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Reuse of oil and gas produced water in south-eastern New Mexico: resource assessment, treatment processes, and policy

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The Permian Basin of south-eastern New Mexico in the United States exemplifies the combination of rapidly expanding oil and gas production with freshwater shortages and aquifer stress. Reuse of saline produced water can provide a stable supply of water for drilling, fracturing and completion and minimize consumptive use of freshwater. We discuss water withdrawals and use by the oil and gas industry in this region, processes for reuse and recycling of produced water in place of freshwater, and operational and policy changes to help improve maximal use of all available water resources in this arid region.

**Keywords:** produced water; hydraulic fracturing; drought; water reuse; Permian Basin

**Introduction**

Freshwater derived from groundwater aquifers is the most frequently used water source for oil and gas development. The use of freshwater in drilling and well completion, and the subsequent disposal of water that flows back to the surface (flowback or produced water) via reinjection are fully consumptive processes with no return to freshwater aquifers or surface streams. Recent assessments of oil and gas production, including unconventional development such as horizontal drilling with hydraulic fracturing, has shown that many locations in the world that are well suited for high recovery of oil or gas also have high water stress and are vulnerable to surface water shortages, drought, and aquifer depletion (Freyman, 2014; Rahm & Riha, 2014). Nicot and Scanlon (2012) report that freshwater use for hydraulic fracturing is increasing rapidly in some areas of Texas, for example. The Permian Basin region of south-eastern and eastern New Mexico in the United States exemplifies the issues that surround the combination of rapidly expanding oil and gas exploration and production, and freshwater shortages and aquifer stress due to extended drought. Between 2008 and 2013, oil production increased 68% in the region, primarily because of horizontal drilling and hydraulic fracturing, a process that requires large amounts of water, historically freshwater. The region also experienced below-average precipitation in five of the last six years, leading to stress on the surface water supply and reduction of aquifer recharge rates. We use this case study to examine how freshwater withdrawals for oil and gas development occur in the context of all water...

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withdrawals in these counties, and to show whether recycling ‘produced water’ rather than using freshwater can reduce stress on local freshwater supplies.

Water produced during extraction of oil and gas within the US has commonly been considered a waste product. By regulatory definition, produced water is an incidental by-product of drilling for or the production of oil and gas (New Mexico Oil and Gas Act, 1978). Most (~80%) of oil and gas produced water is reinjected into deep saline formations (Clark & Veil, 2009). Water is injected into oil and gas wells for multiple purposes, including disposal, enhanced oil recovery and waterflooding, and in some cases, hydraulic fracturing. Reused produced water, however, could be a stable supply of water for drilling, fracturing and completion that would minimize the use of freshwater. There are indications that reuse for the purpose of replacing freshwater in drilling operations is growing (Shattuck, 2015).

Balancing development of energy resources with rapid depletion of freshwater resources is a critical intersection known as the energy–water nexus: water is needed for energy development, while energy is needed to supply freshwater for human uses. We present this case study from the Permian Basin in south-eastern New Mexico, including Eddy, Lea and Chaves Counties, to illustrate the challenges associated with localized freshwater resource assessment, gaps in our knowledge of water inventories and uses for oil and gas production, processes being used to recycle produced water for reuse, and the policy changes that are being implemented to encourage reuse of produced water in this arid region.

