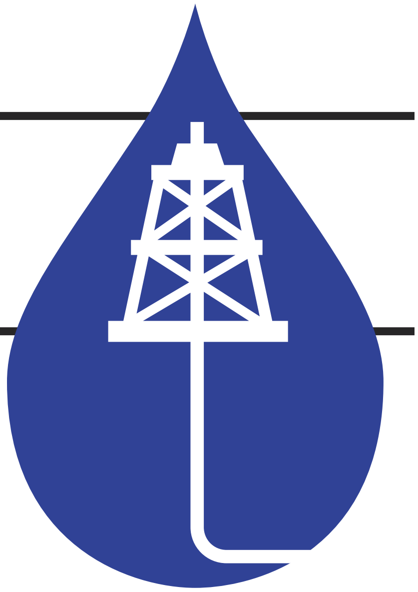
Ceres

HYDRAULIC FRACTURING & WATER STRESS:

Water Demand by the Numbers

Shareholder, Lender & Operator Guide to Water Sourcing



February 2014

A Ceres Report
Authored by
Monika Freyman

To access the interactive maps associated with this report, visit www.ceres.org/shalemaps

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Graphic design by Patricia Robinson Design.

FOR MORE INFORMATION, CONTACT:

Monika Freyman, CFA
Senior Manager, Water Program
Ceres
99 Chauncy Street
Boston, MA 02111
freyman@ceres.org

www.ceres.org

EXPERT REVIEWERS

This report benefited greatly from numerous suggestions and feedback from outside reviewers, including:

- **Laura Belanger**, Western Resource Advocates
- **James D. Bradbury**, James D. Bradbury PLLC
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- **Francis Gassert**, World Resources Institute
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- **Duncan Kenyon**, Pembina Institute
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- **Courtney Lowrance**, Citi
- **Jean-Philippe Nicot**, The Jackson School of Geosciences at the University of Texas
- **Paul Reig**, World Resources Institute
- **Jason Switzer**, Pembina Institute

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Executive Summary

This Ceres research paper analyzes escalating water demand in hydraulic fracturing operations across the United States and western Canada. It evaluates oil and gas company water use in eight regions with intense shale energy development and the most pronounced water stress challenges. The report also provides recommendations to investors, lenders and shale energy companies for mitigating their exposure to water sourcing risks, including improvement of on-the-ground practices. The research is based on well data available at FracFocus.org and water stress indicator maps developed by the World Resources Institute, where water stress denotes the level of competition for water in a given region.[1]

The U.S. portion of the analysis is based on hydraulic fracturing water-use data from 39,294 oil and shale gas wells hydraulically fractured between January 2011 through May 2013, as reported to the website FracFocus.org.[2] The research shows that 97 billion gallons of water were used, nearly half of it in Texas, followed by Pennsylvania, Oklahoma, Arkansas, Colorado and North Dakota. Among more than 250 operating companies reporting to FracFocus in the United States, Chesapeake (ticker: CHK) had the largest amount of water use reported, using nearly 12 billion gallons, followed by EOG Resources (EOG), XTO Energy (owned by Exxon, XOM) and Anadarko Petroleum (APC). Halliburton (HAL), a service provider to many shale energy operators, handled the largest volume of hydraulic fracturing water overall, nearly 25 billion gallons, over a quarter of the water used for hydraulic fracturing nationally, followed by Schlumberger (SLB) and Baker Hughes (BHI).

Nearly half of the wells hydraulically fractured since 2011 were in regions with high or extremely high water stress, and over 55 percent were in areas experiencing drought.

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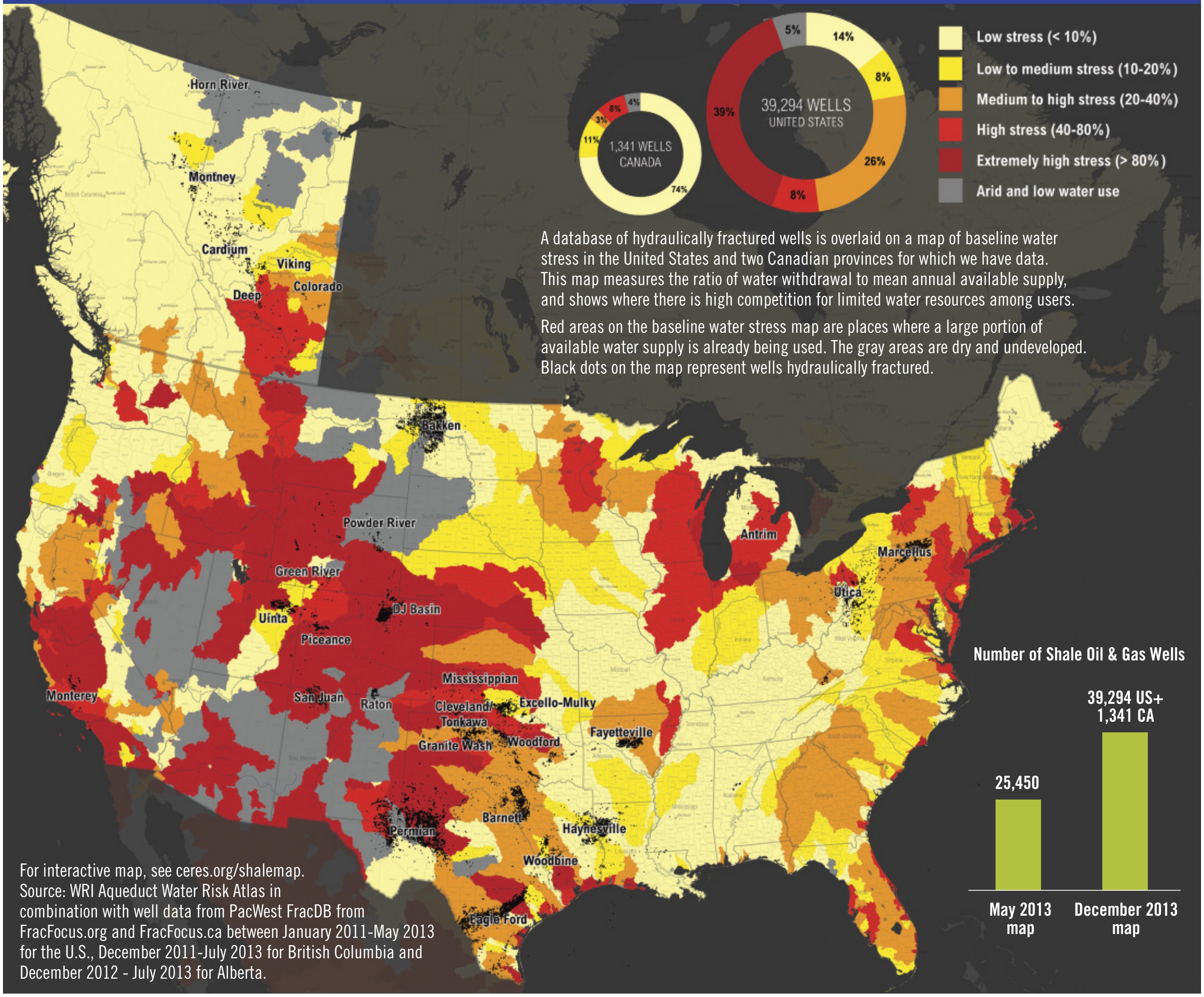
[1] FracFocus well data was obtained via PacWest Consulting Partners' FracDB database and all water stress data and maps were from World Resource Institutes' *Aqueduct Water Risk Atlas*, available at http://pacwestcp.com/research/fracdb/ and http://www.wri.org/our-work/project/aqueduct, respectively.

[2] Eleven states direct or allow operators to report to FracFocus including Texas, Colorado, Pennsylvania, North Dakota, South Dakota, Mississippi, Louisiana, Oklahoma, Ohio, Utah, Montana and two Canadian provinces, Alberta and British Columbia. Reporting to FracFocus is still voluntary in other jurisdictions. The fact that reporting to the site remains voluntary in some jurisdiction means our database may lead to under-reporting of water use. Source: Konschnik, Kate, Margaret Holden and Alexa Shasteen,"Legal Fractures in Chemical Disclosure Laws," Harvard Law School Environmental Law Program, April 23, 2013.

FIGURE ES1: NORTH AMERICAN WATER STRESS & SHALE ENERGY DEVELOPMENT



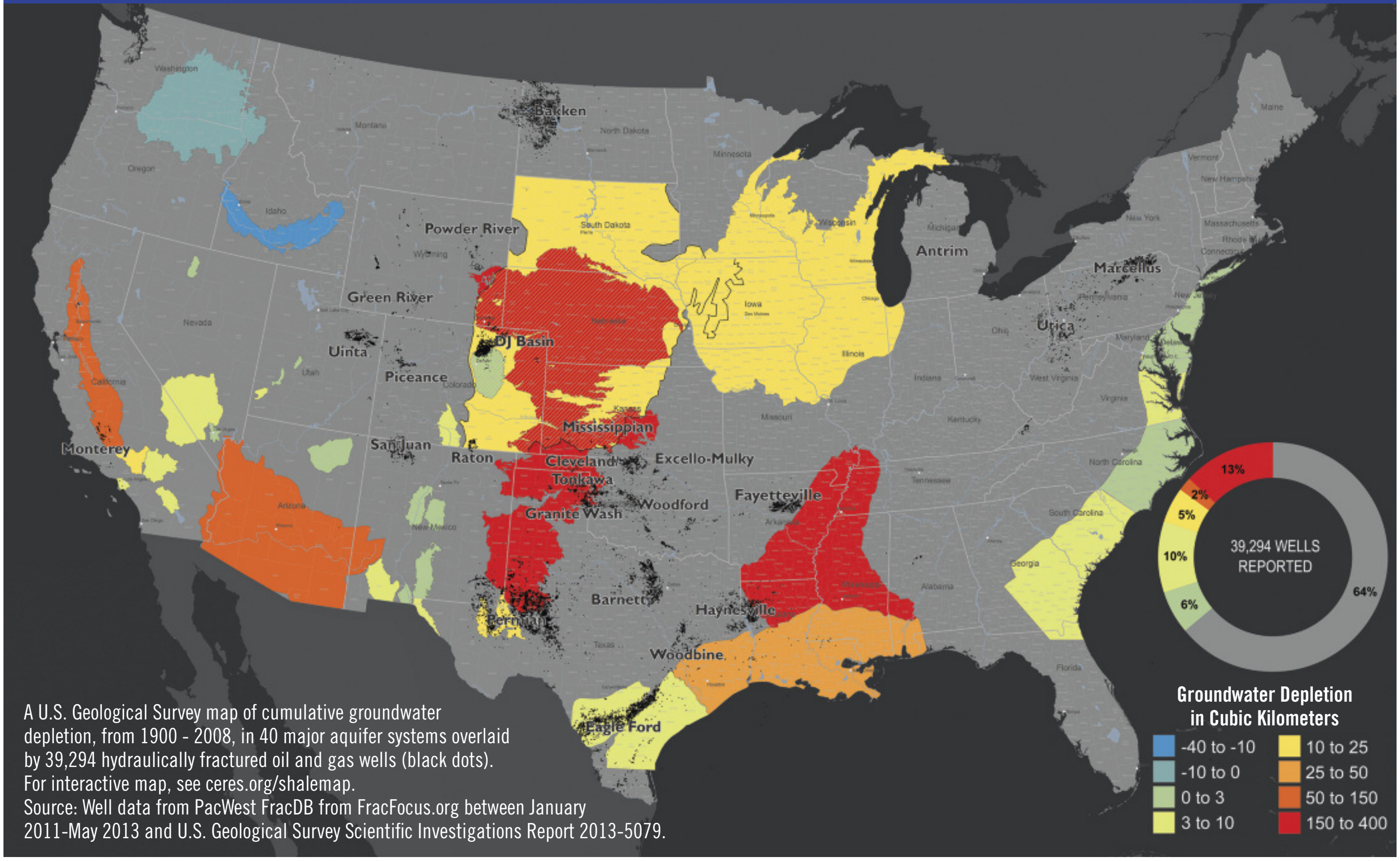
A database of hydraulically fractured wells is overlaid on a map of baseline water stress in the United States and two Canadian provinces for which we have data. This map measures the ratio of water withdrawal to mean annual available supply, and shows where there is high competition for limited water resources among users.

Red areas on the baseline water stress map are places where a large portion of available water supply is already being used. The gray areas are dry and undeveloped. Black dots on the map represent wells hydraulically fractured.

For interactive map, see ceres.org/shalemap.
Source: WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org and FracFocus.ca between January 2011-May 2013 for the U.S., December 2011-July 2013 for British Columbia and December 2012 - July 2013 for Alberta.

Nearly half of the wells hydraulically fractured since 2011 were in regions with high or extremely high water stress (**Figure ES1**), and over 55 percent were in areas experiencing drought. In Colorado and California, 97 and 96 percent of the wells, respectively, were in regions with high or extremely high water stress. In New Mexico, Utah and Wyoming, the majority of wells were in high or extremely high water stress regions. In Texas, which currently has the highest concentration of hydraulic fracturing activity in the U.S., more than half of the wells examined (52 percent) were in high or extremely high water stress regions. Extremely high water stress, using WRI's definition, means over 80 percent of available surface and groundwater is already allocated for municipal, industrial and agricultural uses.

FIGURE ES2: GROUNDWATER DEPLETION & SHALE ENERGY DEVELOPMENT



A U.S. Geological Survey map of cumulative groundwater depletion, from 1900 - 2008, in 40 major aquifer systems overlaid by 39,294 hydraulically fractured oil and gas wells (black dots).
For interactive map, see ceres.org/shalemap.
Source: Well data from PacWest FracDB from FracFocus.org between January 2011-May 2013 and U.S. Geological Survey Scientific Investigations Report 2013-5079.

Shale development in many regions is highly reliant on groundwater resources, which are generally less regulated than surface waters, thus increasing risks of water resource depletion and water competition. Over 36 percent of the 39,294 hydraulically fractured wells in our study overlay regions experiencing groundwater depletion (**Figure ES2**).

Over 36 percent of hydraulically fractured wells were found to overlay regions experiencing groundwater depletion

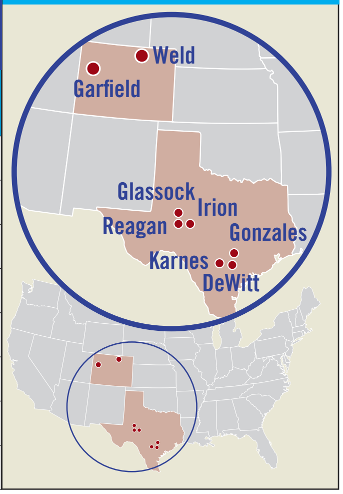
Company exposure to shale water risks is best understood at the county or municipal levels (**Figure ES3**). In many instances, well development was concentrated in just a few counties for each play, with water use for hydraulic fracturing in these regions often exceeding annual water use by local residents. In California, North Dakota's Bakken play and Colorado's Denver-Julesburg basin, most of the hydraulic fracturing wells were concentrated in three or fewer counties. Over 30 different counties used at least one billion gallons of water (roughly equivalent to daily water use of eight million people in New York City) for hydraulic fracturing operations during the report's study period. Dimmit County, Texas in the Eagle Ford play had the largest volume of water use for hydraulic fracturing nationally—about four billion gallons. Garfield and Weld counties in Colorado and Karnes County in Texas were the highest water use counties in regions with extreme water stress—each using over two billion gallons of water for hydraulic fracturing over the multi-year period.

This trend highlights the oftentimes intense and localized nature of shale development, which creates challenges for smaller counties that often lack resources to manage water availability constraints.

FIGURE ES3: COUNTIES WITH HIGHEST WATER STRESS & HIGH WATER USE FOR HYDRAULIC FRACTURING

High Water Use & Stress County	Top Two Oil & Gas Companies By Water Use	Annual Water Use for Hydraulic Fracturing in Billion Gallons*
Garfield (CO)	Encana, WPX	1.9
Karnes (TX)	EOG, Plains	1.7
Weld (CO)	Anadarko, Noble	1.3
Gonzales (TX)	EOG, Penn Virginia	0.9
Glassock (TX)	Apache, Laredo	0.9
Irion (TX)	EOG, Apache	0.8
Reagan (TX)	Pioneer, Laredo Petroleum	0.8
DeWitt (TX)	BHP Billiton, ConocoPhillips	0.6

U.S. Extreme Water Stress Regions



* Hydraulic fracturing annual water use for 2012.
Water may have been sourced from outside county and from non-freshwater sources.

The table explores water use in context for counties in extreme water stress regions with high water use for hydraulic fracturing. Water use for hydraulic fracturing can be relatively high at the local level in comparison to domestic water use.

Source: Water volume data from PacWest FracDB from FracFocus.org for 2012 and compared to U.S. Geological Survey, domestic water use data from last survey year, 2005

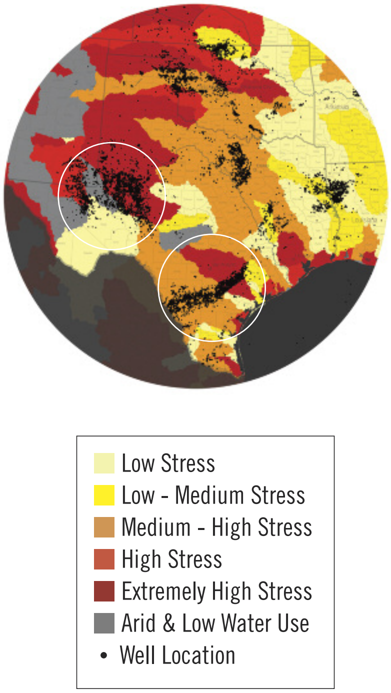
Over 30 different counties used at least one billion gallons of water (roughly equivalent to daily water use of eight million people in New York City) for hydraulic fracturing operations during the report's study period.

Regional Findings

The report includes separate case studies in eight regions (six in the United States, two in western Canada). Among the key regional findings:

Texas:

Texas is ground zero for water sourcing risks due to intense shale energy production in recent years and a projected doubling of hydraulic fracturing-related water use over the next decade. All of this comes as over two-thirds of Texas continues to experience drought conditions, key groundwater aquifers are under stress and the state's population is growing.[3] Water competition challenges are already arising with several shale-producing counties operating under water emergencies, leaving shale producers scrambling to develop alternatives to freshwater sources. Tackling these challenges is made more difficult by the industry's overall poor disclosure on water use, especially groundwater use which has especially weak disclosure and permitting requirements.



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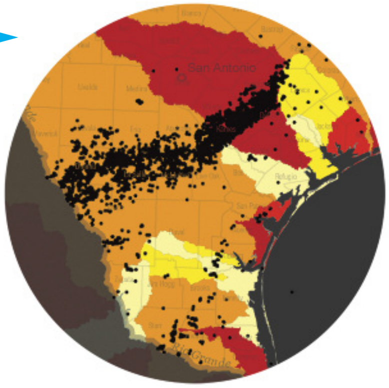
[3] Seventy-two percent of Texas was experiencing abnormally dry to exceptional drought conditions as of December 31, 2013, http://droughtmonitor.unl.edu/Home/StateDroughtMonitor.aspx?TX.

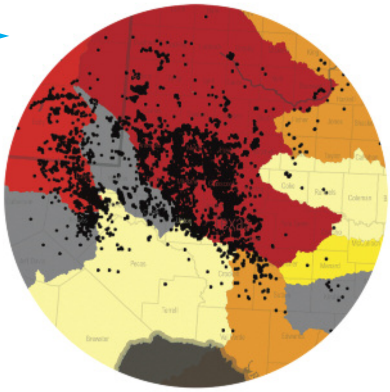
Eagle Ford Play:

The Eagle Ford in south Texas faces some of the biggest water challenges of any shale play. The play's total water use for hydraulic fracturing was the highest in the country, 19.2 billion gallons, and water use per well was also high, averaging over 4.4 million gallons. The region is meeting an estimated 90 percent of water demand from groundwater while concurrently experiencing groundwater depletion challenges. In Dimmit, Zavala, and La Salle counties, local aquifer levels have declined 100-300 feet over the past several decades. These counties are now facing new and growing water demands from rapid and intense shale energy development, which will create additional groundwater pressures. Capital expenditures for shale energy development in the Eagle Ford is expected to reach $30 billion in 2014 alone and development is expected to continue at a rapid pace, potentially doubling production over the next five years.[4] Operators with combined large financial and water risk exposures include Anadarko, EOG Resources, SM Energy (SM), Marathon Oil (MRO), Chesapeake and Murphy Oil (MUR).



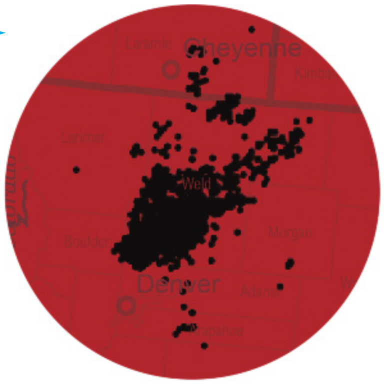
Permian Basin:

The Permian Basin in west Texas is another area with water demand pressures, drought concerns and high groundwater use and concurrent groundwater stress. More than 70 percent of the Permian's wells are in extreme water stress areas—the basin overlaps parts of the depleted Ogallala Aquifer—and hydraulic fracturing water use is forecast to double by 2020. Although average water use per well is much lower than in the Eagle Ford, the sheer number of wells in development is large, with over 9,300 wells reported developed since the beginning of 2011. Capital expenditures in the Permian are expected to reach $20 billion this year and production is expected to grow to 1.9 million barrels of oil per day by 2018, up from 1.3 million this year.[5] Of the many operators that have combined high financial and water stress exposure, Apache (APA), Pioneer (PXD), Devon (DVN), Occidental Petroleum (OXY), Cimarex (XEC), Concho Resources (CXO), Energen (EGN) and Laredo Petroleum (LPI) have the highest.



Denver-Julesburg (DJ) Basin and Across the Rockies:

The DJ Basin in the Niobrara formation in Colorado is another region with intense shale activity, much of it centered in Weld County, with nearly 2,900 wells developed since 2011. It, too, is an area facing extreme water stress. Eighty-nine percent of the water used for hydraulic fracturing in Colorado was concentrated in two counties: Weld and Garfield. Overall water demand for hydraulic fracturing in the state is forecast to double, to six billion gallons by 2015, more than twice what the city of Boulder uses in an entire year. With several municipalities voting recently to ban or place moratoriums on new oil and gas development, this region is emblematic of the pressing need for greater stakeholder engagement by the industry on water sourcing issues and beyond. Anadarko, with over 1,200 wells developed in the basin since 2011, has a major presence in the region.



🟨 Low Stress
🟨 Low - Medium Stress
🟧 Medium - High Stress
🟥 High Stress
🟫 Extremely High Stress
⬛ Arid & Low Water Use
• Well Location

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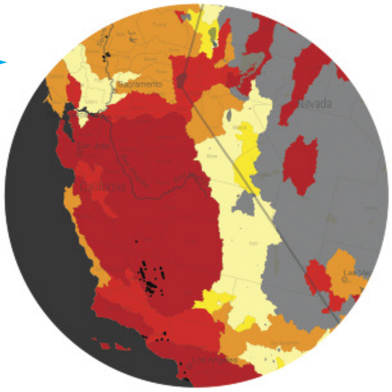
[4] Jennifer Hiller, "Spending in Eagle Ford forecast at $30B this year," *San Antonio Express-News*, January 7, 2014, http://www.expressnews.com/business/eagle-ford-energy/article/Spending-in-Eagle-Ford-forecast-at-30B-this-year-5119298.php.

[5] Tom Fowler, "Second Life for an Old Oil Field," *The Wall Street Journal*, November 19, 2013.

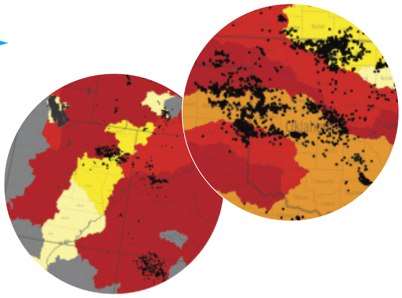
California:

Nearly all hydraulic-fracturing water use in California is in regions of extremely high water stress, although water use per well remains relatively low. Most of the activity to date in California has been in Kern County, which has large agricultural water demand and a growing population. Occidental Petroleum, Aera (owned by Shell and Exxon) and XTO Energy are the operators with the largest water use in the region for hydraulic fracturing. Among service providers, Baker Hughes has the largest water use.



Other Regional Plays:

Many of the smaller shale plays (100 to 2,000 wells) are also in high and extremely high water stress regions, including the Piceance, Uinta, Green River, San Juan, Cleveland/Tonkawa and Anadarko Woodford basins.[6]



🟨 Low Stress
🟨 Low - Medium Stress
🟧 Medium - High Stress
🟥 High Stress
🟫 Extremely High Stress
◼ Arid & Low Water Use
• Well Location

Company Findings:

The report also identifies those companies facing the biggest water sourcing risks both regionally and nationally.

- **Anadarko Petroleum:** Anadarko stands out as having high water risk exposure among leading shale energy producers, with more than 70 percent of its wells located in high or extremely high water stress regions (especially the Eagle Ford and Colorado's DJ Basin). Over the timeframe of our study, the company used more than six billion gallons of water in its hydraulic fracturing operations (**Figure ES4**).
- **Apache, Encana and Pioneer:** Most of the wells developed by each of these companies are in regions of high or extreme water stress.
- **Chesapeake Energy:** This company was by the far the biggest user of water, with most of its wells located in regions of medium water stress, including the Eagle Ford, Barnett and Marcellus region.
- **All of the top 10 operators** by water use, except Southwestern, had the majority of their wells in medium or higher water stress regions. Over 250 operators reported water use data to FracFocus, with the top 10 accounting for about half of the total water used nationally.
- **The top 3 service providers:** Halliburton, Schlumberger and Baker Hughes—accounted for about half of the water used for hydraulic fracturing nationally (**Figure ES5**).

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[6] For map of play or basin locations see Appendix A.

FIGURE ES4: TOP TEN OPERATORS BY NUMBER OF WELLS & EXPOSURE TO WATER STRESS

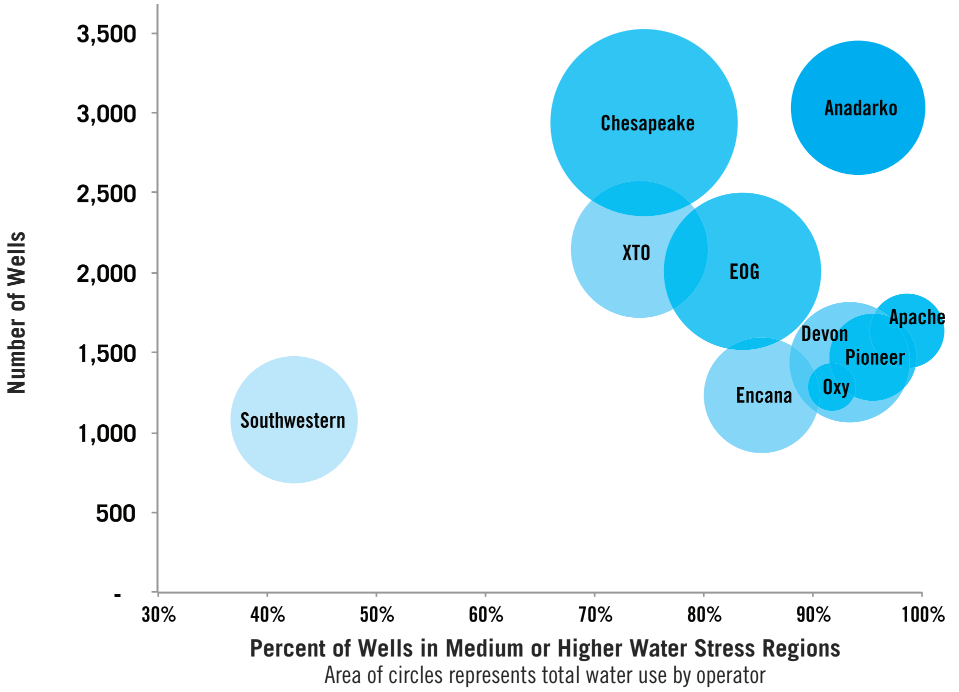

FIGURE ES5: TOP TEN SERVICE PROVIDERS BY WATER USE & WATER STRESS CATEGORY

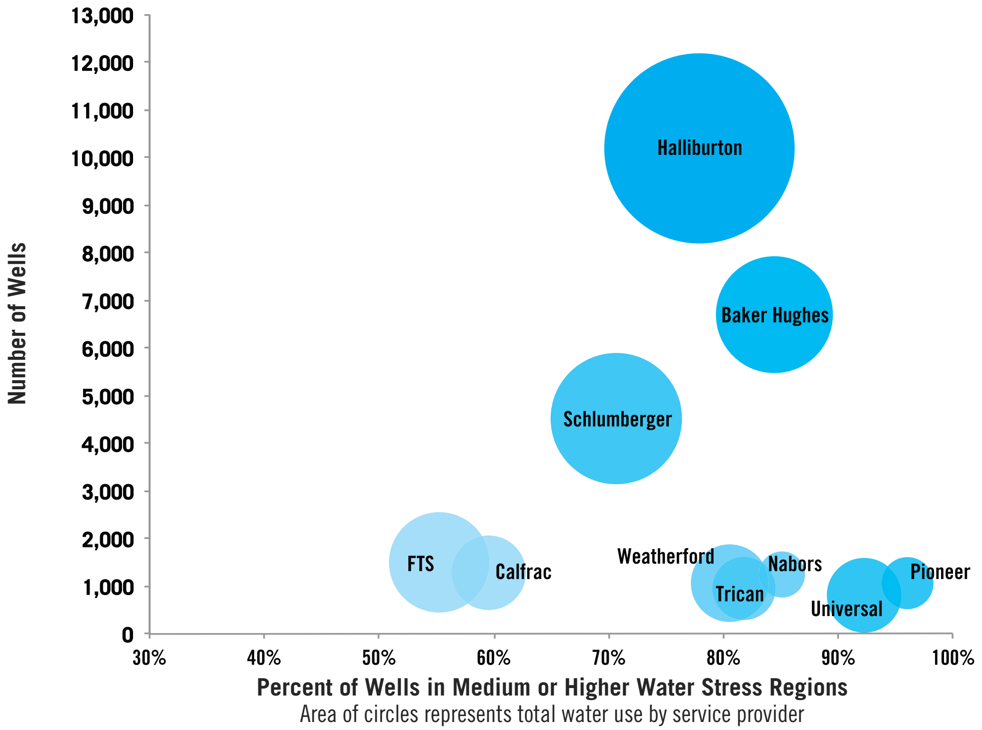

Figure ES4: Top 10 operators by number of wells and exposure to water stress. Sources and type of water not reported.

Figure ES4: Top 10 service providers by number of wells and water stress exposure. Sources and type of water not reported. Approximately 15 percent of the wells did not have sufficient information to identify the service provider since service providers are not required to report to FracFocus.

Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011 - May 2013.

Implications & Recommendations

Future water demand for hydraulic fracturing will only grow with tens of thousands of additional wells slated to be drilled, and many shale basins and plays are just beginning to be developed. In addition, the shale development business model requires continual drilling cycles to maintain production growth.

All across the country, regulators, producers and service providers are scrambling to find technological and regulatory solutions to mitigate localized water sourcing risks from rapid shale energy development. Some pockets of success can be found. Apache, for example, is recycling 100 percent of produced water in the Permian Basin. Anadarko and Shell are buying effluent water from local municipalities. Chesapeake is reusing nearly 100 percent of its produced water and drilling wastewater in the Marcellus region.

Viewed more widely, however, water management best practices are lagging and no single technology alone—whether recycling, brackish water use or greater use of waterless hydraulic fracturing technology—will solve regional water sourcing and water stress problems. Ultimately, all shale operators and service providers should be deploying a variety of tools and strategies—including substantially improved operational practices related to water sourcing, more robust stakeholder engagement, and stronger disclosure—to protect freshwater resources for the future. Investors and lenders, in particular, require fuller disclosure on water use trends and requirements to better balance risk-adjusted returns on their dollars invested. Among the report's key water-sourcing recommendations to operators:

All shale operators and service providers should be deploying a variety of tools and strategies—including substantially improved operational practices related to water sourcing, more robust stakeholder engagement, and stronger disclosure—to protect freshwater resources for the future.

Disclosure & Transparency:

- Disclose total water volumes used in each shale play or basin, from where water is being sourced, including projected future water needs, the security of sourcing options and plans/targets for reducing water use.
- Disclose the percentage of water use in each region from non-freshwater sources, including a breakdown of present use and future use from recycling, brackish supplies and other non-potable water use. Include information on how much water returns to the surface after hydraulic fracturing takes place (flowback water) and during oil or gas production (produced water).
- Disclose the percentage of revenues, operations and future growth estimates coming from regions with high water stress or areas with drought and groundwater challenges.

Operational Practices:

- Minimize water use through improvements in water efficiency, commitments to recycling or reusing water where viable, and sourcing from non-freshwater sources.
- Collaborate and cooperate with industry peers and other industries on local water sourcing challenges and developing local water sourcing and recycling infrastructure.
- Develop local source water protection plans that include addressing regional water risks, engaging with key stakeholders and supporting projects that improve watersheds and aquifers.
- Minimize the use of aquifer exemptions and deep well injection disposal sites.

Stakeholder Engagement:

- Engage with local communities on water needs and challenges both before starting operations and after they begin.
- Establish and support programs to educate and engage employees and suppliers to take ownership of water issues, including incentives for reducing water use.
- Engage proactively with local and regional regulators on water challenges, including transparency about water management plans and future water needs.

Finally, it is critical that shale energy companies embed water risk and opportunity analysis across all business units, from the boardroom to the drill site.

Introduction

Regions of the United States and Canada are in the midst of an extraordinary energy boom due to two technological advances often used together: hydraulic fracturing and horizontal drilling. Hydraulic fracturing allows oil and gas producers to liberate once inaccessible oil and gas reserves trapped in shale formations. It is estimated that U.S. oil and gas reserves have grown by 35 percent and 38 percent, respectively, due to the inclusion of shale resources.[1]

The hydraulic fracturing process uses a combination of chemicals, sand and often large volumes of water under high pressure. The water is drawn from surface resources (lakes, rivers, reservoirs) and often from groundwater resources (fresh and brackish/saline). This process fractures underground formations via hydraulic pressure and props open these fractures with sand to allow the trapped oil or gas to flow to the surface.[2] Hydraulic fracturing is now being utilized to stimulate both conventional oil and gas reservoirs and unconventional reservoirs such as shale and tight oil and gas formations, which historically have been too technically challenging and expensive to exploit. This report focuses primarily on water-related issues associated with hydraulic fracturing and unconventional shale or tight oil or gas formations, hereafter collectively referred to as "shale energy."

Oil Field Definitions

Conventional Oil or Gas Deposits: Reservoirs of natural gas or oil, which have migrated to areas where the fluids/gases are pooled and sealed in place and from which they can readily flow into wellbores.

Unconventional Oil or Gas Deposits: Natural gas or oil which is still associated with the "parent-rock" from which it was formed, often of low permeability and unable to flow to the wellbore on its own. Tight and shale deposits are examples of unconventional oil or gas deposits. Coalbed methane production, also known as coal seam gas, can also be included as an unconventional energy resource.

Tight Oil or Gas Deposits: Areas where natural gas or oil gathers in pore spaces of rocks (mostly sandstone) and where gas or oil cannot flow freely to the wellbore.

Shale Gas or Oil Deposits: Locations where natural gas or oil is attracted to and trapped onto the surfaces of rock particles. More technically challenging procedures, with higher volumes of fluids are required to start the oil or gas flow to the wellbore than production for tight deposits.[3] Some view shale deposits as a subset of tight oil deposits.

Play: A set of known or prospective oil and or gas accumulations sharing similar geologic and geographic properties such as source rock, migration pathways, trapping mechanisms, and hydrocarbon type.[4] Often "play" refers to regions that are commercially viable, whereas basins refer more closely to geologic characteristics.

Basin: A geological area defined by similar sedimentary characteristics. A basin can include multiple plays.

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[1] U.S. Energy Information Administration, "Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States," June 10, 2013, http://www.eia.gov/analysis/studies/worldshalegas.

[2] For an animated video illustrating the process, see: http://ngm.nationalgeographic.com/2013/03/bakken-shale-oil/hydraulic fracturing-animation-video.

[3] Modified from Schlumberger Oilfield Glossary and Wintershall websites, http://www.glossary.oilfield.slb.com and http://www.wintershall.com/en.html.

[4] Modified from USGS National Oil and Gas Assessment Online (NOGA Online) using Arc IMS, http://proceedings.esri.com/library/userconf/proc02/pap0826/p0826.htm.

Water Definitions

Water Withdrawals: Volume of freshwater that is taken from surface or groundwater resources.

Water Consumption: Volume of freshwater that is taken from surface or groundwater resources and is not returned. There are concerns that hydraulic fracturing consumes a large amount of water. The water used in operations and pumped underground may remain in the well or be disposed elsewhere deep underground, making it unavailable for reuse. Water consumption metrics in most regions are poorly measured due to the lack of consistent water sourcing disclosure and measurement statistics of water returning to the surface.

Water Stress: Measures total annual water withdrawals (municipal, industrial and agricultural) expressed as a percentage of water available.[5] This metric denotes the level of competition for water in a given region and is the focus of this study. The highest demand for water in most regions comes from agricultural or municipal uses followed by industrial uses. Water stress tends to be higher in regions of high population density or intense agricultural development. Water stress can be low even in arid regions such as North Dakota, where low population density and non water-intensive agricultural practices do not result in high water demand.

Water Scarcity: Is the volumetric abundance, or lack thereof, of freshwater supply and increasingly accounts for water flow required to maintain the ecological health of rivers and streams.

Water Risk: Refers to the ways in which water-related issues potentially undermine business viability.

Brackish Water: Water that is generally saltier than freshwater, but not as salty as seawater.[6]

Oil and Gas Water Definitions

Flowback Water: Water returning to the surface directly after hydraulic fracturing. This water is often mixed with water found in the geological formation. The amount and quality (often poor) of flowback water returning to the surface varies depending on local geologic conditions and hydraulic fracturing fluids utilized.

Produced Water: Water that returns to the surface along with the oil or gas that is being pumped from the well.

Recycled Water: Water utilized a second time in hydraulic fracturing operations after undergoing treatment for contaminants.

Reused Water: Water utilized a second time in hydraulic fracturing operations with minimal treatment requirements.

Maintenance Water: Water required to continue production over the life of a well. Some wells may require "flushing" with freshwater to prevent salt accumulation in pipelines.

Water Used for Enhanced Oil Recovery (EOR): When water is pumped underground to increase pressure in a well to boost lagging oil production (generally after a reservoir has been depleted). EOR can require far larger volumes of water than the average well requirements for hydraulic fracturing operations.

Drilling Water: Water that is used, often in conjunction with other chemicals, to cool and lubricate the drill bit and carry out drill cuttings during the drilling of the borehole.

