OC	Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills	zero
OC	Benzo(a)pyrene (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines	zero
IOC	Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004
R	Beta particles and photon emitters	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation	zero
DBP	Bromate	0.010	Increased risk of cancer	Byproduct of drinking water disinfection	zero
IOC	Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	0.005
OC	Carbofuran	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa	0.04
OC	Carbon tetrachloride	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities	zero
D	Chloramines (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes	MRDLG=4[1]

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Chlordane	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide	zero
D	Chlorine (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes	MRDLG=4[1]
D	Chlorine dioxide (as ClO_2)	MRDL=0.8[1]	Anemia; infants & young children: nervous system effects	Water additive used to control microbes	MRDLG=0.8[1]
DBP	Chlorite	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection	0.8
OC	Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories	0.1
IOC	Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits	0.1
IOC	Copper	TT[7]; Action Level = 1.3	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits	1.3
M	*Cryptosporidium*	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
IOC	Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories	0.2
OC	2,4-D	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops	0.07
OC	Dalapon	0.2	Minor kidney changes	Runoff from herbicide used on rights of way	0.2
OC	1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	zero
OC	o-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories	0.6
OC	p-Dichlorobenzene	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories	0.075
OC	1,2-Dichloroethane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	1,1-Dichloroethylene	0.007	Liver problems	Discharge from industrial chemical factories	0.007
OC	cis-1,2-Dichloroethylene	0.07	Liver problems	Discharge from industrial chemical factories	0.07
OC	trans-1,2-Dichloroethylene	0.1	Liver problems	Discharge from industrial chemical factories	0.1
OC	Dichloromethane	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories	zero
OC	1,2-Dichloropropane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	Di(2-ethylhexyl) adipate	0.4	Weight loss, live problems, or possible reproductive difficulties	Discharge from chemical factories	0.4
OC	Di(2-ethylhexyl) phthalate	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories	zero
OC	Dinoseb	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables	0.007
OC	Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories	zero
OC	Diquat	0.02	Cataracts	Runoff from herbicide use	0.02
OC	Endothall	0.1	Stomach and intestinal problems	Runoff from herbicide use	0.1

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Endrin	0.002	Liver problems	Residue of banned insecticide	0.002
OC	Epichlorohydrin	TT[8]	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals	zero
OC	Ethylbenzene	0.7	Liver or kidneys problems	Discharge from petroleum refineries	0.7
OC	Ethylene dibromide	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries	zero
IOC	Fluoride	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories	4.0
M	*Giardia lamblia*	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Glyphosate	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use	0.7
DBP	Haloacetic acids (HAA5)	0.060	Increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Heptachlor	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide	zero
OC	Heptachlor epoxide	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor	zero
M	Heterotrophic plate count (HPC)	TT[3]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment	n/a
OC	Hexachlorobenzene	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories	zero
OC	Hexachlorocyclopentadiene	0.05	Kidney or stomach problems	Discharge from chemical factories	0.05
IOC	Lead	TT[7]; Action Level = 0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities; Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits	zero
M	*Legionella*	TT[3]	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems	zero
OC	Lindane	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens	0.0002
IOC	Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	0.002
OC	Methoxychlor	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock	0.04
IOC	Nitrate (measured as Nitrogen)	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	10
IOC	Nitrite (measured as Nitrogen)	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	1

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Oxamyl (Vydate)	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes	0.2
OC	Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories	zero
OC	Picloram	0.5	Liver problems	Herbicide runoff	0.5
OC	Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals	zero
R	Radium 226 and Radium 228 (combined)	5 pCi/L	Increased risk of cancer	Erosion of natural deposits	zero
IOC	Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines	0.05
OC	Simazine	0.004	Problems with blood	Herbicide runoff	0.004
OC	Styrene	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills	0.1
OC	Tetrachloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners	zero
IOC	Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories	0.0005
OC	Toluene	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories	1
M	Total Coliforms (including fecal coliform and *E. coli*)	5.0%[4]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[5]	Coliforms are naturally present in the environment as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste.	zero
DBP	Total Trihalomethanes (TTHMs)	0.10 0.080 after 12/31/03	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle	zero
OC	2,4,5-TP (Silvex)	0.05	Liver problems	Residue of banned herbicide	0.05
OC	1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands	Discharge from textile finishing factories	0.07
OC	1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories	0.20
OC	1,1,2-Trichloroethane	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories	0.003
OC	Trichloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories	zero
M	Turbidity	TT3	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing micro-organisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff	n/a
R	Uranium	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits	zero