Regional basins and drought

Figure 1 shows uplifts and basins associated with current and potential oil and gas development in New Mexico (Broadhead & Price, 2012). The area considered here includes three counties: Eddy, Lea and Chaves. These counties host oil and gas production within the Permian Basin, with the largest production in Lea and Eddy. The Permian Basin is one of the largest oil and gas basins in the United States and covers portions of eastern New Mexico and much of western Texas. Fresh surface water availability is very low, and is effectively limited to the Pecos River drainage basin in parts of Chaves, Eddy and Lea Counties and a small portion of the Texas Gulf River basin in part of Lea County (Longworth, Valdez, Magnuson, & Richard, 2013). Huff (2004) describes some of the important reservoirs of fresh groundwater contained in near-surface aquifers (from ground surface to ~300 m below ground surface), including various alluvial and bolson deposits. Saline groundwater (>10,000 mg/L total dissolved solids) is common in deeper horizons in the region, as well as in deposits such as the Capitan Reef Aquifer, west of the Pecos River (Eddy and Lea Counties), and in the Roswell Basin (Chaves and Eddy Counties). There has been a large ongoing population influx to Eddy and Lea Counties (4% and 14% increase, respectively, in 2005–2010; 3.1% and 5.2% in 2010–2013), mostly to support unconventional oil development (Longworth et al., 2013; U.S. Census Bureau, 2011).

The western United States is in the midst of a mega-drought, with greater than 100-year drought intensity on the whole (Ault et al., 2013; McDowell et al., 2013; Williams et al., 2010). According to the National Oceanographic and Atmospheric Administration, New Mexico has seen 66 dry years versus 47 wet years in 1900–2013 (Figure 2). While wet years often exhibit a strongly positive Palmer Hydrological Drought Index, there are fewer wet years than dry, and there are fewer wet years in a row versus sequential dry years. Severe droughts occurred in 1945–1960, and in 2000–2013, although the most recent drying trend began as early
as 1994. The Permian Basin in New Mexico lies within a high to very high water-stress region, as identified by Freyman (2014). Figure 3 shows drought designations by the US Department of Agriculture for the US in early 2014.

Most of New Mexico has been severely impacted by drought during this time, particularly the eastern portion of the state. Groundwater aquifers reflect drought in a cumulative fashion, particularly when withdrawal overdrafts overlap drought effects and subsequent lack of recharge. An example of ongoing cumulative decrease in well-water levels is shown in Figure 4, left side (USGS, 2014a, 2014b). Water levels in the southern portion of Lea County (near the Texas border) illustrate severe overdrafts from the shallow groundwater aquifer in that region. As another example, a shallow well in Eddy County (Figure 4, right side) shows more variability, indicating recharge between drought events, with intermittent decreases during drought periods in the 1950s, the 1970s, and from 1998 to the present. Rates of decrease in municipal wells in the northern portion of the High Plains Aquifer on the eastern border of New Mexico (Clovis region) are reported to be on the order of 2 feet per year; some wells have less than 20 feet of reserve water above the pump intake (Daly, personal communication on well water levels for Clovis, New Mexico, 2014; McGuire, 2012).
Figure 2. Palmer hydrologic drought index (PHDI) for New Mexico, 1900–2013. Wet years shown in green above baseline, dry years shown in yellow below baseline.

Figure 3. US Department of Agriculture drought designations for 2014. South-east New Mexico drought disaster incidents are shown in red (primary counties) and orange (contiguous counties).
Source: Farm Service Agency, US Department of Agriculture.
Freshwater withdrawal data

Water management and recordkeeping in New Mexico have focused on freshwater withdrawals related to water rights (ownership) for the largest use sectors, to inform users and to preserve water rights for senior rights holders (New Mexico State Water Plan, 2015). Produced-water management has focused on reuse for waterflooding (the use of large quantities of water to flush older oil fields to improve the oil yield), enhanced oil recovery, and disposal of the water as an industrial waste product. Hence, there has been no incentive to combine or coordinate the collection and analysis of these disparate datasets (see e.g. Dahm, 2014). Produced-water recycling in hydraulic fracturing processes specifically to replace freshwater is a recent concept. In this section we highlight what is known regarding freshwater withdrawals for oil and gas purposes in these three counties, in the context of all reported uses, to understand the localized impacts of freshwater withdrawals for oil and gas, and the potential for replacement of freshwater in oil and gas operations with produced water.