Water is an integral part of every step in shale energy extraction, and water requirements per well have grown significantly, often reaching five to six million gallons per production well. Just as importantly, hydraulic fracturing and horizontal drilling have led to the industrialization of many rural areas, with some U.S. counties supporting hundreds and even thousands of wells. Tens of thousands of wells have been drilled in the U.S. and Canada to date and thousands more are being developed every year. This high density drilling and development requires a large array of supporting infrastructure, including new roads, well pads, water reserve pits and tanks, disposal wells, pipelines and compressor stations (**Figure 2**).

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[5] See white paper by Francis Gassert, Matt Landis, Matt Luck, Paul Reig and Tien Shiao, "Aqueduct Metadata Document, Aqueduct Global Maps 2.0," January 2013.

[6] Salt concentrations for brackish water are estimated to be over 1,000 ppm. In comparison seawater contains over 35,000 ppm salt content. U.S. Geological Survey, "National Brackish Groundwater Assessment," http://ne.water.usgs.gov/ogw/brackishgw/brackish.html. See also, "Brackish Groundwater Brief," National Groundwater Association, July 21, 2010.

Water Sourcing Risks in Shale Energy Development

Any discussion of the industry's exposure to water-related risks (as well as other environmental and social risks) must be framed in the broader context of shale energy development, which looks beyond the well pad and the narrow activity of hydraulic fracturing. While most environmental concerns around hydraulic fracturing have focused on the migration of hydraulic fracturing chemicals and methane into groundwater, this is just one of many risks that hydraulic fracturing potentially poses to surface and groundwater resources. Resources for the Future recently conducted a survey of 215 academic, industry, NGO and regulatory experts in shale energy development, and found broad consensus on 12 risk pathways, with seven focused on potential water impacts. Concerns over both surface and groundwater withdrawals were among those risks.[7]

This report focuses only on material risks facing the industry related to water sourcing and the potential impacts on surface and groundwater resources (Stage 1 in the water lifecycle of hydraulic fracturing operations shown in **Figure 1**). Other water risk pathways such as spills, accidents and wastewater management, although important, are beyond the scope of this report.

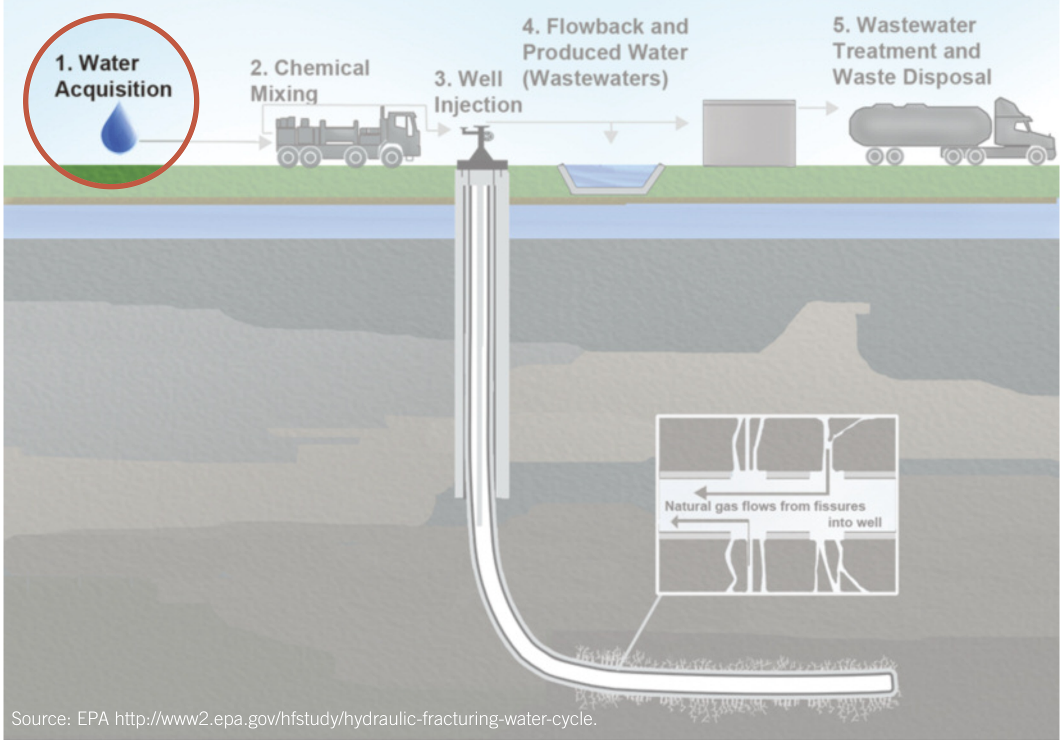
Water sourcing risks fall into three broad categories: physical, regulatory and reputational. Physical water risks—the lack or overabundance (i.e. flooding)[8] of water in a particular place and resulting impacts on water access and quality—are usually the most obvious water sourcing challenges

Water is a Challenge in Most Regions

From: ***"Alberta Desperately Needs a Water-Management Plan, Alberta Oil," July 2013***

"Water is the biggest challenge we have right now in any shale play," Mike Wood, Vice President, Talisman Energy, Canada Shale Division.[9]

FIGURE 1: HYDRAULIC FRACTURING WATER USE CYCLE



Source: EPA http://www2.epa.gov/hfstudy/hydraulic-fracturing-water-cycle.

Simple schematic of five stages of the hydraulic fracturing water lifecycle.
This study focuses on stage number one.

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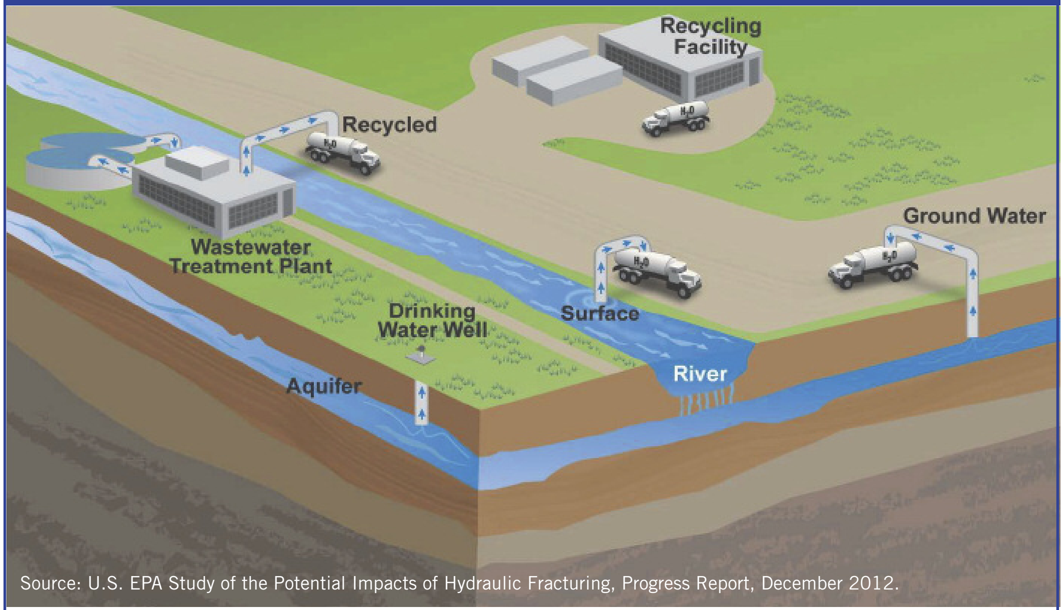
[7] Krupnick, Gordon and Olmstead, "Pathways to Dialogue: What the Experts Say about the Environmental Risks of Shale Gas Development," Resources for the Future, February 2013.

[8] Communities faced contamination concerns in Colorado recently as regions with high density of shale development operations were hit by flooding that overturned tanks and flooded wastewater storage ponds. See Trowbridge, Alexander, "Colorado Floods Spur Fracking Concerns," CBS News, http://www.cbsnews.com/news/colorado-floods-spur-hydraulicfracturing-concerns.

[9] Patrycja Romanowska, "Alberta Desperately Needs a Water-Management Plan," *Alberta Oil*, July 29, 2013, http://www.albertaoilmagazine.com/2013/07/alberta-and-the-life-aquatic/.

companies will face. In the case of shortages, alternative water acquisition strategies such as importing or recycling/reusing water require significant increases in operating and capital expenses. Water-related risks can also include how water resources are regulated and allocated (regulatory risks), as well as how key stakeholders—communities, customers and other groups—view a company's impact on the resource (reputational risks). Water use involves a potent mix of economic, social and environmental values. As pressure on supplies increase and underlying resources are degraded, regulators must make increasingly tough decisions on how local water supplies are to be allocated. Conversely, businesses operating in areas with little or poorly enforced regulation may face risks due to misuse and depletion of common water resources, which can negatively impact all parties. Ultimately community concerns about competition for water can be a significant driver of reputational risk and can jeopardize the industry's social license to operate at the municipal, state, provincial and/or national level.[11, 12, 13]

FIGURE 2: WATER SOURCES FOR HYDRAULIC FRACTURING OPERATIONS



Source: U.S. EPA Study of the Potential Impacts of Hydraulic Fracturing, Progress Report, December 2012.

Water Sources for Hydraulic Fracturing

Water for hydraulic fracturing can be sourced from surface water, groundwater (fresh and saline/brackish), wastewater streams or water recycling facilities (**Figure 2**). The nomadic and transient nature of the industry has created challenges for those trying to study water-sourcing impacts. Often there is inconsistent or no data available on where industry is sourcing water, when they are sourcing, how much is being sourced, what type of water is being sourced (e.g. fresh versus recycled) and how much is being consumed (eliminated from the hydrological water cycle). Timing and location of withdrawals is also poorly understood and documented, a problem made more acute given that water needs for hydraulic fracturing can spike over short time frames. These intense and rapid withdrawals can stress rivers ecosystems and competition for other end users, especially in regions prone to drought and low seasonal flows.

Water Competition with Urban Centers

From: ***"Parched Texans Impose Water-Use Limits for Fracking Gas Wells," Bloomberg News, October 2011***

Increasing drought concerns, growing competition between agriculture, municipal and industrial users have prompted some cities and districts to place restrictions on the use of water for hydraulic fracturing. The city of Grand Prairie, Texas in the Barnett Shale, in August [2011] became one of the first to ban the use of city water for hydraulic fracturing.[14]

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[11] Cathy Proctor, "Fracking Ban Approved in Broomfield After Vote Flip, But Recount is Planned," *Denver Business Journal*, November 15, 2013.

[12] The Canadian Press, "Newfoundland Shuts Door on Fracking Applications Prior to Review," *The Globe and Mail*, November 4, 2013.

[13] David Jolly, "France Upholds Ban on Hydraulic Fracturing," *The New York Times*, October 11, 2013.

[14] Mike Lee, "Parched Texans Impose Water-Use Limits for Fracking Gas Wells," *Bloomberg Businessweek*, October 6, 2011, http://www.businessweek.com/news/2011-10-06/parched-texans-impose-water-use-limits-for-fracking-gas-wells.html.

National Water Use Trends & Water Sourcing Risks

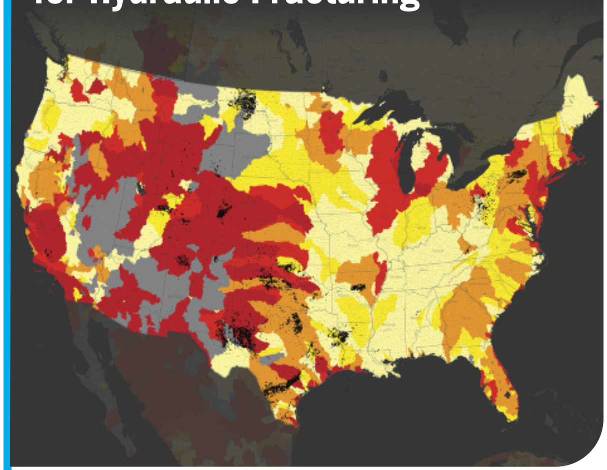
This report analyzes water use by hydraulic fracturing operations in the U.S. and western Canada and explores the extent to which this activity is taking place in areas of water stress, drought and groundwater depletion. Research of U.S. trends is based on oil and gas well data available at FracFocus.org, as well as data from the U.S. Geological Survey, the National Drought Mitigation Center and the World Resources Institute's (WRI) Aqueduct water risk atlas. Analysis of Canadian data is focused on wells in Alberta and British Columbia, as these are the only provinces currently reporting to FracFocus Canada, although hydraulic fracturing is taking place in other parts of the country. A high-level overview of Canadian trends is included in the regional section of this report. For a detailed discussion of methods, see **Appendix A**.

Institutions that invest in and lend to the shale energy sector can better manage their exposure to water sourcing risks and improve their risk-return analysis, due diligence and engagement with companies if they have a better understanding of three key water risks that impact shale development: (1) competition for water (water stress); (2) exposure to groundwater-stressed regions, and; (3) exposure to regions experiencing drought. All three elements can overlap. For example, regions experiencing drought often have higher groundwater pumping and depletion rates, which can lead to greater competitive pressures for water. Exposure to one or any combination of these three risks raises the overall risk profile of an operator or service provider.

Regions experiencing drought often have higher groundwater pumping and depletion rates, which can lead to greater competitive pressures for water.

United States

Water Use Trends for Hydraulic Fracturing



U.S. Data Summary (January 1, 2011 - May 31, 2013) as reported by FracFocus

WATER USE TRENDS

Number of Wells
Used to Calculate Water Volume Data: **39,294**

Total Water Use *(gallons)*: **97.5 billion**

Average Water Use *(gallons/well)*: **2.5 million**

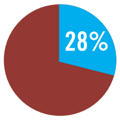
EXPOSURE TO WATER RISKS

Proportion of Wells in **High or Extreme Water Stress:** **48%**

Proportion of Wells in **Medium or Higher Water Stress:** **73%**

Proportion of Wells in **Drought Regions** (as of Jan. 7, 2014): **56%**

LOCAL WATER USE IMPACTS



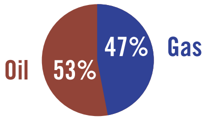
Water Use in Top 10 Counties
as Proportion of Water Use Nationally

Number of Counties with Hydraulic Fracturing Activity: **402**

Highest Water Use by a County *(gallons)*:
Dimmit County, Texas **4 billion**

OPERATING TRENDS

Type of Wells Reported:



Number of Operators Reporting to FracFocus (1st Quarter 2013)

253

OPERATORS
Top Three in U.S. by Water Use:

- Chesapeake
- EOG
- XTO

SERVICE PROVIDERS
Top Three in U.S. by Water Use:

- Halliburton
- Schlumberger
- Baker Hughes

National Water Use Trends

According to U.S. FracFocus data for 39,294 wells, just over 97 billion gallons of water were used between January 2011 and May 2013 for hydraulic fracturing operations, equivalent to the annual water needs of over 55 cities with populations of approximately 50,000 each.[15] It should be stressed that information on the proportion of water that was sourced from non-freshwater sources was unavailable both for the U.S. and Canada since operators do not report this data to FracFocus nor to most state or provincial databases.

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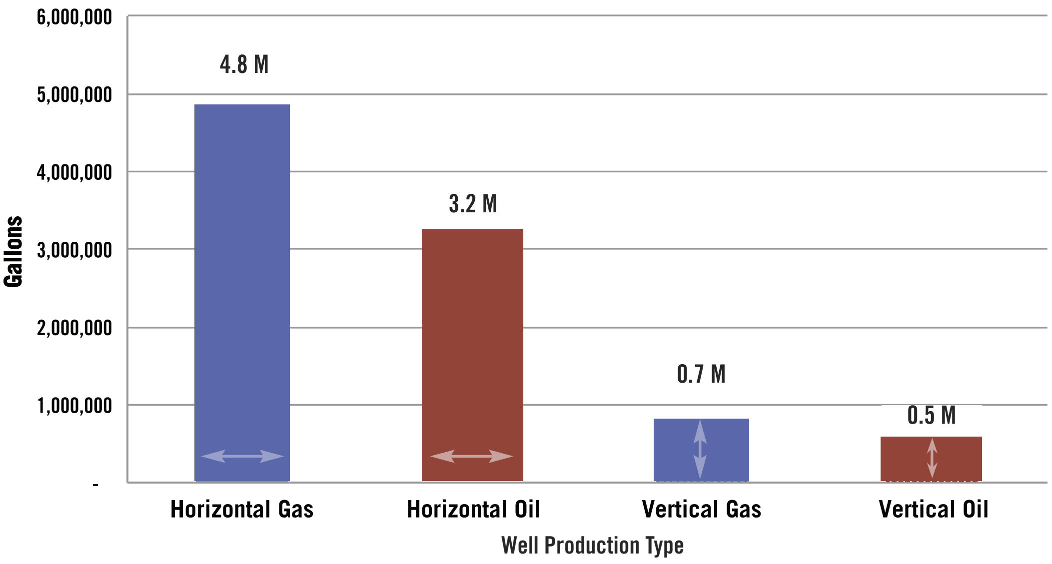
[15] Extrapolating from the EPA's estimates that "70 to 140 billion gallons required for hydraulic fracturing being equivalent to the total amount of water used each year in roughly 40-80 cities with a population of 50,000" in EPA's Draft Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources, February 2011.

Average Water Use Per Well:
Key Drivers and Trends by Play or Basin

The most important factors that drive water use per well are the type of production (oil or gas) and the direction of drilling (vertical or horizontal). Other factors include the characteristics of the local geology and the type of fluid system being deployed in hydraulic fracturing, such as water fracs, acid fracs and energized fracs.[16] Gas production is more water-intensive than oil, and horizontal drilling is far more water-intensive than vertical drilling (**Figure 3**).

FIGURE 3: AVERAGE WATER USE PER WELL BY TYPE OF PRODUCTION



Source: Ceres analysis using PacWest FracDB from FracFocus data from wells drilled January 2011-May 2013.

Average water use per well is higher in gas dominated plays like the Eagle Ford, than in the oil rich Bakken and Permian regions (**Figure 4**). Most hydraulic fracturing is now taking place in oil producing regions: 72 percent of wells hydraulically fractured in the first five months of 2013 were oil wells.

If average water use per well is rising in a region, this might indicate that horizontal (lateral) lengths of pipes are growing. Longer horizontal pipes may decrease the amount of wells that need to be developed, and possibly the environmental surface footprint, as the longer lateral lengths of pipe can reach a greater area of targeted oil or gas resources. However, data is lacking on water use as it is relates to length of horizontal pipes. Both sets of data may be reported to regulators, but little research, beyond Texas, has looked at the relationship between the two. Having data on water use per foot of lateral pipe would be the most productive way to compare water use between operators.

Based on available data, it appears that shale development is comparable to other energy sources such as biofuels and oil sands with respect to water use per unit of energy produced.[17] However, it may still be too early to fully measure shale energy's water requirements since it is unclear how often wells will be refracked or how much water is required for well maintenance.

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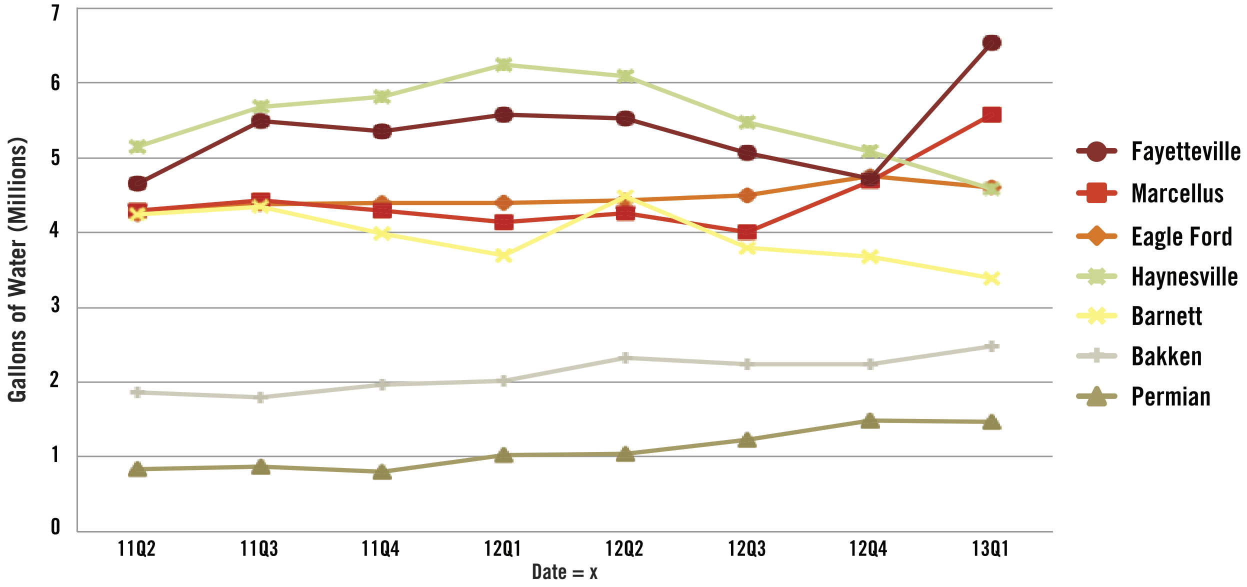
[16] For detailed analysis of water volume trends by hydraulic fracturing fluid system type see: Christopher Robart et al, "Analysis of U.S. Hydraulic Fracturing Fluid System Trends," *Society of Petroleum Engineers 163875*, February 2013.

[17] Yusuke Kuwayama, Olmstead, and Krupnick, Alan, "Water Resources and Unconventional Fossil Fuel Development: Linking Physical Impacts to Social Costs," Resources for the Future, DP 13-34. November 6, 2013, SSRN: http://ssrn.com/abstract=2352481 or http://dx.doi.org/10.2139/ssrn.2352481.

FIGURE 4: AVERAGE WATER USE BY MAJOR PLAY



Average water use for major plays/basins from the first quarter of 2011 to end of the first quarter of 2013. Average water use can increase due to technical or geologic factors, movement from vertical to horizontal drilling or increasing length of pipes used in horizontal drilling.

Source: Ceres analysis using PacWest FracDB from FracFocus.org.

Water Sourcing Risks:
Water Stress & Growing Competitive Pressures for Water

Hydraulic fracturing is largely taking place in regions already experiencing high competition for water. At the global level, a similar pattern is underway.

Nearly half of the 39,294 reported hydraulically fractured wells drilled in the U.S. since 2011 (just over 18,000 wells) are in regions with high or extreme water stress (**Figure 5**). Over 28,000 wells, or 73 percent, are located in regions of at least medium water stress. In extreme water stress regions, municipal, industrial or agricultural users are already using over 80 percent of the annual available flows (from both surface water and shallow groundwater). In high stress regions, 40 to 80 percent is already allocated.[18] In short, hydraulic fracturing is largely taking place in regions already experiencing high competition for water. At the global level, a similar pattern is underway.[19]

Shale development faces significant exposure to water stress in key oil and gas producing states (**Figure 6**). In Texas, nearly half the wells are in areas with high to extremely high water stress. In Colorado, 97 percent of wells are in regions with high or extremely high water stress. In California, New Mexico, Wyoming and Utah, most of the wells are in regions with high or extremely high water stress.

A similar pattern emerges when analyzing the data by shale play or basin (**Figures 7 and 8**). The top five U.S. shale energy regions—Eagle Ford, Marcellus, Permian, Barnett and Haynesville—account for over 70 percent of total national water used in hydraulic fracturing. The Permian, Eagle Ford and DJ basins have anywhere from one-third to nearly 100 percent of their wells in areas with high or extremely high water stress. By contrast, even though North Dakota's Bakken is a very arid, it is not densely populated, so water stress is not as high as in other shale plays.

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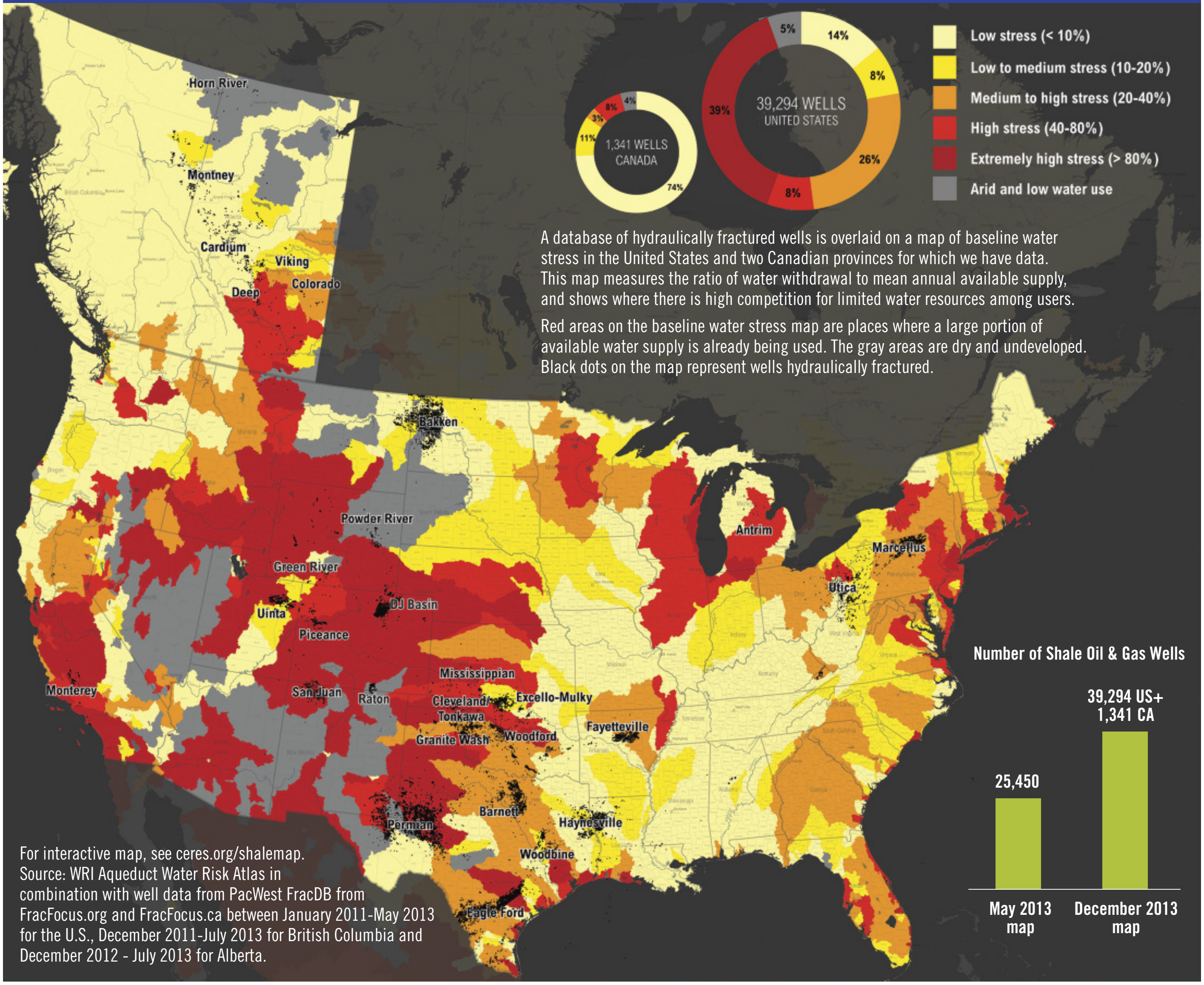
[18] For details on water stress calculation see white paper by Francis Gassert, Matt Landis, Matt Luck, Paul Reig and Tien Shiao, "Aqueduct Metadata Document, Aqueduct Global Maps 2.0," World Resources Institute, January 2013.

[19] Wood MacKenzie "Troubled Waters Ahead? Rising water risks on the global energy industry," *Global Horizons Service Insight*, October 2013.

FIGURE 5: NORTH AMERICAN WATER STRESS & SHALE ENERGY DEVELOPMENT



A database of hydraulically fractured wells is overlaid on a map of baseline water stress in the United States and two Canadian provinces for which we have data. This map measures the ratio of water withdrawal to mean annual available supply, and shows where there is high competition for limited water resources among users.

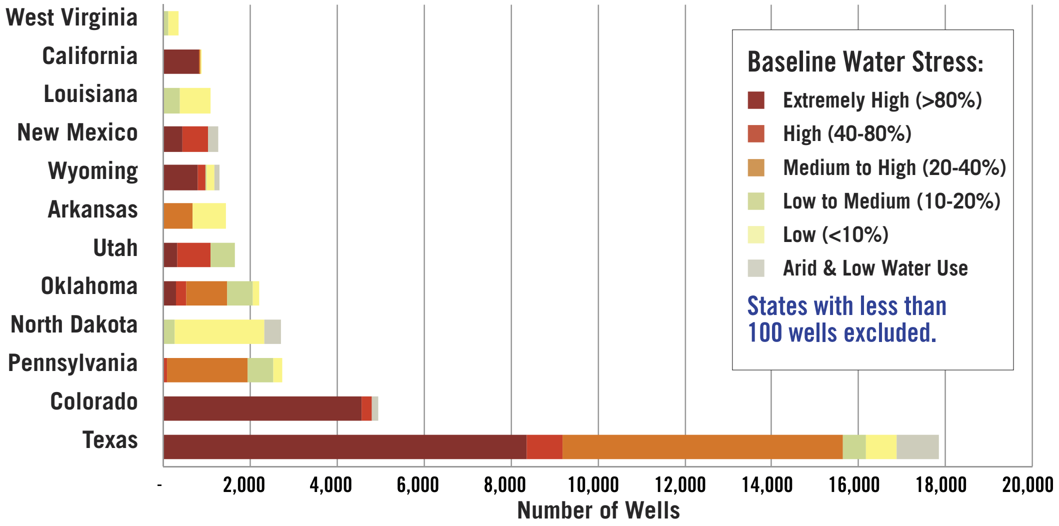
Red areas on the baseline water stress map are places where a large portion of available water supply is already being used. The gray areas are dry and undeveloped. Black dots on the map represent wells hydraulically fractured.

For interactive map, see ceres.org/shalemap.
Source: WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org and FracFocus.ca between January 2011-May 2013 for the U.S., December 2011-July 2013 for British Columbia and December 2012 - July 2013 for Alberta.

The Eagle Ford play in south Texas had the highest total water use, over 19 billion gallons in the report's study period, followed by the Marcellus, Permian, Barnett and Haynesville plays. The Eagle Ford is a region of particular concern due to highly concentrated drilling activity, water stress, drought, groundwater concerns and relatively high water use—about 4.4 million gallons per well (see the Eagle Ford and Permian **Regional Case Studies**).

The Permian Basin in west Texas and southeast New Mexico faces similar water sourcing challenges to the Eagle Ford with one key difference: average water use per well is relatively low at about 1.1 million gallons per well. Still, this region warrants concern due to the high level of current shale energy activity and expected growth. The DJ Basin, which lies primarily in Colorado with some overlap into Wyoming, Kansas and Nevada, also has high exposure to extreme water stress. Weld County, an area experiencing extreme water stress located within Colorado's DJ Basin, recently saw the development of nearly 2,900 new wells.

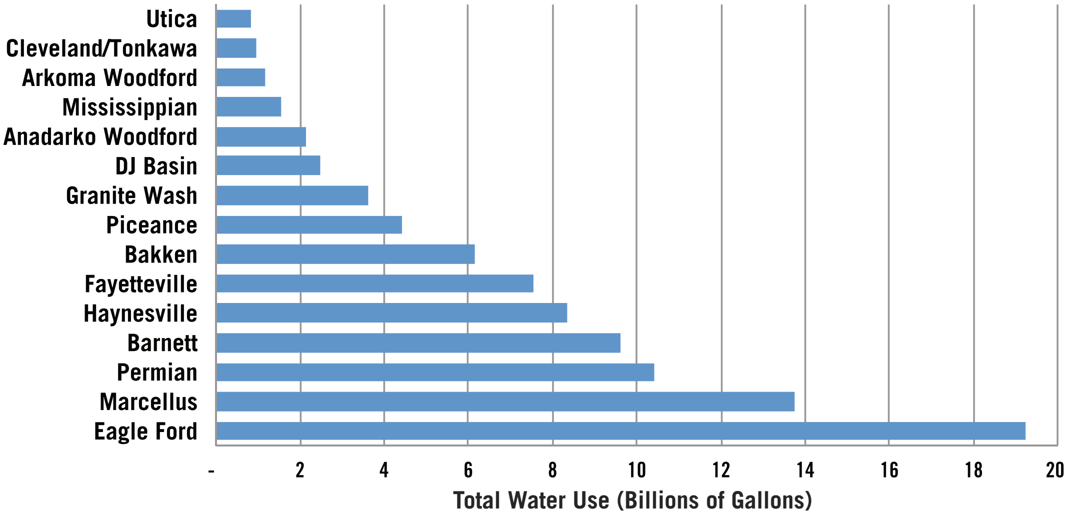
FIGURE 6: STATES WITH MOST REPORTED HYDRAULIC FRACTURING ACTIVITY BY WATER STRESS CATEGORY



In Colorado, 97 percent of wells are in regions with high or extremely high water stress. Texas leads in number of wells hydraulically fractured.

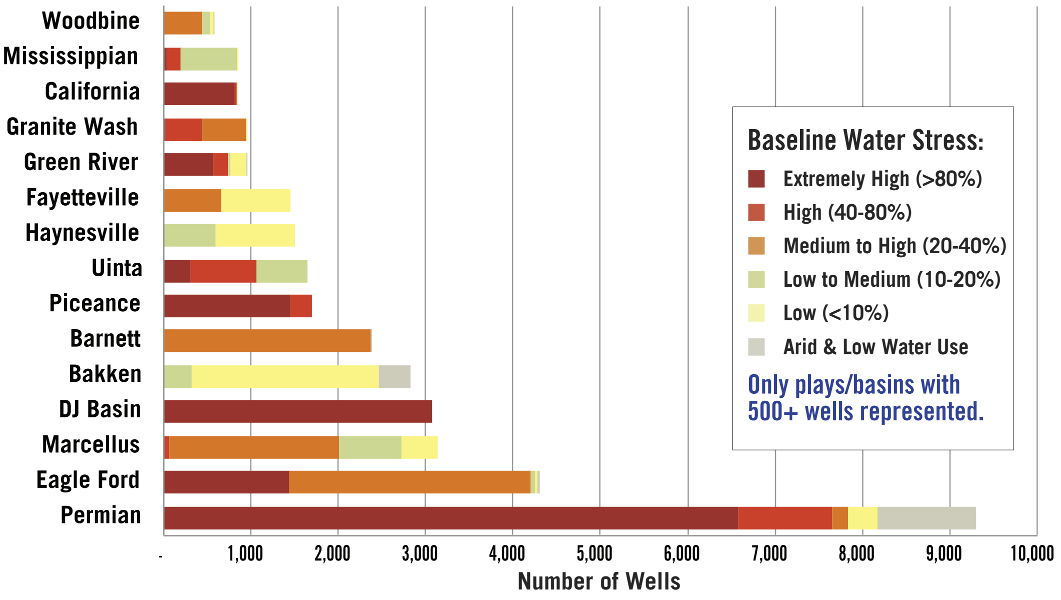
In Wyoming, New Mexico and California the majority of wells have been developed in regions of high or extreme water stress

FIGURE 7: TOP 15 PLAYS BY WATER USE



The Eagle Ford play in south Texas had the highest total water use, over 19 billion gallons in the report's study period, followed by the Marcellus, Permian, Barnett and Haynesville plays.

FIGURE 8: NUMBER OF WELLS DRILLED BY WATER STRESS CATEGORY & PLAY



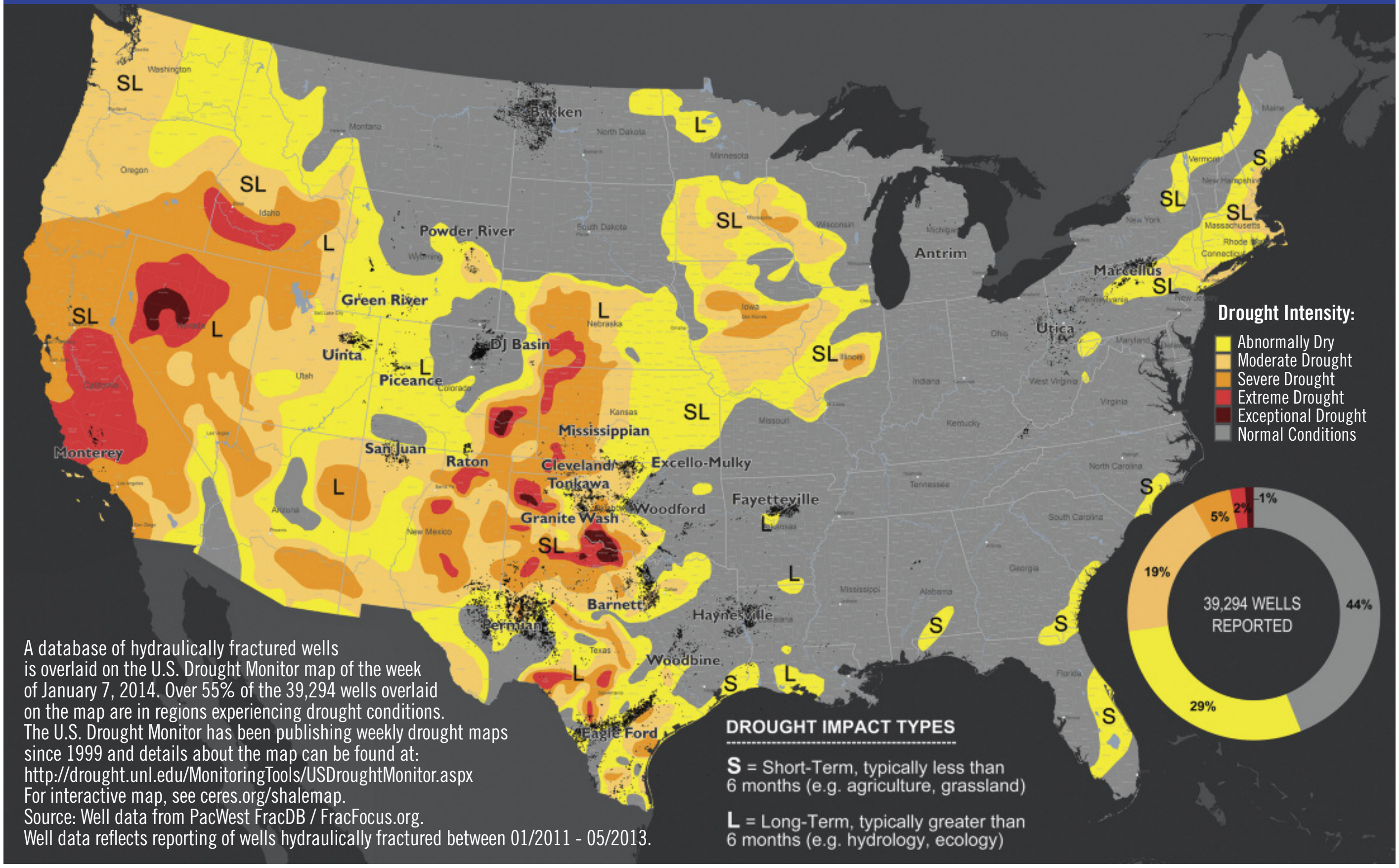
Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

Many of the smaller plays/basins (100 to 2,000 wells developed since 2011) are also experiencing high and extreme water stress, including the Piceance, Uinta, Green River, San Juan, Cleveland/Tonkawa and Anadarko Woodford plays. In Alberta, one of the only two provinces where FracFocus data is available, 14 percent of wells are in regions of high water stress (see **Regional Case Studies**).

