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Analysis of Hydraulic Fracturing Fluid Data from the FracFocus Chemical Disclosure Registry 1.0

United States Environmental Protection Agency
Office of Research and Development

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Preface

The U.S. Environmental Protection Agency (EPA) is conducting a *Study of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources*. The study is based upon an extensive review of the literature; results from EPA research projects; and technical input from state, industry, and non-governmental organizations, as well as the public and other stakeholders. A series of technical roundtables and in-depth technical workshops were held to help address specific research questions and to inform the work of the study.

In Fiscal Year 2010, Congress urged the EPA to examine the relationship between hydraulic fracturing and drinking water resources in the United States. The EPA's *Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources* was reviewed by the agency's Science Advisory Board (SAB) and issued in 2011. The *Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources: Progress Report*, detailing the EPA's research approaches and next steps, was released in late 2012 and followed by a consultation with individual experts convened under the auspices of the SAB.

This report, *Analysis of Hydraulic Fracturing Fluid Data from the FracFocus Chemical Disclosure Registry 1.0*, is the product of one of the research projects conducted as part of the EPA's study. It has undergone independent, external peer review, which was conducted through the Eastern Research Group, Inc. All peer review comments were considered in the report's development. The report has also been reviewed in accordance with agency policy and approved for publication.

The EPA is writing a state-of-the-science assessment that integrates a broad review of existing literature, results from peer-reviewed EPA research products (including this report), and information gathered through stakeholder engagement efforts to answer the fundamental research questions posed for each stage of the hydraulic fracturing water cycle:

- Water Acquisition: What are the possible impacts of large volume water withdrawals from ground and surface waters on drinking water resources?
- Chemical Mixing: What are the possible impacts of surface spills on or near well pads of hydraulic fracturing fluids on drinking water resources?
- Well Injection: What are the possible impacts of the injection and fracturing process on drinking water resources?
- Flowback and Produced Water: What are the possible impacts of surface spills on or near well pads of flowback and produced water on drinking water resources?
- Wastewater Treatment and Waste Disposal: What are the possible impacts of inadequate treatment of hydraulic fracturing wastewaters on drinking water resources?

The state-of-the-science assessment is not a human health or an exposure assessment, nor is it designed to evaluate policy options or best management practices. As a Highly Influential Scientific Assessment, the draft assessment report will undergo public comment and a meaningful and timely peer review by the SAB to ensure all information is high quality.

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List of Acronyms

API	American Petroleum Institute
CASRN	Chemical Abstracts Service Registry Number
CBI	Confidential Business Information
CSV	Comma-Separated Values
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
GWPC	Ground Water Protection Council
IOGCC	Interstate Oil and Gas Compact Commission
MSDS	Material Safety Data Sheet
PDF	Portable Document Format
QA	Quality Assurance
SEAB	Secretary of Energy Advisory Board
TVD	True Vertical Depth
XML	Extensible Markup Language

Executive Summary

Hydraulic fracturing has enabled oil and gas production to expand into areas of the United States where production was once considered impractical. As production has increased, so have public concerns about hydraulic fracturing and its potential effects on drinking water and the environment. In response to public interest in the composition of hydraulic fracturing fluids, the Ground Water Protection Council (GWPC) and the Interstate Oil and Gas Compact Commission (IOGCC) developed the FracFocus Chemical Disclosure Registry (subsequently referred to as "FracFocus"). FracFocus is a publicly accessible website (www.fracfocus.org) where oil and gas production well operators can disclose information about the ingredients used in hydraulic fracturing fluids at individual wells. Although FracFocus was designed for local users, it provides an opportunity to study the composition of hydraulic fracturing fluids nationwide.

This report analyzes data from more than 39,000 FracFocus disclosures provided to the U.S. Environmental Agency (EPA) by the GWPC in March 2013. Each disclosure contained data for an individual oil and gas production well. Data on the composition of hydraulic fracturing fluids were extracted from the disclosures and summarized to address the following research questions from the EPA's *Plan the Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources*:

- What are the identities and quantities of chemicals used in hydraulic fracturing fluids, and how might this composition vary at a given site and across the country?
- How much water is used in hydraulic fracturing operations, and what are the sources of this water?

Data from this study will supplement information obtained from the published literature and other sources being considered by the EPA in the preparation of the agency's assessment of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources.

Disclosures analyzed for this report were submitted to FracFocus by well operators using the FracFocus 1.0 format.[1] Data in the disclosures were extracted from individual portable document format (PDF) files and compiled in a project database.[2] Information on fracture date, operator, well identification and location, production type, true vertical depth, and the total water volume used for hydraulic fracturing were successfully extracted from 38,530 disclosures. Hydraulic fracturing fluid composition data were extracted for 37,017 disclosures. Hydraulic fracturing fluid composition data included trade names of additives, the purpose associated with each additive, and the identity [i.e., chemical name and Chemical Abstracts Services Registry Number (CASRN)] and maximum concentration of each ingredient in an additive and in the overall hydraulic fracturing fluid. The content of the project database was influenced by the data conversion process (i.e., extracting data

[1] FracFocus 2.0 became the exclusive disclosure mechanism in June 2013, which is past the timeframe of this study (January 2011 to February 2013). More information on the FracFocus 1.0 and FracFocus 2.0 formats may be found in the FracFocus 2.0 Operator Training materials available at http://fracfocus.org/node/331. In early 2015, the GWPC and the IOGCC announced new features for FracFocus 3.0. More information on FracFocus 3.0 is available at http://www.fracfocus.org/major-improvements-fracfocus-announced.

[2] The project database and the accompanying *Data Management and Quality Assessment Report* are available at http://www2.epa.gov/hfstudy/published-scientific-papers. The *Data Management and Quality Assessment Report* describes the structure of the database, data fields, and quality assessment of the data.

from PDFs into the project database) as well as the completeness and accuracy of data in the original PDF disclosures. Reviews of data quality were conducted on the project database prior to data analysis to ensure that the results of the analyses reflected the data contained in the PDF disclosures, while identifying obviously invalid or incorrect data to exclude from analyses.

Analyses were conducted on unique (i.e., non-duplicate) disclosures with a fracture date between January 1, 2011, and February 28, 2013, that met appropriate quality assurance criteria for a given analysis. The disclosures identified well locations in 406 counties in 20 states and were reported by 428 well operators. True vertical depths ranged from approximately 2,900 feet to nearly 13,000 feet (5th to 95th percentile), with a median of just over 8,100 feet. Generally, well locations represented by the disclosures were clustered in the northeast (mainly in and around Pennsylvania), the west central portion of the country (from North Dakota and Wyoming through Texas and Louisiana), and in California. Summary statistics performed on the entire dataset reflect a greater contribution of data from states that are better represented in the project database than others—partly due to the locations of oil- and gas-bearing reservoirs, different state reporting requirements,[3] and the success in extracting data from individual PDF disclosures.

State-specific data on the number of unique disclosures with a fracture date in the study time period and summary statistics on total water volumes and additive ingredients per disclosure are reported in Table ES-1. Ingredients reported in the disclosures were generally categorized in analyses as either additive ingredients, base fluids, or proppants depending upon entries in the trade name, purpose, and comments fields as well as the reported maximum ingredient concentration in the hydraulic fracturing fluid. Additive ingredients included ingredients reported for trade names (i.e., additives) that had purposes other than base fluid or proppant. The project database contains 692 unique ingredients reported for additives, base fluids, and proppants. Operators designated 11% of all ingredient records as confidential business information. One or more ingredients were claimed confidential in more than 70% of disclosures.

As shown in Table ES-1, the median number of additive ingredients per disclosure for the entire dataset was 14, with a range of 4 to 28 (5th to 95th percentile). The most commonly reported additive ingredients were methanol, hydrochloric acid, and hydrotreated light petroleum distillates (reported in 71%, 65%, and 65% of disclosures, respectively). Table ES-2 shows the occurrence and median value of reported maximum concentrations in hydraulic fracturing fluid[4] for the most frequently reported additive ingredients in disclosures associated with oil wells and in disclosures associated with gas wells. Among the entire data set, the sum of the maximum hydraulic fracturing fluid concentration for all additive ingredients reported in a disclosure was less than 1% by mass in approximately 80% of disclosures, and the median maximum hydraulic fracturing fluid concentration was 0.43% by mass. Among proppants, quartz was the most common material

[3] During the period of time studied in this report, six of the 20 states with data in the project database began requiring operators to disclose chemicals used in hydraulic fracturing fluids to FracFocus, three states started requiring disclosure to either FracFocus or the state, and five states required or began requiring disclosure to the state.

[4] Well operators reported the maximum concentration of an ingredient in the additive and in the hydraulic fracturing fluid. Therefore, the median concentration values presented in this report represent the median value of the reported maximum concentrations or the "median maximum concentration."

reported (present in at least 98% of disclosures that identified proppants), with a median maximum hydraulic fracturing fluid concentration of 10% by mass.

Base fluids described in the disclosures included water, water with non-aqueous constituents (i.e., gases or hydrocarbons), and hydrocarbons only. More than 93% of the disclosures analyzed in the study are inferred to use water as a base fluid,[5] with a median maximum concentration of 88% by mass in hydraulic fracturing fluids. As shown in Table ES-1, the median total water volume per

Table ES-1. State-specific information on the number of unique disclosures with a fracture date between January 1, 2011, and February 28, 2013; total water volumes reported per disclosure; and the number of unique additive ingredients reported per disclosure.

State	Number of disclosures*	Total water volume per disclosure (gallons)†			Number of additive ingredients per disclosure§		
		Median	5th percentile	95th percentile	Median	5th percentile	95th percentile
Alabama	55	37,691	23,602	51,651	10	10	10
Alaska	37	88,448	36,437	435,638	15	13	16
Arkansas	1,450	5,277,890	2,681,465	7,484,091	10	6	21
California	718	77,154	18,684	356,453	19	10	23
Colorado	4,938	463,659	103,906	4,327,068	13	5	23
Kansas	136	1,421,591	9,866	2,448,300	14	8	17
Louisiana	1,038	5,148,696	277,540	8,942,170	15	1	29
Michigan	15	33,306	15,722	15,127,125	19	10	29
Mississippi	4	9,173,624	4,322,108	12,701,054	14	11	23
Montana	213	1,469,839	216,578	3,197,594	16	9	38
New Mexico	1,162	172,452	22,130	2,851,323	21	7	31
North Dakota	2,254	2,019,513	557,740	3,685,402	15	4	33
Ohio	148	3,887,499	2,526,398	7,442,826	17	8	38
Oklahoma	1,909	2,578,947	114,870	8,288,041	12	5	30
Pennsylvania	2,483	4,184,936	1,092,739	7,475,493	10	4	18
Texas	18,075	1,413,287	26,006	7,407,116	15	4	30
Utah	1,429	303,424	35,070	1,056,654	17	7	23
Virginia	90	33,474	13,322	96,684	9	7	12
West Virginia	277	5,012,238	2,500,529	7,889,759	12	7	22
Wyoming	1,457	306,246	5,503	3,110,272	10	5	24
State Uncertain‡	162	2,770,090	80,067	6,945,958	15	5	27
Entire Dataset	38,050	1,508,724	29,526	7,196,702	14	4	28

* See Table 6 for notes on quality assurance criteria.
† See Table 15 for notes on quality assurance criteria.
§ See Table 7 for notes on quality assurance criteria.
‡ State location did not pass state locational quality assurance criteria (Section 2.2.1).

disclosure was approximately 1.5 million gallons, with a range of nearly 30,000 gallons to approximately 7.2 million gallons (5th to 95th percentile). Non-aqueous constituents (i.e., nitrogen, carbon dioxide, and hydrocarbons) were reported as base fluids or in combination with water as a base fluid in fewer than 3% of disclosures. Twenty-nine percent of disclosures in the project database included information related to water sources. Some of these terms indicated a condition of water quality, such as "fresh," rather than a specific identification of the source of the water (e.g., ground water, surface water). The most commonly reported source of water used for base fluid was "fresh" (68% of disclosures with water source information).

Table ES-2. Most frequently reported additive ingredients in disclosures associated with oil wells and in disclosures associated with gas wells.

Oil Production Type			Gas Production Type		
EPA-standardized chemical name*	**Number (%) of disclosures**	**Median concentration in hydraulic fracturing fluid (% by mass)**	**EPA-standardized chemical name***	**Number (%) of disclosures**	**Median concentration in hydraulic fracturing fluid (% by mass)**
Methanol	12,484 (72%)	0.022	Hydrochloric acid	12,351 (73%)	0.078
Distillates, petroleum, hydrotreated light†	10,566 (61%)	0.087	Methanol	12,269 (72%)	0.0020
Peroxydisulfuric acid, diammonium salt	10,350 (60%)	0.0076	Distillates, petroleum, hydrotreated light†	11,897 (70%)	0.017
Ethylene glycol	10,307 (59%)	0.023	Isopropanol	8,008 (47%)	0.0016
Hydrochloric acid	10,029 (58%)	0.29	Water†	7,998 (47%)	0.18
Guar gum	9,110 (52%)	0.17	Ethanol†	6,325 (37%)	0.0023
Sodium hydroxide	8,609 (50%)	0.010	Propargyl alcohol	5,811 (34%)	0.000070
Quartz†	8,577 (49%)	0.0041	Glutaraldehyde	5,635 (33%)	0.0084
Water†	8,538 (49%)	1.0	Ethylene glycol	5,493 (32%)	0.0061
Isopropanol	8,031 (46%)	0.0063	Citric acid	4,832 (28%)	0.0017
Potassium hydroxide†	7,206 (41%)	0.013	Sodium hydroxide	4,656 (27%)	0.0036
Glutaraldehyde	5,927 (34%)	0.0065	Peroxydisulfuric acid, diammonium salt	4,618 (27%)	0.0045

* See Section 2.2.3 for a description of the standardization process.

† Chemical has a non-normal distribution and the median may not represent the central tendency of the dataset as well as the median of a normally distributed dataset.

Note: Analysis considered 34,675 disclosures and 676,376 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; valid CASRN; and concentrations between 0 and 100%. Disclosures that did not meet quality assurance criteria (3,855 disclosures) or other, query-specific criteria were excluded from analysis.

Data extracted from disclosures submitted by oil and gas well operators to FracFocus 1.0 showed that hydraulic fracturing fluids used between January 2011 and February 2013 generally contained water as a base fluid, quartz as proppant, and various additive ingredients. Three additive ingredients (methanol, hydrochloric acid, and hydrotreated light petroleum distillates) were individually reported in more than 65% of oil and gas disclosures, although 692 unique ingredients were identified. The project database and the summary statistics presented in this report provide useful insights into the chemical composition of hydraulic fracturing fluids and water volumes used for hydraulic fracturing, which are important factors to consider when assessing potential impacts to drinking water resources from hydraulic fracturing.

1. Introduction

1.1. Objective

The objective of this study was to analyze data contained in the FracFocus Chemical Disclosure Registry 1.0 to address the following research questions from the EPA's *Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources* (2011):

- What are the identities and quantities of chemicals used in hydraulic fracturing fluids, and how might this composition vary at a given site and across the country?
- How much water is used in hydraulic fracturing operations, and what are the sources of this water?

FracFocus (www.fracfocus.org) is a national hydraulic fracturing chemical registry developed by the Ground Water Protection Council (GWPC) and the Interstate Oil and Gas Compact Commission (IOGCC). Oil and gas production well operators disclose to FracFocus the composition of hydraulic fracturing fluids used at individual oil and gas production wells across the United States. Disclosures (i.e., the information submitted for a single well) evaluated in this report had fracture dates between January 1, 2011, and February 28, 2013, and were uploaded by operators to FracFocus prior to March 1, 2013. Data extracted from the disclosures included fracture date, operator, well identification and location, production type (i.e., oil or gas), true vertical depth, total water volume, and hydraulic fracturing fluid composition. Hydraulic fracturing fluid composition data include trade names of additives, the purpose associated with each additive, and the identity [i.e., chemical name and Chemical Abstracts Services Registry Number (CASRN)] and maximum concentration of each ingredient in an additive and in the overall hydraulic fracturing fluid. Chemical and water use in hydraulic fracturing fluids was summarized, with some context provided by a limited literature review. Data from this study will supplement information obtained from the published literature and other sources being considered by the EPA in the preparation of the agency's assessment of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources.

1.2. Background

Hydraulic fracturing is a technique used to enable or enhance both conventional and unconventional production of oil and gas from hydrocarbon-containing rock formations. The practice involves the injection of fluids under pressures great enough to fracture the formation. Fractures resulting from the process are held open using proppants, which allows oil and gas to flow from within the rock to the production well. Hydraulic fracturing fluids are composed of a base fluid, proppants, and additives. An additive is added to the hydraulic fracturing fluid to change the fluid's properties (e.g., viscosity, pH) and can be a single chemical or a mixture of chemicals. The choice of additives in fracturing fluids is influenced by many factors, including the geology of the target rock formation to be hydraulically fractured, the pressure and temperature conditions in the target formation, operator preference, and potential interactions between chemicals in the fracturing fluid (NYSDEC, 2011; Rahim et al., 2013). Although hydraulic fracturing has been used to increase hydrocarbon production since the 1940s (GWPC and IOGCC, 2014), recent applications of hydraulic fracturing with directional drilling techniques have expanded domestic production of oil and gas into formations where production was impractical at one time.

In the late 2000s, the public became increasingly interested in understanding the chemical composition of hydraulic fracturing fluids. The GWPC and the IOGCC responded to the public's interest by developing a national hydraulic fracturing chemical registry, FracFocus. Oil and gas well operators began to voluntarily upload information on the composition of hydraulic fracturing fluids used at individual production wells to FracFocus 1.0 in April 2011.[6] At that time, each disclosure included information about the well (e.g., operator name, well identification and location, total water volume, production type) and hydraulic fracturing fluid composition. Hydraulic fracturing fluid composition information included the identity and concentration of ingredients used as base fluids, proppants, and additives. The public could search FracFocus 1.0 for disclosures in their local area, and search results were provided in the form of an individual portable document format (PDF) file for a specific well. In late 2012, the GWPC and the IOGCC launched FracFocus 2.0, which has expanded search parameters for the public and mechanisms, such as dropdown menus and automatic formatting, for certain fields to improve consistency and completeness of reporting by operators. FracFocus 2.0 became the exclusive submission method in June 2013. In early 2015, the GWPC and the IOGCC announced additional updates to FracFocus that include providing public extraction of data in a machine readable format and verification of CASRNs.[7]

Although FracFocus was designed to meet local informational needs, the large number of entries in the registry provides insights into the composition of hydraulic fracturing fluids at county, state, regional, and national scales. To perform the analyses discussed in this report, the GWPC provided the EPA with more than 39,000 FracFocus 1.0 disclosures in PDF format that were submitted by operators before March 1, 2013. The EPA converted the data into a database (termed the "project database" in this report), which is a tool the public, researchers, and state resource managers may use to facilitate analyses of the composition of hydraulic fracturing fluids.[8]

This study was conducted using disclosures with fracture dates between January 1, 2011, and February 28, 2013. Although some disclosures in the project database have fracture dates before January 1, 2011, that date was chosen as a starting point for the study time period because of the agreement between GWPC and participating operators to disclose information for wells fractured after the later of the two following dates: January 1, 2011, or the date the company agreed to participate (GWPC and IOGCC, 2014). The EPA chose February 28, 2013, as the endpoint for the

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[6] Operators could upload information for wells hydraulically fractured after January 1, 2011. Disclosures in FracFocus are assumed to include only chemical and water use information for hydraulic fracturing and not matrix treatments, which avoid fracturing the production formation. Matrix treatments are designed to counteract decreasing permeability resulting from formation damage near the wellbore by introducing acid, solvent, or chemicals into the formation (Schlumberger, 2014).

[7] More information on FracFocus 3.0 is available at http://www.fracfocus.org/major-improvements-fracfocus-announced.

[8] The project database and the accompanying *Data Management and Quality Assessment Report* (US EPA, 2015) are available at http://www2.epa.gov/hfstudy/published-scientific-papers. The *Data Management and Quality Assessment Report* describes the structure of the database, data fields, and quality assessment of the data.

study period because it was the last full day that operators could have uploaded files prior to the GWPC collecting the disclosures to send to the EPA.

During the timeframe of this study, six of the 20 states with data in the project database began requiring operators to disclose chemicals used in hydraulic fracturing fluids to FracFocus (Colorado, North Dakota, Oklahoma, Pennsylvania, Texas, and Utah).[9] Three other states started requiring disclosure to either FracFocus or the state (Louisiana, Montana, and Ohio), and five states required or began requiring disclosure to the state (Arkansas, Michigan, New Mexico, West Virginia, and Wyoming). Alabama, Alaska, California, Kansas, Mississippi, and Virginia did not have reporting requirements during the period of time studied in this report.

Extensive data quality reviews of the information in the project database were conducted. The data were otherwise analyzed "as is" to ensure that the results represent the information disclosed by operators as closely as possible. Because operators can update disclosures in FracFocus after the original submission, the project database may not match the current data in FracFocus.

2. Methodology for Data Extraction and Analysis

This section describes the FracFocus source data and summarizes the methodologies used to extract the data for inclusion in the project database and to analyze the data for presentation in this report. It also describes the data management and quality assurance (QA) procedures used to ensure that the project database and results from analyses conducted using the project database represent data contained in the original PDF disclosures as accurately as possible.

Data extraction and QA methods used in this study are also described in the QA project plan (The Cadmus Group, Inc., 2013). The accompanying *Data Management and Quality Assessment Report* (US EPA, 2015) provides additional detail on methodology for extracting and analyzing data, including specifics about database parameters.

2.1. Database Development

2.1.1. Source Data

The source data provided by the GWPC were a bulk archive of 39,136 disclosures in PDF format that were submitted by well operators to the FracFocus 1.0 website prior to March 1, 2013. Each disclosure was initially submitted by the well operator to FracFocus in the form of a Microsoft Excel spreadsheet and contained information on one production well that was hydraulically fractured with a single fracture date. Each Excel spreadsheet was then converted into a PDF file by the FracFocus website.

The PDF disclosures given to the EPA were created using FracFocus 1.0. Although FracFocus 2.0 became an option for submitting information in late 2012, it was not the exclusive disclosure mechanism until June 2013. Because all disclosures in the project database have information on production type and because disclosures created using FracFocus 2.0 do not contain this

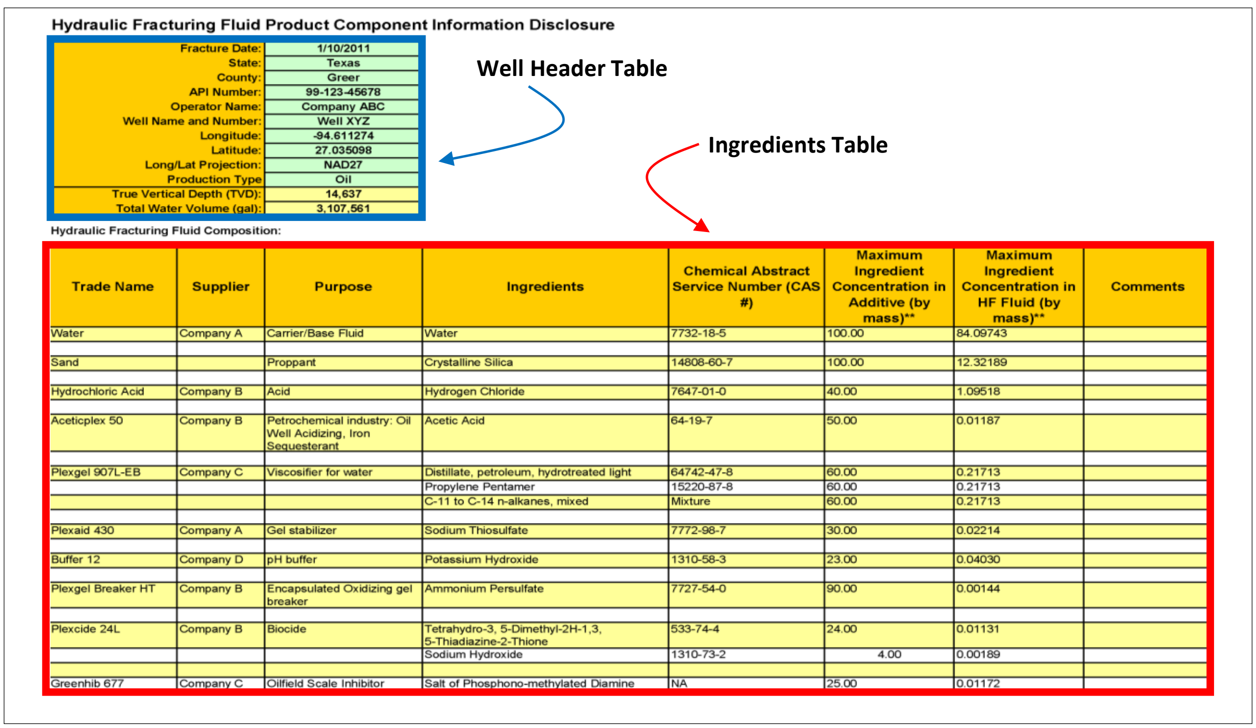
[9] Between February 5, 2011, and April 13, 2012, Pennsylvania required reporting to the state. As of April 14, 2012, Pennsylvania required reporting to both the state and FracFocus.

information, all disclosures used to create the project database are assumed to have been generated using FracFocus 1.0.

Each FracFocus 1.0 disclosure contains two tables of information, referred to as the “well header table” and the “ingredients table” in this report. The well header table (outlined in blue in Figure 1) contains information about the well itself, including: fracture date, location, operator name, well name and number, American Petroleum Institute (API) well number, production type, true vertical depth (TVD), and the total water volume used for hydraulic fracturing. The ingredients table (outlined in red in Figure 1) provides information about the composition of the hydraulic fracturing fluid. Trade names of additives, the purpose associated with each additive, and the identity and maximum concentration of each ingredient in an additive and in the overall hydraulic fracturing fluid are listed in the ingredients table.

2.1.2. Data Conversion and Extraction

To extract data from the disclosures, the original 39,136 PDF files were converted to Extensible Markup Language (XML) 2003 spreadsheet (Microsoft Excel 2003 XML) files using Adobe Acrobat Pro X (Adobe Systems Incorporated, 2011). The XML files were converted to comma-separated values (CSV) files using a script developed in Python 2.7 (Python Software Foundation, 2012); the script used the Beautiful Soup 4 library (Richardson, 2013) to read the XML files. The script parses and sorts the XML data into CSV files. Parsing of the data resulted in two CSV files: one file with data from the well header table and the other file with data from the ingredients table. The project database (Microsoft Access 2013; Microsoft Corporation, 2012) into which the CSV files were incorporated, therefore, has two primary tables: one for well header data and one for ingredient



Hydraulic Fracturing Fluid Product Component Information Disclosure

Fracture Date:	1/10/2011
State:	Texas
County:	Greer
API Number:	99-123-45678
Operator Name:	Company ABC
Well Name and Number:	Well XYZ
Longitude:	-94.611274
Latitude:	27.035098
Long/Lat Projection:	NAD27
Production Type	Oil
True Vertical Depth (TVD):	14,637
Total Water Volume (gal):	3,107,561

Hydraulic Fracturing Fluid Composition:

Trade Name	Supplier	Purpose	Ingredients	Chemical Abstract Service Number (CAS #)	Maximum Ingredient Concentration in Additive (by mass)**	Maximum Ingredient Concentration in HF Fluid (by mass)**	Comments
Water	Company A	Carrier/Base Fluid	Water	7732-18-5	100.00	84.09743	
Sand		Proppant	Crystalline Silica	14808-60-7	100.00	12.32189	
Hydrochloric Acid	Company B	Acid	Hydrogen Chloride	7647-01-0	40.00	1.09518	
Aceticplex 50	Company B	Petrochemical industry: Oil Well Acidizing, Iron Sequesterant	Acetic Acid	64-19-7	50.00	0.01187	
Plexgel 907L-EB	Company C	Viscosifier for water	Distillate, petroleum, hydrotreated light	64742-47-8	60.00	0.21713	
			Propylene Pentamer	15220-87-8	60.00	0.21713	
			C-11 to C-14 n-alkanes, mixed	Mixture	60.00	0.21713	
Plexaid 430	Company A	Gel stabilizer	Sodium Thiosulfate	7772-98-7	30.00	0.02214	
Buffer 12	Company D	pH buffer	Potassium Hydroxide	1310-58-3	23.00	0.04030	
Plexgel Breaker HT	Company B	Encapsulated Oxidizing gel breaker	Ammonium Persulfate	7727-54-0	90.00	0.00144	
Plexcide 24L	Company B	Biocide	Tetrahydro-3, 5-Dimethyl-2H-1,3, 5-Thiadiazine-2-Thione	533-74-4	24.00	0.01131	
			Sodium Hydroxide	1310-73-2	4.00	0.00189	
Greenhib 677	Company C	Oilfield Scale Inhibitor	Salt of Phosphono-methylated Diamine	NA	25.00	0.01172	

Figure 1. Example FracFocus 1.0 disclosure.

data. The two-table structure was chosen because an individual disclosure only has one set of well header values, but can have a variety of ingredients.

The well header and ingredients tables in the project database are linked by a constructed unique identification field. The field was necessary, because combinations of API well number and fracture date were found to not be unique in the dataset and, therefore, could not serve as unique identifiers. Two hundred twenty-eight disclosures were observed to have been updated at times ranging from the same day as the original submission to as late as 588 days after the original submission. In cases where there are duplicate disclosures with the same API well number and fracture date, the most recent file (based on file modified date of the PDF) was deemed the authoritative disclosure.[10] Duplicate disclosures occurred, in part, because well operators occasionally submitted an initial disclosure with preliminary data and later submitted a final disclosure with revised or updated data for the same well/hydraulic fracturing event, but could not then remove the initial disclosure.[11]

2.1.3. Parsing Success

Parsing is defined as converting information from the PDF disclosures into data tables in the project database. Success in parsing depends upon how effectively the software identifies symbols in specific positions on the PDF files and categorizes them into the appropriate data fields in the project database.

Data from more than 98% (38,530 of 39,136) of the original PDF disclosures were parsed and are included in the project database. No data from 606 PDF files could be extracted during the parsing process, and, therefore, none of the data from these disclosures are present in the project database.[12] Well header data were parsed from all of the 38,530 PDF files included in the project database, and ingredient data were also parsed from 37,017 PDF files (96% of disclosures in the project database). Difficulties in extracting all data from an individual PDF disclosure arose because the creation of the CSV files from XML files is highly sensitive to the original file formatting. Most disclosures were prepared in a consistent format that enabled relatively straightforward parsing of data. However, some disclosures were uploaded to the FracFocus 1.0 website using templates that had been modified by well operators, with columns or rows added or removed, or other formatting changes. The modified templates could sometimes cause the parsing script to skip disclosures or portions of disclosures. The effect of excluding data that failed to parse is that, based on percentage, some states (e.g., Colorado, North Dakota, and Utah) with partially parsed or unparsed disclosures are not as fully represented in the project database as they are in the PDF disclosures received from the GWPC. The numbers of fully parsed, partially parsed, and unparsed data by state are presented in Table 1.

[10] The date of file modification was available to this project because it was associated with the PDF files given to the EPA by the GWPC. The file modified date cannot be determined from the PDF disclosures available for public download on the FracFocus website.

[11] FracFocus 2.0 allows operators to remove preliminary disclosures in such cases.

[12] The 606 disclosures accounted for 1.5% of all the disclosures given to the EPA by the GWPC. Data from the 606 disclosures corresponded to a small amount of data compared to the entire project database. Manual entry of the data was not performed.

Additional parsing difficulties were identified during initial analyses of the project database that resulted in unusual query results. Targeted comparisons of the project database to the original PDFs files were performed to investigate the cause of unusual query results.[13] The targeted

Table 1. Number of parsed, partially parsed, and unparsed disclosures, summarized by state.

State	Number of disclosures	Completely parsed	Partially parsed (well header only)	Unparsed
Alabama	55	55	0	0
Alaska	37	37	0	0
Arkansas	1,462	1,461	1	0
California	754	727	16	11
Colorado	5,207	4,755	314	138
Kansas	139	134	3	2
Louisiana	1,058	1,035	8	15
Michigan	16	14	1	1
Mississippi	6	4	0	2
Montana	222	206	8	8
New Mexico	1,181	1,144	26	11
North Dakota	2,378	2,092	176	110
Ohio	156	147	1	8
Oklahoma	1,950	1,861	70	19
Pennsylvania	2,573	2,541	23	9
Texas	18,388	17,502	692	194
Utah	1,495	1,348	90	57
Virginia	90	90	0	0
West Virginia	295	280	4	11
Wyoming	1,503	1,426	67	10
State Uncertain*	171	158	13	0
Entire Dataset	39,136	37,017	1,513	606

* State location did not pass state locational quality assurance criteria (Section 2.2.1).
Note: Analysis considered all disclosures (39,136).

[13] If the results of an analysis indicated one or a few specific disclosures included problematic or unusual data, such as a particularly high water volume in a dataset with low volumes, the data were confirmed with the original PDF file(s). For unusual entries in a few tens of disclosures, approximately one PDF disclosure out of every 10 to 15 containing the unusual data was compared to the project database. For problems more frequently encountered (e.g., problematic data in multiple fields or fields with multiple entries), two dozen disclosures from seven states were selected and the original PDF files, the XML files, and the resulting database entries were compared. Comparisons to the original PDF files were also conducted for some database entries that were not believed to be outliers, but were otherwise noteworthy. For example, in compiling data on non-aqueous base fluid ingredients, the original PDFs for all disclosures that used hydrocarbon-based fracturing fluids without water were compared to the project database to verify that data from the disclosures were accurately parsed into the project database.

comparisons found problematic entries in the project database, such as disclosures with invalid entries in multiple fields, multiple entries in the trade name or purpose fields, infeasible data in the concentration fields (i.e., letters instead of numbers), and unusually high or low water volumes. Comparisons to the original PDF files indicated that problematic entries in the database likely resulted from atypical reporting styles, including modified data templates that interfered with parsing, and possible data entry errors. The types and causes of problematic entries in the project database were not quantified, and the large number of ingredient records made individual correction of these errors infeasible. Instead, problematic entries in the project database were managed through the use of QA filters that were designed to identify data elements that could not be used for analyses (Sections 2.2 and 2.3). No changes were made to the project database as a result of comparisons to the original PDF files, in keeping with the approach of presenting the data as reported in the FracFocus 1.0 disclosures to the greatest degree possible. In summary, the large number of disclosures in the project database and the use of QA filters in analyses ensured that the results reflect the data in the PDF disclosures as accurately as possible.

2.2. Data Standardization and Quality Assurance

An assessment of data quality ensured that results of the analyses reflected the data contained in disclosures, while identifying obviously invalid or incorrect data to exclude from analyses. Data that were parsed and incorporated in the project database must first pass two primary QA criteria to be included in analyses: the combination of fracture date and API well number for each disclosure must be unique (i.e., no duplicates), and the fracture date must occur between January 1, 2011, and February 28, 2013.[14] While duplicate disclosures from the same fracturing event (i.e., same API well number and same fracture date) were excluded from analyses, more than one disclosure for a given well was included if the fracture dates on the disclosures differed. As described in Section 2.1.1, 228 wells had more than one disclosure with the same fracture date, and the PDF file with the most recently modified date was considered to be the authoritative version.

Table 2 lists the numbers of disclosures that were successfully parsed and the met primary QA criteria. It shows that 38,050 disclosures (99% of the 38,530 disclosures in the project database) met the two primary criteria and were candidates for analyses that rely on well header data (e.g., analyses of well locations and water volumes). The number of disclosures with parsed well header and ingredients data that met the two primary criteria was 36,544 (95% of the disclosures in the database). These disclosures were candidates for analyses of additive ingredients, water sources, and proppants

To help identify invalid and extreme data and prepare for data analysis, the fields in the database were subject to further QA review (beyond establishment of the two primary criteria of unique status and date range). Data values in the project database may be invalid, erroneous, extreme, or missing either due to information entered into the original FracFocus 1.0 template or to the parsing process that was used to create the project database. The QA process checks for internal consistency among locational data, sets simple criteria for invalid data (e.g., incorrectly non-numeric entries in fields such as total water volume, fluid concentrations, and CASRNs), and identifies extreme outliers. The QA process cannot, and was not intended to, determine the

[14] Two hundred fifty-one disclosures were excluded because the fracture date did not meet the date criterion.

Table 2. Number and percentage of disclosures that had data successfully parsed from the well header and ingredients tables and that met the primary QA criteria.

Well header parsed	Ingredient table parsed	Primary QA criteria		Number of disclosures	Percentage of disclosures
		Unique disclosures*	Fracture date within study timeframe†		
				39,136	100.0%
Yes				38,530	98.5%
Yes		Yes		38,301	97.9%
Yes		Yes	Yes	38,050	97.2%
Yes	Yes			37,017	94.6%
Yes	Yes	Yes		36,793	94.0%
Yes	Yes	Yes	Yes	36,544	93.4%

* Unique combination of fracture date and API well number (i.e., no duplicates).
† January 1, 2011 through February 28, 2013.

accuracy of the original data as entered by operators. Upon review, certain data fields were subjected to simple standardizations by correcting for capitalization, hyphens, and slashes; spelling; units; punctuation; and synonymous entries.

The project database includes two presentations of the data extracted from the PDF disclosures to enable straightforward review of all changes and streamlined tracing of disclosures back to the source data. The first presentation is the data as originally parsed without any formatting corrections, or standardizations. The second version contains data after formatting, corrections, and standardization were performed and also includes QA fields that indicate whether data in certain fields meet QA criteria. The use of QA fields allows the data to remain unaltered (aside from the standardizations and corrections described below), but permits specific entries to be excluded from an analysis (or properly accounted for) if they do not meet QA criteria. This approach results in different numbers of disclosures being suitable for different types of analyses, and it serves to maximize the number of disclosures that can be analyzed by not being more restrictive than needed.

2.2.1. Quality Assurance of Locational Data

Well locational data in the well header table were subject to QA review to facilitate reliable comparisons of hydraulic fracturing fluid composition among states and counties. Well locations were validated by comparing the three types of locational data reported by operators: latitude and longitude, state and county, and state and county information encoded in the API well number. Because the three locational sources were easily available and comparable, the location was determined to have met QA criteria if all three types of locational data agreed.[15] The QA review was performed separately for state and county information. If a disclosure did not meet locational

[15] Well locations in Alaska were not subject to county-level locational QA criteria, because the five-digit API well numbers in Alaska are not organized by counties. The coordinates for all disclosures from Alaska fall within the boundaries of the North Slope borough, which is shown on maps in this report.

criteria, it was either excluded from analyses that required locational information or was included in a category that indicated the uncertainty in location. For example, tables that provide data by state include a row for "State Uncertain," which includes disclosures with inconsistency among the three types of state locational information. For maps showing data by county, data were excluded from analyses if the disclosures had inconsistent county locational information. A hatched pattern in the map legend represents counties where all disclosures failed the county locational QA review. Disclosures for which state and county locational data did not meet the QA criteria were excluded from analyses that focused on specific counties (Sections 3.1.3 and 3.2.4).

Several steps were conducted to perform the locational QA. The state and county locations derived from the API well number; the state and county assigned using latitude and longitude; and the operator reported state and county locations were compared to one another in Microsoft Excel, resulting in six evaluations of locational accuracy. First, the leading five digits from the API well number were converted to state and county names using lookup tables from the Society of Petrophysicists and Well Log Analysts (2010). Second, the states and counties (US Census Bureau, 2011) that intersect the coordinates reported in the latitude and longitude fields of the well header were determined in a geographic information system (GIS) using ESRI ArcGIS 10.1 software (ESRI, 2012) after transforming all coordinates to the North American Datum 83 geographic coordinate system. The states and counties that correspond to the transformed latitude and longitude fields were joined using the ArcGIS 10.1 Spatial Join geoprocessing tool, and the resulting attribute table was exported to Microsoft Excel (Microsoft Corporation, 2002). The comparisons ignored variations in capitalization, spaces, and hyphens. The QA fields were used in the project database to indicate whether the three locational data fields agreed, allowing the user to select only the data with appropriate QA criteria for any given analysis.

Among the 38,050 disclosures meeting the two primary QA criteria, the state and county entries for the three locational fields agreed in 36,306 disclosures (95% of 38,050). One hundred sixty-two disclosures (0.43% of 38,050) failed to pass state locational QA criteria, and 1,744 disclosures (4.6% of 38,050) did not pass county and state locational QA criteria. State locational data that met QA criteria were available to pair with ingredients data for 36,395 disclosures (96% of 38,050 disclosures). For 34,880 disclosures (92% of 38,050 disclosures), ingredients data were parsed and both state and county locational data met QA criteria.

2.2.2. Addition of Geologic Information

To offer basic geologic context for the location of a disclosure, hydrocarbon basins (US EIA, 2007, 2011a, b; USGS, 1995) are shown on several figures in this report.[16] The hydrocarbon basin and play names were added to the project database to allow analysis at a basin or play level. The assignment of basin and play names to each disclosure is based solely on co-location of the disclosure coordinates with the basin shapefile using ArcGIS 10.1, without further verification by either the state or operator. Basins and plays were joined to each disclosure's latitude and longitude coordinates in the project database using the Spatial Join geoprocessing tool in ArcGIS

[16] Figures 2, 3, 5, 6, and 7 display hydrocarbon basins in addition to data from the project database. Appendix A includes a map of shale basins in the contiguous United States.

10.1. If a disclosure was located within the boundaries of two shale plays (i.e., in an area with stacked plays), both names were indicated in the project database field (e.g., Marcellus/Utica).

The hydrocarbon basin and play datasets are used for general reference purposes with the understanding that the boundaries are approximate and that production may not be occurring from the co-located play.[17] The shale basin boundaries are particularly useful because they capture the general extent of many major sedimentary basins in the contiguous United States and indicate regions with active resource extraction. Geologic basins include all the individual formations within the basin and provide a more confident, albeit general, geologic context to disclosures.

2.2.3. Quality Assurance of Ingredients

Ingredient names and CASRNs are entered by operators in the ingredients table. The names can include a wide range of variations for a given ingredient, including synonyms, misspellings, different punctuations and formatting, and different alpha-numeric spacing. To identify ingredients used in hydraulic fracturing fluids, entries of both names and CASRNs were verified and standardized.[18] The CASRNs were determined valid for analyses after being verified with the Chemical Abstracts Service (2014); ingredient records with invalid CASRNs were excluded from most analyses.[19] Note that this approach assumed that the CASRN entered into the database is correct. The project database contains a total of 692 valid and unique CASRNs for ingredients reported in disclosures that met the primary QA criteria.

Ingredient names for verified CASRNs were standardized using a list of unique chemical names paired with CASRNs developed by the EPA. This standardization was needed because of the above-noted range of presentations of ingredient names. Table 3 shows examples of variations in ingredient names as entered by operators and the standardized chemical name assigned by the EPA; this standardization facilitated analyses of ingredients. Because the ingredient names were standardized, the names found in the report and the project database may differ from the names reported by operators in the original PDF disclosures.

The EPA used standardized chemical names from Appendix A in the agency's *Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources: Progress Report* (2012) for the EPA-standardized chemical names used in the project database and in this report.[20] Chemical name and structure quality control methods were used to standardize chemical names for CASRNs found in

[17] Shale plays assigned to the disclosures in the project database using GIS shapefiles were compared to corresponding information from the commercial database DrillingInfo (2011) to evaluate the accuracy of the GIS method. DrillingInfo records were matched with 7,153 disclosures in the project database using the API well number. Assignment of shale plays to disclosures in the project database using GIS agreed with the play reported to DrillingInfo in 83% (5,929 of 7,153 disclosures) of the disclosure locations (US EPA, 2015).

[18] A CASRN and chemical name combination identify a chemical substance, which can be a single chemical (e.g., hydrochloric acid) or a mixture of chemicals (e.g., hydrotreated light petroleum distillates).

[19] Analyses of additive ingredients, proppants, and non-aqueous base fluid constituents required valid CASRNs. The valid CASRN QA criteria was not used for the analysis of water sources, because operators entered "water" or another term in the trade name field and did not always enter a chemical name or CASRN.

[20] Table A-1 in the *Progress Report*.

Table 3. Examples of ingredient name standardization.

Operator-Reported CASRN	Examples of Operator-Reported Ingredient Names	EPA-Standardized Chemical Name
7647-01-0	Hydrogen chloride Hydrochloric acid HCl Hydrogen Chloride Solution Hydroogen Chloride	Hydrochloric acid
7647-14-5	Sodium chloride Sodium chloide Sodium chlorite	Sodium chloride
64742-47-8	Distillates Distillates (petroleum) Distillates petro Distillates petroleum, hydrotreated	Distillates, petroleum, hydrotreated light
77-92-9	Citric Acid Anhydrous Citric Acid Solution Citric Acid	Citric acid
107-21-1	Ethylene Glycol Ethyene Glycol Ethylene Dlyco Ehtylene Glycol	Ethylene glycol
14808-60-7	Quartz Crystalline silica Silicon dioxide Crystalline silica quartz	Quartz

the project database but not included in Appendix A of the *Progress Report*.[21] The same methods were used in the development of Appendix A of the *Progress Report* and ensure correct chemical names and CASRNs.

In applying the EPA-standardized chemical list to the ingredient records in the project database, standardized chemical names were assigned to 787,522 ingredient records (65% of 1,218,003 records) from the 36,544 unique, fully parsed disclosures that met the date criterion. Because the CASRNs for the remaining 35% (430,481 records) of ingredient records were invalid, they could not be assigned a standardized chemical name and were excluded from analyses of additive ingredients.

Fields were established in the project database to indicate whether each ingredient record met QA criteria for the CASRN, additive concentration, and fracturing fluid concentration fields. Individual

[21] In the majority of cases, valid CASRNs and the associated ingredient names in the project database were paired correctly for a given CASRN. If an ingredient name (whether specific or non-specific) did not match the CASRN reported by the operator, the CASRN was added to a chemical name standardization list and assigned a correct chemical name. The chemical standardization list consists of CASRNs paired with appropriate chemical names and was used to standardize chemical names in the project database based on the CASRNs reported by operators. This process was undertaken because numerous synonyms and misspellings for a given chemical were present in the original data. Standardized, specific chemical names were identified using the EPA's Distributed Structure-Searchable Database Network (US EPA, 2013), the EPA's Substance Registry Services database (US EPA, 2014a), and the U.S. National Library of Medicine ChemID database (US NLM, 2014). Additional information on chemical name and structure quality control methods can be found at http://www.epa.gov/ncct/dsstox/ChemicalInfQAProcedures.html.

concentrations (reported as maximum concentrations) of ingredients in additives and in hydraulic fracturing fluid were considered valid and included in appropriate analyses if they had a value between 0% and 100%. In this way, non-numeric entries and implausibly high numeric values (e.g., typographical errors from operators, invalid entries due to parsing difficulties) were excluded from summary statistics. Ingredient records that did not meet the 0% to 100% criterion for the additive and fracturing fluid concentration fields were excluded from analyses for which median and percentile calculations were performed. A total of 295 disclosures (0.81% of 36,544 disclosures) had no valid entries in either the additive or fracturing fluid concentration field for any of their ingredient records. Invalid entries for both concentration fields were found for 271,312 individual ingredient records (22% of 1,218,003 ingredient records).[22] (Some disclosures had a mix of ingredients with valid and invalid concentrations. Thus, the 271,312 ingredients were spread out over more than the 295 disclosures.)

Lack of a valid CASRN and ingredient concentration data in the proper field may have been due to several factors. Operators sometimes did not list CASRN entries for ingredients.[23] Fields for concentration data were sometimes left blank. Also, operators may have made data entry errors or information from the original PDFs may have been assigned to the wrong fields due to the parsing difficulties related to modified formats.