The New Mexico Office of the State Engineer (NMOSE) collects and reports freshwater withdrawals (also called ‘use’) every five years. The most recent report from NMOSE has data from 2010; the next report will publish data from 2015. We used the most recent reports on water withdrawals (freshwater only) from NMOSE (Longworth, Valdez, Magnuson, Albury, & Keller, 2008; Longworth et al., 2013; Wilson, 2003). The data include reported withdrawals from self-supplied industries and individuals, as well as estimated withdrawals based on calculations for irrigated land. Table 1 shows data for 2000–2010 for Eddy, Lea and Chaves Counties, including withdrawals for agriculture, municipal use, mining, and oil and gas (a subset of the mining category), and totals for all reported categories. Withdrawals of freshwater for agriculture dominate the system, with 78% of total water withdrawals statewide used for agriculture in 2010.

The percentages of mining water withdrawn for oil and gas alone are 2% (Eddy), 91% (Lea) and 45% (Chaves). Lea County sustained more oil and gas development activity in
2010, while Eddy County supports large potash mines that use most mining withdrawals. Clearly, agricultural withdrawals are much larger than other categories.

In the three south-east New Mexico counties in 2010, agricultural use varied from 81% to 89% of total withdrawals (Figure 5, left side). When agriculture allotments are removed from the analysis (Figure 5, right side) we see that mining, which includes oil and gas, along with mineral extraction, comprises 22% of the remaining total withdrawals for Eddy County, 8% for Lea County, and 1% for Chaves County. Given that almost all water in New Mexico is allocated by water rights, the percentages of groundwater used for oil and gas in Lea and Eddy Counties are significant when viewed from a local perspective.

Irrigated agriculture is the largest category of fresh groundwater withdrawn in the region. Figure 6 shows a comparison of these withdrawals for the three counties for

Table 1. Freshwater withdrawals for selected categories, in acre-feet and million m³.

<table>
<thead>
<tr>
<th></th>
<th>Chaves</th>
<th>Lea</th>
<th>Eddy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acre-feet</td>
<td>Million m³</td>
<td>Acre-feet</td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigated agriculture</td>
<td>333,467</td>
<td>416</td>
<td>129,792</td>
</tr>
<tr>
<td>Mining</td>
<td>169</td>
<td>0.208</td>
<td>28,294</td>
</tr>
<tr>
<td>Oil and gas</td>
<td>90</td>
<td>0.111</td>
<td>15,372</td>
</tr>
<tr>
<td>Public</td>
<td>18,205</td>
<td>22.5</td>
<td>14,726</td>
</tr>
<tr>
<td>Total, all categories</td>
<td>369,455</td>
<td>456</td>
<td>186,669</td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigated agriculture</td>
<td>237,225</td>
<td>293</td>
<td>135,371</td>
</tr>
<tr>
<td>Mining</td>
<td>117</td>
<td>0.144</td>
<td>18,365</td>
</tr>
<tr>
<td>Oil and gas</td>
<td>117</td>
<td>0.144</td>
<td>13,624</td>
</tr>
<tr>
<td>Public</td>
<td>16,231</td>
<td>20.0</td>
<td>13,360</td>
</tr>
<tr>
<td>Total, all categories</td>
<td>268,932</td>
<td>332</td>
<td>186,019</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigated agriculture</td>
<td>241,598</td>
<td>298</td>
<td>172,297</td>
</tr>
<tr>
<td>Mining</td>
<td>225</td>
<td>0.278</td>
<td>2,006</td>
</tr>
<tr>
<td>Oil and gas</td>
<td>101</td>
<td>0.125</td>
<td>1,871</td>
</tr>
<tr>
<td>Public</td>
<td>16,559</td>
<td>20.4</td>
<td>13,195</td>
</tr>
<tr>
<td>Total, all categories</td>
<td>270,698</td>
<td>334</td>
<td>197,099</td>
</tr>
</tbody>
</table>

2010, while Eddy County supports large potash mines that use most mining withdrawals. Clearly, agricultural withdrawals are much larger than other categories.