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Vinyl chloride	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories	zero
M	Viruses (enteric)	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Xylenes (total)	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories	10

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

1 Definitions
• Maximum Contaminant Level Goal (MCLG)—The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
• Maximum Contaminant Level (MCL)—The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into
consideration. MCLs are enforceable standards.
• Maximum Residual Disinfectant Level Goal (MRDLG)—The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control
microbial contaminants.
• Maximum Residual Disinfectant Level (MRDL)—The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
• Treatment Technique (TT)—A required process intended to reduce the level of a contaminant in drinking water.
2 Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).
3 EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the
following contaminants are controlled at the following levels:
• Cryptosporidium (as of 1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
• Giardia lamblia: 99.9% removal/inactivation
• Viruses: 99.99% removal/inactivation
• Legionella: No limit, but EPA believes that if Giardia and viruses are removed/inactivated, Legionella will also be controlled.
• Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in
at least 95% of the daily samples in any month. As of January 1, 2002, for systems servicing >10,000, and January 14, 2005, for systems servicing <10,000, turbidity may never exceed 1 NTU, and must not

exceed 0.3 NTU in
95% of daily samples in any month.
• HPC: No more than 500 bacterial colonies per milliliter
• Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced
Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, Cryptosporidium removal requirements, updated watershed control requirements for unfiltered systems).
• Filter Backwash Recycling: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate
location approved by the state.
4 No more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total
coliform must be analyzed for either fecal coliforms or E. coli if two consecutive TC-positive samples, and one is also positive for E. coli fecal coliforms, system has an acute MCL violation.
5 Fecal coliform and E. coli are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea,
headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.
6 Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:
• Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
• Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L)
7 Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps.
For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.
8 Each water system must certify, in writing, to the state (using third-party or manufacturers certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does
not exceed the levels specified, as follows: Acrylamide = 0.05% dosed at 1 mg/L (or equivalent); Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent).

Appendix B. Permit Letter for the San Juan, New Mexico Rangeland Rehabilitation Study; and NPDES Permit for the Wyoming Case Study.

NEW MEXICO ENERGY, MINERALS and NATURAL RESOURCES DEPARTMENT

BILL RICHARDSON
Governor
Joanna Prukop
Cabinet Secretary
Reese Fullerton
Deputy Cabinet Secretary

Mark E. Fesmire, P.E.
Director
Oil Conservation Division

July 2, 2007

Certified Mail
Return Receipt #: 7006 3450 0000 0451 8087

Mr. Ed Hasely
ConocoPhillips/ Burlington Resources
PO Box 4289
Farmington, NM 87499

RE: Request to use produced water for Water Pilot Project on the San Juan 32-8 Unit #237A.

Dear Mr. Hasely:

The New Mexico Oil Conservation Division (OCD) has reviewed ConocoPhillips request, dated June 1, 2007 from your office, to use produced water for revegetation. The application is approved for the San Juan 32-8 Unit #237A well location shown in your application.

The following conditions will apply:

1. ConocoPhillips assumes all liability for potential contamination.
2. A record showing volumes of water used and the appropriate analysis will be provided to both the OCD District III Aztec Office and the OCD Environmental Bureau Office, 1220 South Saint Francis Drive, Santa Fe New Mexico 87505.
3. Chloride analysis for the soil will be required after each application of water in addition to the testing previously performed for the pilot project.
4. ConocoPhillips will be required to apply for, and receive any applicable landowner and other regulatory agencies approvals.

To allow adequate time for the pilot project, this approval for the discharge of produced water in accordance with the pilot project will expire December 1, 2007. Due to the scope of work and the ongoing nature of the project, future applications for approval will need to be submitted to the OCD's Environmental Bureau and a copy sent to the district office.