Confidential Business Information. Operators can specify ingredients as confidential business information (CBI; also referred to as trade secret or proprietary) when submitting disclosures to FracFocus. As a result, the identity of a specific chemical may not be known for the analyses conducted in this report. Operators indicated CBI ingredients using 239 terms in the CASRN and chemical name fields that clearly indicate that the ingredients are considered a trade secret. Omission of the chemical name or CASRN from a CBI record disqualified that record for additive ingredient analyses. The CBI ingredient records in the project database were reviewed to assess the frequency at which operators claimed CBI status and the extent to which disclosures available for summary analyses would be reduced by the exclusion of CBI ingredient records. More than 70% of disclosures contained at least one ingredient identified as CBI, as shown in Table 4. Of the 25,796 disclosures that contained CBI ingredients (excluding duplicates and those that did not meet the date criterion), the average number of CBI ingredients per disclosure was five. The total number of ingredient records claimed as CBI or a related term was 129,311, or 11% of all ingredient records that were completely parsed from disclosures that met the primary QA criteria. Arthur et al. (2014) reported a similar proportion of CBI records in their study of FracFocus data (13% of ingredients; approximately 200,000 records). Although these ingredients are reported as proprietary, information on the general chemical class is frequently provided; related information is summarized in Appendix B.

Atypical Formatting. Atypical formatting of ingredient and trade name information on disclosures also caused information to fail QA criteria and be excluded from analyses. Data were entered in some disclosures so that trade names and purposes were decoupled from ingredient names,

[22] Disclosures containing these ingredient records meet the primary QA criteria.

[23] The FracFocus 2.0 submission system prohibits operators or their registered agents from entering an ingredient without a CASRN and issues a warning if the CASRN is not properly formatted or has the incorrect number of digits.

Table 4. Additive ingredients reported as confidential business information (CBI), summarized by state.

State	Number of disclosures with parsed ingredients table	Percent of disclosures with at least one reported CBI ingredient
Alabama	55	0%
Alaska	37	100%
Arkansas	1,449	78%
California	704	80%
Colorado	4,624	57%
Kansas	133	60%
Louisiana	1,030	60%
Michigan	14	79%
Mississippi	4	100%
Montana	205	68%
New Mexico	1,136	89%
North Dakota	2,078	64%
Ohio	147	86%
Oklahoma	1,839	68%
Pennsylvania	2,463	48%
Texas	17,384	76%
Utah	1,339	91%
Virginia	90	24%
West Virginia	273	40%
Wyoming	1,391	75%
State Uncertain*	149	82%
Entire Dataset	36,544	71%

* State location did not pass state locational quality assurance criteria.
Note: Analysis considered 36,544 disclosures that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; and fracture date between January 1, 2011, and February 28, 2013. Disclosures that did not meet quality assurance criteria (1,986) or other, query-specific criteria were excluded from analysis.

CASRNs, and maximum concentrations. Such reporting styles allow the operator to disclose chemicals while protecting proprietary information. The decoupling of related information occurred in one of three ways:

- An operator entered all trade names into a single cell in the template and all purposes into another cell.
- An operator entered trade names and purposes in a set of rows without ingredient information and entered ingredient names, CASRNs, and maximum concentrations in a series of rows below all of the trade names and purposes. This strategy is proposed by the

Secretary of Energy Advisory Board (SEAB) as appropriate for operators to fully disclose chemicals and remain protective of business interests (SEAB, 2014).

- An operator entered some ingredients in a section separate from other ingredients, which resulted in ingredients being included in unintended, incorrect fields when parsed. An example would be non-hazardous ingredients not found on Material Safety Data Sheets (MSDS) that operators disclosed to FracFocus. The non-MSDS ingredients were entered in a separate section than ingredients found on an MSDS. The disclosures typically included a red cell with explanatory text separating the two areas of the ingredients table. The text in the red separator itself could be incorporated into the ingredient name or CASRN fields incorrectly when parsed.

These entry options rendered it difficult to match ingredients with purposes and trade names and may have resulted in invalid entries in the trade name, supplier, ingredient name, or CASRN fields. Ingredient records that met the critical QA criteria (valid CASRN, valid maximum concentrations) were incorporated into basic analyses of ingredient occurrence even if their associated trade name and purpose fields had problematic entries (because those two fields are not relevant to all analyses.) Quantifying the number of ingredient records and disclosures affected by the data entry formats would require a comprehensive comparison of the original PDFs to the project database, which was infeasible given the large numbers of ingredient records and disclosures.

2.3. Analyses

Analyses were conducted to study disclosure locations and ingredients used in hydraulic fracturing fluids on regional, state, and national scales. Summary information was also compiled to allow a comparison among five counties with extensive hydraulic fracturing activities, as indicated by the number of disclosures in the project database.

Analyses of the project database were designed to ensure that the results presented in this report represent the data contained in the original PDF disclosures, while identifying obviously invalid or incorrect data to exclude from analyses. For these reasons, results of the analyses represent only the data found in the project database, and an extrapolation of the results to the entirety of hydraulically fractured oil and gas production wells in the United States was not conducted.

2.3.1. Specific Criteria for Analyses

For each analysis, information was extracted from the project database by designing a query that included specific QA criteria to address limitations in the project database. As noted in Section 2.2, the following primary QA criteria were applied to all analyses: a unique combination of fracture date and API well number and a fracture date between January 1, 2011, and February 28, 2013 (Table 1; 38,050 disclosures met these two criteria). The search criteria described below were used in queries to help target specific types of information (e.g., use of search terms or selection of certain types of purposes or ingredients). Table 5 identifies search filters and QA criteria used for figures and tables presented in this report, along with the resulting numbers of disclosures and ingredient records included in each analysis.

Specific Criteria and Approaches for Additive Ingredient Analyses. Analyses of the occurrence or concentrations of additive ingredients included ingredient records from trade names with purposes other than those associated with base fluids or proppants. Ingredient records for these analyses were required to have valid maximum concentrations (between 0% and 100%) and valid CASRNs (Section 2.2.3). The above QA criteria were met by 676,376 ingredient records (row for Table 7 in Table 5).

Specific Criteria and Approaches for Base Fluid Analyses. Disclosures were included in analyses of total water volumes if the entry in the total water volume field in the well header table (Figure 1) was less than or equal to 50 million gallons.[24] Two hundred fifty-five disclosures did not meet the volume criterion and were excluded from relevant analyses: 11 disclosures exceeded 50 million gallons; water volume was not reported for 165 disclosures; and for 79 disclosures, the water volume was ambiguous as parsed.

Water as a base fluid was identified by querying the trade name and comments fields for a suite of terms and with the criterion of a maximum hydraulic fracturing fluid concentration greater than or equal to 1% by mass. The threshold of 1% distinguished water as a base fluid from water listed as an additive ingredient. The cutoff of 1% was chosen after considering the median and 95th percentile maximum fluid concentrations of frequently reported additive ingredients as well as the median maximum fluid concentration of all additive ingredients per disclosure.[25] Because operators often left the purpose field blank when listing water as a base fluid, the purpose field was not used for this analysis. The analyses of base fluids included 36,046 unique disclosures with fracture dates in the study time period and used ingredient records with maximum fluid concentrations greater than 1% by mass (Table 5; rows for Tables 17 and 18).

To compile information on water sources, the project database was queried for the use of source water descriptors in the trade name and comments fields. Although not explicitly required by FracFocus, some operators included terminology in their submissions that indicated the source of water used for the base fluid (e.g., “fresh,” “surface water”). Operators most commonly listed source water information as a trade name or in the comments field and usually included estimates of the maximum concentration of water type in the hydraulic fracturing fluid.

To identify base fluid ingredients that were used either to enhance water-based fluid systems or as an alternative to water-based systems, the project database was queried for non-aqueous ingredients with base fluid-related terms in the purpose field. Preliminary queries indicated that non-aqueous constituents such as gases and hydrocarbons were identified by purpose (whereas water used as a base fluid is often not listed with a purpose). Furthermore, some constituents were identified with more than one purpose even when above the 1% threshold (e.g., petroleum

[24] The criterion of 50 million gallons or less for the reported total water volume was chosen based on the identification of extreme values in the distribution of the data and after speaking with Mike Nickolaus of the GWPC regarding the extreme values compared to ranges of known water use. Eleven disclosures indicated water volumes in excess of 50 million gallons per disclosure, with the largest total water volume reported as greater than 100 million gallons. Typical per well water volumes reported by Clark et al. (2013), Jiang et al. (2014), and Nicot and Scanlon (2012), are well below the 50 million gallon per disclosure threshold.

[25] Well operators reported the maximum concentration of an ingredient in the additive and in the hydraulic fracturing fluid. Therefore, the median and 5th and 95th percentile concentration values presented in this report represent those values of the reported maximum concentrations.

Table 5. Filters, QA criteria, disclosures, and ingredient records associated with analyses presented in this report. "N/A" indicates not applicable.

	WELL HEADER CRITERIA							INGREDIENT TABLE CRITERIA							TOTAL COUNTS	
Figure or Table	Well header parsed	Unique disclosure	Fracture date within study timeframe	Valid water volume	Location filter state	Location filter county	Production type	Ingredient table parsed	Valid CASRN	Valid additive & fluid concentrations	Purpose: Proppant	Purpose: Base fluid	Valid purpose	Ingredient type	Disclosures	Ingredients
Figure 2. Geographic distribution of disclosures in the project database	Yes	Yes	Yes		Yes										37,888	N/A
Figure 3. Geographic distribution of disclosures by production type	Yes	Yes	Yes		Yes										37,888	N/A
Figure 4. Distribution of fracture dates in the project database	Yes	Yes	Yes		Yes										37,888	N/A
Figure 5. Cumulative total water use, summarized by county	Yes	Yes	Yes		Yes										37,888	N/A
Figure 6. Median total water volumes per disclosure, summarized by county	Yes	Yes	Yes		Yes										37,888	N/A
Figure 7. Variability in reported total water volumes per disclosure, as measured by the difference between the 5th and 95th percentiles	Yes	Yes	Yes		Yes										37,888	N/A
Table 4. Additive ingredients reported as confidential business information (CBI), summarized by state	Yes	Yes	Yes					Yes						CBI	36,544	N/A
Table 6. Number and percentage of unique disclosures in the project database with a fracture date between January 1, 2011, and February 28, 2013	Yes	Yes	Yes												38,050	N/A
Table 7. Number of unique additive ingredients per disclosure, summarized by state	Yes	Yes	Yes					Yes	Yes	Yes				Additives	34,675	676,376
Table 8. Twenty most frequently reported additive ingredients in oil disclosures, ranked by frequency of occurrence	Yes	Yes	Yes				Yes	Yes	Yes	Yes				Additives	17,640	385,013

Table continued on next page

Figure or Table	WELL HEADER CRITERIA							INGREDIENT TABLE CRITERIA							TOTAL COUNTS	
	Well header parsed	Unique disclosure	Fracture date within study timeframe	Valid water volume	Location filter state	Location filter county	Production type	Ingredient table parsed	Valid CASRN	Valid additive & fluid concentrations	Purpose: Proppant	Purpose: Base fluid	Valid purpose	Ingredient type	Disclosures	Ingredients
Table 9. Twenty most frequently reported additive ingredients in gas disclosures, ranked by frequency of occurrence	Yes	Yes	Yes				Yes	Yes	Yes	Yes				Additives	17,035	291,363
Table 10. Frequently reported additive ingredients and commonly listed purposes for additives that contain the ingredients	Yes	Yes	Yes					Yes	Yes	Yes				Additives	34,675	676,376
Table 11. Counties selected to illustrate diversity in additive ingredients at small scales	Yes	Yes	Yes		Yes	Yes									4,066	N/A
Table 12. Comparison of 20 most frequently reported additive ingredients among selected counties	Yes	Yes	Yes		Yes	Yes		Yes	Yes	Yes				Additives	3,622	61,502
Table 13. Non-aqueous ingredients reported in base fluids	Yes	Yes	Yes					Yes	Yes	Yes		Yes		Base Fluids	34,675	676,376
Table 14. Use of non-aqueous ingredients in base fluids, summarized by state	Yes	Yes	Yes					Yes	Yes	Yes		Yes		Base Fluids	34,675	676,376
Table 15. Total water volumes, summarized by state	Yes	Yes	Yes	Yes											37,796	N/A
Table 16. Total water volumes for selected counties in approximately the 90th percentile of disclosures	Yes	Yes	Yes	Yes											37,796	N/A
Table 17. Number of disclosures having terms suggestive of water sources, summarized by state	Yes	Yes	Yes					Yes		Yes				Base Fluids	36,046	925,972*
Table 18. Median maximum fluid concentrations of water by source, summarized by state	Yes	Yes	Yes					Yes		Yes				Base Fluids	36,046	925,972*

Table continued on next page

Figure or Table	WELL HEADER CRITERIA							INGREDIENT TABLE CRITERIA							TOTAL COUNTS	
	Well header parsed	**Unique disclosure**	**Fracture date within study timeframe**	**Valid water volume**	**Location filter state**	**Location filter county**	**Production type**	**Ingredient table parsed**	**Valid CASRN**	**Valid additive & fluid concentrations**	**Purpose: Proppant**	**Purpose: Base fluid**	**Valid purpose**	**Ingredient type**	**Disclosures**	**Ingredients**
Table 19. Ten most frequently reported proppant ingredients, ranked by frequency of occurrence	Yes	Yes	Yes					Yes	Yes	Yes	Yes			Proppants	34,675	676,376
Table B-1. Chemical families for CBI ingredient records	Yes	Yes	Yes					Yes						CBI	36,544	N/A
Table B-2. Most frequently reported chemical families among CBI ingredients and their most commonly listed purposes	Yes	Yes	Yes					Yes						CBI	36,544	N/A
Appendix C. Histograms of hydraulic fracturing fluid concentrations for most frequently reported additive ingredients	Yes	Yes	Yes				Yes	Yes	Yes	Yes				Additives	34,675	676,376
Table D-1. Disclosures per state, summarized by well operator	Yes	Yes	Yes												38,050	N/A
Table E-1. Reporting regulations for states with data in the project database	Yes	Yes	Yes		Yes										37,888	N/A
Table F-1. Number of disclosures, summarized by additive purpose categories	Yes	Yes	Yes					Yes						Additives / CBI	36,544	1,218,003
Table G-1. Twenty most frequently reported additive ingredients in Andrews County, Texas, ranked by frequency of occurrence	Yes	Yes	Yes		Yes	Yes		Yes	Yes	Yes				Additives	1,088	20,716
Table G-2. Twenty most frequently reported additive ingredients in Bradford County, Pennsylvania, ranked by frequency of occurrence	Yes	Yes	Yes		Yes	Yes		Yes	Yes	Yes				Additives	510	6,002
Table G-3. Twenty-one most frequently reported additive ingredients in Dunn County, North Dakota, ranked by frequency of occurrence	Yes	Yes	Yes		Yes	Yes		Yes	Yes	Yes				Additives	311	6,450

Table continued on next page

	WELL HEADER CRITERIA							**INGREDIENT TABLE CRITERIA**							**TOTAL COUNTS**	
Figure or Table	**Well header parsed**	**Unique disclosure**	**Fracture date within study timeframe**	**Valid water volume**	**Location filter state**	**Location filter county**	**Production type**	**Ingredient table parsed**	**Valid CASRN**	**Valid additive & fluid concentrations**	**Purpose: Proppant**	**Purpose: Base fluid**	**Valid purpose**	**Ingredient type**	**Disclosures**	**Ingredients**
Table G-4. Twenty most frequently reported additive ingredients in Garfield County, Colorado, ranked by frequency of occurrence	Yes	Yes	Yes		Yes	Yes		Yes	Yes	Yes				Additives	1,166	17,337
Table G-5. Twenty most frequently reported additive ingredients in Kern County, California, ranked by frequency of occurrence	Yes	Yes	Yes		Yes	Yes		Yes	Yes	Yes				Additives	547	10,997
Table H-1. Total water volumes, summarized by county	Yes	Yes	Yes	Yes											37,796	N/A

* Valid maximum concentration in additive criteria not used for this analysis.

distillates are listed as a gelling agent as well as a carrier ingredient). It was, therefore, considered reasonable to use the purpose field for this analysis. Purpose terms that were used to identify these ingredients included variations on: base fluid, fracturing fluid, gas, carrier, foamer or foaming agent, energizer or energizing agent, carbon dioxide, and nitrogen. As with water base fluids, a maximum fluid concentration of 1% was chosen as the minimum limit to identify non-aqueous ingredients as base fluids. The analyses of non-aqueous base fluids included 34,675 unique disclosures and used ingredient records with maximum fluid concentrations greater than 1% by mass, and valid CASRN and concentrations (Table 5; rows for Tables 13 and 14).

Description of Figure and Table Footnotes. Footnotes were developed to provide transparency about how data were used for each analysis, because the number of disclosures and ingredient records for individual analyses varied depending on the QA criteria used. The use of QA criteria in the analyses is described in footnotes associated with each figure and table throughout Section 3. The descriptions and numbers in the footnotes do not reflect other analysis-specific choices that were made, such as screening for certain purposes or specific concentrations (e.g. purpose of base fluid, concentration ≥1% by mass). Such decisions are described in the text in this section and in other appropriate sections.

2.3.2. Calculations

The approach to calculations of summary statistics was chosen to support an understandable synopsis of the analysis results, while minimizing the effects of limitations associated with the project database. In addition to the parsing problems discussed above, invalid values in the database also exist due to blank fields in disclosures, possible data entry errors, or non-reporting of CBI. These issues are particularly problematic for data in the ingredients table. In many cases, invalid entries were easily excluded during analysis by use of the previously described QA fields (e.g., when alphabetic characters occur in numeric fields, such as concentration or CASRN fields). In other cases, however, anomalous numbers that still meet QA criteria are seen in the concentration fields (e.g., a maximum fluid concentration of 100% by mass in a field for an ingredient observed to be used in small quantities in other disclosures).

Anomalous data that meet QA criteria, while small in number, tend to disproportionately affect summary statistics by artificially inflating or decreasing the maximum, minimum, or mean. As an example, sodium hydroxide was frequently reported in disclosures (38% of 34,675 disclosures that met the primary QA requirements). The median maximum concentration of sodium hydroxide in hydraulic fracturing fluid is 0.0092% by mass, but the mean maximum fluid concentration is several orders of magnitude greater (0.10%). The mean is influenced by a maximum concentration (100%) that is orders of magnitude greater than the 95th percentile (0.077%). The maximum concentrations, at times, represent extreme values that may be included in the project database due to parsing problems or errors in operator data entry.

To minimize the effects of anomalously high and low concentration values on the summary statistics, the median was used to represent the central tendency of the dataset, and the 5th and 95th percentiles were used to represent the range. Data at the extreme ends of ranges (below the 5th and above the 95th percentiles) remain in the project database. Calculations such as average or variance were not performed on the data. The median and the 5th and 95th percentiles were calculated using the default method in the statistical program R (R Core Team, 2013). Tables and figures state the number of disclosures (i.e., frequency of reporting) to give additional context to the data.

To assess the accuracy of the median as a measure of central tendency and to examine the distributions of maximum additive ingredient concentrations in hydraulic fracturing fluids, histograms were prepared for the twenty most frequently reported additive ingredients (Appendix C). The histogram shapes vary, with some appearing log-normal and others with a more irregular pattern or a roughly bimodal distribution.[26] The variety in distributions indicates that, for some additive ingredients, the median is a more reliable indicator of central tendency than for others. Irregular or bimodal distributions may result from use of an additive ingredient in more than one additive type (necessitating different amounts) or from variable additive needs depending upon factors such as subsurface geochemistry or different operational practices.

If an additive ingredient was listed in more than one additive in a disclosure, the individual maximum fluid concentrations were summed to estimate the total maximum fluid concentration for that additive ingredient in the disclosure.[27] The median and percentile maximum concentrations in hydraulic fracturing fluids were calculated from these summed values. Because the concentrations of each additive ingredient are the maximum possible concentrations, the resulting statistics on hydraulic fracturing fluid concentrations can be considered upper limits. Also, because maximum concentrations were reported (and in some cases operators appeared to have entered additive concentrations or other values in the fracturing fluid concentration field), the cumulative maximum fluid concentrations of an ingredient across all additives in a disclosure sum to greater than 100% by mass in some disclosures.

Frequency of reporting for ingredients at the disclosure level was calculated by summing the number of disclosures that reported a specific ingredient. Frequency of reporting at the ingredient record level was calculated by summing the number of individual ingredient records for a specific ingredient. Percentages presented in the tables were calculated based upon the total number of disclosures or ingredient records that met the QA criteria for a given analysis and other, query-specific criteria.

For analyses of total water volumes, cumulative volumes were calculated by adding the total water volume reported in the well header table for all disclosures in a chosen unit area. Total water volumes were also summarized on a per-disclosure basis by calculating the median and 5th and 95th percentiles among all disclosures for an area of interest (i.e., state, county, entire dataset). Median per-disclosure water volumes for a given area reflect the central tendency of the dataset, and 5th and 95th percentiles provide information on the range of the dataset.

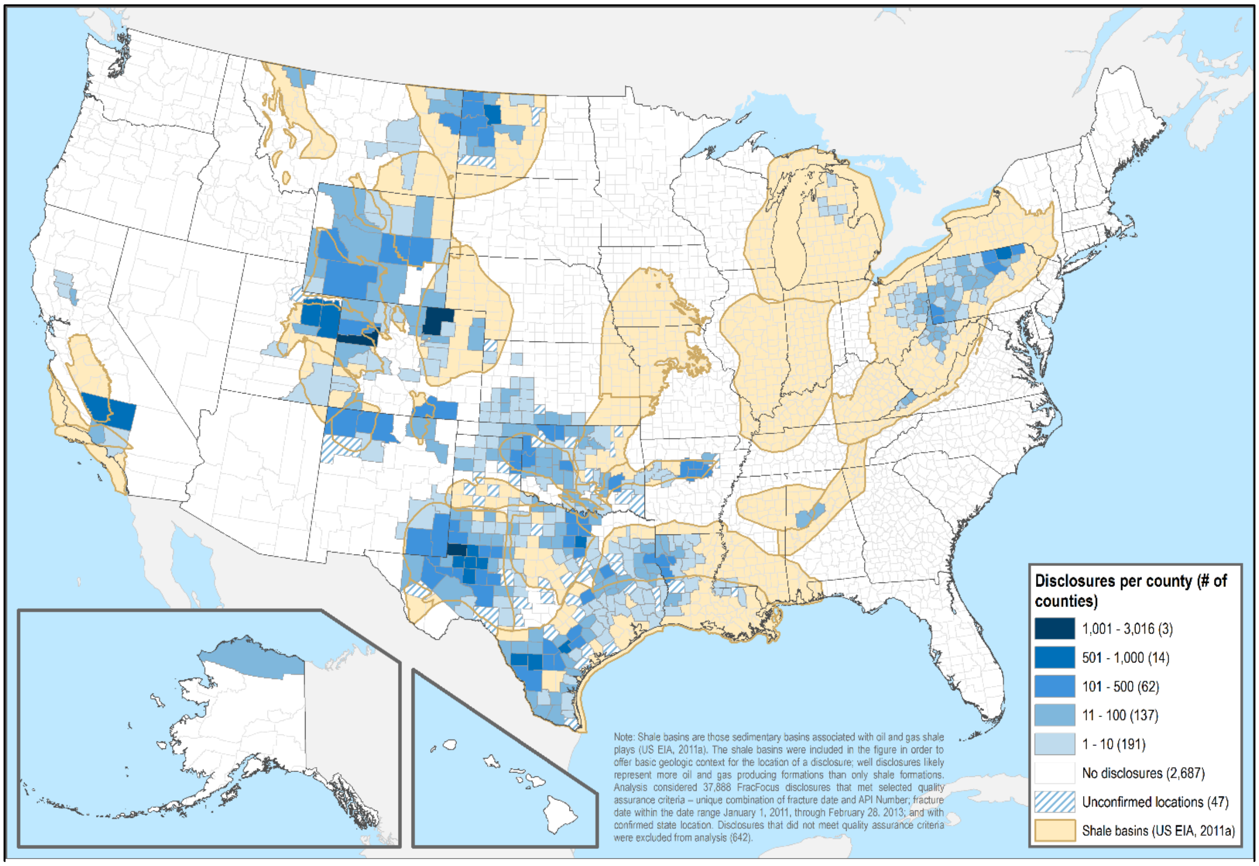
[26] The most frequently reported additive ingredients with non-normal distributions include: 2-butoxyethanol, hydrotreated light petroleum distillates, ethanol, naphthalene, potassium hydroxide, quartz, and heavy aromatic petroleum solvent naphtha.

[27] Fluid concentrations for individual ingredient records must meet the initial QA criteria of maximum fluid concentration by mass between 0% and 100% prior to inclusion in the analysis.

3. Results

The project database includes data extracted from 38,530 disclosures in 20 states that were uploaded to FracFocus before March 1, 2013.[28] Operators identified 19,908 disclosures as oil-producing wells and 18,622 as gas-producing wells.[29] Analyses included well locational data, total water volumes, and production type for 38,050 disclosures that met primary QA criteria (19,769 oil wells and 18,281 gas wells). Ingredient data were considered for 36,544 disclosures that met primary QA criteria (Table 1).

Operators provided locational information for the wells represented in the disclosures. This information enabled comparisons among hydraulic fracturing fluid composition in different regions of the country on a state or county basis. Figure 2 shows the geographic distribution of well



Note: Shale basins are those sedimentary basins associated with oil and gas shale plays (US EIA, 2011a). The shale basins offer basic geologic context for the location of a disclosure; disclosures likely represent more oil and gas producing formations than only shale formations. Analysis considered 37,888 disclosures that met selected quality assurance criteria, including: unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; and with confirmed state location. Disclosures that did not meet quality assurance criteria were excluded from analysis (642).

Figure 2. Geographic distribution of disclosures in the project database.

[28] Nine hydraulic fracturing service companies reported that they hydraulically fractured nearly 25,000 wells in 30 states between approximately September 2009 and September 2010 (US EPA, 2012). Assuming that hydraulic fracturing continued to occur in the 30 states through March 2013, this suggests that disclosures uploaded to FracFocus and analyzed for this study may not encompass all hydraulic fracturing activity that occurred between 2011 and 2013.

[29] Appendix D identifies the operators that submitted disclosures and the states where their wells are located.

locations as reported in the project database. Generally, the locations of wells represented in the disclosures are clustered in the northeast (mainly in and around Pennsylvania), the west central portion of the country (from North Dakota and Wyoming through Texas and Louisiana), and in California.

Many counties are represented in the project database, but a large number of counties have few disclosures in the database. The project database indicates well locations in 406 counties, with a range of 1 to 3,016 disclosures per county. Approximately 50% of counties represented in the project database have less than 13 disclosures, and 26% of the counties have only one or two disclosures.

Counties with particularly large numbers of disclosures are in California, Colorado, North Dakota, Pennsylvania, and Texas. This distribution is generally consistent with areas of the country that have experienced the greatest growth in oil and gas production since the late 2000's—namely, the Bakken (North Dakota and Montana), the Eagle Ford (Texas), the Haynesville (Texas, Louisiana, and Arkansas), the Marcellus (Pennsylvania, West Virginia, Ohio, New York, and Maryland), the Niobrara (Colorado, Wyoming, Nebraska, and Kansas), the Permian Basin (Texas and New Mexico), and the Utica (Ohio). These basins and formations accounted for nearly 95% of growth in domestic oil production and virtually all of the growth in domestic natural gas production during 2011 and 2012 (US EIA, 2014).

The geographic distribution of disclosures should be considered when interpreting results of analyses presented in this report, because certain parts of the country are more heavily represented than others, as shown in Table 6. For example, 48% of all disclosures in the project database are located in Texas. Arthur et al. (2014) also noted that almost half the disclosures in FracFocus are from Texas. Therefore, the disclosure data associated with Texas influence summary analyses of the entire project database toward hydraulic fracturing practices in Texas.

Because operators provided information on production type in FracFocus 1.0, it is possible to use production type to add additional context to the data in the project database. Figure 3 identifies the production type by county as a proportion of disclosures. Although production in many counties was predominantly (>80%) oil or gas, some counties had a mix of oil- and gas-reporting disclosures. Disclosures in Ohio, Pennsylvania, and West Virginia indicated predominantly gas production (>80%), whereas disclosures in North Dakota, West Texas, and northern Wyoming showed predominantly oil production. Disclosures from many states indicated the presence of both oil and gas production wells.

Influence of State Reporting Requirements. By February 2013, six of the 20 states with data in the project database had implemented regulations that required well operators to disclose chemicals used in hydraulic fracturing fluids to FracFocus: Colorado, North Dakota, Oklahoma, Pennsylvania, Texas, and Utah.[30] Three additional states (Louisiana, Montana, and Ohio) required disclosure to

[30] Between February 5, 2011, and April 13, 2012, Pennsylvania required reporting to the state. As of April 14, 2012, Pennsylvania required reporting to both the state and FracFocus.

Table 6. Number and percentage of unique disclosures in the project database with a fracture date between January 1, 2011, and February 28, 2013.

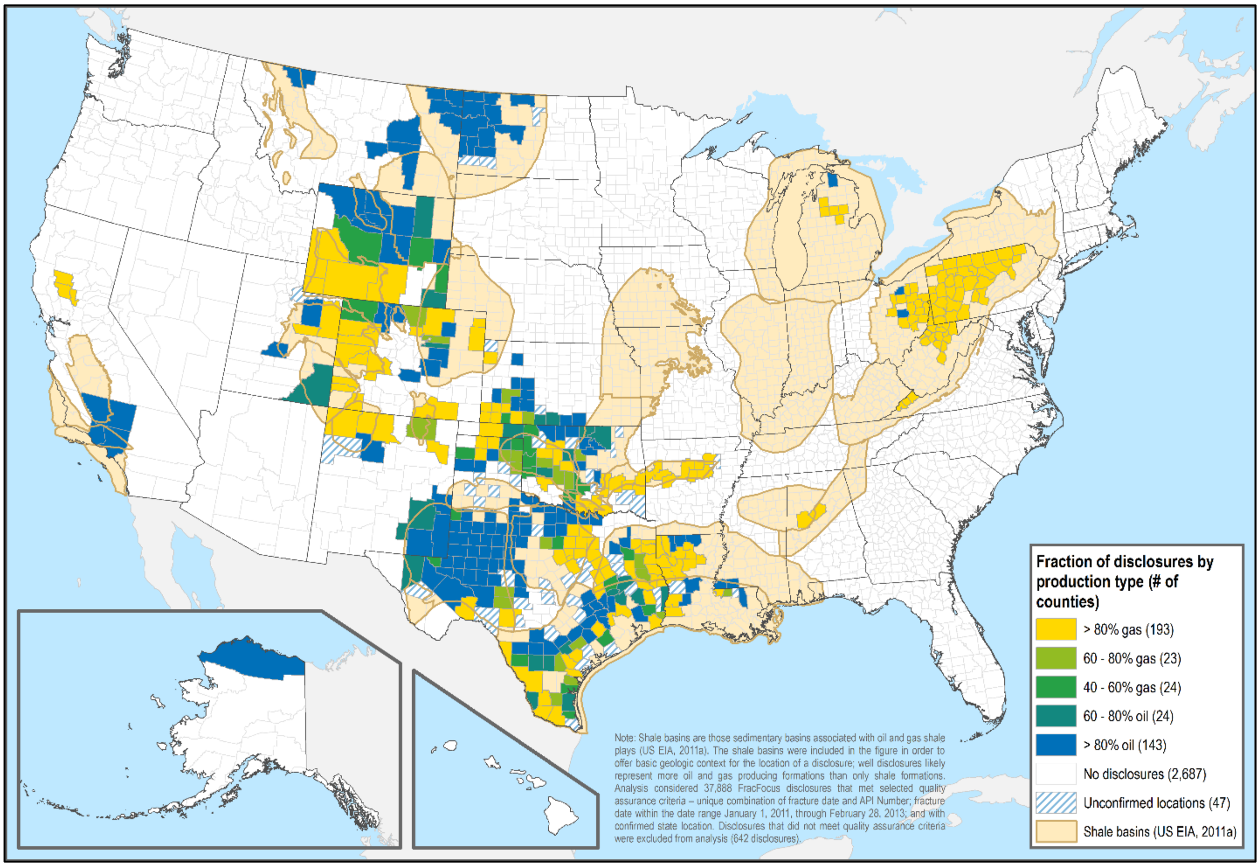
State	Number of disclosures	Percentage of disclosures
Texas	18,075	48%
Colorado	4,938	13%
Pennsylvania	2,483	6.5%
North Dakota	2,254	5.9%
Oklahoma	1,909	5.0%
Wyoming	1,457	3.8%
Arkansas	1,450	3.8%
Utah	1,429	3.8%
New Mexico	1,162	3.1 %
Louisiana	1,038	2.7%
California	718	1.9%
West Virginia	277	0.73%
Montana	213	0.56%
Ohio	148	0.39%
Kansas	136	0.36%
Virginia	90	0.24%
Alabama	55	0.14%
Alaska	37	0.097%
Michigan	15	0.039%
Mississippi	4	0.011%
State Uncertain*	162	0.43%
Entire Dataset	38,050	100%

* State location did not pass state locational quality assurance criteria.
Note: 480 disclosures that did not meet primary quality assurance criteria were excluded from analysis.

either FracFocus or the state, and five states (Arkansas, Michigan, New Mexico, West Virginia, and Wyoming) required reporting to the state.[31] Reporting requirements for the six states with mandatory reporting to FracFocus became effective during the time period studied in this report. The changing nature of reporting requirements may have influenced both the number and geographic distribution of disclosures in the project database.

Figure 4 shows the distribution of fracture dates in the project database and indicates whether the disclosure was mandatory or voluntary. Mandatory disclosures are defined, in this report, as

[31] Appendix E describes reporting requirements for the 20 states discussed in this study.



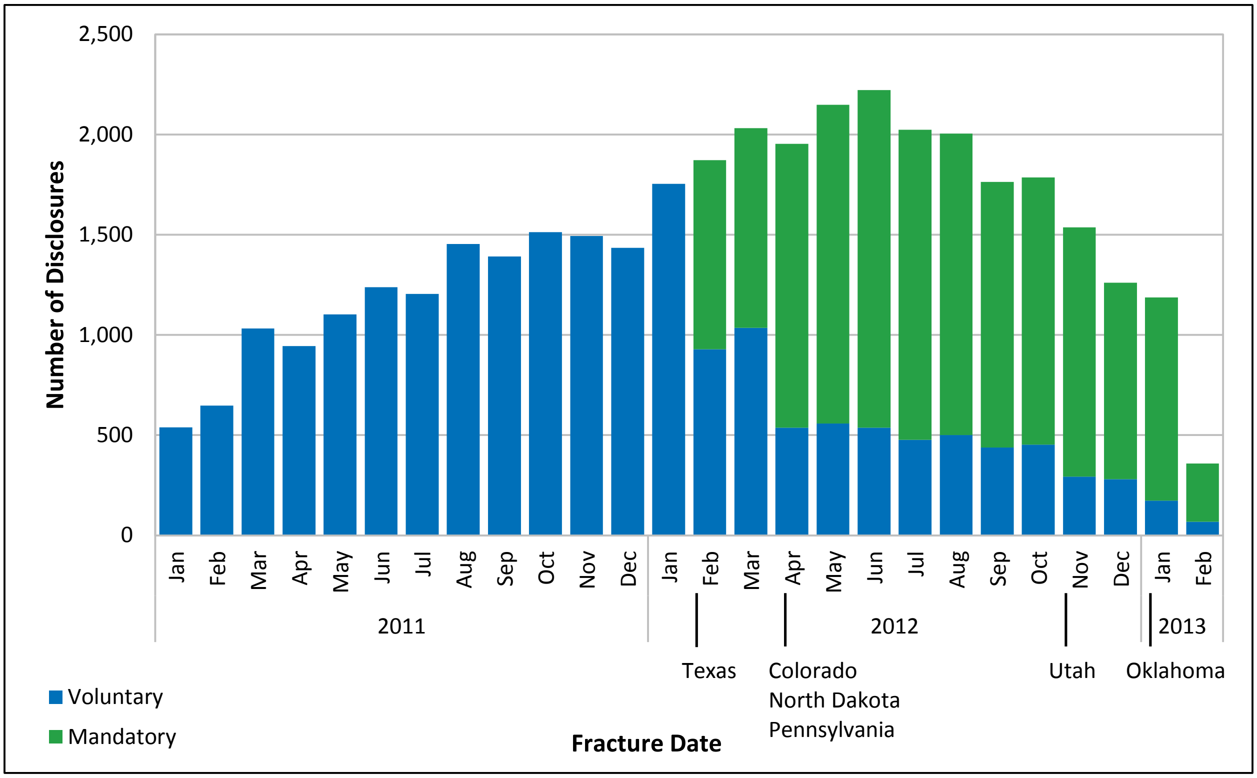
Note: Shale basins are those sedimentary basins associated with oil and gas shale plays (US EIA, 2011a). The shale basins offer basic geologic context for the location of a disclosure; disclosures likely represent more oil and gas producing formations than only shale formations. Analysis considered 37,888 disclosures that met selected quality assurance criteria, including: unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; and with confirmed state location. Disclosures that did not meet quality assurance criteria were excluded from analysis (642 disclosures).

Figure 3. Geographic distribution of disclosures by production type.

disclosures that occurred in one of the six states with mandatory reporting to FracFocus and had a fracture date after the state's regulatory effective date.[32] Voluntary disclosures included disclosures that fell into one of the following categories: disclosures from states with no reporting requirements, states with reporting requirements that did not mandate reporting to FracFocus (i.e., states requiring disclosure to the state and states requiring disclosure to either the state or FracFocus), or disclosures that had a fracture date prior to a state's regulatory effective date for mandatory reporting to FracFocus. Data presented in Figure 4 suggest that, overall, the number of disclosures in the project database increased when mandatory reporting requirements to FracFocus were in place.[33] The observed increase in the number of disclosures in the project

[32] For five of the six states with mandatory reporting requirements to FracFocus, reporting is required for hydraulic fracturing operations on or after the regulatory effective date. For Texas, the reporting requirements apply to hydraulic fracturing operations conducted at wells with drilling permits issued on or after the regulatory effective date.

[33] There is typically a delay of one to three months between the fracture date and the date of required disclosure reporting in states with mandatory reporting to FracFocus (Appendix E). The reporting delay may have led to artificially low reporting rates for the months toward the end of the analysis (late 2012 and early 2013).



Note: Analysis considered 37,888 disclosures that met selected quality assurance criteria, including: unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; and with confirmed state location. Disclosures that did not meet quality assurance criteria were excluded from analysis (642). During the timeframe of this study, six states mandated reporting to FracFocus: Colorado, North Dakota, Oklahoma, Pennsylvania, Texas, and Utah. Vertical lines in the figure indicate when mandatory reporting to FracFocus became effective. Voluntary disclosures included disclosures that fell into one of the following categories: disclosures from states with no reporting requirements, states with reporting requirements that did not mandate reporting to FracFocus (i.e., states requiring disclosure to the state and states requiring disclosure to either the state or FracFocus), or disclosures that had a fracture date prior to a state's regulatory effective date for mandatory reporting to FracFocus. A list of state disclosure requirements is provided in Appendix E.

Figure 4. Distribution of fracture dates in the project database.

database is largely driven by disclosures in Texas, which has the largest percentage of disclosures in the project database. In Texas, the number of disclosures per day increased by 89% after the regulatory effective date for mandatory reporting to FracFocus.[34] A similar trend was found for North Dakota, which had an 84% increase in disclosures per day after the regulatory effective date. Opposite trends were observed for Colorado, Oklahoma, Pennsylvania, and Utah: the number of disclosures per day for these states decreased after the regulatory effective date for mandatory reporting to FracFocus.[35]

[34] The number of disclosures per day was calculated for the time periods before and after a state's disclosure requirement became effective. The number of disclosures with a fracture date between January 1, 2011, and a state's effective date (i.e., before regulations) was divided by the number of days in that period. The number of disclosures between the effective date and February 28, 2013, (i.e., after regulations) was similarly divided by the number of days in that time period.

[35] The number of disclosures per day decreased by 37% in Colorado, 19% in Oklahoma, 13% in Pennsylvania, and 21% in Utah. In Oklahoma, the regulatory effective date for mandatory disclosures to FracFocus was January 1, 2013, which was two months prior to the end of the time period of the study. This may account for the decrease in the number of disclosures observed for Oklahoma, because well operators had 60 days to report to FracFocus.

Changes in the number of disclosures reported to FracFocus per day or per month may be due to a variety of factors, including fluctuations in the number of wells hydraulically fractured and shifts in state reporting requirements as new regulations were adopted. Available information indicates that the percentage of wells within a state reporting data to FracFocus increases when states have mandatory reporting requirements to FracFocus. This may or may not relate to the increases and decreases in disclosures per day discussed above, depending on other factors that can influence the number of wells hydraulically fracturing, including the price of oil and gas. Hansen et al. (2013) compared the number of disclosures in FracFocus from Pennsylvania to the number of wells that started drilling in the same year and found that the percentage of wells reporting to FracFocus increased from 59% in 2011 to 85% in 2012, which coincides with mandatory reporting requirements to FracFocus implemented by Pennsylvania in April 2012. A similar observation was made by the Railroad Commission of Texas, which reported that, prior to the passage of reporting regulations in Texas, well operators were voluntarily uploading data to FracFocus for about half of all wells undergoing hydraulic fracturing in Texas (Railroad Commission of Texas, 2015).

The observations from Hansen et al. (2013) and the Railroad Commission of Texas (2015) suggest that the project database is likely incomplete, because the majority of the states with data in the project database (14 out of 20) did not have mandatory reporting requirements to FracFocus during the study timeframe.[36] For the six states that implemented mandatory reporting requirements to FracFocus during the time period studied in this report, the earliest regulatory effective date was February 1, 2012 (Texas), and the latest date was January 1, 2013 (Oklahoma). Because the majority of disclosures in the project database (58%) were reported in states without mandatory reporting requirements to FracFocus or had fracture dates prior to regulatory effective dates for mandatory reporting to FracFocus, the project database cannot be assumed to be complete.

3.1. Additive Ingredients

The project database contains 692 unique ingredients reported for base fluids, proppants, and additives in hydraulic fracturing fluids.[37] Of these, 598 ingredients are associated with valid maximum fluid and additive concentrations (individual record values between 0% and 100%). Similarly large numbers of chemicals associated with hydraulic fracturing have been estimated elsewhere. In a survey of 14 leading oil and gas service companies, Waxman et al. (2011) found that the additives used contained 750 chemicals. Colborn et al. (2011) used information from MSDS for additives used in the natural gas industry to compile an estimate of 632 chemicals used during drilling and hydraulic fracturing of natural gas wells.

This section primarily summarizes ingredients reported in hydraulic fracturing fluid additives that have purposes other than base fluid or proppant, but also includes ingredients identified as non-

[36] Eight of the 14 states had or implemented reporting requirements during the study's timeframe that either required reporting to the state or allowed reporting to the state or FracFocus. Six states had no reporting requirements during the study's timeframe.

[37] Unique ingredients are defined by valid CASRN and chemical name.

aqueous base fluids (Section 3.2.1) and resin coatings for proppants.[38] Analyses focused primarily on the ingredients in additives rather than the additives (i.e., the trade name field) because chemical information is more useful to assess toxicity, exposure, and therefore potential impacts on drinking water resources. Additives may be single-ingredient additives, as suggested by additive concentrations of 100%, or they may contain several ingredients. Additives are added to a hydraulic fracturing fluid to change the fluid's properties. For example, some additives in the fracturing fluid help manage viscosity for delivery of proppant into the fractures, while other additives serve to minimize damage to the formation or maximize flow of oil or gas from the formation to the well (Gupta and Valkó, 2007). Additives chosen for hydraulic fracturing fluids can vary significantly based on factors such as geologic conditions, well design, and operator or service company preferences (Arthur et al., 2014; GWPC and ALL Consulting, 2009; Waxman et al., 2011).

The median number of unique additive ingredients per disclosure was 14 and, summarized by state, ranged from nine in Virginia to 21 in New Mexico. Table 7 shows the median number of unique additive ingredients per disclosure for the 20 states identified in the project database. The median number of additive ingredients per disclosure was 16 for oil disclosures and 12 for gas disclosures (not shown in Table 7). The range of additive ingredients per disclosure, however, was four to 28 (5th to 95th percentile) for the entire dataset. Apparent differences between oil and gas disclosures may not be statistically significant.

3.1.1. Reported Frequency and Fluid Concentrations of Additive Ingredients

The 20 most frequently reported additive ingredients were analyzed separately for oil and gas disclosures in the project database. Tables 8 and 9 list the most frequently reported chemicals for hydraulic fracturing in oil and gas disclosures, respectively, with median and 5th and 95th percentiles for maximum hydraulic fracturing fluid concentrations reported.[39] Median as well as 5th and 95th percentiles for the maximum concentrations of the chemicals in their respective additives are also included in Tables 8 and 9.[40] Maximum ingredient concentrations (in hydraulic fracturing fluids and additives) are reported as mass percents in Tables 8 and 9 to be consistent with concentrations reported by operators to FracFocus 1.0 (Figure 1), although volumes may be more useful for understanding potential impacts on drinking water resources from releases of hydraulic fracturing fluids or additives.[41] Both maximum additive concentrations and fluid concentrations for each additive ingredient may be important to consider when assessing potential impacts on

[38] Resin coatings are added to proppants and enhance the ability of proppants to keep fractures open; resin coatings do not function as proppants themselves.

[39] If an additive ingredient appeared more than once in a disclosure (e.g., the same solvent used in multiple additives), then the maximum fluid concentrations were added. For example, methanol may be an ingredient in two additives on a disclosure with maximum fluid concentrations of 0.1% and 0.05% by mass, respectively. The maximum fluid concentration of methanol for this disclosure would be the sum of 0.1% and 0.05%, which is 0.15% by mass.

[40] Maximum concentrations of ingredients in additives reflect the concentration for each individual ingredient record, not the sum of the reported concentrations.

[41] Mass percents could be converted to volumes by assuming a density for total water volumes reported in the well header table (Figure 1).

Table 7. Number of unique additive ingredients per disclosure, summarized by state.

State	Number of disclosures	Number of additive ingredients per disclosure		
		Median	5th percentile	95th percentile
Alabama	55	10	10	10
Alaska	20	15	13	16
Arkansas	1,337	10	6	21
California	585	19	10	23
Colorado	4,561	13	5	23
Kansas	97	14	8	17
Louisiana	1,026	15	1	29
Michigan	14	19	10	29
Mississippi	4	14	11	23
Montana	193	16	9	38
New Mexico	1,115	21	7	31
North Dakota	1,989	15	4	33
Ohio	146	17	8	38
Oklahoma	1,810	12	5	30
Pennsylvania	2,419	10	4	18
Texas	16,405	15	4	30
Utah	1,253	17	7	23
Virginia	79	9	7	12
West Virginia	239	12	7	22
Wyoming	1,198	10	5	24
State Uncertain*	130	15	5	27
Entire Dataset	34,675	14	4	28

* State location did not pass state locational quality assurance criteria.

Note: Analysis considered 34,675 disclosures and 676,376 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; valid CASRN; and valid concentrations. Disclosures that did not meet quality assurance criteria (3,855 disclosures) or other, query-specific criteria were excluded from analysis.

drinking water resources from hydraulic fracturing, because an accidental release of a relatively small volume of a concentrated additive being stored on a well pad may have different potential impacts than a release of a greater volume of hydraulic fracturing fluid with more dilute additive ingredient concentrations.