In the three south-east New Mexico counties in 2010, agricultural use varied from 81% to 89% of total withdrawals (Figure 5, left side). When agriculture allotments are removed from the analysis (Figure 5, right side) we see that mining, which includes oil and gas, along with mineral extraction, comprises 22% of the remaining total withdrawals for Eddy County, 8% for Lea County, and 1% for Chaves County. Given that almost all water in New Mexico is allocated by water rights, the percentages of groundwater used for oil and gas in Lea and Eddy Counties are significant when viewed from a local perspective.

Irrigated agriculture is the largest category of fresh groundwater withdrawn in the region. Figure 6 shows a comparison of these withdrawals for the three counties for

Figure 5. Freshwater withdrawal category comparison for Chaves, Lea and Eddy Counties. Left: all reported categories. Right: all categories except irrigated agriculture. Mining category includes oil and gas withdrawals.

Source: NMOSE.
2000–2010, along with the number of irrigated farms and the irrigated area. All three counties were impacted by drought during this time, and all three experienced a decrease in irrigated farm numbers; only Lea County showed an increase in irrigated area, indicating more irrigation on fewer farms. Lea County experienced an increase in groundwater withdrawals for agriculture of 33% while in Eddy and Chaves it decreased by 17% and 28% respectively. Chaves County is most indicative of the effects of drought alone on groundwater withdrawals, absent oil and gas production. The changes in water withdrawals measured during this time are thus most likely a result of farms responding to the drought conditions, and not withdrawals for oil and gas use.

**Freshwater use in oil and gas production**

Understanding the sources and sinks for water processes related to oil and gas has not historically been a goal for water management purposes. Assigning values for relative volumes for these processes is complex and subject to availability of specific data, as well as uncertainties and variations in the processes used. Sources in New Mexico include not only fresh groundwater, but at times brackish groundwater (>1000 mg/L total dissolved solids) or other waste waters (Figure 7). Disposal by reinjection or evaporation is the ultimate sink for these waters; however, reuse occurs during drilling and production.

![Diagram of water handling processes](image)

Figure 7. Generalized process flow for handling of source, produced and flowback waters, including disposal. Both ‘frac’ and produced water are products and can be recycled. Ultimately, all waters are disposed, mostly via deep well injection.
Typically, the largest-magnitude source is freshwater, while the largest-magnitude product is produced water. Freshwater is consumed via production because it is mixed with subsurface produced water and used as drilling or fracturing fluid.

We compared the trends of oil and gas production, including well ‘starts’ – wells that are completed and brought into production in a given year – with the water withdrawn for oil and gas production, for each county during 2000–2010 (Figure 8). Lea County withdraws by far the most water for oil and gas production, both overall and on a per well basis, of the three counties. Trends in oil production are relatively level for this time period; trends in gas production are variable, with decreasing production overall. An expected trend is that water withdrawals (the ‘potential source’ in Figure 7) will follow well starts. This is true for both Eddy and Lea Counties. Overall, the average quantity of water used per well started increased over time for Eddy and Chaves counties and decreased for Lea County. Horizontal drilling and large multi-stage hydraulic fracturing methods do not appear to have substantially increased water requirements for drilling and completion during the period evaluated.

**Trends in water use for hydraulic fracturing and production**

Conventional production constituted the majority of oil and gas production prior to 2005, when unconventional production (including horizontal drilling and hydraulic
fracturing techniques) began to be commonly used in the US, including in south-east New Mexico. There was considerable growth in the number of directional (horizontal, hydraulically fractured) wells drilled in all New Mexico counties from 2008 to 2013 (Figure 9).

Based on information from producers, most of the water used to date in these applications in New Mexico is freshwater; but recycling of produced water for hydraulic fracturing began sometime around 2012 and is expanding (Adams, 2014; Crawford, personal communication on costs of produced water desalination treatment testing in New Mexico, 2014; Delasanta, 2014; Livingston, 2014, Shattuck, 2015).