Oil Conservation Division * 1000 Rio Brazos Road * Aztec, New Mexico 87410
Phone: (505) 334-6178 * Fax (505) 334-6170 * http://www.emnrd.state.nm.us

Please be advised OCD approval does not relieve ConocoPhillips from liability should contamination pose a future threat to surface water, groundwater, human health or the environment. OCD approval does not relieve ConocoPhillips of compliance with other federal, state, tribal, or local laws and regulations.

If you have any questions, please call me at 505-334-6178, ext. 15.

Sincerely yours,

Brandon Powell

Brandon Powell
Environmental Specialist
Brandon.Powell@state.nm.us

CC: Dave Mankiewicz, Bureau of Land Management

Wyoming Study NPDES Permit:

SUBMIT IN TRIPLICATE

For Agency Use Only
Application Number
WY00
Date Received:
JAN 3 0 2006
(mo/day/yr)

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM
APPLICATION FOR PERMIT TO SURFACE DISCHARGE PRODUCED WATER FROM COAL BED METHANE NEW DISCHARGES, RENEWALS, OR MAJOR MODIFICATIONS

Revised 12-19-03

PLEASE PRINT OR TYPE

1. Check the box corresponding to the type of application being applied for

☐ New CBM permit

☐ CBM permit renewal Permit number ____________

☒ CBM permit major modification Permit number WY0051772

2. Select a permit option

☐ Option 1A - complete containment to an off-channel man made containment unit(s) (class 4C), no discharge allowed to surface waters of the state outside the containment unit.

☐ Option 1B - complete containment to a natural closed basin or playa lake (class 3A), no discharge allowed to surface waters of the state outside the basin or playa.

☐ Option 2 - surface discharge to class 2 or 3 receiving stream of the Belle Fourche River or Cheyenne River drainage (class 2ABWW).

☐ Option 2 - surface discharge to class 2 or 3 receiving stream of the Powder River or Little Powder Rivers (class 2ABWW).

☒ Option 2 – surface discharge to class 2 or 3 receiving streams of the Tongue, Clear Creek, or Crazy Woman Creek (class 2AB)– this option requires the permittee to demonstrate that quality of the effluent at the discharge point is equal to or better than the ambient quality of the perennial class 2 receiving water.

3. Name, mailing address, e-mail address, location and telephone number of the individual or company which owns the facility producing the discharge.

Name: Fidelity Exploration & Production Company

Street Address: 1700 Lincoln Street, Suite 4600

City, State, and Zip Code: Denver, CO 80203

Telephone Number: 303-893-3133

E-Mail Address: mike.bergstrom@fidelityepco.com

Fidelity Exploration & Production Company/2006/January/26/Major Modification/0810090101/ WY0051772

4. Name(s) and mailing address(es) of owner(s) of the surface rights on whose land the discharge occurs (in cases where the land is owned by the state or federal government but surface rights are leased to a private individual, provide lessee's name and address)
Name: John E. Rice and Sons
Street Address: 247 Decker Road
City, State, and Zip Code: Sheridan WY 82801
Telephone Number: 307-751-2764

5. Name of the facility producing the discharge (this is the facility name that will appear on the NPDES permit. It is not necessary to name every well contributing to this facility's discharge in this section)

WY0051772 – Wrench Ranch 49 Battery

6. For Option 1A or 1B permit, attach a water balance that demonstrates, considering total maximum projected discharge inflows, natural precipitation, evaporation and infiltration, that the containment unit will be adequately sized to contain all projected discharge and stormwater runoff from a 100 year, 24 hour storm event. If actual flow rates are available, use the maximum flow rate from all active wells within the previous six months of operation in the water balance.

7. For an Option 2 permit utilizing on-channel reservoirs, attach a water balance and mixing analysis documenting the amount of CBM discharge that, under normal operating conditions, can be contained within the reservoirs, the amount and circumstances under which the reservoirs will discharge, and the expected water quality upon discharge from the reservoirs.
See previously submitted water management plan for this permit.

