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Data Regarding Hydraulic Fracturing Distributions and Treatment Fluids, Additives, Proppants, and Water Volumes Applied to Wells Drilled in the United States from 1947 through 2010

Data Series 868

U.S. Department of the Interior
U.S. Geological Survey

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SALLY JEWELL, Secretary

U.S. Geological Survey
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Tables

Conversion Factors

Multiply	By	To obtain
	Volume	
cubic meter (m^3)	6.290	barrel (petroleum, 1 barrel = 42 gal)
cubic meter (m^3)	264.2	gallon (gal)
cubic meter (m^3)	0.0002642	million gallons (Mgal)
cubic meter (m^3)	35.31	cubic foot (ft^3)
cubic meter (m^3)	1.308	cubic yard (yd^3)
cubic meter (m^3)	0.0008107	acre-foot (acre-ft)

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Abstract

Comprehensive, published, and publicly available data regarding the extent, location, and character of hydraulic fracturing in the United States are scarce. The objective of this data series is to publish data related to hydraulic fracturing in the public domain. The spreadsheets released with this data series contain derivative datasets aggregated temporally and spatially from the commercial and proprietary IHS database of U.S. oil and gas production and well data (IHS Energy, 2011). These datasets, served in 21 spreadsheets in Microsoft Excel (.xlsx) format, outline the geographical distributions of hydraulic fracturing treatments and associated wells (including well drill-hole directions) as well as water volumes, proppants, treatment fluids, and additives used in hydraulic fracturing treatments in the United States from 1947 through 2010. This report also describes the data—extraction/aggregation processing steps, field names and descriptions, field types and sources. An associated scientific investigation report (Gallegos and Varela, 2015) provides a detailed analysis of the data presented in this data series and comparisons of the data and trends to the literature.

Overview

This data series contains a derivation of data from the larger commercial IHS database of U.S. production and well data (IHS Energy, 2011) to which the U.S. Geological Survey (USGS) subscribes. The original IHS database, as received by the USGS, includes records of about 1.8 million hydraulic fracturing treatments and about 1 million hydraulically fractured wells drilled from 1947 through 2010. This report presents the details regarding the selection and processing of hydraulic fracturing data from the proprietary source (IHS Energy, 2011), the data review process, the creation of temporally and spatially aggregated data tables (21 spreadsheets) to be released to the public through this data series, and a complete description of each field within each spreadsheet.

Purpose

The intent of this data series is to contribute data on hydraulic fracturing to the public domain to help improve the understanding of the current and historical character and occurrence of hydraulic fracturing in the United States on a broad, national scale.

Hydraulic Fracturing in Brief

This section provides a brief description of the overall hydraulic fracturing process and related characteristics placed into the context of the table/spreadsheet and field element names from both the IHS database and this data series. Note that terms from the IHS database are set in all capital letters: table names are underlined, field names (column headings) are in plain format, and attributes (table entries) are set in italic. Terms from the datasets released with this data series are set in all capital letters and in bold: spreadsheet names are underlined, field names (column headings) are simply bold, and attributes (table entries) are set in italic. See table 1 for examples of the format used to identify table/spreadsheet terms.

Hydraulic fracturing is one of several different reservoir stimulation methods used in the United States to increase oil and gas production from low-permeability reservoirs (such as tight sands, coal beds, shale) and, in some cases, to remove damage (for example, scale or paraffin deposited within the wellbore during drilling and (or) production). Hydraulic fracturing treatments are applied to wells drilled with horizontal (*H*), vertical (*V*), and directional (*D*) drill-hole (borehole) orientations (HOLE_DIRECTION), as defined in the original IHS database; in reality, however, actual

Table 1. Typographical format for database terms mentioned in the text.