Additive ingredients listed in Tables 8 and 9 were generally present in hydraulic fracturing fluids in low concentrations. The medians of the maximum fluid concentrations of the frequently reported

Table 8. Twenty most frequently reported additive ingredients in oil disclosures, ranked by frequency of occurrence.

EPA-standardized chemical name	CASRN	Maximum concentration in hydraulic fracturing fluid (% by mass)				Maximum concentration in additive (% by mass)			
		Number (%) of disclosures	Median	5th percentile	95th percentile	Number (%) of ingredient records	Median	5th percentile	95th percentile
Methanol	67-56-1	12,484 (72%)	0.022	0.00064	0.16	26,482 (7.7%)	30	0.39	100
Distillates, petroleum, hydrotreated light*	64742-47-8	10,566 (61%)	0.087	0.00073	0.39	15,995 (4.6%)	40	0.60	70
Peroxydisulfuric acid, diammonium salt	7727-54-0	10,350 (60%)	0.0076	0.00028	0.067	12,723 (3.7%)	100	0.10	100
Ethylene glycol	107-21-1	10,307 (59%)	0.023	0.00086	0.098	12,281 (3.5%)	30	0.50	60
Hydrochloric acid	7647-01-0	10,029 (58%)	0.29	0.013	1.8	11,817 (3.4%)	15	2.9	50
Guar gum	9000-30-0	9,110 (52%)	0.17	0.027	0.43	9,316 (2.7%)	50	1.6	100
Sodium hydroxide	1310-73-2	8,609 (50%)	0.010	0.000050	0.075	10,300 (3.0%)	10	0.025	45
Quartz*†	14808-60-7	8,577 (49%)	0.0041	0.000040	12	12,636 (3.7%)	2.0	0.020	93
Water*†	7732-18-5	8,538 (49%)	1.0	0.0050	9.1	23,340 (6.7%)	67	15	97
Isopropanol	67-63-0	8,031 (46%)	0.0063	0.000070	0.22	11,975 (3.5%)	15	0.17	100
Potassium hydroxide*	1310-58-3	7,206 (41%)	0.013	0.000010	0.052	8,050 (2.3%)	15	0.15	50
Glutaraldehyde	111-30-8	5,927 (34%)	0.0065	0.00027	0.020	6,211 (1.8%)	15	0.030	50
Propargyl alcohol	107-19-7	5,599 (32%)	0.00022	0.000030	0.0030	6,129 (1.8%)	5.0	0.0029	10
Acetic acid	64-19-7	4,623 (27%)	0.0047	0.000000§	0.047	5,552 (1.6%)	30	0.82	100
2-Butoxyethanol*	111-76-2	4,022 (23%)	0.0053	0.000000§	0.17	5,096 (1.5%)	10	0.25	100
Solvent naphtha, petroleum, heavy arom.*	64742-94-5	3,821 (22%)	0.0060	0.000000§	0.038	4,129 (1.2%)	5.0	0.00	35
Sodium chloride*	7647-14-5	3,692 (21%)	0.0071	0.000000§	0.27	4,445 (1.3%)	25	0.0040	100
Ethanol*	64-17-5	3,536 (20%)	0.026	0.000020	0.16	4,178 (1.2%)	45	1.0	60
Citric acid	77-92-9	3,310 (19%)	0.0047	0.00016	0.024	3,491 (1.0%)	60	7.0	100
Phenolic resin	9003-35-4	3,109 (18%)	0.13	0.019	2.0	3,238 (0.94%)	5.0	0.94	20

* Chemical has a non-normal distribution and the median may not represent the central tendency of the dataset as well as the median of a normally distributed dataset.

† See the text for a discussion of why water and quartz were included in the table.

§ Concentration is less than a millionth of a percentage by mass.

Note: Analysis considered 17,640 disclosures and 385,013 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; valid CASRN; and valid concentrations. Disclosures that did not meet quality assurance criteria (2,268 disclosures) or other, query-specific criteria were excluded from analysis.

Table 9. Twenty most frequently reported additive ingredients in gas disclosures, ranked by frequency of occurrence.

EPA-standardized chemical name	CASRN	Maximum concentration in hydraulic fracturing fluid (% by mass)				Maximum concentration in additive (% by mass)			
		Number (%) of disclosures	Median	5th percentile	95th percentile	Number (%) of ingredient records	Median	5th percentile	95th percentile
Hydrochloric acid	7647-01-0	12,351 (73%)	0.078	0.0063	0.67	13,754 (5.3%)	15	2.7	60
Methanol	67-56-1	12,269 (72%)	0.0020	0.000040	0.053	19,074 (7.3%)	30	0.50	90
Distillates, petroleum, hydrotreated light*	64742-47-8	11,897 (70%)	0.017	0.0021	0.27	14,289 (5.5%)	30	3.1	70
Isopropanol	67-63-0	8,008 (47%)	0.0016	0.000010	0.051	10,326 (3.9%)	30	2.5	60
Water*†	7732-18-5	7,998 (47%)	0.18	0.000090	91	17,690 (6.8%)	63	5	100
Ethanol*	64-17-5	6,325 (37%)	0.0023	0.00012	0.090	7,062 (2.7%)	5.0	1.0	60
Propargyl alcohol	107-19-7	5,811 (34%)	0.000070	0.000010	0.0016	5,963 (2.3%)	10	0.0037	40
Glutaraldehyde	111-30-8	5,635 (33%)	0.0084	0.00091	0.023	5,827 (2.2%)	30	0.18	60
Ethylene glycol	107-21-1	5,493 (32%)	0.0061	0.000080	0.24	7,733 (3.0%)	35	1.0	100
Citric acid	77-92-9	4,832 (28%)	0.0017	0.000050	0.011	4,885 (1.9%)	60	30	100
Sodium hydroxide	1310-73-2	4,656 (27%)	0.0036	0.000020	0.088	5,642 (2.2%)	5.0	1.0	60
Peroxydisulfuric acid, diammonium salt	7727-54-0	4,618 (27%)	0.0045	0.000050	0.045	6,402 (2.4%)	100	0.26	100
Quartz*†	14808-60-7	3,758 (22%)	0.0024	0.000030	11	4,729 (1.8%)	10	0.20	100
2,2-Dibromo-3-nitrilopropionamide	10222-01-2	3,668 (22%)	0.0018	0.000070	0.022	3,728 (1.4%)	100	10	100
Sodium chloride*	7647-14-5	3,608 (21%)	0.0091	0.000000§	0.12	4,176 (1.6%)	30	1.0	40
Guar gum	9000-30-0	3,586 (21%)	0.10	0.00057	0.38	3,702 (1.4%)	60	1.6	100
Acetic acid	64-19-7	3,563 (21%)	0.0025	0.000000§	0.028	3,778 (1.4%)	50	5.0	90
2-Butoxyethanol*	111-76-2	3,325 (20%)	0.0035	0.000010	0.041	4,186 (1.6%)	10	3.0	40
Naphthalene*	91-20-3	3,294 (19%)	0.0012	0.0000027	0.0050	3,355 (1.3%)	5.0	0.0071	5.0
Solvent naphtha, petroleum, heavy arom.*	64742-94-5	3,287 (19%)	0.0044	0.000030	0.030	3,750 (1.4%)	30	0.026	30

* Chemical has a non-normal distribution and the median may not represent the central tendency of the dataset as well as the median of a normally distributed dataset.

† See the text for a discussion of why water and quartz were included in the table.

§ Concentration is less than a millionth of a percentage by mass.

Note: Analysis considered 17,035 disclosures and 291,363 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; valid CASRN; and valid concentrations. Disclosures that did not meet quality assurance criteria (1,587) or other, query-specific criteria were excluded from analysis.

additive ingredients, except for water, were less than 0.3% by mass of the fracturing fluid, and the 95th percentiles for maximum fluid concentration did not exceed 2.0%, except for water and quartz. The sum of the maximum fluid concentrations for all additive ingredients in a disclosure, excluding proppant and base fluid ingredients, was less than 1% by mass in approximately 80% of disclosures. The median value for this sum was 0.43% by mass. The additive ingredient concentrations observed in the project database appear to be consistent with published estimates that report that the total concentration of all additive ingredients constitutes approximately 1% to 2% or less of the fracturing fluid (GWPC and ALL Consulting, 2009; Lee et al., 2011).

Eighteen of the 20 most frequently reported additive ingredients were common to hydraulic fracturing fluids used in both the oil and gas disclosures analyzed. In particular, methanol, hydrochloric acid, and hydrotreated light petroleum distillates were among the additive ingredients most frequently reported for both oil and gas disclosures in the project database. Among the entire dataset, methanol was reported in 71% of disclosures (24,753 out of 34,675), hydrochloric acid in 65% (22,380 disclosures), and hydrotreated light petroleum distillates in 65% (22,463 disclosures). Methanol was associated with additives such as corrosion inhibitors and surfactants, while reported purposes for additives that contain hydrochloric acid included serving as a scale control agent, controlling iron, serving as a solvent, and a more general designation of "acid" or "acidizing" (see Section 3.1.2 for further discussion). Hydrochloric acid is known to be commonly used to clean the well perforations (Economides and Baumgartner, 2008).

Methanol, hydrochloric acid, and light petroleum distillates were each reported in 70% or more of gas disclosures (Table 9). The next most frequently reported additive ingredient for gas disclosures (isopropanol) was reported in less than 50% of gas disclosures. This suggests that methanol, hydrochloric acid, and hydrotreated light petroleum distillates were consistently used in hydraulic fracturing fluids for gas wells between January 2011 and February 2013. In contrast, additive ingredients reported for oil disclosures did not show a similar pattern: seven additive ingredients were each reported in 50% or more of oil disclosures, with only one additive ingredient (methanol) reported in more than 70% of oil disclosures (Table 8).

Maximum fluid concentrations (medians, 5th and 95th percentiles) for the most frequently reported additive ingredients appear to be greater in disclosures for oil wells than gas wells (Tables 8 and 9). For example, the median of the maximum fluid concentration for hydrochloric acid reported for oil disclosures was 0.29% by mass, compared to 0.078% for gas disclosures. The range of observed maximum fluid concentrations for hydrochloric acid was also an order of magnitude larger in oil disclosures, 0.013% to 1.8% by mass (5th to 95th percentile), compared to gas disclosures (0.0063% to 0.67% by mass). Similar to hydrochloric acid, reported maximum fluid concentrations for methanol were an order of magnitude greater in oil disclosures, which ranged from 0.00064% to 0.16% by mass (5th to 95th percentile), than in gas disclosures, which ranged from 0.000040% to 0.053% by mass.

Water and Quartz as Additive Ingredients. Water was commonly reported as an ingredient in additives as well as being listed as a base fluid. Quartz, the proppant ingredient most commonly reported, was also reported as an ingredient in other additives. Both Tables 8 and 9 list water and quartz among the 20 most frequently reported additive ingredients used in hydraulic fracturing fluids. Water was reported as an additive ingredient in 49% of oil disclosures and 47% of gas disclosures, and quartz was reported as an additive ingredient in 49% and 22% of oil and gas disclosures, respectively.

The 95th percentile values observed for maximum fracturing fluid concentrations of water and quartz as additive ingredients were larger than expected: 9.1% and 12% by mass in oil disclosures and 91% and 11% by mass in gas disclosures, respectively (Tables 8 and 9). The larger values were more reflective of maximum fluid concentrations associated with base fluids (Section 3.2) and proppants (Section 3.3) and may have been included in the analyses of additive ingredients in oil and gas disclosures due to mislabeled or unlabeled purposes in the project database or original PDF disclosures.[42] For example, 99 ingredient records with valid concentrations contained no purpose information for quartz; of these, 75 had trade names that were readily identifiable as proppants. Ultimately, the small number of disclosures with unidentified purposes was included to avoid any assumptions that may have introduced bias in the results.

Diesel Fuels. To evaluate the use of diesel fuel in hydraulic fracturing fluids, the project database was analyzed for any of the following CASRNs:[43]

- 68334-30-5: Fuels, diesel
- 68476-30-2: Fuel oil no. 2
- 68476-31-3: Fuel oil no. 4
- 68476-34-6: Fuels, diesel, no. 2
- 8008-20-6: Navy fuels JP-5; kerosene[44]

Three of the five CASRNs were identified in the project database: 68334-30-5, 68476-34-6, and 8008-20-6. The CASRNs were reported in 302 gas disclosures (1.7% of 17,594 gas disclosures with parsed ingredients and valid CASRNs) and 40 oil disclosures (0.22% of 18,363 oil disclosures with parsed ingredients and valid CASRNs).[45] No disclosures reported use of more than one of these five CASRNs.

The most frequently reported diesel fuel CASRN was 8008-20-6, with 281 disclosures, 270 of which were for gas disclosures. Fifty-seven disclosures listed 68476-34-6, and four disclosures included 68334-30-5. The state with the largest number of disclosures listing a diesel fuel CASRN was Arkansas, with 173 disclosures (primarily 8008-20-6), followed by New Mexico (54 disclosures), Pennsylvania (43 disclosures), and Texas (30 disclosures).

[42] The database filter applied to the data query excluded additive ingredients associated with base fluids and proppants or their synonyms.

[43] The five CASRNs were used to define diesel fuels in the *Permitting Guidance for Oil and Gas Hydraulic Fracturing Activities Using Diesel Fuels: Underground Injection Control Program Guidance #84* (US EPA, 2014b).

[44] Navy fuels JP-5 (CASRN 8008-20-6) is referred to as kerosene in the *Permitting Guidance for Oil and Gas Hydraulic Fracturing Activities Using Diesel Fuels: Underground Injection Control Program Guidance #84* (US EPA, 2014b).

[45] An additional 20 disclosures (19 gas and 1 oil) that did not pass QA criteria reported two of the same three compounds.

3.1.2. Additive Purposes

Operators generally reported purposes for each additive (i.e., trade name) listed on a disclosure (Figure 1).[46] The purpose describes the function of the additive in the hydraulic fracturing fluid, rather than the function of individual ingredients in the additive. In the project database, additive purposes are assigned to each ingredient in the additive. Thus, regardless of whether a particular ingredient serves as an active or inactive ingredient in an additive, its purpose as listed in the database will be the same as that reported by the operator for the additive itself. Information submitted to FracFocus neither indicates whether chemicals are active or inactive ingredients nor the specific purpose a given ingredient serves in the additive.

The project database developed for this study indicated a median number of 10 additives per disclosure. Commonly cited estimates of the numbers of additives used for hydraulic fracturing suggest three to 12 such additives, serving a variety of purposes (GWPC and ALL Consulting, 2009). The number of additives used depends upon the specifics of the well in addition to operator practices (Carter et al., 2013).

Additive ingredients are often associated with multiple purposes in the project database, because different additives may have similar ingredients. Table 10 provides a list of the most commonly reported purposes for additives that contain the most frequently reported additive ingredients listed in Tables 8 and 9.

Some additive types (as identified by purpose) were associated with large numbers of ingredients. For example, in the general category of biocides, there were 197 unique ingredients (as identified by CASRNs), and 309 trade names for biocide additives. Similarly, 177 ingredients and 277 trade names were found in the project database for gelling agent and gel stabilizer additives. However, because of parsing difficulties from variations in reporting styles, some additive purpose assignments are likely to be erroneous. Therefore, the data are likely to represent overestimates of the total numbers of chemicals associated with various purposes. Suspicious ingredient-purpose associations generally occur in one or two ingredient records each; therefore, greater frequency of reporting for a particular additive purpose and ingredient combination in the project database allows for greater confidence that the results reflect actual associations. Nonetheless, the data indicate that a number of additives are used for a given purpose and that many of these additives contain several ingredients.

3.1.3. Comparing Variability of Additive Ingredients in Selected Counties

The summary of additive ingredients reported for the entire dataset provided in Tables 8 and 9 may be helpful in determining large-scale similarities across the country. Diversity in additive ingredients observed in the project database, however, implies that smaller-scale aggregation of the

[46] Appendix F contains a list of additive purpose categories identified from the project database and identifies the number of disclosures containing additives for each purpose category.

Table 10. Frequently reported additive ingredients and commonly listed purposes for additives that contain the ingredients.

EPA-standardized chemical name	CASRN	Purposes commonly associated with additives containing the ingredients*
2,2-Dibromo-3-nitrilopropionamide	10222-01-2	Biocide
2-Butoxyethanol†	111-76-2	Surfactant, corrosion inhibitor, non-emulsifier
Acetic acid	64-19-7	Buffer, iron control
Citric acid	77-92-9	Iron control
Distillates, petroleum, hydrotreated light†	64742-47-8	Friction reducer, gelling agent, crosslinker
Ethanol	64-17-5	Surfactant, biocide
Ethylene glycol	107-21-1	Crosslinker, scale inhibitor, corrosion inhibitor, friction reducer
Glutaraldehyde	111-30-8	Biocide
Guar gum	9000-30-0	Gelling agent
Hydrochloric acid	7647-01-0	Acidizer, solvent, scale dissolver, perforation breakdown
Isopropanol	67-63-0	Corrosion inhibitor, non-emulsifier, surfactant
Methanol	67-56-1	Corrosion inhibitor, surfactant, non-emulsifier, scale inhibitor, biocide, crosslinker
Naphthalene†	91-20-3	Surfactant, non-emulsifier, corrosion inhibitor
Peroxydisulfuric acid, diammonium salt	7727-54-0	Gel breaker
Phenolic resin	9003-35-4	Proppant (resin coating)
Potassium hydroxide*	1310-58-3	Crosslinker, buffer
Propargyl alcohol	107-19-7	Corrosion inhibitor
Quartz†§	14808-60-7	Breaker, gelling agent, scale inhibitor, crosslinker, biocide, corrosion inhibitor, viscosifier
Sodium chloride†	7647-14-5	Breaker, friction reducer, scale inhibitor, clay control, biocide
Sodium hydroxide	1310-73-2	Crosslinker, biocide, buffer, scale inhibitor
Solvent naphtha, petroleum, heavy arom.†	64742-94-5	Surfactant, non-emulsifier, inhibitor, corrosion inhibitor
Water†§	7732-18-5	Acid, biocide, clay control, scale inhibitor, iron control, breaker, crosslinker, buffer, surfactant, friction reducer

* Definitions of additive purposes are included in the Glossary.

† Chemical has a non-normal distribution and the median may not represent the central tendency of the dataset as well as the median of a normally distributed dataset.

§ See Section 3.1.1 for a discussion of why water and quartz were included in the table.

Note: Analysis considered 34,675 disclosures and 676,376 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; valid CASRN; and valid concentrations. Disclosures that did not meet quality assurance criteria (3,855 disclosures) or other, query-specific criteria were excluded from analysis.

data may provide useful information on the composition of hydraulic fracturing fluids at more local scales (e.g., states and counties). Five counties were selected to illustrate diversity in additive ingredients at small scales. Disclosures used in this analysis are from Andrews County, Texas;

Bradford County, Pennsylvania; Dunn County, North Dakota; Garfield County, Colorado; and Kern County, California (Table 11). The five counties displayed a range of geography, geology, and production type, and the number of disclosures for each of these counties exceeded the 90th percentile for the entire dataset (288 disclosures per county). The relatively large number of disclosures per county illustrated the extent of oil and gas development in these areas during the study time period, and allowed selection of a dataset large enough to increase confidence in the results of the analysis.

Table 11. Counties selected to illustrate diversity in additive ingredients at small scales.

County, State	Sedimentary basin*	Production type	Number of disclosures	Number of operators
Andrews County, Texas	Permian	98% oil	1,180	39
Bradford County, Pennsylvania	Appalachian	100% gas	513	6
Dunn County, North Dakota	Williston	100% oil	334	18
Garfield County, Colorado	Uinta-Piceance	99% gas	1,362	9
Kern County, California	San Joaquin	100% oil	677	6

* Sedimentary basins associated with oil and gas shale plays (US EIA, 2011a).
Note: Analysis considered 4,066 disclosures that met selected quality assurance criteria, including: unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; with confirmed state location; and with confirmed county location. Disclosures that did not meet quality assurance criteria (142 disclosures) or other, query-specific criteria were excluded from analysis.

Generally, comparisons of additive ingredients across the five counties showed less similarity than the comparison of additive ingredients between each county and the entire dataset. The 20 most frequently reported additive ingredients for each county (Appendix G) were compared with the other selected counties and with the entire dataset.[47] The number of frequently reported additive ingredients in common between datasets was expressed as a percentage of the total number of frequently reported additive ingredients using the following equation:

$$\text{Percentage of Similarity} = \frac{\text{Number of additive ingredients in common between County A and County B}}{\text{Average number of additive ingredients in Counties A and B}}$$

The denominator for the above equation was 20 unless two additive ingredients were tied in rank in one of the counties. The percentage of similarity in additive ingredients between pairs of counties ranged from 15% to 65%, as shown in Table 12. Overlap with the twenty most frequently reported additive ingredients for the entire dataset ranged from 35% to 85%. This suggests a degree of variability as would be expected given factors such as production type, geology, and operator preference. However, the 60% to 85% similarity with the entire dataset shown by four of the counties (excluding Kern County) also suggests that certain additive ingredients were commonly used in hydraulic fracturing fluids in disparate parts of the country. Similarity in additive ingredients across counties is consistent with the notion that similar factors influence the composition of hydraulic fracturing fluids. Similarity may also be influenced by economics and the availability of additives at local or regional scales. Patterns in additive ingredients could be found

[47] Some additive ingredients may overlap between two counties, but fall below the twenty most frequently reported chemicals on a list.

Table 12. Comparison of twenty most frequently reported chemicals among selected counties.

County, State	Percentage of similarity (%)				
	Andrews, TX*	Dunn, ND*	Kern, CA*	Bradford, PA†	Garfield, CO†
Andrews, TX*		49%	35%	65%	45%
Dunn, ND*	49%		39%	34%	39%
Kern, CA*	35%	39%		20%	15%
Bradford, PA†	65%	34%	20%		60%
Garfield, CO†	45%	39%	15%	60%	
Entire Dataset	85%	63%	35%	65%	60%

* >98% of disclosures in county specify oil production
† >99% of disclosures in county specify gas production
Note: Analysis considered 3,622 disclosures and 61,502 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; with confirmed state location; with confirmed county location; valid CASRN; and valid concentrations. Disclosures that did not meet quality assurance criteria (586 disclosures) or other, query-specific criteria were excluded from analysis.

by performing spatial analysis on formulations or selected additive ingredients of interest, although these types of analyses were not conducted in this study. Among the five counties, Kern County was notably less similar to the other counties and to the entire dataset than the other four counties. Fewer disclosures from Kern County used surfactants than the other two oil-producing counties. Disclosures from Kern County also showed less use of friction reducers and non-emulsifiers.

The percentage of similarity was found to be greater between the selected counties and their states (73% to 95% similarity; data not shown) than between the selected counties and the entire dataset. This suggests that additive ingredient information compiled at the state level may provide some useful insights into the composition of hydraulic fracturing fluids at the county level.

3.2. Base Fluids

Base fluids are the fluids into which additives and proppants are mixed to create the fracturing fluid. More than 93% of disclosures in the project database appear to use water as a base fluid.[48,49] The median maximum reported concentration of water in hydraulic fracturing fluid was 88% by mass, with a range of 68% to 99% (5th and 95th percentile), suggesting its primary use as a base fluid.[50]

[48] In this report, the term "water use" refers to the volume of water used for a hydraulic fracturing job as reported by operators in the total water volume field of the well header table of a FracFocus disclosure; it does not refer to withdrawals from a water source. The determination of water used as a base fluid was based on disclosures that include at least one water ingredient record with a maximum fluid concentration greater than or equal to 1% by mass (Section 2.3.1).

[49] Disclosures that met criteria for unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; completely parsed; with a valid maximum fracturing fluid concentration greater than or equal to 1% by mass; and having "water" as a term in the trade name or chemical name field.

[50] The total mass of fracturing fluid includes the masses of base fluids, additives, and proppants. Therefore, a fracturing fluid with 88% by mass of water would be composed of approximately 12% proppant and additive ingredients by mass.

Data from the project database were compiled to assess volumes and sources of water used as base fluids, as well as the frequency with which gases and hydrocarbons were used to either augment water-based fracturing fluids or to provide non-aqueous alternative fracturing fluids.[51]

3.2.1. Use of Non-Aqueous Fluids in Base Fluids

Non-aqueous fluids, such as gases and hydrocarbons, were reported to be used alone or blended with water to form a base fluid in 761 disclosures.[52] More than 96% of these disclosures reported a base fluid consisting of a blend of non-aqueous fluids and water. Table 13 describes the frequency of reporting and maximum concentrations for non-aqueous base fluid ingredients, and Table 14 shows the numbers of disclosures that reported non-aqueous base fluid ingredients by state.[53] Non-aqueous base fluid ingredients were most frequently reported in disclosures from Colorado, New Mexico, and Texas.

Liquid nitrogen and carbon dioxide were the most frequently observed non-aqueous ingredients combined with water to form the base fluid. These gas-water blends are used by operators to generate foams and energized fluids.[54] Using gas in base fluids reduces water use and thus reduces contact between water and the formation, making these fluid systems useful in water-sensitive formations. Energized fracturing fluids also promote flowback by expanding when the well is produced (Friehauf and Sharma, 2009; Gupta and Hlidek, 2010; Gupta et al., 1997).

Liquid nitrogen was reported in 643 (84%) of the disclosures identifying non-aqueous fluid ingredients, with a median maximum fluid concentration of 16% by mass (Table 13). The greatest reported use of liquid nitrogen was in New Mexico, with 296 disclosures (Table 14). Among the disclosures that reported liquid nitrogen as a base fluid ingredient, 519 of the 643 were for gas-producing wells and 124 were for oil-producing wells. The median maximum fluid concentration of water in disclosures that reported liquid nitrogen in addition to water was 59% by mass. Among disclosures that listed liquid nitrogen and water as base fluid ingredients, the median volume of water reported was approximately 77,000 gallons.

Carbon dioxide was listed in 83 disclosures identifying non-aqueous base fluid ingredients (11%), with a median maximum fluid concentration of 32% by mass (Table 13). Of the 83 disclosures that listed carbon dioxide as a base fluid ingredient, 73 were for gas-producing wells. The greatest

[51] The analysis does not account for brines formulated by the operator through the addition of salts (e.g., potassium chloride or sodium chloride) to water.

[52] 2.2% of 34,675 unique disclosures that met the date criterion and that had parsed ingredients with valid CASRNs and valid maximum concentrations. Disclosures reporting gas or hydrocarbon ingredients in their base fluids were identified through the presence of terms determined to be synonymous with "base fluid" in the purpose field of an additive and through the presence in the ingredient field of certain chemical names identified through preliminary queries. Based on a preliminary analysis, ingredients that made up less than 1% by mass of the hydraulic fracturing fluid were excluded from this analysis (Section 2.3.1). To determine water use in these disclosures, all disclosures identifying the use of a non-aqueous fluid were searched for the presence of "water" in the trade name field or in the chemical name field, specifying a maximum fluid concentration greater than or equal to 1% by mass.

[53] Because hydrocarbons were generally reported in combinations, one disclosure may be represented in more than one row of Table 7, and values in the columns cannot be totaled.

[54] Foams consist of gas volumes greater than 53% by volume (generally 65% to 80% gas); energized fluids contain less than 53% gas by volume, with typical volumes about 20% to 30% gas (Gupta and Valkó, 2007; Montgomery, 2013).

Table 13. Non-aqueous ingredients reported in base fluids.

EPA-standardized chemical name	CASRN	Maximum concentration in hydraulic fracturing fluid (% by mass)				Maximum concentration in additive (% by mass)			
		Number (%) of disclosures	Median	5th percentile	95th percentile	Number (%) of ingredient records	Median	5th percentile	95th percentile
Nitrogen, liquid	7727-37-9	643 (84%)	16	3.8	30	643 (80%)	100	25	100
Carbon dioxide	124-38-9	83 (11%)	32	11	46	83 (10%)	100	100	100
Petroleum distillates	8002-05-9	18 (2.4%)	46	29	67	18 (2.2%)	100	100	100
Propane	74-98-6	15 (2.0%)	63	1.6	79	16 (2.0%)	100	2.0	100
Isobutane	75-28-5	12 (1.6%)	29	8.0	52	13 (1.6%)	50	10	100
Butane	106-97-8	10 (1.3%)	2.2	1.5	59	11 (1.4%)	80	36	100
Hexane	110-54-3	4 (0.53%)	14	11	15	4 (0.50%)	20	18	20
Pentane	109-66-0	4 (0.53%)	9.8	5.8	14	4 (0.50%)	13	10	19
Butene	25167-67-3	3 (0.39%)	25	8.1	49	3 (0.37%)	65	34	65
1-Propene	115-07-1	2 (0.26%)	3.0	1.2	4.8	2 (0.25%)	5.0	5.0	5.0
2-Methylbutane	78-78-4	2 (0.26%)	16	14	18	2 (0.25%)	25	25	25
Benzene	71-43-2	2 (0.26%)	3.3	2.8	3.7	2 (0.25%)	5.0	5.0	5.0
Ethane	74-84-0	2 (0.26%)	2.3	1.6	3.1	3 (0.37%)	2.0	2.0	9.2
Ethylene	74-85-1	1 (0.13%)	2.1	2.1	2.1	1 (0.12%)	10	10	10
Methane	74-82-8	1 (0.13%)	2.1	2.1	2.1	1 (0.12%)	10	10	10
White mineral oil, petroleum	8042-47-5	1 (0.13%)	12	12	12	1 (0.12%)	100	100	100

Note: Analysis considered 34,675 disclosures and 676,376 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; valid CASRN; and valid concentrations. Disclosures that did not meet quality assurance criteria (3,855) or other, query-specific criteria were excluded from analysis.

Table 14. Use of non-aqueous ingredients in base fluids, summarized by state.

EPA-standardized chemical name	Number of disclosures													
	CO	LA	MI	ND	NM	OH	OK	PA	TX	UT	VA	WY	State Uncertain*	Total
Nitrogen, liquid	150	2			296		15	5	146	18	4	6	1	643
Carbon dioxide	38		1	1	3	1	1		5	15		18		83
Petroleum distillates									18					18
Propane	6								9					15
Isobutane	1								11					12
Butane	5								5					10
Hexane									4					4
Pentane									4					4
Butene									3					3
1-Propene									2					2
2-Methylbutane									2					2
Benzene									2					2
Ethane									2					2
Ethylene									1					1
Methane									1					1
White mineral oil, petroleum									1					1

* State location did not pass state locational quality assurance criteria.

Note: Analysis considered 34,675 disclosures and 676,376 ingredients that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; valid CASRN, and valid chemical concentrations. Disclosures that did not meet quality assurance criteria (3,855 disclosures) or other, query-specific criteria were excluded from analysis.

reported use of carbon dioxide was in Colorado, with 38 disclosures (Table 14). The median maximum fluid concentration of water in disclosures that reported carbon dioxide in addition to water was 61% by mass. Among disclosures that listed carbon dioxide and water as base fluid ingredients, the median volume of water reported was approximately 40,000 gallons.

Hydrocarbons can be used with water to create emulsions to control fluid loss in low-permeability gas-producing formations (Penny, 1982). Petroleum distillates and water were reported as the base fluid in 17 disclosures located in Texas (median maximum fluid concentrations of 44% by mass for petroleum distillates and 32% by mass for water). Among disclosures that listed petroleum distillates and water as base fluid ingredients, the median volume of water reported was approximately 11,000 gallons.

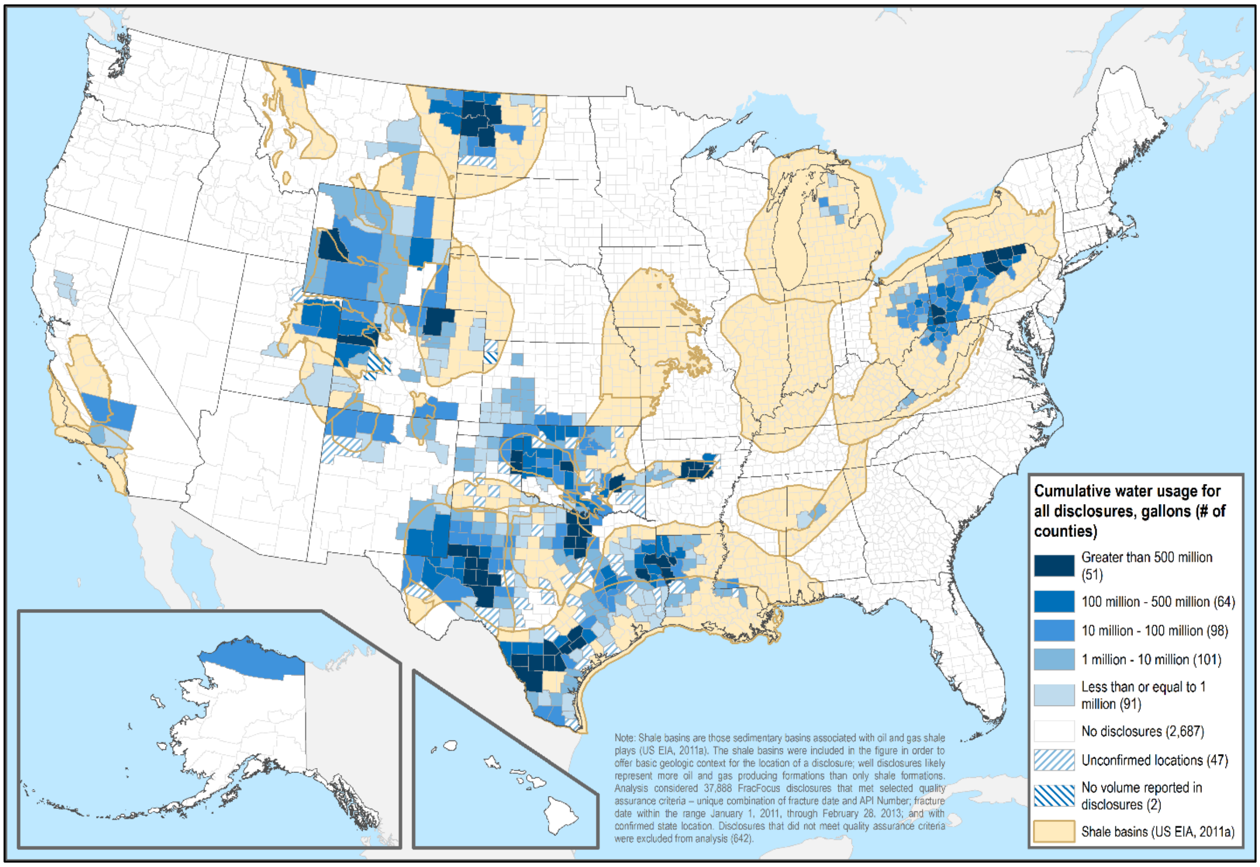
Although most hydraulic fracturing fluids described in the project database indicated water as all or part of the base fluid, a small number of disclosures reported entirely non-aqueous bas fluids. Non-aqueous base fluids, including those based on hydrocarbons or alcohols, may be used in water-sensitive formations or in oil-wet formations (DeVine et al., 2003; Gupta et al., 1997; Rae and Di Lullo, 1996). Hydrocarbon mixtures were reported as base fluids in 18 disclosures (2.4% of 761 disclosures that reported non-aqueous bas fluids); 12 disclosures were reported in Texas, and six disclosures were reported in Colorado. Eleven disclosures in Texas reported oil production, and the six disclosures in Colorado and one from Texas reported gas production. Among disclosures reporting hydrocarbon mixtures as base fluids, propane was identified as the primary base fluid ingredient in 10 disclosures, with a median maximum fluid concentration of 64% by mass.[55] Other disclosures reported other mixtures of the hydrocarbons listed in Table 13. The total water volume field was blank on the 18 disclosures that reported only hydrocarbons as base fluids.

3.2.2. Cumulative Total Water Volumes

Data from the project database indicate that nearly 92 billion gallons of water were used for hydraulic fracturing throughout the time period studied: 36 billion gallons in 2011, 52 billion gallons in 2012, and 3.8 billion gallons in the first two months of 2013. Cumulative total water volumes were calculated for each county with disclosures in the project database and are shown in Figure 5.[56] Counties with the greatest reported cumulative total water volumes are clustered in areas of northeastern Pennsylvania, northern Colorado, western North Dakota, and parts of Texas. Cumulative total water volumes should be considered lower limit estimates of water use for hydraulic fracturing within a county, as the information in the project database from counties in a state with voluntary reporting may be incomplete. The estimates of cumulative total water volumes may be useful, when paired with local information on water availability and total water use, for identifying areas of the country that may be vulnerable to water stress resulting from hydraulic fracturing.

[55] Butanes were also reported as base fluids in these 10 disclosures, with a median maximum fluid concentration of 3.4% by mass. One disclosures also reported 1-propene, with a maximum fluid concentration of 4.8% by mass.

[56] Appendix H lists cumulative total water volumes for each county as well as per-disclosure water volumes.



Note: Shale basins are those sedimentary basins associated with oil and gas shale plays (US EIA, 2011a). The shale basins offer basic geologic context for the location of a disclosure; well disclosures likely represent more oil and gas producing formations than only shale formations. Analysis considered 37,888 disclosures that met selected quality assurance criteria, including: unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; and with confirmed state location. Disclosures that did not meet quality assurance criteria were excluded from analysis (642).

Figure 5. Cumulative total water volumes, summarized by county.

Given the common use of water in hydraulic fracturing fluids, it is expected that the greatest cumulative total water volumes would be found in counties with a large number of disclosures in the project database (Figure 2).[57] For example, nine of the 20 counties with the largest cumulative total water volumes are also in counties with a large number of disclosures. Cumulative total water volumes for these nine counties ranged from 1.3 billion gallons in Gonzales County (344 disclosures) to 3.9 billion gallons in Dimmit County (715 disclosures). For context, Appendix H, shows that nearly half of the 406 counties represented in the project database have 10 or fewer disclosures.

State-level cumulative total water volumes were typically greatest in states with a large number of disclosures, as shown in Table 15. For example, Texas had both the greatest reported cumulative total water volume (approximately 45 billion gallons) and the largest number of disclosures

[57] The relationship between the number of disclosures and reported water volumes is shown further in Appendix H, which presents, for each county, the number of unique disclosures meeting the date and water volume criteria, the cumulative water use, and water volumes per disclosure (median, 5th and 95th percentiles).

Table 15. Total water volumes, summarized by state.

State	Number of disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
			Median	5th percentile	95th percentile
Texas	17,934	44,580,000,000	1,413,287	26,006	7,407,116
Pennsylvania	2,467	10,600,000,000	4,184,936	1,092,739	7,475,493
Arkansas	1,444	7,500,000,000	5,277,890	2,681,465	7,484,091
Oklahoma	1,898	6,666,000,000	2,578,947	114,870	8,288,041
Colorado	4,924	6,652,000,000	463,659	103,906	4,327,068
Louisiana	1,031	5,408,000,000	5,148,696	277,540	8,942,170
North Dakota	2,235	4,789,000,000	2,019,513	557,740	3,685,402
West Virginia	277	1,394,000,000	5,012,238	2,500,529	7,889,759
Wyoming	1,449	1,109,000,000	306,246	5,503	3,110,272
New Mexico	1,159	787,700,000	172,452	22,130	2,851,323
Ohio	146	614,200,000	3,887,499	2,526,398	7,442,826
Utah	1,421	534,400,000	303,424	35,070	1,056,654
Montana	213	337,500,000	1,469,839	216,578	3,197,594
Kansas	134	145,200,000	1,421,591	9,866	2,448,300
California	718	94,440,000	77,154	18,684	356,453
Michigan	15	55,100,000	33,306	15,722	15,127,125
Mississippi	4	35,140,000	9,173,624	4,322,108	12,701,054
Alaska	37	13,150,000	88,448	36,437	435,638
Virginia	77	3,021,000	33,474	13,322	96,684
Alabama	55	2,065,000	37,691	23,602	51,651
State Uncertain*	158	488,100,000	2,770,090	80,067	6,945,958
Entire Dataset	37,796	91,810,000,000	1,508,724	29,526	7,196,702

* State location did not pass state locational quality assurance criteria.

Note: Analysis considered 37,796 disclosures that met selected quality assurance criteria, including: unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; and criteria for water volumes. Disclosures that did not meet quality assurance criteria were excluded from analysis (734).

(17,934; 47% of disclosures that met the analysis criteria). Pennsylvania had the third largest number of disclosures (2,467; 6.5% of disclosures) and the second largest cumulative total water volume (approximately 11 billion gallons). The cumulative total water volume was the smallest in Alabama (approximately 2.1 million gallons, 55 disclosures).

Cumulative total water volumes for a few states (e.g., Arkansas, Louisiana, Mississippi, Ohio, and West Virginia) were larger than what might be expected based solely on the numbers of disclosures included in the project database. This is consistent with relatively large volumes of water reported per disclosure in these states, as reflected by median, 5th percentile, and 95th percentile values

(Table 15; see Section 3.2.3 for more discussion). The high per-disclosure total water volumes may reflect well length, geologic characteristics, and operator practices in these areas.

3.2.3. Total Water Volumes per Disclosure

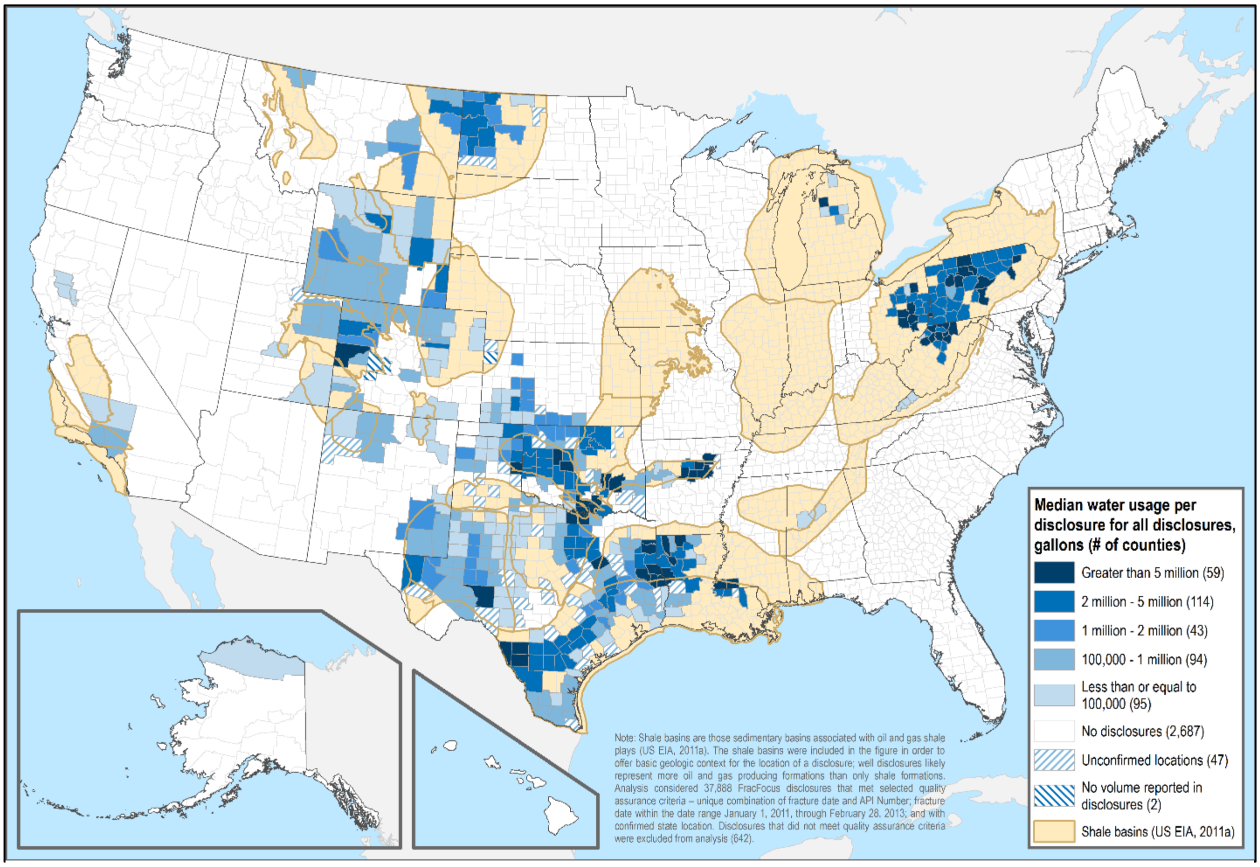
Some factors that influence water volumes used for hydraulic fracturing include formation type, total measured depth of the well, length of the production interval of the well (which can be horizontal), fracturing fluid properties, and the design of the fracturing job (Nicot and Scanlon, 2012). Hydraulic fracturing is sometimes referred to as low-volume or high-volume depending on the relative amount of fluid used to fracture the target rock formation. Low-volume hydraulic fracturing, typically conducted in vertical wells, can require between 20,000 and 80,000 gallons of water or other fluid (NYSDEC, 1992). Hydraulic fracturing of a coalbed methane reservoir may require 50,000 to 350,000 gallons per well (Holditch, 1993; Jeu et al., 1988; Palmer et al., 1991; Palmer et al., 1993).

High-volume hydraulic fracturing for wells located in low permeability formations such as shales can require millions of gallons of water (GWPC and ALL Consulting, 2009; Lee et al., 2011; Nicot and Scanlon, 2012) and often include long horizontal well segments. Water volumes in the Marcellus Shale, for example, have been reported to range from 3 to more than 5 million gallons per well (Aminto and Olson, 2012). Vengosh et al. (2014) report that up to 13 million gallons of water is needed per well for hydraulic fracturing of unconventional reservoirs. The New York State Department of Environmental Conservation (2011) estimates that a multi-stage fracturing operation for a well with a 4,000-foot long lateral (the horizontal segment of the well) would typically involve between 8 and 13 stages and use 300,000 to 600,000 gallons of water per stage, for a total of 2.4 to 7.8 million gallons per well.

The project database provides a snapshot of total water volumes reported on a per-disclosure basis, although interpretation is somewhat limited by lack of information on the total measured depth of the well (which can be greater than the true vertical depth) and the length of the production interval.[58] Figure 6 shows the median total water volume per disclosure for each county in the project database. The median total water volume per disclosure in the project database was approximately 1.5 million gallons, with a range of reported total water volumes of nearly 30,000 gallons to almost 7.2 million gallons (5th to 95th percentile). The wide range likely reflects hydraulic fracturing practices that include low-volume stimulation of vertical wells, high-volume fracturing of horizontal wells in shales and tight sands, and fracturing in coalbed methane plays.

Gas disclosures reported a median total water volume of approximately 2.9 million gallons, and oil disclosures reported a median total water volume of approximately 1.1 million gallons. Total water volumes reported in gas disclosures ranged from approximately 91,000 gallons to approximately 7.8 million gallons (5th to 95th percentile). Total water volumes reported in oil disclosures ranged from approximately 18,000 gallons to approximately 6.1 million (5th to 95th percentile).

[58] FracFocus 1.0 disclosures do not indicate whether a well is vertical or horizontal or the length of the production interval.



Note: Shale basins are those sedimentary basins associated with oil and gas shale plays (US EIA, 2011a). The shale basins offer basic geologic context for the location of a disclosure; well disclosures likely represent more oil and gas producing formations than only shale formations. Analysis considered 37,888 disclosures that met selected quality assurance criteria, including: unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; and with confirmed state location. Disclosures that did not meet quality assurance criteria were excluded from analysis (642).