8. Attach a description and a clear, legible, detailed topographic map of the discharging facility. Include the following: **See revised map (Figure 1). One Irrigation Monitoring Point (IMP) and two Water Quality Monitoring Stations (WQMS) have been deleted from previously-submitted map.**
   a. A legend
   b. Well locations
   c. Ponds
   d. Reservoirs
   e. Stock tanks
   f. Discharge points (outfalls)
   g. Immediate receiving streams
   h. Water quality monitoring stations
   i. Irrigation compliance points
   j. Location of nearest downstream irrigator.
   k. Section, Township, and Range information
   If any of the above are not applicable please indicate in the description and include a brief explanation as to why the item is not applicable)

9. Describe the control measures that will be implemented to prevent significant damage to or erosion of the receiving water channel at the point of discharge.
Produced water will be piped to a tire-tank and overflow into the existing irrigation diversion ditch. Crushed rock underlain with fabric will be placed within the ditch at the point of discharge and extend 20 feet downstream to prevent erosion to the receiving channels. See December 6, 2004 Addendum to NPDES Application for Permit (WY0051772) for details of outfall design.

10. Describe the control measures that will be implemented to achieve water quality standards and effluent limits. If proposing to utilize a treatment process, provide a detailed description of the treatment process, including, but not limited to: Water quality analyses demonstrating the effluent quality before and after treatment; waste stream volumes and planned method of disposal; aquatic life toxicity data for any chemicals being used in the treatment process; description of how the chemicals will be handled at the facility and the potential for any impacts to waters of the state in the event of a spill; and diagrams of the facility indicating the water treatment path. Additional sheets and diagrams may be attached.
Produced water quality discharged at Outfall 001 is expected to meet Class 3 end-of-pipe effluent limits. Numerous laboratory reports and mixing analyses tables have been previously provided in support of this permit application in the original application and subsequent addenda.

11. Outfall locations must be established as part of a preliminary field reconnaissance survey using GPS or conventional survey equipment and documented in Table 1. Please document the type of equipment used, the expected accuracy of your measurements, and a brief rationale for locating the outfalls at the requested sites below.
Topcon survey grade GPS receiver was used to measure outfall coordinates. Field GPS units are typically accurate to 2-5 meters.

12. Complete the attached **Table 1**. Provide all the information in the table for each proposed discharge point or monitoring point. If proposing changes (a major modification) to an existing facility, **clearly** indicate the desired changes on the table. Additional tables may be attached. Use the format provided.
See attached revised Table 1.

13. Complete the attached **Table 2**. Provide all the information in the table for each well associated with this proposed discharge authorization. If proposing changes (a major modification) to an existing facility, **clearly** indicate the desired changes on the table. Additional tables may be attached. Use the format provided.
See attached Table 2 previously provided for this facility. Wells completed to the Monarch, Carney and Dietz coal formations will be discharged at the outfall listed in this application.

14. Provide the results of water analyses for a sample collected from a location representative of the quality of the water being proposed for discharge for the 25 chemical parameters listed below. The sample must be collected from well(s) or outfall(s) within a twenty mile radius of the proposed facility's location, and from the same coal formation(s) and the same approximate depth(s) as proposed in this application. If filing an application for a permit renewal or modification, the representative sample must be collected from the facility being proposed for renewal or modification. Explain why this sample is representative of the produced water to be discharged.
See produced water chemical analyses included in the January 10, 2005 Addendum to NPDES Application for Permit (WY0051772).

Samples from co-mingled coal seams are acceptable as long as the sample(s) meet the following criteria:
A. all of the coal seams being proposed for development are represented in the co-mingled sample,
B. the ratio of each coal seam's contribution is approximately the same in the sample and the proposed development,
C. documentation is provided to verify the criteria listed in A. and B.

The analyses must be conducted in accordance with approved EPA test procedures (40 CFR Part 136). Include a signed copy of your lab report that includes the following:
a. detection limits
b. results of each of the 25 chemical parameters at the chemical state given below
c. quarter/quarter, section, township and range of the sample collection location

d. Time and date of sample collection
e. Time and date of analysis for each parameter
f. Analyst's initials for each parameter
g. Detection limit for each parameter as achieved by the laboratory
h. NPDES permit number and outfall number, where the sample was collected.
i. Origin of produced water (coal seam)

If more than one coal seam is being proposed for development, the permittee must submit a lab analysis and complete information characterizing water quality from each coal seam being proposed for development. If the permittee is proposing to include discharges from a coal seam not previously developed at this facility, the permittee must submit a lab analysis and complete information characterizing water quality from the new coal seam being proposed for development. Analyses must be provided in the units listed below.