As hydraulic fracturing increases, the amount of water needed for drilling, fracturing, and production operations will also increase. The amount of water used in hydraulic fracturing in New Mexico is now recorded, as a result of new reporting requirements (instituted in 2012; Table 2). The state of New Mexico requires reporting of frac-related fluid quantities, but does not collect information about the sources of water or the initial quality as the water enters the system. An alternate source of information is the FracFocus website (http://fracfocus.org/); however, the information reported there is voluntary and thus is not necessarily as complete as that reported to the state.

Table 2 shows the trends in fracture volumes disclosed in a year-on-year comparison of similar periods in 2012 and 2013 for the three counties. The increase in the volume used in Lea County for this time is the largest for the state and shows the significance of the volumes needed for horizontal well development. Specific average volumes per well varied from 3200 m$^3$ to 5500 m$^3$. Approximately 6.5 million m$^3$ (41 million barrels) of fluid, composed mostly of water, was used for fracturing in 2013 in New Mexico (the first full-year report). In 2014, the average quantity of hydraulic fracturing fluid used per well in Eddy county was 7183 m$^3$ (45,185 barrels); in Lea county, 8866 m$^3$ (55,767 barrels); and in all other counties 1998 m$^3$ (12,571 barrels), based on a partial-year report (NMOCD, 2014).

Oil and gas companies typically purchase water from local suppliers for frac jobs; some of this water is reused, but most is disposed. Certain oil and gas companies have reported 100% reuse of their frac ‘flowback’ water in New Mexico in personal communications (Adams, 2014; Livingston, 2014). New Mexico does not collect information on recycling of water related to hydraulic fracturing.
Table 2. Fracture disclosures, total volumes of water used, and average volumes per well used for fracture operations by county and year.

<table>
<thead>
<tr>
<th>County</th>
<th>Fracture disclosures 2012</th>
<th>Volume, m³ (US gal.)</th>
<th>Specific volume per well, m³</th>
<th>Fracture disclosures 2013</th>
<th>Volume, m³ (US gal.)</th>
<th>Specific volume per well, m³</th>
<th>Percentage volume change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaves</td>
<td>9</td>
<td>44,590 (11,779,572)</td>
<td>4,955</td>
<td>11</td>
<td>36,058 (9,525,644)</td>
<td>3,278</td>
<td>-19.13</td>
</tr>
<tr>
<td>Eddy</td>
<td>846</td>
<td>3,092,253 (816,886,834)</td>
<td>3,655</td>
<td>798</td>
<td>3,388,470 (895,139,086)</td>
<td>4,246</td>
<td>9.58</td>
</tr>
<tr>
<td>Lea</td>
<td>234</td>
<td>1,022,168 (270,028,447)</td>
<td>4,368</td>
<td>440</td>
<td>2,446,833 (646,384,843)</td>
<td>5,561</td>
<td>139.38</td>
</tr>
</tbody>
</table>

Note: Each year is 15 February–31 December for purposes of comparison; reporting did not start until February 15 in 2012, so data from the same period are reported for 2013.
Trends in produced water

Unconventional production includes frac flowback water as well as drilling fluids and hydraulic fracturing fluids. ‘Flowback’ is an operational term that includes return flow after hydraulically fracturing a well bore. Flowback water may differ in chemical quality from the ‘formation water’ that is extracted with the oil or gas resource. By regulatory definition it is considered produced water, because it is also a by-product from oil and gas production. Flowback volumes are variable, depending upon the formation, the time since the frac was performed, the method used for hydraulic fracturing, and the length of the fractured horizontal well segment (Dahm, 2014). Recycled produced water has been used since the 1960s for conventional waterflooding and enhanced oil recovery processes in the oilfield (Martin & Colpitts, 1996). These methods are used to improve recovery of hydrocarbon products in conventional oil and gas production. The reuse of produced and flowback waters for hydraulic fracturing is a newer (‘unconventional’) process that has increased since approximately 2012 in the US.