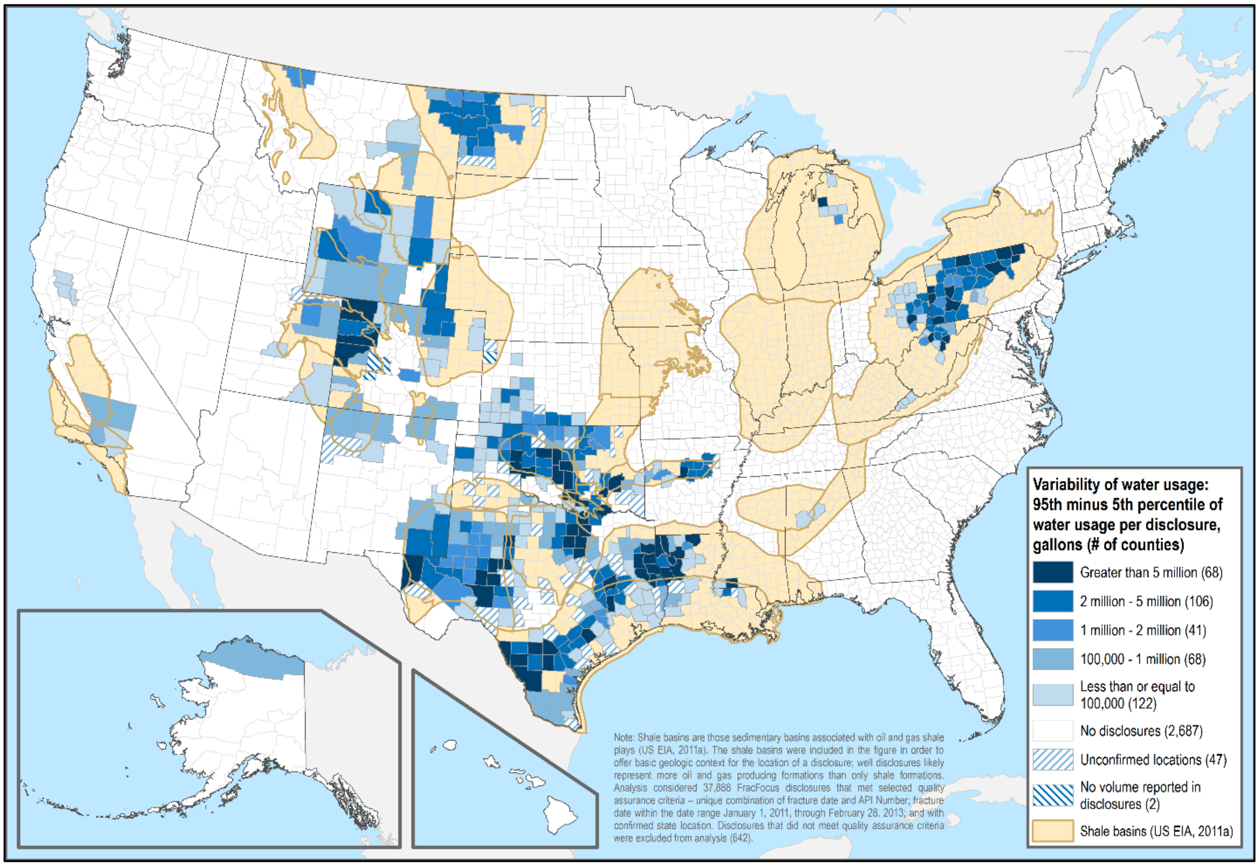
Figure 6. Median total water volumes per disclosure, summarized by county.

Assessed geographically in Table 15, the median total water volume per disclosure was highest for Mississippi (nearly 9.2 million gallons; 4 disclosures) and lowest for Michigan (approximately 33,000 gallons; 15 disclosures). However, Michigan also had the highest 95th percentile value of any state (more than 15 million gallons), suggesting a wide range of water volumes used within that state.

At the county level, median total water volumes per disclosure ranged from less than 5,000 gallons to more than 14 million gallons (Appendix H). Counties that appeared to have relatively high median per-disclosure total water volumes are clustered in a few parts of the country: Pennsylvania, West Virginia, and Ohio; parts of Texas, Oklahoma, and Louisiana; and North Dakota (Figure 6).

In assessing the range of total water volumes, it is important to consider the median in relation to the 5th and 95th percentiles, which indicate variability in total water volumes reported in a particular area. Within-state variability, as measured by the range (5th to 95th percentile) of total water volumes reported per disclosures in the state, spans three orders of magnitude in some cases

(Table 15), suggesting a range of operating practices, well lengths, or target formation geologies in an area. Figure 7 shows the geographic distribution of variability in total water volumes as indicated by the difference between the 5th and 95th percentiles. The figure shows areas of large variability in total water volumes reported in parts of Colorado, Louisiana, Pennsylvania, and Texas.



Note: Shale basins are those sedimentary basins associated with oil and gas shale plays (US EIA, 2011a). The shale basins offer basic geologic context for the location of a disclosure; well disclosures likely represent more oil and gas producing formations than only shale formations. Analysis considered 37,888 disclosures that met selected quality assurance criteria, including: unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; and with confirmed state location. Disclosures that did not meet quality assurance criteria were excluded from analysis (642).

Figure 7. Variability in reported total water volumes per disclosure, as measured by the difference between the 5th and 95th percentiles.

3.2.4. Comparing Variability of Total Water Volumes in Selected Counties

Variability in reported total water volumes was examined by selecting and summarizing data on cumulative and per-disclosure total water volumes from several counties that represented a variety of geographic settings and were anticipated to represent a variety of fracturing operations.[59] Because cumulative total water volumes are strongly influenced by the number of wells in a location (Section 3.2.2), counties with a similar number of disclosures were chosen to minimize one factor contributing to variability in cumulative total water volumes. The counties chosen for comparison had 254 to 331 disclosures per county (around the 90th percentile for number of

[59] The comparisons of total water volumes do not attempt to differentiate between vertical and directional or horizontal wells, because this information was not readily available in the FracFocus 1.0 disclosures.

disclosures per county) to increase the confidence and robustness in the observed results for both cumulative and per-disclosure total water volumes. Table 16 summarizes total water volume information from the disclosures for the selected counties.

Data from the selected counties indicated a large variability in total water volumes reported for hydraulic fracturing. Cumulative total water volumes for the selected counties ranged from approximately 9.8 million gallons to almost 1.8 billion gallons. Median per-disclosure total water volumes ranged from 16,000 gallons to nearly 6.3 million gallons. The lowest and highest values for median total water volumes were both within Texas (Milam and Wheeler counties, respectively).

Disclosures from counties in which gas production was predominant (>80% of disclosures) appeared to have greater cumulative and median per-disclosure total water volumes than disclosures from counties in which oil production was predominant (Table 16). Of the nine counties in Table 16 with the greatest per-disclosure and cumulative total water volumes, seven were predominantly gas-producing, and two had slightly more gas production than oil production (between 60% and 80% of disclosures). The median total water volume for the nine counties was 1.7 to 3.1 times larger than the greatest median per-disclosure total water volume reported for a predominantly oil-producing county (approximately 2.0 million gallons for Dunn County, North Dakota).

Conversely, eight of the 10 counties in Table 16 with the lowest per-disclosure and cumulative total water volumes were predominantly oil-producing. The data suggest that total water volumes were generally lower in counties where oil production was predominant. The observed difference in total water volume by production type may be due to a number of factors, including well depths, the length of the fractured segment of the well, the formation types that are represented, and other aspects of the fracturing design (Nicot and Scanlon, 2012).

The majority of the counties in Table 16 are located in Texas, providing an opportunity for within-state comparisons of total water volumes. Texas, generally speaking, is a region with a mature oil and gas industry, a variety of geologic settings, and both conventional and unconventional production. Total water volumes for the counties in Texas appeared to vary, in part, according to the predominant production type and geologic setting.[60] For example, median per-disclosure total water volumes in Denton, Wise, and Johnson counties (99% to 100% natural gas production), located in the Fort Worth Basin in central Texas, ranged from approximately 1.8 to nearly 4.0 million gallons. This is two to four times greater than the median per-disclosure total water volumes reported for disclosures in Howard and Irion counties (about 900,000 gallons each), which were predominantly oil-producing and located in the Permian Basin in western Texas. However, there is also considerable variability within the Permian Basin: median per-disclosure total water volumes from disclosures in Mitchell and Gaines counties (approximately 30,000 and 79,000 gallons, respectively) ranged from 11 to almost 30 times lower than Howard and Irion counties.

[60] The counties were grouped by geologic basin, and the EPA assumed that counties within the same basin may have similar influences on operations due to comparable geology, geography, infrastructure, and policies.

Table 16. Total water volumes for selected counties in approximately the 90th percentile of disclosures.

State	County	Number of disclosures	Percent oil disclosures	Percent gas disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
						Median	5th percentile	95th percentile
Texas	Wheeler	283	35%	65%	1,774,000,000	6,292,608	879,360	12,398,544
Arkansas	White	309	0.00%	100%	1,749,000,000	5,782,854	3,655,427	7,416,763
Arkansas	Conway	302	0.00%	100%	1,596,000,000	5,266,774	2,919,365	7,957,921
Pennsylvania	Susquehanna	327	0.00%	100%	1,546,000,000	4,798,290	940,909	7,816,150
Arkansas	Cleburne	263	0.00%	100%	1,489,000,000	5,974,108	3,401,011	7,538,336
Texas	Johnson	289	0.00%	100%	1,191,000,000	3,969,422	1,754,012	7,202,405
Texas	Wise	291	0.34%	100%	1,157,000,000	3,875,046	918,692	7,969,196
Pennsylvania	Tioga	286	0.00%	100%	1,133,000,000	3,598,474	2,285,636	6,572,202
Texas	DeWitt	320	28%	72%	1,104,000,000	3,426,088	2,028,110	4,790,741
Texas	Irion	284	99%	0.70%	945,600,000	895,468	45,494	11,729,639
Texas	Denton	263	0.76%	99%	934,700,000	1,836,744	1,014,405	9,008,399
North Dakota	Dunn	331	100%	0.00%	630,100,000	2,017,621	409,803	3,361,183
Texas	Reeves	263	100%	0.38%	352,600,000	1,081,442	104,447	3,865,365
New Mexico	Lea	286	98%	1.7%	244,300,000	183,645	53,235	3,730,169
Texas	Howard	286	100%	0.00%	219,500,000	895,986	26,018	1,523,373
Wyoming	Sweetwater	321	1.6%	98%	84,850,000	229,974	79,090	435,011
Texas	Gaines	298	100%	0.00%	44,090,000	79,411	18,330	269,241
Texas	Mitchell	278	100%	0.36%	22,020,000	30,402	14,154	88,003
Texas	Milam	254	100%	0.00%	9,844,000	16,000	16,000	18,900
All 90th Percentile Counties		5,534	45%	55%	16,230,000,000	2,503,683	16,000	7,471,633
Entire Dataset		37,796	52%	48%	91,810,000,000	1,508,724	29,526	7,196,702

Note: Analysis considered 37,796 disclosures that met selected quality assurance criteria, including: unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; and criteria for water volumes. Disclosures that did not meet quality assurance criteria were excluded from analysis (734 disclosures).

When comparing the ranges (5th to 95th percentile) of per-disclosure total water volumes reported for each county, those reported in Mitchell, Gaines, and Milam counties (100% oil disclosures) appeared to be smaller than those reported in Wheeler, Johnson, Wise, DeWitt, and Denton counties (65% to 100% gas disclosures).

Within the Texas counties in Table 16, the range of total water volumes reported per disclosure (as represented by the 5th and 95th percentiles) differed by as much as 11 million gallons, as observed in Irion County, and as little as 2,900 gallons (Milam County). The large amount of variability in some counties suggests that wells located within a relatively short surface distance of each other used different volumes of water for hydraulic fracturing. Use of non-aqueous ingredients, such as gases or hydrocarbons, in base fluids, which could decrease the total volume of water needed in fracturing fluids, did not appear to contribute appreciably to the variability in counties in Texas; liquid nitrogen was reported in 59 disclosures in Mitchell County and 10 disclosures in Howard County.

A wide range of reported total water volumes within a county may be a result of hydraulic fracturing in multiple formations within the county and the influence of specific formation conditions on operations. The TVD of wells in Irion and Milam counties was assessed as an indicator of the number of formations that may be hydraulically fractured in the area.[61] A relatively small range of depths might indicate that one formation was being developed for production, whereas clusters of ranges or a broad range of depths might indicate concurrent development in multiple formations in an area. The TVDs in Milam County disclosures were generally shallower than Irion County disclosures, with 99% of disclosures in Milam County ranging from 650 to 998 feet (median 940 feet) below surface.[62] In Irion County, TVDs were deeper and ranged (minimum to maximum) from 3,766 to 9,184 feet (median 7,038 feet) below surface. The relatively narrow range of TVDs reported in disclosures from Milam County, in combination with the relatively narrow range of per-disclosure total water volumes reported in Table 16, suggest that a single formation is represented by the disclosures for Milam County in the project database. Additional information on producing formations in Milam County would be needed to verify this observation.

3.2.5. Water Sources

Although FracFocus 1.0 disclosures do not have a specific data field for identifying water sources, some operators used terminology in their submissions that indicated the source or quality of water used for base fluids. Twenty-nine percent of disclosures (10,301 of 36,046 disclosures) included information related to water sources, though rates of reporting varied by state (Table 17). Some of these terms indicated a condition of water quality, such as “fresh,” rather than a specific identification of the source of the water (e.g., ground water, surface water). Twenty-three different source water-related terms and combinations of terms were identified in the project database,

[61] A relationship between TVD and water volumes was not apparent for the entire dataset.

[62] The range (minimum to maximum) of depths reported on the 254 disclosures from Milam County, Texas, were below the 5th percentile of TVD values found in the project database. Two hundred ninety-eight disclosures in the project database indicated a TVD less than 1,000 feet in depth. For the project database, the 5th percentile for TVD was 2,872 feet below surface, the 95th percentile was 12,796 feet, and the median was 8,140 feet.

Table 17. Number of disclosures having terms suggestive of water sources, summarized by state.

Reported water source	Number of disclosures																			
	AK	AR	CA	CO	KS	LA	MI	MS	MT	ND	NM	OH	OK	PA	TX	UT	WV	WY	State Uncertain*	Total
Fresh																				
Fresh	6	45		1,042	33	489	6	2	18	503	142	40	914	118	3,020	60	46	543	18	7,045
Lease water			8		1	5				1			20		31	9				75
Surface		40																		40
Reused																				
Produced		8	8	10										75						101
Produced/recycled													31		5					36
Recycled		2		181										1				143		327
Mixed/Other																				
Brine			3	4	6	15		1		3			2		42			3	1	80
Brine/fresh				3		3		1			1		3		13				1	25
Brine/lease water															1					1
Brine/salt water				2																2
Flowback/salt water															1					1
Fresh/lease water													1		1					2
Fresh/nominal recycled				4		82									2					88
Fresh/produced						1														1
Fresh/produced/ recycled		42										94	37	470	127		76			846
Fresh/recycled		261		25										35			8	1		330
Fresh/salt water				2																2
Fresh/treated water											1									1
Nominal fresh/ recycled				224																224
Recycled/surface		907																		907
Salt water	2			18		14				2					63					99
Sea water	11																			11
Treated water				36		1							1		19					57

Table continued on next page

Reported water source	Number of disclosures																		
	AK	**AR**	**CA**	**CO**	**KS**	**LA**	**MI**	**MS**	**MT**	**ND**	**NM**	**OH**	**OK**	**PA**	**TX**	**UT**	**WV**	**WY**	**State Uncertain***	**Total**
All water sources																				
Disclosures with water sources	19	1,305	19	1,551	40	610	6	4	18	509	144	134	1,009	699	3,325	69	130	690	20	10,301
Disclosures in entire dataset	37	1,409	704	4,622	100	1,029	14	4	201	2,073	1,136	147	1,832	2,458	17,056	1,279	273	1,388	139	36,046
Percentage that identify water source	51%	93%	2.7%	34%	40%	59%	43%	100%	9.0%	25%	13%	91%	55%	28%	19%	5.4%	48%	50%	14%	29%
Water (source unspecified)	17	20	624	2,536	34	308	1	0	83	965	863	11	418	1,121	10,024	1,008	69	595	57	18,809

* State location did not pass state locational quality assurance criteria.

Note: Analysis considered 36,046 disclosures and 925,972 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; and valid concentrations. Disclosures that did not meet quality assurance criteria (2,484) or other, query-specific criteria were excluded from analysis.

reflecting inconsistency and possible redundancy in terminology used. Operators often described water using general terms, such as “fresh” or “brine,” for which no standard definitions were provided. Source water analyses are therefore limited to operator-reported terminology.

The term “fresh” was most often used to describe water used for base fluids and was listed as the only term in 68% of disclosures with information on source water (7,045 of 10,301) across 17 states (Table 17). It is not known whether any of these disclosures used the term “fresh” to refer to recycled fluids that was treated to achieve the quality of fresh water. Disclosures listing only the term “fresh” were found in 99% of all disclosures reporting a source of water in North Dakota (503 of 509 disclosures) and 91% of those in Texas (3,020 of 3,325 disclosures). By contrast, the term “fresh” was used exclusively in only 3% of disclosures reporting a water source in Arkansas (45 of 1,305). Differences observed among disclosures from different states are likely due, in part, to variations in the rate of overall reporting of water sources and inconsistencies in terminology used.

After disclosures that reported only use of fresh water, mixtures of more than one source were most commonly found in the project database. Twenty-four percent of disclosures (2,466 of 10,301 disclosures; Table 17) that identified a source of water used more than one term, with the most common combination being “recycled” and “surface” (907 of 10,301 disclosures, all from Arkansas).

As shown in Table 18, when the term “fresh” was used in combination with other source water types, fresh water tended to make up a larger proportion of the hydraulic fracturing fluid. For instance, for disclosures in which the term “fresh” was used in combination with “recycled” or “produced,” the median maximum fluid concentration of “fresh” water in hydraulic fracturing fluid ranged from 79% to 90% by mass. The median maximum fluid concentrations associated with “recycled” or “produced” water, when used with “fresh” water, ranged from 4% to 90% by mass.

Given inconsistencies in the use of terms associated with recycling of water, the frequency of use of recycled water was not clear from this analysis. Reporting of the terms “flowback,” “recycled,” or “produced” in disclosures could indicate that recycling of flowback or produced water occurred. Table 17 shows that the terms “flowback,” “recycled,” and “produced,” either alone or in combination with other water source terms, were included in 28% of disclosures containing water source information (2,861 of 10,301 disclosures). Disclosures in several states indicated the use of brine, which may also represent the use of flowback or produced water. Disclosures that contained only the terms “recycled” or “produced” (either alone or together) occurred in Arkansas, California, Colorado, Oklahoma, Pennsylvania, Texas, and Wyoming. For these states, the median maximum fluid concentrations for “recycled” and “produced” were generally in excess of 70% by mass, suggesting substantial use of some quantity of produced water in base fluids for some disclosures.

Of the disclosures that included information on water sources, the greatest number of disclosures indicating the use of “recycled” or “produced” water, either alone or in combination with other water sources, was found in disclosures from Arkansas (93% or 1,220 of 1,305 disclosures). Median maximum fluid concentrations of “recycled” or “produced” water ranged from 10% to 93% depending on whether these water sources were blended with other sources. These concentrations

Table 18. Median maximum fluid concentrations of water by source, summarized by state.

Reported water source	**Number of disclosures**																			
	AK	**AR**	**CA**	**CO**	**KS**	**LA**	**MI**	**MS**	**MT**	**ND**	**NM**	**OH**	**OK**	**PA**	**TX**	**UT**	**WV**	**WY**	**State Uncertain***	**Entire dataset**
Fresh																				
Fresh	84	92		81	94	87	91	88	87	86	85	84	90	83	87	91	86	82	87	87
Lease water			77		95	89				84			94		86	40				86
Surface		92																		92
Reused																				
Produced		25	72	93										86						85
Produced/ recycled													94/94		90/90					94/94
Recycled		93		100										54				93		98
Mixed																				
Brine			71	83	91	88		95		84			92		83			87	87	86
Brine/fresh				13/69		7/84		4/85			3/86		3/93		13/77				5/82	13/78
Brine/lease water															6/86					6/86
Brine/salt water				2/90																2/90
Flowback/salt water															27/27					27/27
Fresh/lease water													53/41		94/94					74/68
Fresh/nominal recycled				81		88									90					88
Fresh/produced						87/4														87/4
Fresh/produced/ recycled		80/10/10										76/8/8	85/2/2	71/15/15	85/3/3		77/8/8			76/10/10
Fresh/recycled		79/13		81/81										90/90			90/90	84/84		81/16
Fresh/salt water				51/36																51/36
Fresh/treated water											81/81									81/81

Table continued on next page

Reported water source	Number of disclosures																			
	AK	**AR**	**CA**	**CO**	**KS**	**LA**	**MI**	**MS**	**MT**	**ND**	**NM**	**OH**	**OK**	**PA**	**TX**	**UT**	**WV**	**WY**	**State Uncertain***	**Entire dataset**
Nominal fresh/ recycled				100																100
Recycled/surface		29/62																		29/62
Salt water	100			91		87				81					94					92
Sea water	81																			81
Treated water				93		89							95		85					93
All water sources																				
Median (source specified)	82	47	74	84	94	87	91	88	87	86	85	14	90	26	87	90	23	85	87	83
Median (source unspecified)	99	91	78	91	92	90	92		87	86	80	89	92	88	88	89	90	80	87	88

* State location did not pass state locational quality assurance criteria.

Note: Analysis considered 36,046 disclosures and 925,972 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; and valid concentrations. Disclosures that did not meet quality assurance criteria (2,484) or other, query-specific criteria were excluded from analysis.

suggest substantial use of recycled water during some hydraulic fracturing operations. Notable use of recycled and produced water was also indicated in Pennsylvania (83% of disclosures with source water terms), Ohio (70%), and West Virginia (65%), although the total numbers of disclosures were much lower in Ohio and West Virginia than in Arkansas and Pennsylvania.

3.3. Proppants

Proppants, or materials that frequently functioned as proppants, were often reported in the ingredients table. The proppant analyses in this section included 26,935 unique disclosures in the project database with fracture dates between January 1, 2011, and February 28, 2013. Proppants were identified through entries in the purpose field (i.e., an entry similar to proppant, sand, quartz, or silica). The strategy of identifying proppants using the purpose field was conservative but consistent with the study's approach of reporting data as closely as possible to the original PDF disclosures. Because some operators listed proppant ingredients without providing an entry in the purpose field, this analysis provides a lower limit on information regarding proppant use.[63] Ingredients associated with resin coatings on proppants were excluded from this analysis and instead included in the additive ingredient analyses described in Section 3.3.

The median maximum concentration of proppant ingredients in hydraulic fracturing fluids was 11% by mass, with a range of 2.4% to 24% by mass (5th to 95th percentile). Table 19 lists the ingredients most frequently reported as proppants in the project database and shows the maximum concentrations of the ingredients in hydraulic fracturing fluids and in additives. The 10 ingredients in the table represent over 99% of disclosures that have ingredients with proppant-related purposes in the project database.

Quartz was the most prevalent proppant ingredient reported and was identified in 98% of all disclosures that identified proppants by purpose, with a median maximum fluid concentration of 10% by mass (Table 19). Silicate minerals, most notably quartz, are commonly used as proppants due to their mechanical strength and availability in large quantities (Beckwith, 2011). Other minerals identified as proppants in the project database include mullite, corundum, calcined bauxite, bauxite, titanium dioxide, ferric oxide, and alumina, as well as other less frequently reported minerals not present in Table 19. Proppants also have been manufactured from other materials, including glass, fly ash, and metallurgical slags (Beckwith, 2011), which were not observed in the project database.

For almost 90% of the disclosures represented in the proppant analysis, quartz was the only ingredient listed. Other proppant ingredients were reported in many fewer disclosures than quartz, and they had lower median maximum fluid concentrations (Table 19), indicating their usage in mixtures that may be designed to achieve a certain strength or density, which suggests that they may be part of proppant mixtures or may be incorporated into the proppant at different stages of a

[63] A broader screening of multiple fields for proppant-related terms suggested the number of disclosures that included information on proppant use likely exceeded 34,000. This analysis queried for unique disclosures that met the date criterion with "sand" in the trade name, purpose, or comments fields; "prop" in the purpose field; or a chemical name of "sand" or "quartz" with a valid maximum fluid concentration greater than 5% by mass.

Table 19. Ten most frequently reported proppant ingredients, ranked by frequency of occurrence.

EPA-standardized chemical name	CASRN	Maximum concentration in hydraulic fracturing fluid (% by mass)				Maximum concentration in additive (% by mass)			
		Number (%) of disclosures	Median	5th percentile	95th percentile	Number (%) of ingredient records	Median	5th percentile	95th percentile
Quartz	14808-60-7	26,273 (98%)	10	2.4	24	40,337 (80%)	100	97	100
Mullite	1302-93-8	1,352 (5.0%)	3.4	0.000000*	12	1,592 (3.2%)	85	20	100
Cristobalite	14464-46-1	1,048 (3.9%)	0.80	0.000000*	3.9	1,201 (2.4%)	30	5.0	30
Silica, amorphous	7631-86-9	946 (3.5%)	1.1	0.000000*	3.9	1,048 (2.1%)	30	10	35
Ferric oxide	1309-37-1	867 (3.2%)	0.012	0.00038	0.66	1,406 (2.8%)	0.10	0.10	10
Alumina	1344-28-1	793 (2.9%)	0.14	0.050	16	1,347 (2.7%)	1.1	0.80	100
Titanium dioxide	13463-67-7	711 (2.6%)	0.012	0.0042	0.44	1,244 (2.5%)	0.10	0.10	5.0
Corundum (Aluminum oxide)	1302-74-5	668 (2.5%)	3.0	0.000000*	32	681 (1.4%)	60	35	90
Bauxite	1318-16-7	198 (0.74%)	3.4	0.52	12	218 (0.43%)	100	58	100
Calcined bauxite	66402-68-4	197 (0.73%)	2.8	0.022	20	210 (0.42%)	85	2.3	100

* Concentration is less than a millionth of a percentage by mass.

Note: Analysis considered 34,675 disclosures and 676,376 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; valid CASRN; and valid concentrations. Disclosures that did not meet quality assurance criteria (3,855) or other, query-specific criteria were excluded from analysis.

fracturing job. In 1,093 disclosures, quartz was reported with mullite (sometimes with other proppant ingredients); mullite is an aluminosilicate material that is a significant component in lightweight ceramic proppants (Brannon and Pearson, 2008). In 508 disclosures, quartz was reported in combination with corundum and mullite; corundum offers the benefit of very high strength and is a suitable component of proppant mixes for deep wells (Brannon and Pearson, 2008). In 301 disclosures, quartz was used with bauxite or calcined bauxite, either as the only two materials or in combination with other proppant ingredients. Some proppant ingredients, such as hematite, magnesium iron silicate, and rutile had median maximum fluid concentrations under 1% by mass, suggesting their presence as minor constituents in sand mixtures.

Although ingredients associated with resin coatings were not included in the proppants analysis in Table 19, information in the project database was analyzed to estimate the use of resin-coated proppants. Disclosures with proppant-related purposes were further queried for indications of the use of resin-coated proppants in the trade name, chemical name, purpose, and comments fields. The fields were searched for use of the word "resin" or a common resin ingredient (e.g., phenolic resin, methenamine, and epoxy resin). Entries in these fields showed that 11,452 disclosures indicated the use of a resin-coated proppant (43% of the 26,935 disclosures containing ingredients with proppant-related purposes).[64] The largest numbers of disclosures including resin-coated proppants were from Colorado (2,116) and Texas (5,824), where they represent 55% and 46%, respectively, of the disclosures containing ingredients with proppant-related purposes in each state. Several hundred disclosures with resin-coated proppants were also identified in Oklahoma (597 disclosures, 47% of 1,260 disclosures with proppants in that state), New Mexico (597 disclosures, 62% of 959 disclosures with proppants), and North Dakota (481 disclosures, 32% of 1,525 disclosures with proppants). These data are lower limits for resin-coated proppant use, because the analysis was limited to disclosures that identified a proppant-related purpose for an ingredient record.

4. Conclusions

The summary statistics presented in this report reflect the information included in the FracFocus 1.0 disclosures (i.e., records of hydraulic fracturing events at individual wells) submitted by well operators for hydraulic fracturing conducted between January 2011 and February 2013. The project database compiled from the disclosures and the accompanying *Data Management and Quality Assessment Report* (US EPA, 2015) are available at www2.epa.gov/hfstudy/published-scientific-papers.

More than 39,000 PDF disclosures were provided to the EPA by the GWPC in March 2013. Information on fracture date, well operator, well identification and location, production type, true vertical depth, and total water volume were successfully extracted from 38,530 disclosures. Hydraulic fracturing fluid composition data were extracted for 37,017 disclosures. Hydraulic fracturing fluid composition data included trade names of additives, the purpose associated with each additive, and the identity (i.e., chemical name and CASRN) and maximum concentration of

[64] An additional 3,116 disclosures indicate the use of resin-coated proppants when disclosures are included for which the operator did not indicated a purpose for the proppants are included in the analysis.

each ingredient in an additive and in the overall hydraulic fracturing fluid. Reviews of data quality were conducted on the project database prior to data analysis to ensure that the results of the analyses reflected the data contained in the PDF disclosures, while identifying obviously invalid or incorrect data to exclude from analyses.

Analyses were conducted on unique (i.e., non-duplicate) disclosures with a fracture date between January 1, 2011, and February 28, 2013, that met appropriate quality assurance criteria for a given analysis. The disclosures identified well locations in 406 counties in 20 states and were reported by 428 well operators. True vertical depths ranged from approximately 2,900 feet to nearly 13,000 feet (5th to 95th percentile), with a median of just over 8,100 feet. Generally, well locations represented by the disclosures were clustered in the northeast (mainly in and around Pennsylvania), the west central portion of the country (from North Dakota and Wyoming through Texas and Louisiana), and in California. Summary statistics performed on the entire dataset reflect a greater contribution of data from states that are better represented in the project database than others—partly due to the locations of oil and gas-bearing reservoirs, different state reporting requirements, and the success in extracting data from individual PDF disclosures.

Because of the large number of disclosures included in the project database (38,530 disclosures), the extensive quality checks conducted on the data, and the design of the analyses, the summary statistics presented in this report represent the central tendency of measures of chemical and water use for the disclosures in the project database. Although caution is used in drawing broad national, state, or local inferences in chemical or water use from the summary statistics presented in this report, the data provide a valuable two-year snapshot of the composition of hydraulic fracturing fluids.

Ingredients reported in the disclosures were categorized in analyses as either additive ingredients, base fluid ingredients, or proppant ingredients depending upon entries in the trade name, purpose, and comments fields as well as the reported maximum ingredient concentration in the hydraulic fracturing fluid. Additive ingredients generally included chemicals reported for trade names that had purposes other than base fluid or proppant. The project database contains 692 unique ingredients reported for additives, base fluids, and proppants. Hydraulic fracturing fluids were generally found to contain 88% by mass water, 10% by mass quartz, and <1% by mass additive ingredients (median maximum hydraulic fracturing fluid concentrations).

Additive Ingredients. The project database identified the additive ingredients most frequently reported and their concentrations in both hydraulic fracturing fluids and additives. Although chemicals claimed as CBI contributed to the incompleteness of the project database, a valid CASRN was identified and a standardized chemical name was assigned to 65% of the over 1.2 million ingredient records in the project database. The median number of unique additive ingredients per disclosure was 14, with a range of 4 to 28 additive ingredients (5th to 95th percentile). Additive ingredients found in more than half of all disclosures analyzed included methanol (in 71% of disclosures), hydrochloric acid (65%), and hydrotreated light petroleum distillates (65%). The sum of the maximum fluid concentration for all additive ingredients reported in a disclosure was less than 1% by mass of the hydraulic fracturing fluid in approximately 80% of disclosures, and the median maximum fluid concentration was 0.43% by mass. Operators designated 11% of all ingredient records in the project database as CBI. At least one ingredient was claimed confidential in over 70% of disclosures.

Some disclosures in this study reflected a reporting approach that decoupled trade names from additive ingredient names and concentrations, which allowed operators to disclose chemicals while protecting CBI. This approach is consistent with suggestions by the SEAB and referred to as the "systems approach" to reporting (SEAB, 2011; 2014). The systems approach allowed additive ingredients to be included in analyses for this project, while protecting the ingredients from being connected to trade names. Additive ingredients were claimed as CBI by operators in a portion of the disclosures reported used in this study that had formatting consistent with the systems approach.

Base Fluids. Base fluids described in the disclosures included water, water with non-aqueous ingredients (e.g., gases or hydrocarbons), and hydrocarbons only. More than 93% of the disclosures analyzed in the study were inferred to use water as a base fluid with a median maximum fluid concentration of 88% by mass. Total water volumes reported per disclosure ranged from nearly 30,000 gallons to almost 7.2 million gallons (5th to 95th percentile), with a median total water volume per disclosure of approximately 1.5 million gallons. Non-aqueous constituents (e.g., nitrogen, carbon dioxide, and hydrocarbons) were reported as base fluids or in combination with water as a base fluid in fewer than 3% of disclosures.

Operators reported the source(s) of water used for base fluids, as suggested by the SEAB (SEAB, 2011), in 29% of disclosures (10,301 of 36,046 disclosures), even though the FracFocus 1.0 disclosures did not have a specific data field for identifying water sources. The term "fresh" was the most commonly reported water source, although this term may reflect a condition of water quality rather than a source. It could not be determined from the disclosures whether the source of the fresh water was ground water, some type of surface water body, produced water treated to "fresh" quality standards, or purchased from a public water system.

A large proportion of disclosures in several states west of the Mississippi River reported fresh water use in base fluids. More than 90% of disclosures that identified water sources in North Dakota, Oklahoma, and Texas reported fresh water as the only water source. In contrast, more than 70% of disclosures that identified water sources in Ohio and Pennsylvania identified some amount of reused and associated types of water in base fluids. These data indicate that base fluids were more likely to be made up of some reused or recycled water in several of the eastern states compared to several western states in the project database.

Possible Differences between Oil and Gas Production. Data in the project database suggested some differences in additive ingredients and total water volumes reported for disclosures associated with oil wells and disclosures associated with gas wells. Oil disclosures reported a slightly larger number of additive ingredients per disclosure and a greater maximum concentrations of some of the more frequently reported additive ingredients (e.g., methanol and hydrochloric acid). Total water volumes appeared to be greater for gas disclosures: The median per-disclosure total water volume reported for gas disclosures was approximately 2.9 million gallons, while the median per-disclosure total water volume reported for oil disclosures was approximately 1.1 million gallons (although the range of water volumes per disclosure overlapped). Differences may reflect any of a number of factors, including geologic properties of the formations being fractured, the well design (e.g., horizontal versus vertical wells), or operator practices.

Limitations to the Analyses. Conclusions drawn from the analyses presented in this report reflect data included in the project database. The content of the project database was influenced by the data conversion process (i.e., extracting data from PDFs into the project database) as well as the completeness and accuracy of data in the original PDF disclosures.

As identified throughout this report, the completeness and accuracy of the data in the original PDF disclosures may be affected by many factors, including state reporting requirements and ingredient reporting practices. By February 2013, six of the 20 states with data in the project database had implemented regulations that required well operators to disclose chemicals used in hydraulic fracturing fluids to FracFocus: Colorado, North Dakota, Oklahoma, Pennsylvania, Texas, and Utah. Three additional states (Louisiana, Montana, and Ohio) required disclosure to either FracFocus or the state, and five states (Arkansas, Michigan, New Mexico, West Virginia, and Wyoming) required reporting to the state. Because the majority of disclosures in the project database (58%) were reported in states without mandatory reporting requirements to FracFocus or had fracture dates prior to regulatory effective dates for mandatory reporting to FracFocus, the project database cannot be assumed to be complete.

Designations of CBI, reporting of invalid CASRNs and ingredient concentrations, and the modification of FracFocus 1.0 disclosure templates by operators contributed to an incomplete record of chemical use in the project database. Furthermore, parsing problems with the modified templates generated erroneous ingredient records. Additionally, reporting inconsistencies in additive purposes, chemical names, sources of water for base fluid, and identification of base fluid or proppant in the purpose field prevented a stronger statistical evaluation or interpretation of results in this project. Despite the challenges to adapting a dataset originally created for local use and single-PDF viewing to answer broader questions, the project database provided substantial insight into water and chemical use for hydraulic fracturing.

FracFocus 2.0, developed in late 2012, provides features such as dropdown menus, warning and error messages during submission, and automatic formatting of certain fields that can enhance the quality and consistency of data submitted by operators.[65] The FracFocus 2.0 infrastructure was also updated to store data in XML format rather than PDF. In early 2015, the GWPC and the IOGCC announced additional updates to FracFocus that include providing public extraction of data in a machine readable format and verification of CASRNs.

Contribution of FracFocus to Scientific Studies. Understanding the chemical composition of hydraulic fracturing fluids and the water volumes used for hydraulic fracturing is important for assessing or minimizing potential drinking water impacts related to hydraulic fracturing and for planning to avoid those potential impacts. The wide diversity of additive ingredients and total water volumes reported in disclosures submitted to FracFocus 1.0 emphasizes the importance of analyzing hydraulic fracturing practices at different scales (from local to state to regional) as well as by

[65] Although FracFocus 2.0 became an option for submitting information in late 2012, it was not the exclusive disclosure mechanism until June 2013.

production type. The project database and the summary statistics presented in this report could serve as a general reference, as well as a local or regional resource, for a variety of stakeholders, including tribal, state, and local governments; academic researchers; the oil and gas industry; non-governmental organizations; and the public.

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Glossary

Acid	An acid is a chemical that reduces the pH of an aqueous solution by increasing the ratio of hydronium (H_3O^+) ions to hydroxide (OH^-) ions in solution. In hydraulic fracturing, acids such as hydrochloric, hydrofluoric, acetic, formic and fluoroboric are used alone or as blends to achieve greater fracture penetration and to reduce clogging of the pore spaces and fractures by dissolving minerals and clays.
Additive	An ingredient or combination of ingredients that is added to a hydraulic fracturing base fluid to serve a specific purpose. Additives improve the efficiency and effectiveness of a hydraulic fracturing job by, for example, limiting the growth of bacteria and preventing corrosion of the well casing. Additives and their purposes are defined within the context of hydraulic fracturing, although some additives may also be used for other activities than hydraulic fracturing. In this report, an additive corresponds to the entry in the "trade name" field of a disclosure.
Additive ingredient	For the purpose of this report, generally the ingredients in additives with purposes other than those associated with base fluids or proppants, but also includes non-aqueous base fluid ingredients and resin coatings for proppants.
API well number	A unique identifying number assigned using a system developed by the American Petroleum Institute (API). The system applies to oil and gas wells drilled in the United States.
Base	A base is a chemical that increases the pH of an aqueous solution by increasing the ratio of hydroxide (OH^-) ions to hydronium (H_3O^+) ions in solution. In hydraulic fracturing, bases help control the pH of fracturing fluids and optimize their performance.
Base fluid	The fluid into which additives and proppants are mixed to formulate a hydraulic fracturing fluids.
Basin	A depression in the crust of the Earth formed by plate tectonic activity. Sediments may accumulate in the basin after the depression is created, or they may be deposited before tectonic activity forms the basin.
Biocide	An additive that can be used to control bacterial growth, which can affect the viscosity of the fracturing fluid or reduce permeability in the formation. Common problematic bacteria include sulfate-

	reducing bacteria, slime-forming bacteria, iron-oxidizing bacteria, and bacteria that attack polymers in fracturing fluids.
Breaker	Also referred to as a gel breaker, an additive used to reduce the viscosity of a gelled fracturing fluid. This is accomplished by breaking long-chain polymer molecules into shorter segments. Use of a breaker facilitates flowback of the fluid after fracturing.
Buffer	A buffer allows an aqueous solution to resist changes in pH. It consists of water, a weak acid or weak base, and a salt of the weak acid or weak base. Buffers are used to optimize performance of fracturing fluids that use complex polymers or crosslinked gelling agents.
CASRN	Chemical Abstracts Service Registry Number (CASRN). A unique numeric identifier assigned by the Chemical Abstracts Service for a single substance. The substance can be composed of a single chemical (e.g., methanol) or can be a mixture of chemicals (e.g., hydrotreated light petroleum distillates).
CBI	Confidential Business Information. Information that contains trade secrets, commercial or financial information, or other information that has been claimed as confidential by the submitter.
Clay control	An additive used in hydraulic fracturing to prevent swelling and migration of formation clays when water-based fluids are used. Swelling and migration of clays can cause reduced permeability and productivity by clogging pore spaces in the formation.
Conventional production	Crude oil and natural gas that is produced by a well drilled into a geologic formation in which the reservoir and fluid characteristics permit oil and natural gas to readily flow to the wellbore.
Corrosion inhibitor	An additive used to protect iron and steel equipment and wellbore components from corrosive ingredients used in acid treatments. These corrosive agents include various types of acids and hydrogen sulfide.
Crosslinker	An additive, typically a metallic salt, added to a linear gel base fluid to create a more viscous gel. This enables a fracturing fluid to carry more proppant. Crosslinkers increase the viscosity of the linear gel fluid by connecting polymer molecules in a three dimensional structure. After fracturing, the viscosity is reduced by a breaker to facilitate flowback of the fluid to the well.

CSV	Comma-separated values (CSV). File format where tabular data are presented as plain text with values separated by a special character, commonly a comma (,).
Disclosure	As used in this report, a disclosure refers to all data submitted for a specific oil and gas production well for a specific fracture date.
Flowback	After the hydraulic fracturing procedure is completed and pressure is released, the direction of fluid flow reverses, and fracturing fluids, any fluids naturally found in the formation, and excess proppant flow up through the wellbore to the surface. The fluids that return to the surface are commonly referred to as flowback. Flowback also refers to the process of allowing these fluids to flow from the well following a treatment.
Formation	A continuous body of rock with distinctive properties and large enough dimensions for mapping.
Friction reducer	An additive used to reduce friction in the wellbore, allowing fluid to move more quickly and efficiently.
Gelling agent	An additive used to increase fluid viscosity. Gels may be linear or cross-linked. The greater viscosity serves several purposes, including increasing the ability of the fluid to carry proppant and helping to minimize fluid loss.
Geoprocessing tool	Tool available in ArcGIS that is used to analyze and process spatial data.
Hydraulic fracturing fluid	A mixture of base fluid, additive ingredients, and proppants pumped under high pressure into a well to create fractures in the target formation and to carry proppant into the fractures.
Iron control agent	An additive used to increase the solubility of iron, removing and preventing the precipitation of iron-bearing additives such as iron hydroxide and iron sulfide. This helps control rust, sludges, and scale that can damage the formation.
Non-emulsifier	A chemical or mixture of chemicals used to prevent or minimize the formation of emulsions. Emulsions may form from the interaction of the fracturing fluid with hydrocarbons in the subsurface. A non-emulsifier facilitates separation of oil or gas from the flowback.
Parsing	Process of analyzing a string of symbols to identify and separate various components.

pH control	An additive that either adjusts the pH of the fluid or buffers the pH against change (buffer). Control of pH is needed for effective performance of the fracturing fluid, including facilitating the crosslinking of gels and use of breakers.
Play	An area in which hydrocarbon accumulations occur. The accumulations typically have similar geologic, geographic, and temporal properties such as source rock, hydrocarbon type, migration pathway, and trapping mechanism.
Proppant	Solids of a particular size, shape, and material that are carried into the fractures in a hydrocarbon formation by the hydraulic fracturing fluid. Their purpose is to hold the fractures open after hydraulic fracturing. In addition to naturally occurring sand, engineered materials, such as resin-coated sand or high-strength ceramic materials (e.g., sintered bauxite) may also be used.
Reservoir	Generally, a subsurface body of rock able to store fluids such as oil and natural gas and allow the flow of fluids within the rock.
Scale inhibitor	An additive used to control or prevent the formation of mineral scales in the formation or the well tubing. Scale deposition can inhibit hydrocarbon flow.
Stacked plays	Multiple reservoirs located at different depths within a sedimentary basin. Stacked plays may be accessed using a single vertical well or multiple horizontal wells, and may be either conventional or unconventional.
Surfactant	A chemical with polar and non-polar regions that allow it to reduce the surface tension at the interface between two liquids or between a liquid and a solid. This property means that surfactants can be used as emulsifiers, foaming agents, defoaming agents, and dispersants.
True vertical depth (TVD)	The vertical distance from a subsurface point in the well to a point at the surface, usually the rotary kelly bushing.
Unconventional production	Oil and natural gas that cannot be produced by the methods that are typically used for permeable sandstone and carbonate hydrocarbon reservoirs. Reservoirs that require unconventional production have porosities, permeabilities, or other properties that necessitate techniques such as hydraulic fracturing to stimulate the flow of hydrocarbons to a well. Unconventional production may occur in hydrocarbon reservoirs including coalbeds, shales, and sandstones.

Viscosifier	An additive used to increase the viscosity of a fluid. Viscosity is a fluid property that indicates the fluid's resistance to flow.
Well operator	A company that owns and/or operates oil and gas wells.
Wellbore	The drilled hole in which the well is constructed including the openhole or uncased portion of the well. The term "wellbore" is independent of the materials that form the well such as casing and tubing.
XML file	A file coded according to the Extensible Markup Language (XML) for easy sharing of data and formatting.

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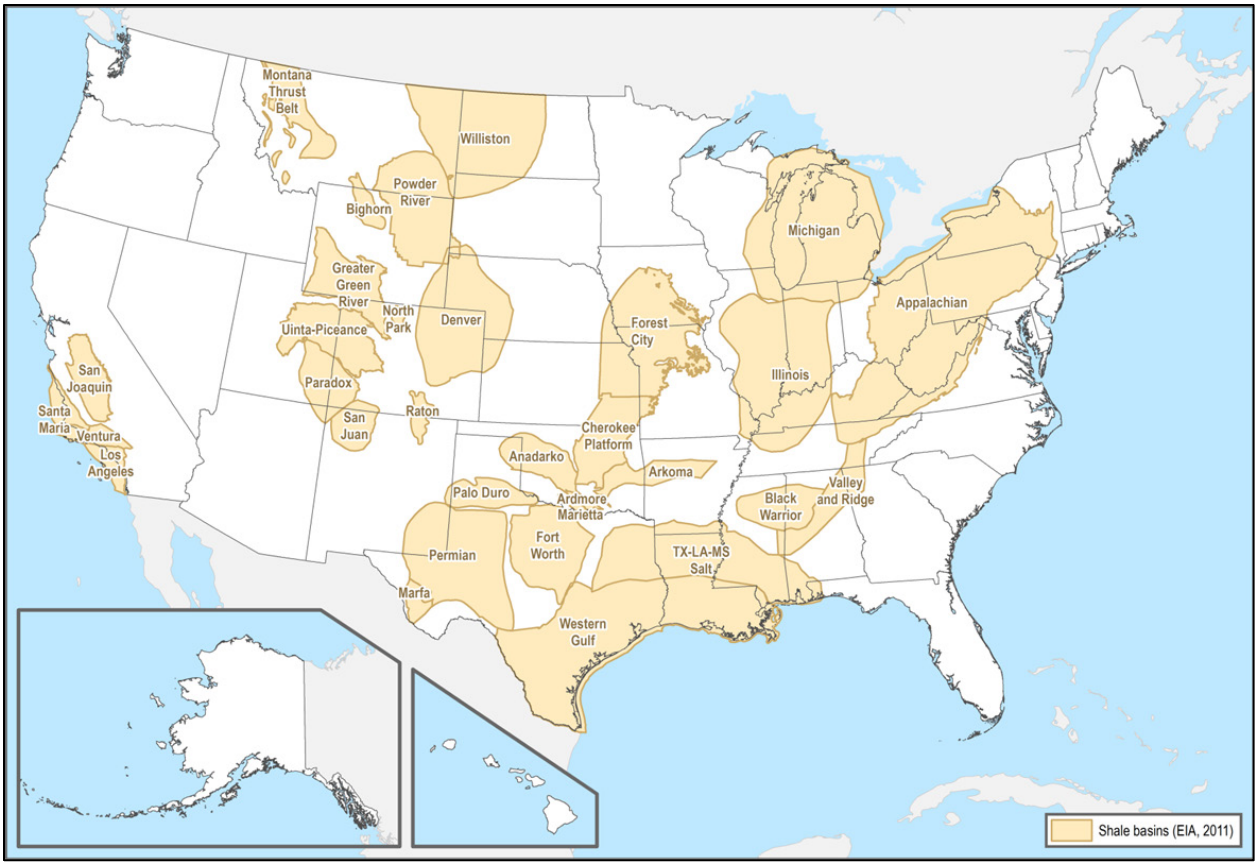
Appendix A. Shale Basin Map



Note: Shale basins are those sedimentary basins associated with oil and gas shale plays (US EIA, 2011a). The EIA-delineated shale basins provide basic geologic context for the locations of disclosures in the project database. Disclosures also represent oil and gas wells producing from tight sand plays and coalbed methane plays; maps of tight gas basins and coalbed methane basins are available from the U.S. Energy Information Administration. The shale gas basins are presented here because they represent many major sedimentary basins in the United States.