Water Sourcing Risks: Drought Conditions Affecting Many Regions

Fifty-six percent of hydraulically fractured wells in the United States are in regions experiencing short- to long-term drought conditions (**Figure 9**). Areas experiencing prolonged drought conditions include California and much of Texas, Colorado, Oklahoma, New Mexico, Arkansas and Louisiana. Operating in drought conditions makes it more difficult to physically source water. It can also lead to increasing groundwater depletion, competitive pressures over existing water resources and loss of social-license-to-operate.

FIGURE 9: U.S. DROUGHT MONITOR MAP & SHALE ENERGY DEVELOPMENT



A database of hydraulically fractured wells is overlaid on the U.S. Drought Monitor map of the week of January 7, 2014. Over 55% of the 39,294 wells overlaid on the map are in regions experiencing drought conditions.
The U.S. Drought Monitor has been publishing weekly drought maps since 1999 and details about the map can be found at:
http://drought.unl.edu/MonitoringTools/USDroughtMonitor.aspx
For interactive map, see ceres.org/shalemap.
Source: Well data from PacWest FracDB / FracFocus.org.
Well data reflects reporting of wells hydraulically fractured between 01/2011 - 05/2013.

DROUGHT IMPACT TYPES

S = Short-Term, typically less than 6 months (e.g. agriculture, grassland)

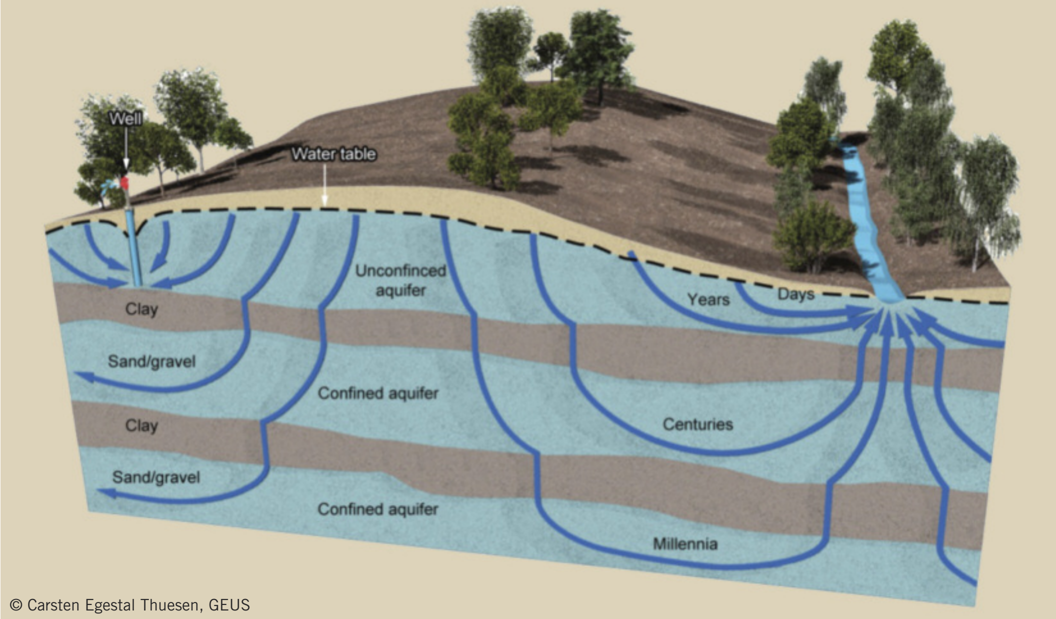
L = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)

Water Sourcing Risks:
Groundwater Depletion a Growing Concern

Shale development in many regions is highly reliant on groundwater resources, which are generally less regulated than surface waters, thus increasing risks of water resource depletion and water competition. Most water sourced for hydraulic fracturing in Texas, for example, comes from groundwater sources, yet there is no consistent requirement that groundwater used for hydraulic fracturing be reported, monitored or permitted.[21, 22]

Overuse of groundwater is an increasingly serious problem that leads to land subsidence, reductions in surface water flows and ultimately unsustainable water supplies.[23] Groundwater sources—from water in the soil to deep aquifers—are interconnected with one another and with surface water resources. Precipitation ultimately replenishes groundwater supplies, but in many cases this process can take decades, if not centuries or even longer (**Figure 10**).[24] Surface and groundwater are in reality, a single resource although regulators and end-users often have historically viewed them separately.[25]

FIGURE 10: SURFACE & GROUND WATER RESOURCES



Interconnected nature of surface and groundwater resources. This diagram shows groundwater supplying surface water resources. In some regions flows are reversed with surface water leaching into groundwater. Travel times of groundwater from recharge areas to various aquifers can take anywhere from days, years, centuries to millennia.

Source: USGS, Ground Water and Surface Water: A Single Resource, Circular 1139.

Growing Water Concerns in California, Impacting Bonds

From: ***"Water Bonds Shrivel as California Sees Driest Year," Bloomberg, January 2014***

About two-thirds of Californians get at least part of their water from northern mountain rains and snow through a network of reservoirs and aqueducts known as the State Water Project, according to a December 16 report by the Water Resources Department. The water content of the snowpack is about 20 percent of normal for this time of year, the Water Department said December 30 in a statement. The system supplies households and businesses from the San Francisco Bay area to Southern California and irrigates crops in the San Joaquin Valley near the center of the state—the world's most productive agricultural region.

With reservoirs at 66 percent of average, and a third dry year predicted, revenue is likely to fall short for the Water Resources Department and the local agencies that depend on it, Moody's Investors Service said in a December 5th note. That may harm the credit of such authorities as the Metropolitan Water District of Southern California, currently rated Aa1, second-highest, the company said. Lower credit ratings mean higher borrowing costs.[20]

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[20] James Nash, "Water Bonds Shrivel as California Sees Driest Year," *Bloomberg*, January 1, 2014.

[21] PG Bené, et al, "Northern Trinity/Woodbine aquifer groundwater availability model: assessment of groundwater use in the northern Trinity aquifer due to urban growth and Barnett Shale development," Report to the Texas Water Development Board, 2007, http://www.twdb.state.tx.us/groundwater/models/gam/trnt_n/trnt_n.asp.

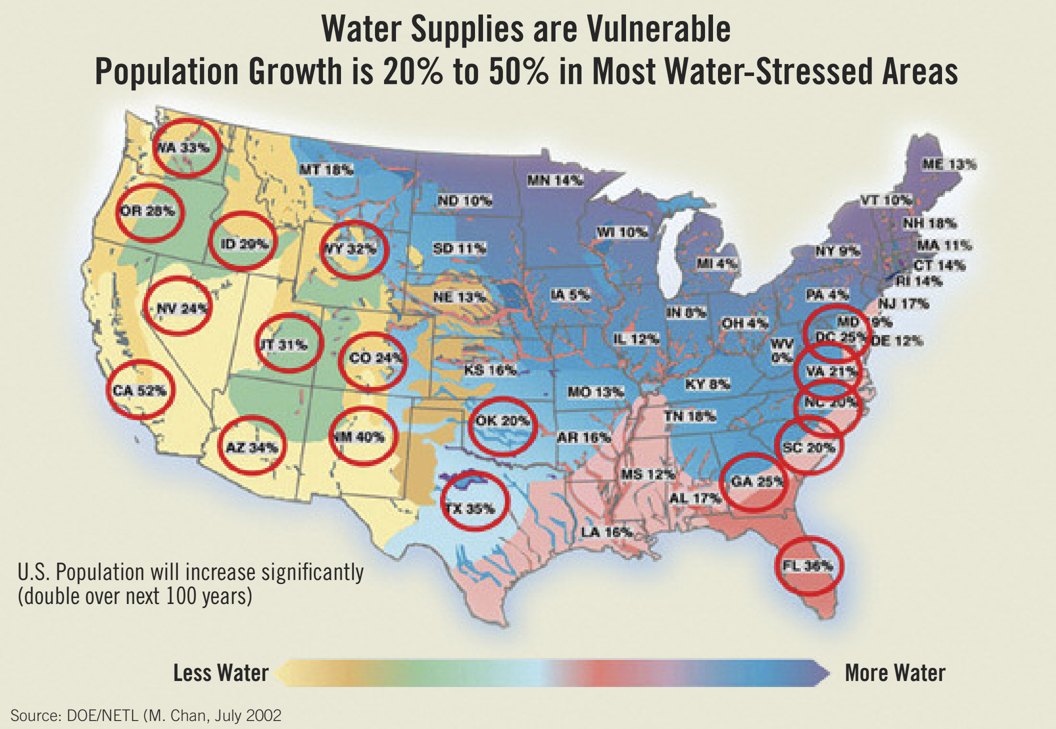
[22] JP Nicot and Bridget Scanlon, "Water Use for Shale-Gas Production in Texas," *U.S. Environmental Science and Technology*, March 2012.

[23] M. Giordano, "Global Groundwater Issues and Solutions," *The Annual Review of Environment and Resources*, 34, 153-187, 2009.

[24] Confined aquifers exist in some regions and contain fossilized water trapped in some cases millions of years ago. These aquifers are considered a non-renewable resource.

[25] Thomas Winter et al, "Ground Water and Surface Water, A Single Resource," U.S. Geological Survey Circular 1139, 1989.

FIGURE 11: WATER RESOURCE STRESS & POPULATION GROWTH, 2000-2020



Source: DOE/NETL (M. Chan, July 2002

Many areas of high water stress are also expected to see high population growth through 2020. Texas, Colorado, Wyoming, New Mexico, Oklahoma and California face expected population growth, water stress and shale energy development.

Source: Sandia National Labs, "Energy-Water Nexus Overview," http://www.sandia.gov/energy-water/nexus_overview.htm.

Policymakers are increasingly recognizing that regional economic reliance on groundwater in many regions may not be sustainable and that groundwater withdrawals by all users must be carefully balanced with declining groundwater levels and impacts on surface water flows.

Policymakers are increasingly recognizing that regional economic reliance on groundwater in many regions may not be sustainable and that groundwater withdrawals by all users must be carefully balanced with declining groundwater levels and impacts on surface water flows. Adding to the complexity of this challenge are prolonged drought conditions, growing climate change impacts and anticipated population growth in many of these shale oil and gas producing regions. Texas, Colorado, Oklahoma, Wyoming, New Mexico and California are all expected to experience 20 percent or higher population growth by the end of this decade (**Figure 11**). Texas is projected to experience 80 percent population growth by 2060.[26]

A recent U.S. Geological Survey (USGS) report highlights the systematic over-exploitation of 40 major U.S. aquifers, with the highest loss rates being from 2000 to 2008 (nearly 25 cubic kilometers on average per year).[27] Major shale energy activity and depleted aquifers overlap in the High Plains (Ogallala) aquifer (including parts of the Permian Basin), California's Central Valley aquifer and in the Rockies. In all of these regions, withdrawals from aquifers greatly exceed recharge rates.[28] Of the 39,294 wells studied, 36 percent overlay regions of groundwater depletion (**Figure 12**).

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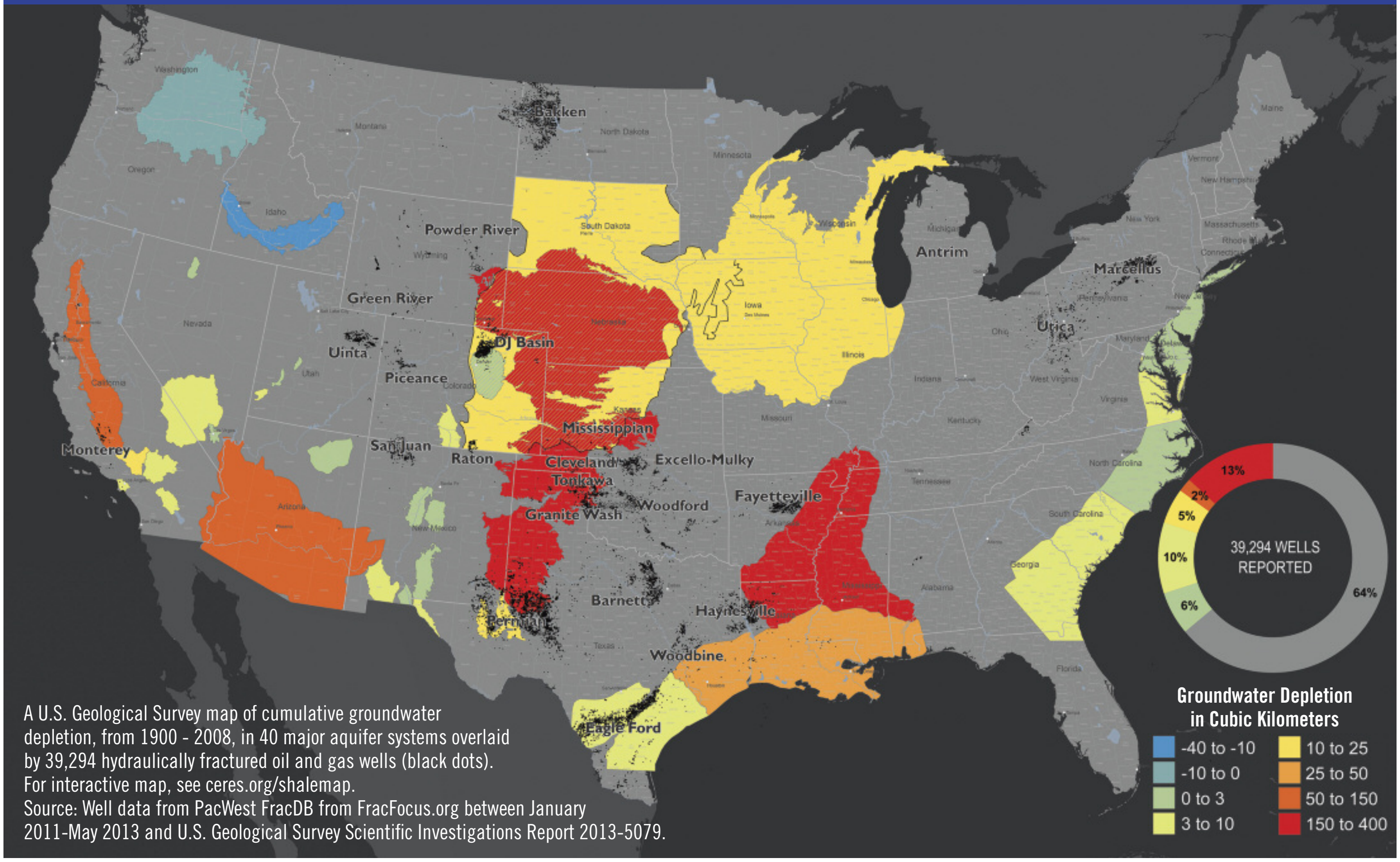
[26] Edward Vaughan et al, "Water for Texas 2012 State Water Plan, "Texas Water Development Board, January 2012.

[27] Leonid Konikow, U.S. Geological Survey, "Groundwater Depletion in the United States (1900-2008)," *Scientific Investigations Report* 2013-5079, May 14, 2013.

[28] Tom Gleeson, Yoshihide Wada, Marc Bierkens and Ludovicus van Beek, "Water Balance of Global Aquifers Revealed by Groundwater Footprint," *Nature*, Vol. 488, August 9, 2012.

FIGURE 12: GROUNDWATER DEPLETION & SHALE ENERGY DEVELOPMENT



A U.S. Geological Survey map of cumulative groundwater depletion, from 1900 - 2008, in 40 major aquifer systems overlaid by 39,294 hydraulically fractured oil and gas wells (black dots).
For interactive map, see ceres.org/shalemap.
Source: Well data from PacWest FracDB from FracFocus.org between January 2011-May 2013 and U.S. Geological Survey Scientific Investigations Report 2013-5079.

Local-Level Water Use Impacts:
The Best Scale for Understanding Water Sourcing Risks

Company exposure to shale water risks is best understood at the regional, municipal or county level. For example, in several counties in the Eagle Ford, water demand for hydraulic fracturing is projected to reach levels equivalent to all the water being used by all the residents in the county. Counties reliant on local groundwater sources or small water reservoirs, and which have minimal resources to build water-supply infrastructure to import water, are particularly vulnerable to the impacts of greater shale industry demand for water. Larger municipalities with greater financial resources, infrastructure and ability to import needed supplies are better able to absorb higher water demand. For example, in the Fort Worth/Tarrant County area in Texas, hydraulic fracturing water demands are very high, but can likely be partially met by sourcing water from beyond county borders.[29] However, even large jurisdictions will be challenged—physically, financially and politically—to meet future demand.

Several U.S. counties, including eight in extreme water stress regions, have used more than one billion gallons of water for hydraulic fracturing (**Figure 13**).[30] For many of these regions there is no data available regarding where this water is being sourced and how much derives from non-freshwater resources. Weld County, located in Colorado's DJ Basin, provides an example of just how dense well development can be within one county (**Figure 14**). Among these impacts are hundreds of trucks supplying water to each and every well pad for hydraulic fracturing.

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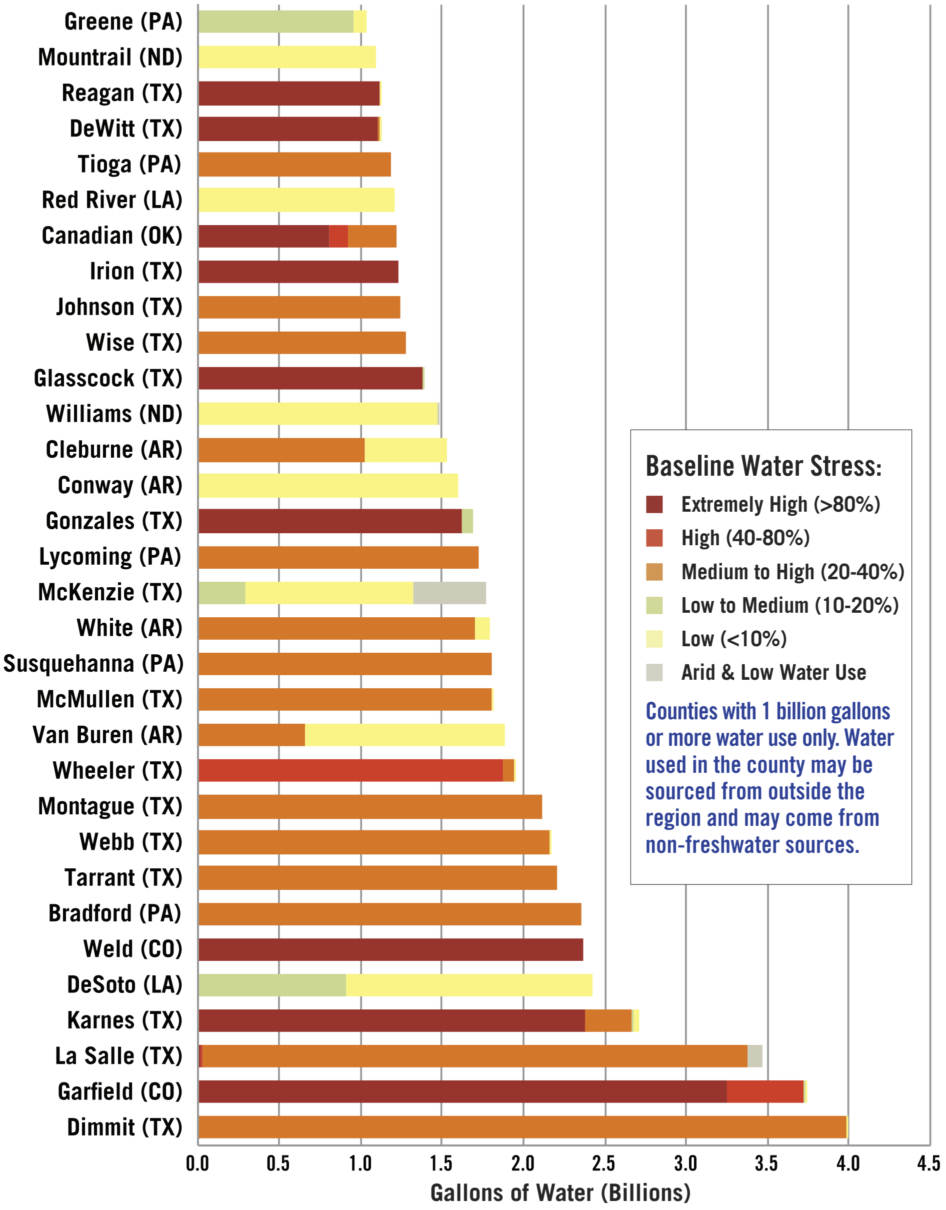
[29] Integrated Pipeline Program Management Office, Tarrant Regional Water District, http://www.iplproject.com/about-the-ipl/.

[30] One billion gallons is the equivalent of roughly 1,500 Olympic-sized swimming pools.

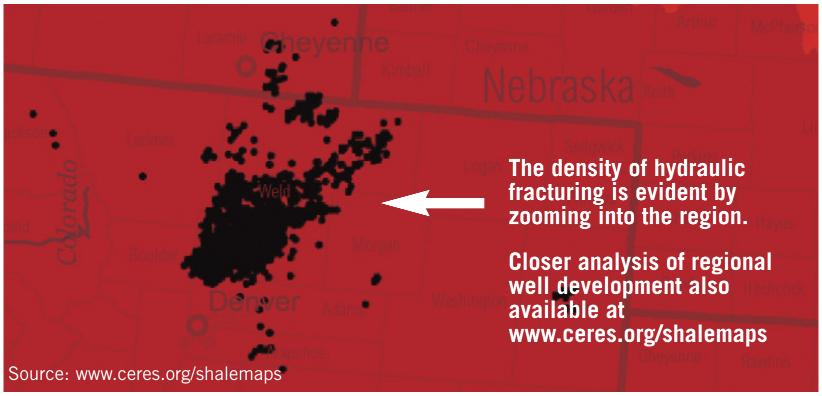
FIGURE 13: HIGHEST WATER USE COUNTIES BY WATER STRESS CATEGORY



Counties with 1 billion gallons or more water use only. Water used in the county may be sourced from outside the region and may come from non-freshwater sources.

Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

FIGURE 14: WELD COUNTY IN THE DJ BASIN OF COLORADO



The density of hydraulic fracturing is evident by zooming into the region.

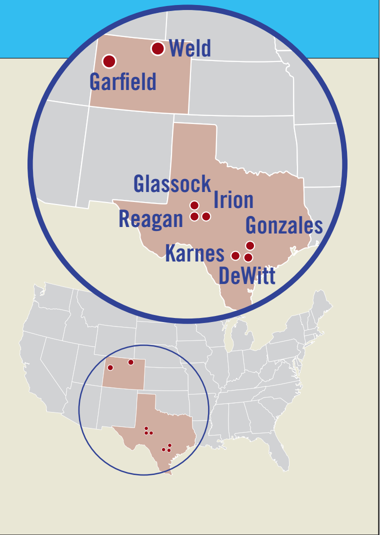
Closer analysis of regional well development also available at www.ceres.org/shalemaps

Source: www.ceres.org/shalemaps

TABLE 1: COUNTIES WITH HIGHEST ANNUAL WATER USE IN EXTREME WATER STRESS REGIONS

High Water Use & Stress County	Population	Annual Water Use for Hydraulic Fracturing in Billion Gallons*	Water Use for Domestic Supply in Billion Gallons**	Hydraulic Fracturing Water Use as Proportion of Domestic Water Use	Top Two Operators By Water Use
Garfield (CO)	49,810	1.9	5.3	36%	Encana, WPX
Karnes (TX)	15,351	1.7	.8	213%	EOG, Plains
Weld (CO)	228,943	1.3	8.9	15%	Anadarko, Noble
Gonzales (TX)	19,587	0.9	1.8	50%	EOG, Penn Virginia
Glassock (TX)	1,327	0.9	0	NA	Apache, Laredo
Irion (TX)	1,756	0.8	.03	2667%	EOG, Apache
Reagan (TX)	2,995	0.8	.4	200%	Pioneer, Laredo Petroleum
DeWitt (TX)	20,507	0.6	.8	75%	BHP Billiton, ConocoPhillips

U. S. Extreme Water Stress Regions



* Hydraulic fracturing annual water use for 2012. Water may have been sourced from outside county and from non-freshwater sources.

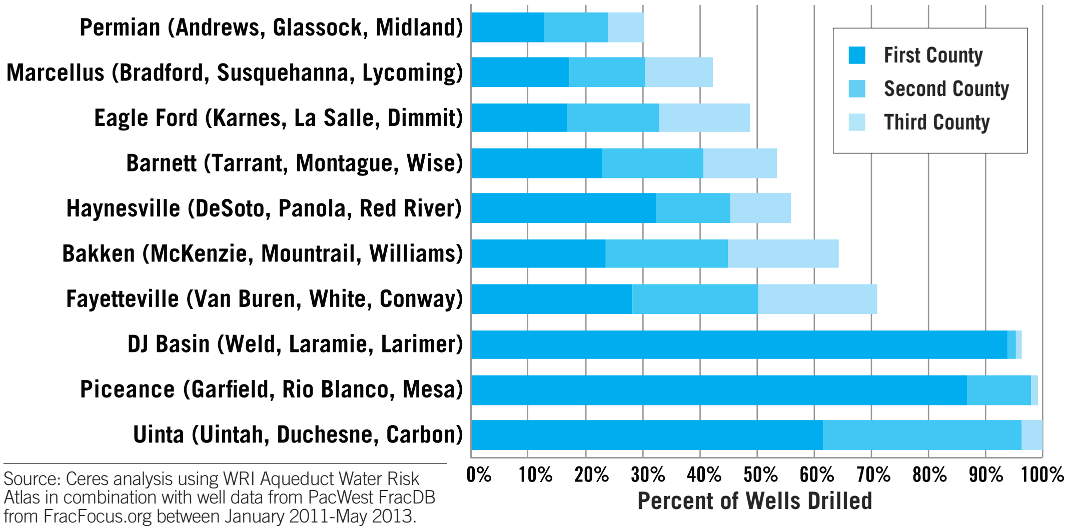
**All withdrawals for domestic supply (both fresh and saline) in county. From USGS 2005 national water survey.

Table 1: Water use for hydraulic fracturing can be relatively high at the local level in comparison to domestic water use.

In **Table 1**, water use for hydraulic fracturing for 2012 is compared to annual residential water use for 2005, the most recent year for which data was available. Water used in each county for hydraulic fracturing is often many times higher than water used for domestic residential water use, highlighting how at this geographic scale, water demand for hydraulic fracturing can potentially strain local communities.

Water use in certain counties can be very high because shale development tends to concentrate in "sweet spots" where wells may be particularly productive. As a result, development often focuses on a small number of counties within each play or basin. For example, in each of three major plays/basins—the Uinta in Utah and the Piceance and DJ Basins centered in Colorado—more than 80 percent of wells are concentrated within three counties or fewer (**Figure 15**). In many of the other major plays/basins, well development within the top three counties is a significant percentage of the total number of wells developed in the entire play/basin.

FIGURE 15: PERCENTAGE OF WELLS IN TOP THREE MOST ACTIVE COUNTIES PER PLAY



Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

Figure 15: Proportion of wells developed in top three counties by activity versus all wells developed for entire play/basin.

Company Exposure to Water Sourcing Risks

This chapter analyzes the water risk exposure of shale energy operators and service providers (see **Appendices B and C** for full data). Operators make strategic exploration and production decisions and are ultimately liable for the environmental impacts of production, whereas service providers conduct field operations, including hydraulic fracturing operations.[31] Service providers in turn often subcontract parts of their operations to a variety of specialists, notably companies that mine the sand used in hydraulic fracturing.[32, 33] Investors and lenders should be aware of the water risks facing all of the companies engaged in the hydraulic fracturing value chain, but this report focuses on operators and their first-tier service providers.

The top 10 operators measured by number of wells developed (**Figure 16**) accounted for 56 percent of the water used for hydraulic fracturing across the U.S. and have relatively high exposure to water stress. Chesapeake was the biggest user of water, using nearly 12 billion gallons from January 2011 to May 2013, mostly in medium water stress regions. EOG used over 8 billion gallons, while several others reported use between 5-6 billion gallons,

FIGURE 16: TOP TEN OPERATORS BY NUMBER OF WELLS & EXPOSURE TO WATER STRESS

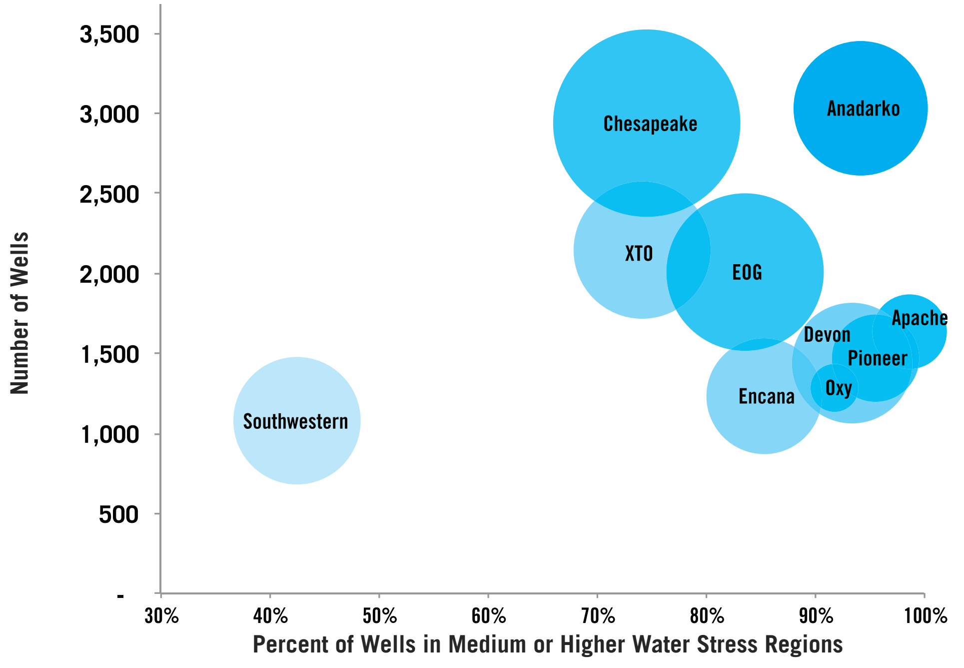


Figure 16: Areas of circles represent volumes of water used for hydraulic fracturing, with Chesapeake using approximately 12 billion gallons, Anadarko at 6 million gallons and Oxy at approximately 600,000 gallons.

Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

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[31] There are a handful of companies that are vertically integrated, such as Pioneer.

[32] In addition to the environmental impacts from mining the sand, these operations also require a large amount of water to wash and sort the sand. See http://www.fracdallas.org/docs/sand.html and http://dnr.wi.gov/topic/Mines/documents/SilicaSandMiningFinal.pdf.

[33] Publicly-listed sand suppliers for hydraulic fracturing include US Silica (SLCA) and Hi-Crush (HCLP). EOG, Pioneer and Halliburton also own sand mining operations for hydraulic fracturing.

including XTO, Anadarko, Devon, Encana and Southwestern, with the latter having the lowest exposure to water-stressed regions (water volumes reported do not distinguish between fresh, brackish, recycled and wastewater sources).

Operators vary in their exposure to water stress and in the amount of water they use in each region (**Figure 18** and **Appendix B**). Anadarko used a relatively large amount of water and has exposure to medium or higher water stress regions across five different plays where it has significant operations. Most of the major operators had significant exposure to water stress, especially in the larger water-use basins and plays. Pockets of high operator water stress exposure also exist in the Fayetteville, Piceance, Granite Wash and DJ Basin.

Service providers are also exposed to varying degrees of water stress. These companies play a crucial role in orchestrating the entire supply chain, including acting as technical advisors on key operational strategies. The structure of this sector is far more concentrated with the top three service providers—Halliburton, Schlumberger and Baker Hughes—collectively accounting for 55 percent of all hydraulic fracturing wells reported and just under half of the water used for hydraulic fracturing nationally.

Halliburton alone handled nearly 25 billion gallons of water for hydraulic fracturing operations, nearly a quarter of all the water used nationally, followed by Schlumberger, Baker Hughes and FTS (**Figure 17**). All of the top 10 service providers (by number of wells developed) had the majority of their operations in medium or higher water stress regions.

For 15 percent of the well data, it was not possible to identify which service provider hydraulically fractured the wells. Service providers are unfortunately not currently required to report to FracFocus. (For more details of service provider data analysis and exposure to water stress by play/basin, see **Appendix A and C**).

FIGURE 17: TOP TEN SERVICE PROVIDERS BY NUMBER OF WELLS & EXPOSURE TO WATER STRESS

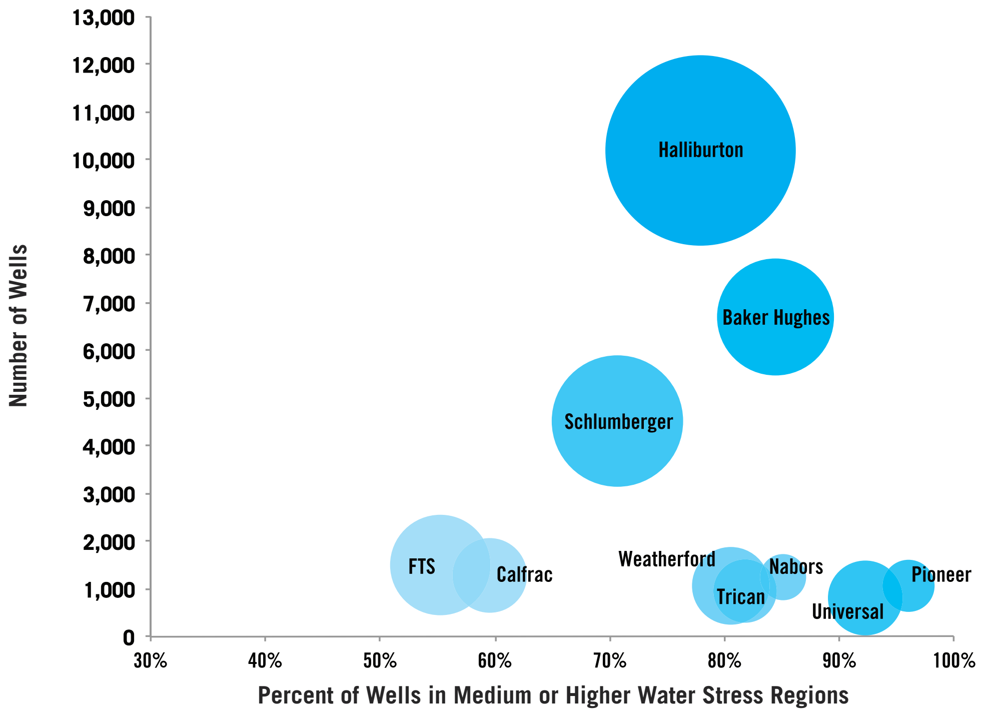

Figure 17: Area of circles represents total water use by service provider. Approximately 15 percent of the wells did not have sufficient information to identify the service provider since service providers are not required to report to FracFocus.

Source Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

FIGURE 18: OPERATORS BY WATER USE & EXPOSURE TO WATER STRESS

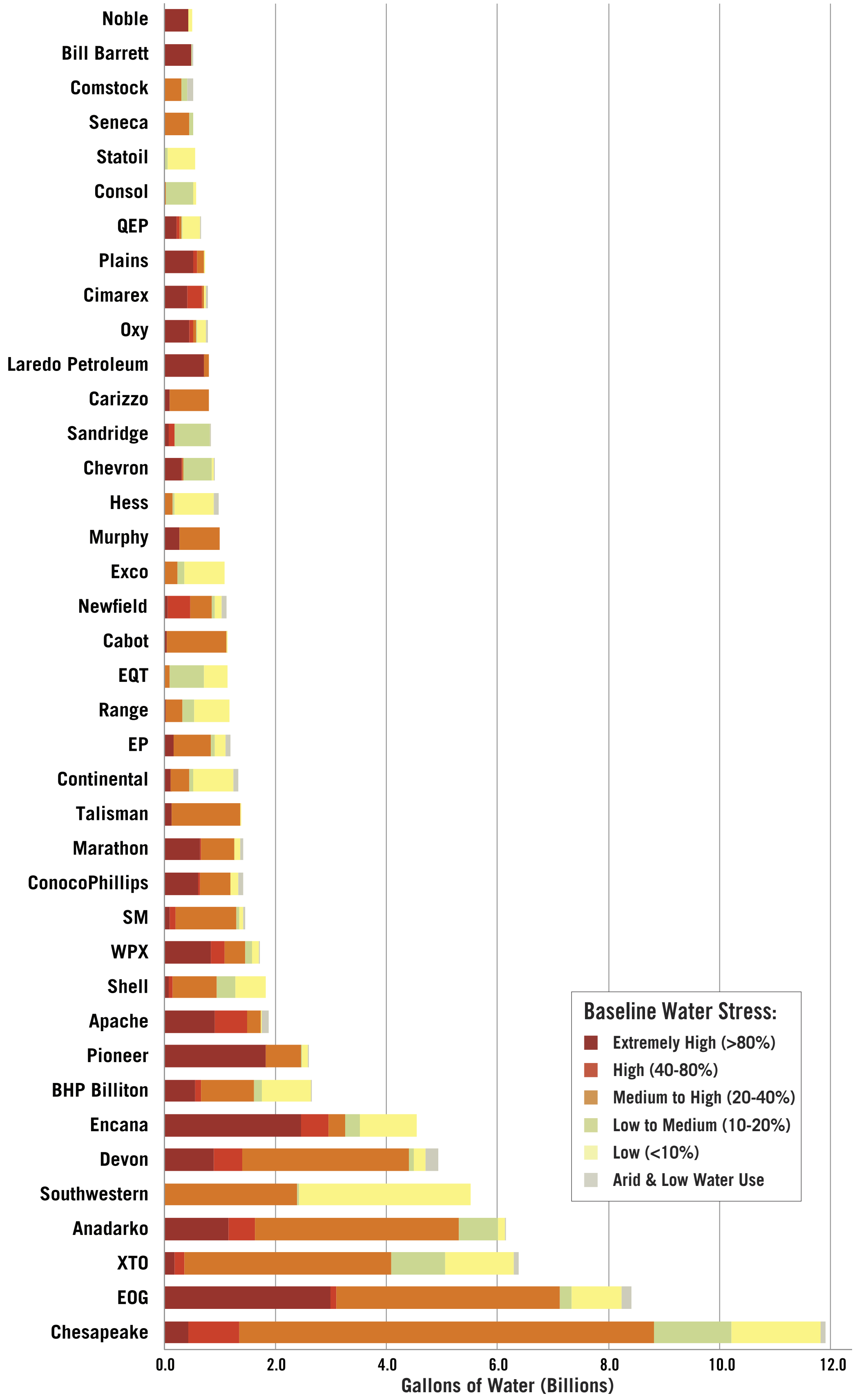

Figure 18: Operators ranked by water volume used for hydraulic fracturing and water stress category. Companies reporting less than 500 million gallons of water were excluded. Sources and type of water not reported.

Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

Growing Investor Focus

The investment and financial community is increasingly doing more to better understand and address water and other environmental risks associated with hydraulic fracturing. Nearly 40 shareholder resolutions have been filed with companies on hydraulic fracturing-related water risks in the past few years. Investors have also been engaging companies on the environmental and social risks around hydraulic fracturing. A coalition of investors recently published a set of expectations for companies around transparency and best practices, as well as a follow-up publication showing that companies are failing to meet investor expectations on even the basic parameters of better disclosure.[34, 35] Also, over 593 (of 1,000 asked) global corporations responded to the most recent CDP survey on water risk, which was backed by 530 institutional investors managing approximately $57 trillion in assets. Of the sectors represented by the surveyed companies, the energy sector persistently remains at the bottom of the list in terms of a response rate at only 47 percent.[36] Securities regulators are also looking at the sector: the U.S. Securities and Exchange Commission has sent over 70 letters to companies asking for further information on potential risks from hydraulic fracturing.[37]

Financial institutions with lending and investment banking relationships with companies engaged in hydraulic fracturing are approaching the risks in different ways, with some developing more robust risk assessment frameworks[38] and others avoiding lending to or investment in hydraulic fracturing operations altogether.[39]

Investors and lenders must prioritize their analysis of and engagement with companies. Given the factors that shape shale oil and gas company exposure to water sourcing risks, priority should be given to operators and service providers with the most significant exposure in regions of highest water stress, groundwater depletion and drought conditions. Ultimately, the companies that are taking the lead in addressing the rising costs of accessing water and the potential loss of the social license to operate will differentiate themselves from others in terms of shareholder value.

Given the factors that shape shale oil and gas company exposure to water sourcing risks, priority should be given to operators and service providers with the most significant exposure in regions of highest water stress, groundwater depletion and drought conditions.

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[34] Richard Liroff, Investor Environmental Health Network and Interfaith Center on Corporate Responsibility, "Extracting the Facts: An Investor Guide to Disclosing Risks from Hydraulic Fracturing Operations," December 2011.

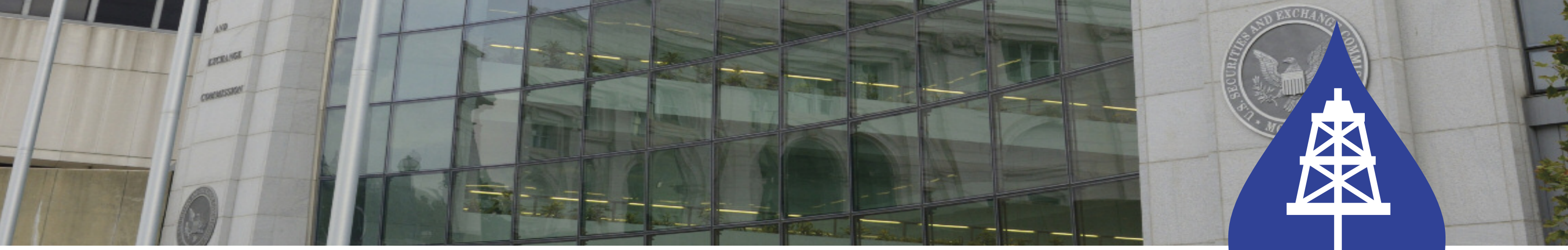
[35] Richard Liroff, Danielle Fugere, Lucia von Reusner, Steven Heim and Leslie Samuelrich, "Disclosing the Facts: Transparency and Risk in Hydraulic Fracturing Operations," November 2013.

[36] CDP, "Moving Beyond Business as Usual, A Need for a Step Change in Water Risk Management," CDP Global Water Report 2013.

[37] Ceres analysis of SEC Comment Letters issued between January 1, 2010 to November 30, 2012.

[38] JPMorgan and Bank of America have described improving due diligence practices considering risks in hydraulic fracturing in their 2012 corporate responsibility reports.

[39] "Rabobank Turns Against Shale Gas," *PressEurop*, July 1, 2013, http://www.presseurop.eu/en/content/news-brief/3928871-rabobank-turns-against-shale-gas.



Water Sourcing Regulatory Landscape

Rapidly growing demand for water for hydraulic fracturing has challenged water resource managers in many regions. Many state and regional water plans have quickly become outdated as demand for water for shale oil and gas development increases and expands into new regions.[40]

States or provinces have the primary responsibility for permitting oil and gas development and related water sourcing, but there is currently significant disparity in their approaches to regulating shale water requirements and associated impacts.

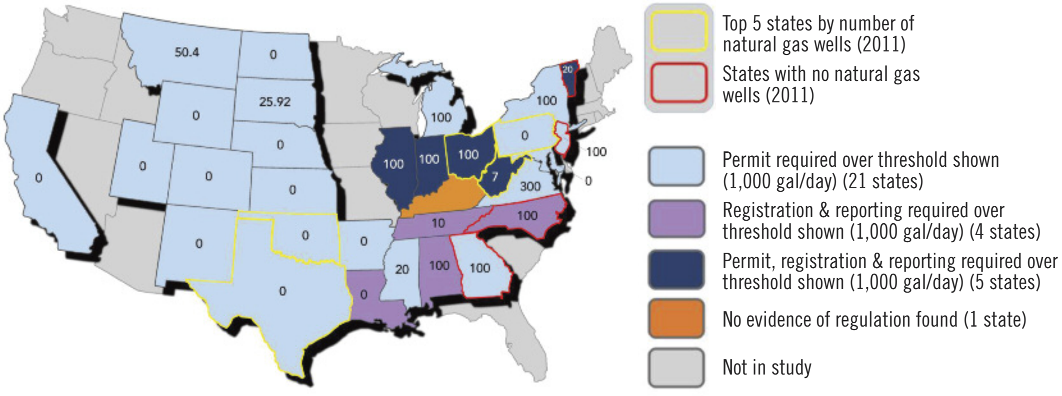
A recent study by Resources for the Future looked at regulations relevant to shale energy development and found markedly different water withdrawal policies across 30 states surveyed, including those with major shale energy development (**Figure 19**, states with major shale energy development are outlined in yellow). The study found that for most of the 26 states with any water withdrawal permitting requirements, only half require permits for all withdrawals. Several states do not require permits at all, but only disclosure of water use over a certain threshold, as represented by the light purple states.

States or provinces have the primary responsibility for permitting oil and gas development and related water sourcing, but there is currently significant disparity in their approaches to regulating shale water requirements and associated impacts.

In addition, some states and provinces exempt the oil and gas industry from permitting requirements for water withdrawals, including:

- **Kentucky**, which exempts the industry from both surface and groundwater reporting.
- **Texas**, which requires permits for surface water withdrawals, but generally not for groundwater.
- **British Columbia**, where no reporting or permitting requirements exist for groundwater withdrawals by any industrial users. The British Columbia Water Act is currently being reviewed to correct this.

FIGURE 19: WATER WITHDRAWAL REGULATIONS BY STATE



Source: Nathan Richardson, Madeline Gottlieb, Alan Krupnick and Hannah Wiseman, Resources for the Future, *The State of State Shale Gas Regulation*, June 2013.

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[40] Kiah Collier, “Oil Industry Focuses on Water-Use,” *San Angelo Standard Times*, December 2, 2011, http://www.gosanangelo.com/news/2011/dec/02/oil-industry-mulls-need-to-get-water-consumption/?print=1.

Regulatory Leading Practices

Although individual states or provinces must adapt regulations that are sensitive to their local water resource landscapes, some broader policies are being utilized that all regulators should consider to better protect water sources from shale energy impacts. Leading practices include:

Detailed Operator Reporting on Water Use

Pennsylvania is leading the way in requiring strong disclosure of freshwater and recycled water use during hydraulic fracturing. Within 30 days after completion of a well, the operator must submit a completion report to the Department of Environmental Protection (DEP). That report must include a stimulation record, which provides technical details associated with hydraulic fracturing, and list water resources that were used under an approved water management plan, including volume of water used from each source.[41,42] Operators must also disclose the volume of recycled water used during well drilling.[43] The DEP then reviews plans and approves them provided that water withdrawals (1) do not adversely affect the quantity or quality of water available to other users of the same water sources; (2) protect and maintain the designated and existing uses of water sources; (3) do not cause adverse impact to water quality in the watershed considered as a whole; and (4) are mitigated through a reuse plan for fluids that will be used to hydraulically fracture wells.[44]

Cradle-to-Grave Water Lifecycle Analysis

River basin commissions, created by states that share river basins or watersheds, are invested with varying levels of authority to manage water resources and prevent environmental damage across entire watersheds. One such body, the Susquehanna River Basin Commission (SRBC) in Pennsylvania, has an important but limited role with respect to natural gas development and water use.[45] Because very little was known regarding quantities of water needed and water use patterns when shale development began in 2008, the SRBC decided to regulate all surface and groundwater withdrawals and all consumptive use of water for unconventional gas development beginning at "gallon one."[46] With the comprehensive water use data collected by the SRBC and the state of Pennsylvania, a full water lifecycle study for hydraulic fracturing has just been completed, showing that the average Marcellus shale well consumed about 5.3 million gallons, of which 65 percent was associated with direct water consumption at the well site and 35 percent with indirect water consumption across the supply chain. The study estimated that $59,000 to $270,000 would be required to treat well wastewater with desalination to surface discharge standards.[47] More water lifecycle studies such as this one are vitally needed across other major shale plays.

The average Marcellus shale well consumed about 5.3 million gallons, of which 65 percent was associated with direct water consumption at the well site and 35 percent with indirect water consumption across the supply chain.

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[41] 25 Pa. Code § 78.122(b)(6).

[42] 25 Pa. Code § 78.122(b)(6)(vi).

[43] 25 Pa. Code § 78.122(b)(6)(vii).

[44] 58 Pa. Cons. Stat § 3211(m)(2).

[45] According to the SRBC, the commission "requires natural gas companies to seek approval from the commission before withdrawing or using any amount of water for unconventional natural gas development. SRBC adopted this threshold for natural gas projects in October 2008 (For withdrawals by project sponsors other than natural gas companies, the regulatory thresholds [as 30-day averages] are 100,000 or more gallons per day for withdrawals and 20,000 or more gallons per day for consumptive uses)." Id. "FAQ: SRBC's Role in Regulating Natural Gas Development," SRBC 1, March 26, 2012, http://www.srbc.net/programs/docs/NaturalGasFAQ_20120323_140574v1.pdf.

[46] Summary of the "Technical Workshop on Water Acquisition Modeling: Assessing Impacts Through Modeling and Other Means," EPA, June 4, 2013.

[47] Mohan Jiang et al, "Life Cycle Water Consumption and Wastewater Generation Impacts of a Marcellus Shale Gas Well," *Environmental Science and Technology*, December 31, 2013.

Public Transparency

The Susquehanna River Basin Commission is transparent in its publicly available water permitting and data disclosure through its Water Resource Portal, an interactive map showing the location and amount of permitted withdrawals.[48] Information provided to the public includes the location of the proposed withdrawal or use (latitude/longitude), the maximum instantaneous rate of the requested withdrawal and the maximum daily amount of the withdrawal or consumptive use. Public notices and legal notices must be filed along with adjacent landowner notices. Once a project has been approved, daily monitoring and compliance data are required and must be submitted online quarterly.

Environment Alberta also provides valuable information to the public on both the water allocated and consumed (including water withdrawn and returned to the system) as a percentage of natural flows by major river basin. Maps provided clearly illustrate those river basins most at risk for increasing competition over water with a high percentage of their flows already allocated for use by municipalities, industry or agriculture.[49]

Groundwater Source Identification

Ohio's freshwater and recycled water use rules require operators to identify each proposed source of groundwater and surface water that will be used.[50] Ohio does not, however, require post-drilling disclosure of actual volumes of freshwater and recycled water used.

Improved Wastewater Recycling

The Texas Railroad Commission (the agency that regulates the state's oil and gas industry) recently amended its rules to make it easier to recycle wastewater streams from hydraulic fracturing operations. Operators no longer need permits to recycle water and can even accept water from other areas or companies, as long as the recycling takes place on land leased by the operator so that oversight can be maintained. This new rule also allows operators to turn around and sell the water to other operators.[51]

Minimizing the Spread of Invasive Species

A small number of states have established measures to minimize the spread of invasive species through water sourcing practices from hydraulic fracturing. Colorado requires disinfection of water suction hoses when water withdrawals occur in cutthroat trout habitats to avoid transfer of invasive or harmful species.[52] Pennsylvania requires operators to demonstrate how they will prevent damage to aquatic life during water withdrawals.[53] The spread of invasive species costs the U.S. economy an estimated $120 billion in damages every year.[54]

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[48] Susquehanna River Basin Commission, Water Resource Portal, http://www.srbc.net/wrp/.

[49] Environment Alberta, "Water Allocations Compared to Average Natural Flow," July 2011, http://environment.alberta.ca/01722.html

[50] Ohio Rev. Code §1509.06(A)(8)(a). The regulatory language reads in full: the operator must disclose "[a]n identification, to the best of the owner's knowledge, of each proposed source of groundwater and surface water that will be used in the production operations of the well. The identification of each proposed source of water shall indicate if the water will be withdrawn from the Lake Erie watershed or the Ohio river watershed. In addition, the owner shall provide, to the best of the owner's knowledge, the proposed estimated rate and volume of the water withdrawal for the production operations. If recycled water will be used in the production operations, the owner shall provide the estimated volume of recycled water to be used. The owner shall submit to the chief an update of any of the information that is required by division (A)(8)(a) of this section if any of that information changes before the chief issues a permit for the application." *Id.*

[51] James Osborne, "State Rule Change Makes Recycling Fracking Wastewater Easier," *Dallas News*, March 26, 2013, http://www.dallasnews.com/business/energy/20130326-state-rule-change-makes-recycling-fracking-wastewater-easier.ece.

[52] Colo. Code Regs. § 404-1:1204, Westlaw 2012.

[53] See section C.6 titled "Withdrawal Impacts Analysis," in the Pennsylvania Department of Environmental Protection Water Management Plan For Unconventional Gas Well Development Example Format, May 2013, http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-95182

[54] David Pimental et al, "Update on the Environmental and Economic Costs Associated with Alien-Invasive Species in the United States," *Ecological Economics* 52, 273-28, 2005.

General Guidelines for Leading Regulatory Practices on Water Sourcing

- Catalogue the consumptive water use from hydraulic fracturing operations, including sources of water used and the amounts recycled.
- Require information on how operators are planning to manage wastewater streams including final disposal of water.
- Create integrated management structures for joint oversight of ground and surface water (as some are now proposing in British Columbia).
- Realize that higher disclosure requirements alone will not solve water sourcing impacts and risks, and must be accompanied by proactive water management plans that include monitoring and enforcement components.
- Ensure that water-sourcing oversight is independent from the department granting oil and gas permits to minimize conflicting mandates and objectives.
- Create systems of incentives and/or mandate requirements to encourage recycling and non-freshwater use.
- Implement measures to prevent invasive species transfers.
- Provide more resources to map and monitor groundwater resources, including remote aquifers and brackish water resources, across North America.
- Reduce reliance on aquifer exemptions and create incentives to minimize use of deep well injection sites.

Overall there is strong need for better information sharing among state and local regulatory bodies tasked with regulating oil and gas development. Several information-sharing efforts are underway (e.g. the Ground Water Protection Council's Risk Based Data Management System and Intermountain Oil and Gas Project and database) that are beginning to address this gap. Better communication and collaboration with agencies responsible for agricultural and municipal water use is also needed.

Recommendations

Given the significant water risks operators and service providers are facing in the shale energy sector, investors and lenders need to understand how those water risks could impact their investments. The following recommendations related to **corporate governance and management** of water risk, **operational practices**, **stakeholder engagement**, and **disclosure** capture crucial steps companies should take to lower their water impacts and exposure to water risk.

Institutionalizing Water Management

1

Management Recommendation #1: Embed water risk and opportunity analysis across all company business units, and provide executive and board level oversight of water risk management.

Analysis of water risks should be embedded into the DNA of shale development operators, with all major operational, investment and strategic decisions taking water risk into account, including future impacts of water use on local communities. Water risks should be factored in when selecting new regions for development. Executive management should have explicit oversight of all strategic water-related issues and there should be clear lines of responsibility between executives and operating personnel. Leading practice should include tying senior executive compensation to performance on water management goals. Board-level briefings on water issues should be institutionalized and explicit oversight put in place. Likewise board-level expertise and accountability should exist on sustainability issues.

Improving Operational Practices

Across many water-stressed regions, engineers, technicians, chemists and water managers are actively trying to find technical solutions that will allow them to use less water. They are being supported by a multibillion-dollar shale energy water management industry that comprises more than 400 companies providing everything from water logistics and infrastructure for sourcing water, to metering water use, storage, treatment and recycling services. These companies range from Fortune 500 companies to small operations focused on single niche technologies.[55, 56] While these technical efforts are vital, they alone will not solve water-sourcing challenges. Unless there is a major breakthrough in waterless hydraulic fracturing technology (using propane, nitrogen, or other mediums), shale energy extraction will continue to require substantial amounts of water.[57] This requires utilizing a broad array of approaches to better manage water usage.

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[55] Personal communication with PacWest Consulting Partners.

[56] Su Gao, "Hydraulic fracturing's water problem: what goes down must come up," *Bloomberg New Energy Finance Research Note*, July 2012.

[57] See http://www.gasfrac.com.

1 *Operational Recommendation #1: **Minimize freshwater use.***

RECYCLING

Measures to improve water efficiency across the shale development water lifecycle should be priority number one in regions of high water stress. Also, if water immediately flowing back from a hydraulically fractured well (flowback) or rising back to the surface over time (produced water) is of sufficient quality and quantity, recycling should be considered. Recycling technology has improved in the past few years, offering both centralized and distributed treatment solutions that can provide operators with high enough quality water for reuse in future hydraulic fracturing operations. Recycled water can also be used for other industrial and agricultural uses provided it has been sufficiently treated and is authorized by regulators.[58]

Recycling water doesn't always make sense. In some cases water returning to the surface may be insufficient volume or too contaminated (whether with salt, heavy metals or naturally occurring radioactive materials) to clean without using large amounts of energy. Solid waste byproducts are another impediment. Risk to human health from handling contaminated water must also be carefully considered and managed as wastewater recycling increases.[59]

Even when it does make sense to recycle and operators are doing so, freshwater demand will still be significant. Only a portion of the water pumped into a hydraulically fractured well returns to the surface, so supplemental water resources will always be needed to maintain or expand development. The bottom line: recycling will never be a silver bullet for solving all water-sourcing constraints.

WASTEWATER

In regions where recycling is not viable, wastewater sourced from municipalities and other industries should be used instead of freshwater. Using available wastewater streams relieves competitive pressures on local water resources while saving energy because the selling entity doesn't have to treat the water to a high standard. On the negative side, municipal wastewater diverted for hydraulic fracturing use means less water being returned to local streams and rivers, thus potentially compromising the hydrogeological cycle. Other industries are making good use of wastewater: a recent study found power plants in western Texas now draw 45 percent of their water from treated municipal wastewater sources. The same study also highlighted that natural gas power plants, which have invested in water efficient cooling systems, use far less water than coal plants that have not made investments in water efficiency technologies.[62]

BRACKISH WATER

Brackish water is sometimes a viable alternative for sourcing from limited freshwater surface and groundwater resources. Brackish water is generally saltier than freshwater but not as salty as seawater.[63] In many plays in Texas, brackish groundwater use is far higher than recycled water use and sometimes accounts for the largest proportion of water used for hydraulic fracturing. The Horn River, Permian and Anadarko basins stand out as high brackish water-use regions.[64]

Even 100% Recycling Will Not Eliminate the Need for Large Volumes of Additional Water

From: ***"Technical Workshop on Water Use," EPA, 2011***

"Chesapeake is reusing nearly 100 percent of all produced water and drilling wastewater in Pennsylvania. This reuse can reduce the volume of freshwater needed to drill and hydraulically fracture subsequent Marcellus Shale wells by 10 percent to 30 percent."

— Matthew E. Mantell, Environmental Engineer, Chesapeake[60]

Recycling Rates in Texas are Low

From: ***"Water Recycling is Big Business for Oil, Gas Support Firms," Star Telegram, April 2013***

When the Barnett shale began operating a decade ago as one of the country's first shale plays, water reuse was a novelty. Producers could acquire plenty of water at relatively low prices, and disposal wells provided a ready means of disposing contaminated flowback.

Even today, water reuse and recycling is the exception rather than the rule in the Barnett. According to a 2012 study by the Bureau of Economic Geology at the University of Texas, only about 5 percent of the total water used for hydraulic fracturing was recycled or reused.

"We expected it to become more prolific earlier, especially in Texas," said Brent Halldorson, chief operating officer of Fountain Quail, a recycler of industrial wastewater, who got into the business nearly a decade ago.[61]

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[58] The Cawelo Water District in California gets some of its water for irrigation from Chevron's produced water flow. See http://www.swhydro.arizona.edu/archive/V4_N6/feature5.pdf.

[59] Charles Schmidt, "Estimating Wastewater Impacts from Hydraulic Fracturing," *Environmental Health Perspectives*, April 2013.

[60] U.S. EPA, Proceedings of the Technical Workshops for the Hydraulic Fracturing Study, Water Resources Management, May 2011.

[61] Jim Fuquay, "Water Recycling is Big Business for Oil, Gas Support Firms," *Star Telegram*, April 27, 2013.

[62] Bridget Scanlon et al, "Drought and the Water-Energy Nexus in Texas," *Environmental Research Letters*, December 20, 2013, doi:10.1088/1748-9326/8/4/045033.

[63] USGS National Brackish Groundwater Assessment, http://ne.water.usgs.gov/ogw/brackishgw/brackish.html.

[64] JP Nicot et al, "Oil and Gas Water Use in Texas: Update to the 2011 Mining Water Use Report," *Bureau of Economic Geology*, University of Texas at Austin, prepared for the Texas Oil and Gas Association, September 2012.

Using brackish water has risks, however. Before deciding to source from brackish water resources, companies working with local water managers should consider two questions. First, is the brackish groundwater aquifer targeted for hydraulic fracturing use likely to be used for future drinking water supplies? Many parched communities are already turning to brackish water resources for drinking water supplies due to declines in fresh groundwater resources. The USGS predicts that use of brackish groundwater could in some areas supplement or even replace use of freshwater sources.[66] Second, is the brackish groundwater aquifer connected to freshwater aquifers? If so, using brackish water may compromise the quality and availability of the freshwater aquifer. Once it is deemed that there are no impacts on drinking water supplies and resources, brackish water is a viable option for supplementing freshwater supplies.

WATER CONSERVATION

Of course, every effort should be made to minimize water use in the first place. Water efficiency should be encouraged and integrated across all operating units. Some companies, such as food and beverage giant Nestlé, use shadow prices for water use that helps justify investments in water efficiency even when water is provided at minimal cost.[68]

Some companies within the industry are also being innovative, such as Pioneer's use of evaporation control covers on water storage sites in the Permian that save up to six feet of water per year.[69] In lieu of using water to reduce dust levels on dirt roads to its Texas wells, Anadarko has built these roads with limestone which require less dust-suppression.

2 *Operational Recommendation #2:* ***Collaborate with industry peers and other sectors in watersheds and aquifers that are being shared.***

While water treatment technology is often no longer a barrier to recycling, lack of planning and collaboration remains an impediment. It is expensive and often energy-intensive to recycle water on a site-by-site basis. Centralized water storage and recycling infrastructure and water pipeline networks across contiguous large areas makes recycling more practical, cost effective and energy efficient. Larger operators with sizeable tracts of acreage in a play should take the lead in setting up water recycling networks from which they can then potentially sell recycled water to smaller operators in the region to help recover costs.

When there is no single large operator in a region, smaller operators should consider creating water cooperative agreements. In addition to protecting water supplies, these networks would reduce significant truck traffic in local communities hauling water and wastewater. With water acquisition, hauling and management costs reaching almost half of well development costs in some regions, centralized recycling networks and infrastructure planning can have large cost savings.[70]

Wastewater as a Viable Alternative to Freshwater

From: ***"Town Sells Treated Wastewater for Hydraulic Fracturing," Edson Leader, November 2013***

Kevin Henderson, director of infrastructure and sustainable development at Dawson Creek, British Columbia, finalized such an agreement with Shell in order to help fund its proposed water treatment plant. "We needed to build infrastructure for treatment. Shell was the preferred proponent at that time. It was a great proposal and offered really to pay for just about the entire project," Henderson said.

Shell greatly benefitted from the project since it eliminated most of its the need for potable water for hydraulic fracturing.[65]

Brackish Water Pumping Can Impact Freshwater Resources if Not Carefully Managed

From: ***"Texas Alliance of Groundwater Districts," Irrigation Leader," June 2013***

Early versions of [groundwater utilization] bills would have essentially deregulated groundwater with a total-dissolved-solids (TDS) level of 1,000 parts per million or more [generally called brackish water] to promote its treatment and use. Texas GCDs (Groundwater Conservation Districts) had serious concerns with such a management strategy for numerous reasons, the most significant being that brackish groundwater is often hydrologically connected to other sources of water. Production of such water may cause freshwater levels to drop or actually affect the quality of freshwater as the hydraulic pressure regimes change.[67]

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[65] Ed Moore, "Town sells treated wastewater for hydraulic fracturing," *Edson Leader*, November 12, 2013.

[66] Reference footnote 63.

[67] Stacey Steinbach, "Texas Alliance of Groundwater Districts," *Irrigation Leader*, V. 4 Issue 6, June 2013.

[68] "Nestlé makes case for water pricing to boost efficiency gains," *Edie.net*, December 18, 2013, http://www.edie.net/news/4/Nestle-makes-case-for-water-pricing-to-boost-efficiency-gains/23751/

[69] Greg Manuel, "Pioneer, Hydraulic Fracturing Sustainable Development Initiatives, November 12 2013, http://ipec.utulsa.edu/Conf2013/Manuscripts_pdfs/Manuel_HydraulicFracturing.pdf

[70] Phil Winner, Niobrara and Bakken: How Water Management is Improving Operational Efficiencies, Niobrara Report, June 23 2013, http://www.niobrarareport.com/uncategorized/niobrara-and-bakken-how-water-management-is-improving-operational-efficiencies

Several analyses layout the compelling economic case for collaborative or centralized recycling:

- **In the Bakken**, cost reduction per barrel of oil of up to 46 percent could be realized, through advanced water recycling planning, equivalent to approximately $350 million annual savings for the region.[71]
- **The Niobrara formation** could realize up to 24 percent cost savings, resulting in $60 million regional savings. Savings are lower in this region compared to the Bakken due to lower produced water volumes and lower wastewater disposal fees.[72]
- **In the Eagle Ford**, an analysis of an operator's plans to drill approximately 1,400 wells over a five year period found a cost savings of 44 percent by pre-planning and establishing a centralized recycling system, which involved an initial outlay of $184 million but a net savings of $1.2 billion over a five year period.[73]
- **In the Marcellus**, an estimated $150,000 savings per well could be realized (~10 percent of total costs) by 100 percent recycling of flowback water, which minimizes trucking wastewater long distances often across the border to Ohio.[74]

For these cost savings to be realized, operators must be willing to take a longer-term view (e.g. five years) and commit to up-front capital expenditures. The economics can be compelling.

Some operators have already done the math are ramping up recycling efforts. Apache is already recycling 100 percent of its produced water in the Permian Basin.[75] Likewise, Approach Resources is also demonstrating that recycling can be done at scale by creating a network of pipelines and water-recycling infrastructure.[76] Other collaborative models include developing joint infrastructure for sourcing non-potable water resources.

Proactive water planning can potentially save 10 to 46 percent of well development costs which can result in tens of million of dollars in regional savings.

Benefits of Recycling

From: ***"Fracking Without Freshwater at a West Texas Oilfield," Reuters, November 2013***

"In these plays, every dollar counts," John Christmann, who runs the Permian operation for Apache, told Reuters recently. Excluding outlays for its homegrown recycling system, Apache says it costs 29 cents a barrel to treat flowback water, a fraction of the $2.50 per barrel it costs to dispose of water using a third party.[77]

3 *Operational Recommendation #3:* ***Limit use of deep disposal wells.***

Most operators, especially in drier regions, don't recycle water because of the availability of deep well injection sites where hydraulic fracturing wastewater can be disposed of at almost no cost (excluding trucking costs). The U.S. Environmental Protection Agency (EPA) oversees the Underground Injection Control (UIC) program under the authority of the federal Safe Water Drinking Act (SDWA). This law sets minimum standards for construction, monitoring, and testing of injection wells for oil and gas wastes (Class II wells). The wells, although regulated, are often owned and operated by private owners or by the operators themselves. Fees charged for disposing of this water are low or non-existent.

To minimize trucking costs, disposal wells have been built out across entire regions for the sole purpose of receiving wastewater. Ironically, one of the more water abundant shale plays in the country, the Marcellus, has the highest recycling rates (estimated at 66 percent) because geologic conditions are poorly suited for deep disposal wells.[79]

Disposal Wells Make it Too Easy to Dispose Water that Otherwise Could be Recycled

From: ***"Drillers Begin Reusing 'Frack Water,'" Wall Street Journal, November 2012***

Clay Terry, strategic business manager of Halliburton's Water Solutions unit, said operators in areas such as Texas have been slow to embrace recycling, largely because using injection wells there is fairly inexpensive.[78]

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[71] Reference footnote 70

[72] Reference footnote 70

[73] Christopher Robart, "Water Management Economics in the Development and Production of Shale Resources," *International Association for Energy Economics*, First Quarter 2012.

[74] Marcus Gay et al, "Water Management in Shale Gas Plays," *IHS Water White Paper*, August 2012.

[75] Anna Driver and Terry Wade, "Fracking without Freshwater at a West Texas Oilfield," *Reuters*, November 21, 2013.

[76] Walter Glascow, VP of Operations, presentation on "Designing, Selecting Materials and Installing Pipeline Infrastructure for Water Recycling, for Shale Play Water Management Summit in the Southern States," Dallas, Texas, November 2013.

[77] Reference footnote 75

[78] Alison Sider, Russell Gold and Ben Lefebvre, "Drillers Begin Reusing 'Frack' Water," *Wall Street Journal*, November 20, 2012.

[79] Brian Lutz, Aurana Lewis and Martin Doyle, "Generation, transport, and disposal of wastewater associated with Marcellus Shale gas development," *Water Resources Research*, Vol. 49, Issue 2, February, 2013.

Deep well injection of water represents consumptive use of water, which is no longer available to the hydrological cycle. By contrast, water use for other purposes such as watering golf courses or generating electricity can be high, but a large percentage of the water remains in the hydrological cycle. Most of the water used for cooling during electricity generation, for example, is released back into local water sources.

Disposal wells also have risks. And although other industries have historically used deep well injection sites to dispose wastewater, shale energy developers have taken their use to an entirely different level. Numerous research studies in Colorado, Arkansas, Ohio, Oklahoma and Texas have connected wastewater injection sites to seismic activity.[80, 81, 82] Oklahoma's insurance commissioner is now encouraging citizens to buy earthquake insurance—at an estimated cost of $100-$600 per household.[83] Oklahoma has experienced about 40 earthquakes a year since 2009, up from just one to three a year between 1978-2008. The upswing tracks closely with rising wastewater disposal from over 4,500 hydraulic fracturing wells across the state, according to a recent USGS study.[84]

Another risk associated with deep well injection sites is the possibility that contaminated fluids may migrate to aquifers or groundwater through natural fractures or abandoned or old wells.[86, 87] As shale development has grown, so has the proliferation of these disposal sites. There are an estimated 12,000-plus known disposal wells in Texas alone, but anywhere from 10,000 to 110,000 additional abandoned or orphaned wells about which little is known.[88]

Rising Externalities from Deep Disposal Wells

***From:** "Earthquakes: Victims Think Drilling Triggered Shaking and That's OK," Energy Wire, July 2012*

Joe Reneau bought an insurance policy a few years ago after earthquakes started rattling Oklahoma City's eastern suburbs and after one shook his house in February 2010. Shortly before the November earthquake, he received a notice saying the policy would be canceled Dec. 1, 2011.

"I won the earthquake lottery," he quipped.

Annual premiums have since risen from $25 to $600 and that's for reduced coverage. His newest policy has 18 pages of exclusions, and his deductible has gone up five-fold, to 10 percent of the house's value.

Meanwhile, some companies have stopped offering any new quake coverage in the state.[85]

4 *Operational Recommendation #4: **Develop source water protection plans that address water risks, support projects that improve watersheds or aquifers and include participation from key stakeholders.***

Operators must understand the nature of their impacts on water resources and think comprehensively and long-term about water source planning by addressing competition risks, scarcity concerns, engaging stakeholders and becoming more invested in local aquifer and watershed protection. For example, if water is sourced from environmentally sensitive headwater streams that have large seasonal fluctuations, perhaps through better planning, hydraulic fracturing water can be withdrawn and stored during high flows. Models such as "groundwater banking" schemes should also be considered.[89]

Often shale energy relies on water resources that are shared with agriculture. More effort should be made to work together to invest in water efficiency measures and to protect shared water resources.

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[80] Scott Davis and Cliff Frohlich, "Did (or Will) Fluid Injection Cause Earthquakes? Criteria for a Rational Assessment," *Seismological Research Letters*, Vol. 64, No. 3-4 July-December 1993.

[81] Cliff Frohlich, "Two-Year Survey Comparing Earthquake Activity and Injection-Well Locations in the Barnett Shale, Texas," *Proceedings of the National Academy of Sciences*, July 2012.

[82] National Research Council, "Induced Seismicity Potential in Energy Technologies," June 2012.

[83] Assumes median insurance premium of $350 and 1,342,293 households in OK. See: http://www.census-charts.com/HF/Oklahoma.html.

[84] USGS and Oklahoma Geological Survey, "Earthquake Swarm Continues in Central Oklahoma," October 2, 2013.

[85] Mike Soraghan, "Earthquakes: Victims Think Drilling Triggered Shaking, and That's OK," *Energy Wire*, July 24, 2012.

[86] Railroad Commission of Texas, "Injection/Disposal Well Permit Testing and Monitoring Seminar Manual, Technical Discussion of Area of Review Issues," March 15 2012, http://www.rrc.state.tx.us/forms/publications/HTML/pmt-outl.php.

[87] Paul Bertetti, Ronald Green and Alan Morris, Southwest Research Institute, "Risk Concerns Associated with Waste Disposal of Hydraulic Fracturing Fluids by Deep Well Injection," presented at the Unconventional Oil and Gas Water Management Forum, July 9-11, 2013.

[88] The environmental risks from the use of deep well injection sites is not part of the EPA's "Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources: Progress Report," December 2012, http://www2.epa.gov/hfstudy.

[89] For more information on the concept see: Juliet Christian Smith, The Pacific Institute, "Improving Water Management through Groundwater Banking: Kern County and Rosedale-Rio Bravo Water Storage District," 2013, http://www.pacinst.org/wp-content/uploads/2013/02/groundwater_banking3.pdf.

5 *Operational Recommendation #5:* ***Minimize the use of aquifer exemptions.***

Regulations of varying degrees are already in place that outline how shale oil and gas wells are to be drilled and cemented to protect aquifers and drinking water sources. The goal of these regulations is to fully isolate aquifers and other drinking water sources from hydraulic fracturing fluids going into wells and wastewater and oil and gas coming back out. However, oil and gas operators can often apply for an "aquifer exemption" in regions where aquifers are "not currently being used or will not be used in the future as a drinking water resource."[91, 92] Once exempt, the operator does not need to protect the aquifer during drilling operations and can oftentimes use it for wastewater disposal. Local communities are increasingly protesting the granting of aquifer exemptions for oil and gas and other mining operations.[93]

Widespread use of these exemptions is short-sighted. Prolonged drought, potential climate change impacts and population growth means that aquifers once deemed too remote or brackish may be needed as future water sources. The U.S. Geological Survey is only now beginning to locate and map brackish groundwater resources as potential future drinking water sources.[94]

6 *Operational Recommendation #6:* ***Engage with companies in the hydraulic fracturing supply chain, especially suppliers of hydraulic fracturing sand proppant.***

Water is used in many stages of the upstream energy development process and water consumption isn't limited to the well operators alone. Suppliers throughout the operator's supply chain also consume large quantities of water. Sound water stewardship associated with hydraulic fracturing therefore requires that operators engage companies throughout their supply chain on water efficiency efforts. One especially water-intensive activity is the mining and preparing/processing of sand used in the hydraulic fracturing process.[95] Also, sand is sometimes mined near rivers which can be impacted by disturbance to the nearby habitat. Large amounts of sand, called proppant, are used to "prop" open the fractures in the rock created by drilling (up to two pounds for every gallon of water pumped into a Barnett well, for example).[96] Several operators and service providers own their own sand mining operations, while other companies specialize in sand mining and delivery for hydraulic fracturing.[97] Operators should engage with all suppliers to ensure that sand not be mined in areas that impact local waterways.

Groundwater Risks Associated with Disposal Wells

From: ***"Fracking Disposal Wells Pose Challenges in Texas," NPR's State Impact Texas, March 2013***

Disposal well operators are generally required to leave at least 250 feet of impermeable rock or clay between "usable quality water" and the area where the wastewater will be injected.

When applying for a permit, they must also promise to survey (and plug, if necessary) all wells within a quarter mile. But some older oil wells may not be in state databases, according to Ronald Green, a scientist with the Southwest Research Institute, a nonprofit organization based in San Antonio that has done research on hydraulic fracturing and groundwater.

Green also said that "when you inject fluids, they may not only go a quarter mile, they may go a fair bit further than that."

Railroad Commission records show at least five violations against disposal wells last year for the improper plugging of old wells.[90]

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[90] Terrence Henry and Kate Galbraith, "Fracking Disposal Wells Pose Challenges in Texas," NPR's StateImpact Texas, March 29, 2013, http://stateimpact.npr.org/texas/2013/03/29/fracking-disposal-wells-pose-challenges-in-texas/.

[91] Legal Information Institute, "40 CFR Part 146—Underground Injection Control Program: Criteria and Standards," Cornell University Law School website, http://www.law.cornell.edu/cfr/text/40/part-146.

[92] Bill Freeman and Daniel Arthur, "Aquifer Exemptions: Wise use of environmental protection resources," SPE 29760, 1995.

[93] Petition by Goliad County Farm Bureau to Fifth Circuit to review EPA action that would exempt portion of the Goliad aquifer from protection from uranium mining operations. Case 13-60040.

[94] USGS, "National Brackish Groundwater Assessment Factsheet," http://ne.water.usgs.gov/ogw/brackishgw/files/brackish_infosheet_v8.pdf.