Over the past six years in New Mexico, an average of 118 million m$^3$ (741 million barrels, or Mbbl) of water has been produced annually as a by-product of oil and gas production. In south-east New Mexico alone, 647 million m$^3$ (4069 Mbbl) of water was produced in 2008–2013 (an average of 107.8 million m$^3$/y or 678.2 Mbbl/y), making this region the highest water-producing region in the state (New Mexico Oil Conservation Division, 2014). Production of oil and water, and injection of water, have increased steadily in the region over time. The water-to-oil ratio (~7:1) has decreased, showing improved oil recovery efficiency, while the water-to-gas ratio (~100 bbls:1 MMcf) ratio has varied widely. These values indicate that the amount of produced water that could be available for drilling operations, hydraulic fracturing and well completions far exceeds the amount of freshwater that is currently withdrawn for oil and gas use.

Treatment implementation and processes for recycling of produced water

The oil and gas industry has only recently begun to consider recycling and reuse of produced water as a replacement for freshwater. Reuse of produced water will require infrastructure changes and capital investments by the industry, such as pipelines, large tank storage or pit storage (1–10 million gallon capacities), treatment systems configured to handle high-salinity waters (including leak detection systems), additional pump installations, and disposal facilities for treatment wastes (solids or liquids). Regulations will need to be adapted to encourage this investment in reuse, and to adequately protect the environment (e.g. from leaks or emissions).

Produced water can be treated for reuse in drilling and hydraulic fracturing operations without desalination. New formulations of cross-linking gels and ‘slickwater’ chemical additives for frac waters are now used in a wide range of salinities (DeFosse & Cooper, 2015; Welch, 2015). Treatments thus focus on specific constituents of concern that can disrupt frac chemistry, including scale-forming minerals (calcium or magnesium sulphate, calcium carbonate, iron and manganese oxides), boron, iron, silica, and microbial contamination. A treatment system thus may consist of preliminary storage, followed by initial filtration, pH adjustment and/or flocculant addition for prevention of mineral scale formation; mixing and settling; and a final filtration before the water is reused. If the water is reused quickly enough, microbicides may not be needed; otherwise, they can be used to prevent microbial growth during water storage. Some flocculants also effectively remove microbes along with scale-forming minerals. Benefits of recycling include fewer trucks on
roadways, reduced use of freshwater (>1100 m³ or 7000 barrels per well) and a reported 300,000 fewer miles driven per year for truck transportation (Adams, 2014; Livingston, 2014). Initial capital costs for large desalination plants can be high (up to USD 195 M), but for high-volume treatment plants operation and maintenance costs can approach USD 0.45–0.52/m³ (Borsani & Rebagliati, 2005). Recent desalination testing in south-east New Mexico and Texas indicated costs of USD 5.53–50.00/m³ (USD 0.88–8.00/barrel) for treated (outlet) water (Crawford, 2014; Delasanta, 2014). Plant location is critical to overall costs because transportation of influent water, treated water and concentrated wastes can be considerable (Sullivan, Chu, Stauffer, Middleton, & Pawar, 2013).

Ultimately, achieving a water balance to understand inflows and outflows to oil and gas operations in south-eastern and eastern New Mexico is challenging because of the differences in accounting and reporting methods between different state agencies (Oil and Gas Conservation Division and NMOSE), the differences in characterizing ‘types’ of water (oil and gas produced, flowback, brackish or freshwater), the limited transfers of information between water users and consumers, and varied policies governing water information. Considerable gaps exist in measuring, reporting and accounting systems that could be addressed via policy and/or market (price of water) influence, and data uncertainties are unknown. Recycling of oil and gas produced or flowback waters could result in considerable savings of freshwater for other human uses in south-eastern and eastern New Mexico, when reported withdrawals for oil and gas are considered. Although the absolute quantities of produced water are low compared to statewide and regional allocations and withdrawals for agriculture, when viewed on a local basis the water quantities withdrawn in 2010 are comparable in magnitude to water for livestock, domestic, commercial and power supplies and worth consideration for recycling and reuse in times of extreme drought.