Figure A-1. Shale basins map (US EIA, 2011a)**.**

Appendix B. Chemical Families for Ingredients Listed as Confidential Business Information

This appendix includes a tabulation of information provided by well operators on the chemical families of the ingredients that were claimed to be confidential business information (CBI). We evaluated 122,915 ingredient records (from disclosures with unique combinations of fracture date and API well number and with a fracture date between January 1, 2011, and February 28, 2013) that have a CBI synonym in the CASRN field and an entry in the chemical name field.[1] An additional 696 ingredient records had a CBI entry in the CASRN field, but no information in the chemical name field.

Ingredient records containing "CBI" or a synonym in the CASRN field were sorted into the categories listed in the table below. Entries in the records were minimally standardized to correct for misspellings and capitalization and to consolidate nearly identical entries. Those entries with partially defined chemical information were tabulated to list the number and percentage of disclosures associated with each of the standardized chemical families listed in Table B-1. The partial definition provided enough description to narrow the scope of potential chemicals or indicate a general chemical group.

Type of entry in the chemical name field	Percentage of ingredient records
CBI synonym	9.6%
Partially defined chemical (enough description to narrow the list of potential chemicals or indicate a general chemical group)	79%
Ingredient (specifically defined chemical) (e.g., hydrochloric acid, ammonium chloride, amorphous silica)	2.1%
Purpose (entries provides information on purpose rather than chemical family) (e.g., surfactant)	7.5%
Multiple entries (more than one chemical name in the field)	0.088%
Other (an entry that does not provide information on a specific chemical or chemical grouping and does not fall into one of the other categories)	1.3%
Total	100%

[1] The 122,915 ingredient records are a subset of the 129,311 ingredient records identified as CBI ingredient records in Section 2.2.3. The 129,311 ingredient records were identified by the presence of "CBI" or a synonym in either the CASRN field or chemical name field. The 122,915 ingredient records have "CBI" or a synonym in the CASRN field and a non-null entry in the chemical name field.

Table B-1. Chemical families for CBI ingredient records.

Standardized chemical family name	Number of chemical names with this standardized family name*	Number of CBI ingredient records	CBI records as percent of total CBI ingredient records
Oxyalkylated alcohol	12	5,809	4.7%
Petroleum distillates	23	4,974	4.0%
Quaternary ammonium compounds	27	4,461	3.6%
Aromatic aldehyde	9	2,227	1.8%
Polyoxyalkylenes	6	1,955	1.6%
Olefins	9	1,933	1.6%
Fatty acids	4	1,920	1.6%
Aliphatic acids	3	1,748	1.4%
Cured acrylic resin	9	1,701	1.4%
Polyglycol ester	4	1,697	1.4%
Polyol ester	3	1,695	1.4%
Aliphatic alcohols, ethoxylated #1	3	1,627	1.3%
Vinyl copolymer	3	1,600	1.3%
Amino alkyl phosphonic acid	4	1,530	1.2%
Alcohol ethoxylate surfactants	6	1,528	1.2%
Aliphatic hydrocarbon	3	1,527	1.2%
Carbohydrate polymer	2	1,439	1.2%
Alkylene oxide block polymer	6	1,412	1.1%
Copolymer	2	1,390	1.1%
Organic amine resin salt	5	1,304	1.1%
Oxyalkylated alkyl alcohol	6	1,257	1.0%
Aliphatic polyol	2	1,073	0.87%
Phosphonate salt	6	1,044	0.85%
Organic sulfur compounds	8	1,029	0.84%
Oxyalkylated fatty acid	5	984	0.80%
Ethoxylated alcohol blend	2	971	0.79%
Polymer	9	968	0.79%
Quaternary amines	10	927	0.75%
Inorganic salt	7	917	0.75%
Alkoxylated amines	6	882	0.72%
Aliphatic alcohol glycol ether	3	876	0.71%
Haloalkyl heteropolycycle salt	8	858	0.70%
Ethoxylated alcohol	5	855	0.70%
Alcohols	6	841	0.68%
Borate salt	12	810	0.66%

Table continued on next page

Standardized chemical family name	Number of chemical names with this standardized family name*	Number of CBI ingredient records	CBI records as percent of total CBI ingredient records
Amine salt	9	802	0.65%
Alcohol ethoxylate	9	794	0.65%
Polyquaternary amine	3	781	0.64%
Alcohol alkoxylate	5	766	0.62%
Aldehyde	7	754	0.61%
Organic phosphonate	5	747	0.61%
Inorganic chemical	3	737	0.60%
Polyelectrolyte	4	737	0.60%
n-olefins	5	711	0.58%
Oxyalkylated phenolic resin	8	708	0.58%
Guar gum derivative	6	696	0.57%
Branched alcohol oxyalkylate	1	653	0.53%
Cocoamido tertiary amine	2	607	0.49%
Sulfonate	7	568	0.46%
Cyclic alkanes	2	546	0.44%
Ethoxylated alcohols	4	493	0.40%
Ammonium salt	10	491	0.40%
Hydrocarbon	3	477	0.39%
Quaternary ammonium salt	8	463	0.38%
Glycol ether	4	458	0.37%
Amine phosphonate 1	2	424	0.34%
Carbohydrates	5	415	0.34%
Essential oils	3	414	0.34%
Alkyl phosphate ester	3	412	0.34%
Fatty acid amidoalkyl betaine	1	412	0.34%
Clay	6	406	0.33%
Sulfonated polystyrene	1	405	0.33%
Polyethoxylated alkanol (1)	1	404	0.33%
Polyethoxylated alkanol (2)	1	404	0.33%
Polyacrylamide copolymer	5	393	0.32%
Acrylamide	2	380	0.31%
Organophilic clays	7	369	0.30%
Substituted alcohol	2	369	0.30%
Ethoxylated nonylphenol	8	340	0.28%
Acid phosphate ester	2	337	0.27%
Alkyl alkoxylate	3	335	0.27%
Polyacrylate	7	329	0.27%
Ethoxylated fatty acid	4	327	0.27%

Table continued on next page

Standardized chemical family name	Number of chemical names with this standardized family name*	Number of CBI ingredient records	CBI records as percent of total CBI ingredient records
Aliphatic alcohol	2	306	0.25%
Organic polyol	3	304	0.25%
Castor oil	3	303	0.25%
Fatty acid	1	303	0.25%
Fatty acid salt	1	303	0.25%
Polysaccharide blend	2	299	0.24%
Polysubstituted aromatic hydrocarbon solvent	1	286	0.23%
Synthetic organic polymer	2	281	0.23%
Oxyalkylated alkanols	2	280	0.23%
Neutralized polymer	2	278	0.23%
Non-hazardous salts (Choline)	2	276	0.22%
Nonylphenol ethoxylate	6	275	0.22%
Ethoxylated alcohols 2	2	267	0.22%
Cationic water soluble polymer emulsion	2	266	0.22%
Organic sulfonic acid salt	2	265	0.22%
Oxyalkylated polyamine	2	264	0.21%
Synthetic polymer	3	256	0.21%
Quaternary salt	2	252	0.21%
Anionic copolymer	2	248	0.20%
Polyglycol	1	245	0.20%
Anionic polyacrylamide	2	242	0.20%
Acrylamide modified polymer	3	241	0.20%
Neutralized polycarboxylic acid	2	234	0.19%
Fatty acids, tall oil	5	231	0.19%
Amine phosphonate 5	1	228	0.19%
Non-hazardous salts	5	226	0.18%
Amine derivative	2	220	0.18%
Hemicellulase enzyme concentrate	1	219	0.18%
Secondary alcohol	4	218	0.18%
Mannanase enzymes	6	215	0.17%
Neutralized traceable polymer	1	214	0.17%
Cationic polyacrylamide copolymer	8	209	0.17%
Enzyme	7	207	0.17%
Organic alcohol	1	199	0.16%
Proprietary methanol	1	199	0.16%

Table continued on next page

Standardized chemical family name	Number of chemical names with this standardized family name*	Number of CBI ingredient records	CBI records as percent of total CBI ingredient records
1,3-propanediol, 2-amino-2(hm)-polymer	2	192	0.16%
Polyacrylamide polymer	1	192	0.16%
Polyoxyalkylenes surfactant	1	192	0.16%
Anionic polymer	4	185	0.15%
Inorganic base	2	177	0.14%
Ammonium alkyl ether sulfate	1	175	0.14%
Anionic polyacrylamide copolymer	3	173	0.14%
Enzyme solution	1	170	0.14%
Amine phosphonate 5, potassium salt	2	169	0.14%
Substituted alkylamine	1	162	0.13%
Olefin sulfonate	2	160	0.13%
Polyester	1	158	0.13%
Hexyl alcohol, ethyxylated	1	157	0.13%
Alkyl alcohol	1	152	0.12%
Hydrotreated light petroleum distillate	4	146	0.12%
Acyclic hydrocarbons	4	145	0.12%
Oxylated alkanols	1	145	0.12%
Acrylate polymer	5	144	0.12%
Light aromatic hydrocarbon solvent	1	144	0.12%
Acrylamide polymer	3	143	0.12%
Cellulase enzyme	3	143	0.12%
Phosphonic acid	3	140	0.11%
Alkanolamine/aldehyde condensate	1	134	0.11%
Ethoxylated phenolic resin	1	128	0.10%
Amines	2	127	0.10%
Oxyalkylated alkylphenol	3	127	0.10%
Salt	4	127	0.10%
Modified carboxylic acid polymer salt	2	123	0.10%
Sodium salt	3	122	0.10%
Acetylenic alcohol	2	121	0.10%
Complex alkylaryl polyo-ester	2	121	0.10%
Phosphoric acid ester	3	120	0.10%
Organic phosphonic acid salts	6	119	0.10%

Table continued on next page

Standardized chemical family name	Number of chemical names with this standardized family name*	Number of CBI ingredient records	CBI records as percent of total CBI ingredient records
Unsulphonated matter	2	117	0.10%
Modified alkane	4	111	0.090%
Polyacrylamide	2	107	0.087%
Polymer blend	3	107	0.087%
Modified thiourea polymer	4	105	0.085%
Amines, coco alkyl, acetates	1	104	0.085%
Terpenes and terpenoids	4	100	0.081%
Acrylate copolymer, sodium salt	2	99	0.081%
Sodium polyphosphate	1	99	0.081%
Ammonium alkyl sulfate	1	98	0.080%
Silica organic polymer	2	96	0.078%
Phosphonate compound	1	95	0.077%
Borate suspension	1	94	0.076%
Alkenes	3	89	0.072%
Formic acid additive	1	88	0.072%
Aliphatic alcohols, ethoxylated #2	2	82	0.067%
Epoxy resin	3	82	0.067%
Phosphate ester	5	78	0.063%
Phosphonic acid derivative	3	74	0.060%
Polycarboxylic acid polymer	1	74	0.060%
Poly phosphonate	1	71	0.058%
Organo phosphorous salt	3	69	0.056%
Nickel chelate catalyst	3	68	0.055%
Acrylate phosphonate copolymer	1	67	0.055%
Neutralized organic acid	1	67	0.055%
Resin based nonionic inhibitor	1	67	0.055%
Sodium polycarboxylate	2	65	0.053%
Terpene	2	65	0.053%
Mannase enzymes	1	64	0.052%
Poly (acrylamide-co-acrylic acid)	1	64	0.052%
Inorganic mineral	3	62	0.050%
Alcoholic amine	2	59	0.048%
Anionic water soluble polymer	4	56	0.046%
Tallow soap	3	56	0.046%
Aliphatic copolymer	2	54	0.044%
Alkyl sulfate	1	54	0.044%

Table continued on next page

Standardized chemical family name	Number of chemical names with this standardized family name*	Number of CBI ingredient records	CBI records as percent of total CBI ingredient records
Amine phosphonate salt	1	52	0.042%
Modified bentonite	5	52	0.042%
Alkene sulfonate	1	51	0.041%
Polyamine	1	51	0.041%
Polysaccharide	5	51	0.041%
Quaternary ammonium	4	51	0.041%
Sulfate	1	51	0.041%
Weak acid	1	51	0.041%
Acid	1	50	0.041%
Inner salt of alkyl amines	3	49	0.040%
Alcohol alkoxy sulfate	1	48	0.039%
Ethoxylated oil	1	48	0.039%
Organic acid salts	1	48	0.039%
Propylene glycol copolymer	1	47	0.038%
Zirconium complex	2	46	0.037%
Aromatic amine	1	45	0.037%
Hemicellulase	1	45	0.037%
Inorganic material	1	44	0.036%
Ethoxylated alcohol linear 2	2	42	0.034%
Cellulose	1	41	0.033%
Modified amine	1	41	0.033%
Oxalkylated fatty acid	1	41	0.033%
Acrylate copolymer	1	40	0.033%
Alkyl amine surfactant	4	39	0.032%
Inorganic borate	3	39	0.032%
Non-hazardous polymers	2	38	0.031%
Organic salt	5	37	0.030%
Ester solvents	1	36	0.029%
Cationic polymer	2	35	0.028%
Fatty acid amine salt mixture	6	35	0.028%
Polycationic organic polymer	4	35	0.028%
Synthetic resin fibers	1	34	0.028%
Amine phosphonate 7	2	33	0.027%
Iso-alkanes/n-alkanes	1	33	0.027%
Organic acid esters	2	33	0.027%
Oxoalkyl compounds	2	33	0.027%
Vegetable oil	2	33	0.027%
Alkylalcohol ethoxylated	1	32	0.026%

Table continued on next page

Standardized chemical family name	Number of chemical names with this standardized family name*	Number of CBI ingredient records	CBI records as percent of total CBI ingredient records
Oxyalkalated alkyl alcohol (1)	1	32	0.026%
Isomeric aromatic ammonium salt	1	31	0.025%
Nonylphenol	2	29	0.024%
Quaternized alkyl nitrogenated compound	8	29	0.024%
Secondary alcohol ethoxylate	1	29	0.024%
Nonylphenol ethoxylate surfactant	1	28	0.023%
Zirconium complexes (2)	1	27	0.022%
Cocamide based surfactant	1	25	0.020%
Alcohols, C12-16, ethoxylated	3	24	0.020%
Phosphorous compound	2	24	0.020%
Resin	4	23	0.019%
Resin compound	2	23	0.019%
Anionic inverse-emulsion polymer	1	22	0.018%
Aromatic ketones mixture	2	22	0.018%
Dimer fatty acids	2	22	0.018%
Polymers derived from fatty acids	1	22	0.018%
Stearates	1	21	0.017%
Aliphatic polymer	1	20	0.016%
Polyanionic Cellulose	2	20	0.016%
Tall oil acid diethanolamide	3	20	0.016%
Amine surfactant	1	19	0.015%
Complex alkylamine	4	19	0.015%
Distillates (petroleum), hydrotreated light	1	19	0.015%
Amine phosphonate	2	18	0.015%
Complex fatty acid compound	3	18	0.015%
Fatty acid ester	1	18	0.015%
Polyethoxylated alcohol	2	18	0.015%
Siloxane	1	18	0.015%
Alkyl quaternary ammonium chlorides	5	17	0.014%
Alkylated quaternary chloride	1	17	0.014%
Antimonate salt	1	17	0.014%
Cocoamido tertiary amine additive	1	17	0.014%
Emulsion polymer	1	17	0.014%

Table continued on next page

Standardized chemical family name	Number of chemical names with this standardized family name*	Number of CBI ingredient records	CBI records as percent of total CBI ingredient records
Ethoxylated amine	2	17	0.014%
Fused inorganics	1	17	0.014%
Organometallic salt	2	17	0.014%
Salt of phosphate ester	2	17	0.014%
Alcohol ethoxylate C-10/16 with 6.5 EO	1	16	0.013%
Ethoxylated alcohol linear 1	1	16	0.013%
Ethoxylated alcohol linear 3	1	16	0.013%
Fatty alkyl heteroclyclic amine salt	2	16	0.013%
Organo clay	2	15	0.012%
Sodium salt of phosphonodimethylated diamine	3	15	0.012%
Oxyalkylated ammonium salt	1	14	0.011%
Polyethoxylated fatty amine salt	2	14	0.011%
Polyurethane resin	1	14	0.011%
Quaternary ammonium chloride	3	14	0.011%
Alkyl amine salts	2	13	0.011%
Ethoxylated decyl alcohol	1	13	0.011%
Alkaline salt	2	12	0.0098%
Chloride compound	1	12	0.0098%
Complex ester	1	12	0.0098%
Ester mixture	1	12	0.0098%
Ethoxylated surfactant	1	12	0.0098%
Glycol	4	12	0.0098%
Hydrocarbon solvent	1	12	0.0098%
Acrylic polymer	5	11	0.0089%
Amine phosphate 5	1	11	0.0089%
Amine phosphate 5, potassium salt	1	11	0.0089%
Bis quaternary compond	1	11	0.0089%
Organic chloride	1	11	0.0089%
alpha-(4-nonylphenyl)-omega-hydr oxy-, branched	2	10	0.0081%
Complex carbohydrate	3	10	0.0081%
Hydrotreated mineral oil	1	10	0.0081%
Propoxylated alcohol	1	10	0.0081%
Alcohols, C14-C15, ethoxylated	3	9	0.0073%
Amine sulfonate	2	9	0.0073%

Table continued on next page

Standardized chemical family name	Number of chemical names with this standardized family name*	Number of CBI ingredient records	CBI records as percent of total CBI ingredient records
Ethylene/propylene oxide polymer	2	9	0.0073%
Phosphonic acid salt	1	9	0.0073%
Phosphonium salt	2	9	0.0073%
Oxyalkylated polymer	1	8	0.0065%
Oxyalkylated resin	1	8	0.0065%
Polyoxyalkenes	2	8	0.0065%
Amino compounds	1	7	0.0057%
Carbonates	1	7	0.0057%
Carboxylic acid salt	1	7	0.0057%
Ether salt	1	7	0.0057%
Isobutyl ketone I	1	7	0.0057%
Isobutyl ketone II	1	7	0.0057%
Isomeric aromatic ammonium	1	7	0.0057%
Modified polyacrylate	1	7	0.0057%
Phosphonate	1	7	0.0057%
Polylactide resin	2	7	0.0057%
Quaternary ammonium compounds, dicoco alkyldimethyl, chlorides - TS	1	7	0.0057%
Alkoxylated alcohol	1	6	0.0049%
Anionic polyacrylamide emulsion in mineral oil	1	6	0.0049%
Aromatic alcohol glycol ether	1	6	0.0049%
Cationic polyamine	1	6	0.0049%
Cationic polyamine blend	1	6	0.0049%
Ethoxylated alkyl amines	1	6	0.0049%
Hydrotreated petroleum distallate	1	6	0.0049%
Mineral oil	1	6	0.0049%
Organophosphonate	2	6	0.0049%
Oxyalkylated fatty acid derivative	2	6	0.0049%
Phosphonate of a diamine, sodium salt	1	6	0.0049%
Alkyl phosphonate	1	5	0.0041%
Alkyl thiol	1	5	0.0041%
Alkylarylpyridinium quaternary	1	5	0.0041%
Amino alcohols	1	5	0.0041%
Carboxylate salt	1	5	0.0041%

Table continued on next page

Standardized chemical family name	Number of chemical names with this standardized family name*	Number of CBI ingredient records	CBI records as percent of total CBI ingredient records
Citrus rutaceae extract	2	5	0.0041%
Cured resin	1	5	0.0041%
Mixed alkyl phosphate ester (mixture)	1	5	0.0041%
Naphthenic acid ethoxylate	2	5	0.0041%
Phosphonate, amine salt	1	5	0.0041%
Polyacrylate polymer	1	5	0.0041%
Polycarboxylate	1	5	0.0041%
2,7-Naphthalenedisulfonic acid,	1	4	0.0033%
Alkanolamine	2	4	0.0033%
Alkylpyridinium quaternary	1	4	0.0033%
Alphiatic polyol	1	4	0.0033%
Amine phosphate	1	4	0.0033%
Amino methylene phosphonic acid	1	4	0.0033%
Aromatic alcohol polyglycol ether	2	4	0.0033%
Aromatic ammonium salt	1	4	0.0033%
Aromatic hydrocarbon	2	4	0.0033%
Ester salt	1	4	0.0033%
Ethoxylated alcohol linear 1,2 and 3	1	4	0.0033%
Fatty alcohol polyglycol ether surfactant	1	4	0.0033%
Heavy aromatic petroleum naphtha	1	4	0.0033%
Inorganic oxygen compound	1	4	0.0033%
Modified acrylamide copolymer	2	4	0.0033%
Oxylated alcohol	2	4	0.0033%
Polyether	1	4	0.0033%
Polyoxyalkylated ether	2	4	0.0033%
Aliphatic alcohol polyglycol ether	1	3	0.0024%
Aliphatic amide derivative	1	3	0.0024%
Amide	1	3	0.0024%
Amine phosphonate 7, ammonium salt	1	3	0.0024%
Amino phosphonate 5	1	3	0.0024%
Amino phosphonate 5, potassium salt	1	3	0.0024%
Aromatic acid derivative	1	3	0.0024%

Table continued on next page

Standardized chemical family name	Number of chemical names with this standardized family name*	Number of CBI ingredient records	CBI records as percent of total CBI ingredient records
Aromatic amine, TOFA salt	1	3	0.0024%
Condensed alkanolamine	1	3	0.0024%
Dicarbonous ethoxylate	2	3	0.0024%
Ether compound	1	3	0.0024%
Ethoxylated C12-15 alcohols	1	3	0.0024%
Imidazolium compound	1	3	0.0024%
Phosphate acid blend	1	3	0.0024%
Phosphoric acid salt	1	3	0.0024%
Phosphorous based chemical blend	1	3	0.0024%
Ployacrylate/phosphonate acid blend	1	3	0.0024%
Polyester castor	1	3	0.0024%
Quaternary compound	1	3	0.0024%
Silicate mineral	2	3	0.0024%
Sulfur compound	1	3	0.0024%
Alcohol amine	1	2	0.0016%
Aliphatic ester	1	2	0.0016%
Aliphatic synthetic polymer	1	2	0.0016%
Alkanes	1	2	0.0016%
Alkyl aryl amine sulfonate	1	2	0.0016%
Amines, coco alkyl, ethoxylated	1	2	0.0016%
Aminofunctional polymer	1	2	0.0016%
Carboxymethylhydroxypropyl guar blend	1	2	0.0016%
Ester	1	2	0.0016%
Ethoxylated oleyl amine	1	2	0.0016%
Formaldehyde polymer	1	2	0.0016%
Hemicellulase enzyme	2	2	0.0016%
Liquid salt	1	2	0.0016%
Non-anionic surfactant	1	2	0.0016%
Organic amino silane	2	2	0.0016%
Organic polymer	1	2	0.0016%
Oxyalkylate polymer	1	2	0.0016%
Oxylated phenolic resin	1	2	0.0016%
Polycarboxylic acid	1	2	0.0016%
Polyoxyethylene derivative	2	2	0.0016%
Raffinates(Petroleum)	1	2	0.0016%
Salt of aliphatic acid	1	2	0.0016%

Table continued on next page

Standardized chemical family name	Number of chemical names with this standardized family name*	Number of CBI ingredient records	CBI records as percent of total CBI ingredient records
Silicane derivative	2	2	0.0016%
Sodium xylene sulfonate	1	2	0.0016%
Terpenes and terpenoids, sweet orange-oil	1	2	0.0016%
Terpolymer sodium salt	1	2	0.0016%
Acrylamide copolymer	1	1	0.00081%
Acrylic acid polymer	1	1	0.00081%
Alcohol amine salts	1	1	0.00081%
Alcohol ethoxylate distillate	1	1	0.00081%
Alcohol ethoxylates	1	1	0.00081%
Alkalines	1	1	0.00081%
Alkanolamine chelate of zirconium	1	1	0.00081%
Alkanolamine chelate of zirconium alkoxide	1	1	0.00081%
Alkenens, C15-C18	1	1	0.00081%
Alkkoxylated alkylphenol	1	1	0.00081%
Alkyl sulfonate	1	1	0.00081%
Alkyl sulfonate amine salts	1	1	0.00081%
Alkylamine halide salt	1	1	0.00081%
Alkylamine salts	1	1	0.00081%
Alkylammonium	1	1	0.00081%
Alkylbenzenesulfonic acid	1	1	0.00081%
Amine phosphate 1	1	1	0.00081%
Amphoteric alkyl amine	1	1	0.00081%
Aromatic polymer	1	1	0.00081%
Chloromethylnapthalene quinoline quaternary amine	1	1	0.00081%
Citrus terpenes	1	1	0.00081%
Copolymer resin	1	1	0.00081%
Cycloparrafins	1	1	0.00081%
Derivative of acrylic acid copolymer	1	1	0.00081%
Enzyme protein	1	1	0.00081%
Ethoxylated lauryl alcohol	1	1	0.00081%
Fatty amine quaternary	1	1	0.00081%
Guar - carbohydrate	1	1	0.00081%
Guar gum	1	1	0.00081%
Heavy aromatic petroleum	1	1	0.00081%
Hydrotreated light	1	1	0.00081%

Table continued on next page

Standardized chemical family name	Number of chemical names with this standardized family name*	Number of CBI ingredient records	CBI records as percent of total CBI ingredient records
Hydrotreated paraffinic solvent	1	1	0.00081%
Metal chloride	1	1	0.00081%
Methanol complex fatty-acid compound	1	1	0.00081%
Modified acrylate polymer	1	1	0.00081%
Modified cycloaliphatic amine	1	1	0.00081%
m-olefins	1	1	0.00081%
Noionic fluorsurfactant	1	1	0.00081%
Non hazardous sodium polyacrylate solution	1	1	0.00081%
Non-hazardous synthetic acid	1	1	0.00081%
Olefins oganic salt	1	1	0.00081%
Oranophilic clay	1	1	0.00081%
Organic acid zirconium salt	1	1	0.00081%
Organic amine	1	1	0.00081%
Organic phosphonate salts	1	1	0.00081%
Organophosphorous salt	1	1	0.00081%
Oxyalkylated fatty amine	1	1	0.00081%
Polacrylamide copolymer	1	1	0.00081%
Poly(dimethylaminoethyl methacrylate dimethyl sulfate quat)	1	1	0.00081%
Polyamine polymer	1	1	0.00081%
Polyolycol ester	1	1	0.00081%
Quarternary ammonium salt	1	1	0.00081%
Quaternary amine compounds	1	1	0.00081%
Quaternary heteropolycycle salt	1	1	0.00081%
Resin coated cellulose	1	1	0.00081%
Sodium carboxylate	1	1	0.00081%
Sodium salt of aliphatic amine acid	1	1	0.00081%
Sodium salt phosphonodimethylated	1	1	0.00081%
Surface base on cocamide	1	1	0.00081%
Zirconium salt solution	1	1	0.00081%
Zirconium/triethanolamine complex	1	1	0.00081%
Total		97,610	79%

* Counts in this column represent the number of distinct combinations of chemical name and CASRN (for example, “borate salts” with a CASRN of “CBI” and “borate salts” with a CASRN of “Confidential” are counted separately).

Table B-2. Most frequently reported chemical families among CBI ingredients and their most commonly listed purposes.

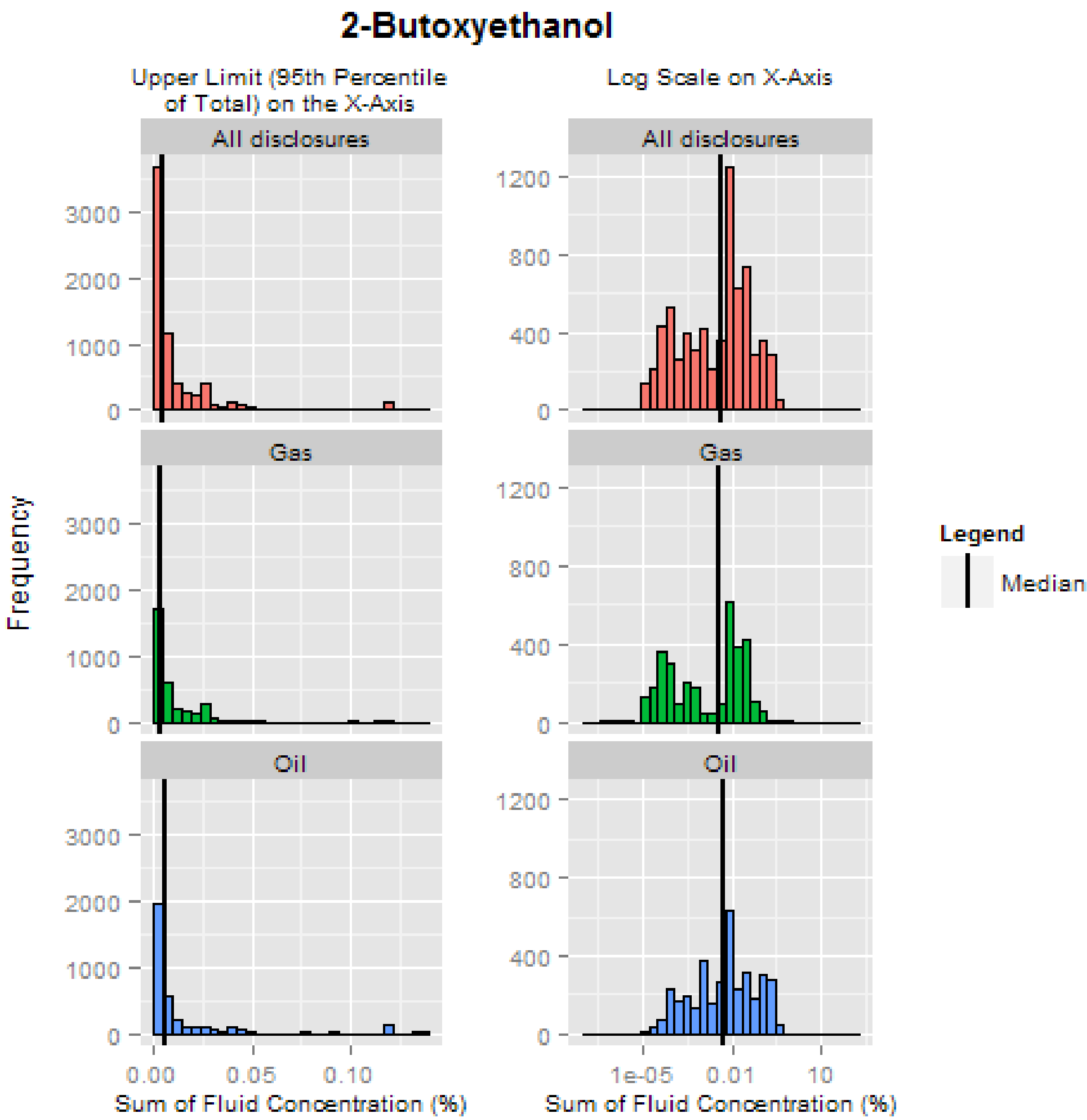
Standardized chemical family name	Most commonly listed purposes for additives containing the chemical
Alcohol ethoxylate surfactants	Friction Reducers, Corrosion Inhibitors, Surfactants
Aliphatic acids	Corrosion Inhibitors
Aliphatic alcohols, ethoxylated #1	Corrosion Inhibitors
Aliphatic hydrocarbon	Surfactants, Scale Control, Friction Reducers
Alkylene oxide block polymer	Surfactants, Corrosion Inhibitors, Scale Control
Amino alkyl phosphonic acid	Scale Control
Aromatic aldehyde	Corrosion Inhibitors
Carbohydrate polymer	Gelling Agents and Gel Stabilizers
Copolymer	Surfactants, Scale Control, Solvents
Cured acrylic resin	Surfactants, Breakers and Breaker Catalysts, Scale Control
Fatty acids	Corrosion Inhibitors, Clean Perforations
Olefins	Corrosion Inhibitors, Iron Control Agents, Clean Perforations, Gelling Agents and Gel Stabilizers
Organic amine resin salt	Corrosion Inhibitors
Oxyalkylated alcohol	Non-Emulsifiers, Surfactants, Friction Reducers, Scale Control
Petroleum distillates	Gelling Agents and Gel Stabilizers, Solvents, Friction Reducers, Crosslinkers and Related Additives
Polyglycol ester	Surfactants, Scale Control, Solvents, Biocides
Polyol ester	Surfactants, Scale Control, Solvents, Biocides
Polyoxyalkylenes	Corrosion Inhibitors, Clean Perforations
Quaternary ammonium compounds	Corrosion Inhibitors, Non-Emulsifiers, Surfactants
Vinyl copolymer	Surfactants, Scale Control, Solvents

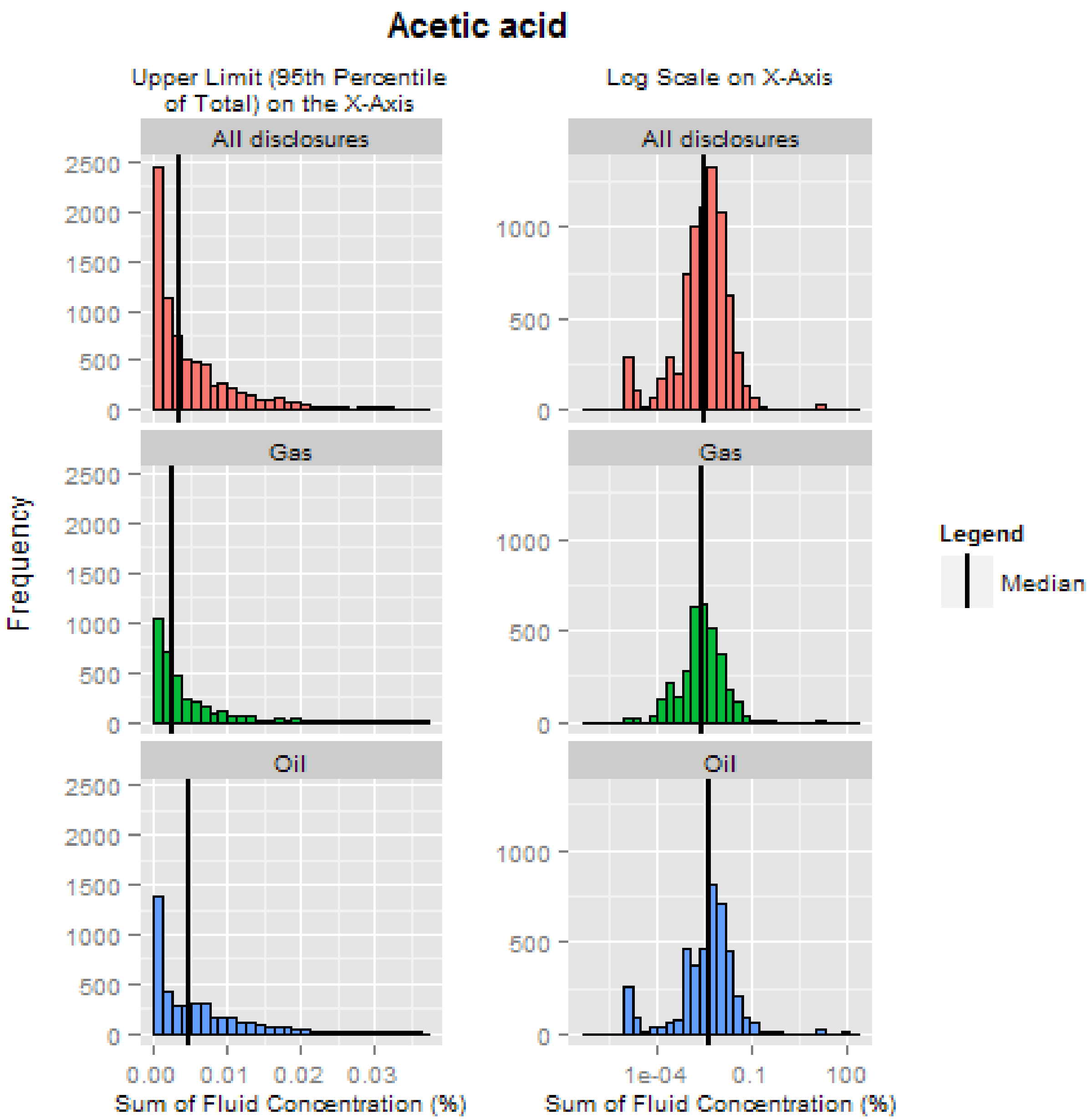
Note: Analysis considered 36,544 disclosures and 1,218,003 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; and fracture date between January 1, 2011, and February 28, 2013. Disclosures that did not meet quality assurance criteria (1,986 disclosures) or other, query-specific criteria were excluded from analysis.

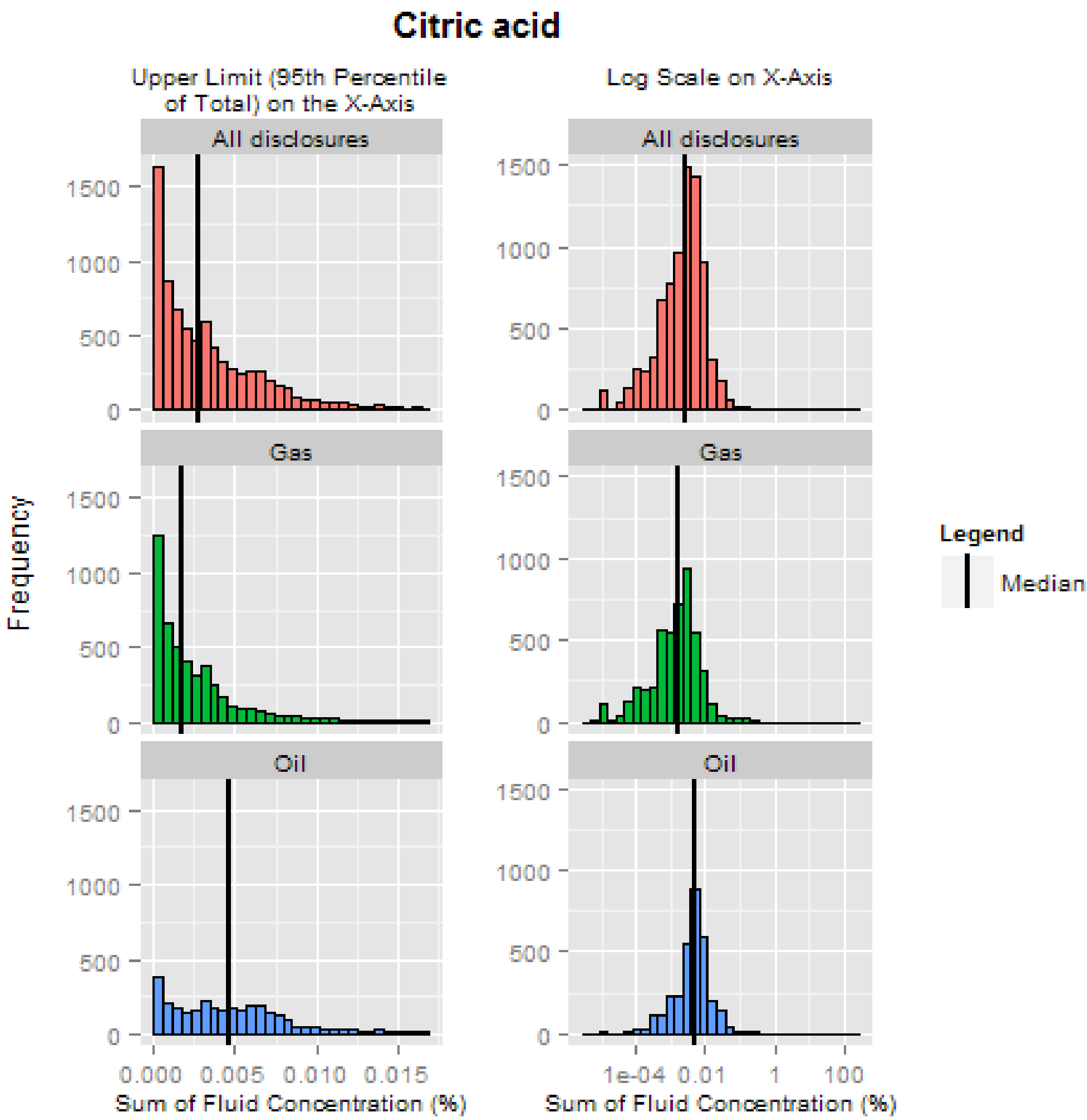
Appendix C. Histograms of Hydraulic Fracturing Fluid Concentrations for Most Frequently Reported Additive Ingredients

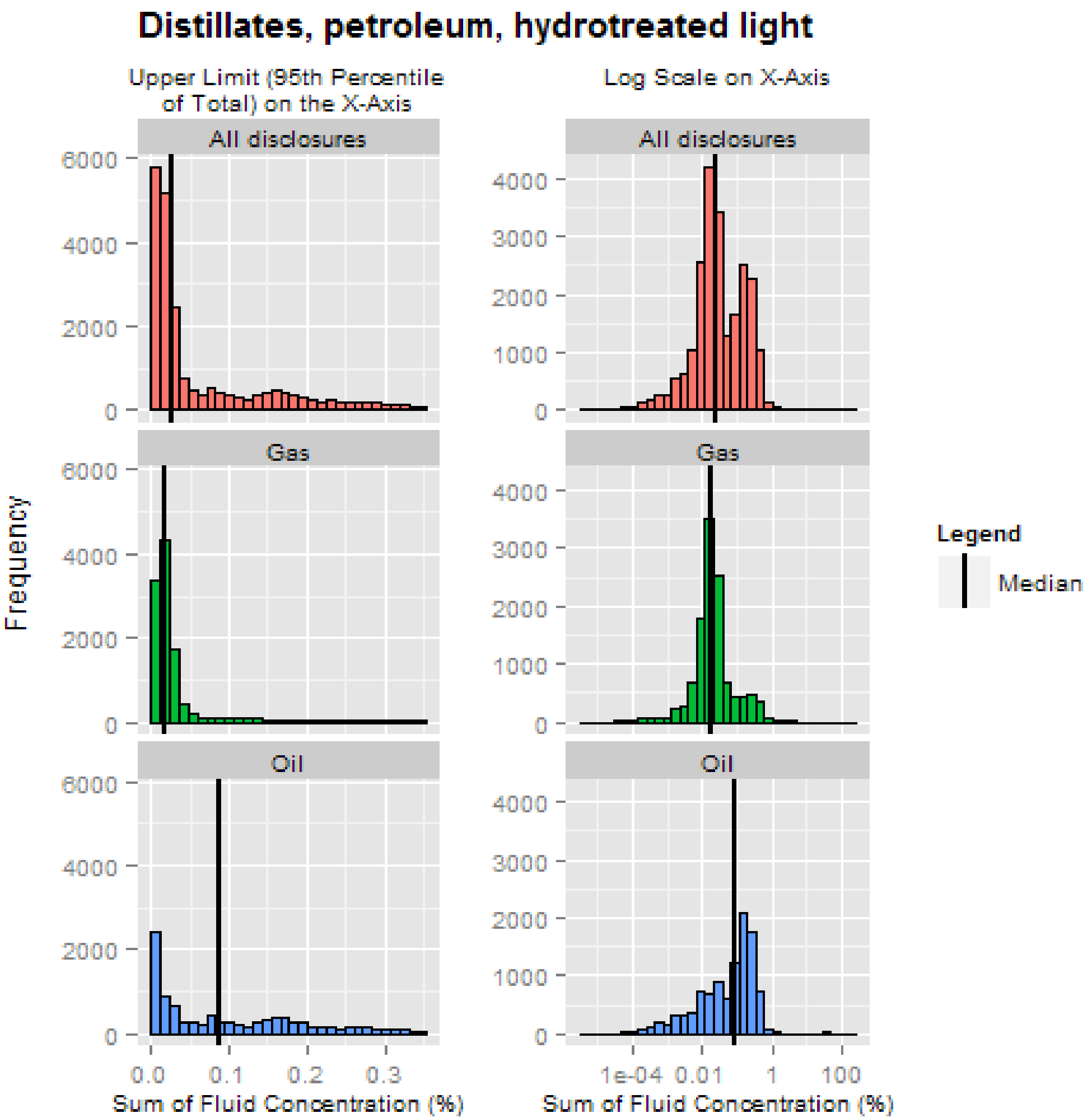
The histograms in this appendix display the distributions of the median maximum hydraulic fracturing fluid concentrations for the twenty most frequently reported additive ingredients. The graphs were developed to supplement the data provided in Tables 8 and 9 by providing a visual display data that can help in assessing how effectively the median indicates central tendency for these additive ingredients. Graphs indicate the median for oil wells (graph heading "Oil"), gas wells ("Gas"), and oil plus gas wells ("All disclosures") for the entire project database and are displayed with both a linear *x*-axis scale and a log normal *x*-axis scale.