[95] In addition to the environmental impacts from mining the sand, these operations also require a large amount of water to wash and sort the sand. See http://www.fracdallas.org/docs/sand.html and http://dnr.wi.gov/topic/Mines/documents/SilicaSandMiningFinal.pdf.

[96] Curry et al, "Less Sand May Not be Enough," *Society of Petroleum Engineers Paper*, 131783, 2010.

[97] Publicly listed sand suppliers for hydraulic fracturing include US Silica (SLCA) and Hi-Crush (HCLP). EOG, Pioneer and Halliburton also own sand mining operations for hydraulic fracturing.

Strengthening Stakeholder Engagement

Determining how water resources will be protected for current and future needs by end-users is often a long and complicated process involving a broad array of stakeholders. One reason hydraulic fracturing is sparking public concern in various regions is that it is a relatively new demand for water. At the regional, municipal and county levels, in particular, existing long-term water supply and demand management plans must now cope with a new and often substantial demand on their supplies.

Operators in other extractive industries, such as mining, are often required to develop comprehensive water sourcing plans with local water managers and in consultation with surrounding communities before they begin operating. It is in their self-interest to ensure that water needs and demands are carefully projected and shared with other local stakeholders. The shale energy industry, however, is highly fragmented: there may be hundreds of operators in any given region, making it hard to measure the cumulative impact on local water resources. This fragmentation heightens the need for such efforts to ensure no loss of license to operate.

The recommendations below represent leading practices on external and internal stakeholder engagement, many of them based on frameworks outlined in the Ceres Aqua Gauge.[99]

1 *Stakeholder Recommendation #1:* ***Engage with communities before operations commence and continue engagement on an ongoing basis.***

A common complaint from communities about shale energy development is that they felt unprepared to deal with the rapid pace of development. The more proactive communication with stakeholders in targeted areas of future development, the better. For example, in the Haynesville play in Louisiana, communities received advance notice of future development. This allowed local policymakers, in conjunction with Louisiana State University, to set up a network of groundwater monitors to collect important baseline aquifer data before shale development commenced. This gave the community both key data and a sense of control in managing the development.[100]

Robust community engagement is a commitment to systematically establish a two-way communication process between companies and diverse stakeholders. Listening is just as important, if not more so, than having rapid-fire answers to community concerns.

Exempting Aquifers from Protection May be Short-Sighted

From: ***"Poisoning the Well: How the Feds Let Industry Pollute the Nation's Underground Water Supply," ProPublica, December 2012***

"You are sacrificing these aquifers," said Mark Williams, a hydrologist at the University of Colorado and a member of a National Science Foundation team studying the effects of energy development on the environment. "By definition, you are putting pollution into them... If you are looking 50 to 100 years down the road, this is not a good way to go…

…Still, more than 100 exemptions for natural aquifers have been granted in California, some to dispose of drilling and hydraulic fracturing waste in the state's driest parts. Though most date back to the 1980s, the most recent exemption was approved in 2009 in Kern County, an agricultural heartland that is the epicenter of some of the state's most volatile rivalries over water.[98]

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[98] Abrahm Lustgarten, "Poisoning the Well: How the Feds Let Industry Pollute the Nation's Underground Water Supply," *ProPublica*, December 11, 2012.

[99] For further guidance on the recommendations, refer to the Ceres Aqua Gauge at http://www.ceres.org/aquagauge.

[100] Gary Hanson, "How are Appropriate Water Sources for Hydraulic Fracturing Determined? Pre-development Conditions and Management of Development Phase Water Usage," Louisiana State University Shreveport, as part of the proceedings of the Technical Workshops for the Hydraulic Fracturing Study: Water Resource Management, EPA, May 2011.

2 *Stakeholder Recommendation #2:* ***Work within and across industries to address water risks and impacts, including sharing water infrastructure and collective regional water management.***

While exploration for oil and gas is a competitive business, communities and operators benefit by working collectively on mutual water needs. By sharing water-sourcing infrastructure such as pipelines and treatment facilities, companies can reduce the trucking of water. Such shared facilities can also facilitate the buying and selling of wastewater and recycled water among operators and service providers.

The oil and gas industry can learn from other industries and sectors that have already begun to work collectively on managing common water resources. The "Roadmap to Zero" initiative, for example, is a shared commitment from major apparel and footwear companies to lead the industry towards zero discharge of hazardous chemicals by 2020.[101]

3 *Stakeholder Recommendation #3:* ***Establish programs to educate and encourage employees to take ownership of water issues, including incentives for reducing water use.***

Employees in the field are often the best agents for creative thinking to improve water efficiency and water management planning. Operator and service providers in the hydraulic fracturing industry should establish systems to communicate ideas up and down the corporate ladder and provide employee incentives for minimizing environmental and social impacts. Many companies in the industry have made significant progress in embedding health and safety issues into the culture of their organizations. Similar steps in employee awareness-building and training should be undertaken around environmental and water-related issues.

4 *Stakeholder Recommendation #4:* ***Integrate performance indicators and incentives around reducing water use into agreements with service providers and other contractors.***

Given that contractors in upstream oil and gas development are responsible for the majority of field-level activity, it is imperative that agreements with contractors include the requirement to publicly disclose key environmental indicators. In addition, incentives should be in place to drive water-use efficiency and to encourage reuse and recycling. Operators should also engage with contractors across the industry to achieve better communication and idea generation around improving water management.

Better Lines of Communication with Regulators is a Win-Win on All Sides

From: ***"Proceedings of the Technical Workshops for the Hydraulic Fracturing Study," Water Resources Management, EPA, May 2011***

Prior to beginning production in the Haynesville shale play, the voluntary Water Resources Committee of Northwest Louisiana (WRCNL) group, comprised of state, federal, water transfer specialists and operators, was formed to reduce reliance on the Wilcox aquifer. Groundwater users, such as district water systems and agriculture, were particularly concerned about hydraulic fracturing's impact on the aquifer. A non-potable aquifer was subsequently identified as an alternative supply for hydraulic fracturing water.[102]

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[101] See http://www.roadmaptozero.com.

[102] U.S. EPA, Proceedings of the Technical Workshops for the Hydraulic Fracturing Study, Water Resources Management, May 2011.

5 **Stakeholder Recommendation #5: *Engage with local and regional water regulators and communicate transparently water management plans and future needs.***

It is important to set up two-way channels of communication with regulators. Local regulators often have decades of experience managing local water resources and demand for that water. They can also steer companies toward alternative water resources when water competition and community concerns arise.

Providing local regulators in advance with information on water sourcing and development plans is another effective way to engage with local communities. Local regulators are typically the first to be called if local citizens have concerns. Being armed with information about operators' water sourcing plans will allow them to more effectively respond to local concerns.

A regulator's key objective is to ensure the sustainability of water resources and balance of competing water demands. In many regions, there is little or no data on groundwater resources. This lack of information typically increases local concerns about the impacts of hydraulic fracturing. The industry should consider capturing and sharing information it learns during operations about local water supplies with local regulators. Any information gathered during drilling on the location and depth of fresh and brackish groundwater layers found, for example, is invaluable for mapping and characterizing groundwater resources, thereby helping to ensure their long-term viability.

Helping Collect Data on and Monitor Groundwater Resources with Regulators

From: ***"The South Texas Drought and the Future of Groundwater Use for Hydraulic Fracturing in the Eagle Ford Shale," St. Mary's Law Journal, 2013***

In places such as west Texas, some operators have installed water meters on water sourcing wells to track water levels in the aquifers they are drawing from. Others are sharing pumping data with groundwater conservation districts in an effort to better monitor water usage and impacts on water levels in the area.[103]

Advancing Disclosure

Many disclosure channels are available for operators to make water data available to the investment community. These include company websites, annual reports, regulatory filings, sustainability reports, Carbon Disclosure Project (CDP) responses and the FracFocus reporting framework.

1 **Disclosure & Management Recommendation #1: *Provide information on total water volumes used for each play/basin, sources of water, future water requirements and water use efficiency goals.***

To fully understand water impacts, it is important to know not only how much water an operator uses, but also the sources being tapped. For example, operators should be required to disclose how much is being sourced from groundwater versus surface water. Data on how much water pumped underground, is returning to the surface (flowback) and is then reused for hydraulic fracturing (versus disposal in deep well injection sites) is critical for understanding how much freshwater is permanently being taken out of the system. This is the key metric that regulators and water managers need to have a complete picture of water requirements. This information is lacking in most state water use regulatory reporting requirements and in disclosures to investors. Many water managers readily concede they cannot assess the impacts of new hydraulic fracturing water demands because the data is missing. Investors similarly lament that they don't have full information to assess water risks.

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[103] Taelor Allen, "The South Texas Drought and the Future of Groundwater Use for Hydraulic Fracturing in the Eagle Ford Shale," *St. Mary's Law Journal: 2013*, Vol. 44, Issue 2, 2013.

Providing information on use of non-freshwater sources in regions, including breakdowns on recycling, brackish and non-potable water use and future use targets by play, will provide investors with an overview of how reliant operations are on local freshwater resources and if the company is vulnerable to potential water competition constraints.

2 *Disclosure Recommendation #2:* ***Provide information on percentage of revenues, operations and future growth estimates that come from regions facing water risks.***

To determine how material water risks are to current and future growth projections, investors need to know how reliant operators are on revenues from operations in regions facing water risk. Other water risks, such as seasonal variability of water, can also impact companies and water resources. For example, when the Susquehanna River Basin Commission withdrew water-sourcing permits for hydraulic fracturing in headwater streams in 2012, it had significant financial impacts on operators.[104]

Providing information on local water requirements for shale energy development versus local availability and use provides important context to judge the security of a company's future access to water and thereby growth. If current water use and future demand are high versus local needs and available resources, operators should have plans and programs in place for addressing such challenges.

3 *Disclosure Recommendation #3:* ***Provide data for current and future water volumes for operations other than hydraulic fracturing, such as sand-mining, drilling, water-flooding, and for maintaining wells.***

As noted earlier, water is used in many ancillary processes associated with hydraulic fracturing such as sourcing sand and drilling. Studies in Texas suggest that these two additional uses increased water use per well by 25 percent.[105]

For oil production, in particular, large amounts of water may be required to re-pressurize a well, a process called water-flooding. Limited information is available on how widely this technique is being used in shale oil plays, but volumes of water required have historically been many times greater than for hydraulic fracturing. Maintenance water (water that is flushed down into the well bore to dissolve the large amounts of salt precipitating in the well and pipes) is another key water use, especially in North Dakota's Bakken region, which requires high "maintenance" flows due to the high salt levels in the wells. This could add up to 6.6 million to 8.8 million gallons per well over the entire life of the well (which could reach 30 years), more than three to four times the water required for the initial hydraulic fracturing.[106]

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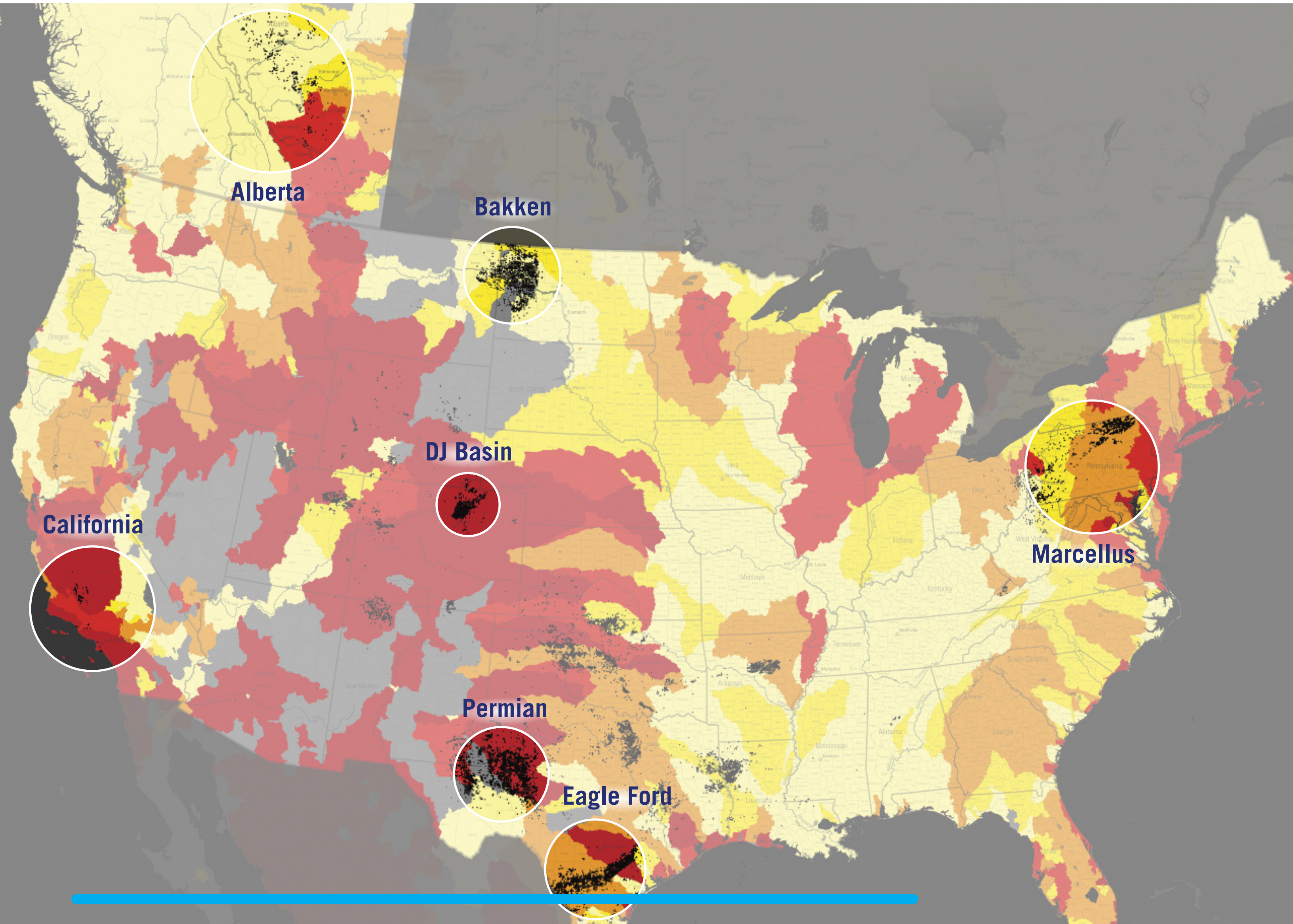
[104] Susquehanna River Basin Commission, Press Release, "64 Water Withdrawals for Natural Gas Drilling and Other Uses Suspended to Protect Streams," July 16, 2012.

[105] JP Nicot and Bridget Scanlon, "Water Use for Shale-Gas Production in Texas, US, Environmental Science and Technology, Supporting Information," March 2012.

[106] Patrick Kiger, "North Dakota's Salty Hydraulically Fractured Wells Drink More Water to Keep Oil Flowing," *National Geographic*, November 11, 2013.

Regional Case Studies

To provide a more in-depth view of hydraulic fracturing water sourcing trends and issues, this section analyzes eight regions—six in the United States, two in western Canada—that are in different stages of shale development and facing widely varying water challenges. These case studies explore the Eagle Ford play and Permian Basin in Texas, California's Monterey shale region, the Bakken region of North Dakota, the Marcellus (centered in Pennsylvania), Colorado's Denver-Julesburg Basin (Niobrara formation) and water use patterns in British Columbia and Alberta. Insights from these regions will be helpful as shareholders, lenders, producers and policymakers confront future water scarcity and competition concerns at the local and regional levels.



Texas

Rapid hydraulic fracturing growth in Texas, the nation's most active shale energy state by far, is causing serious water competition challenges. Growing water demand from the industry is coupled with prolonged drought conditions, aquifer depletion from irrigation and population growth.

Total water use for hydraulic fracturing in 2012 was an estimated 25 billion gallons—half of the total hydraulic fracturing-related water use nationwide that year—with the Eagle Ford, Permian, Barnett and Haynesville shale plays/basins being the biggest water users. Looking forward, Texas water use for hydraulic fracturing is expected to reach approximately 40 billion gallons by the 2020s.[1]

Though conditions have improved from the drought three years ago, over 70 percent of the state is experiencing drought.[2] According to the Texas Water Development Board's Reservoir Status Tracker, many reservoirs, especially in west Texas, are still less than 25 percent full.[3]

Additionally, the state's population is expected to rise by an additional 10 million to 34 million by 2030.[4] Testament to widespread concerns about meeting future water demand, Texas voters in November 2013 approved a constitutional amendment to use $2 billion from the state's rainy day fund (replenished by oil and gas revenues) to invest in new water infrastructure.

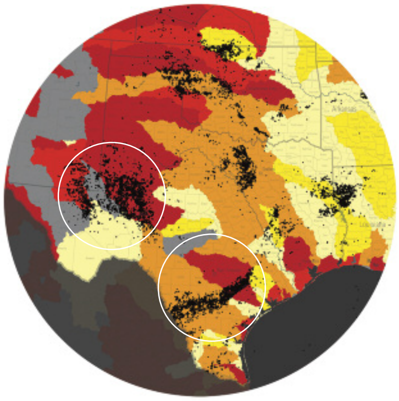
The Texas Water Development Board stressed the seriousness of the state's water challenges:

> *"The primary message of the 2012 State Water Plan is simple: In serious drought conditions, Texas does not and will not have enough water to meet the needs of its people, its businesses and its agricultural enterprises."*[5]

Meeting the state's shale energy water needs is complicated by the industry's lack of disclosure:

> *"The mining category has been particularly difficult to analyze and project due to the isolated and dispersed nature of oil and gas facilities, the transient and temporary nature of water used, and the lack of reported data for the oil and gas industry."*[6]

Overall, water use for shale production in Texas is relatively small compared to that used for irrigation (56 percent) and municipal water (27 percent).[7] Nonetheless, shale producers are having significant impacts at the county level, especially in smaller rural counties with limited water infrastructure capacity. With water use requirements for shale producers in the Eagle Ford already high and expected to double in the next 10 years, these rural counties can expect severe water stress challenges in the years ahead.[8]



Total water use for hydraulic fracturing in Texas in 2012 was an estimated 25 billion gallons—half of the total hydraulic fracturing-related water use nationwide that year.

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[1] JP Nicot et al, "Oil and Gas Water Use in Texas: Update to the 2011 Mining Water Use Report," Bureau of Economic Geology, The University of Texas, Austin, September 2012.

[2] Eric Berger, "Weekly Weather: Texas Drought Condition are the Best They've Been in Three Years," November 11, 2013, http://droughtmonitor.unl.edu/Home/StateDroughtMonitor.aspx?TX.

[3] Ryan Murphy and Kate Galbraith, "Data App: Track Texas Reservoir Levels," *Texas Tribune*, January 15, 2014, http://www.texastribune.org/library/data/texas-reservoir-levels/.

[4] Texas State Water Development Board, Quick Facts, Chapter 3: "Population and Water Demand Projections," 2012, http://www.twdb.state.tx.us/publications/state_water_plan/2012/03.pdf.

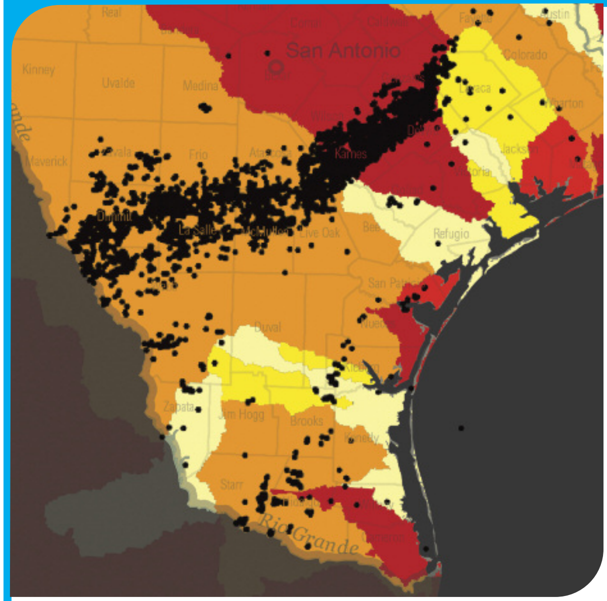
[5] Reference footnote 4

[6] Reference footnote 4

[7] Reference footnote 4

[8] JP Nicot et al, "Oil and Gas Water Use in Texas: Update to the 2011 Mining Water Use Report," Bureau of Economic Geology, University of Texas at Austin, prepared for the Texas Oil and Gas Association, September 2012.

Eagle Ford



Eagle Ford Data Summary (January 1, 2011 - May 31, 2013)

WATER USE TRENDS

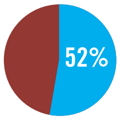
Total Water Use *(gallons)*:	**19.2 billion**
Average Water Use *(gallons/well)*:	**4.5 million**

EXPOSURE TO WATER RISKS

Proportion of Wells in **High or Extreme Water Stress:**	**28%**
Proportion of Wells in **Medium or Higher Water Stress:**	**98%**
Drought Region as of January 7, 2014 *(yes or no)*:	**Yes**
Groundwater Challenges *(yes or no)*:	**Yes**

LOCAL WATER USE IMPACTS

Concentration of Water Use: Top Three Water Use Counties as a Proportion of Total Water Use in Play



OPERATING TRENDS

	Gas	Oil
Total Wells Reported:	1,516	2,795

Number of Operators in Region: 68

OPERATORS
Top Three by Water Use

- Chesapeake
- Anadarko
- EOG

SERVICE PROVIDERS
Top Three by Water Use

- Halliburton
- Schlumberger
- C&J

Water Use Trends

Shale energy development in south Texas' Eagle Ford play began in earnest in 2008 and the play is now the state's biggest water user. Twenty-eight percent of the wells in the Eagle Ford are in high or extremely high water stress areas. Water use over our study period, at 19 billion gallons, is the highest in the country, coupled with relatively high average water use per well at 4.5 million gallons. The Eagle Ford is already far exceeding previous peak annual water demand estimates of 11 billion gallons.[9] Given the tremendous growth of shale energy activity—there are 68 operators reporting to FracFocus in the region—reassessment of water management plans and investor evaluation of water risks is needed.

Water Sourcing Risks:
Ongoing Drought & Groundwater Resources Under Stress

Much of the water sourced for this region is pumped from groundwater resources, which often belong to surface landowners (while oil and gas reserves belong to mineral landowners), making the long-term sustainability of groundwater use in the Eagle Ford region a big concern.[10] The region's primary groundwater resource is the Carrizo-Wilcox aquifer. Due to major drawdowns from pumping over decades of overuse and very slow recharge rates (hundred of years), the southern part of this aquifer is rapidly being depleted. Groundwater wells have seen water

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[9] Reference footnote 8

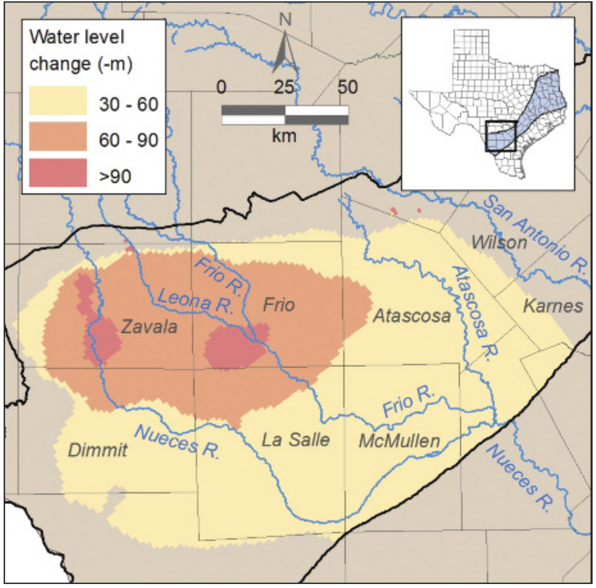
[10] Taelor Allen, "The South Texas Drought and the Future of Groundwater Use for Hydraulic Fracturing in the Eagle Ford Shale," *St. Mary's Law Journal: 2013*, Vol. 44, Issue 2, 2013.

levels drop between 100 feet to more than 300 feet over the last 50 years in parts of Dimmit, La Salle and Zavala counties (**Figure 20**).[11]

The continued drought in many of these regions is further exacerbating these challenges, especially after the Texas governor recently extended drought emergency measures across the high hydraulic fracturing water use counties of Dimmit, La Salle, Webb and Zavala.[12]

The large reductions in water levels in the Carrizo-Wilcox aquifer have already reduced the flows of many streams. Across an estimated 40 percent of the aquifer system, water which previously flowed toward the surface, is now flowing away from it. This change in natural water flows decreases ground and surface water availability and reduces overall water quality.

FIGURE 20: CHANGE IN WATER LEVEL IN THE CARRIZO AQUIFER FROM PRE-DEVELOPMENT TO 1999



Dimmit, La Salle, Zavala and Frio counties are experiencing rapid groundwater declines as well as intense shale gas development.

Source: Huang et al, Sources of Groundwater Pumpage in a Layered Aquifer System in the Upper Gulf Coastal Plain, USA, *Hydrogeology Journal*, 20:783-796, 2012.

Aquifer depletion concerns have prompted several groundwater conservation districts to enact groundwater withdrawal restrictions for shale energy operators, however this requirement is far from state-wide as it is up to individual groundwater districts to enact these types of measures.[13] However, these restrictions and other legislative proposals looking to limit groundwater use may hit legal obstacles as the state's "Rule of Capture" law (which affords landowners the right to pump unlimited volumes of water) is seen as crucial to many in protecting their property rights. However, given competition of increasingly scarce water in Texas, old models around governing groundwater will be increasingly put into question.

High Water Use Counties

The Eagle Ford has two core plays, one in the west in Dimmit, La Salle and Zavala counties, the other south of San Antonio in Karnes and DeWitt counties. Of the top 10 counties with the highest reported hydraulic fracturing water use (**Figure 21**), Karnes, Gonzales and DeWitt stand out as counties highly exposed to water stress. Water use for hydraulic fracturing will continue to grow, triggering unprecedented county water demands.[15]

Aquifer Declines in the Eagle Ford Winter Garden Region

From: ***"Texas Groundwater Districts Face Bevy of Challenges," The Texas Tribune, August 2013***

"The water table continues to drop," said Paul Bertetti of the Southwest Research Institute in San Antonio, which studies the effects of hydraulic fracturing on water quantity and quality, particularly in the Eagle Ford Shale. He estimated that hydraulic fracturing accounts for one-third of the total water use in the Wintergarden Conservation District in South Texas.[14]

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[11] Yun Huang et al, "Sources of Groundwater Pumpage in a Layered Aquifer System in the Upper Gulf Coastal Plain USA," *Hydrogeology Journal*, 20:783-796, 2012.

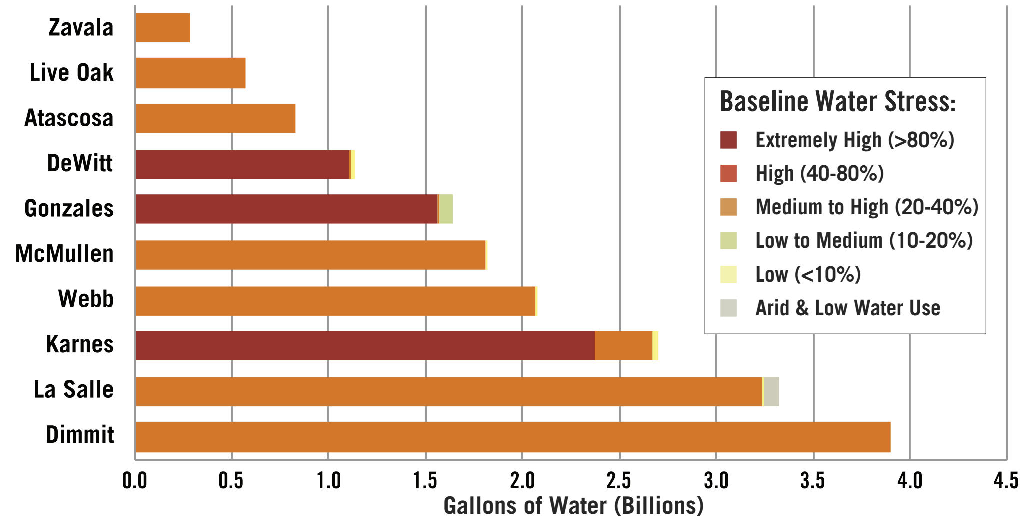
[12] Office of the Governor, "Gov. Perry Again Renews Proclamation Extending Drought Emergency," November 26, 2013, http://governor.state.tx.us/news/proclamation/19122/.

[13] Kate Galbraith, "Senate Committee Discusses Hydraulic Fracturing Groundwater Rules," *The Texas Tribune*, April 2, 2013.

[14] Neena Satija, "Texas Groundwater Districts Face Bevy of Challenges," *The Texas Tribune*, August 29, 2013, http://www.texastribune.org/2013/08/29/groundwater-districts-beset-increasing-water-/.

[15] JP Nicot et al, "Oil & Gas Water Use in Texas: Update to the 2011 Mining Water Use Report, Bureau of Economic Geology," The University of Texas at Austin, September 2012.

FIGURE 21: HIGHEST WATER USE COUNTIES IN THE EAGLE FORD BY WATER STRESS CATEGORY

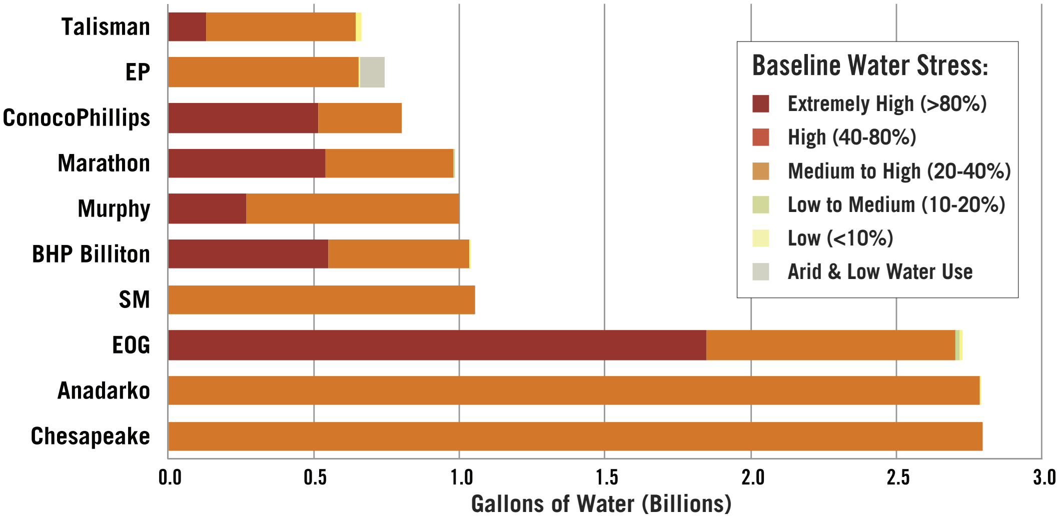


Top 10 counties in the Eagle Ford basin by hydraulic fracturing water use and water stress category.

Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

The Eagle Ford play has seen intense activity with over 4,300 wells drilled during the report's study period. Anadarko, EOG and Chesapeake are the most active operators, each having drilled about 500 wells (**Figure 22** and **Appendix C**). These companies, along with Marathon, SM Energy and Murphy, have large financial and water stress exposure to the region (**Figure 23**). Halliburton, Schlumberger and C&J were the most active service providers. All service providers in the region (many of which are unidentified since they are not reporting to FracFocus) are exposed to medium and extreme water stress (**Figure 24**).

FIGURE 22: HIGHEST WATER USE OPERATORS IN THE EAGLE FORD BY WATER STRESS CATEGORY



Sources: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

The Western Portion of the Carrizo-Wilcox Aquifer Recharges Very Slowly

From: ***"Eagle Ford Shale Turns Water into Gold as Need Outstrips Supply," San Antonio Express-News, December 2013***

The Texas Water Development Board's monitoring well in La Salle County last week showed water in the Carrizo-Wilcox aquifer at 496 feet below the surface, a drop of 247 feet from where it was 10 years ago.

"Water is like a piece of gold here, and it will continue to be," Cotulla City Administrator Larry Dovalina said at a recent Eagle Ford event. "At some point in time, we will look for water transfers from another region."…

…To the east, where average rainfall increases dramatically, the Carrizo-Wilcox generally is more prolific, recharges more easily and there are more aquifers that provide drinking water.

But in the Wintergarden district, it's the primary and best water source.

It's not like the limestone Edwards Aquifer in San Antonio, which rises nearly as soon as it rains. Water can move a mile a day through the Edwards. In the tight sandstone, it [Western Carrizo-Wilcox] moves feet per year, recharging slowly.[16]

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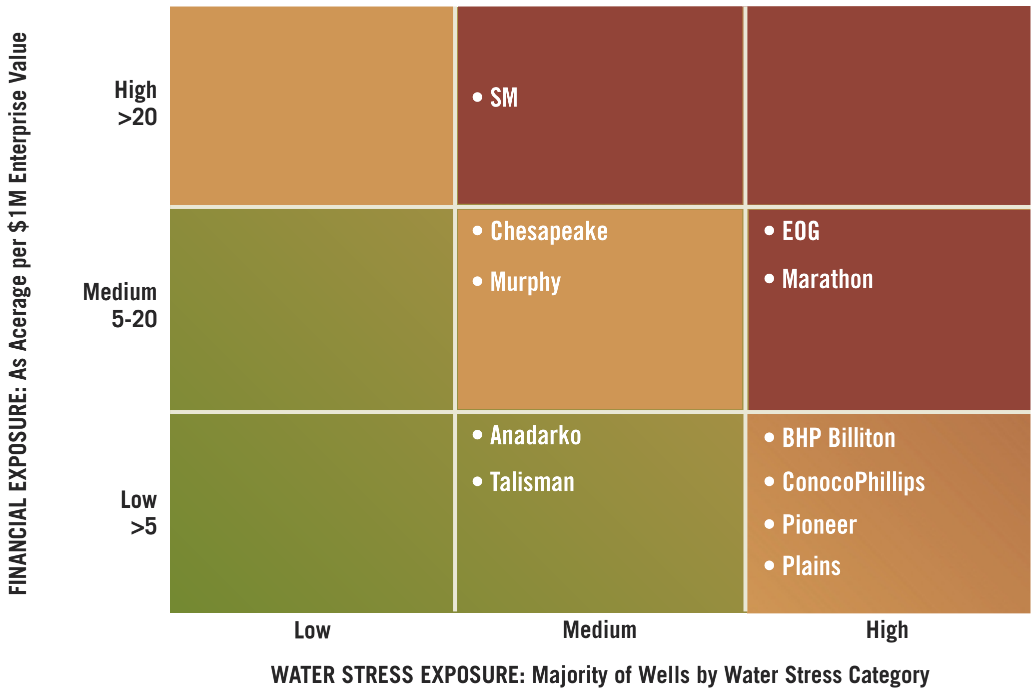
[16] Jennifer Hiller, "Eagle Ford Shale Turns Water into Gold as Need Outstrips Supply, Drilling is Draining on Drought-Stricken Area," *San Antonio Express-News*, December 21, 2013.

FIGURE 23: OPERATORS IN THE EAGLE FORD REGION BY FINANCIAL & WATER STRESS EXPOSURE

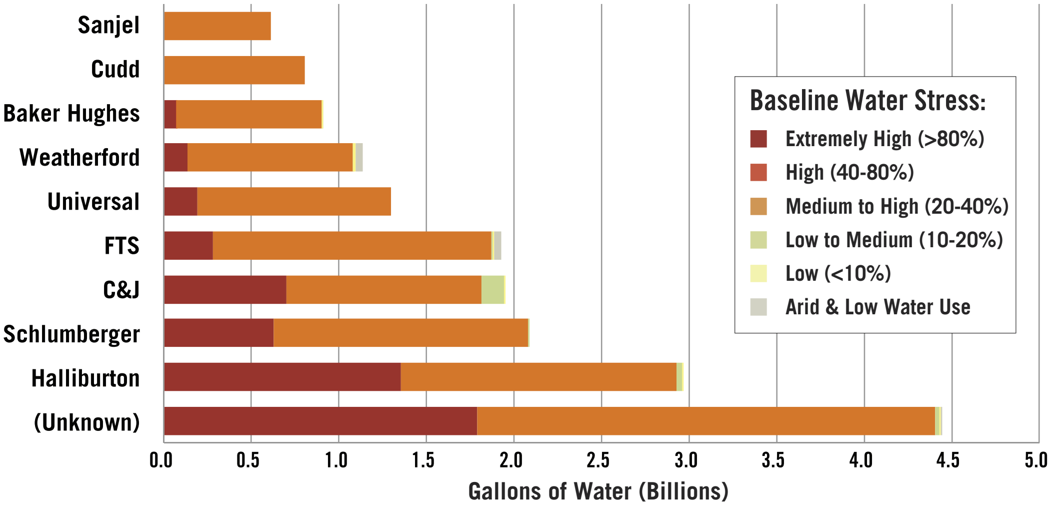
Analysis for publicly-listed operators with over 100 wells in region only.



FINANCIAL EXPOSURE: As Acerage per $1M Enterprise Value	Low	Medium	High
High >20		• SM	
Medium 5-20		• Chesapeake • Murphy	• EOG • Marathon
Low >5		• Anadarko • Talisman	• BHP Billiton • ConocoPhillips • Pioneer • Plains

Sources: Financial exposure data from Bloomberg BI as of 3Q 2013 for all operators except Chesapeake and Plains which is for 1Q 2013. Water stress exposure data: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org.

FIGURE 24: HIGHEST WATER USE SERVICE PROVIDERS IN THE EAGLE FORD BY WATER STRESS CATEGORY



Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

In many regions of the Eagle Ford recycling is seen as having low potential due to minimal volumes of water that return to the surface (flowback water) from hydraulic fracturing. The use of brackish groundwater as an alternative to freshwater is gaining popularity and currently provides an estimated 20 percent of water being used.[17] As identified previously, some brackish supplies may be needed in the future to meet local drinking water needs, so this water source should be carefully assessed.

➲ Engagement Recommendations for Lenders & Investors

Due to wide ranging challenges cited above, investors and lenders should prioritize companies with exposure in the Eagle Ford for engagement on water sourcing risks. Considering the large number of operators with significant investments in the region, collaborative action on water sourcing issues is required. Operational, engagement and disclosure recommendations outlined previously in this report provide best practice models. Anadarko, EOG, and Chesapeake, followed by many other operators that are committed to and active in this region should be looked to lead the way.