Parameter* **(See notes following the table on chemical states)**	**Required Detection Limits and Required Units**
Alkalinity, Total	**1 mg/l as $CaCO_3$**
Aluminum, Total Recoverable	**50 µg/l**
Arsenic, Total	**1 µg/l**
Barium, Total	**100 µg/l**
Bicarbonate	**10 mg/l**
Cadmium, Dissolved	**5 µg/l**
Calcium, Total	**50 µg/l, report as meq/l**
Calcium, Total	**50 µg/l, report as mg/l**
Chlorides	**5 mg/l**
Chlorides	**5 mg/l**
Copper, Dissolved	**10 µg/l**
Dissolved Solids, Total	**5 mg/l**
Hardness, Total	**10 mg/l as $CaCO_3$**
Iron, Dissolved	**50 µg/l**
Lead, Dissolved	**2 µg/l**
Magnesium, Total	**100 µg/l, report as meq/l**
Magnesium, Total	**100 µg/l, report as mg/l**
Manganese, Dissolved	**50 µg/l**
Mercury, Dissolved	**1 µg/l**
pH	**to 0.1 pH unit**
Radium 226, Total	**0.2 pCi/l**
Selenium, Total Recoverable	**5 µg/l**
Sodium Adsorption Ratio	**Calculated as unadjusted ratio**
Sodium, Total	**100 µg/l, report as meq/l**
Sodium, Total	**100 µg/l, report as mg/l**
Specific Conductance	**5 micromhos/cm**
Sulfates	**10 mg/l**
Zinc, Dissolved	**50 µg/l**

**Discharges into drainages other than the Powder River geologic basin may require analysis of additional parameters, please contact the WDEQ for a separate list.*

Fidelity Exploration & Production Company/2006/January/26/Major Modification/0810090101/ WY0051772

15. For new facilities, provide the expected (estimated) flow volume from each well in gallons per day, and provide the rationale behind the flow volume estimate. For existing facilities, provide actual flow data from all wells within the last six months.
Fidelity requests a maximum volume of 150 acre-feet per year, with discharge rate of up to 0.288 mgd or 200 gallons per minute (gpm) for the outfall listed in this application. The individual wells within the Wrench Ranch development area are expected to produce approximately 4 gpm.

16. For applications for new facilities, are any of the required chemical constituents in the laboratory analysis present in concentrations above Wyoming Water Quality Standards?

☐ YES ☐ NO

If the answer to question # 16 is yes, answer 16.a. – 16.b below. If no, proceed to question 18.

a. Which constituents? ______
b. Has this constituent been addressed in the response to question 10? ______

17. For applications for existing facilities, has the facility ever exceeded permit limits or water quality standards? **This facility has not discharged at this proposed outfall. Representative water quality samples from wells within this project area indicate compliance with Class 3 effluent limits and with requested SAR and specific conductance limits at the end-of-pipe.**

☐ YES ☒ NO

If the answer to question 17 is yes, answer 17.a. – 17.b. If no, proceed to question 18.

a. Which constituents? ______
b. Has the exceedance been addressed? ______
c. Describe how the exceedance is being addressed. ______

18. Is there active irrigation, (including but not limited to irrigation of cultivars or flood irrigation) in the drainage of the discharge?

☒ YES ☐ NO

If the answer to question #18 is yes, then documentation demonstrating one of the following must be provided: **See attached landowner letter which establishes the protection of irrigation uses on the Wrench Ranch surface when produced water containing specific conductance and SAR values below 2,000 micromhos/cm and 25, respectively, is discharged at the proposed outfall into Windy Draw Reservoir.**

A. Effluent will meet SAR and specific conductance (EC) values that are equal or of better quality to ambient values in the mainstem or highest quality receiving stream; or
B. Demonstrate that a higher level of EC and SAR at the point of irrigation diversion can be tolerated by irrigated soils and crops without a significant reduction in crop yield and soil quality/permeability.

This information should include, but is not limited to the following:

I (CEO or other authorized person) certify that I am familiar with the information contained in this application and that to the best of my knowledge and belief, such information is true, complete, and accurate. I am requesting one outfall in this application.

Darwin Subart — **President**
Printed Name of Person signing* — Title*

January 27, 2006
Signature — Date

*All permit applications must be signed in accordance with 40 CFR Part 122.22, "for" or "by" signatures are not acceptable.