	Table/spreadsheet names	Field names (column headings)	Attributes (table entries)
IHS database	Capitalized Underlined	Capitalized	Capitalized Italicized
	ex.: WELL_TREATMENT	ex.: TRTM_ TYPE	ex.: *FRAC*
DS 868 datasets	Capitalized Bold Underlined	Capitalized Bold	Capitalized Bold Italicized
	ex.: **FRAC_ADDITIVE**	ex.: **ADDITIVE_TYPE**	ex.: ***FRAC***

drill-hole directions include a spectrum of these orientations. The current practice for a single-stage hydraulic fracturing operation (*FRAC* or *REFRAC* TRTM_TYPE) consists of a series of sequenced substages, commonly including a number of different treatment fluid types (TRTM_FLUID_TYPE); for example: (1) *ACID*, followed by (2) one or more sequences of a fracturing fluid (mostly *WATER* that could include *FOAM*, *OIL*, *SLICK WATER*, and (or) *GEL*, etc.) mixed with a proppant (AGENT_TYPE, such as *SAND*, etc.) and an additive (ADDITIVE_TYPE, such as *GELLING AGENT*, *ACID*, *CROSSLINKING AGENTS*, and (or) *SURFACTANT*, etc.), followed by (3) a freshwater flush (for example, *WATER*) (Arthur and others, 2008).

This data series provides temporally aggregated data on hydraulic fracturing treatments (**FRAC_TRTM_TYPE**) and

1. treatment characteristics such as the use of hydraulic fracturing treatment fluids (**FRAC_TRTM_FLUID**), additives (**FRAC_ADDITIVE**), proppants (**FRAC_PROPPANT**), water-based treatment fluid volumes (**WATER-BASED_VOL_PER_WELL_1-99_PERCENTILE**), and drill-hole directions of wells to which the treatments are applied (**FRAC_HOLE_DIRECTION**);

2. hydraulically fractured well characteristics such as drill-hole direction (**FRAC_WELL_HOR_DIR**, **FRAC_WELL_VERT**) and final status or intent of well (**FRAC_WELL_FINAL_STATUS**; for example, ***OIL WELL*** or ***GAS WELL***); and

3. the spatial distributions of locations of both hydraulic fracturing treatments and associated wells spudded in the United States from 1947 through 2010, as a function of **SPUD_YEAR** (initial drill year) and state (**FRAC_WELL_STATE** and **FRAC_TREAT_STATE**), hydrologic unit code (**FRAC_WELL_HUC_US**, **FRAC_WELL_HUC_AK**, **FRAC_TREAT_HUC_US**, and **FRAC_TREAT_HUC_AK**), and geologic province (**FRAC_TREAT_GEO_PROV_5k_00-10**).

Using the Data

This data series can be accessed at *http://dx.doi.org/10.3133/ds868*. This Web page provides links to this document, in portable document format (.pdf), and to a "Downloads directory" that contains the data tables (spreadsheets), in Microsoft Excel (.xlsx) format, organized into five subdirectories. Report files can be accessed through Internet Explorer or another supported Internet browser and Acrobat Reader 7.0 or higher.

Original Data Sources and Processing Steps

Data Source

The original source of the data is the commercial and proprietary IHS database of U.S. production and well data (IHS Energy, 2011).

Hydraulic Fracturing Data Selection

Two standard tables within the original IHS database (IHS Energy, 2011) were used to extract hydraulic fracturing related data: the WELL_TREATMENT and WELL tables. The WELL_TREATMENT table describes the various [well stimulation] treatment (TRTM: *ACID*, acid; *BDA*, breakdown acid; *BKDN*, breakdown fluid; *FLSH*, flush; *NTRL*, natural; *REACID*, re-acidization; *TRET*, treatment; *U*, unreported treatment; *FRAC*, fracturing; and *REFRAC*, refracturing) jobs performed during the life of a well (IHS Energy, 2011). All of these TRTM_TYPEs, except for *FRAC* and *REFRAC*, could be indicative of a number of different types of well stimulation treatments not necessarily related to hydraulic fracturing (such as acidizing jobs to remove damage occurring during drilling and (or) production, or another completion step such as well back-flushing to clean sediments and acid from the well bore).