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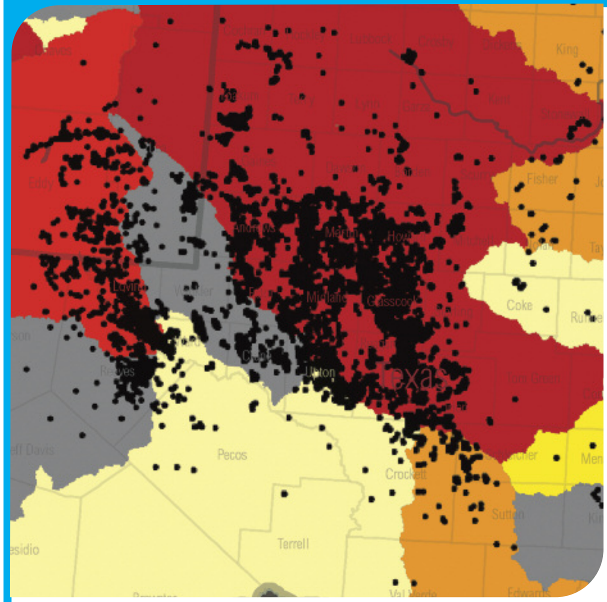
[17] JP Nicot et al, “Oil and Gas Water Use in Texas: Update to the 2011 Mining Water Use Report,” Bureau of Economic Geology, University of Texas at Austin, prepared for the Texas Oil and Gas Association, September 2012.

Permian Region



Permian Data Summary (January 1, 2011 - May 31, 2013)

WATER USE TRENDS

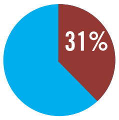
Total Water Use *(gallons)*:	**10.4 billion**
Average Water Use *(gallons/well)*:	**1.1 million**

EXPOSURE TO WATER RISKS

Proportion of Wells in **High or Extreme Water Stress:**	**87%**
Proportion of Wells in **Medium or Higher Water Stress:**	**88%**
Drought Region as of January 7, 2014 *(yes or no)*:	**Yes**
Groundwater Challenges *(yes or no)*:	**Yes**

LOCAL WATER USE IMPACTS

Concentration of Water Use: Top Three Water Use Counties as a Proportion of Total Water Use in Play



OPERATING TRENDS

Total Wells Reported:	
Gas	291
Oil	9,017

Number of Operators in Region:

155

OPERATORS
Top Three by Water Use

- Pioneer
- EOG
- Apache

SERVICE PROVIDERS
Top Three by Water Use

- Baker Hughes
- Halliburton
- Pioneer (as integrated operator & service provider)

Water Use Trends

The Permian Basin in west Texas and southeast New Mexico is noteworthy for its high percentage of wells—87 percent—situated in high or extremely high water stress areas. Average water use per well has been relatively low at 1.1 million gallons, however with increasing numbers of horizontal wells being developed average water use is up to 1.5 million gallons in 2013. [18] Overall water use in the Permian region was 6.6 billion gallons in 2012 and over 10 billion in our study period, and is expected to peak at approximately 13 billion gallons in 2020.[19, 20]

Water Sourcing Risks:

Continued Drought, Strained Groundwater Resources & Water Stress

The Permian Basin overlaps the southern portion of the High Plains aquifer (also known as the Ogallala aquifer), the Edwards-Trinity aquifers and the smaller Pecos River Basin. Much of the Permian Basin sits atop the southern portion of the High Plains aquifer, which has experienced some of the steepest water level declines in the United States, with an estimated 337 cubic kilometers of water withdrawn since 1950.[21]

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[18] JP Nicot et al, "Oil and Gas Water Use in Texas: Update to the 2011 Mining Water Use Report," Bureau of Economic Geology, University of Texas at Austin, prepared for the Texas Oil and Gas Association, September 2012.

[19] Reference footnote 18

[20] Jennifer Warren, "Permian Basin's Cline Play Reinforces Growth Potential," *Seeking Alpha*, November 21, 2013.

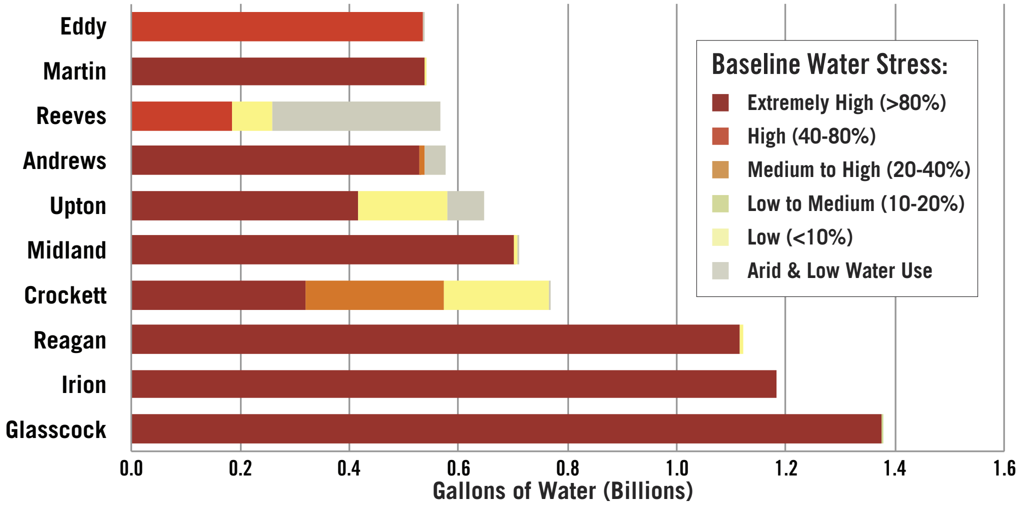
[21] V.L. McGuire et al, "Water-Level Changes in the High Plains Aquifer, Predevelopment to 2007, 2005-06, and 2006-07," U.S. Geological Survey Scientific Investigations Report 2009–5019.

Much of the water sourced from this region is pumped from groundwater resources. As previously mentioned, the oil and gas industry in Texas is largely exempt from reporting groundwater use (depending on the specific groundwater conservation district) and the precise amount of groundwater used by the industry is oftentimes unknown. As in the Eagle Ford, ongoing drought and escalating water competition in the Permian may lead to more widespread restrictions on water use and stronger management of water resources, especially with respect to groundwater withdrawals.

High Water Use Counties

The counties with the highest shale industry water use are Glasscock, Irion and Reagan (**Figure 25**). The amount of water used for hydraulic fracturing in Glasscock County—1.4 billion gallons—is about 10 percent of the amount of water reportedly used for irrigation in this 2,000-person county, according to the USGS's last survey.[22] This pattern repeats itself in much of the Permian region where there is low rural population density and competing water use from agriculture.

FIGURE 25: HIGHEST WATER USE COUNTIES IN THE PERMIAN BY WATER STRESS CATEGORY



Top 10 counties in the Permian Basin by hydraulic fracturing water use and water stress category. All counties are in Texas except for Eddy, which is in New Mexico.

Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

The highest water use operators in the Permian are Pioneer, EOG and Apache (**Figure 26**). These and other companies face high water stress and significant financial exposure in the region (**Figure 27**). High water competition challenges are encouraging companies to boost alternative water sourcing, especially through recycling and use of brackish water resources. Baker Hughes, Halliburton and Pioneer (as a fully integrated company) are the top three service providers in the region (**Figure 28**).

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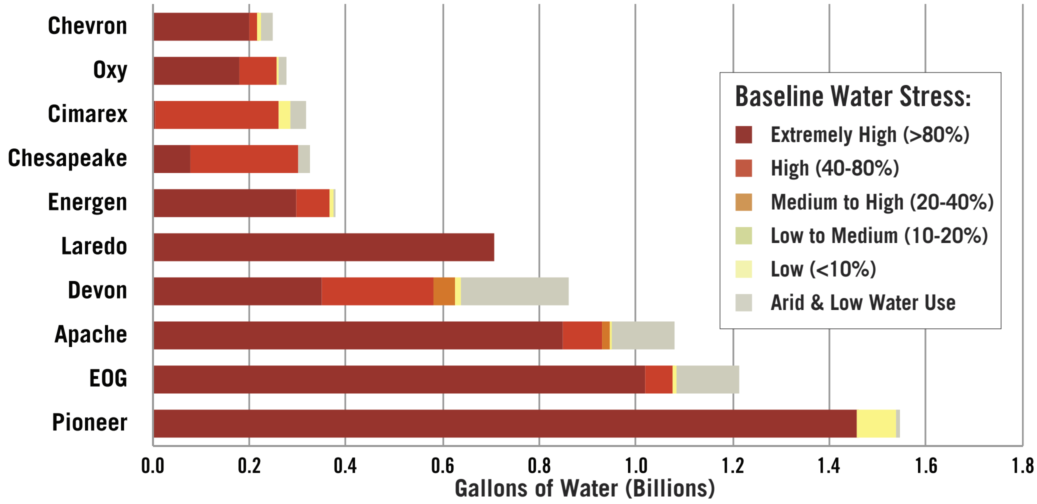
[22] U.S. Geological Survey, "Water Use in the United States, County-Level Data for 2005," http://water.usgs.gov/watuse/data/2005/.

FIGURE 26: HIGHEST WATER USE OPERATORS IN THE PERMIAN BY WATER STRESS CATEGORY



Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011 - May 2013.

FIGURE 27: OPERATORS IN THE PERMIAN REGION BY FINANCIAL & WATER STRESS EXPOSURE

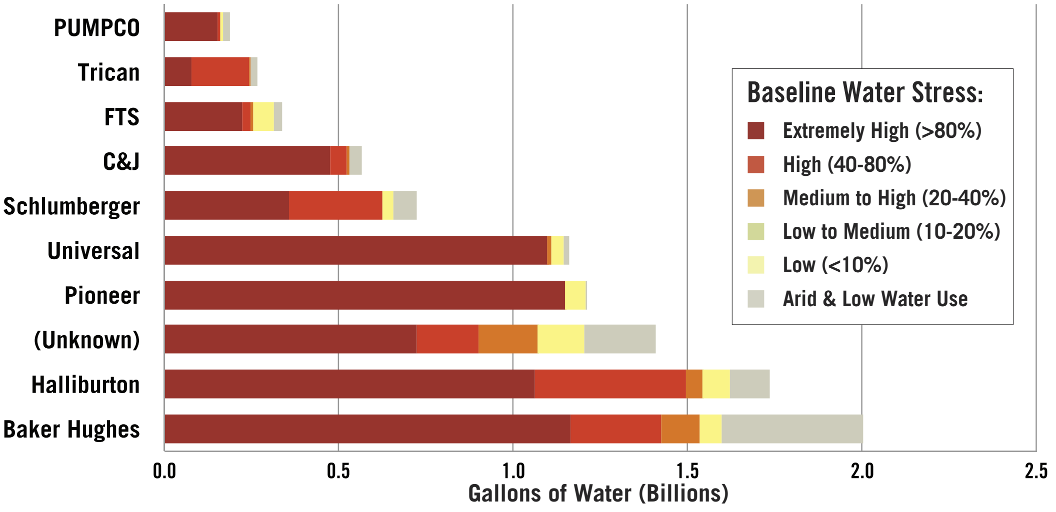
Analysis for publicly-listed operators with over 100 wells in region only.

	Low	Medium	High
High >20			• Cimarex • Concho • Energen • Apache • Pioneer • Devon • Laredo Petroleum • Oxy
Medium 5-20			• ConocoPhillips • Whiting • Anadarko • Chevron • EOG
Low >5			

Financial exposure data unavailable for Chesapeake, Athlon and XTO. Note all operators in the Permian face high water stress exposure.

Sources: Financial exposure data from Bloomberg BI as of 3Q 2013 for all operators. Water stress exposure data: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org.

FIGURE 28: HIGHEST WATER USE SERVICE PROVIDERS IN THE PERMIAN BY WATER STRESS CATEGORY



Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

Top operators in the region are beginning to take steps to mitigate water sourcing risks. Apache, in its most recent CDP water survey response, outlined water challenges it is facing in the region and how it is recycling most of its water.[23] EOG, in its CDP water survey response, states that it is experimenting with new ways to reuse water in the Permian.

Water recycling is seen as a promising option in many areas of the Permian due to high flowback levels and low salinity of produced water. Service providers and operators have been experimenting to make water recycling more technically feasible.[24] Brackish water use, available in the southern part of the High Plains aquifer, is also being used, although it should be carefully managed now and in the future.

➲ Engagement Recommendations for Lenders & Investors

Groundwater concerns, water stress and drought conditions are all extremely high in this region. Engagement with companies should focus on operational recommendations that will help minimize freshwater use. Collaborative water networks and longer-term planning around water infrastructure for oil and gas development should be a top priority. Groundwater banking and other creative measures such as evaporation covers on water pits (as practiced by Pioneer) should be expanded. In addition, it is critical that Board and executive level commitments be made to water management. Pioneer, EOG, Apache, Devon and Laredo have been the biggest water users in the Permian and should lead on several fronts, especially around the build-out of water infrastructure networks. Baker Hughes and Halliburton, as the biggest service providers, should also participate in advancing better practices.

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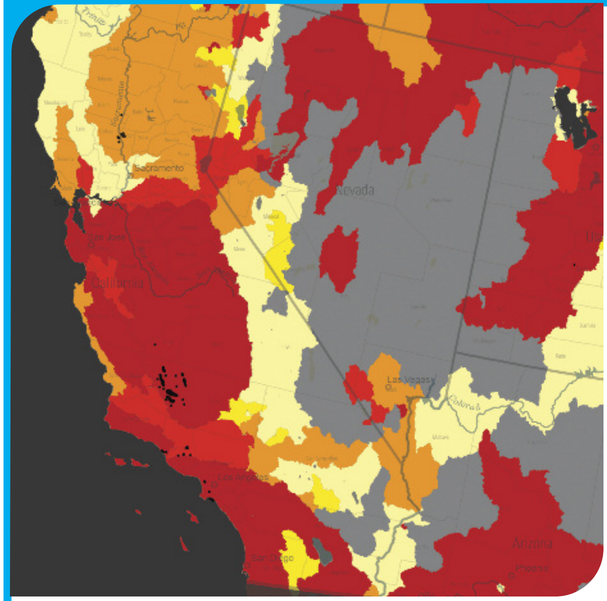
[23] Anna Driver and Terry Wade, "Hydraulic fracturing without freshwater at a west Texas oilfield," Reuters, November 21, 2013.

[24] For examples see: http://www.halliburton.com/public/pe/contents/Case_Histories/web/A_through_R/H09855.pdf and http://www.permianbasin360.com/news-article/more-oil-companies-reusing-water-at-hydraulic fracturing-sites/d/news-article/Wb6UzAi5uU2_BHz20HsU1A.

California



California Data Summary (January 1, 2011 - May 31, 2013)

WATER USE TRENDS

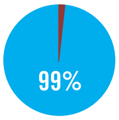
Total Water Use *(gallons)*:	113 million
Average Water Use *(gallons/well)*:	134,000

EXPOSURE TO WATER RISKS

Proportion of Wells in **High or Extreme Water Stress:**	98%
Proportion of Wells in **Medium or Higher Water Stress:**	100%
Drought Region as of January 7, 2014 *(yes or no)*:	Yes
Groundwater Challenges *(yes or no)*:	Yes

LOCAL WATER USE IMPACTS

Concentration of Water Use: Top Three Water Use Counties as a Proportion of Total Water Use in Play



OPERATING TRENDS

Total Wells Reported:	
Gas	19
Oil	829

Number of Operators in Region: 8

OPERATORS
Top Three by Water Use

- Occidental
- Aera (Shell & Exxon)
- XTO (Exxon)

SERVICE PROVIDERS
Top Three by Water Use

- Baker Hughes
- Halliburton
- Schlumberger

Water Use Trends

California's Monterey Shale formation is estimated to contain over 15 billion barrels of oil, or about two-thirds of shale oil reserves in the lower 48 states. Because the geology of the Monterey is technically challenging, fewer than 50 hydraulic fracturing wells have been drilled there and operators are trying different methods to extract oil from the formation.[1, 2] Most of the wells hydraulically fractured in California are outside of the Monterey play and most are in regions of high or extreme water stress (98 percent). Many wells are in the agriculture-rich Central Valley, which accounts for nearly half of U.S. fruit and vegetable production. Analysis of hydraulic fracturing-related water use is preliminary due to the small number of wells in production reported to FracFocus. Water use per well appears to be very low because of the region's reliance on acid fracs to stimulate the wells.[3] Nonetheless, between groundwater concerns and the state's recently declared "drought emergency," any expansion of water use for hydraulic fracturing in this region will likely spark strong public concern that could jeopardize the industry's social license to operate.[4]

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[1] Personal communication PacWest Consulting Partners.

[2] Jim Carlton, "Oil Firms Seek to Unlock Big California Field," *Wall Street Journal*, September 22, 2013, http://online.wsj.com/article/SB10001424127887323932604579052933974060844.html.

[3] Braden Carroll and Rory Reddall, "As California Sets the Ground Rules for Drilling in the Monterey Oil Formation, a Hard to Reach Shale Reserve that is the Largest in the United States, Some Environmentalists Worry that Politicians, Regulators and Fellow Activists are Fighting the Wrong Battle," *Reuters*, May 28, 2013.

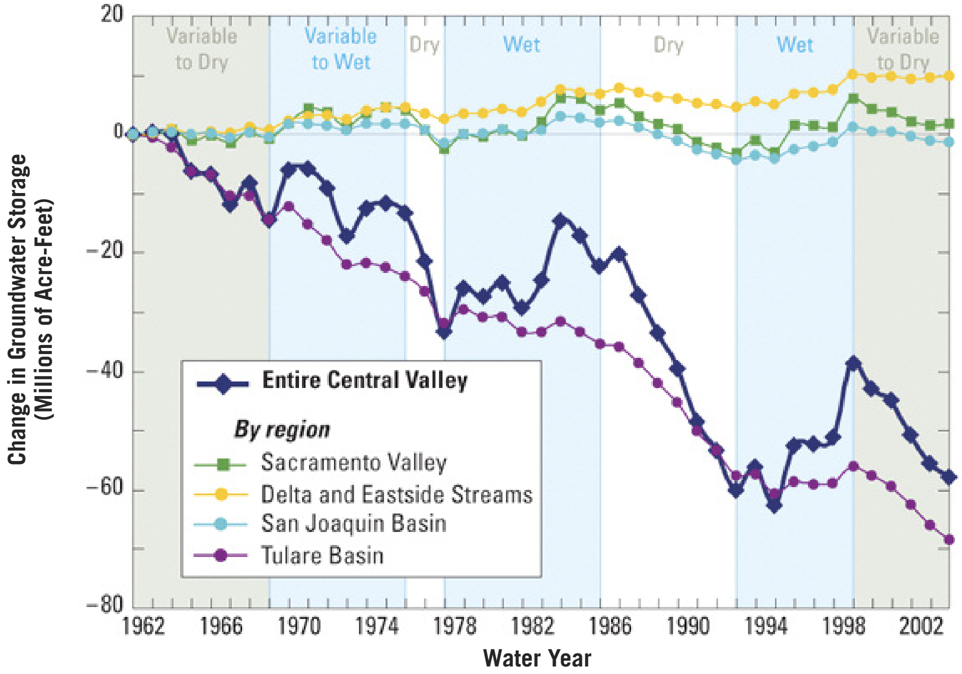
[4] Anthony York, "Gov. Jerry Brown Declares Drought Emergency in California," *The Los Angeles Times*, January 17, 2014.

Water Sourcing Risks: Groundwater Concerns, Growing Population Pressures & High Competition for Water

Groundwater provides an estimated one-third or more of the state's water supplies and these supplies are increasingly threatened.[5] Since the early 1960s, groundwater has been depleted by almost 60 million acre-feet (~19 trillion gallons), which is on average enough to supply every resident of California with water for eight years (**Figure 29**).[6] Like Texas, the state's groundwater governance and regulations are weak.[7]

About one-sixth of the nation's irrigated land is in the Central Valley and this region is one of the world's most productive agricultural areas, with over 250 crops grown with an estimated value of $17 billion annually. This agriculture depends on a combination of surface water irrigation (imported largely from the northern part of the state) and groundwater. However, ongoing drought in California and legal restrictions on water imports in recent years has forced Central Valley farmers to increasingly rely on pumping groundwater.[8]

FIGURE 29: VOLUMETRIC GROUNDWATER DECLINES IN CALIFORNIA'S CENTRAL VALLEY



Source: Claudia Faunt, Groundwater Availability of the Central Valley, U.S. Geological Survey, Paper 1766, 2009.

Over the near-term, water withdrawals are not a major issue given the reliance on acid well stimulation. However as operators experiment with different techniques to withdraw oil from the complex Monterey formation, water volume demands may change rapidly. Likewise, regardless of the low average volumes currently used, as in Texas, when citizens see convoys of trucks loaded with water going to hydraulic fracturing operations, there will likely be growing strains on the social license to operate, especially as the drought in California continues.

Groundwater Concerns are Significant in California

From: ***"Fracking Industry Eyes an Already Water-Starved California," Mintpress News, September 2013***

"Water levels are dropping dramatically in some areas," Steven Arthur, vice president for Arthur and Orum Well Drilling, told the Sacramento Bee. "It's never been this bad."

According to the U.S. Geological Survey, California's San Joaquin Valley, along with the Central Coast and Southern California areas are in crisis mode, as more water is being drawn from groundwater supplies than the amount of water entering the system.

The desperation expressed in the state's water wars doesn't bode well for the oil and gas industry, eager to put down the welcome mat for hydraulic fracturing operations.[9]

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[5] Jay Famiglietti and Sasha Richey, "California's Water House of Cards, " *Los Angeles Times* Oped, September 23, 2013, http://www.latimes.com/opinion/commentary/la-oe-famiglietti-california-groundwater-20130923,0,7356002.story.

[6] U.S. Geological Survey, "California's Groundwater Study," USGS -3057, 2009, http://pubs.usgs.gov/fs/2009/3057/.

[7] David Sneed, "California's Groundwater Management is like Texas: It's the Wild West," *The Tribune*, June 16, 2013.

[8] In September, the California Department of Water Resources (DWR) cautioned state residents to prepare for a possible third consecutive dry year in 2014, as the state moves into winter with little surplus in its reservoirs. Robert Lansing, "California Ag Board Examines State Water Issues, Drought Concerns," *Wine Business*, September 12, 2013.

[9] Tisha Marczak, "Hydraulic Fracturing Industry Eyes An Already Water-Starved California," *MintPress News*, September 11, 2013.

If the Monterey shale begins to be developed at scale, there will likely be more calls for greater rates of recycling. This will be needed as most existing deep well injections sites in California are already being used for the large volumes of wastewater coming from conventional oil development (~16 gallons for every gallon of oil produced).[10] Concerns about seismicity risks linked to deep well injection further underscore the potential importance of water recycling.[11]

Regulatory Trends

In September 2013, Governor Jerry Brown signed legislation regulating hydraulic fracturing (SB 4) which will require companies to apply for a permit to conduct hydraulic fracturing, publicly disclose the hydraulic fracturing chemicals they use, and report on the volume of water used and disposition of wastewater and monitor groundwater, among other requirements.[13]

With 47 percent of California's land federally owned, the Bureau of Land Management (BLM) also plays an important role in regulating activities in the state.[14] The BLM has put forth a new proposed set of environmental regulations to govern hydraulic fracturing, which are now under active review. These include stricter provisions that require a deeper analysis of cumulative impacts on the environment, including water resources, as part of the permitting process.[15]

High Water Use Counties

Most hydraulic fracturing activity to date has been centered in Kern County which is exposed to extremely high water stress, followed by Ventura, Los Angeles, Kings, Colusa, Glen and Sutter counties (**Figure 30**).

Kern County in southern California has a long history of oil development, pumping about three-quarters of California's oil from over 40,000 conventional oil wells in 2010. Kern also has an active agricultural sector with over 800,000 acres of irrigated farmland. Although the county meets demand through both surface and groundwater sources, its strong reliance on groundwater pumping the last several decades has resulted in substantial groundwater declines. Credit rating firm Moody's recently identified the Kern County Water Agency as being at risk of a credit rating downgrade, reflecting this region's vulnerability to growing water supply challenges.[17]

Although the oil and agricultural industries have coexisted for many years in Kern County, elevated water use for hydraulic fracturing in the context of massive drought could alter this course. There are growing concerns that the agriculture sector will find it more lucrative to sell their water for oil exploration than growing crops.

Population Almost Doubling

From: ***"California's Central Valley Groundwater Study," USGS, 2009***

"Competition for water resources is growing throughout California, particularly in the Central Valley. Since 1980, the Central Valley's population has nearly doubled to 3.8 million people. It is expected to increase to 6 million by 2020. Statewide population growth, anticipated reductions in Colorado River water deliveries, drought, and the ecological crisis in the Sacramento-San Joaquin Delta have created an intense demand for water."[12]

Groundwater Banking One Potential Way Forward

From: ***"Improving Water Management through Groundwater Banking: Kern County and the Rosedale-Rio Bravo Water Storage District," Pacific Institute***

Due to competition over water and groundwater depletion concerns Kern County has implemented water banking programs as one important water supply management tool to increase water supply reliability. Groundwater banking allows an entity to deposit water within an aquifer that can later be withdrawn by that entity and can be particularly useful in managing seasonal variability of water supplies.[16]

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[10] Department of Conservation, Division of Oil, Gas and Geothermal Resources, California, "Preliminary Report of California Report of California Oil and Gas Production Statistics 2012," Publication No. PRO3, April 2013.

[11] California Department of Conservation, http://www.consrv.ca.gov/dog/general_information/Pages/class_injection_wells.aspx.

[12] U. S. Geological Survey, "California's Central Valley Groundwater Study: A Powerful New Tool to Assess Water Resources in California's Central Valley, Fact Sheet 2009-3057, 2009, http://pubs.usgs.gov/fs/2009/3057/.

[13] For a narrative of the proposed rules see: http://www.conservation.ca.gov/dog/general_information/Documents/121712NarrativeforHFregs.pdf.

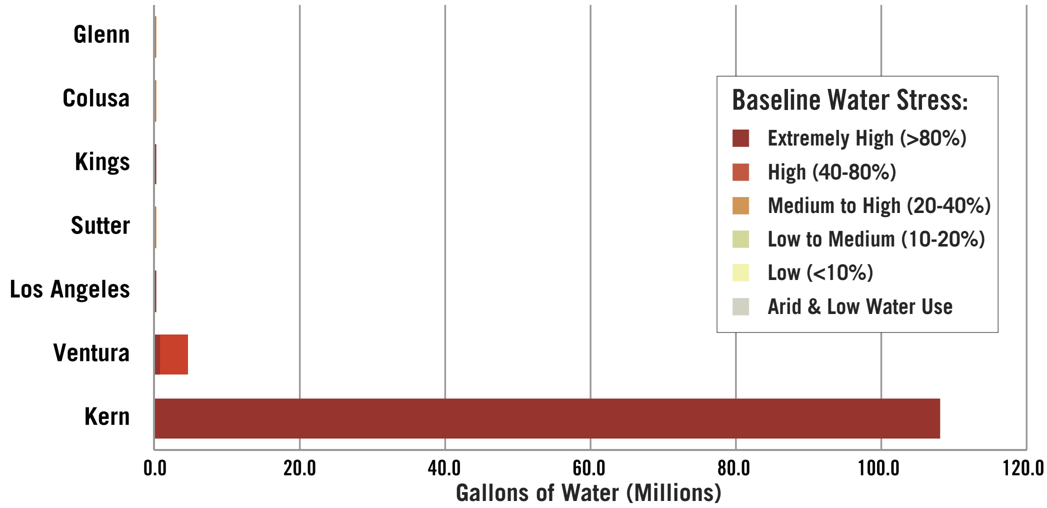
[14] Ross W. Gorte et al, "Federal Land Ownership: Overview and Data, Congressional Research Service," February 8, 2012, http://www.fas.org/sgp/crs/misc/R42346.pdf.

[15] Letter from The Nature Conservancy, "The Nature Conservancy Commends the Bureau of Land Management's Proposed Hydraulic Fracturing Rule as Progress Toward Safer Oil and Gas Development While Recommending Stronger Safeguards," http://www.nature.org/newsfeatures/pressreleases/nature-conservancy-commends-the-bureau-of-land-management.xml#sthash.zs5zwXRF.dpuf.

[16] Juliet Christian-Smith, Pacific Institute, "Improving Water Management through Groundwater Banking: Kern County and the Rosedale-Rio Bravo Water Storage District."

[17] James Nash, "Water Bonds Shrivel as California Sees Driest Year," *Bloomberg*, January 1, 2014.

FIGURE 30: HIGHEST WATER USE COUNTIES IN CALIFORNIA BY WATER STRESS CATEGORY



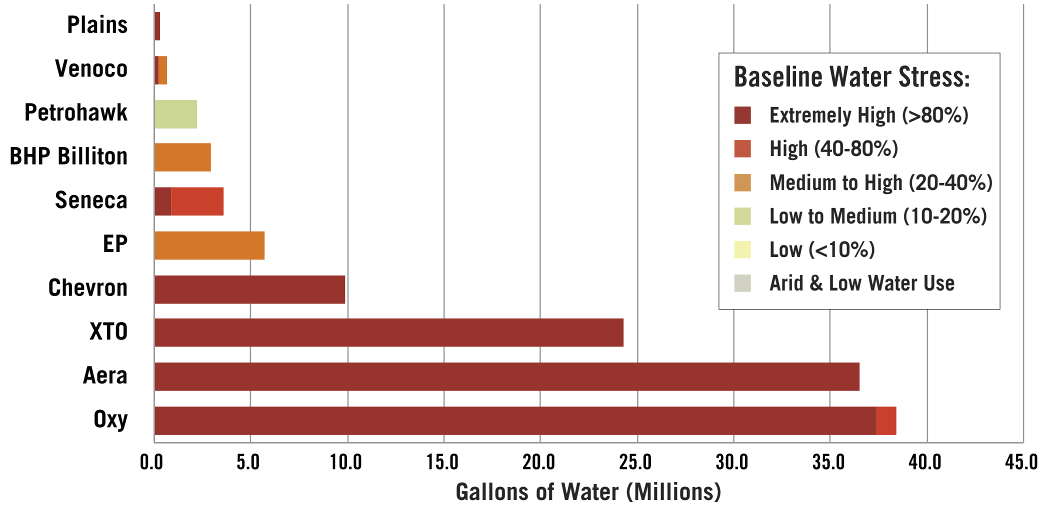
Highest hydraulic fracturing water use counties in California by water stress category. Total water use is relatively small versus other regions due to less water-intensive techniques such as acid stimulation.

Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

Companies Active and Exposed to Water Risks in the Region

Occidental Petroleum (Oxy), Aera (owned by Shell and Exxon) and XTO (owned by Exxon) are the highest hydraulic fracturing water users in California (**Figure 31**). Baker Hughes was by far the most active service provider (**Figure 32**).

FIGURE 31: HIGHEST WATER USE OPERATORS IN CALIFORNIA BY WATER STRESS CATEGORY



Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

Water Competition Rising as Water Supplies are Being Curtailed

From: ***"Integrated Water Management Plan for Kern County," October 2011***

Water demands within the Kern Region are serviced by a variety of water purveyors, including the large wholesale agency, The Kern County Water Agency (KCWA) and its member districts (both agricultural and municipal) and industrial, irrigation districts, investor-owned water companies, mutual water companies, municipalities and private well owners. Water supplies utilized in the region are the State Water Project (SWP) via the California Aqueduct, the Central Valley Project (CVP) via the Friant-Kern Canal, and local surface supplies from the Kern River and other local streams, as well as the largest common groundwater basin, the San Joaquin Valley groundwater basin, covering the majority of the managed resources in the Region.

Increasing development demands on water availability and quality for agricultural and Municipal and industrial purposes, coupled with curtailments of imported SWP and CVP deliveries due to prolonged drought and regulatory restrictions, have intensified the competition for available water supplies in the region.[18]

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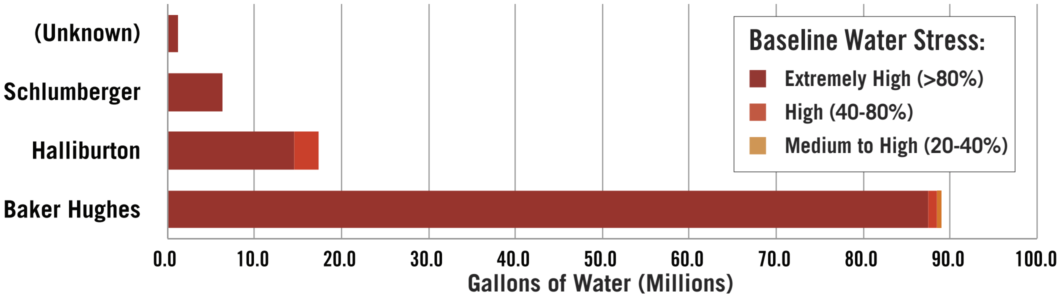
[18] Tulare Lake Basin Portion of Kern Council, Integrated Resource Water Management Plan, Kennedy/Jenks Consultants, prepared for Kern County Water Management Plan, October 2011.

FIGURE 32: HIGHEST WATER USE SERVICE PROVIDERS IN CALIFORNIA BY WATER STRESS CATEGORY

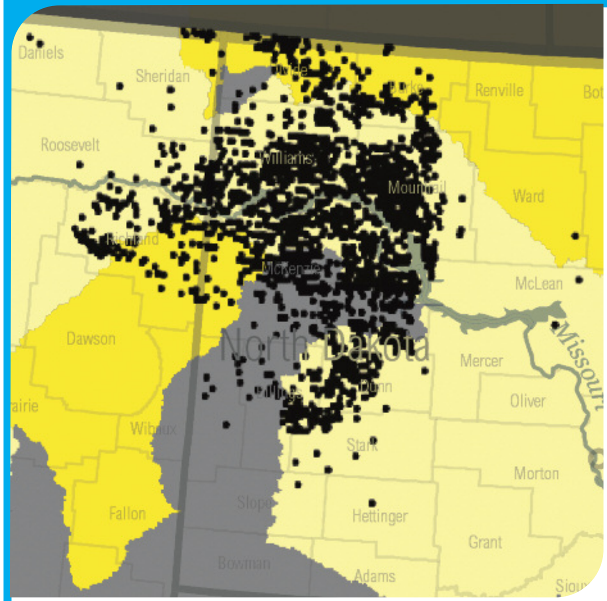


Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

➲ Engagement Recommendations for Lenders & Investors

In light of the intense competition for water from the agricultural community in this region, growing groundwater concerns and intense drought, investors and lenders should focus their engagement on companies with significant presence or expansion plans in the region. Baker Hughes, the dominant service provider in the region, as well as Occidental, Shell, Exxon and Chevron, the largest operators, should be prioritized for engagement on their stakeholder engagement practices and policies. In addition, given large produced water volumes and seismicity concerns, recommendations related to collaboratively recycling produced water and avoiding deep well injection are particularly relevant. Industry should also be asked to contribute to innovative aquifer protection projects in the region, such as local groundwater banking.

Bakken



Bakken Data Summary (January 1, 2011 - May 31, 2013)

WATER USE TRENDS

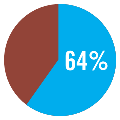
Total Water Use *(gallons)*:	**6.2 billion**
Average Water Use *(gallons/well)*:	**2.2 million**

EXPOSURE TO WATER RISKS

Proportion of Wells in **Arid Regions:**	13%
Proportion of Wells in **Medium or Higher Water Stress:**	0%
Drought Region as of January 7, 2014 *(yes or no)*:	No
Groundwater Challenges *(yes or no)*:	Yes

LOCAL WATER USE IMPACTS

Concentration of Water Use: Top Three Water Use Counties as a Proportion of Total Water Use in Play



OPERATING TRENDS

	Total Wells Reported:
Gas	15
Oil	2,816

Number of Operators in Region: 41

OPERATORS
Top Three by Water Use
- Continental
- Hess
- Statoil

SERVICE PROVIDERS
Top Three by Water Use
- Halliburton
- Schlumberger
- Sanjel

Water Use Trends

Shale oil production has risen dramatically the past two years in the Bakken and has made North Dakota the second largest oil-producing state after Texas. The Bakken play, which includes western North Dakota and parts of Montana and Saskatchewan, uses more water per well than other shale oil-producing regions due to its high utilization of horizontally drilled wells. In 2012, shale oil development used about 5.5 billion gallons of water for hydraulic fracturing, more than the amount used by the 110,000 residents of Fargo, the state's biggest city. When the play is fully developed in the next 10 to 20 years, with an expected additional 40,000-45,000 new oil wells, the industry will likely require double that annual amount, according to a July 2013 North Dakota Department of Mineral Resources presentation.[19]

Water Sourcing Risks: Groundwater Concerns and Potentially High Future Water Needs to Maintain Wells

The Bakken is generally exposed to less water stress than Texas and California, primarily because of the region's low population. However, large parts of the region are arid (represented in gray in maps and graphs), groundwater resource depletion is a serious concern and surface water access is limited. As a result, anticipated shale energy growth will surely heighten water competition among farmers, ranchers, shale energy producers and municipal users.

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[19] Lynn Helms, Director, Department of Mineral Resources, Presentation "Regarding the Status of Oil and Gas Development in the State, Projected State Drilling Activities, and the Effect on State and Local Infrastructure," July 30, 2013, http://www.legis.nd.gov/files/committees/63-2013nma/appendices/gf073013appendixc.pdf?20131104162315.

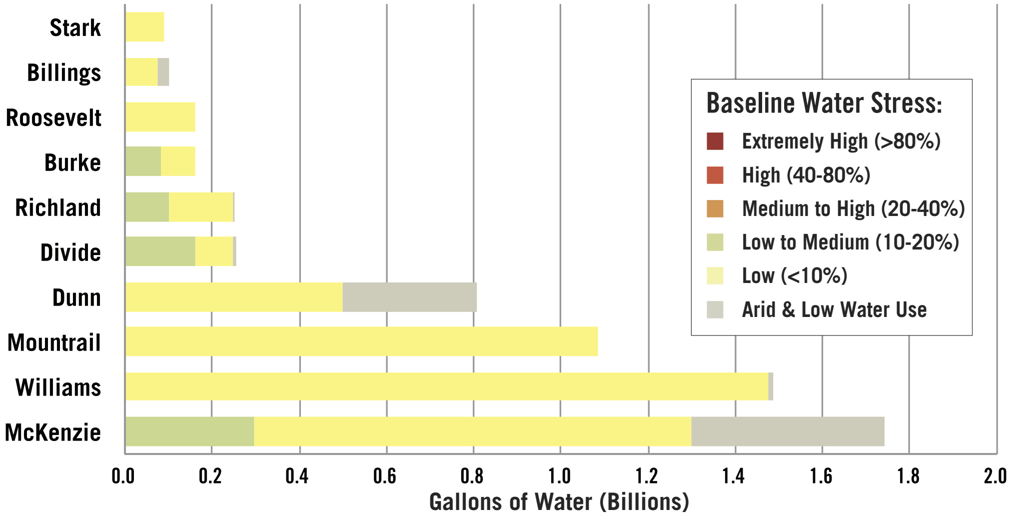
Due to depletion concerns across the region, permits for groundwater use are not always granted. Permit requests are often contested by local stakeholders and when granted can take over nine months to be completed with only partial access to water requested.[20] With the exception of the Missouri River system, most regional surface waters do not provide a reliable supply of water because of seasonal flow variations. These water supply concerns are compounded by water use restrictions on industrial water withdrawals from Lake Sakakwea, a major reservoir of the Missouri River, due to a regulatory dispute between the state and the Army Corps of Engineers.[21, 22] Studies are underway to assess the potential of brackish water supplies for hydraulic fracturing water use.[23]

The water demand side of the equation is also challenging. Flowback water from Bakken wells are high in salt content, making recycling challenging in this region.[24] In addition, these salts precipitate in production pipes, requiring continual daily volumes of freshwater to be flushed into wells to maintain oil flows over the entire production lifecycle (up to 30 years). As a result, the average water use per well could reach over eight million gallons, which is three to four times the water required for initial hydraulic fracturing activity.[25]

High Water Use Counties

The highest water use counties are McKenzie, Williams and Mountrail, each with over 500 wells, and Dunn County with 395 wells. The wells in these counties, all in North Dakota, collectively represent 78 percent of all the water used in the Bakken (**Figure 33**).