Section 35-11-901 of Wyoming Statutes provides that:
Any person who knowingly makes any false statement, representation, or certification in any application ... shall upon conviction be fined not more than $10,000 or imprisoned for not more than one year, or both.

Mail this application to:

NPDES Permits Section
Department of Environmental Quality/WQD
122 West 25th Street, Herschler Building, 4W
Cheyenne, WY 82002

Please include unique footer information on each page of this application and on all supporting documentation using the following format:
Company Name: Year/Month/Day/NEW, MOD, RENEWAL/10 Digit HUC Code/Permit # (if a modification or renewal) or Application # (from this particular company) for that particular day

Appendix C: Additional Resources

- https://www.epa.gov/eg - EPA homepage for Effluent Guidelines
- https://www.epa.gov/eg/unconventional-extraction-oil-and-gas-industry--EPA information on UOG effluent rulemaking and background.
- https://www.epa.gov/eg/coalbed-methane-extraction-industry --Effluent guidelines from EPA on coalbed methane extraction
- http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OW-2014-0598-0001 EPA information on UOG effluent rulemaking and background- more information and a summary from Regulations.gov information source.
- EPA solid waste (40 CFR §261.2). EPA defines solid waste as garbage, refuse, sludge, or other discarded material (including solids, semisolids, liquids, and contained gaseous materials). If a waste is considered solid waste, it must then be determined if it is hazardous waste (§262.11). Wastes are defined as hazardous by EPA if they are specifically named on one of four lists of hazardous wastes located in Subpart D of Part 261 (F, K, P, U) or if they exhibit one of four characteristics located in Subpart C of Part 261 (characteristic wastes): http://waste.supportportal.com/link/portal/23002/23023/Article/22091/What-is-a-RCRA-hazardous-waste?__utma=172919287.658988263.1401825591.1401828189.1413912325.3&__utmb=172919287.12.8.1413912518462&__utmc=172919287&__utmx=-&__utmz=172919287.1413912325.3.2.utmcsr=google|utmccn=(organic)|utmcmd=organic|utmctr=(not%20provided)&__utmv=172919287.|1=visitor%20id=658988263=1&__utmk=89205083
- Information on Oil and Gas regulations: http://water.epa.gov/scitech/wastetech/guide/oilandgas/
- Current regulatory framework for UOG: http://water.epa.gov/scitech/wastetech/guide/oilandgas/unconv.cfm
- Clean Water Act regulation of Coastal subcategory: http://www.gpo.gov/fdsys/pkg/FR-1996-12-16/pdf/96-28659.pdf

Some subparts of the CWA and later amendments are relevant to produced water use and handling, as follows:

- Clean Water Act (40 CFR part 435)-1979 and later amendments. "Subpart C covers wastewater discharges from field exploration, drilling, production, well treatment, and well completion activities in the oil and gas industry." (Onshore)
- CWA Subpart E-applies to onshore facilities located in the continental US and west of the 98th meridian for which the produced water has a use in agriculture or wildlife propagation when discharged into navigable waters. Limits oil and grease and waste pollutants, must be good enough quality, and put to such use during periods of discharge.
- 1979 final rule for all categories: http://water.epa.gov/scitech/wastetech/guide/oilandgas/upload/O-G-Final-Int-Final-Rule_Apr-13-1979_44-FR-22069.pdf

- Clean Water Act regulation of Coastal subcategory: http://www.gpo.gov/fdsys/pkg/FR-1996-12-16/pdf/96-28659.pdf

Additionally, parts of the CWA apply to injection methods for waste disposal and underground storage of water:

- Underground Injection Control rules-UIC rules are intended to protect groundwater-Class II UIC permits.
- Aquifer Storage and Recovery (ASR)

Recent changes to the CWA include rules related to waters from hydraulic fracturing operations:

- Unconventional Extraction in the Oil and Gas industry—Federal Register Notice April 7, 2015-focus on regulating under the Clean Water Act discharges from oil and gas operations to POTWs.http://www.gpo.gov/fdsys/pkg/FR-2015-04-07/pdf/2015-07819.pdf. http://water.epa.gov/scitech/wastetech/guide/oilandgas/unconv.cfm

- 1979 final rule for all categories: http://water.epa.gov/scitech/wastetech/guide/oilandgas/upload/O-G-Final-Int-Final-Rule_Apr-13-1979_44-FR-22069.pdf

NETL regulatory and information page:

http://energy.gov/fe/science-innovation/oil-gas/shale-gas-rd/produced-water-rd

NETL state regs link (New Mexico)

http://www.netl.doe.gov/research/coal/crosscutting/pwmis/fed-state-regulations/new-mexico

Note: this was clearly part of PWMIS but links directly to PWMIS seem to be broken.