Generally, the use of a proppant to hold open the fractures is unique to hydraulic fracturing (Elbel and Britt, 2000). The correlation of greater than 99 percent of reported propping agents with *FRAC*/*REFRAC* stimulation treatment types lends credence to the use of *FRAC*/*REFRAC* treatment types to indicate hydraulic fracturing. Therefore, only the records showing *FRAC* or *REFRAC* in the TRTM_TYPE column from the original IHS database WELL_TREATMENT table (IHS Energy, 2011) were queried to most clearly indicate wells in which hydraulic fracturing treatments had been conducted during completion. As such, this data series pertains only to the hydraulic fracturing treatments and associated wells and does not address other stimulation treatments or other well drilling, well completion, or post-completion steps (oil/gas/water production, storage, disposal, etc.).

Stages

Horizontal well completions require multiple stages because it is difficult to maintain pressures sufficient to induce fractures over the complete length of a lateral leg (Arthur and others, 2008). In the original IHS database (IHS Energy, 2011), a single unique well may have one or more hydraulic fracturing or refracturing (*FRAC*/*REFRAC*) treatments (TRTM) associated with it, each consisting of a unique treatment fluid (TRTM_FLUID). Therefore, each *FRAC*/*REFRAC* TRTM_TYPE record could define either a complete single stage or a substage, depending on whether (1) the data were entered separately for each substage as a *FRAC*/*REFRAC* TRTM_TYPE, (2) the data were entered collectively as a single *FRAC*/*REFRAC* TRTM_TYPE, or (3) other stimulation treatment types were considered as part of the scope of the hydraulic fracturing operation. This information is not known because the data were recorded, compiled, and reported by others (IHS Energy, 2011). Ideally, the STAGE or TRTM_OBS_NO columns in the original IHS database WELL_TREATMENT table (IHS Energy, 2011) would provide direct information regarding the stage of the hydraulic fracturing treatment or interval that could be used to indirectly ascertain the stage. These columns, however, are not populated with data. Therefore, multiple stages are not distinguished in this data series—only the total number of ***FRAC/REFRAC*** treatment (**TRTM_TYPE**) records applied to a given well for a given treatment fluid type (**TRTM_FLUID_TYPE**).

Hydraulic Fracturing Data Extraction

Inasmuch as a single well could have multiple *FRAC*/*REFRAC* records, the WELL_TREATMENT table has a primary key comprising multiple attributes, one of which is a foreign key to the WELL table. Therefore, the WELL_TREATMENT table was queried to return only the records with a given stimulation treatment type (TRTM_TYPE) of *FRAC* or *REFRAC* (hydraulic fracturing treatments). It was assumed that each *FRAC*/*REFRAC* record listed in the WELL_TREATMENT table represents a single hydraulic fracturing treatment; therefore, each reference to a "treatment" in the text is actually a reference to a "record."

The WELL table has only one record for each well and uses a single attribute primary key. Once all the queried *FRAC*/*REFRAC* records were compiled, the relation of the WELL table to the WELL_TREATMENT table (such as "one-to-many") was invoked to also get information from the WELL table, as described below.

FRAC/REFRAC TRTM_TYPE Attributes

The *FRAC*/*REFRAC* TRTM_TYPE records from the original IHS database WELL_TREATMENT table were associated with a UWI or unique well identifier in the WELL table (IHS Energy, 2011). The UWIs are not disclosed in this data series (as per USGS agreements with IHS, Inc.) but are used to obtain (1) the well latitude and longitude (PI_SURFACE_LAT and PI_SURFACE_LONG) for grouping/aggregating the wells and treatment records within a given area (state, hydrologic unit, geologic province); (2) the initial drill year (spud year as SPUD_DATE) and (or) the year that the well is ready to produce oil or gas (completion year as PI_COMP_DATE); (3) the associated drill-hole (borehole) direction (HOLE_DIRECTION); and (4) the intent of the well (final status as FINAL_STATUS, such as *OIL WELL* or *GAS WELL*) to which the hydraulic fracturing treatment is applied. After merging all the information, six records without a spud date were removed, inasmuch as the temporal analysis was based on the start date of drilling operations. Removal of these wells is not expected to affect the final statistical summary. Using this master table, subqueries were created to analyze each hydraulic fracturing treatment or hydraulically fractured well attribute individually.