**Adaptation to facilitate produced-water reuse**

New Mexico is actively looking for ways to promote produced-water recycling and reuse. Updates in 2013 and 2014 to the New Mexico Oil Conservation Division’s Rule 17, commonly known as the Pit Rule, encourage water recycling through allowance of multi-well fluid management pits. In addition, the division issued a notice in 2013 to clarify that no permit or authorization is required for produced-water reuse as a drilling or completion fluid or for other oilfield fluid use. Further modifications to rules are proposed to encourage produced-water reuse. Updates to Rules 34 (Produced Water) and 36 (Surface Waste Management) were finalized in 2015 and will make recycling and reuse more accessible to the industry. Rule 34 is likely to include a ‘permit by rule’ provision for produced-water recycling that further clarifies the regulatory framework for produced-water recycling and eases the potential for regulatory burden.

Despite fairly straightforward means to reuse fluids within the oil and gas industry, there are no distinct regulatory pathways to treat and reuse produced water for other beneficial uses outside the industry, such as agricultural water uses; no regulations exist in this grey area in many states, including New Mexico. At this time, agricultural use of produced water is limited to specific regions (examples are California and Wyoming) where produced-water qualities are acceptable for discharge without treatment. Treatment costs for brackish and saline waters with greater than 3000 mg/L total dissolved solids are thought to be prohibitive for the large volumes needed for agriculture. However, if less expensive methods of
treating or blending produced water could be found, the volumes available are considerable and could be a significant resource on a local to regional scale. More research is needed to explore and evaluate opportunities to reuse produced water both within and outside of the oilfield.

To continue to reduce freshwater use in oil and gas operations, regulatory entities will need better data on water usage, quality and tracking, from the initial water source to disposal, throughout the oil and gas production process. The scarcity of accurate water use and recycling data in New Mexico is a barrier to motivating regulatory action or industry change. Data are needed on a year-to-year basis to monitor changes and impacts (positive and negative) in the short term, including trends derived from human use and climate variability.

It may also be helpful for water planning processes to expand to incorporate non-traditional and non-righted (nonassigned) sources of water, such as produced water from oil and gas. An emphasis on righted freshwater sources in state water planning precludes discussion of greater utilization of produced, brackish or wastewater ‘sources’, and these unconventional water sources may gain importance as drought continues and water demands grow.

Conclusions
The amount of freshwater withdrawn for oil and gas in south-east New Mexico is significant when compared to other non-agricultural uses. The amount of produced water available for recycling, however, is much larger than freshwater withdrawals and could become a valuable resource for oil and gas production and hydraulic fracturing activities. Current data on oil and gas sector freshwater withdrawals do not show an increase when viewed on a county-by-county basis, or when compared with well starts. However, partial-year data appear to show increases in per well freshwater use in the highest-activity regions of Lea and Eddy Counties. Changes in agricultural-sector use reflect drought conditions in New Mexico and are not clearly related to withdrawals for oil and gas.

Treatment of oil and gas produced water is evolving, and companies are applying various methods, with and without desalination, to expedite reuse. A consistent source of water is the primary goal of this effort. Treatment costs can be high, particularly for desalination; however, desalination is not always needed, and the costs are outweighed by the industry’s need for a reliable water supply during drought.

Policies are changing to support reuse of produced water in place of freshwater extractions. Proposed policies will enable infrastructure and permitting changes that could accelerate recycling efforts, reducing withdrawals of freshwater for the oil and gas sector and reducing truck traffic on roadways. Reductions of freshwater withdrawals should be further monitored to determine whether there are positive impacts to groundwater storage or to freshwater availability for other sectors (e.g. domestic supplies).

Improved coordination among state agencies, federal agencies, researchers and industry is needed to collect the most relevant and impactful data-sets for analysis and prediction. New data-collection efforts are underway by the Bureau of Reclamation, the USGS, state geological surveys and state agencies, and the oil and gas industry. The recognition that recurrent drought is impacting fresh surface and groundwater resources, and that all sectors may be affected by overdrafts during extended droughts, is an
incentive for the reuse and recycling of produced water for the benefit of the oil and gas industry and other regional freshwater users.

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**References**