FIGURE 33: HIGHEST WATER USE COUNTIES IN THE BAKKEN BY WATER STRESS CATEGORY



Top 10 counties in the Bakken by hydraulic fracturing water use and water stress category. All counties are in North Dakota with the exception of Richland and Roosevelt, which are in Montana.

Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

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[20] North Great Plains Water Consortium, "Bakken Water Opportunities Assessment—Phase 2, Evaluation of Brackish Groundwater Treatment for use in Hydraulic Fracturing of the Bakken Play, North Dakota," prepared for the North Dakota Industrial Commission, December 2011.

[21] Mark Trechock,"Gone for Good, Fracking and Water Loss in the West," Western Organization of Resource Councils, 2013.

[22] Jennifer Nunez, "Who says Water and Oil Can't Mix?" *Profile Magazine*, fourth quarter 2013.

[23] Reference footnote 22

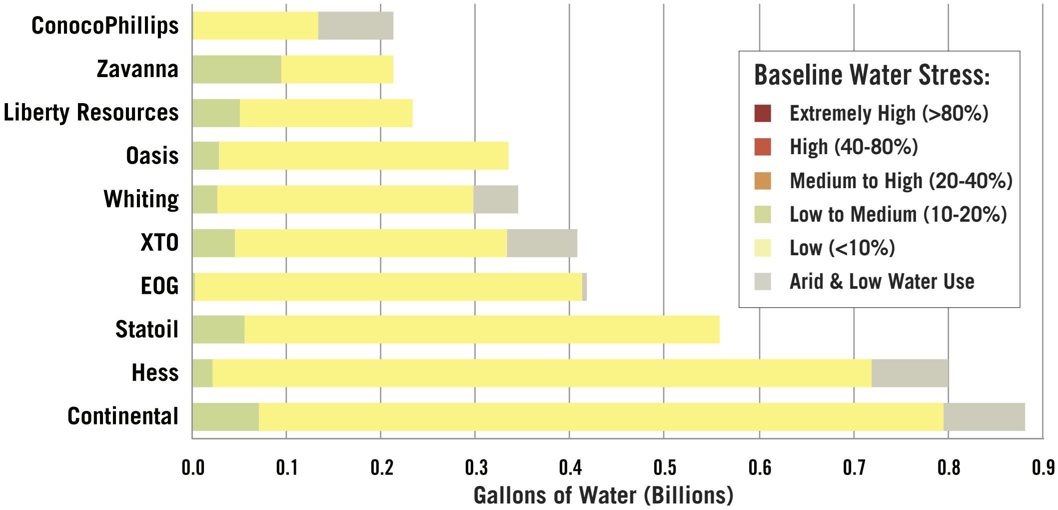
[24] Reference footnote 22

[25] Patrick Kiger, "North Dakota's Salty Hydraulically Fractured Wells Drink More Water to Keep Oil Flowing," *National Geographic*, November 11, 2013.

Companies Active and Exposed to Water Risks in the Region

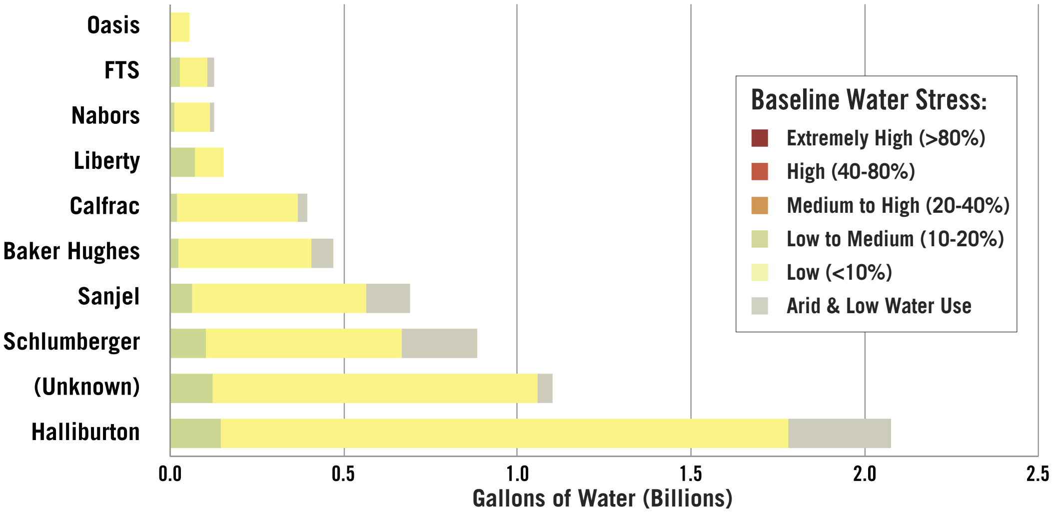
Continental and Hess are the biggest operators and water users in the region followed by Statoil, EOG, XTO, Whiting and Oasis (**Figure 34**). Halliburton is the dominant service provider, handling twice as much water for hydraulic fracturing as Schlumberger and Sanjel (**Figure 35**).

FIGURE 34: HIGHEST WATER USE OPERATORS IN THE BAKKEN BY WATER STRESS CATEGORY



Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

FIGURE 35: HIGHEST WATER USE SERVICE PROVIDERS IN THE BAKKEN BY WATER STRESS CATEGORY

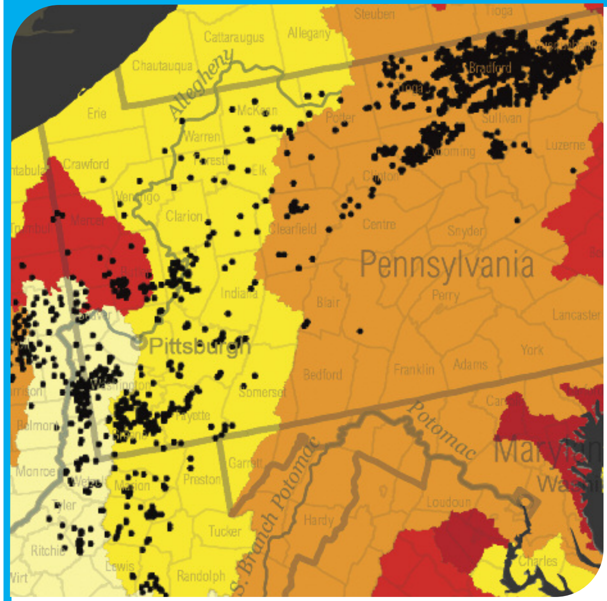


Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

➲ Engagement Recommendations for Lenders & Investors

Given how arid the region is and regulatory uncertainty over water sourcing from Lake Sakakwea, and groundwater depletion in the region, company engagement should be focused on understanding future water needs and improving operational practices to use less water. Baker Hughes, the dominant service provider in the region, as well as Continental, Hess and Statoil, the largest operators, and Halliburton, the largest service provider, should be prioritized for engagement. Due to potentially high future maintenance water demands and potential enhanced oil recovery activity, companies should disclose data on water requirements beyond the volumes needed for hydraulic fracturing. Continental, Hess and Statoil should also lead on efforts on collaborative water sourcing solutions, including a pilot-scale water recycling effort that Halliburton and Statoil have been pursuing.

Marcellus



Marcellus Data Summary (January 1, 2011 - May 31, 2013)

WATER USE TRENDS

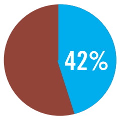
Total Water Use *(gallons)*:	**13.7 billion**
Average Water Use *(gallons/well)*:	**4.4 million**

EXPOSURE TO WATER RISKS

Proportion of Wells in **High or Extreme Water Stress:**	**2%**
Proportion of Wells in **Medium or Higher Water Stress:**	**62%**
Drought Region as of January 7, 2014 *(yes or no)*:	**No**
Groundwater Challenges *(yes or no)*:	**No**

LOCAL WATER USE IMPACTS

Concentration of Water Use: Top Three Water Use Counties as a Proportion of Total Water Use in Play



OPERATING TRENDS

Total Wells Reported:	
Gas	3,140
Oil	2

Number of Operators in Region: 39

OPERATORS
Top Three by Water Use
- Chesapeake
- EQT
- Range Resources

SERVICE PROVIDERS
Top Three by Water Use
- Halliburton
- FTS
- Baker Hughes

Water Use Trends

The Marcellus was the second highest water use play behind the Eagle Ford, using over 13.7 billion gallons of water. Eighty-six percent of the water volumes reported in the Marcellus were from wells located in Pennsylvania, with the balance from West Virginia. Less than one percent was from Virginia. Average water use per well is relatively high at about 4.4 million gallons. Wastewater disposal has been a big challenge, with much of it being trucked for disposal in underground wells in Ohio.

Water Sourcing Risks:
Seasonal Flows and Variability of Surface Water Supplies

The Marcellus region is centered in Pennsylvania and also extends into West Virginia, Virginia, Ohio, New York and into southern Ontario (**Figure 36**). It has a very small proportion of wells in high or extreme water stress areas; more than 60 percent of the wells are in medium water stress regions. Most of the industry's water is withdrawn from surface water sources. Despite lower levels of water stress, regulators in Pennsylvania have had to limit withdrawals from several streams used for hydraulic fracturing due to low stream flows during summer months.[26] Therefore the timing of withdrawals is as much an issue in this region as the amounts being withdrawn.

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[26] Staff writer, "SRBC Withdraws Permits in Marcellus Region, Cites Low-flow Conditions," *Bay Journal*, April 30, 2012.

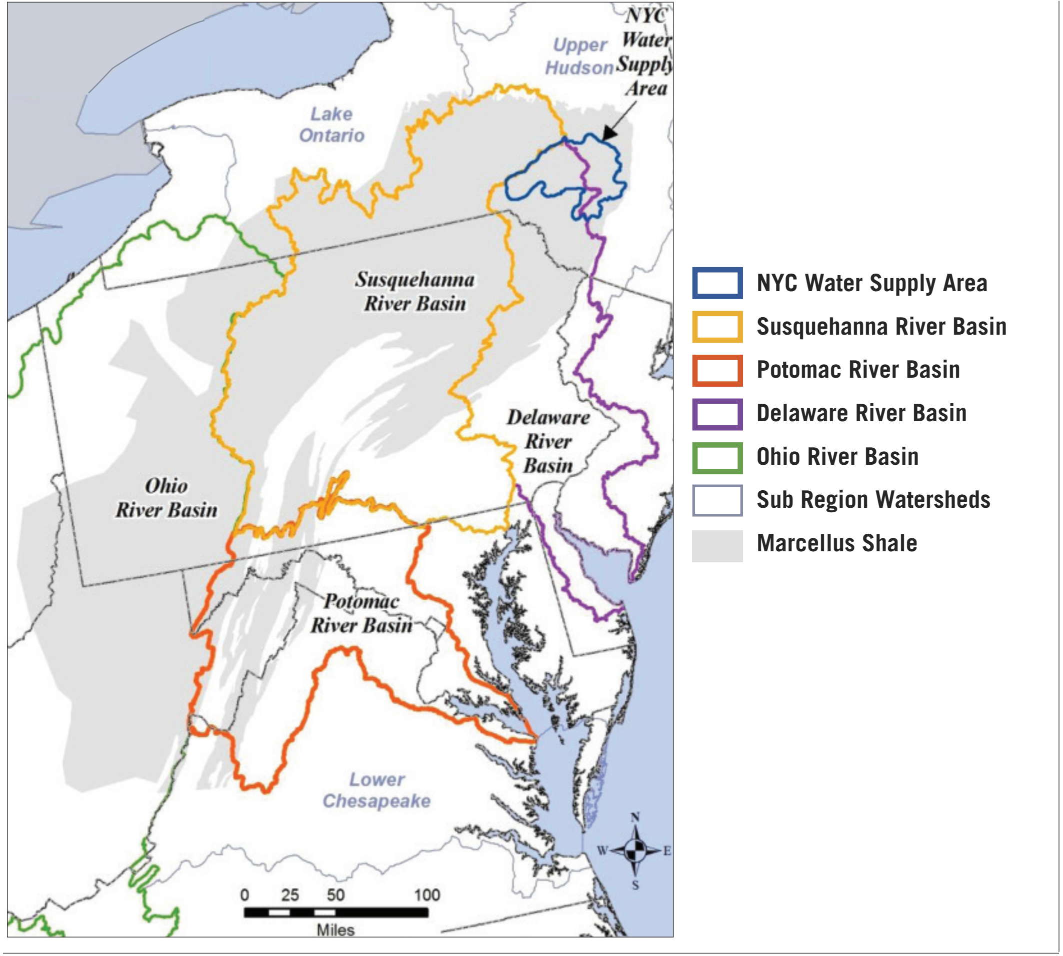
To reduce the industry's use of freshwater in Pennsylvania, state lawmakers have proposed the use of treated abandoned coal mine water as an alternative water source. The quality of the mine water varies, however, and it may be too contaminated for treatment and use for hydraulic fracturing due to acid contamination concerns. The proposed regulations are now being hotly contested by local environmental groups concerned about the transfer of this water out of source watersheds.

Regulatory Trends

In recent years, numerous state regulatory agencies and regional authorities in the Marcellus region (including the Delaware, Susquehanna and Ohio River basin commissions) have been actively working to improve oversight of hydraulic fracturing water use.

The Pennsylvania Department of Environmental Protection has a water management plan that governs shale energy water use, including the quantity and timing of withdrawals allowed based on annual stream-flow statistics. Operators in Pennsylvania are required to have water management plans and demonstrate that withdrawals will not harm water resources.[28]

FIGURE 36: THE MAJOR RIVER BASINS OF THE MID-ATLANTIC AND EXTENT OF MARCELLUS SHALE



Source: J. Daniel Arthur et al, Water Resources and Use for Hydraulic Fracturing in the Marcellus Shale Region, ALL Consulting, LLC.

Timing and Location of Water Withdrawals Can Be as Important as Amounts Withdrawn

From: ***"Drought Conditions Strain Driller's Water Use in Major Pa. Watershed," Energy Wire, July 2012***

The Susquehanna River Basin Commission (SRBC) earlier this week said it had suspended 64 permits to withdraw water from streams and other sources in the 27,000-square-mile watershed. Suspensions kick in when water levels hit a predetermined low point, and the requirement to stop withdrawing is written into permits for gas companies operating in the watershed.[27]

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[27] Joel Kirkland, "Drought conditions strain driller's water use in major Pa. watershed," *Energywire*, July 19, 2012, http://www.eenews.net/energywire/stories/1059967527.

[28] Act 13 of 2012, HB 1950 § 3211(m)(1.)

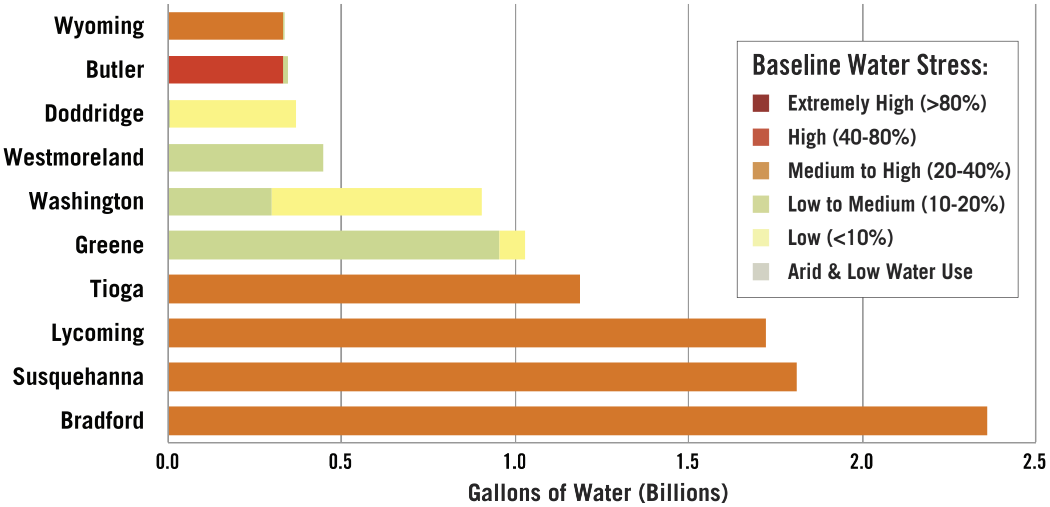
The Susquehanna River Basin Commission (SRBC), which oversees the water needs of approximately 4.2 million residents, has among the strongest water sourcing disclosure requirements and overall understanding of the industry's cumulative water sourcing impacts. Permitting is required to withdraw any amount of water, and full disclosure of where water is sourced and how much is consumed is easily accessed by the public on a web-based portal.

In 2009, the Delaware River Basin Commission determined that shale gas production should be delayed due to water concerns. The Delaware River is the longest free-flowing river east of the Mississippi and provides drinking water to about 15 million people in New York, New Jersey, Pennsylvania and Delaware. About one-third of the Delaware River basin lies above the Marcellus. The Commission subsequently released proposed shale development regulations that are still being intensely debated by all sides.[29] There is no timeframe for approving the draft regulations or lifting the moratorium.[30]

High Water Use Counties

Most hydraulic fracturing and water use takes place in a relatively small number of counties in northern Pennsylvania, led by Bradford, Susquehanna, Lycoming, and Tioga counties and in the southwest in Greene and Washington counties (**Figure 37**).

FIGURE 37: HIGHEST WATER USE COUNTIES IN THE MARCELLUS BY WATER STRESS CATEGORY



Top 10 counties in the Marcellus by hydraulic fracturing water use and water stress category. All counties are in Pennsylvania with the exception of Doddridge, which is located in West Virginia.

Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

Companies Active and Exposed to Water Risks in the Region

Chesapeake is the dominant operator in this region, using twice as much water as peer companies EQT, Range and Cabot (**Figure 38**). Halliburton, FTS and Baker Hughes are the most active service providers by water use (**Figure 39**).

The newly formed Center for Sustainable Shale Development, representing a rare collaborative effort by industry and NGOs, has among its performance standards required operators to recycle a minimum of 90% of flowback and produced water in core operating areas by September 2014.

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[29] State Impact, NPR, "Delaware River Basin Commission: Battleground for Gas Drilling," http://stateimpact.npr.org/pennsylvania/tag/drbc/.

[30] Delaware River Basin Commission, Natural Gas Drilling Index Page, http://www.state.nj.us/drbc/programs/natural/.

FIGURE 38: HIGHEST WATER USE OPERATORS IN THE MARCELLUS BY WATER STRESS CATEGORY

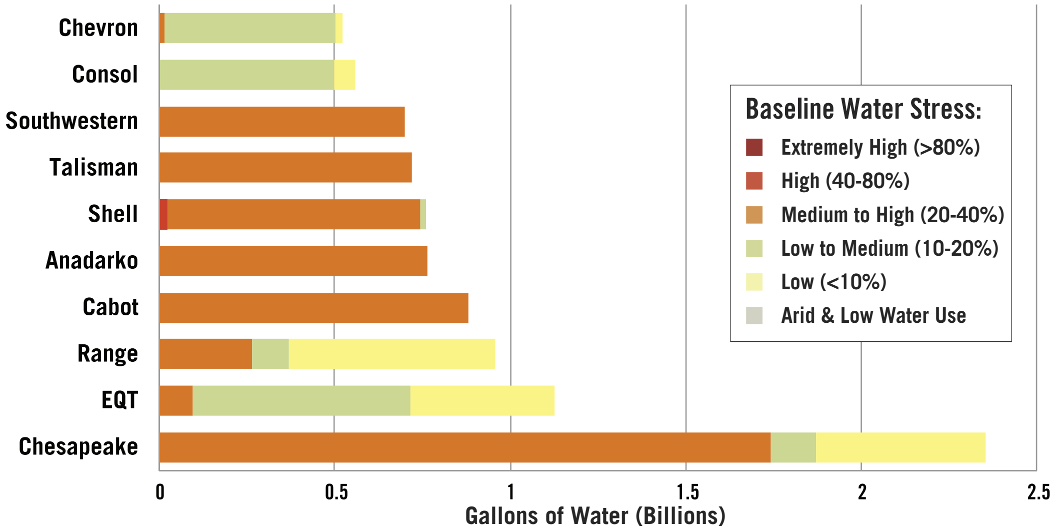
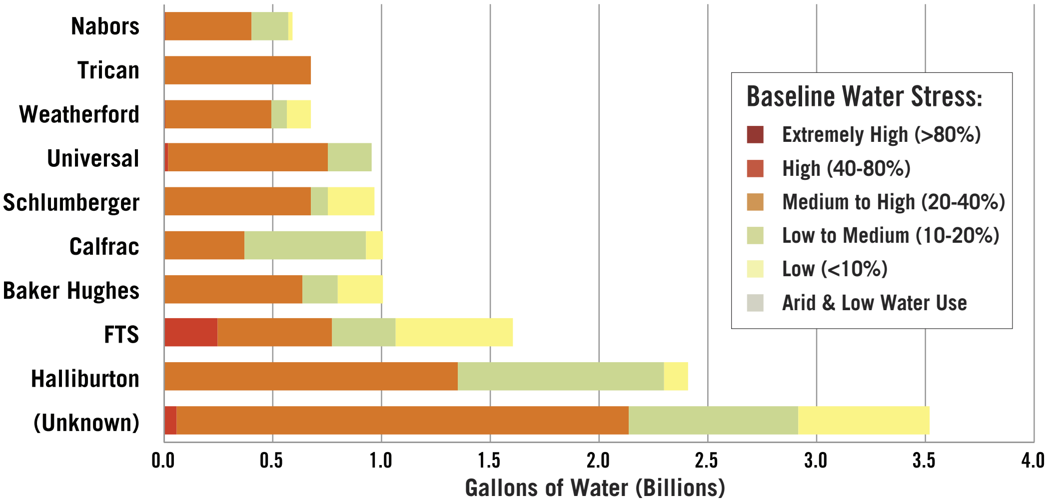


FIGURE 39: HIGHEST WATER USE SERVICE PROVIDERS IN THE MARCELLUS BY WATER STRESS CATEGORY



Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

➲ Engagement Recommendations for Lenders & Investors

Given its dominant role, Chesapeake should take the lead on addressing water sourcing issues in the region. Although the company reports it is actively recycling water in the region, more data is needed on its water use by region, where water is currently being sourced, future water use targets and sourcing plans.[31] Chesapeake, EQT, Range, Cabot and other companies in the region should also be encouraged to support the build out of collaborative water networks and infrastructure, given the lack of disposal wells in this region and the need to limit the already high truck traffic. Considering the large community impacts from rapid large scale development, the stakeholder engagement recommendations previously discussed are directly relevant.

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[31] Proceedings of the Technical Workshops for the Hydraulic Fracturing Study, Water Resources Management, EPA, May 2011.

DJ Basin

DJ Basin Data Summary (January 1, 2011 - May 31, 2013)

WATER USE TRENDS

Total Water Use *(gallons)*: **2.5 billion**

Average Water Use *(gallons/well)*: **810,000**

EXPOSURE TO WATER RISKS

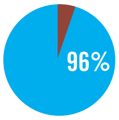
Proportion of Wells in **High or Extreme Water Stress:** **100%**

Drought Region as of January 7, 2014 *(yes or no)*: **Yes**

Groundwater Challenges *(yes or no)*: **Yes**

LOCAL WATER USE IMPACTS

Concentration of Water Use: Top Three Water Use Counties as a Proportion of Total Water Use in Play



OPERATING TRENDS

Total Wells Reported:	Gas	Oil
	2,562	507

Number of Operators in Region: 32

OPERATORS
Top Three by Water Use
- Anadarko
- Noble
- Encana

SERVICE PROVIDERS
Top Three by Water Use
- Halliburton
- Baker Hughes
- Calfrac

Rockies Region: Focus on DJ Basin (Niobrara)

The Rockies region includes the Piceance, Denver-Julesburg Basin (known as the DJ Basin, located in the Niobrara formation), Green River, Uinta, Powder River, Wind River, San Juan and Raton basins, which extend to Colorado, Wyoming, Utah and New Mexico. Overall, of the roughly 8,000 wells developed in this region, over 90 percent are exposed to extreme or high water stress regions. This analysis focuses on the Colorado-based DJ Basin, as an example of water risks characteristic of the Rockies region.

Water Use Trends

Water use for hydraulic fracturing in Colorado during the study period was just under 7 billion gallons. Looking at 2012 alone, 3.3 billion gallons were reportedly used, well within the state's own projections of water use for hydraulic fracturing of 5.2 billion gallons.[32]

In just the DJ Basin, water use for hydraulic fracturing (which includes the Wattenberg natural gas field) over the reported time period was approximately 2.5 billion gallons. As a comparison, Boulder, Colorado uses about 2.7 billion gallons per year for municipal purposes.[33]

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[32] Colorado Division of Water Resources, the Colorado Water Conservation Board and the Colorado Oil and Gas Conservation Commission, "Water Sources and Demand for the Hydraulic Fracturing of Oil and Gas Wells in Colorado from 2010 through 2015," http://cogcc.state.co.us/Library/Oil_and_Gas_Water_Sources_Fact_Sheet.pdf.

[33] Every Drop Counts, Valuing the Water Used to Generate Electricity, *Western Resource Advocates*, January 2011.

Water Sourcing Risks:
Drought, Growing Population and Existing Extreme Water Stress

The region is exposed to wide ranging water-sourcing risks, including extreme water stress, drought conditions and groundwater challenges. In most parts of the state, surface streams are "over appropriated," meaning that water rights on those streams cannot be satisfied with the quantity of water physically available. Because Colorado's water rights system is based on the prior appropriation doctrine, surface water required for hydraulic fracturing either has to be imported from other states or must be purchased from another end-user that holds those water rights.

The industry's ability to seek out and secure supplies in this way creates impacts on other water users. The biggest impact is water price increases driven by the industry's willingness to pay considerably more for water than agriculture, up to $2,000 an acre foot of water.[34] This dynamic can be attractive to local municipalities that can fortify shrinking budgets by selling water to industry at high prices. On the negative side, local residents worry that farmers will go out of business or that local water resources will run dry.

Future projected water needs for hydraulic fracturing can be equal to future water supply volumes expected from large infrastructure projects. This has been illustrated by a study comparing projected water requirements for hydraulic fracturing to several proposed and large-scale water supply projects in Colorado. The Moffat Collection System reservoir expansion was projected to provide an additional 5.8 billion gallons to Denver at an estimated cost of $140 million—roughly the same volume estimated to be required for hydraulic fracturing by 2015.[35, 36] The Windy Gap Firming Project, proposed to divert Colorado River water and provide more reliable supplies to 13 municipalities in northeastern Colorado, would cost an estimated $270 million and provide about 10 billion gallons of supply.[37] The cost of building these projects would be borne primarily by local water users and state taxpayers.

As in Texas, water recycling rates remain low, predominantly driven by the easy access to deep disposal wells in many parts of the state. In regions where water recycling is higher, deep disposal wells are harder to find.

Reflecting these challenges, Colorado has become a key battle zone for the industry's license to operate in four municipalities—Boulder, Broomfield, Fort Collins and Lafayette—all passing measures in 2013 to ban or restrict hydraulic fracturing.

Water Competition Can Limit Farmers' Ability to Grow Crops

From: ***"Fracking Fuels Water Fights in Nation's Dry Spots," Associated Press, June 2013***

Along Colorado's Front Range, fourth-generation farmer Kent Peppler said he is fallowing some of his cornfields this year because he can't afford to irrigate the land for the full growing season, in part because deep-pocketed energy companies have driven up the price of water.

"There is a new player for water, which is oil and gas," said Peppler, of Mead, Colo. "And certainly they are in a position to pay a whole lot more than we are."[38]

High Water Use Counties

Weld County, CO accounted for over two billion gallons of water use with 2,888 wells hydraulically fractured during the study period, adding to the estimated 19,000 wells already developed (**Figure 40**). Garfield County, in the Piceance Basin is a distant second in water use, with 1,481 wells and hydraulic fracturing water use representing 36 percent of local residential demand. Combined, these two counties account for 89 percent of the water used for hydraulic fracturing in the state.

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[34] Jack Healy, "For Farms in the West, Oil Wells are Thirsty Rivals," *The New York Times*, September 5, 2012.

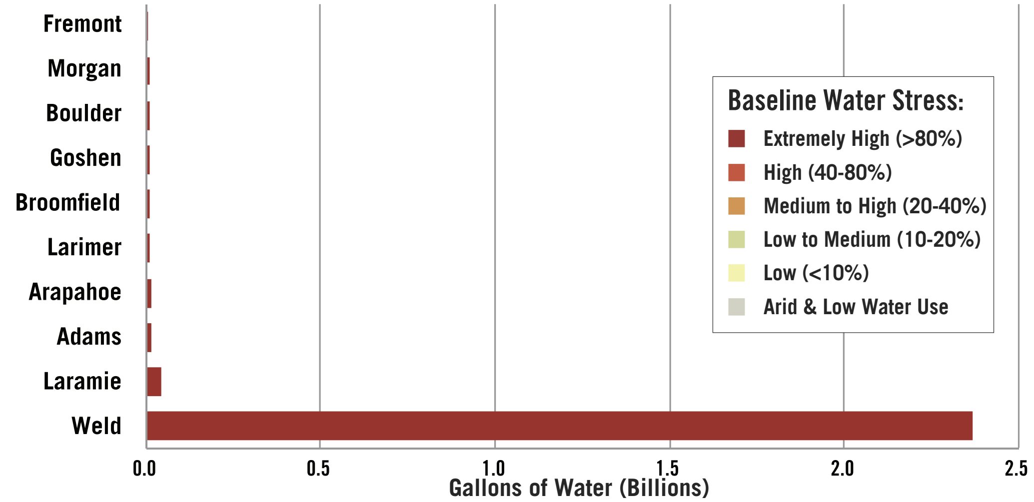
[35] Denver Water, "Frequently asked questions about Moffat collection system project," http://www.denverwater.org/SupplyPlanning/WaterSupplyProjects/Moffat/FAQs/.

[36] Western Resource Advocates, "Fracking our Future: Measuring Water & Community Impacts from Hydraulic Fracturing," June 2012.

[37] Duggan, Kevin, "Windy Gap Firming Project Update: Chimney Hollow Reservoir could get a green light for construction later this year," *Coyote Gulch*, https://coyotegulch.wordpress.com/2012/01/08/windy-gap-firming-project-update-chimney-hollow-reservoir-could-get-a-green-light-for-construction-later-this-year/.

[38] Garance Burke, "Fracking fuels water fights in nation's dry spots," *The Denver Post*, June 16, 2013, http://www.denverpost.com/business/ci_23472294/fracking-fuels-water-fights-nations-dry-spots.

FIGURE 40: HIGHEST WATER USE COUNTIES IN THE DJ BASIN (NIOBRARA) BY WATER STRESS CATEGORY



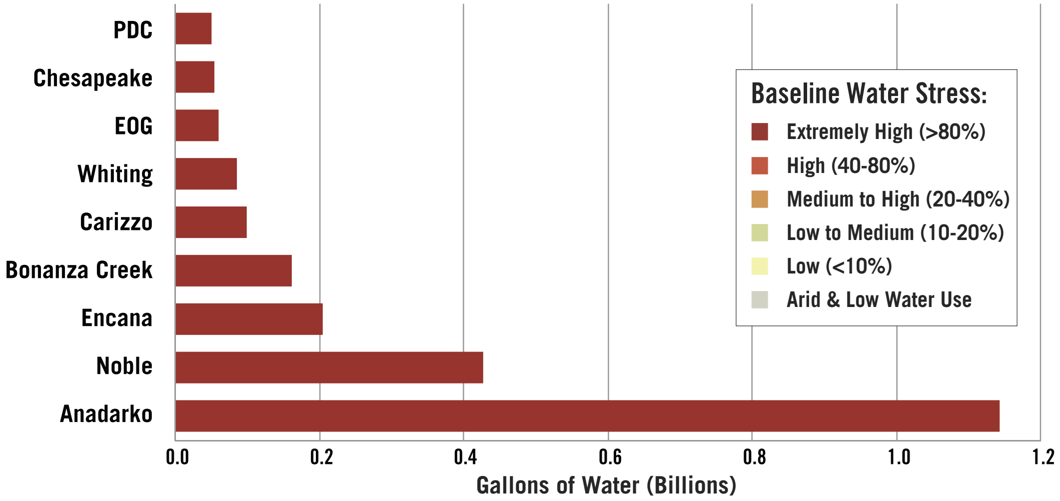
Top 10 counties in the DJ Basin (Niobrara) by hydraulic fracturing water use and water stress category. All counties are in Colorado with the exception of Laramie and Goshen, which are located in Wyoming.

Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

Companies Active and Exposed to Water Risks in the Region

Anadarko is the largest water user in the region, followed by Noble and Encana (**Figure 41**). Halliburton, Baker Hughes and Calfrac are the three most active service providers by water use (**Figure 42**).

FIGURE 41: HIGHEST WATER USE OPERATORS IN THE DJ BASIN (NIOBRARA) BY WATER STRESS CATEGORY



All water use falls under extreme water stress conditions.

Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

Operators Get Water from a Diverse Set of Sources

From: ***"Managing Water Resources is Key Issue for Niobrara Drillers," The Greeley Tribune, March 2013***

Clay Terry, Halliburton's water liaison for the U.S. Northern Region, said his company puts great emphasis on acquiring water rights at the outset, too. He said Halliburton looks at a number of sources: municipalities, water districts, private sources, industrial waste water and water co-produced by oil and gas operations.[39]

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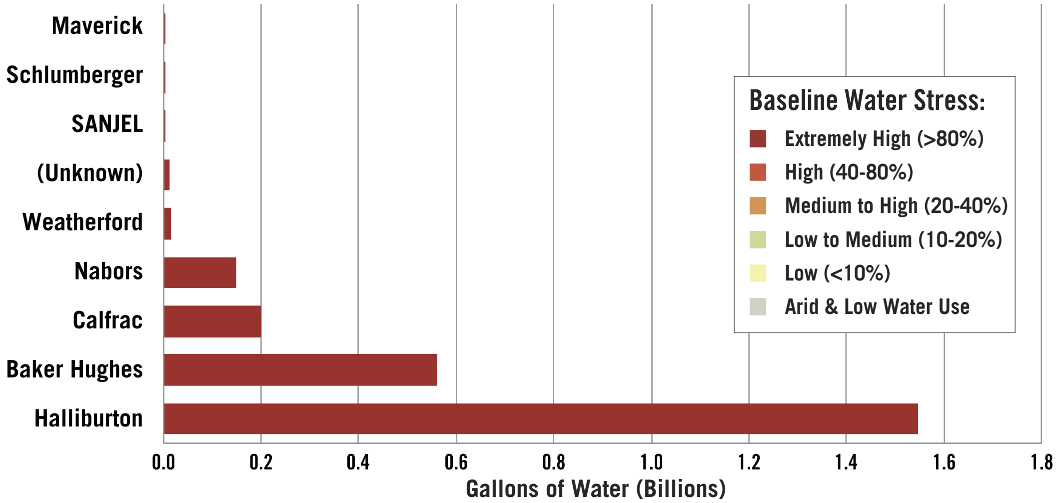
[39] David Persons, "Managing water resources is key issue for Niobrara drillers," *Greeley Tribune*, March 24, 2013, http://www.greeleytribune.com/news/local/5648726-113/hydraulicfracturing-gas-oil-state.

FIGURE 42: HIGHEST WATER USE SERVICE PROVIDERS IN THE DJ BASIN (NIOBRARA) BY WATER STRESS CATEGORY



Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

➲ Engagement Recommendations for Lenders & Investors

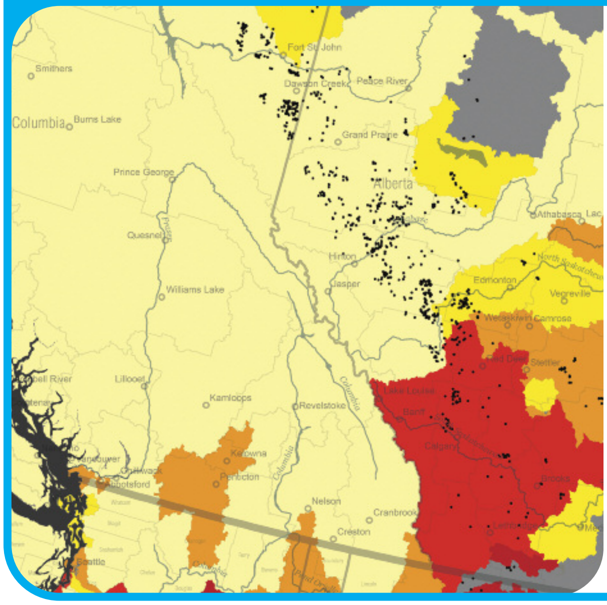
Investors and lenders should focus their engagement on Anadarko, Noble and Encana as the dominant operators in the region, and Halliburton as the dominant operator. Given that almost all development in the DJ Basin is taking place in Weld County, operators should be asked to provide data on local water use, where water is currently being sourced, future water use targets and sourcing plans. Operators should also be encouraged to lead on the creation of collaborative water management plans and networks. Considering the level of water stress in the region and growing community concerns about hydraulic fractury, operators should look to implement the operational recommendations previously outlined and demonstrate sound stakeholder engagement practices.

Western Canada

Significant shale deposits exist across western Canada, specifically in the Horn River and Montney formations, which are initial targets of significant development.

The data analyzed for this region was sourced from FracFocus Canada via PacWest FracDB and includes 743 reported wells in Alberta (January-July 2013) and 598 reported wells in British Columbia (December 2011-July 2013). Currently very few operators and service providers are reporting to FracFocus Canada and as a result the data analyzed represents a very small proportion of the overall activity taking place. Due to water volume reporting inconsistencies, water use trends could not be analyzed for the Canadian data.[41]

Alberta



Alberta Data Summary (January 1, 2011 - May 31, 2013)

EXPOSURE TO WATER RISKS

Proportion of Wells in **High or Extreme Water Stress:**	14%
Proportion of Wells in **Medium or Higher Water Stress:**	20%

OPERATING TRENDS

Number of Operators in Region:	OPERATORS Top Three by Wells Reported	SERVICE PROVIDERS Top Three by Wells Reported
88	• Encana • Apache • Peyto	Not available

Alberta Water Use Trends

The province of Alberta alone has an estimated 174,000 wells that have been hydraulically fractured since the 1950s, many of which are smaller conventional fractures.[42] The Alberta government has proactively tracked water use for oil and gas development since the 1970s. Since that decade, the industry's water use trailed gradually downward as conventional oilfield development declined. The trend reversed in 2002, due primarily to increasing water demand from the oil sands industry. Freshwater use has since leveled off, as saline groundwater use has become more prevalent at 40 percent of total oil and gas industry water use (**Figure 43**).[43] As previously noted, the increasing use of brackish/saline groundwater resources should be carefully studied and managed given the potential for brackish water to be used in the future for drinking water. Withdrawals of brackish groundwater can also adversely impact interconnected freshwater resources.