Although a single unique well could have multiple *FRAC*/*REFRAC* treatment records, each *FRAC*/*REFRAC* record may have the following unique attributes: proppant (AGENT_TYPE), treatment fluid type (TRTM_FLUID_TYPE), treatment fluid volume (TRTM_AMOUNT), and (or) additive (ADDITIVE_TYPE). Not every attribute had a value for every *FRAC*/*REFRAC* record, so each attribute analysis had a different sample size. The number of records of each of these reported attributes—including treatment fluid, additive, and proppant types and associated well attributes such as final status and drill-hole directions—were summed for a given spud year to construct the derivative datasets published in this data series, based on the original IHS database (IHS Energy, 2011).

Hydraulic Fracturing Treatment Fluid Volume Data Selection

Water-based treatment fluid volumes (TRTM_AMT) reported in each *FRAC*/*REFRAC* treatment record for water-based treatment fluid types (TRTM_FLUID_TYPE) were converted to common units of cubic meters, m^3 (CUM). Fluid volume data that were reported in units of volume (TRTM_UNIT) lacking standard conversion definitions or that did not have sufficient information to convert to cubic meters (such as *FOOT*, *HOLE*, or *SACK*) were not included in these analyses. The total water volume per well was obtained by summing the volumes of the top 99 percent of all presumed water-based treatment fluid types applied to a given well, reported per era, as follows:

- 1947–1952: *WATER, ACID, FRACTURING, FLUID, SAND GEL FRAC*;
- 1953–1999: *WATER, MY-T-FRAC, ACID, FRACTURING, SAND GEL FRAC, SAND ACID FRAC*; and
- 2000–2010: *WATER, FLUID, GEL, SLICK WATER, CROSSLINK GEL, ACID*.

Temporal Aggregation of Hydraulic Fracturing Data

Ideally, the date of the hydraulic fracturing treatment would be listed in the IHS database (IHS Energy, 2011) WELL_TREATMENT table, in the TRTM_START_DATE column. This column, however, is not populated with data. Because hydraulic fracturing takes place at some time between the well spud date (SPUD_DATE) and the completion date (PI_COMP_DATE), either of these dates could be used to reasonably estimate the date of the *FRAC*/*REFRAC* treatments. In this data series, the *FRAC*/*REFRAC* treatment years were derived by associating the treatments with the spud year of the well rather than the completion year for several reasons:

- the completion year differed from the spud year by no more than one year in 98.5 percent of the wells;
- although the well completion date might refer to hydraulic fracturing activities, it could also possibly refer to a number of other post-drilling activities; the spud date consistently represents the initiation of well drilling and is considered unique;
- more data points (approximately 4,400) were available for the spud year than for the completion year, thus allowing for examination of a larger dataset; and
- the possibility exists that although the well was fractured, the well completion may not have been finalized, which might explain why the final completion date was not reported in some cases.

Data were aggregated temporally over time periods between 1947 (the year hydraulic fracturing was first applied; Montgomery and Smith, 2010) and 2010 (the date of the extent of data availability at the time of compilation) (IHS Energy, 2011). The original IHS database (IHS Energy, 2011) contains approximately 38,903 treatment records associated with well spud years earlier than 1947. These *FRAC*/*REFRAC* treatment records (1) may have been associated with wells fractured using methods other than hydraulic fracturing, (2) may be wells that were originally spudded prior to 1947 and hydraulically fractured at a later date, or (3) may have erroneous spud dates. Because these distinctions cannot be made using these data, the aggregation of data strictly pertaining to hydraulic fracturing is best represented in wells with spud dates from 1947 onward, which was the first year that hydraulic fracturing is thought to have been used to stimulate oil and gas production (Montgomery and Smith, 2010).

Spatial Aggregation of Hydraulic Fracturing Data

The hydraulically fractured well locations (sorted by drill dates and (or) drill-hole directions) were aggregated spatially within USGS hydrologic units,[1] states, and geologic provinces. Distribution counts were created by first overlaying each unique well location (latitude/longitude) on one of the following polygon boundary shape files:

- 1:250,000-scale Hydrologic Units of the United States (by USGS 8-digit hydrologic unit code (HUC)),
- ArcGIS layer of states in the United States, including the 50 states, the District of Columbia, and Puerto Rico, and
- Geologic Provinces of the United States (as defined for the USGS National Oil and Gas Resource Assessment Project).