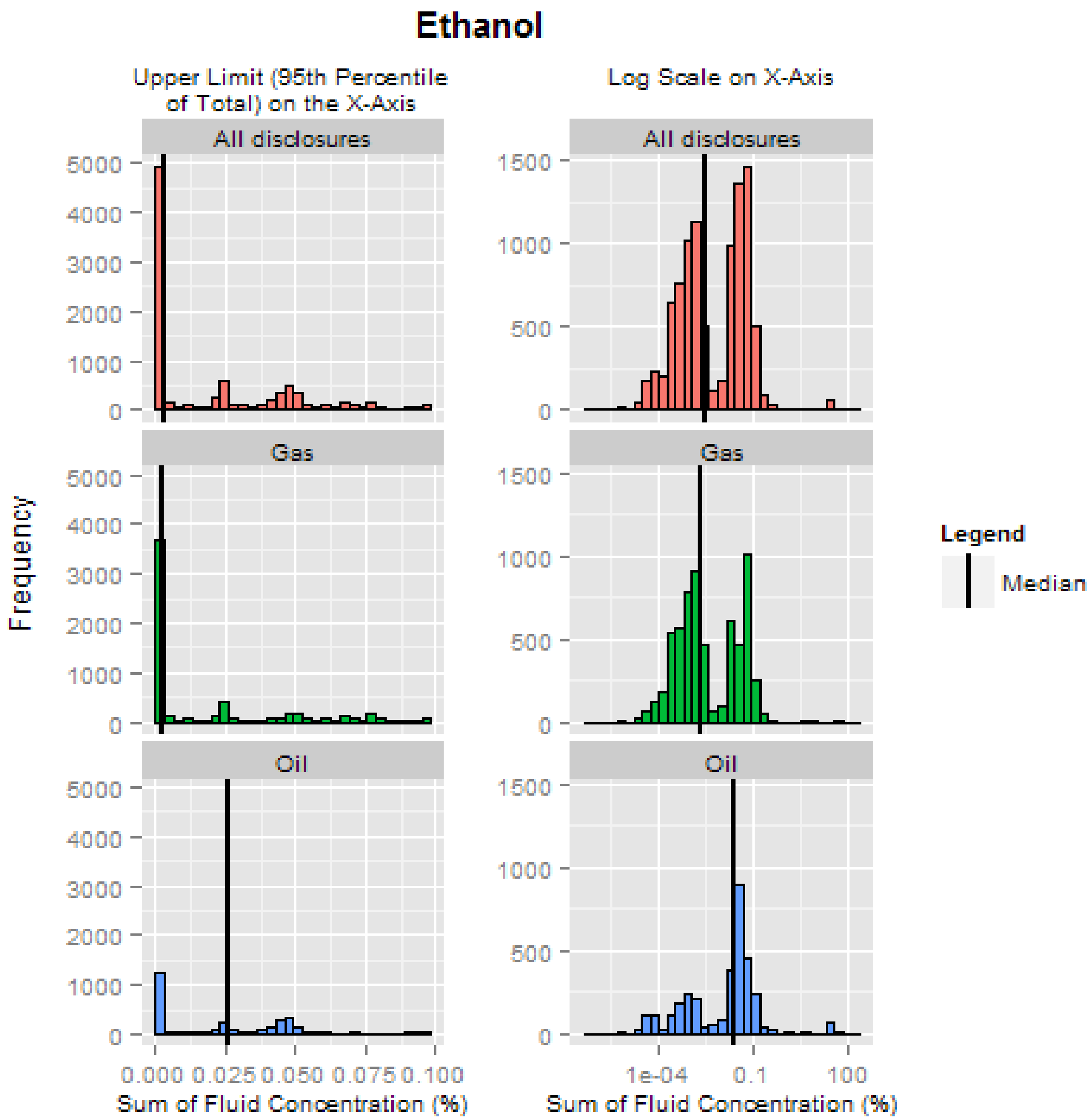
The data for the histograms were based on the QA criteria used to produce Tables 8 and 9. The data included in analyses came from unique disclosures (unique combination of fracture date and API well number) with fracture dates between January 1, 2011, and February 28, 2013, successfully parsed ingredients data, valid CASRNs for ingredient records, and valid additive and fluid concentrations for ingredient records.

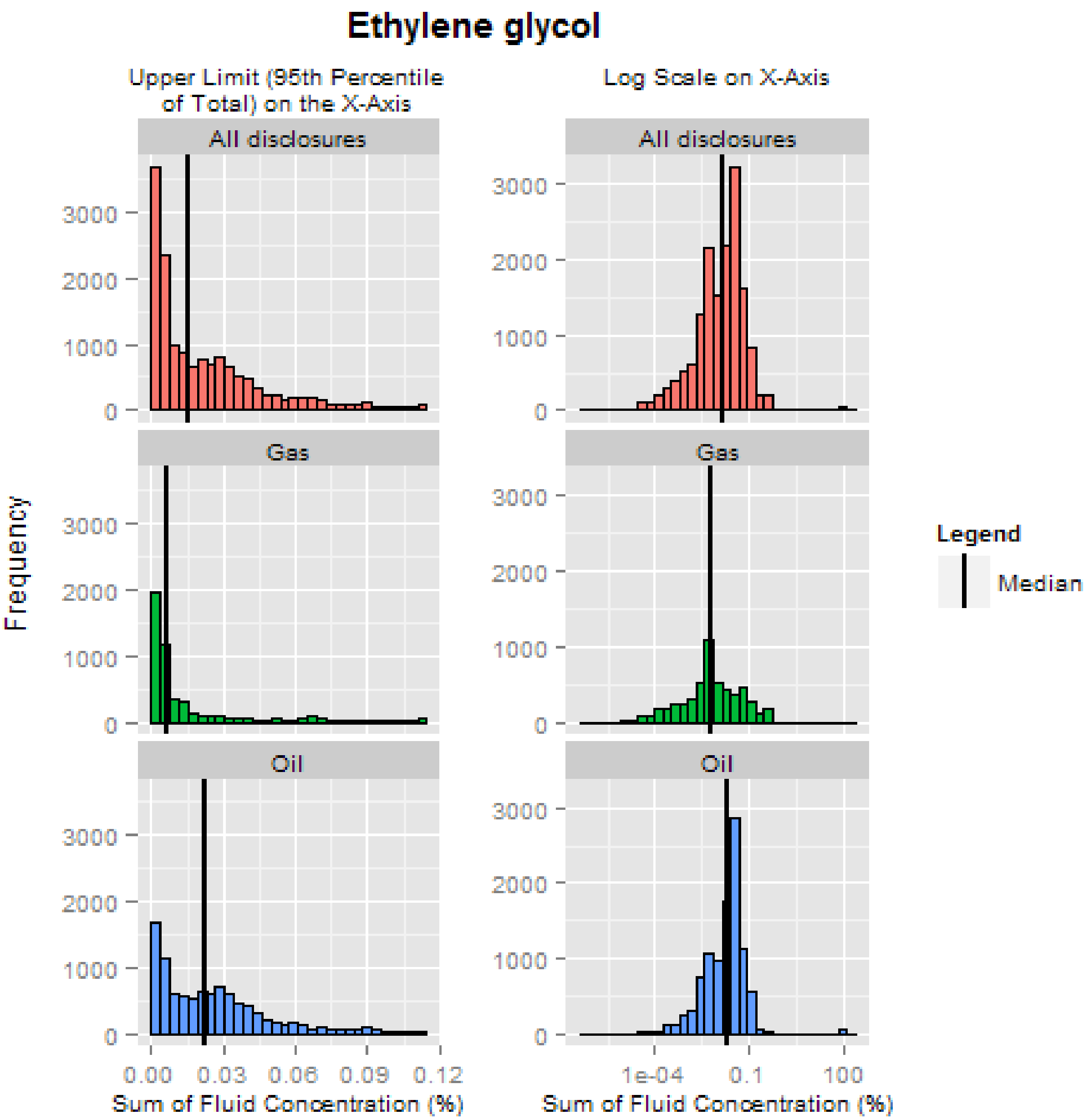

2-Butoxyethanol
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
0
1000
2000
3000
400
800
1200
0.00
0.05
0.10
1e-05
0.01
10
Sum of Fluid Concentration (%)
Legend
Median

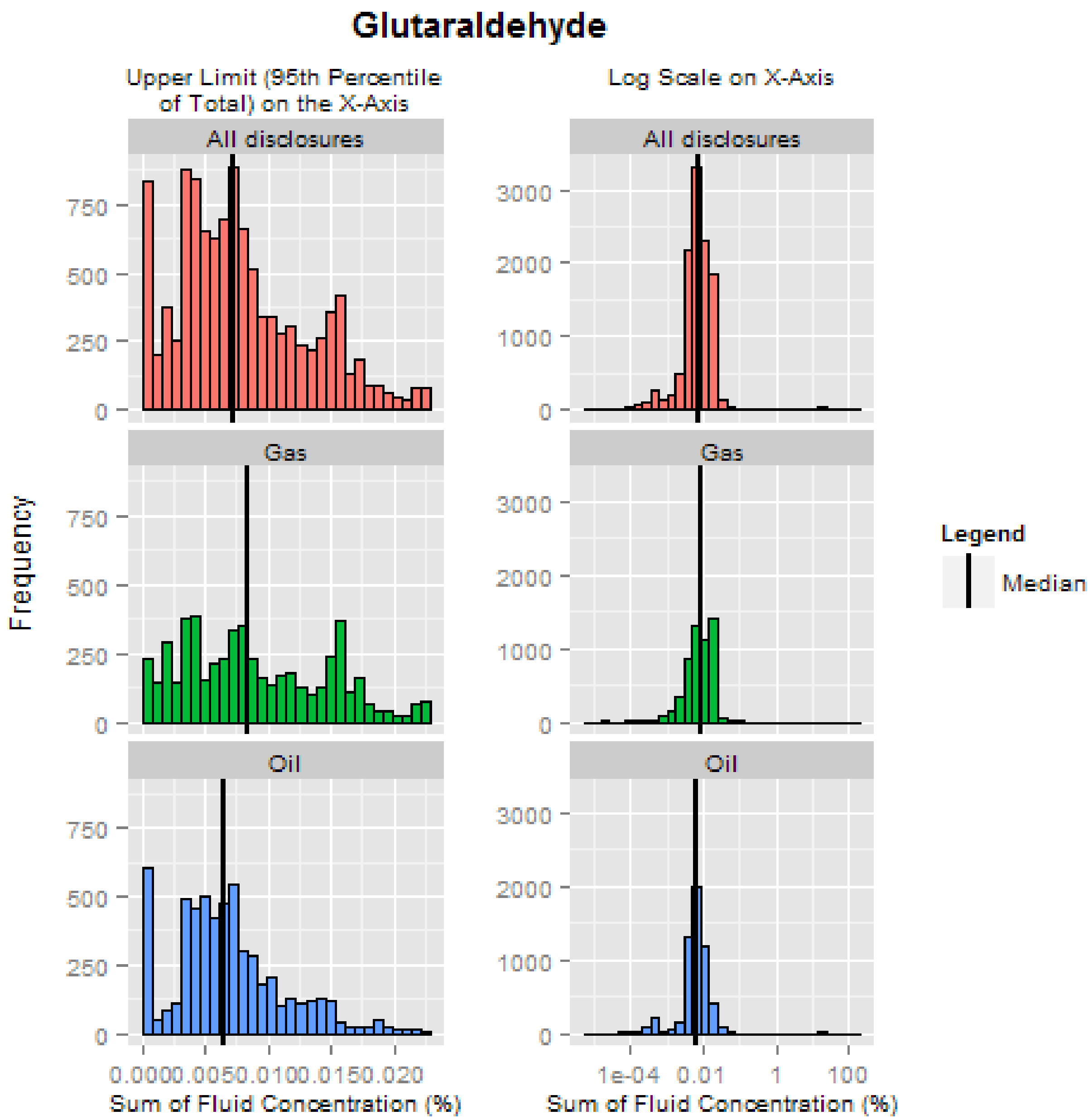

Acetic acid
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
2500
2000
1500
1000
500
0
0.00
0.01
0.02
0.03
1e-04
0.1
100
Sum of Fluid Concentration (%)
Legend
Median

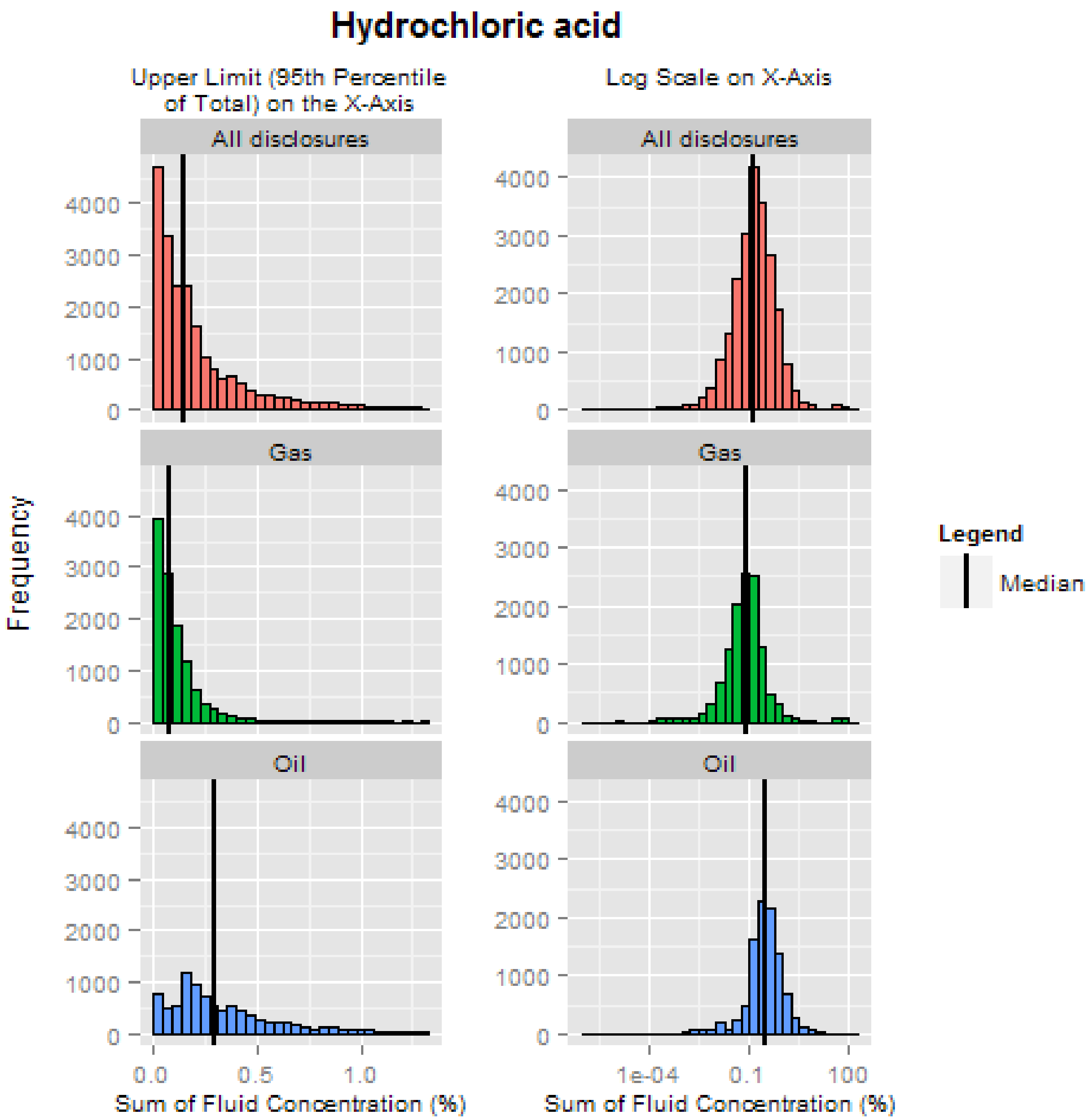

Citric acid
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
0
500
1000
1500
0.000
0.005
0.010
0.015
1e-04
0.01
1
100
Sum of Fluid Concentration (%)
Legend
Median

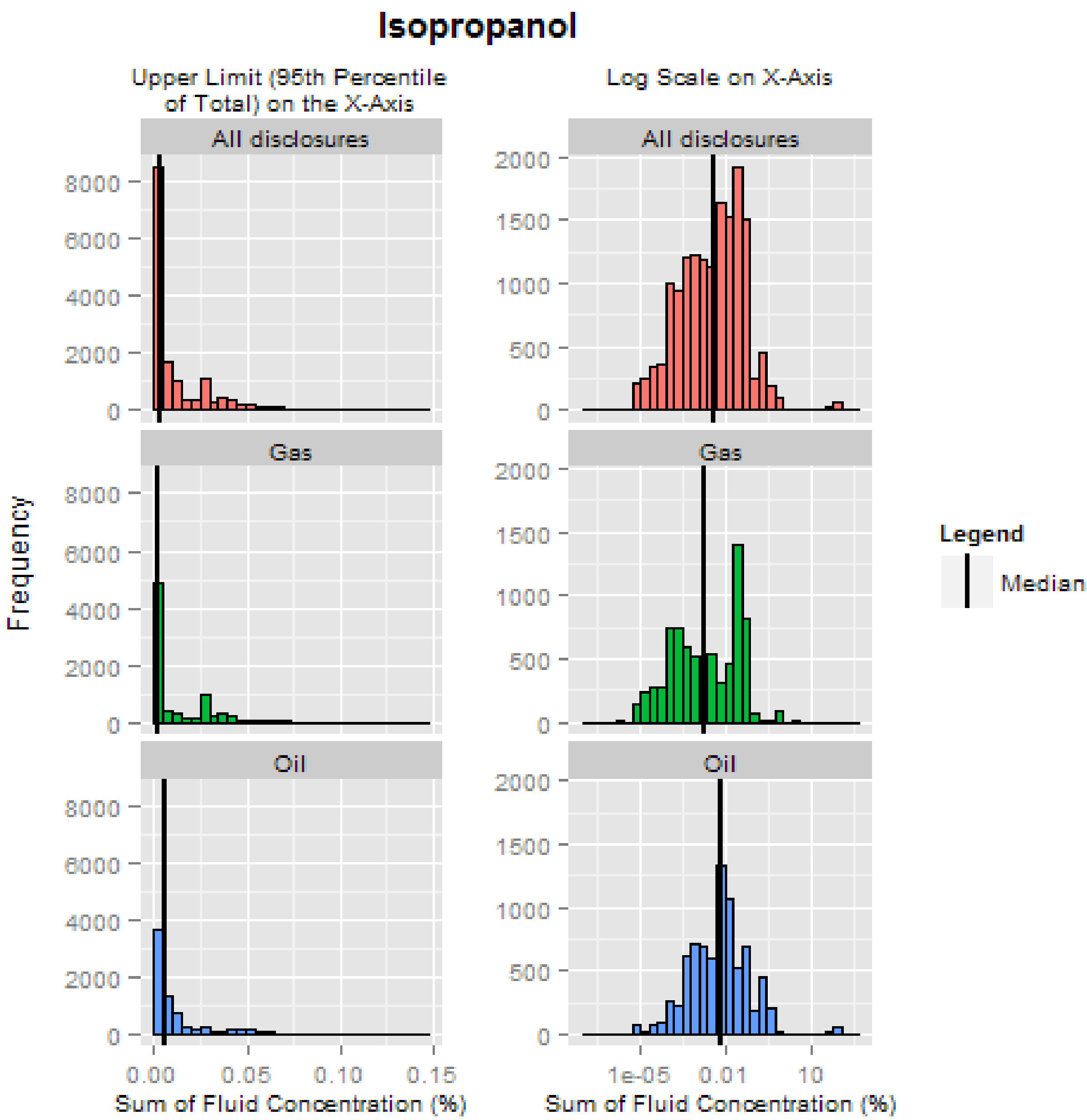

Distillates, petroleum, hydrotreated light
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
Legend
Median
0.0 0.1 0.2 0.3
1e-04 0.01 1 100
Sum of Fluid Concentration (%)
Sum of Fluid Concentration (%)

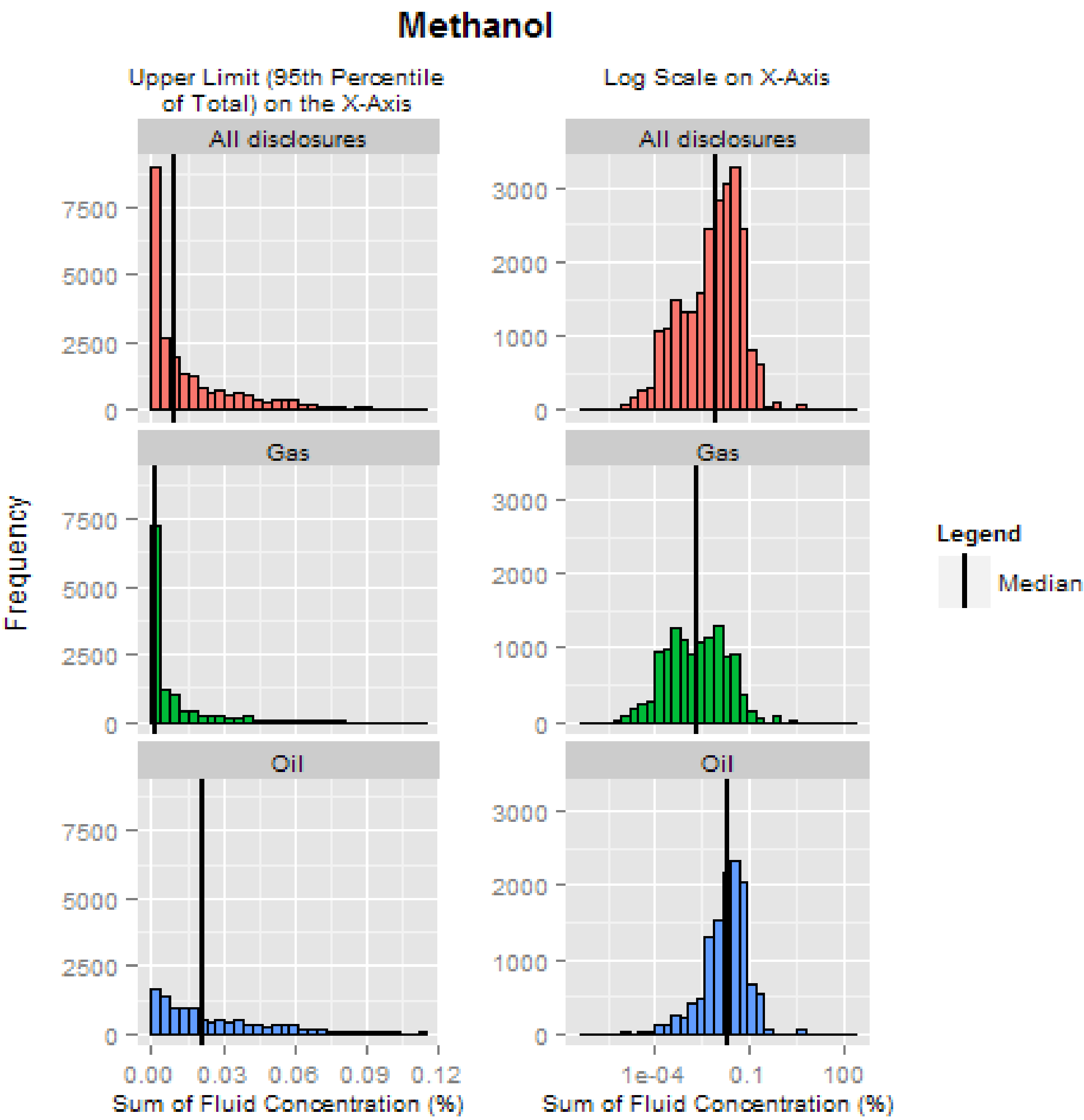

Ethanol
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
5000
4000
3000
2000
1000
0
1500
1000
500
0.000
0.025
0.050
0.075
0.100
1e-04
0.1
100
Sum of Fluid Concentration (%)
Legend
Median

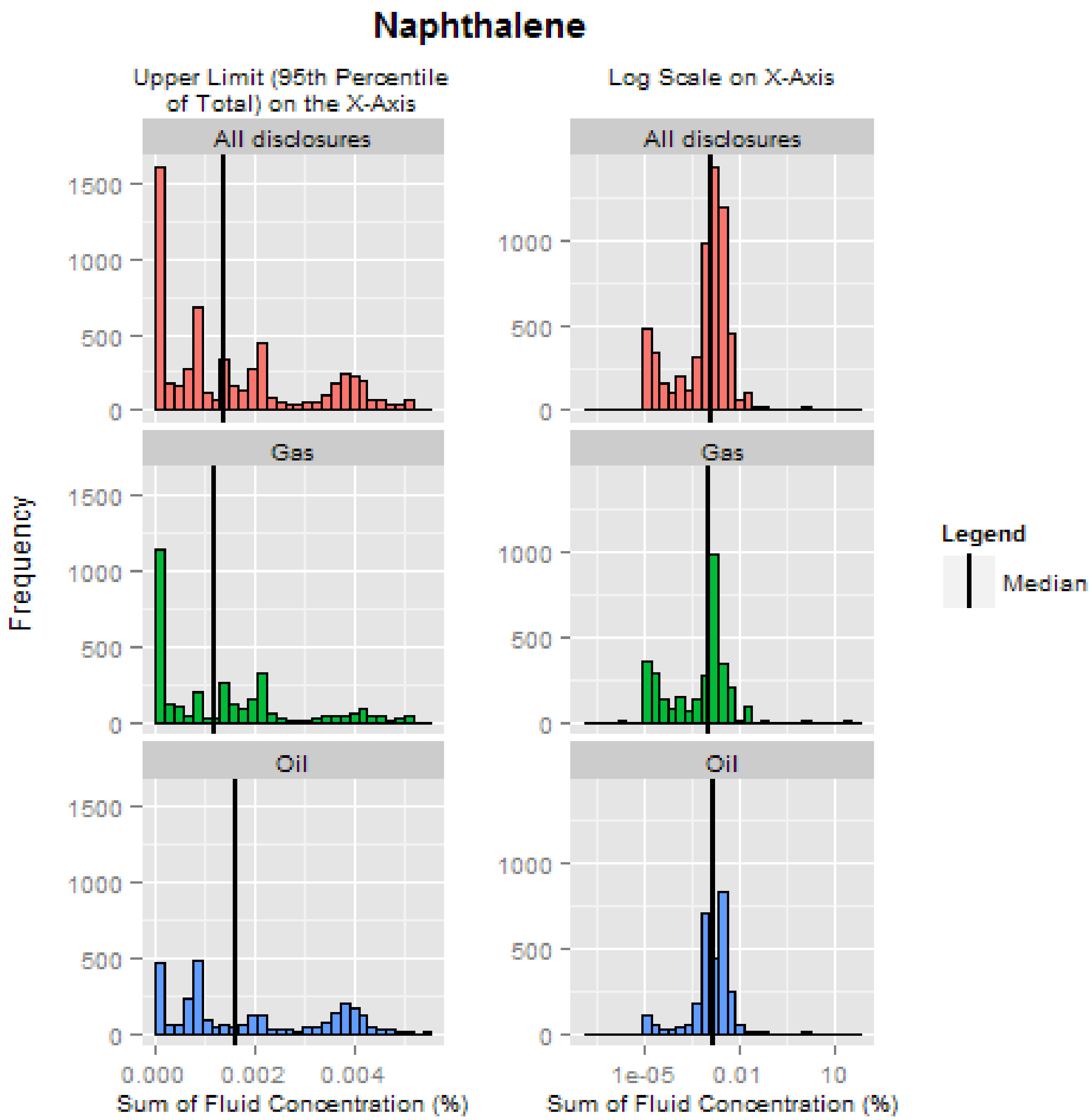

Ethylene glycol
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
0
1000
2000
3000
0.00
0.03
0.06
0.09
0.12
1e-04
0.1
100
Sum of Fluid Concentration (%)
Legend
Median

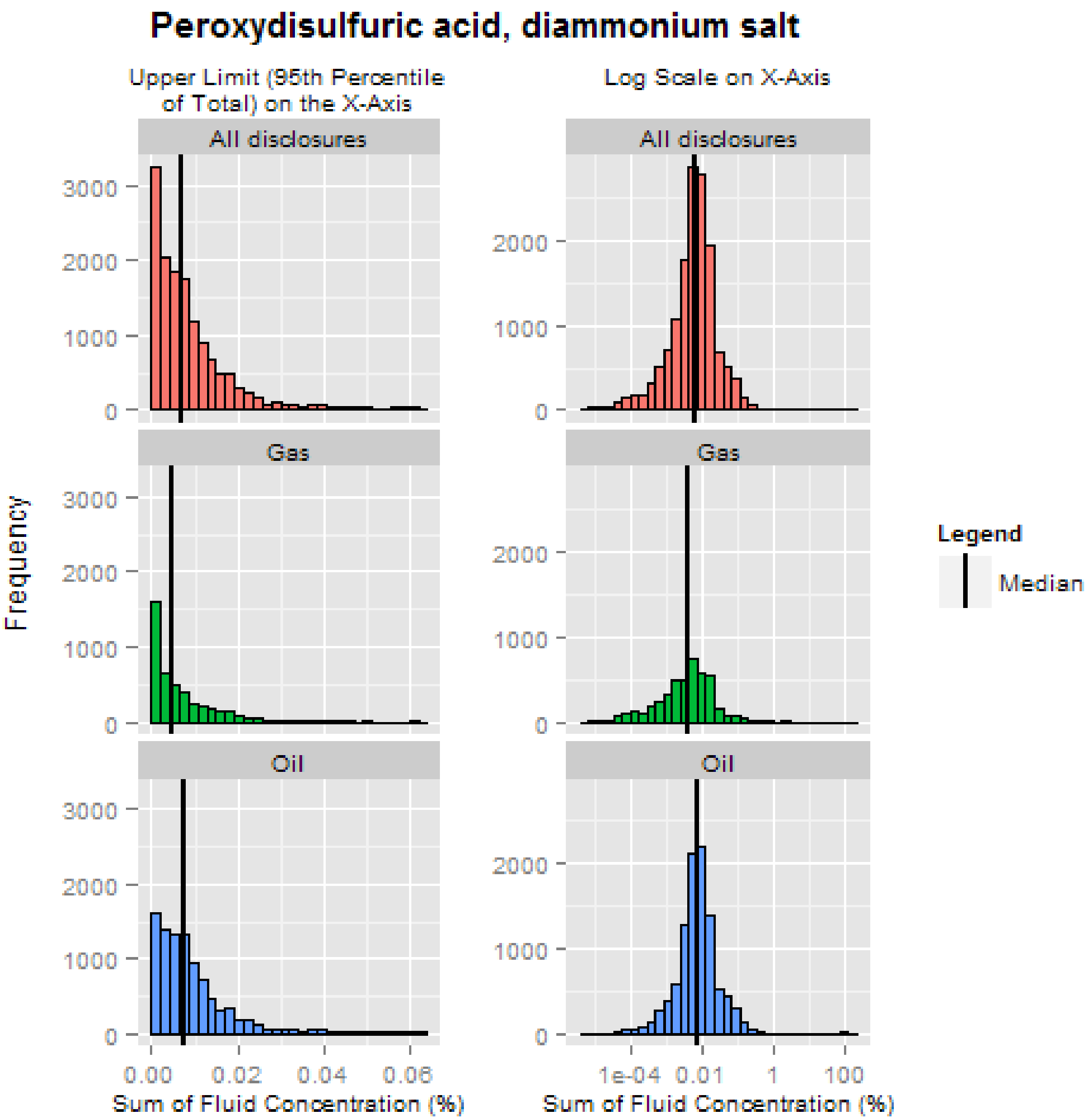

Glutaraldehyde
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
750
500
250
0
3000
2000
1000
0.000
0.005
0.010
0.015
0.020
1e-04
0.01
1
100
Sum of Fluid Concentration (%)
Legend
Median

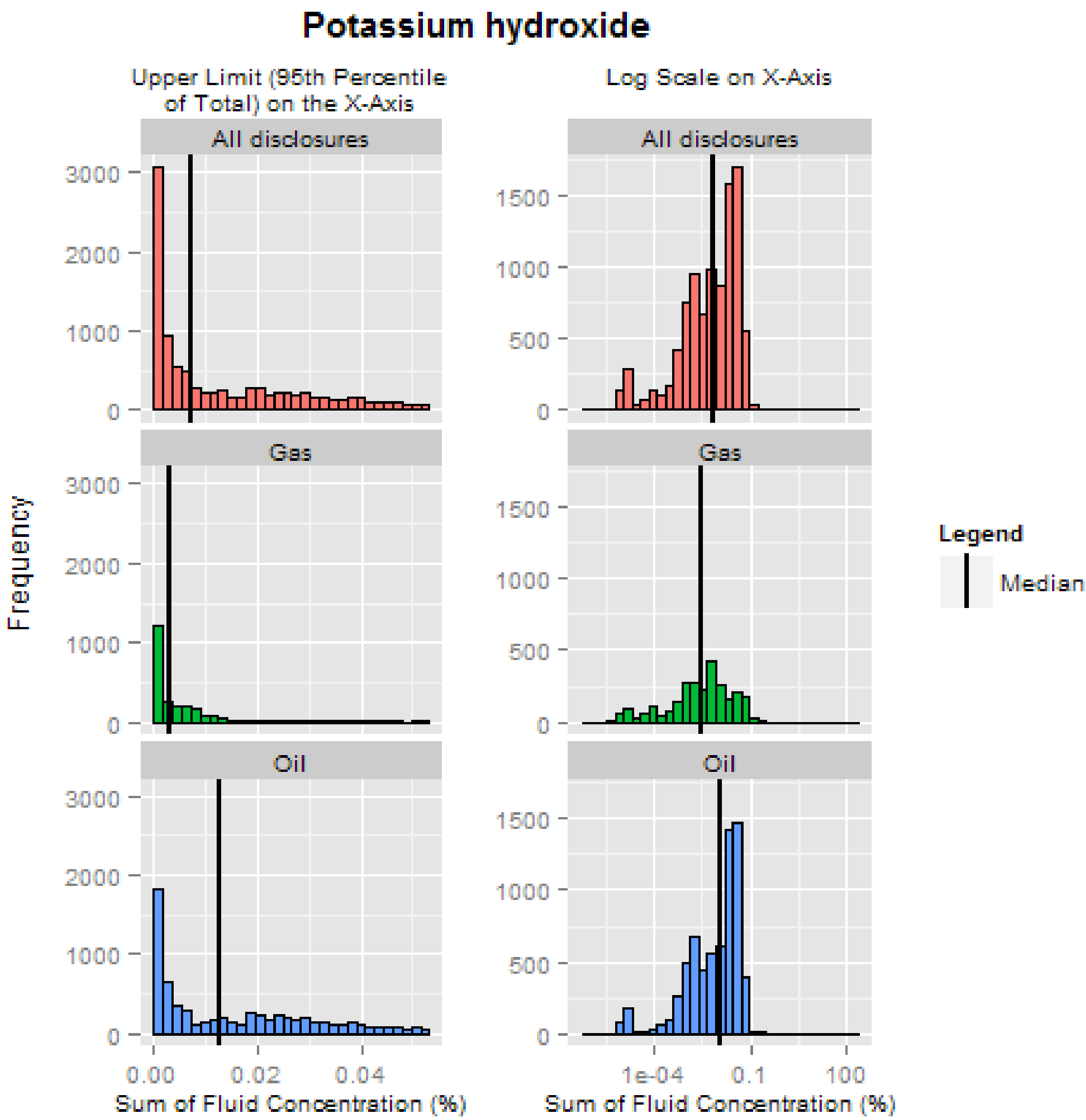

Hydrochloric acid
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
0
1000
2000
3000
4000
0.0
0.5
1.0
1e-04
0.1
100
Sum of Fluid Concentration (%)
Legend
Median

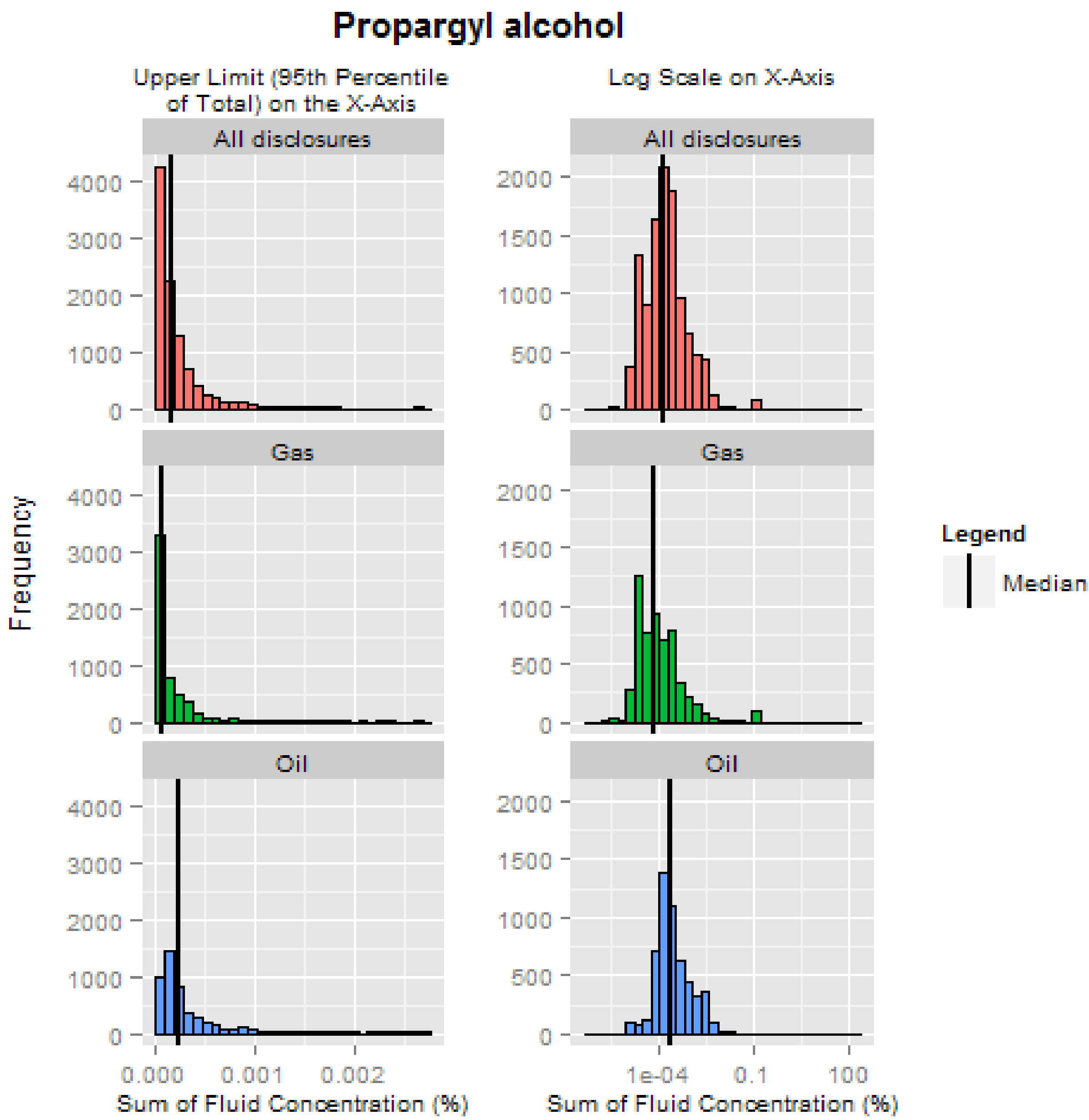

Isopropanol
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
8000
6000
4000
2000
0
2000
1500
1000
500
0
0.00
0.05
0.10
0.15
1e-05
0.01
10
Sum of Fluid Concentration (%)
Legend
Median


Methanol
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
0
2500
5000
7500
1000
2000
3000
0.00
0.03
0.06
0.09
0.12
1e-04
0.1
100
Sum of Fluid Concentration (%)
Legend
Median

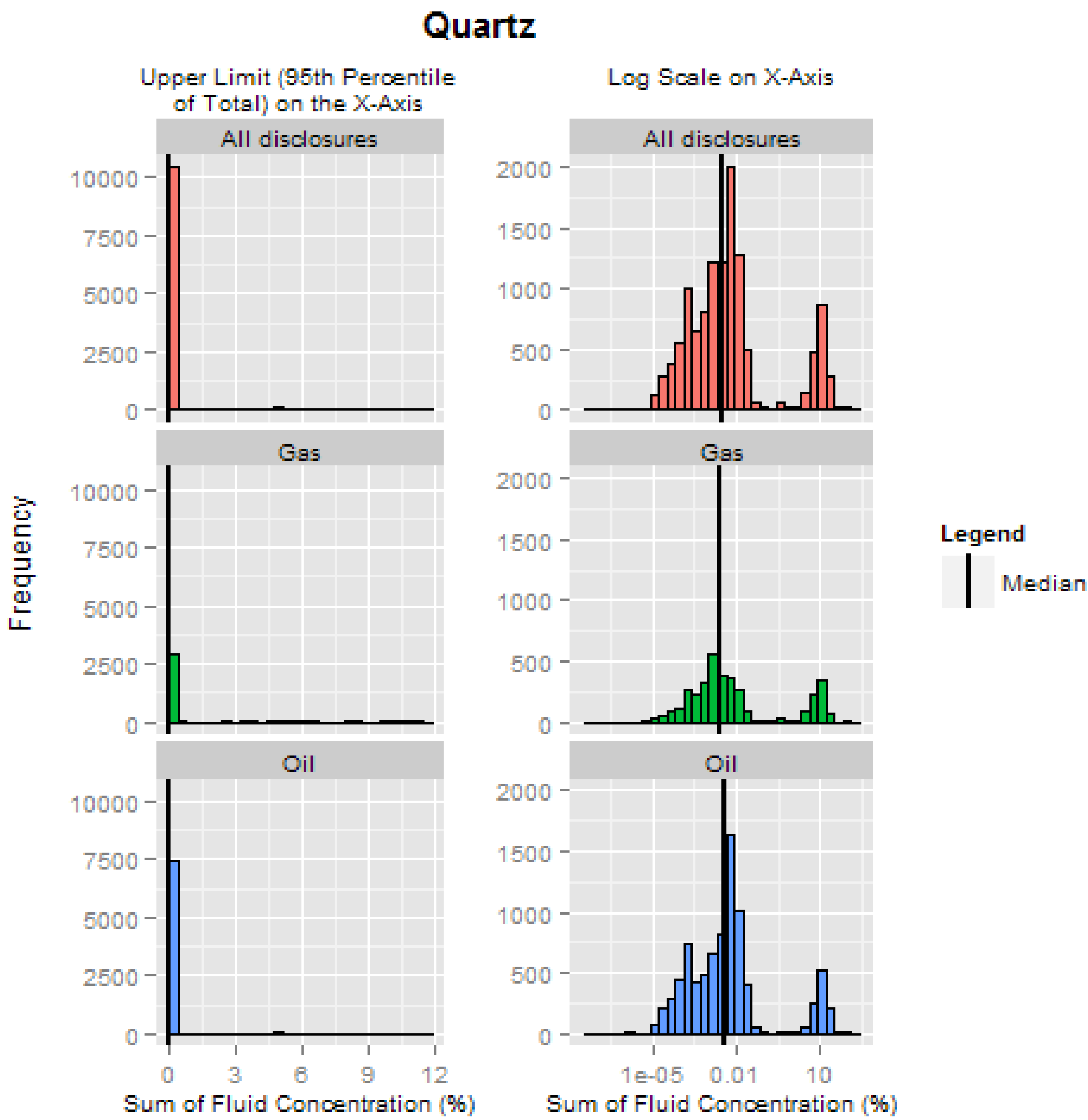

Naphthalene
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
1500
1000
500
0
0.000
0.002
0.004
1e-05
0.01
10
Sum of Fluid Concentration (%)
Legend
Median

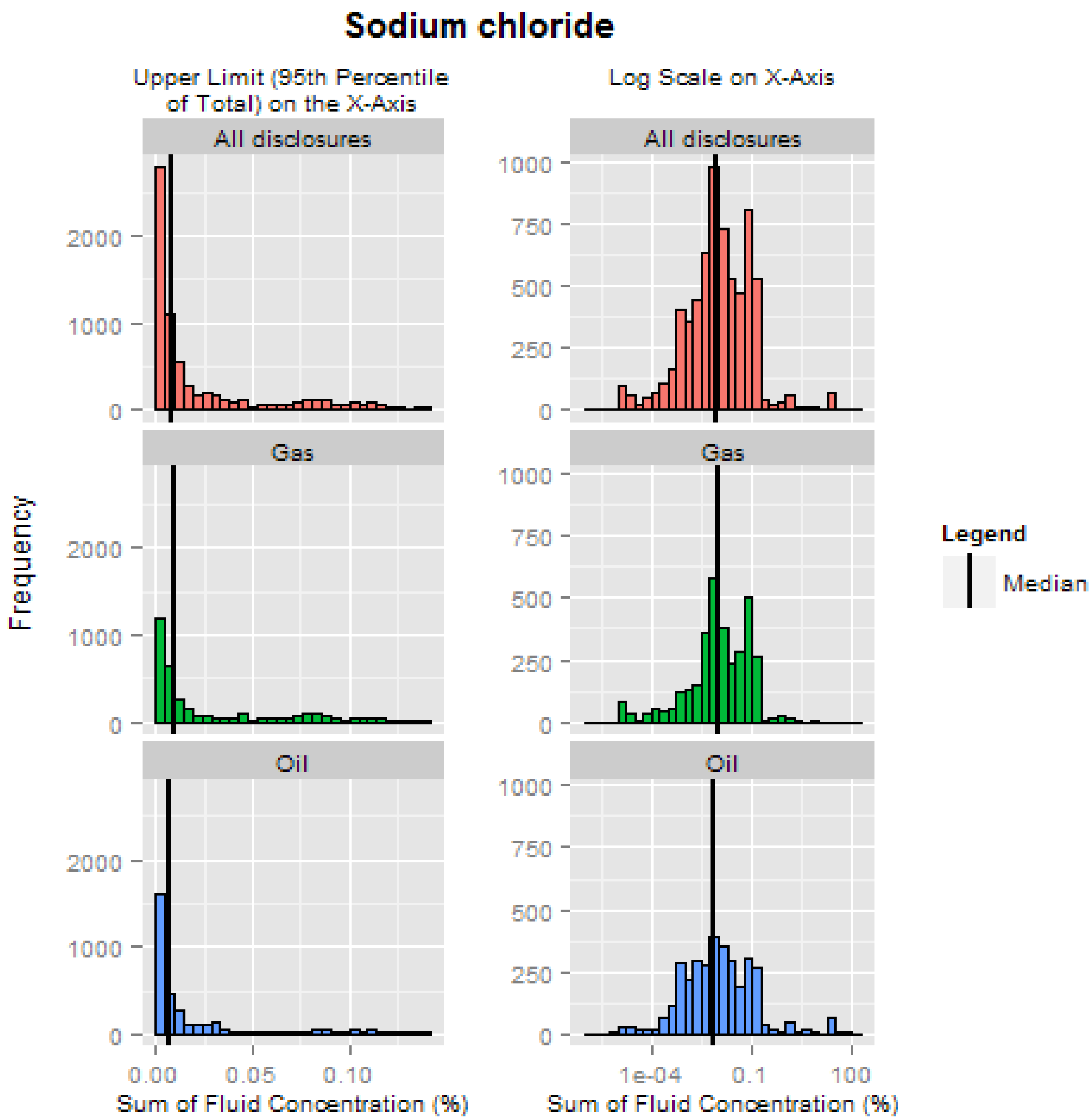

Peroxydisulfuric acid, diammonium salt
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
3000
2000
1000
0
0.00
0.02
0.04
0.06
1e-04
0.01
1
100
Sum of Fluid Concentration (%)
Legend
Median