Produced Water Reuse Initiative 2014 conference site:

http://www.produced-water-reuse-rockies-2014.com/sponsor-or-exhibit/

CBM rules-Colorado, Aqwatec at Colo School of mines:

http://aqwatec.mines.edu/produced_water/regs/state/co/

Veolia Treatment systems information including SAGD and produced water treatments:

http://www.vwsoilandgas.com/resourcecenter/case-studies/27696.htm

Appendix D. Text of HR 388 (2002).

HOUSE BILL 388

45th legislature - STATE OF NEW MEXICO - second session, 2002

INTRODUCED BY Robert M. Burpo

AN ACT

RELATING TO TAXATION; PROVIDING FOR INCOME TAX AND CORPORATE INCOME TAX CREDITS FOR INVESTMENTS IN CLEANING WATER PRODUCED FROM OIL AND GAS DRILLING.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF NEW MEXICO:

Section 1. A new section of the Income Tax Act is enacted to read:

"[NEW MATERIAL] CREDIT FOR PRODUCED WATER.--

A. A taxpayer who files an individual New Mexico income tax return who is not a dependent of another taxpayer and who produces water in the course of drilling for oil or gas may take a tax credit in an amount equal to one thousand dollars ($1,000) per acre-foot of produced water not to exceed four hundred thousand dollars ($400,000) per year if the following conditions are met:

(1) the taxpayer discharges the water into the Pecos river in compliance with the requirements of the New Mexico Water Quality Act, the New Mexico water quality control commission regulations and the federal clean water acts;

(2) the taxpayer discharges the water in a manner approved by the interstate stream commission to contribute to delivery obligations pursuant to the Pecos River Compact; and

(3) the produced water discharged into the Pecos river is available for appropriation only to meet terms of the Pecos River Compact.

B. A husband and wife who file separate returns for a taxable year in which they could have filed a joint return may each claim only one-half of the credit that would have been allowed on a joint return.

C. The tax credit provided in this section may only be deducted from the taxpayer's personal income tax liability. Any portion of the tax credit provided in this section that remains unused at the end of the taxpayer's taxable year may be carried forward for three consecutive taxable years.

D. As used in this section, "produced water" means water produced from oil or gas drilling from a depth of three thousand feet or more below the surface."

Section 2. A new section of the Corporate Income and Franchise Tax Act is enacted to read:

"[NEW MATERIAL] CREDIT FOR PRODUCED WATER.--

A. A taxpayer that files a New Mexico corporate income tax return that produces water in the course of drilling for oil or gas may take a tax credit in an amount equal to one thousand dollars ($1,000) per acre-foot of produced water not to exceed four hundred thousand dollars ($400,000) per year if the following conditions are met:

(1) the taxpayer discharges the water into the Pecos river in compliance with the requirements of the New Mexico Water Quality Act, the New Mexico water quality control commission regulations and the federal clean water acts;

(2) the taxpayer discharges the water in a manner approved by the interstate stream commission to contribute to delivery obligations pursuant to the Pecos River Compact; and

(3) the produced water discharged into the Pecos river is available for appropriation only to meet terms of the Pecos River Compact.

B. The tax credit provided in this section may only be deducted from the taxpayer's corporate income tax liability. Any portion of the tax credit provided in this section that remains unused at the end of the taxpayer's taxable year may be carried forward for three consecutive taxable years.

C. As used in this section, "produced water" means water produced from oil or gas drilling from a depth of three thousand feet or more below the surface."

Section 3. DELAYED REPEAL.--Sections 1 and 2 of this act are repealed effective January 1, 2006.

Section 4. APPLICABILITY.--The provisions of this act apply to taxable years beginning on or after January 1, 2002.

- 4 -