At the onset of the spatial analysis, the ESRI[2] base map was referenced to the 1984 World Geodetic System (WGS 84), the IHS data locations were referenced to the 1927 North American Datum (NAD 27), the HUC-8 polygons were referenced to the Albers NAD 27 datum (lower 48 states) and the Clark 1866 Albers datum (Alaska), and the Geologic Province polygons were referenced to the 1983 North American Datum (NAD 83). Prior to analysis, all data

[1] A USGS hydrologic unit used is essentially a cataloging unit, which is the smallest geographic area in the hydrologic unit hierarchy and represents part or all of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature, typically a specific stream or river watershed or a part of a larger river watershed.

[2] See appendix 1 for ESRI contact information.

(except for the base map) were re-projected to the WGS 84 datum within ArcGIS. All final maps are referenced to the WGS 84 datum.

The JOIN function in ArcGIS software by ESRI was then used to associate each well location point (latitude/longitude) with an individual area defined by the polygon. Well locations (latitude/longitude) that were not associated with an HUC were removed. As such, offshore wells were excluded from this analysis. The total number of points (of either hydraulically fractured wells or the associated number of hydraulic fracturing treatment records) were then counted within the polygon unit boundaries to create the distributions. The counts provided in this data series represent the number of new wells or treatments applied to new wells that were initially drilled (spudded) in a given year.

Data Series Spreadsheets—Definitions and Attributes

The directories listed below (accessible at *http://dx.doi.org/10.3133/ds868* in the Downloads directory) contain the derivative breakout spreadsheets, in Microsoft[3] Excel (.xlsx) format, that are the result of the spatial and temporal aggregation of data from the original IHS database (IHS Energy, 2011), described above. Spreadsheets are sorted into five directories: Volumes, Distributions, Wells, Treatments, and Keys.

Volumes

- **WATER-BASED_VOL_PER_WELL_1-99_PERCENTILE**—The 1st through 99th percentile of hydraulic fracturing water-based treatment fluid volumes applied to wells spudded from 1947 through 2010, extracted by era and drill-hole direction. Data include the spud year of well, final status of well, drill-hole (borehole) direction of well, sum of volumes of water-based treatment fluid types applied to the well, and units of volume (cubic meters, abbreviated as ***CUM***). Data are arranged into seven sheets/tabs by era (00-10, 2000–2010; 53-99, 1953–1999; 47-52, 1947–1952) and drill-hole direction (***D***, directional; ***V***, vertical; ***H***, horizontal). The water-based fluid types considered in each time period are listed below:
  - 2000–2010: ***WATER, FLUID, GEL, SLICK WATER, CROSSLINK GEL, ACID***;
  - 1953–1999: ***WATER, MY-T-FRAC, ACID, FRACTURING, SAND GEL FRAC, SAND ACID FRAC***; and
  - 1947–1952: ***WATER, ACID, FRACTURING, FLUID, SAND GEL FRAC***.

This spreadsheet includes only the original IHS database well data (IHS Energy, 2011) that had a treatment type of *FRAC* or *REFRAC*, a spud year from 1947 through 2010, a treatment fluid amount, and a volumetric unit. Each row represents a unique well. Note that the median volumes of these data are generally slightly lower than the average volumes (Gallegos and Varela, 2015) and that these data likely do not include all water volumes related to hydraulic fracturing. However, the water-based hydraulic fracturing treatment fluid volume medians and average values were found to be consistent with water-based fluid volumes used to hydraulically fracture wells reported in the literature (Gallegos and Varela, 2015). (Record count: 529,203)