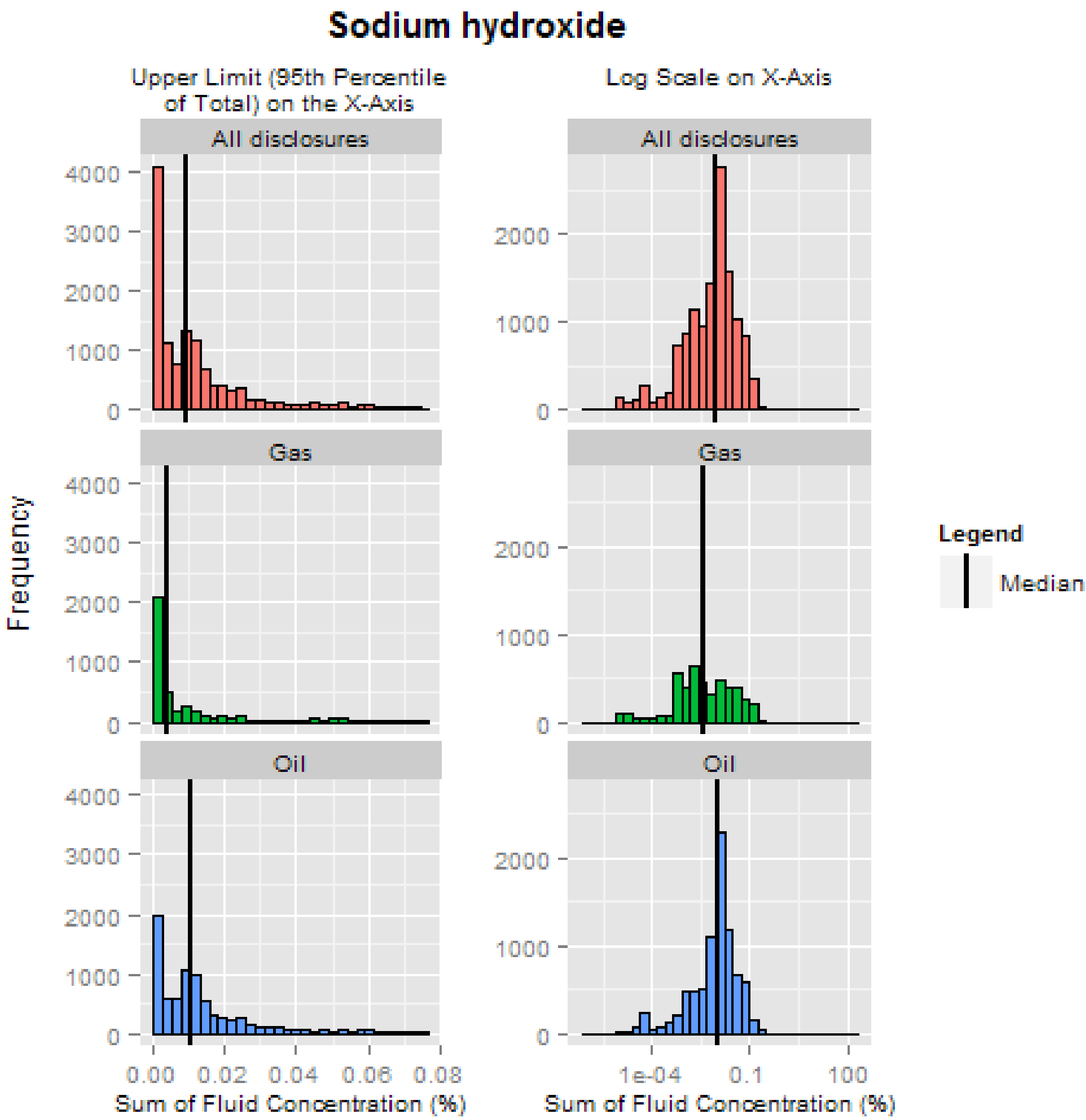

Potassium hydroxide
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
3000
2000
1000
0
1500
1000
500
0.00
0.02
0.04
1e-04
0.1
100
Sum of Fluid Concentration (%)
Legend
Median



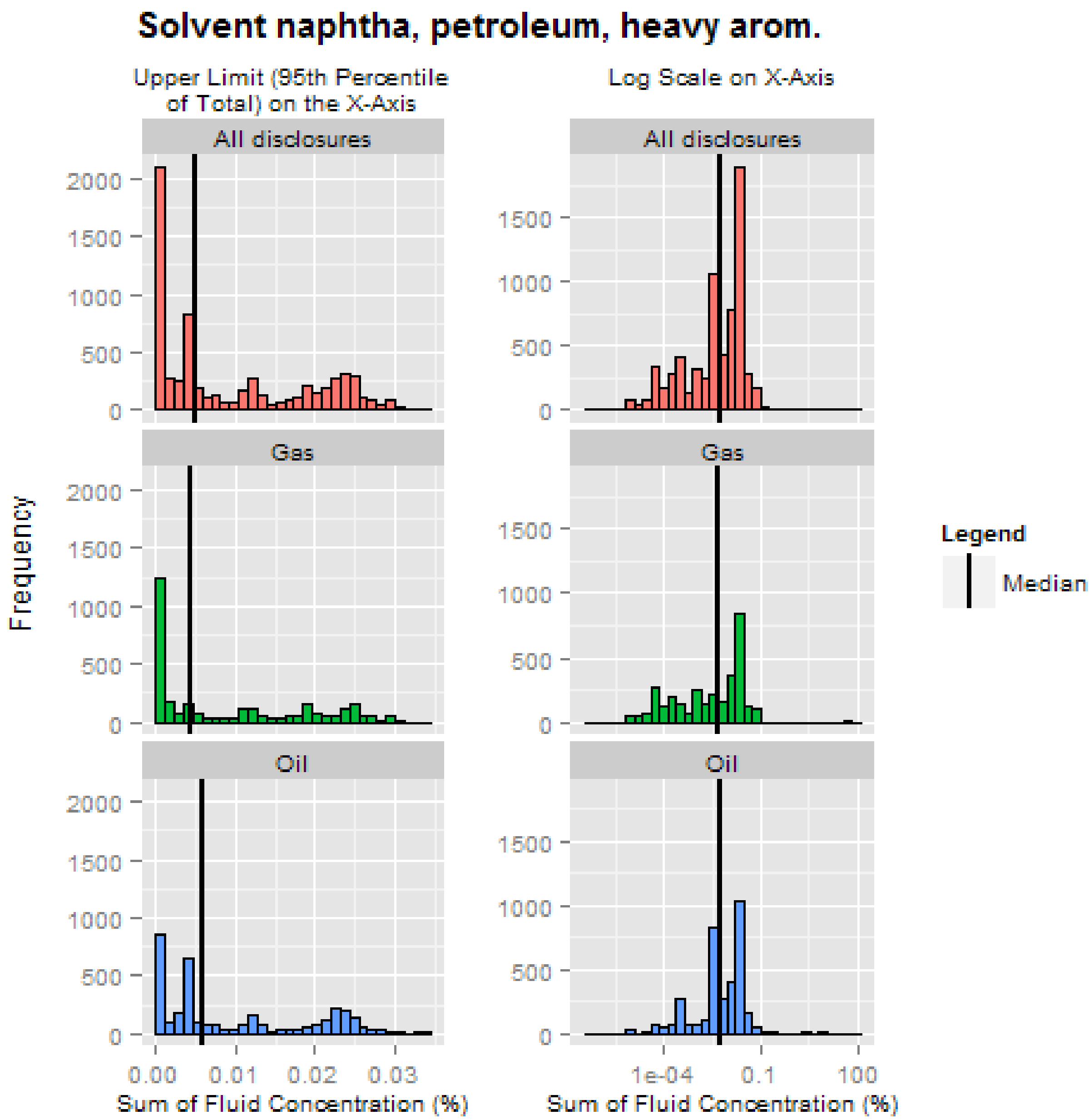
Propargyl alcohol
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
4000
3000
2000
1000
0
2000
1500
1000
500
0
0.000
0.001
0.002
1e-04
0.1
100
Sum of Fluid Concentration (%)
Legend
Median

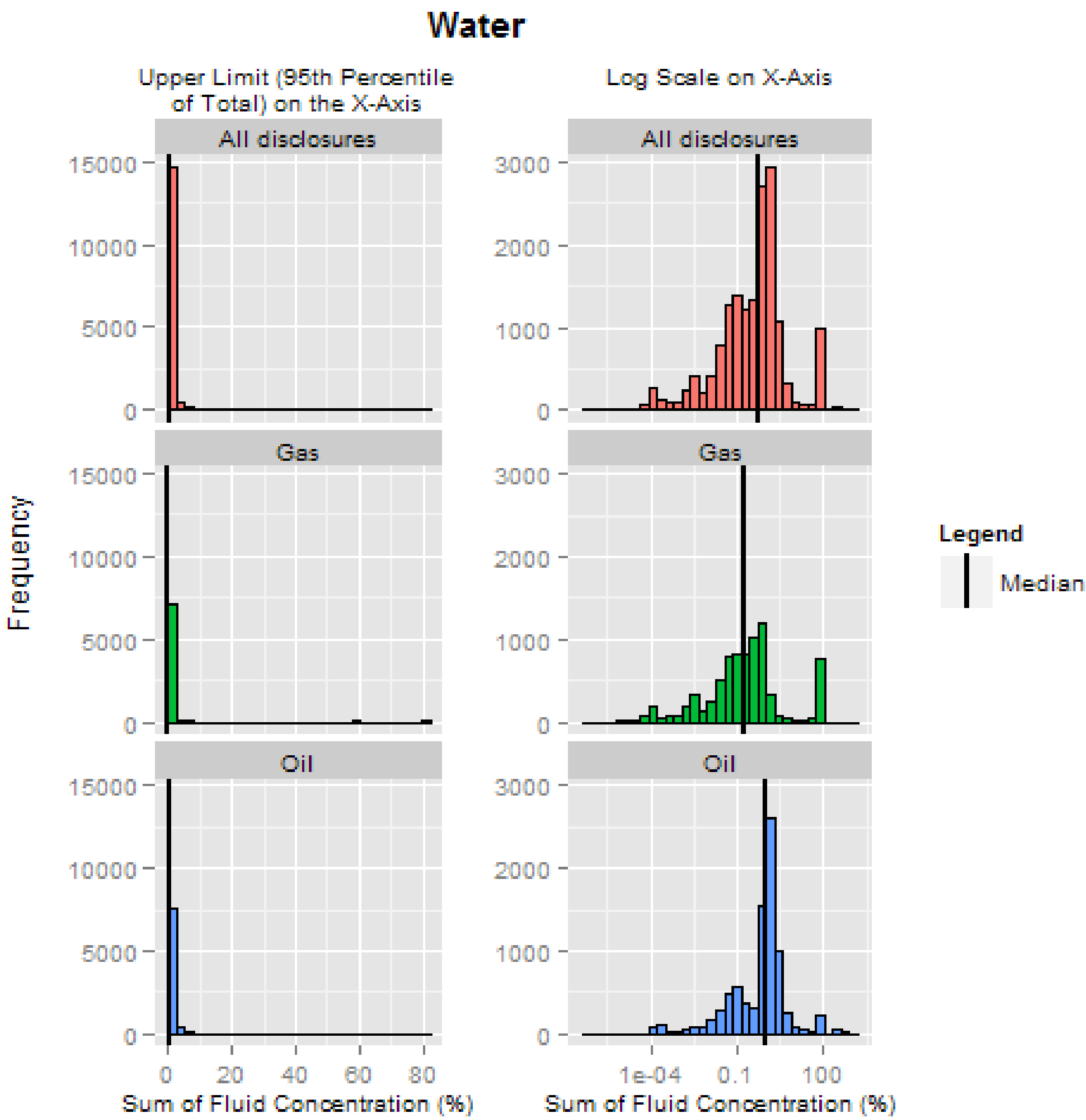

Quartz
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
10000
7500
5000
2500
0
2000
1500
1000
500
0
3
6
9
12
1e-05
0.01
10
Sum of Fluid Concentration (%)
Sum of Fluid Concentration (%)
Legend
Median


Sodium chloride
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
2000
1000
0
1000
750
500
250
0
0.00
0.05
0.10
1e-04
0.1
100
Sum of Fluid Concentration (%)
Legend
Median



Sodium hydroxide
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
4000
3000
2000
1000
0
0.00
0.02
0.04
0.06
0.08
1e-04
0.1
100
Sum of Fluid Concentration (%)
Legend
Median


Solvent naphtha, petroleum, heavy arom.
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
2000
1500
1000
500
0
0.00
0.01
0.02
0.03
1e-04
0.1
100
Sum of Fluid Concentration (%)
Legend
Median


Water
Upper Limit (95th Percentile of Total) on the X-Axis
Log Scale on X-Axis
All disclosures
Gas
Oil
Frequency
15000
10000
5000
0
3000
2000
1000
0
20
40
60
80
1e-04
0.1
100
Sum of Fluid Concentration (%)
Legend
Median

Appendix D. List of Operators

Table D-1. Disclosures per state, summarized by well operator (428 operators included in the project database).

Operator	Number of disclosures																					
	AK	AL	AR	CA	CO	KS	LA	MI	MS	MT	ND	NM	OH	OK	PA	TX	UT	VA	WV	WY	N/A	All
Unspecified					8	2					3			2		19						34
3-M Energy Corporation																4						4
Abraxas Petroleum Corporation										1	1					4				1		7
Aera Energy				447																		447
Alpha Shale Resources LP															5							5
Alta Mesa Holdings																1						1
Amerada Hess Corporation												1										1
Amexco LLC																1						1
Anadarko E & P Company LP															1	4						5
Anadarko E&P Onshore LLC															11	44						55
Anadarko Petroleum Corporation					1								7		171	621	654			101	1	1556
Anschutz Exploration Corporation										3						3						6
Antero Resources					25														20			45
Apache Corporation						1				2		278		112		1078					9	1480
Apollo Operating, LLC					15																	15
Approach Resources																22						22
Arabella Petroleum Company LLC																2						2
ARCO Permian												1										1
Argent Energy (US) Holdings																1						1
Aruba Petroleum																23						23
Athlon Energy																99						99
Athlon Energy Operating																1						1
Athlon Fe Operating LLC																4						4
Atlantic Operating																7						7

Table continued on next page

Operator	Number of disclosures																					
	AK	AL	AR	CA	CO	KS	LA	MI	MS	MT	ND	NM	OH	OK	PA	TX	UT	VA	WV	WY	N/A	All
Atlas																2						2
Atlas Barnett LLC																5						5
Atlas Energy, L.P.															25	2						27
Austin Exploration, Inc.					2																	2
Axia Energy LLC					2												11					13
Aztec Drilling and Operating																30						30
BASA Resources, Inc.																5						5
Bass Enterprises Production Company												7										7
Bayswater Exploration and Production					43																	43
Baytex Energy USA LTD											21											21
BC Operating												1				46						47
Berry Oil Company																5						5
Berry Petroleum					2											45	29					76
Best Petroleum Exploration																6						6
BHP Billiton Petroleum			138				111									262					3	514
Big Star Oil & Gas LLC																19						19
Bill Barrett Corp					190												140			4	2	336
Bird Creek Resources Inc.												1										1
Black Hills Exploration and Production												1										1
Black Hills Plateau Production					1																	1
Black Raven Energy					19																	19
Blackbrush Oil and Gas																17						17
BLS Production																3						3
Bluestem Energy																16						16
Bluestone Natural Resources																8						8
BLX Inc															2							2
Boaz Energy LLC																1						1

Table continued on next page

Operator	Number of disclosures																					
	AK	AL	AR	CA	CO	KS	LA	MI	MS	MT	ND	NM	OH	OK	PA	TX	UT	VA	WV	WY	N/A	All
Bonanza Creek Energy, Inc.					121																	121
BP America Production Company	17											9		51		43				230		350
Brammer Engineering							1															1
Breck Operating Corporation																3						3
Bridwell Oil Co.																6						6
Brigham										9	102										2	113
BTA Oil Producers												4				4						8
Burk Royalty Co., LTD																10						10
Burlington Resources Oil and Gas Company											8	12		1		51						72
Burnett Oil Co., Inc.															4							4
BVX Operating Inc																5						5
Cabot Oil & Gas Corp														14	155	44						213
Callon Petroleum Company																1						1
Canan Operating, Inc.																4						4
Cannon Oil and Gas					1																	1
Capstone Natural Resources, LLC												1				4						5
Carrizo Oil and Gas Inc.					30										35	56						121
Cazar Energy, Inc.																1						1
Cd Consulting and Operating Company																1						1
Chaparral Energy														10		6					2	18
Chesapeake Energy																1						1
Chesapeake Operating, Inc.			46		22	5	277				6	23	130	608	383	1414			114	61		3089
Chevron USA Inc.				21	72							62		5	102	492				9	1	764
Cheyenne Petroleum Company																22						22
Chief Oil & Gas															88							88
Choice Exploration, Inc.																2						2
Cimarex Energy Company												70		60		46						176

Table continued on next page

Operator	Number of disclosures																					
	AK	**AL**	**AR**	**CA**	**CO**	**KS**	**LA**	**MI**	**MS**	**MT**	**ND**	**NM**	**OH**	**OK**	**PA**	**TX**	**UT**	**VA**	**WV**	**WY**	**N/A**	**All**
Cinco Resources																7				2		9
Cirque Resources LP										3												3
Citation Oil and Gas											2			45		35					1	83
Citrus Energy Corporation															11							11
Clayton Williams Energy, Inc.												1				46					1	48
Clear Fork Inc																3						3
CML Exploration																8						8
Cobra Oil and Gas Corporation																24						24
Collins & Ware Inc																1						1
Compass																33						33
Comstock Oil & Gas							21									71						92
Concho Operating Group												4				314						318
Condor Energy					1																	1
ConocoPhillips Company	17				3						60	227				346					2	655
CONSOL Energy Inc.													1		91				10		1	103
Continental Resources, Inc					8					43	291			78		1					2	423
Corinthian Exploration Corp.											5											5
Corlena Oil Company																10						10
Crescent Energy																	19				2	21
Crimson Exploration Inc.																6						6
Crown Equipment Corporation																1						1
CrownQuest																128					1	129
David H. Arrington Oil and Gas																2						2
Delta CO2, LLC																2						2
Delta Oil and Gas																29						29
Denali Oil and Gas																2						2
Denbury Resources											25											25

Table continued on next page

Operator	Number of disclosures																					
	AK	AL	AR	CA	CO	KS	LA	MI	MS	MT	ND	NM	OH	OK	PA	TX	UT	VA	WV	WY	N/A	All
Devon Energy Corporation																25						25
Devon Energy Production Company L. P.							9	3				128	5	199		1027	4			51	2	1428
Diamondback E&P LLC																21						21
Diamondback Energy																12						12
Diamondback Resources LLc																					1	1
Discovery Operating																6						6
DTE Gas Resources, LLC																35						35
Eagle Energy Acquisitions LP																11						11
Eagle Rock Energy																1						1
EagleRidge Energy, LLC																11						11
Edge Barnett Operating Company																1						1
EF Energy																6						6
EGL Resources, Inc.																9						9
El Paso E&P Company					13		63					30				89	27				9	231
Element Petroleum Operating, LLC																13						13
Elk Prod Uintah Llc																	1					1
Elm Ridge Exploration Company, LLC					3																	3
Empresa Energy LP																1						1
Encana Oil & Gas (USA) Inc.					787	3	132	5	4			8				74				193		1206
Endeavor Energy Resources																94						94
Enduring Resources II, LLC																8						8
Energen Resources Corporation		55			1		8					21				804						889
Energy Corporation of America															35				8			43
Enerplus											24											24
EnerQuest Operating LLC																1						1
Enervest Energy Partners LP																1						1
EnerVest, Ltd.					1							11				127					5	144

Table continued on next page

Operator	Number of disclosures																					
	AK	**AL**	**AR**	**CA**	**CO**	**KS**	**LA**	**MI**	**MS**	**MT**	**ND**	**NM**	**OH**	**OK**	**PA**	**TX**	**UT**	**VA**	**WV**	**WY**	**N/A**	**All**
Entek Energy, Ltd.					2																	2
EOG Resources, Inc.					37		17			13	158	33		53	87	1381	20			18	5	1822
Eor Operating Co												1										1
EP Energy							7									65	16				23	111
EP Energy E&P Company LP																3						3
EQT Production															54				43			97
Equal Energy Us Inc														3								3
Estancia Oil & Gas LLC																3						3
EV Energy Partners																14						14
EXCO Resources, Inc.							136								74	82						292
EXL Petroleum																10						10
Extex Operating Company																4						4
ExxonMobil				89	49	6								1		46						191
Fair Oil Limited																2						2
Fairway Resources														1		1						2
Fairways Exploration and Production, LLC																1						1
Fasken Oil and Ranch, Ltd.																114						114
FIML Natural Resources, LLC																160						160
Finley Resources, Inc.																12	3				9	24
Fivestones Energy LLC																1						1
Foree Oil Company																4						4
Forest Oil Corporation			5				4							5		43					1	58
Forge Energy LLC																8						8
Franks Operating Company, LLC							1															1
Front Range Oil & Gas					3																	3
G3 Operating, LLC.										1	17										4	22
GeoResources											2											2

Table continued on next page

Operator	Number of disclosures																					
	AK	AL	AR	CA	CO	KS	LA	MI	MS	MT	ND	NM	OH	OK	PA	TX	UT	VA	WV	WY	N/A	All
GeoSouthern Energy Corporation																5						5
Getty Oil Company																2						2
GMX Resources Inc											5											5
Goodrich Petroleum Company, LLC							1									24						25
Gordon Creek LLC																	8					8
Gosney & Sons Inc.					1																	1
Great Plains Operating LLC															1	2						3
Great Western Oil and Gas Company					76																	76
Guinn Investments, Inc																1						1
Gulf Oil Corporation																3						3
Gunn Oil Company																2						2
Gunnison Energy Corporation					3																1	4
H&L Exploration Company																4						4
Hadaway Consulting and Engineering, LLC																2						2
Halcon Resources							2									43						45
Hannathon Petroleum LLC																6						6
Helis Oil & Gas Company, LLC											9											9
Henry Resources, LLC																78					2	80
Hess Corporation											377	20	3			33					4	437
Hibernia Resources, LLC																5						5
HighMount Exploration & Production														30		103						133
Hilcorp Energy Company															1							1
Howell Petro. Corp.																				222		222
Hunt Oil Company											17	1			11	50					2	81
Huntington Energy LLC																2						2
Indigo II Louisiana Operating, LLC							1															1
Indigo Minerals							39									1						40

Table continued on next page

Operator	Number of disclosures																					
	AK	AL	AR	CA	CO	KS	LA	MI	MS	MT	ND	NM	OH	OK	PA	TX	UT	VA	WV	WY	N/A	All
Ironwood Oil & Gas LLC																5						5
J CLEO THOMPSON																101						101
JAMEX INC																2						2
JDL Operating, LLC																1						1
Jetta Operating Company																4					3	7
Johnson And Ernst Operating Company																6						6
Jones Energy														12		12						24
Juno Operating Company II, LLC																51						51
J-W Operating Company							28								1	5						34
K.P. Kauffman Company					18																	18
Kaler Energy Corporation																1						1
Keith F. Walker Oil and Gas Company														2								2
KERR-MCGEE OIL & GAS ONSHORE LP					1250																1	1251
Keystone Petroleum LP																1						1
Killam Oil Co Ltd																4						4
Kinder Morgan																2						2
Kodiak Oil & Gas Corporation											64											64
Lakota Energy Ltd																2						2
Laredo Petroleum, Inc.														13		296						309
Layline Petroleum LLC																20						20
LCS Production Company																16						16
Le Norman Operating LLC																16					2	18
LeClair Operating Co., Inc.																1						1
Legacy Reserves Operating LP																6						6
Legado Permian, LLC																13						13
Legend Natural Gas, LLC												1				48					1	50
Lewis Energy Group																78						78

Table continued on next page

Operator	Number of disclosures																				
	AK	**AL**	**AR**	**CA**	**CO**	**KS**	**LA**	**MI**	**MS**	**MT**	**ND**	**NM**	**OH**	**OK**	**PA**	**TX**	**UT**	**VA**	**WV**	**WY**	**N/A**	**All**
Lewis Operating Corporation																1						1
Liberty Resources LLC											21											21
Limestone Exploration II, LLC																1						1
Linn Energy, LLC														3		112						115
Llewellin Operating Company																1						1
Louis Dreyfus Highbridge Energy														1								1
Lowe Royalty Partners LP																1						1
LP Operating, LLC																2						2
M & A Oil Co Ltd																1						1
Magnet Oil																1						1
Magnum Hunter Resources Corporation																12					3	15
Marathon Oil					23					5	172			55		261				127	1	644
Mariner Energy Inc																1						1
Marlin Oil Corporation																2						2
Matador Production Company																14						14
McClure Oil Company																1						1
McElvain Energy Inc.					1							1										2
MDS Energy Development LLC															7							7
MDU Resources										10	32					8						50
Medders Oil Company, Inc																1						1
Merit Energy Company																36						36
Meritage Energy Co.																2						2
Mesa Energy Partners, LLC					7																	7
Mestena Operating Ltd.																2						2
Mewbourne Oil Company														13		52						65
Midenergy Operating LLC																4						4
Midland Oil And Gas, Inc.																4						4

Table continued on next page

Operator	Number of disclosures																					
	AK	AL	AR	CA	CO	KS	LA	MI	MS	MT	ND	NM	OH	OK	PA	TX	UT	VA	WV	WY	N/A	All
Mid-States Operating Company																5						5
Milagro Exploration, LLC														1								1
Mitchell Energy and Development Corporation												1										1
Mohican Operating LLC																3						3
Molopo Energy Texas LLC																6						6
Momentum Oil & Gas LLC																1						1
Mountain V Oil & Gas																			7			7
Murphy Exploration and Production																113						113
MWS Producing Inc.																6						6
Navidad Resources, LLC																7						7
New Gulf Resources, LLC														2		2						4
Newark E&P Operating, LLC																13						13
Newfield Exploration										4	46			54		56	437					597
Newfield Production Company																	1					1
NFR Energy, LLC																8					1	9
NMR Energy																2						2
Noble Energy, Inc.					942														20	4	1	967
NorthStar Operating Company																1						1
Oasis Petroleum										33	69										2	104
O'Brien Energy Company																1						1
Occidental Permian Ltd																7						7
Occidental Petroleum Corporation				93	184	37					66	65		1		655					6	1107
Ohio Valley Energy Systems Corp.													1									1
Omni Oil and Gas, Inc.																230						230
Opal Resources Operating Company																18						18
Osborn Heirs Company																1						1
Overland Resources LLC					3																	3

Table continued on next page

Operator	Number of disclosures																					
	AK	**AL**	**AR**	**CA**	**CO**	**KS**	**LA**	**MI**	**MS**	**MT**	**ND**	**NM**	**OH**	**OK**	**PA**	**TX**	**UT**	**VA**	**WV**	**WY**	**N/A**	**All**
P O & G Operating LLC																5						5
Pacesetter Energy LLC																2						2
Paloma Resources																10						10
Parallel Petroleum, LLC																15						15
Parsley Energy Operations																84						84
Partee Drilling Company																4						4
Parten Operating Inc.																1						1
Patara Oil & Gas, LLC					6											2	9					17
Patriot Resources, Inc.																31						31
PDC Energy					56											17			11			84
Peak Powder River Resources LLC																				1		1
Peak Resources, LLC																4						4
Pecos Operating Company LLC																5						5
Penn Virginia Oil & Gas Corporation														1		60					1	62
Pennsylvania General Energy															62						2	64
PETEX																9						9
Petroglyph Operation Company																	23					23
Petrohawk Energy Corporation							8									64					4	76
Petro-Hunt, LLC											77										2	79
Petroquest Energy, Inc.														31		6					3	40
Piceance Energy LLC					2																	2
Piedra Resources, Ltd.																6						6
Pioneer Natural Resources	3				80	3										1500						1586
Pitts Energy Company																5						5
Plains Exploration & Production Company				2												167				2	1	172
Plantation Petroleum Company Inc.																5						5
Price Operating LLC																20						20

Table continued on next page

Operator	Number of disclosures																					
	AK	AL	AR	CA	CO	KS	LA	MI	MS	MT	ND	NM	OH	OK	PA	TX	UT	VA	WV	WY	N/A	All
Primexx Energy Partners																7						7
Propel Energy, LLC																3						3
Prospect Energy LLC					6																	6
QEP Energy Company							38				11			18		3	4			119		193
Quantum Resources Management, LLC												3				26						29
Questar					5															33		38
Quicksilver Resources, Inc.					4											23						27
Range Operating New Mexico, Inc.												2										2
Range Resources Corporation														27	277	20		90			1	415
Red Willow Production Company					1											2						3
Reliance Energy, Inc.																47					1	48
Renegade Oil and Gas					4																	4
Resolute Energy																26				6		32
Rex Energy													1		41						3	45
Rice Drilling B, LLC															7							7
Ricochet Energy																3						3
Rife Energy																1						1
Riley Exploration, LLC																3						3
RIM Operating, Inc.																1						1
RK Petroleum																8						8
RKI Exploration and Production																15					1	16
Robert Bayless Producer LLC												2										2
Roff Operating Company																4						4
Roff Resources																2						2
Rosetta Resources, Inc.										5						67						72
Rosewood Resources																	1					1
Royalty Land & Development Corporation																1						1

Table continued on next page

Operator	Number of disclosures																					
	AK	AL	AR	CA	CO	KS	LA	MI	MS	MT	ND	NM	OH	OK	PA	TX	UT	VA	WV	WY	N/A	All
RSP Permian, LLC																52						52
S.B. Street Operting Inc.																6						6
Sabine Oil & Gas																3						3
Sahara Operating Company																1						1
Samson Oil & Gas Ltd					6		10			4	62			14		60				45		201
Sandalwood Oil and Gas Exploration and Production																1						1
SandRidge Energy						56						4		188		653					2	903
Santa Fe Energy Resources Inc.												1										1
Schlachter Operating Corporation																3						3
Seaboard Oil Company																3						3
Seaboard Operating Company																3						3
Seneca Resources Corporation				7											82							89
Sequel Energy, LLC											2											2
SG Interests Inc.					1																	1
Sharp Image Energy, Inc.																2						2
Shell Exploration & Production Company						12	100								224	99				73		508
Silver Creek Oil & Gas, LLC																3						3
Sinclair Oil & Gas Company										1	5											6
Slawson Exploration Company, Inc.										19	23			2		1					1	46
SM Energy										2	58	10		20		162				9	2	263
Snyder Brothers, Inc.															21							21
Southern Bay Operating, L.L.C.																9						9
Southwest Royalties, Inc.																21						21
Southwestern Energy			964		1		4								71	6						1046
Stanolind Operating																1						1
Statoil										3	23											26

Table continued on next page

Operator	Number of disclosures																					
	AK	AL	AR	CA	CO	KS	LA	MI	MS	MT	ND	NM	OH	OK	PA	TX	UT	VA	WV	WY	N/A	All
Steller Energy and Investment																5						5
Stephens and Johnson Operating Company												4		1		7						12
Steward Energy, LLC																1						1
Stone Energy Corporation																			21			21
Stout Energy																2						2
Strat Land Exploration Company						3								5		9						17
Suemaur Exploration and Production LLC																4						4
Summit Oil and Gas																2						2
Summit Petroleum																29						29
Sundance Energy					15																	15
Swift Energy Company																68					1	69
Sydson Energy, Inc																1						1
Synergy Resources Corporation					41																	41
Tacor Resources Inc.																3						3
Talisman Energy USA Inc.															179	111					7	297
Tanos Exploration, LLC																3						3
TAQA North Ltd.										20												20
Tecpetrol Operating LLC																16					1	17
Tekton Windsor Llc					3																	3
Telesis Operating Company																1						1
Tema Oil and Gas Company																1						1
Tenneco Inc.												1										1
Texaco Inc.																12						12
Texakoma Operating																5						5
Texas Energy Operations, LLC																2						2
Texas International Operating, LLC																3						3

Table continued on next page

Operator	Number of disclosures																					
	AK	**AL**	**AR**	**CA**	**CO**	**KS**	**LA**	**MI**	**MS**	**MT**	**ND**	**NM**	**OH**	**OK**	**PA**	**TX**	**UT**	**VA**	**WV**	**WY**	**N/A**	**All**
Texas Royalty Corporation																2						2
Texland Petroleum, LP												1				21						22
Texon Oil Company																2						2
The Cumming Company																8						8
The Termo Company				1																	1	2
Thompson Engineering and Production Company					2																	2
Three Rivers Operating Company																27						27
Thums Long Beach Co				2																		2
Timmerman					5																	5
Titan Operating, LLC																41						41
Trap Rock Oil, Ltd.																3						3
Treadstone Energy Partners LLC																9						9
Trey Resources Inc.																2						2
Triana Energy															4							4
Triangle Petroleum Corporation											14											14
Tri-C Resources, LLC																3						3
Trilogy Resources LLC					7																	7
Trio Operating Company																4						4
Trivium Operating LLC																3						3
True Oil LLC											2											2
Tug Hill Operating						6																6
Ultra Resources					1										6					144		151
Unit Petroleum														6		36						42
US Enercorp Ltd																2						2
Vaalco Energy Inc.										3												3
Valence Operating Company																20						20
Vanguard Permian LLC																1						1

Table continued on next page

Operator	Number of disclosures																					
	AK	**AL**	**AR**	**CA**	**CO**	**KS**	**LA**	**MI**	**MS**	**MT**	**ND**	**NM**	**OH**	**OK**	**PA**	**TX**	**UT**	**VA**	**WV**	**WY**	**N/A**	**All**
Vantage Energy																	1					1
Vantage Energy Appalachia LLC															4							4
Vantage Fort Worth Energy LLC																10						10
Venoco Inc.				20																		20
Veritas Energy, LLC																11						11
Vintage Production of California				36																		36
W&T Offshore																94					1	95
Walsh and Watts, Inc.																10						10
Walsh Petroleum																8						8
Walter Exploration Company																10						10
Wapiti Operating Llc																3						3
Ward Petroleum														11								11
Warren American Oil Company																5						5
Wellstar Corporation					3																	3
WG Operating																9						9
Whiting Petroleum					19			7		24	208					175				1	1	435
William H. Lackey Oil & Gas																2						2
Williams Production					340							12			38	18						408
Willowbend Investments																4						4
Windsor Permian, LLC																8						8
Wolverine Gas & Oil Corporation																	1					1
Woodbine Acquisition, LLC																11						11
Woolsey Operating Company						2																2
WPX Energy					300						49				50	7						406
XTO Energy			297		60		20			5	66	98		150	62	1092	20		23	1	6	1900
Zavanna, LLC											26											26

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Operator	Number of disclosures																					
	AK	**AL**	**AR**	**CA**	**CO**	**KS**	**LA**	**MI**	**MS**	**MT**	**ND**	**NM**	**OH**	**OK**	**PA**	**TX**	**UT**	**VA**	**WV**	**WY**	**N/A**	**All**
ZaZa Energy Services																18						18
Zenergy Operating Company											25										1	26

Note: Analysis considered 38,050 disclosures and 428 operators that met selected quality assurance criteria, including: unique combination of fracture date and API well number and fracture date between January 1, 2011, and February 28, 2013. Disclosures that did not meet quality assurance criteria were excluded from analysis (480).

Appendix E. Reporting Requirements for States with Data in the Project Database

Table E-1 presents information on reporting requirements for the 20 states with data in the project database, as of February 28, 2013. Table E-1 also shows the number of unique disclosures with fracture dates between January 1, 2011, and February 28, 2013, for each state. Fourteen of 20 states with data in the project database enacted reporting requirements either before or during the time period studied in this report. Six of those states (Colorado, North Dakota, Oklahoma, Pennsylvania, Texas, and Utah) mandated reporting to FracFocus. The other eight states required reporting to the state or to either the state or FracFocus. Six of the 20 states with data in the project database had no reporting requirements in effect prior to February 28, 2013.

Table E-1. Reporting regulations for states with data in the project database.

State	Regulatory effective date	State regulation	Number of disclosures
Alabama	None	--	55
Alaska	None	--	37
Arkansas	1/15/2011	State Rule B-19. Applicable to wells issued a new drilling permit on or after effective date. Report to the state within 30 days of well completion or recompletion.	1,450
California	None	--	718
Colorado	4/1/2012	State regulation Rule 205A. Applicable to all hydraulic fracturing treatments performed on or after effective date. Reporting must occur within 60 days after the conclusion of fracturing, or no later than 120 days after commencement. Reporting is required to FracFocus.	4,938
Kansas	None	--	136
Louisiana	10/20/2011	State regulation LAC 43:XIX.118. Applicable to all new wells issued an initial drilling permit on or after effective date. Reporting to the state must occur within 20 days after the conclusion of fracturing. Alternatively, reporting may be made to FracFocus or any other similar registry.	1,038
Michigan	6/22/2011	State Supervisor of Wells Instruction 1-2011. Applicable to large water withdrawals (average of 100,000 gallons per day over 30 day period) on or after effective date. Reporting to the state must occur within 60 days after well completion.	15
Mississippi	None	--	4

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State	Regulatory effective date	State regulation	Number of disclosures
Montana	8/26/2011	State regulation 36.22.1015. Applicable to all treatments performed on or after effective date. Reporting to the state must occur upon well completion or treatment. Alternatively, reporting may be made to FracFocus.	213
New Mexico	2/15/2012	State regulation NMAC 19.15.16.19. Applicable to all treatments on or after effective date. Reporting to the state within 45 days after completion of well.	1,162
North Dakota	4/1/2012	State regulation 43-02-03-27.1. Applicable to all treatments performed on or after effective date. Reporting to FracFocus must occur within 60 days after the conclusion of fracturing.	2,254
Ohio	9/10/2012	State regulation ORC 1509.10. Applicable to hydraulic fracturing performed on or after effective date. Reporting to the state must occur within 60 days after the conclusion of fracturing. Alternatively, reporting may be made to FracFocus or other means acceptable to the state.	148
Oklahoma	1/1/2013	State regulation OAC 165:10-3-10. Applicable to horizontal wells hydraulically fractured on or after effective dates. Reporting to FracFocus (or to the state, which will post the information to FracFocus) must occur within 60 days after the conclusion of fracturing. Regulation effective for other wells that are hydraulically fractured on January 1, 2014.	1,909
Pennsylvania	2/5/2011	State statute 78.122. Applicable to wells completed on or after the effective date. Reporting to the state must occur within 30 days after completion.	2,483
	4/14/2012	State statute 58.3222 and 3222.1. Applicable to hydraulic fracturing of unconventional wells performed on or after effective date. Reporting to FracFocus must occur within 60 days after conclusion of fracturing. Reporting is also required to the state agency within 30 days after well completion.	
Texas	2/1/2012	State regulation 16 TAC 3.29. Applicable to wells issued an initial drilling permit on or after effective date. Reporting to FracFocus must occur within 30 days of well completion or 90 days after drilling operation is completed (whichever is earlier).	18,075

Table continued on next page

State	Regulatory effective date	State regulation	Number of disclosures
Utah	11/1/2012	State regulation R649-3-39. Applicable to hydraulic fracturing performed on or after effective date. Reporting to FracFocus must occur within 60 days after the conclusion of fracturing.	1,429
Virginia	None	--	90
West Virginia	8/29/2011	Emergency rule § 35-8. Applicable to horizontal wells issued permits after effective date and which withdraw more than 210,000 gallons of water per month. Reporting to the state is required within 90 days after well completion.	277
	12/14/2011	WV Code §§ 22-6A-7. Applicable to horizontal wells issued permits after effective date and which disturb more than three acres of surface or operations withdrawing more than 210,000 gallons of water per month. Reporting to the state is required within 90 days after well completion.	
Wyoming	8/17/2010	State regulation Wyoming Code of Rules and Regs. Chapter 3. Applicable to new drilling permits approved on or after effective date. Reporting to the state prior to stimulation and within 30 days after completion.	1,457

Note: Analysis considered 37,888 disclosures that met selected quality assurance criteria, including: unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; and with confirmed state location. Disclosures that did not meet quality assurance criteria were excluded from analysis (642 disclosures).

Appendix F. Additive Purposes

Table F-1. Number of disclosures, summarized by additive purpose categories.

EPA-standardized additive purpose	Number of disclosures	Number of ingredient records reported as CBI
Proppants	27,943	896
Biocides	27,057	3,339
Breakers and breaker catalysts	22,283	5,325
Friction reducers	18,935	6,618
Crosslinkers and related additives	18,353	7,137
Gelling agents and gel stabilizers	18,243	7,719
Acids	18,138	266
Corrosion inhibitors	17,824	21,519
Surfactants	17,778	21,581
Base fluid	16,112	486
Scale control	15,335	13,090
Iron control agents	13,472	1,071
Clay control	11,432	4,526
pH control	11,200	245
Non-emulsifiers	10,943	7,587
Other/Multiples	4,207	1,406
Solvents	4,115	2,551
Activators	2,652	1,031
Inhibitors	1,998	1,129
Resin curing agents	1,473	422
Clean perforations	1,373	955
Fluid foaming agents and energizers	1,262	147
Stabilizers	917	198
Viscosifiers	900	455
Reducing agent	796	4
Acid inhibitors	786	378
Fluid loss additives	604	139
Oxidizer	513	5
Emulsifiers	510	44
Oxygen scavengers	428	218
Antifoaming agents	351	349
Flow enhancers	247	91
Tracers	200	1,127
Sulfide scavengers	190	161
Sealers	136	70
Formation breakdown	87	0
Antisludge agents	57	4

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EPA-standardized additive purpose	Number of disclosures	Number of ingredient records reported as CBI
Antifreeze	45	0
Flowback control	44	64
Fluid diverters	3	3
Delaying agents	1	0
Proppant resin	1	1

Note: Analysis considered 36,544 disclosures and 1,218,003 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; and fracture date between January 1, 2011, and February 28, 2013. Disclosures not meeting quality assurance criteria (1,986) or other, query-specific criteria were excluded from analysis.

Appendix G. Most Frequently Reported Additive Ingredients for Five Selected Counties

Table G-1. Twenty most frequently reported additive ingredients in Andrews County, Texas, ranked by frequency of occurrence.

EPA-standardized chemical name	CASRN	Maximum concentration in hydraulic fracturing fluid (% by mass)				Maximum concentration in additive (% by mass)			
		Number (%) of disclosures	Median	5th percentile	95th percentile	Number (%) of ingredient records	Median	5th percentile	95th percentile
Methanol	67-56-1	885 (81%)	0.022	0.0014	0.11	1,570 (8.8%)	50	5.0	96
Peroxydisulfuric acid, diammonium salt	7727-54-0	852 (78%)	0.010	0.0017	0.045	929 (5.2%)	100	60	100
Ethylene glycol	107-21-1	765 (70%)	0.030	0.0083	0.13	959 (5.4%)	40	10	69
Glutaraldehyde	111-30-8	724 (67%)	0.013	0.0033	0.020	724 (4.0%)	15	14	30
Sodium hydroxide	1310-73-2	563 (52%)	0.010	0.00013	0.028	606 (3.4%)	10	2.0	30
Potassium hydroxide	1310-58-3	544 (50%)	0.025	0.0015	0.057	554 (3.1%)	23	0.17	50
Distillates, petroleum, hydrotreated light	64742-47-8	527 (48%)	0.23	0.0025	0.35	671 (3.8%)	55	21	70
Tetradecyl dimethyl benzyl ammonium chloride	139-08-2	521 (48%)	0.0046	0.0012	0.0062	521 (2.9%)	5.0	5.0	5.0
Hydrochloric acid	7647-01-0	457 (42%)	0.53	0.15	4.3	486 (2.7%)	20	4.3	60
Isopropanol	67-63-0	439 (40%)	0.014	0.00038	0.35	537 (3.0%)	30	0.60	100
Water	7732-18-5	417 (38%)	1.3	0.0017	14	815 (4.6%)	72	5.0	97
Guar gum	9000-30-0	407 (37%)	0.17	0.032	0.36	407 (2.3%)	50	1.1	100
Alcohols, C12-14-secondary, ethoxylated	84133-50-6	391 (36%)	0.026	0.0021	0.053	395 (2.2%)	70	7.0	70
Quartz	14808-60-7	363 (33%)	0.0028	0.000070	8.8	415 (2.3%)	5.0	1.0	89
Polyethylene glycol	25322-68-3	331 (30%)	0.0018	0.00016	0.0045	334 (1.9%)	5.0	0.016	5.0
2-Butoxyethanol	111-76-2	304 (28%)	0.011	0.000068	0.33	334 (1.9%)	1.1	0.10	60
Propargyl alcohol	107-19-7	290 (27%)	0.00040	0.000070	0.0049	301 (1.7%)	5.0	0.0082	35
Sodium chloride	7647-14-5	260 (24%)	0.026	0.00026	0.29	291 (1.6%)	40	0.081	100
Citric acid	77-92-9	205 (19%)	0.0078	0.0012	0.028	230 (1.3%)	70	7.0	70
Acetic acid	64-19-7	198 (18%)	0.0061	0.00000*	0.047	221 (1.2%)	50	5.0	100

* Concentration is less than a millionth of a percentage by mass.

Note: Analysis considered 1,088 disclosures and 20,716 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; with confirmed state location; with confirmed county location; valid CASRN; and valid concentrations. Disclosures that did not meet quality assurance criteria (132) or other, query-specific criteria were excluded from analysis. A total of 880 disclosures (77% of 1,147 disclosures that met quality assurance criteria) reported a total of 3,159 ingredient records (8.1% of 39,099 ingredient records) with information indicating the data were confidential business information.

Table G-2. Twenty most frequently reported additive ingredients in Bradford County, Pennsylvania, ranked by frequency of occurrence.

EPA-standardized chemical name	CASRN	Maximum concentration in hydraulic fracturing fluid (% by mass)				Maximum concentration in additive (% by mass)			
		Number (%) of disclosures	Median	5th percentile	95th percentile	Number (%) of ingredient records	Median	5th percentile	95th percentile
Hydrochloric acid	7647-01-0	458 (93%)	0.061	0.0059	0.63	539 (9.9%)	15	1.0	20
Methanol	67-56-1	374 (76%)	0.001	0.000034	0.011	570 (10%)	40	5.0	100
Propargyl alcohol	107-19-7	357 (73%)	0.000052	0.000000*	0.00078	364 (6.7%)	10	1.0	40
Water	7732-18-5	321 (66%)	0.30	0.039	100	582 (11%)	85	40	99
Distillates, petroleum, hydrotreated light	64742-47-8	232 (47%)	0.016	0.010	0.033	250 (4.6%)	30	27	40
Glutaraldehyde	111-30-8	200 (41%)	0.0073	0.0013	0.030	229 (4.2%)	27	5.0	30
Citric acid	77-92-9	172 (35%)	0.00083	0.00011	0.0099	172 (3.1%)	50	30	60
2,2-Dibromo-3-nitrilopropionamide	10222-01-2	144 (29%)	0.0046	0.0024	0.026	144 (2.6%)	10	10	100
2-Butoxyethanol	111-76-2	138 (28%)	0.000080	0.000030	0.0027	138 (2.5%)	15	5.0	40
Ethanol	64-17-5	135 (28%)	0.0015	0.00034	0.0018	135 (2.5%)	5.0	1.0	5.0
Isopropanol	67-63-0	135 (28%)	0.00042	0.000015	0.0039	140 (2.6%)	35	5.0	60
Quaternary ammonium compounds, benzyl-C12-16-alkyldimethyl, chlorides	68424-85-1	130 (27%)	0.0026	0.0015	0.0041	143 (2.6%)	7.0	5.5	10
Sodium hydroxide	1310-73-2	126 (26%)	0.000030	0.000010	0.011	136 (2.5%)	1.0	1.0	100
Sodium erythorbate	6381-77-7	124 (25%)	0.00028	0.00013	0.0043	125 (2.3%)	100	100	100
Polyethylene glycol	25322-68-3	117 (24%)	0.023	0.0080	0.039	117 (2.1%)	70	60	70
Acetic acid	64-19-7	100 (20%)	0.0011	0.00017	0.0021	100 (1.8%)	50	50	60
Didecyl dimethyl ammonium chloride	7173-51-5	98 (20%)	0.0026	0.0021	0.0032	98 (1.8%)	8.0	8.0	10
Ethylene glycol	107-21-1	96 (20%)	0.0043	0.00025	0.018	132 (2.4%)	40	5.0	60
Ammonium chloride	12125-02-9	95 (19%)	0.0025	0.00070	0.0046	95 (1.7%)	5.0	1.5	10
Sodium sulfate	7757-82-6	86 (18%)	0.000040	0.000023	0.00010	86 (1.6%)	2.0	2.0	2.0

* Concentration is less than a millionth of a percentage by mass.