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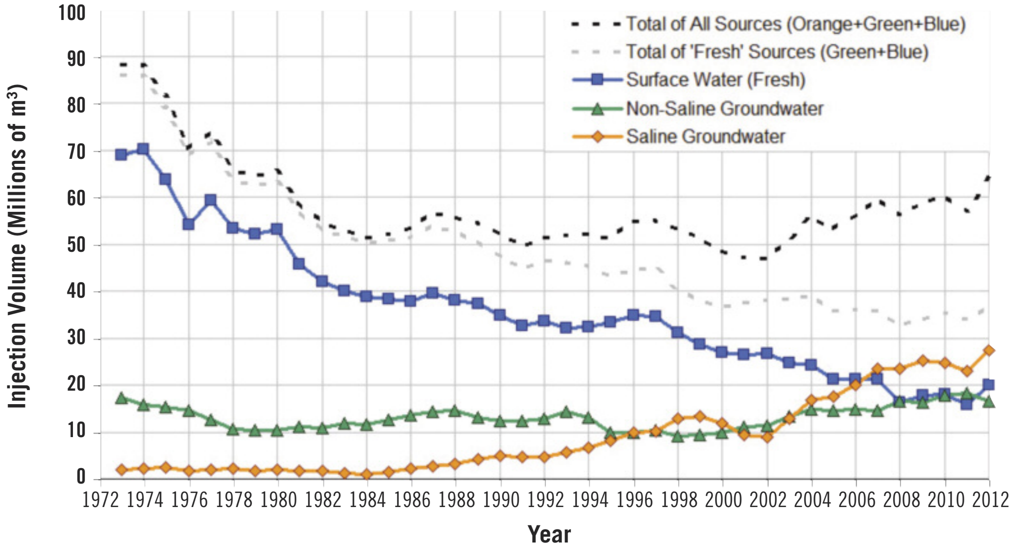
[41] As operators and service providers become more accustomed to reporting to the website, we expect water volume reporting to improve.

[42] Environment Alberta, "Hydraulic Fracturing, Where We Are Today," http://environment.alberta.ca/04131.html.

[43] Environment Alberta, "Water Used for Oilfield Injection Purposes," June 2013, http://environment.alberta.ca/01729.html.

FIGURE 43: SOURCE WATER USE OVER TIME (1973-2012*) FOR OIL & GAS DEVELOPMENT IN ALBERTA



Source: Alberta Environment, "Water Used for Oilfield Injection Purposes," June 2013.

*Data Source: Alberta Energy Resources Conservation Board (ERCB). Chart produced by Water Policy Branch, Alberta Environment & Sustainable Resource Development.

Water Sourcing Risks:
Arid Conditions, Climate Change and Agriculture Water Demand

Alberta is vulnerable to water shortages due to its location in the rain shadow of the Rocky Mountains. In addition, many of Alberta's rivers are fed by glaciers in the Rockies that have been projected to shrink by up to 90 percent by the end of the century due to climate change.[44] Growing urban centers, as well as farming, ranching, and oil sands production bring additional pressure on water supplies.

In Alberta, 14 percent of wells reported to FracFocus were drilled in high water stress regions, and 20 percent in regions of medium or higher water stress, predominantly the Red Deer, Calgary and Medicine Hat regions. Environment Alberta, through its tracking and disclosure of consumptive water use information by major river basin, reaffirms the concern that water demand is very high relative to supply, especially in in the Bow, Oldman, Pakowki Lake and Milk River basins in southern and central Alberta (**Figure 44**). Competition with agriculture is an especially big concern in this region. Alberta holds only two percent of Canada's water supply, but accounts for the majority of its irrigated agricultural lands.[45]

Water licenses are currently given out on a first-come first-serve basis after assessing the water source. Increasing competition for water has many advocating for new water sourcing policies that require industry to demonstrate that other non-potable water sources have been tapped before groundwater is considered.[46] Concerns about over reliance on brackish water resources are growing here also. There have also been calls for Alberta's government to create more independent oversight of the environment and water resources from oil and gas development.[47]

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[44] Alberta Web Portal, http://www.albertawater.com/index.php/glaciers/summary-and-recommendations.

[45] Justina Reichel, "Alberta Faces Drought if Water System not Improved Report Warns," *Epoch Times*, October 9, 2012.

[46] Patrycja Romanowska, "Alberta desperately needs a water-management plan, A strategy to manage water use in Alberta must coexist with the oil and gas sector's appetite for this precious resource," *Alberta Oil Magazine*, July 30, 2013.

[47] Andrew Read, "Alberta's new monitoring bill mixes science with politics," Pembina Institute, November 15, 2013.

FIGURE 44: CONSUMPTIVE ALLOCATIONS IN 2010 BY RIVER BASIN COMPARED TO AVERAGE NATURAL FLOW

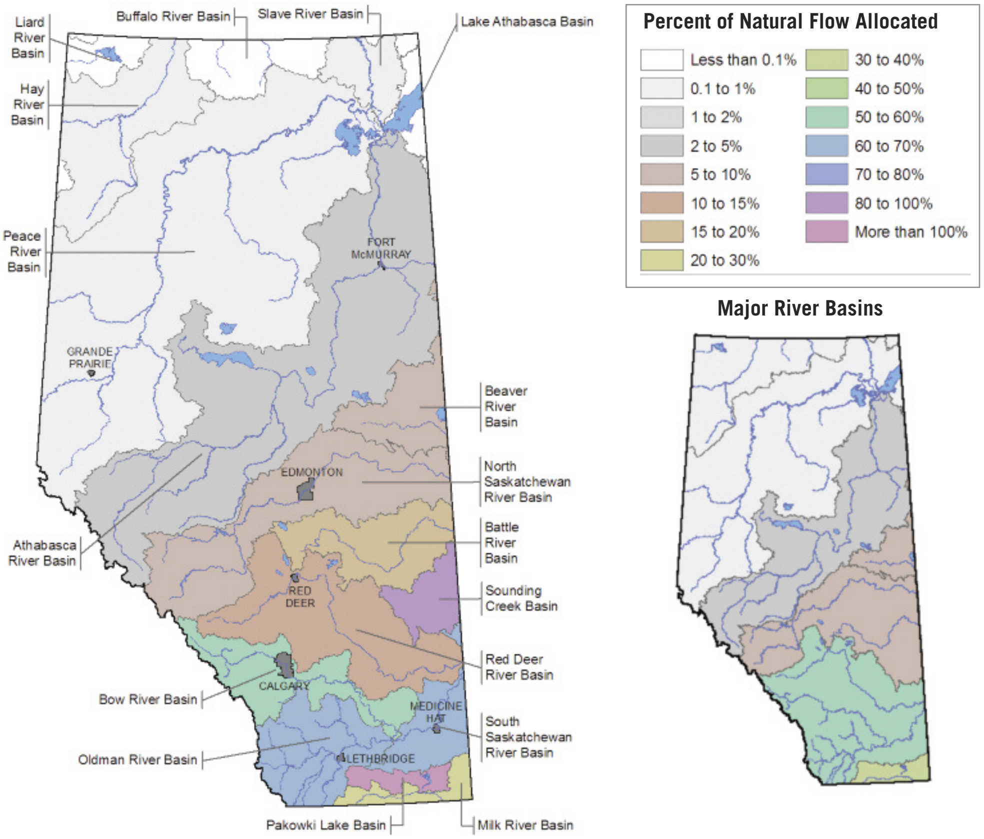


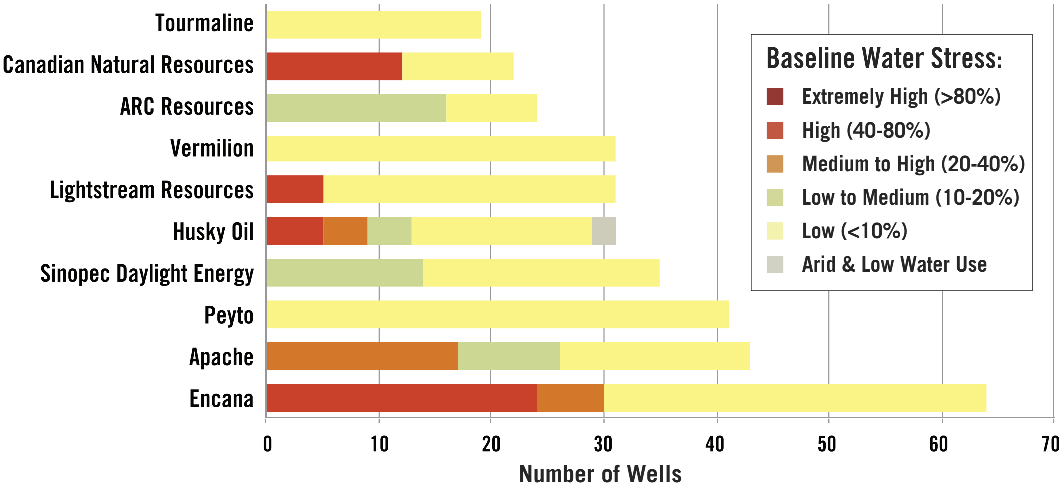
Figure 44: Note that allocations do not represent actual water use—only maximum amount that may be diverted under the terms of a license. Consumptive allocations provide an accounting within the license of the portion that can be expected to be consumed or lost.

Source: Environment Alberta, "Water Allocations Compared to Average Natural Flow," http://environment.alberta.ca/01722.html

Companies Active and Exposed to Water Risks in the Region

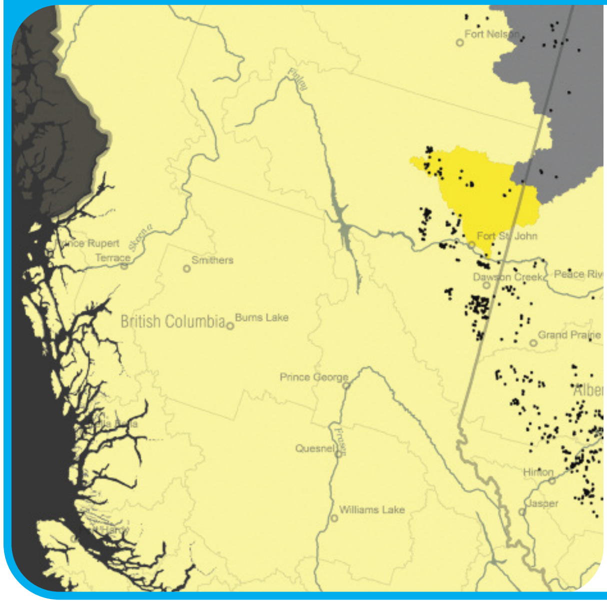
Encana, Apache and Peyto are the three most active operators reporting to FracFocus Alberta in the short time frame in which data has been collected (first half of 2013). Encana and Canadian Natural Resources, in particular, have a significant proportion of wells recently developed in high water stress regions (**Figure 45**).

FIGURE 45: HIGHEST WATER USE OPERATORS IN ALBERTA BY WATER STRESS CATEGORY



Source: WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.ca between January-July 2013.

British Columbia



British Columbia Data Summary (December 31, 2011 - July 31, 2013)

EXPOSURE TO WATER RISKS

Proportion of Wells in **High or Extreme Water Stress:** 0%

Proportion of Wells in **Medium or Higher Water Stress:** 0%

OPERATING TRENDS

Number of Operators in Region:	OPERATORS Top Three by Wells Reported	SERVICE PROVIDERS Top Three by Wells Reported
39	• Encana • Shell • Progress	Not provided

In British Columbia, data on well activity was available from FracFocus.ca between December 2011 through July 2013. Most of the 598 wells reported were in low water stress regions, with a small subset in arid regions north of Fort St. Johns (4 percent). The province reported that 4.3 billion gallons of water were approved for withdrawal by the oil and gas industry in 2013.

Water Sourcing Risks:

Seasonal Variability, First Nations' Concerns and Regulatory Changes

Although there is relatively low water stress due to a low population density and high precipitation rates in many regions, this region is very much affected by seasonal variability in surface water flows. Several regions in northeast British Columbia, for example, in 2012 experienced snowpack at 61 percent of average levels, half of normal rainfall levels and record low levels in some rivers, prompting regulators to limit withdrawals from these sources.[48] The Horn River and Montney regions have also experienced drought conditions recently, compounding regional water sourcing concerns.

Lack of regulation around groundwater withdrawals has stirred concerns. Large-scale users of water previously could withdraw groundwater without any limits or costs. To address this issue and further improve water stewardship in the province major changes to the provincial water act are now being proposed.[49] Another controversy in British Columbia is the alleged overreliance by industry on short-term water permits to gain access to water, which has resulted in a lawsuit filed against the British Columbia Oil and Gas Commission and Encana for alleged B.C. Water Act violations. These short-term permits avoid additional oversight provisions that would normally be required through water licenses.[50]

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[48] BC Oil and Gas Commission, "Low Streamflow Conditions in Northeast BC," *Industry Bulletin*, 2012-10.

[49] For overview of regulatory issues see letter to Ministry of Environment from Craig Nichol, "Proposal for Water Sustainability Act," of the Earth & Environmental Sciences, Physical Geography, The Irving K. Barber School of Arts and Sciences, The University of British Columbia, November 15, 2013.

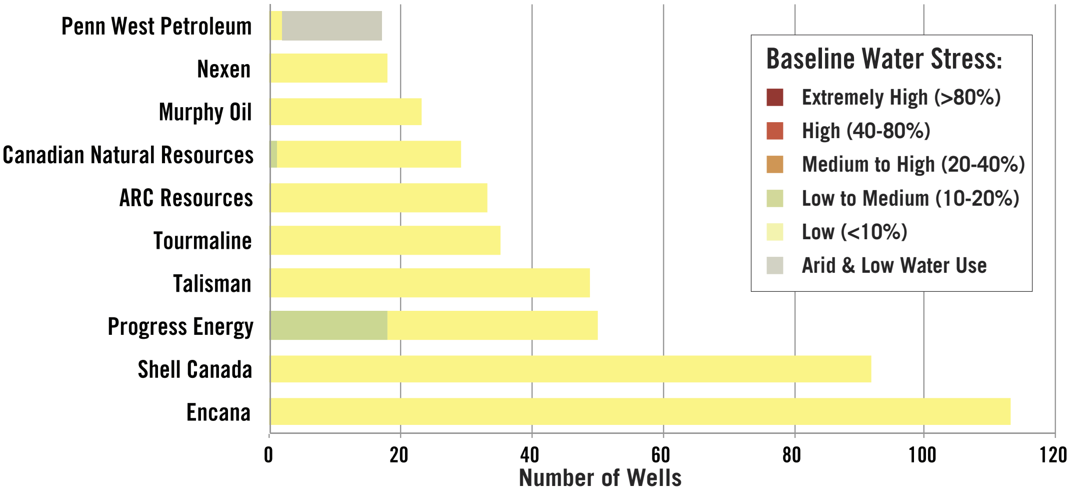
[50] Dene Moore, "Encana's water use permits for hydraulic fracturing face challenge," *The Vancouver Sun*, November 14, 2013.

Canadian energy development leases often take place on First Nations' land. Therefore, in addition to the traditional list of stakeholders, western Canadian operators should also be engaging First Nations communities. Past drops in river and stream levels, affecting key fishing grounds used by First Nations, have been blamed on the industry's use of water for hydraulic fracturing. First Nations' concerns, especially related to Encana's withdrawals from the Fort Nelson River in northern B.C., have created controversy due to a lack of stakeholder engagement and overall transparency of industry water use.

Company Exposure to Water Sourcing Risks in the Region

Encana, Shell and Progress Energy, followed closely by Talisman, are the most active operators in British Columbia reporting to FracFocus Canada (**Figure 46**).

FIGURE 46: HIGHEST WATER USE OPERATORS IN BRITISH COLUMBIA BY WATER STRESS CATEGORY



Operators with 20 or more wells reported shown.

Source: WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.ca between December 2011-July 2013.

➲ Engagement Recommendations for Lenders & Investors

Given water-sourcing concerns in Alberta and more water-rich British Columbia, operators led by Encana should look to implement operational recommendations that promote recycling, brackish water use and sourcing from wastewater streams. Collaborative efforts to increase water recycling and fully develop regional watershed protection plans should be actively pursued. Greater disclosure on stakeholder engagement, especially around First Nations' concerns, should also be a priority.[51]

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[51] The Canadian Association of Petroleum Producers has outlined guiding principles for water sourcing for hydraulic fracturing. Several of the principles align with this report's recommendations, especially regarding proper decision-making frameworks, processes and data collection systems to ensure better water sourcing protection. More progress is needed on these principles however to encourage minimization of freshwater use and better disclosure on company water use, targets and sourcing plans. See "CAPP Hydraulic Fracturing Operating Practice: Water Sourcing, Measurement and Reuse," http://www.capp.ca/getdoc.aspx?DocId=218142&DT=NTV.

Methodology

This Ceres report analyzes water use in hydraulic fracturing operations in the United States and Western Canada and the extent to which this activity is taking place in areas experiencing water stress, drought and groundwater depletion. The research is based on well data available at FracFocus.org and FracFocus.ca (for the United States, British Columbia and Alberta) and maps from the U.S. Geological Survey, the National Drought Mitigation Center and the World Resources Institute.

FracFocus

FracFocus.org was launched in 2011 as a voluntary national hydraulic fracturing chemical registry and is managed by the Ground Water Protection Council, a nonprofit group whose members consist of state groundwater regulatory agencies[52] and the Interstate Oil and Gas Compact Commission, a multi-state government agency.[53] The FracFocus database provides the location of each hydraulically fractured well, the date it was hydraulically fractured and chemical additives and total volume of water pumped into the well. Information on the source and type of water used (e.g. freshwater, recycled, saline) is not disclosed and trade secret exemptions are often claimed regarding chemical use. Eleven states direct or allow operators to report to FracFocus including Texas, Colorado, Pennsylvania, North Dakota, South Dakota, Mississippi, Louisiana, Oklahoma, Ohio, Utah, Montana and two Canadian provinces, Alberta and British Columbia. Since disclosure to FracFocus is still voluntary in many regions, the number of wells and cumulative regional volumes of water used are underreported.[54]

Ceres' analysis of U.S. wells and water volumes was sourced from PacWest Consulting Partners' FracDB database, which obtained its data from Fracfocus.org.[55] PacWest provided quality assurance/quality control analysis on all of the FracFocus data and provided Ceres with information on 43,339 wells hydraulically fractured between January 2011 and May 2013. Ceres conducted a second set of quality assurance/quality control analysis on the water data including eliminating water-use data that was outside the range of three standard deviations, which resulted in a database of 39,294 wells.[56]

The data obtained from PacWest included the following parameters for each well: API number, fracture date, state, county, associated play or basin, latitude and longitude, production type, total vertical depth, water volume used in hydraulic fracturing, operator name and service provider name. Most of the parameters can be found in the FracFocus database, with the exception of service provider names and play/basin names, which were developed through custom analysis by PacWest. Although service providers are not obliged to disclose their names to FracFocus, PacWest identified them through an analysis of chemical supplier information. The plays or basins referenced in this report are based on PacWest's play/basin—county classification system (**Figure 47**).

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[52] "The Ground Water Protection Council (GWPC) is a nonprofit 501(c)6 organization whose members consist of state ground water regulatory agencies which come together within the GWPC organization to mutually work toward the protection of the nation's ground water supplies," http://www.gwpc.org/about-us

[53] "The IOGCC (Interstate Oil and Gas Compact Commission) advocates for environmentally-sound ways to increase the supply of American energy. We accomplish this by providing governors of member states with a clear and unified voice to Congress, while also serving as the authority on issues surrounding these vital resources." http://www.iogcc.state.ok.us/about-us.

[54] Konschnik, K. Holden, M. and Shasteen, "A. Legal Fractures in Chemical Disclosure Laws," Harvard Law School, Environmental Law Program, Policy Initiative, April 2013.

[55] "FracDB is the definitive database of fracs and frac chemicals that can be used to conduct sophisticated market analyses." http://pacwestcp.com/research/fracdb/.

[56] In some regions, shale energy development began well before 2011. For example, the Barnett Shale in Texas was estimated to have had approximately 15,000 wells operating by mid-2011. The Ceres dataset does not capture information prior to 2011.

FIGURE 47: PACWEST HAS MAPPED ALL U.S. STATES/COUNTIES TO A PLAY & REGION FOR THE PURPOSE OF ANALYZING THE MARKET

Play/basin-county classification for shale plays and basins.

Source: PacWest Consulting Partners. Copyright © PacWest 2013

PacWest also assisted in sourcing and interpreting FracFocus Canada data. Limited data on hydraulic fracturing was available for Alberta and British Columbia. Information on hydraulic fracturing was available from January to July 2013, with 743 reported wells for Alberta. In British Columbia, data was available on 598 wells from December 2011 to July 2013. Water volume data was not analyzed due to inconsistencies with the units reported.

WRI Aqueduct Water Risk Atlas

The World Resource Institute's Aqueduct Water Risk Atlas (Aqueduct) provides companies, investors and governments with a comprehensive analysis of geographic water-related risks worldwide. This report relied on the Aqueduct's water stress indicator, which denotes of the level of competition for water in a given region and measures total annual water withdrawals (municipal, industrial and agricultural) expressed as a percentage of water available.[57]

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[57] Baseline water stress measures total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percent of the total annual available flow. Higher values indicate more competition among users. Arid areas with low water use are shown in gray, but scored as high stress when calculating aggregated scores. Calculation: Water withdrawals (2010) divided by mean available blue water (1950–2008). Areas with available blue water and water withdrawal less than 0.03 and 0.012m/m2 respectively are coded as "arid and low water use." See white paper by Francis Gassert, Matt Landis, Matt Luck, Paul Reig and Tien Shiao, "Aqueduct Metadata Document, Aqueduct Global Maps 2.0," World Resources Institute, January 2013.

Operator Exposure To Water Stress & Water Use Metrics By Play

Top ten plays/basins by water use featured. Only operators with one billion gallons or more of water use included.

🟥 **Red quadrant show significant operational (100+ wells) exposure to water stress (majority of wells in medium or higher water stress). *Market cap as of 01/02/14**

⬅ **Increasing water volumes by play and by company**

— PLAY — Operator Ticker Mkt Cap (millions)*	EAGLE FORD Total Water Use (G) Average Water/Well # of Wells	MARCELLUS Total Water Use (G) Average Water/Well # of Wells	PERMIAN Total Water Use (G) Average Water/Well # of Wells	BARNETT Total Water Use (G) Average Water/Well # of Wells	HAYNESVILLE Total Water Use (G) Average Water/Well # of Wells	FAYETTEVILLE Total Water Use (G) Average Water/Well # of Wells	BAKKEN Total Water Use (G) Average Water/Well # of Wells	PICEANCE Total Water Use (G) Average Water/Well # of Wells	GRANITE WASH Total Water Use (G) Average Water/Well # of Wells	DJ BASIN Total Water Use (G) Average Water/Well # of Wells	ALL OTHER PLAYS Total Water Use (G) Average Water/Well # of Wells	TOTAL VOLUME Total Water Use (G) Average Water/Well # of Wells
Chesapeake Energy Corp.	2,797,262,299	2,353,803,047	325,899,464	1,641,081,372	1,526,940,630	182,939,072	10,153,836		1,174,966,119	53,943,010	1,842,029,079	**11,909,017,928**
CHK	4,881,784	4,924,274	1,780,871	4,296,025	5,106,825	3,976,936	2,030,767		3,865,020	2,157,720	2,855,859	**4,050,686**
$17,858	573	478	183	382	299	46	5		304	25	645	**2,940**
EOG Resources Inc.	2,729,087,967	277,725,543	1,213,510,181	2,775,601,480	617,131,091		417,384,497		7,791,118	59,940,981	312,223,162	**8,410,396,020**
EOG	3,972,472	3,192,248	7,444,848	5,121,036	7,714,139		2,244,003		1,947,780	1,498,525	1,406,411	**4,182,196**
$45,491	687	87	163	542	80		186		4	40	222	**2,011**
XTO Energy Inc.	122,800,052	421,718,240	75,881,752	972,266,297	680,129,115	1,946,053,578	408,725,619	213,215,411			1,546,215,557	**6,387,005,621**
(owned by Exxon)	3,148,719	4,685,758	174,041	3,230,121	10,627,017	6,297,908	2,586,871	2,733,531			2,304,345	**2,976,237**
	39	90	436	301	64	309	158	78			671	**2,146**
Anadarko Petroleum Corp.	2,791,640,251	763,555,085	216,882,267		781,492,147					1,142,159,114	436,042,412	**6,131,771,276**
APC	6,082,005	3,817,775	1,919,312		6,512,435					881,976	514,201	**2,020,353**
$39,491	459	200	113		120					1,295	848	**3,035**
Southwestern Energy Co.		697,811,466			15,950,322	4,772,607,428	803,397			2,466,967	17,355,040	**5,506,994,620**
SWN		5,964,201			2,658,387	5,023,797	803,397			2,466,967	3,471,008	**5,099,069**
$13,704		117			6	950	1			1	5	**1,080**
Devon Energy Corp.	17,125,757		860,022,380	2,408,760,066	195,996,983				201,985,743		1,245,558,423	**4,929,449,352**
DVN	1,902,862		1,977,063	4,028,027	3,919,940				4,390,994		4,179,726	**3,432,764**
$24,863	9		435	598	50				46		298	**1,436**
Encana Corp.				283,032,414	1,115,499,870			2,362,341,018		204,783,714	578,615,394	**4,544,272,410**
ECA				6,738,867	7,800,698			5,571,559		556,477	2,225,444	**3,673,624**
$13,130				42	143			424		368	260	**1,237**
BHP Billiton Ltd.	1,041,620,043		202,643,561		733,877,267	659,963,728					11,244,269	**2,649,348,868**
BHP	3,360,065		5,066,089		6,167,036	4,747,940					3,748,090	**4,336,087**
$172,613	310		40		119	139					3	**611**
Pioneer Natural Resources Co.	576,568,784		1,545,109,177	372,530,547							96,555,238	**2,590,763,746**
PXD	3,515,663		1,405,923	4,656,632							731,479	**1,756,450**
$24,564	164		1,099	80							132	**1,475**
Apache Corp.	313,110		1,079,578,510		101,863		1,280,951		680,903,714		122,321,757	**1,884,499,905**
APA	156,555		822,223		101,863		640,476		3,354,205		1,072,998	**1,152,599**
$34,228	2		1,313		1		2		203		114	**1,635**
Royal Dutch Shell PLC	85,170,618	760,564,797	18,099,285		801,308,215						156,581,997	**1,821,724,912**
RDS/A	4,482,664	3,457,113	2,262,411		7,631,507						1,477,189	**3,977,565**
$230,117	19	220	8		105						106	**458**
WPX Energy Inc.		390,283,299	372,692	98,535,678			137,211,487	1,084,270,577			16,612,461	**1,727,286,194**
WPX		4,108,245	93,173	3,941,427			1,960,164	1,471,195			535,886	**1,795,516**
$4,014		95	4	25			70	737			31	**962**
SM Energy Co.	1,055,710,984		82,823,821		32,900,402		111,201,636		123,690,030	13,223,028	44,020,108	**1,463,570,009**
SM	8,183,806		1,840,529		5,483,400		2,647,658		4,265,173	2,203,838	3,386,162	**5,420,630**
$5,478	129		45		6		42		29	6	13	**270**
ConocoPhillips	800,659,575		59,537,432	274,032,509			212,971,451			14,626,464	63,071,386	**1,424,898,817**
COP	3,228,466		428,327	4,724,698			1,953,867			2,925,293	233,598	**1,718,816**
$85,736	248		139	58			109			5	270	**829**
Marathon Oil Corp.	979,670,958				5,434,044		150,035,539		380,731	35,566,629	252,753,495	**1,423,841,396**
MRO	3,061,472				5,434,044		1,200,284		126,910	2,092,155	1,309,604	**2,160,609**
$24,208	320				1		125		3	17	193	**659**
Talisman Energy Inc.	666,297,518	721,153,218										**1,387,450,736**
TLM	4,271,138	3,815,625										**4,021,596**
$11,981	156	189										**345**
Continental Resources Inc.							882,572,992			6,755,787	443,207,904	**1,332,536,683**
CLR							2,190,007			3,377,894	5,540,099	**2,747,498**
$19,967							403			2	80	**485**
	752,244,480		159,930,993		247,276,124						44,852,338	**1,204,303,935**
EP Energy Corp.	5,223,920		3,634,795		4,665,587						448,523	**3,531,683**
	144		44		53						100	**341**
Range Resources Corp.		956,585,178	28,508,655	3,755,067					13,687,787		171,873,925	**1,174,410,612**
RRC		2,620,781	1,900,577	3,755,067					1,244,344		3,242,904	**2,639,125**
$13,335		365	15	1					11		53	**445**
EQT Corp.		1,125,046,604			4,388,454							**1,129,435,058**
EQT		6,215,727			4,388,454							**6,205,687**
$13,517		181			1							**182**
Cabot Oil & Gas Corp.	201,232,504	880,099,549			83,118						37,333,655	**1,118,748,826**
COG	5,030,813	5,177,056			83,118						2,488,910	**4,950,216**
$16,330	40	170			1						15	**226**
Newfield Exploration Co.	126,768,226						120,884,263		357,713,292		511,276,861	**1,116,642,642**
NFX	4,371,318						2,197,896		8,516,983		916,267	**1,632,518**
$3,291	29						55		42		558	**684**
EXCO Resources Inc.			3,798,564		712,516,032						364,593,867	**1,080,908,463**
XCO			73,049		4,318,279						4,797,288	**3,689,107**
$1,426			52		165						76	**293**
	4,476,916,292	4,387,077,389	4,547,808,887	779,414,214	885,196,920	669,021	3,719,513,722	744,402,197	1,043,293,122	953,877,593	3,635,522,304	**25,173,691,661**
All Other Operators	4,554,340	4,617,976	871,395	2,220,553	3,000,668	133,804	2,220,605	1,625,332	3,376,353	728,151	919,454	**1,623,167**
	983	950	5,219	351	295	5	1,675	458	309	1,310	3,954	**15,509**
	19,221,089,418	**13,735,423,415**	**10,420,407,621**	**9,609,009,644**	**8,356,222,597**	**7,562,232,827**	**6,172,739,390**	**4,404,229,203**	**3,604,411,656**	**2,487,343,287**	**11,949,860,632**	**97,522,969,690**
Totals	**4,458,615**	**4,371,554**	**1,119,511**	**4,037,399**	**5,537,590**	**5,218,932**	**2,180,410**	**2,595,303**	**3,790,128**	**810,474**	**1,381,966**	**2,481,879**
	4,311	**3,142**	**9,308**	**2,380**	**1,509**	**1,449**	**2,831**	**1,697**	**951**	**3,069**	**8,647**	**39,294**

Service Provider Exposure To Water Stress & Water Use Metrics By Play

Top ten plays/basins by water use featured. Only service providers with one billion gallons or more water use included.

🟥 **Red quadrant show significant operational (100+ wells) exposure to water stress (majority of wells in medium or higher water stress). *Market cap as of 01/02/14**

⬅ **Increasing water volumes by play and by company**

— PLAY — **Service Provider** **Ticker** **Mkt Cap (millions)***	**EAGLE FORD** Total Water Use (G) Average Water/Well # of Wells	**MARCELLUS** Total Water Use (G) Average Water/Well # of Wells	**PERMIAN** Total Water Use (G) Average Water/Well # of Wells	**BARNETT** Total Water Use (G) Average Water/Well # of Wells	**HAYNESVILLE** Total Water Use (G) Average Water/Well # of Wells	**FAYETTEVILLE** Total Water Use (G) Average Water/Well # of Wells	**BAKKEN** Total Water Use (G) Average Water/Well # of Wells	**PICEANCE** Total Water Use (G) Average Water/Well # of Wells	**GRANITE WASH** Total Water Use (G) Average Water/Well # of Wells	**DJ BASIN** Total Water Use (G) Average Water/Well # of Wells	**ALL OTHER PLAYS** Total Water Use (G) Average Water/Well # of Wells	**TOTAL VOLUME** Total Water Use (G) Average Water/Well # of Wells
Halliburton Co. HAL $42,309	2,994,690,678 4,130,608 725	2,407,179,909 4,524,774 532	1,736,432,660 1,228,029 1,414	2,408,243,200 4,649,118 518	2,655,925,998 5,533,179 480	1,192,262,206 6,242,211 191	2,075,058,899 1,972,489 1,052	1,813,412,171 1,530,306 1,185	1,222,598,165 4,596,234 266	1,547,041,307 1,157,099 1,337	4,681,477,441 1,871,842 2,501	**24,734,322,634** **2,424,696** **10,201**
UNKNOWN	4,447,785,459 4,141,327 1,074	3,516,053,489 4,351,551 808	1,416,498,478 889,202 1,593	571,092,200 2,379,551 240	909,404,149 5,613,606 162	174,698,664 4,260,943 41	1,102,824,610 2,849,676 387	785,298,109 5,732,103 137	617,228,980 3,070,791 201	13,386,931 405,665 33	1,813,686,763 1,460,295 1,242	**15,367,957,832** **2,596,816** **5,918**
Schlumberger Ltd. SLB $116,813	2,088,281,013 3,503,827 596	968,917,533 4,703,483 206	724,831,280 655,956 1,105	755,702,472 4,175,152 181	1,218,169,540 5,390,131 226	2,261,380,877 4,633,977 488	884,315,412 2,290,973 386	479,535,508 3,805,837 126	517,925,756 3,363,154 154	2,054,220 342,370 6	1,878,971,719 1,765,951 1,064	**11,780,085,330** **2,595,876** **4,538**
Baker Hughes Inc. BHI $23,947	903,619,642 3,861,622 234	1,004,590,065 4,311,545 233	2,000,952,486 915,349 2,186	1,368,203,421 3,026,999 452	425,331,411 4,129,431 103		468,584,053 1,661,646 282	1,019,049,851 6,138,855 166	450,756,243 3,494,234 129	559,423,826 648,984 862	1,131,314,460 554,838 2,039	**9,331,825,458** **1,395,726** **6,686**
FTS International (pending listing)	1,932,162,434 6,192,828 312	1,600,013,495 4,371,622 366	339,062,721 1,430,644 237	123,055,758 4,922,230 25	2,255,399,863 6,672,781 338		125,138,133 2,720,394 46		157,871,460 4,385,318 36		354,400,190 2,513,477 141	**6,887,104,054** **4,588,344** **1,501**
Weatherford International WFT $11,656	1,135,500,062 4,615,854 246	677,564,771 3,528,983 192	130,607,835 1,573,588 83	260,251,902 4,819,480 54	112,899,560 3,763,319 30	834,864,282 6,324,729 132	40,429,319 1,617,173 25	163,694,036 4,092,351 40	148,934,210 3,039,474 49	14,827,265 423,636 35	672,220,813 3,653,374 184	**4,191,794,055** **3,917,565** **1,070**
Universal Owned by Patterson-UTI - ticker: PTEN $3,738	1,298,797,094 5,903,623 220	952,858,698 5,383,382 177	1,160,129,111 3,536,979 328	369,957,641 4,932,769 75							33,832,195 2,819,350 12	**3,815,574,739** **4,698,984** **812**
Calfrac Well Services CFW $1,357		1,004,551,972 4,829,577 208				2,039,430,690 5,269,847 387	393,554,127 1,929,187 204	135,680,483 3,392,012 40		199,290,800 447,844 445	27,229,426 1,815,295 15	**3,799,737,498** **2,925,125** **1,299**
Pumpco Services		186,271,665 4,901,886 38	187,105,215 8,909,772 21	2,741,691,982 4,623,427 593							16,600,584 5,533,528 3	**3,131,669,446** **4,781,175** **655**
Trican Well Service Ltd TCW USD 1,812	338,217,953 4,227,724 80	672,538,497 3,821,241 176	268,067,380 783,823 342	250,184,105 4,633,039 54	466,211,592 5,123,204 91	129,966,399 3,512,605 37	8,787,503 585,834 15		365,831,915 5,716,124 64		243,310,389 3,003,832 81	**2,743,115,733** **2,918,208** **940**
C&J Energy Services Inc CJES $1,230	1,958,001,444 4,470,323 438		565,015,804 1,883,386 300		9,560,040 4,780,020 2				763,503 763,503 1		75,630,300 1,080,433 70	**2,608,971,091** **3,216,980** **811**
Cudd Owned by RPC Inc – ticker: RES $3,955	805,177,904 6,339,983 127	105,574,014 3,299,188 32	124,937,539 420,665 297		197,841,924 6,381,998 31	928,175,711 5,459,857 170			931,056 310,352 3		30,920,604 2,061,374 15	**2,193,558,752** **3,249,717** **675**
Nabors Industries NBR $4,979	3,873,156 3,873,156 1	591,609,548 3,542,572 167	59,934,967 3,154,472 19	297,888,444 3,971,846 75	1,685,334 187,259 9	151,998 75,999 2	125,752,696 2,566,382 49		17,457,762 5,819,254 3	148,084,035 434,264 341	206,745,840 364,631 567	**1,453,183,780** **1,178,576** **1,233**
Sanjel Corporation	610,652,916 7,446,987 82		85,668,211 2,379,673 36				691,980,106 2,116,147 327			2,629,998 2,629,998 1	56,028,985 2,436,043 23	**1,446,960,216** **3,085,203** **469**
All Other Service Providers	704,329,663 4,001,873 176	47,699,759 6,814,251 7	1,621,163,934 1,203,537 1,347	462,738,519 4,095,031 113	103,793,186 2,805,221 37	1,302,000 1,302,000 1	256,314,532 4,419,216 58	7,559,045 2,519,682 3	104,112,606 2,313,613 45	604,905 67,212 9	727,490,923 1,054,335 690	**4,037,109,072** **1,623,938** **2,486**
Totals	**19,221,089,418** **4,458,615** **4,311**	**13,735,423,415** **4,371,554** **3,142**	**10,420,407,621** **1,119,511** **9,308**	**9,609,009,644** **4,037,399** **2,380**	**8,356,222,597** **5,537,590** **1,509**	**7,562,232,827** **5,218,932** **1,449**	**6,172,739,390** **2,180,410** **2,831**	**4,404,229,203** **2,595,303** **1,697**	**3,604,411,656** **3,790,128** **951**	**2,487,343,287** **810,474** **3,069**	**11,949,860,632** **1,381,966** **8,647**	**97,522,969,690** **2,481,879** **39,294**

Ceres

Ceres
99 Chauncy Street
Boston, MA 02111
T: 617-247-0700
F: 617-267-5400

www.ceres.org