Distributions

- **FRAC_WELL_HUC_US**—Annual count of wells associated with hydraulic fracturing treatment records, spudded in the contiguous United States from 1947 through 2010, during a given year, within USGS hydrologic units, sorted by 8-digit hydrologic unit code (HUC) code, HUC name, drill-hole direction, and spud year. (Record count: 30,842)
- **FRAC_TREAT_HUC_US**—Annual count of hydraulic fracturing treatment records applied to wells spudded in the contiguous United States from 1947 through 2010, during a given year, within USGS hydrologic units, sorted by 8-digit hydrologic unit code (HUC) code, HUC name, drill-hole direction, and spud year. (Record count: 31,991)
- **FRAC_WELL_HUC_AK**—Annual count of wells associated with hydraulic fracturing treatment records, spudded in Alaska from 1947 through 2010, during a given year, within USGS hydrologic units, sorted by 8-digit hydrologic unit code (HUC) code, drill-hole direction, and spud year. (Record count: 74)
- **FRAC_TREAT_HUC_AK**—Annual count of hydraulic fracturing treatment records applied to wells spudded in Alaska from 1947 through 2010, during a given year, within USGS hydrologic units, sorted by 8-digit hydrologic unit code (HUC) code, drill-hole direction, and spud year. (Record count: 74)
- **FRAC_WELL_STATE**—Annual count of wells associated with hydraulic fracturing treatment records, spudded within each state in the United States from 1947 through 2010, during a given year, sorted by state and spud year. (Record count: 1,652)

[3]See appendix 1 for Microsoft contact information.

- **FRAC_TREAT_STATE**—Annual count of hydraulic fracturing treatment records applied to wells spudded within each state in the United States from 1947 through 2010, during a given year, sorted by state and spud year. (Record count: 1,652)
- **FRAC_TREAT_GEO_PROV_5k_00-10**— Number of hydraulic fracturing treatments applied to wells spudded from 2000 through 2010 within each geologic province having at least 5,000 treatments. (Record Count: 16)

Treatments

- **FRAC_ADDITIVE**—Annual count of additive types reported in hydraulic fracturing treatment records applied to wells spudded in the United States from 1947 through 2010, sorted by treatment type (***FRAC*** or ***REFRAC***), additive type, and spud year. (Record count: 1,081)
- **FRAC_HOLE_DIRECTION**—Annual count of hydraulic fracturing treatment records corresponding to drill-hole direction record(s) of associated wells spudded in the United States from 1947 through 2010, sorted by treatment type (***FRAC*** or ***REFRAC***), hole direction type, and spud year. (Record count: 212)
- **FRAC_TRTM_FLUID**—Annual count of treatment fluid types reported in hydraulic fracturing treatment records applied to wells spudded in the United States from 1947 through 2010, sorted by treatment type (***FRAC*** or ***REFRAC***), treatment fluid type, and spud year. (Record count: 1,433)
- **FRAC_PROPPANT**—Annual count of proppant types reported in hydraulic fracturing treatment records applied to wells spudded in the United States from 1947 through 2010, sorted by treatment type (***FRAC*** or ***REFRAC***), proppant [propping agent] type, and spud year. (Record count: 260)
- **FRAC_TRTM_TYPE**—Annual count of hydraulic fracturing treatment type (***FRAC*** or ***REFRAC***) records applied to wells spudded in the United States from 1947 through 2010, sorted by treatment type and spud year. (Record count: 87)

Wells

- **FRAC_WELL_HOR_DIR**—Annual count of horizontal and directional wells associated with hydraulic fracturing treatment records, spudded in the United States from 1947 through 2010, sorted by spud year. (Record count: 62)
- **FRAC_WELL_VERT**—Annual count of vertical wells associated with hydraulic fracturing treatment records, spudded in the United States from 1947 through 2010, sorted by spud year. (Record count: 64)
- **FRAC_WELL_FINAL_STATUS**—Annual count of final status records of wells associated with hydraulic fracturing treatments, spudded in the United States from 1947 through 2010, sorted by treatment type (***FRAC*** or ***REFRAC***), final status, and spud year. (Record count: 609)

Keys

- **ADDITIVE_KEY**— Definitions of abbreviated attributes used in **ADDITIVE_TYPE** fields.
- **HOLE_DIRECTION_KEY**— Definitions of abbreviated attributes used in **HOLE_DIRECTION_TYPE** fields.
- **PROPPANT_KEY**— Definitions of abbreviated attributes used in **PROPPANT_TYPE** fields.
- **TRTM_FLUID_KEY**— Definitions of abbreviated attributes used in **TRTM_FLUID_TYPE** fields.
- **TRTM_TYPE_KEY**—Definitions of abbreviated ***FRAC*** and ***REFRAC*** treatment types.