Note: Analysis considered 510 disclosures and 6,002 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; with confirmed state location; with confirmed county location; valid CASRN; and valid concentrations. Disclosures that did not meet quality assurance criteria (12) or other, query-specific criteria were excluded from analysis. A total of 180 disclosures (35% of 513 disclosures that met quality assurance criteria) reported a total of 448 ingredient records (3.6% of 12,590 ingredient records) with information indicating the data were confidential business information.

Table G-3. Twenty-one most frequently reported additive ingredients in Dunn County, North Dakota, ranked by frequency of occurrence.

EPA-standardized chemical name	CASRN	Maximum concentration in hydraulic fracturing fluid (% by mass)				Maximum concentration in additive (% by mass)			
		Number (%) of disclosures	Median	5th percentile	95th percentile	Number (%) of ingredient records	Median	5th percentile	95th percentile
Potassium hydroxide	1310-58-3	231 (75%)	0.022	0.000000*	0.051	235 (4.2%)	15	0.25	50
Guar gum	9000-30-0	213 (69%)	0.25	0.10	0.42	231 (4.1%)	60	1.6	100
Methanol	67-56-1	200 (65%)	0.025	0.0014	0.12	378 (6.8%)	30	0.36	100
Quartz	14808-60-7	185 (60%)	0.011	0.0000020	9.4	248 (4.4%)	5.0	0.20	69
Peroxydisulfuric acid, diammonium salt	7727-54-0	184 (59%)	0.0037	0.000080	0.023	242 (4.3%)	100	0.016	100
Distillates, petroleum, hydrotreated light	64742-47-8	176 (57%)	0.18	0.0037	0.43	238 (4.3%)	43	0.56	70
Solvent naphtha, petroleum, heavy arom.	64742-94-5	136 (44%)	0.0047	0.000000*	0.025	137 (2.4%)	5.0	0.028	30
Water	7732-18-5	136 (44%)	0.022	0.017	87	211 (3.8%)	80	30	100
Tetrakis(hydroxymethyl) phosphonium sulfate	55566-30-8	127 (41%)	0.012	0.0021	0.016	130 (2.3%)	60	0.022	60
Sodium hydroxide	1310-73-2	106 (34%)	0.022	0.000000*	0.093	115 (2.1%)	30	0.17	60
Carbonic acid, dipotassium salt	584-08-7	102 (33%)	0.069	0.022	0.19	105 (1.9%)	60	48	60
Naphthalene	91-20-3	101 (33%)	0.0014	0.000000*	0.0041	102 (1.8%)	5.0	0.0057	5.0
Formic acid, potassium salt	590-29-4	100 (32%)	0.065	0.0084	0.12	100 (1.8%)	60	50	60
Diatomaceous earth, calcined	91053-39-3	86 (28%)	0.024	0.0032	0.032	87 (1.6%)	100	100	100
Ethylene glycol	107-21-1	84 (27%)	0.037	0.0050	0.11	104 (1.9%)	30	0.70	100
Ethanol	64-17-5	78 (25%)	0.042	0.000000*	0.062	82 (1.5%)	60	30	60
Boric acid	10043-35-3	77 (25%)	0.0028	0.00065	0.025	78 (1.4%)	30	15	100
Tetramethylammonium chloride	75-57-0	76 (25%)	0.047	0.030	0.11	76 (1.4%)	0.43	0.28	60
Isopropanol	67-63-0	74 (24%)	0.026	0.00021	0.049	84 (1.5%)	30	0.18	60

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EPA-standardized chemical name	CASRN	Maximum concentration in hydraulic fracturing fluid (% by mass)				Maximum concentration in additive (% by mass)			
		Number (%) of disclosures	Median	5th percentile	95th percentile	Number (%) of ingredient records	Median	5th percentile	95th percentile
Nonyl phenol ethoxylate	9016-45-9	73 (24%)	0.0039	0.0034	0.0092	73 (1.3%)	10	8.8	10
White mineral oil, petroleum†	8042-47-5	73 (24%)	0.049	0.012	0.076	73 (1.3%)	100	91	100

* Concentration is less than a millionth of a percentage by mass.

† White mineral oil, petroleum is included as a 21st chemical because it had the same number of disclosures as nonyl phenol ethoxylate.

Note: Analysis considered 311 disclosures and 6,450 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; with confirmed state location; with confirmed county location; valid CASRN; and valid concentrations. Disclosures that did not meet quality assurance criteria (35) or other, query-specific criteria were excluded from analysis. A total of 258 disclosures (80% of 323 disclosures that met quality assurance criteria) reported a total of 1,435 ingredient records (12% of 12,003 ingredient records) with information indicating the data were confidential business information.

Table G-4. Twenty most frequently reported additive ingredients in Garfield County, Colorado, ranked by frequency of occurrence.

EPA-standardized chemical name	CASRN	Maximum concentration in hydraulic fracturing fluid (% by mass)				Maximum ingredient concentration in additive (% by mass)			
		Number (%) of disclosures	Median	5th percentile	95th percentile	Number (%) of ingredient records	Median	5th percentile	95th percentile
Ethanol	64-17-5	996 (86%)	0.025	0.00043	0.055	1,001 (6.4%)	60	5.0	60
Distillates, petroleum, hydrotreated light	64742-47-8	932 (80%)	0.014	0.0059	0.022	934 (6.0%)	30	30	40
Methanol	67-56-1	830 (71%)	0.0045	0.0012	0.016	1,481 (9.5%)	30	5.0	70
Solvent naphtha, petroleum, heavy arom.	64742-94-5	770 (66%)	0.019	0.0010	0.027	1,101 (7.0%)	30	5.0	30
Sodium hypochlorite	7681-52-9	759 (65%)	0.023	0.0038	0.077	985 (6.3%)	30	13	100
Sodium hydroxide	1310-73-2	691 (59%)	0.0018	0.00096	0.0049	866 (5.5%)	2.0	2.0	5.0
Naphthalene	91-20-3	664 (57%)	0.0021	0.000030	0.0045	669 (4.3%)	5.0	1.0	5.0
Hydrochloric acid	7647-01-0	656 (56%)	0.037	0.010	0.078	659 (4.2%)	10	7.5	30
Sodium chloride	7647-14-5	651 (56%)	0.0059	0.000000*	0.55	677 (4.3%)	10	1.0	100
1,2,4-Trimethylbenzene	95-63-6	618 (53%)	0.00043	0.00027	0.00092	623 (4.0%)	1.0	1.0	1.0
Poly(oxy-1,2-ethanediyl)-nonylphenyl-hydroxy (mixture)	127087-87-0	617 (53%)	0.0022	0.0012	0.0085	622 (4.0%)	5.0	5.0	10
Isopropanol	67-63-0	493 (42%)	0.034	0.00011	0.044	810 (5.2%)	30	5.0	60
Acetic acid	64-19-7	397 (34%)	0.0018	0.00076	0.0028	397 (2.5%)	60	60	60
1-Benzylquinolinium chloride	15619-48-4	396 (34%)	0.000060	0.000028	0.000090	396 (2.5%)	10	10	10
Acetic anhydride	108-24-7	396 (34%)	0.0030	0.0013	0.0046	396 (2.5%)	100	100	100
Glutaraldehyde	111-30-8	393 (34%)	0.016	0.0066	0.016	393 (2.5%)	30	30	30
Didecyl dimethyl ammonium chloride	7173-51-5	336 (29%)	0.0052	0.0026	0.0055	336 (2.1%)	10	10	10
Quaternary ammonium compounds, benzyl-C12-16-alkyldimethyl, chlorides	68424-85-1	336 (29%)	0.0026	0.0013	0.0038	336 (2.1%)	5.0	5.0	7.0

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EPA-standardized chemical name	CASRN	Maximum concentration in hydraulic fracturing fluid (% by mass)				Maximum ingredient concentration in additive (% by mass)			
		Number (%) of disclosures	Median	5th percentile	95th percentile	Number (%) of ingredient records	Median	5th percentile	95th percentile
Ammonium chloride	12125-02-9	331 (28%)	0.0031	0.0010	0.0074	359 (2.3%)	7.0	0.017	10
Water	7732-18-5	293 (25%)	0.050	0.0012	0.22	303 (1.9%)	100	60	100

* Concentration is less than a millionth of a percentage by mass.

Note: Analysis considered 1,166 disclosures and 17,337 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; with confirmed state location; with confirmed county location; valid CASRN; and valid concentrations. Disclosures that did not meet quality assurance criteria (254) or other, query-specific criteria were excluded from analysis. A total of 516 disclosures (44% of 1,169 disclosures that met quality assurance criteria) reported a total of 1,493 ingredient records (6.1% of 24,505 ingredient records) with information indicating the data were confidential business information.

Table G-5. Twenty most frequently reported additive ingredients in Kern County, California, ranked by frequency of occurrence**.**

EPA-standardized chemical name	CASRN	Maximum concentration in hydraulic fracturing fluid (% by mass)				Maximum concentration in additive (% by mass)			
		Number (%) of disclosures	Median	5th percentile	95th percentile	Number (%) of ingredient records	Median	5th percentile	95th percentile
Guar gum	9000-30-0	511 (93%)	0.18	0.11	0.34	513 (5.1%)	60	0.74	60
Quartz	14808-60-7	486 (89%)	0.013	0.000010	27	979 (9.8%)	1.0	1.0	94
Water	7732-18-5	452 (83%)	0.055	0.034	80	508 (5.1%)	97	60	100
Peroxydisulfuric acid, diammonium salt	7727-54-0	451 (82%)	0.0062	0.0033	0.051	462 (4.6%)	100	0.15	100
Diatomaceous earth, calcined	91053-39-3	388 (71%)	0.012	0.00060	0.030	580 (5.8%)	60	60	100
Sodium hydroxide	1310-73-2	388 (71%)	0.0099	0.0062	0.016	391 (3.9%)	10	5.0	30
Hemicellulase Enzyme Concentrate	9025-56-3	363 (66%)	0.0015	0.0010	0.0046	363 (3.6%)	3.0	3.0	3.0
2-Methyl-3(2H)-isothiazolone	2682-20-4	360 (66%)	0.00011	0.000030	0.00027	360 (3.6%)	5.0	5.0	5.0
5-Chloro-2-methyl-3(2H)-isothiazolone	26172-55-4	360 (66%)	0.00023	0.000060	0.00055	360 (3.6%)	10	10	10
Cristobalite	14464-46-1	360 (66%)	0.000020	0.000010	0.000060	360 (3.6%)	1.0	1.0	1.0
Magnesium chloride	7786-30-3	360 (66%)	0.00011	0.000030	0.00027	360 (3.6%)	5.0	5.0	5.0
Magnesium nitrate	10377-60-3	360 (66%)	0.00023	0.000060	0.00054	360 (3.6%)	10	10	10
Boron sodium oxide	1330-43-4	352 (64%)	0.029	0.020	0.045	352 (3.5%)	30	10	30
Ethylene glycol	107-21-1	349 (64%)	0.029	0.014	0.045	349 (3.5%)	30	30	30
1,2-Ethanediaminium, N, N'- bis[2-[bis(2-hydroxyethyl) methylammonio] ethyl]- N,N'bis (2-hydroxyethyl)-N,N'-dimethyl-,tetrachloride	138879-94-4	339 (62%)	0.055	0.043	0.075	343 (3.4%)	60	60	60
Distillates, petroleum, hydrotreated light	64742-47-8	316 (58%)	0.079	0.052	0.16	318 (3.2%)	30	30	30
1-Butoxy-2-propanol	5131-66-8	311 (57%)	0.013	0.0088	0.026	311 (3.1%)	5.0	5.0	5.0
Distillates, petroleum, hydrotreated light paraffinic	64742-55-8	310 (57%)	0.080	0.054	0.16	310 (3.1%)	30	30	30

Table continued on next page

EPA-standardized chemical name	CASRN	Maximum concentration in hydraulic fracturing fluid (% by mass)				Maximum concentration in additive (% by mass)			
		Number (%) of disclosures	Median	5th percentile	95th percentile	Number (%) of ingredient records	Median	5th percentile	95th percentile
Isotridecanol, ethoxylated	9043-30-5	308 (56%)	0.013	0.0090	0.026	308 (3.1%)	5.0	5.0	5.0
Phosphonic acid	13598-36-2	220 (40%)	0.00021	0.000090	0.00033	220 (2.2%)	1.0	1.0	1.0

Note: Analysis considered 547 disclosures and 10,997 ingredient records that met selected quality assurance criteria, including: completely parsed; unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; with confirmed state location; with confirmed county location; valid CASRN; and valid concentrations. Disclosures that did not meet quality assurance criteria (153) or other, query-specific criteria were excluded from analysis. A total of 523 disclosures (79% of 666 disclosures that met quality assurance criteria) reported a total of 767 ingredient records (3.9% of 19,854 ingredient records) with information indicating the data were confidential business information.

Appendix H. Total Water Volumes by County

Table H-1. Total water volumes, summarized by county.

State	County	Number of disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
				Median	5th percentile	95th percentile
Colorado	Weld	3,011	2,335,336,985	407,442	128,100	2,977,508
Colorado	Garfield	1,355	3,624,211,889	1,707,024	695,047	8,093,060
Texas	Andrews	1,171	518,991,576	91,697	29,631	1,429,964
Texas	County Uncertain	1,049	2,441,366,185	1,306,225	25,241	6,868,724
Texas	Glasscock	935	1,241,568,473	981,372	569,677	2,662,435
Utah	Uintah	835	326,559,958	340,715	81,509	804,497
Texas	Martin	823	937,501,845	1,099,924	494,534	1,705,162
Texas	Ector	822	497,360,705	209,209	40,444	1,886,442
Texas	Upton	777	974,777,378	1,216,685	30,060	1,924,754
Texas	Tarrant	747	2,968,194,610	3,678,696	1,324,407	7,575,669
Texas	Dimmit	715	3,938,854,414	5,322,954	3,076,202	8,709,221
California	Kern	677	89,129,306	77,238	19,135	328,606
Texas	Karnes	595	2,254,998,809	3,514,377	2,148,427	6,484,902
Texas	La Salle	568	2,683,074,962	4,488,267	2,684,300	7,498,348
Texas	Midland	530	654,029,168	1,254,809	455,722	1,892,398
North Dakota	Mountrail	520	916,997,966	1,558,022	707,235	3,357,661
Pennsylvania	Bradford	513	2,168,115,265	4,350,571	213,158	7,181,555
Utah	Duchesne	501	183,472,997	129,079	18,228	1,297,842
North Dakota	McKenzie	483	1,241,789,756	2,433,648	784,762	4,216,218
Wyoming	Sublette	474	629,569,835	1,099,287	675,704	3,464,024
Louisiana	De Soto	457	2,233,883,199	4,796,568	2,851,654	7,677,568
Texas	Reagan	450	885,418,227	1,145,983	414,863	8,962,874
New Mexico	Eddy	442	475,792,263	566,934	60,256	3,590,099
Texas	Webb	439	2,294,331,122	4,983,952	1,228,471	11,178,023
North Dakota	Williams	430	1,163,067,734	2,390,827	907,390	5,878,448
Arkansas	Van Buren	401	1,816,523,710	4,341,724	2,455,755	7,247,129
Texas	McMullen	384	1,641,511,084	3,933,824	210,720	8,545,215
Texas	Montague	375	1,958,947,601	5,137,420	3,286,042	7,334,297
Pennsylvania	Lycoming	361	1,498,219,767	3,877,797	1,597,625	7,475,978
Texas	Ward	345	227,837,517	246,085	7,795	2,156,625
Texas	Gonzales	344	1,253,423,805	3,632,223	1,890,399	5,892,711
North Dakota	Dunn	331	630,097,859	2,017,621	409,803	3,361,183
Pennsylvania	Susquehanna	327	1,546,179,194	4,798,290	940,909	7,816,150
Wyoming	Sweetwater	321	84,850,331	229,974	79,090	435,011
Texas	DeWitt	320	1,104,210,329	3,426,088	2,028,110	4,790,741

Table continued on next page

State	County	Number of disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
				Median	5th percentile	95th percentile
Arkansas	White	309	1,749,005,205	5,782,854	3,655,427	7,416,763
Arkansas	Conway	302	1,596,170,693	5,266,774	2,919,365	7,957,921
Texas	Gaines	298	44,087,004	79,411	18,330	269,241
Texas	Wise	291	1,157,129,977	3,875,046	918,692	7,969,196
Texas	Johnson	289	1,190,791,843	3,969,422	1,754,012	7,202,405
New Mexico	Lea	286	244,252,238	183,645	53,235	3,730,169
Pennsylvania	Tioga	286	1,132,668,079	3,598,474	2,285,636	6,572,202
Texas	Howard	286	219,523,127	895,986	26,018	1,523,373
Texas	Irion	284	945,564,352	895,468	45,494	11,729,639
Texas	Wheeler	283	1,773,621,591	6,292,608	879,360	12,398,544
Texas	Mitchell	278	22,018,458	30,402	14,154	88,003
Arkansas	Cleburne	263	1,489,329,655	5,974,108	3,401,011	7,538,336
Texas	Denton	263	934,748,202	1,836,744	1,014,405	9,008,399
Texas	Reeves	263	352,616,549	1,081,442	104,447	3,865,365
Texas	Milam	254	9,844,030	16,000	16,000	18,900
Texas	Crane	245	196,718,764	175,308	26,277	2,794,840
Wyoming	Natrona	226	3,663,585	5,648	5,032	7,685
Pennsylvania	Washington	223	867,457,663	3,358,519	2,553,790	7,031,557
Oklahoma	Alfalfa	199	385,043,193	1,865,304	1,266,922	2,923,830
Texas	Yoakum	190	16,252,142	65,966	26,097	138,354
New Mexico	San Juan	188	24,032,553	72,200	19,998	476,978
Texas	Live Oak	182	612,387,421	3,334,502	1,992,043	4,466,792
Texas	Cooke	178	930,155,506	5,361,300	1,791,556	7,915,538
Oklahoma	Roger Mills	177	490,227,227	2,488,248	662,273	4,991,475
New Mexico	Rio Arriba	174	33,138,782	114,732	24,531	452,176
Oklahoma	Woods	166	327,924,769	1,916,477	1,306,536	2,664,942
Oklahoma	Ellis	165	398,559,056	2,301,505	732,749	4,023,155
State Uncertain	County Uncertain	158	488,083,669	2,770,090	80,067	6,945,958
Oklahoma	Canadian	158	966,487,571	6,340,910	3,045,404	8,472,344
Pennsylvania	Greene	157	781,556,032	4,305,363	2,433,957	10,493,381
Texas	Loving	155	282,297,269	1,517,208	56,095	4,341,797
Louisiana	Red River	153	1,139,265,130	7,179,763	4,293,341	11,653,648
Colorado	Las Animas	146	15,768,503	95,974	20,424	260,255
Texas	Parker	144	554,945,907	3,665,336	1,340,232	7,112,669
Colorado	Rio Blanco	143	294,677,269	2,248,291	96,911	3,232,073
Texas	Panola	143	696,572,353	3,804,948	26,987	14,494,738
Texas	Atascosa	137	694,264,027	4,089,792	2,289,300	9,904,570
Texas	Hemphill	136	549,108,685	3,059,675	460,143	7,574,170

Table continued on next page

State	County	Number of disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
				Median	5th percentile	95th percentile
North Dakota	Divide	133	212,401,131	1,580,796	678,912	2,536,918
Louisiana	Sabine	129	790,459,623	6,424,656	3,557,957	9,120,145
North Dakota	County Uncertain	126	274,188,475	1,986,598	376,173	3,555,922
Oklahoma	County Uncertain	115	354,593,378	1,654,044	16,796	9,930,348
Texas	Freestone	113	108,863,226	784,482	151,016	2,485,651
Texas	Crockett	107	596,159,001	6,882,549	64,223	10,739,690
Arkansas	Faulkner	106	567,953,587	5,289,045	3,204,945	8,067,928
Oklahoma	Pittsburg	106	756,599,235	6,939,435	3,607,478	11,799,127
Montana	Richland	104	173,612,043	1,604,648	359,501	3,211,767
Wyoming	Converse	98	230,123,849	2,303,838	866,463	4,693,910
Oklahoma	Washita	95	215,800,796	2,510,928	320,170	3,201,844
Texas	Lipscomb	92	182,722,458	1,482,313	312,653	4,038,008
Oklahoma	Grant	89	165,254,145	1,792,535	1,490,734	2,219,473
Pennsylvania	Westmoreland	89	413,919,647	4,382,954	2,602,314	7,766,369
Texas	Nacogdoches	89	543,371,967	6,478,122	190,003	10,899,353
Wyoming	Fremont	85	56,372,038	273,651	13,706	1,875,955
Oklahoma	Dewey	82	331,068,664	3,774,240	790,768	6,455,102
Louisiana	Caddo	80	311,083,907	4,010,916	167,521	6,956,650
Oklahoma	Blaine	79	414,164,933	5,109,410	2,743,823	8,789,371
Ohio	Carroll	78	334,774,734	4,104,765	3,127,692	5,738,399
Texas	Robertson	75	92,251,731	739,196	148,897	3,382,029
Texas	Ochiltree	71	71,885,269	852,457	358,029	2,179,675
Texas	Schleicher	69	54,035,392	93,282	23,663	4,415,300
North Dakota	Burke	68	130,039,568	2,181,879	92,238	2,916,078
North Dakota	Stark	67	97,818,062	1,485,580	687,725	1,903,938
Louisiana	County Uncertain	65	417,334,020	6,099,364	2,141,777	12,166,446
Pennsylvania	Fayette	65	243,844,255	3,614,704	1,982,122	5,899,561
Texas	Frio	61	256,406,734	4,248,636	1,424,183	6,901,482
Texas	Jack	61	36,154,895	414,918	25,200	2,594,283
Utah	Carbon	60	14,656,123	234,643	122,492	363,483
Oklahoma	Beckham	59	221,343,112	3,231,150	87,765	8,214,126
Pennsylvania	Wyoming	59	319,383,314	5,360,166	1,131,136	9,250,744
Louisiana	Bienville	56	217,714,155	4,514,531	86,517	6,986,721
Texas	Roberts	56	80,958,031	1,203,233	40,661	3,316,569
Wyoming	Park	56	1,802,669	28,412	15,488	41,300
Texas	Hidalgo	55	17,112,033	287,654	77,524	647,891

Table continued on next page

State	County	Number of disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
				Median	5th percentile	95th percentile
Oklahoma	Grady	54	253,307,556	4,864,995	73,199	7,757,636
Pennsylvania	Butler	53	256,960,489	4,748,310	3,075,507	7,167,812
Texas	San Augustine	53	364,221,026	6,307,110	1,748,771	12,199,824
Texas	Crosby	51	2,808,045	58,296	36,905	78,430
Montana	Roosevelt	50	110,068,800	2,427,634	860,538	3,227,131
Pennsylvania	Clearfield	50	222,985,275	4,219,803	2,721,829	7,109,046
Texas	Zavala	50	273,942,903	6,147,960	3,163,445	7,218,131
Texas	Harrison	49	293,540,779	5,717,723	875,642	10,451,956
Oklahoma	Carter	48	340,585,434	8,224,986	37,298	8,983,229
Wyoming	Carbon	48	8,909,624	182,173	70,660	285,534
North Dakota	Billings	47	88,868,499	2,149,224	732,783	2,819,213
Texas	Hood	47	163,449,153	3,402,126	1,926,744	5,561,762
Pennsylvania	Armstrong	46	126,190,783	171,396	101,966	6,931,090
Texas	Wilson	46	174,790,616	3,822,813	1,434,854	5,635,023
West Virginia	Ohio	45	245,169,636	5,509,812	3,406,789	7,881,980
Pennsylvania	Clinton	44	188,730,732	4,257,620	2,798,770	5,723,557
Texas	Dawson	44	42,668,983	1,133,139	43,394	1,457,678
Louisiana	Bossier	42	220,225,439	5,269,992	92,427	8,328,128
Texas	Winkler	42	15,930,828	103,501	12,115	1,638,809
Wyoming	County Uncertain	41	6,508,970	129,640	6,550	305,735
Colorado	Larimer	40	10,832,123	224,906	71,698	470,367
Colorado	La Plata	39	6,967,007	196,744	36,136	227,087
Texas	Madison	39	99,968,464	2,378,670	431,446	4,848,839
Texas	Stephens	39	5,270,482	71,484	6,002	214,294
Pennsylvania	Sullivan	38	140,540,343	4,009,971	943,893	5,851,066
Texas	Leon	38	112,445,340	2,709,214	165,049	7,517,538
Texas	Starr	37	10,683,140	255,412	58,081	531,802
Alaska	North Slope (the borough of)	37	13,150,891	88,448	36,437	435,638
Texas	Borden	36	15,968,027	111,756	22,427	1,357,392
Virginia	Buchanan	36	1,267,707	33,243	20,559	52,605
West Virginia	Marshall	36	168,954,993	4,596,144	3,217,379	6,367,568
Alabama	Jefferson	35	1,157,495	33,335	22,668	40,846
Texas	Shelby	35	277,531,622	6,327,720	88,089	17,230,326
Texas	Sterling	35	86,577,074	345,374	160,584	10,062,476
Virginia	Dickenson	34	1,562,380	37,430	16,865	113,089
West Virginia	Doddridge	34	180,858,468	5,281,962	2,200,764	7,939,842
Texas	Culberson	32	83,961,631	2,515,323	40,181	5,496,785

Table continued on next page

State	County	Number of disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
				Median	5th percentile	95th percentile
Montana	Sheridan	31	21,734,049	410,690	236,019	1,712,485
Oklahoma	Noble	31	67,438,727	2,166,133	854,988	3,423,273
West Virginia	Marion	31	140,220,776	4,718,028	2,231,481	6,620,712
Oklahoma	Coal	30	180,062,029	4,824,002	246,744	11,560,111
Texas	Kleberg	30	7,048,508	223,965	49,495	488,846
Texas	Medina	30	505,485	17,031	14,868	19,099
Texas	Pecos	30	16,588,529	139,020	61,410	1,960,109
Texas	Rusk	30	141,023,149	4,837,499	29,078	9,800,251
Kansas	Comanche	29	53,072,084	1,796,122	1,064,162	2,616,347
New Mexico	Colfax	29	1,470,173	38,640	1,054	113,820
Oklahoma	Marshall	29	221,714,808	8,006,838	5,420,209	9,310,417
Texas	Terry	29	14,987,507	173,754	30,441	3,220,820
West Virginia	Wetzel	29	156,461,105	5,288,881	3,922,061	7,170,799
Arkansas	Independence	28	160,687,548	5,588,037	4,208,795	7,447,169
Oklahoma	Beaver	28	58,081,436	2,328,146	109,363	2,960,234
Wyoming	Campbell	28	27,762,544	964,350	166,791	2,092,830
Texas	Lavaca	27	103,054,135	4,329,321	39,991	6,242,700
Texas	Scurry	27	6,853,945	41,118	19,265	493,856
Colorado	County Uncertain	26	45,171,994	2,118,956	122,484	3,175,880
Texas	Stonewall	26	1,785,353	38,391	17,042	198,744
West Virginia	Brooke	26	109,537,029	4,222,596	3,128,344	5,722,616
Texas	Brooks	25	3,179,142	93,450	42,428	326,259
Texas	Wilbarger	25	345,979	14,791	4,368	21,216
Colorado	Broomfield	24	9,046,089	397,068	295,096	421,458
Colorado	Yuma	24	733,530	29,673	25,626	36,582
Colorado	Boulder	23	8,258,548	410,424	129,738	422,881
Kansas	Harper	23	36,664,604	1,839,936	47,855	2,551,977
Ohio	Columbiana	23	69,107,766	3,213,420	1,709,912	3,850,190
Pennsylvania	McKean	23	120,961,008	5,758,704	456,830	8,030,157
Texas	Hockley	23	6,058,250	27,578	19,971	274,995
Wyoming	Laramie	23	36,626,308	1,561,077	77,990	3,326,760
Oklahoma	Stephens	22	63,381,549	1,664,689	38,529	7,941,127
Pennsylvania	County Uncertain	22	84,860,930	4,219,781	984,400	5,973,536
Texas	Wichita	22	305,152	11,290	2,564	25,568
Arkansas	County Uncertain	21	114,187,387	5,816,748	3,386,662	6,923,322
New Mexico	Harding	21	219,163	6,048	4,662	8,694

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State	County	Number of disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
				Median	5th percentile	95th percentile
Alabama	Tuscaloosa	20	907,701	45,255	35,353	57,480
Texas	Limestone	20	21,484,098	645,913	163,792	3,583,703
Colorado	Mesa	19	244,114,104	14,542,836	444,333	22,609,230
North Dakota	Mclean	19	24,325,679	1,177,851	675,033	1,958,939
Oklahoma	Caddo	19	50,903,859	3,955,052	41,756	5,098,028
West Virginia	Taylor	19	105,771,236	5,849,046	3,646,583	7,669,007
Colorado	Adams	18	6,504,057	211,902	46,661	880,173
Louisiana	Beauregard	18	4,763,121	225,936	62,555	532,135
Oklahoma	Harper	17	17,614,411	1,266,798	23,226	1,713,123
West Virginia	Upshur	17	69,820,643	4,081,094	643,516	7,880,985
Ohio	Jefferson	16	66,343,492	4,257,225	2,942,478	5,471,193
Oklahoma	Kay	16	42,971,113	2,746,611	1,411,278	3,847,714
Pennsylvania	Beaver	16	64,700,812	3,677,835	309,456	8,591,746
Texas	Maverick	16	104,761,837	7,381,269	2,363,809	9,588,600
Texas	San Patricio	16	2,120,580	70,539	23,457	369,348
West Virginia	Harrison	16	98,359,628	5,923,491	4,334,106	8,748,747
California	Sutter	15	373,086	20,622	12,046	40,900
Colorado	Phillips	15	346,374	23,100	22,890	23,264
Pennsylvania	Centre	15	76,929,372	5,663,806	2,431,605	6,406,011
Texas	Cochran	15	5,959,787	316,176	20,152	827,270
Texas	Palo Pinto	15	20,579,492	620,510	139,033	3,155,617
Utah	County Uncertain	15	9,138,125	772,448	79,276	1,134,760
Kansas	Barber	14	19,858,588	1,436,880	212,300	2,260,322
Kansas	Haskell	14	205,387	12,306	8,620	24,215
New Mexico	County Uncertain	14	2,351,840	61,383	21,544	624,674
Oklahoma	Custer	14	38,094,335	2,510,865	1,119,405	4,325,305
Oklahoma	Pawnee	14	31,321,465	2,317,287	1,375,338	2,850,122
Pennsylvania	Elk	14	74,994,059	5,337,218	3,910,733	6,608,196
Texas	Oldham	14	2,752,335	195,751	99,457	338,459
Texas	Zapata	14	2,344,265	168,845	43,197	374,312
Kansas	County Uncertain	13	7,730,168	104,971	12,029	2,031,354
Texas	Bee	13	39,984,197	3,413,242	1,278,998	4,225,536
Texas	Houston	13	23,865,860	1,743,168	599,830	3,109,102
Wyoming	Hot Springs	13	537,703	41,948	34,372	46,919
California	Ventura	12	3,597,475	350,642	48,682	518,445
Colorado	Moffat	12	29,096,450	138,711	22,841	13,201,470

Table continued on next page

State	County	Number of disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
				Median	5th percentile	95th percentile
Montana	Glacier	12	10,241,652	950,581	46,805	1,589,657
Ohio	Harrison	12	50,031,353	4,058,040	3,447,473	5,102,299
Texas	Grayson	12	18,556,255	515,193	5,678	4,773,123
Kansas	Finney	11	4,835,816	13,188	10,059	2,333,068
Pennsylvania	Lawrence	11	53,944,488	4,144,434	2,668,953	10,003,861
Texas	Fayette	11	27,381,679	2,297,402	482,811	4,430,664
Texas	Hutchinson	11	630,263	55,772	40,469	79,461
Texas	Nolan	11	9,094,250	65,600	15,701	4,334,946
Wyoming	Lincoln	11	1,546,099	132,976	107,553	194,334
Arkansas	Logan	10	4,767,333	185,451	31,370	1,302,000
Oklahoma	Hughes	10	61,080,038	6,028,764	4,663,997	7,603,304
Oklahoma	Johnston	10	74,444,034	7,866,033	5,653,253	8,375,373
Pennsylvania	Indiana	10	32,371,373	3,323,237	1,051,461	5,060,509
Texas	Fisher	10	11,899,478	64,416	31,895	5,949,028
Texas	Hansford	10	5,769,487	85,920	9,824	2,437,602
Texas	Sutton	10	3,130,092	88,452	26,678	1,418,926
Oklahoma	Latimer	9	1,190,337	132,750	58,479	245,112
Pennsylvania	Allegheny	9	27,247,149	2,834,574	2,389,479	4,223,652
Pennsylvania	Potter	9	32,966,493	4,210,510	2,386,660	4,603,434
Texas	Sabine	9	62,217,624	6,447,042	5,435,480	9,144,929
Utah	San Juan	9	510,880	54,739	25,469	104,540
Wyoming	Uinta	9	1,172,285	137,313	103,664	153,696
Texas	Archer	8	308,847	21,653	1,000	119,221
Texas	Brazos	8	25,800,462	2,731,726	781,841	5,760,135
Texas	Coke	8	11,989,003	91,686	37,289	7,450,787
Texas	Gregg	8	18,754,840	2,230,473	186,877	4,466,825
Texas	Montgomery	8	471,869	58,611	45,614	75,174
California	County Uncertain	7	808,494	106,176	70,897	168,278
Oklahoma	Garvin	7	34,777,900	4,801,914	3,734,442	6,484,745
Oklahoma	Kingfisher	7	26,868,858	3,046,680	1,871,734	6,396,409
Texas	Erath	7	1,682,982	270,186	101,039	329,339
Texas	Grimes	7	30,986,483	2,703,960	1,745,520	12,057,746
Virginia	Wise	7	190,722	29,946	9,043	39,421
West Virginia	Barbour	7	39,824,792	5,299,900	2,721,541	8,103,067
Colorado	Morgan	6	7,705,597	21,766	18,462	4,144,234
Colorado	San Miguel	6	570,386	88,618	24,107	179,672
Kansas	Morton	6	78,104	11,424	7,709	22,457
Louisiana	Natchitoches	6	25,340,370	4,163,259	1,517,208	6,944,319

Table continued on next page

State	County	Number of disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
				Median	5th percentile	95th percentile
Louisiana	Webster	6	2,317,926	273,395	54,306	840,096
Montana	County Uncertain	6	11,894,148	2,515,023	225,288	3,028,253
Montana	Rosebud	6	7,027,827	1,072,667	836,642	1,763,954
North Dakota	Golden Valley	6	9,148,766	1,514,858	1,123,363	1,980,707
Oklahoma	Bryan	6	20,568,752	2,242,258	122,955	8,047,494
Oklahoma	Logan	6	8,439,674	498,015	43,493	3,690,810
Oklahoma	Major	6	2,389,800	356,034	215,492	667,853
Texas	Newton	6	625,073	77,241	62,387	211,680
Texas	Orange	6	684,146	105,385	88,559	167,470
Wyoming	Big Horn	6	5,765,641	55,162	12,381	2,953,715
Wyoming	Goshen	6	11,555,075	2,000,185	285,903	3,526,013
Colorado	Jackson	5	1,915,902	326,830	61,733	663,932
North Dakota	Bottineau	5	479,974	97,744	83,732	108,279
Pennsylvania	Jefferson	5	27,574,346	5,302,920	4,801,747	6,469,091
Texas	Burleson	5	6,071,020	1,154,644	1,054,014	1,522,626
Texas	Haskell	5	169,100	32,394	7,115	60,191
Texas	Potter	5	855,385	176,538	123,606	210,865
Texas	Runnels	5	68,082	6,930	5,888	31,542
Texas	Washington	5	5,307,569	936,726	336,941	1,930,527
Michigan	Gladwin	4	2,157,052	360,827	14,730	1,313,607
Michigan	Kalkaska	4	47,996,702	10,511,866	6,250,906	19,829,679
Michigan	Missaukee	4	87,660	21,971	18,272	25,480
Oklahoma	Le Flore	4	513,318	128,066	98,134	158,894
Oklahoma	Oklahoma	4	2,317,560	463,008	462,126	859,589
Oklahoma	Payne	4	19,797,691	4,734,292	3,989,483	6,210,545
Oklahoma	Texas	4	149,766	22,302	7,256	88,822
Texas	Austin	4	4,159,098	1,163,621	147,045	1,759,120
Texas	Hardeman	4	716,148	215,661	60,175	246,626
Texas	Kent	4	899,295	19,326	10,983	726,362
Texas	Lynn	4	2,278,945	415,474	97,330	1,258,110
West Virginia	County Uncertain	4	19,386,108	4,514,832	3,182,953	6,974,474
California	Colusa	3	61,614	15,162	13,612	31,227
California	Los Angeles	3	437,350	143,892	127,112	165,778
Colorado	Arapahoe	3	7,947,553	2,580,173	2,430,678	2,915,999
Colorado	Delta	3	1,071,931	490,320	109,451	512,063
Kansas	Clark	3	1,557,336	45,864	44,730	1,324,768
Kansas	Gray	3	6,518,606	2,227,926	1,882,288	2,424,909

Table continued on next page

State	County	Number of disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
				Median	5th percentile	95th percentile
Kansas	Hodgeman	3	5,475,838	1,839,978	1,790,202	1,850,068
Louisiana	East Feliciana	3	7,323,225	3,087,995	536,804	3,892,502
Louisiana	Union	3	9,721,910	180,586	74,089	8,549,220
Mississippi	Amite	3	28,706,118	11,916,618	4,746,676	12,747,197
New Mexico	Chaves	3	5,558,331	1,772,439	1,406,084	2,355,707
Ohio	Guernsey	3	16,806,622	5,205,007	3,182,721	8,299,734
Oklahoma	Osage	3	7,680,204	2,847,348	1,476,002	3,443,038
Pennsylvania	Blair	3	11,814,180	3,628,968	3,551,365	4,541,120
Pennsylvania	Clarion	3	16,245,996	5,128,302	4,612,694	6,418,891
Pennsylvania	Forest	3	15,439,662	4,062,366	4,040,555	7,011,484
Pennsylvania	Somerset	3	11,510,817	2,978,576	2,710,144	5,564,588
Texas	Dallas	3	11,267,802	3,716,580	3,716,315	3,823,100
Texas	Garza	3	1,175,632	27,174	23,772	1,015,275
Texas	Kenedy	3	487,536	128,478	65,125	283,723
Texas	Nueces	3	2,001,377	141,690	104,748	1,597,309
Texas	Polk	3	388,072	115,786	115,113	153,102
Texas	Somervell	3	9,651,992	3,283,022	3,068,408	3,320,269
Texas	Van Zandt	3	275,610	93,626	88,362	94,149
Texas	Walker	3	6,757,968	1,766,352	621,163	4,224,562
West Virginia	Preston	3	16,839,606	5,566,722	5,552,471	5,706,469
Arkansas	Sebastian	2	1,257,652	628,826	194,392	1,063,260
Colorado	Fremont	2	1,178,755	589,378	63,886	1,114,869
Kansas	Grant	2	308,196	154,098	152,359	155,837
Kansas	Ness	2	3,291,918	1,645,959	1,304,682	1,987,236
Kansas	Seward	2	27,782	13,891	13,258	14,524
Kansas	Stanton	2	21,672	10,836	10,685	10,987
Louisiana	Calcasieu	2	140,231	70,116	40,572	99,659
Louisiana	Jackson	2	31,731	15,866	3,365	28,366
Louisiana	Lincoln	2	6,627,470	3,313,735	2,375,712	4,251,758
Montana	Daniels	2	1,280,951	640,476	403,146	877,805
Ohio	Noble	2	16,634,545	8,317,273	7,767,089	8,867,456
Ohio	Tuscarawas	2	13,470,465	6,735,233	5,553,163	7,917,302
Oklahoma	McClain	2	4,133,534	2,066,767	1,033,703	3,099,831
Pennsylvania	Cameron	2	13,246,674	6,623,337	5,046,907	8,199,767
Pennsylvania	Columbia	2	11,253,084	5,626,542	4,225,750	7,027,334
Pennsylvania	Venango	2	4,885,144	2,442,572	577,880	4,307,264
Pennsylvania	Warren	2	4,694,917	2,347,459	296,766	4,398,151
Texas	Ellis	2	8,320,032	4,160,016	3,673,341	4,646,691

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State	County	Number of disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
				Median	5th percentile	95th percentile
Texas	Hardin	2	245,322	122,661	95,993	149,329
Texas	Hartley	2	3,889,590	1,944,795	263,049	3,626,541
Texas	Jim Hogg	2	252,728	126,364	69,028	183,700
Texas	King	2	19,278	9,639	9,545	9,734
Texas	Lee	2	2,338,433	1,169,217	1,111,741	1,226,692
Texas	Marion	2	11,877,776	5,938,888	5,684,831	6,192,945
Texas	Smith	2	413,170	206,585	154,079	259,091
Texas	Terrell	2	221,625	110,813	103,115	118,510
Texas	Upshur	2	462,828	231,414	114,818	348,010
Texas	Waller	2	229,891	114,946	106,473	123,418
Texas	Wharton	2	90,173	45,087	35,202	54,971
Texas	Willacy	2	220,164	110,082	84,000	136,164
Texas	Wood	2	345,995	172,998	58,585	287,410
Texas	Young	2	136,836	68,418	11,605	125,231
West Virginia	Monongalia	2	13,665,036	6,832,518	6,545,503	7,119,533
West Virginia	Ritchie	2	12,994,464	6,497,232	5,775,554	7,218,910
West Virginia	Webster	2	4,504,584	2,252,292	2,246,017	2,258,567
Wyoming	Niobrara	2	194,418	97,209	92,012	102,407
Arkansas	Franklin	1	6,384	6,384	6,384	6,384
Arkansas	Yell	1	29,946	29,946	29,946	29,946
California	Glenn	1	31,752	31,752	31,752	31,752
Colorado	Dolores	1	107,969	107,969	107,969	107,969
Colorado	Elbert	1	39,215	39,215	39,215	39,215
Colorado	El Paso	1	55,019	55,019	55,019	55,019
Colorado	Routt	1	142,372	142,372	142,372	142,372
Kansas	Ford	1	1,797,019	1,797,019	1,797,019	1,797,019
Kansas	Kearny	1	18,942	18,942	18,942	18,942
Kansas	Lane	1	1,645,896	1,645,896	1,645,896	1,645,896
Kansas	Meade	1	20,286	20,286	20,286	20,286
Kansas	Sheridan	1	1,474,872	1,474,872	1,474,872	1,474,872
Kansas	Stevens	1	124,291	124,291	124,291	124,291
Kansas	Sumner	1	455,532	455,532	455,532	455,532
Louisiana	Allen	1	172,116	172,116	172,116	172,116
Louisiana	Caldwell	1	40,110	40,110	40,110	40,110
Louisiana	Claiborne	1	7,603,184	7,603,184	7,603,184	7,603,184
Louisiana	Rapides	1	3,388,095	3,388,095	3,388,095	3,388,095
Louisiana	Tangipahoa	1	3,823,858	3,823,858	3,823,858	3,823,858
Louisiana	West Feliciana	1	4,605,619	4,605,619	4,605,619	4,605,619

Table continued on next page

State	County	Number of disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
				Median	5th percentile	95th percentile
Louisiana	Winn	1	2,150,872	2,150,872	2,150,872	2,150,872
Michigan	Cheboygan	1	33,306	33,306	33,306	33,306
Michigan	Ogemaw	1	20,701	20,701	20,701	20,701
Michigan	Roscommon	1	4,804,620	4,804,620	4,804,620	4,804,620
Mississippi	Wilkinson	1	6,430,629	6,430,629	6,430,629	6,430,629
Montana	Garfield	1	927,438	927,438	927,438	927,438
Montana	Musselshell	1	713,908	713,908	713,908	713,908
New Mexico	Roosevelt	1	79,212	79,212	79,212	79,212
New Mexico	Sandoval	1	792,616	792,616	792,616	792,616
Ohio	Ashland	1	2,932,422	2,932,422	2,932,422	2,932,422
Ohio	Belmont	1	3,778,068	3,778,068	3,778,068	3,778,068
Ohio	Coshocton	1	10,816,646	10,816,646	10,816,646	10,816,646
Ohio	Knox	1	2,204,454	2,204,454	2,204,454	2,204,454
Ohio	Medina	1	2,572,682	2,572,682	2,572,682	2,572,682
Ohio	Muskingum	1	10,170,198	10,170,198	10,170,198	10,170,198
Ohio	Portage	1	6,415,458	6,415,458	6,415,458	6,415,458
Ohio	Stark	1	4,752,384	4,752,384	4,752,384	4,752,384
Ohio	Summit	1	94,537	94,537	94,537	94,537
Ohio	Wayne	1	3,309,559	3,309,559	3,309,559	3,309,559
Oklahoma	Jefferson	1	4,620	4,620	4,620	4,620
Oklahoma	Kiowa	1	216,871	216,871	216,871	216,871
Oklahoma	Love	1	8,708,742	8,708,742	8,708,742	8,708,742
Oklahoma	Seminole	1	187,740	187,740	187,740	187,740
Pennsylvania	Crawford	1	4,803,563	4,803,563	4,803,563	4,803,563
Pennsylvania	Huntingdon	1	5,325,418	5,325,418	5,325,418	5,325,418
Texas	Angelina	1	1,542,275	1,542,275	1,542,275	1,542,275
Texas	Bosque	1	1,444,143	1,444,143	1,444,143	1,444,143
Texas	Cherokee	1	1,025,574	1,025,574	1,025,574	1,025,574
Texas	Clay	1	25,536	25,536	25,536	25,536
Texas	Colorado	1	104,244	104,244	104,244	104,244
Texas	Concho	1	29,946	29,946	29,946	29,946
Texas	Cottle	1	671,286	671,286	671,286	671,286
Texas	Edwards	1	91,350	91,350	91,350	91,350
Texas	Franklin	1	13,524	13,524	13,524	13,524
Texas	Goliad	1	44,226	44,226	44,226	44,226
Texas	Jefferson	1	77,291	77,291	77,291	77,291
Texas	Jones	1	56,667	56,667	56,667	56,667
Texas	Knox	1	17,178	17,178	17,178	17,178

Table continued on next page

State	County	Number of disclosures	Cumulative total water volume (gallons)	Total water volume per disclosure (gallons)		
				Median	5th percentile	95th percentile
Texas	Liberty	1	58,668	58,668	58,668	58,668
Texas	Menard	1	15,708	15,708	15,708	15,708
Texas	Moore	1	37,026	37,026	37,026	37,026
Texas	Navarro	1	9,606,805	9,606,805	9,606,805	9,606,805
Texas	Sherman	1	67,171	67,171	67,171	67,171
Texas	Tyler	1	216,174	216,174	216,174	216,174
Utah	Sevier	1	77,859	77,859	77,859	77,859
West Virginia	Hancock	1	2,420,124	2,420,124	2,420,124	2,420,124
West Virginia	Lewis	1	4,737,978	4,737,978	4,737,978	4,737,978
West Virginia	Pleasants	1	32,340	32,340	32,340	32,340
West Virginia	Tyler	1	4,168,710	4,168,710	4,168,710	4,168,710
Wyoming	Johnson	1	68,250	68,250	68,250	68,250
Wyoming	Washakie	1	2,146,866	2,146,866	2,146,866	2,146,866
Entire Dataset		37,796	91,805,425,640	1,508,724	29,526	7,196,702

Note: Analysis considered 37,796 disclosures that met selected quality assurance criteria, including: unique combination of fracture date and API well number; fracture date between January 1, 2011, and February 28, 2013; and criteria for water volumes. Disclosures that did not meet these criteria were excluded from analysis (734).

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