Field Names—Definitions, Data Types, and Descriptions

- **ADDITIVE**—(text) Long name of chemical additive used in the treatment fluid during the hydraulic fracturing well treatment job (***ACID***, ***SURFACTANT***, ***GELLING AGENT***, etc.) (IHS Energy, 2011).
- **ADDITIVE_TYPE**—(text) Code identifying the type of additive (***ACID***, ***SFAC***, ***GELLA***, etc.) (IHS Energy, 2011).
- **FINAL_STATUS**—(text) The final status or intent of the well (***OIL WELL***, ***GAS WELL***, etc.) (IHS Energy, 2011).
- **HOLE_DIRECTION**—(text) Long name of the direction of the borehole (***VERTICAL***, ***DIRECTIONAL***, ***HORIZONTAL***, etc.) (IHS Energy, 2011).
- **HOLE_DIRECTION_TYPE**—(text) Code indicating borehole direction (***V***, ***D***, ***H***, etc.).

- **HUC_CODE**—(number) Unique 8-digit code indicating a USGS hydrologic unit.
- **HUC_NAME**—(text) Name associated with the 8-digit hydrologic unit code.
- **NUM_FRAC_WELLS_HORIZ_DIR**—(number) Count of horizontal and directional wells associated with hydraulic fracturing treatment record(s), spudded in the United States from 1947 through 2010, per given spud year.
- **NUM_FRAC_WELLS_VERT**—(number) Count of vertical wells associated with hydraulic fracturing treatment record(s), spudded in the United States from 1947 through 2010, per given spud year.
- **NUM_TRTM_RECORDS_00-10**—(number) Count of treatment records listed from 2000 through 2010.
- **PROPPANT_TYPE**—(text) Code identifying the type of proppant (propping agent) used in the hydraulic fracture treatment (***SAND***, ***CER***, ***WLNT***, etc.).
- **PROPPANT**—(text) Long name of proppant (propping agent) used in the hydraulic fracturing treatment fluid (***SAND***, ***CERAMICS***, ***WALNUT HULLS***, etc.) (IHS Energy, 2011).
- **PROVINCE_NAME**—(text) name of the geologic boundaries of provinces as defined for the U.S. Geological Survey's National Oil and Gas Resource Assessment Project.
- **SPUD_YEAR**—(year) Date the drilling operations began on the well, as YYYY (IHS Energy, 2011).
- **STATE**—(text) Name of the U.S. state.
- **SUM_WATER_AMT**—(number) Sum of all water-based fluid volumes (for the top 99 percent of water-based treatment fluid types reported during the periods of 1947–1952, 1953–1999, 2000–2010) used to hydraulically fracture a given well (IHS Energy, 2011). Units converted to cubic meters (abbreviated ***CUM*** in the table).
- **TRTM**—(text) Long name of [stimulation] treatment job (***FRACTURING*** or ***RE-FRACTURING***) (IHS Energy, 2011).
- **TRTM_FLUID**—(text) Long name of treatment fluid used in drilling operation of the well (***WATER***, ***ACID***, ***SLICK WATER***, etc.) (IHS Energy, 2011).
- **TRTM_FLUID_TYPE**—(text) Code identifying the type of treatment fluid (***W***, ***A***, ***SLKWTR***, etc.) (IHS Energy, 2011).
- **TRTM_TYPE**—(text) Code identifying the type of treatment job (***FRAC*** or ***REFRAC***).
- **WATER_AMT_UNIT**—(text) Water volume units in cubic meters. Units acquired from the original version of the database were converted to cubic meters. If there was no apparent unit conversion available, the data were not included.

Links to Spatial Files Used

- 1:250,000-scale Hydrologic Units of the United States (by USGS 8-digit hydrologic unit codes): *http://water.usgs.gov/GIS/metadata/usgswrd/XML/huc250k.xml*
- ArcGIS layer of states in the United States, including the 50 states, the District of Columbia, and Puerto Rico: *http://www.arcgis.com/home/item.html?id=1a6cae723af14f9cae228b133aebc620*
- Geologic Provinces of the United States: *http://certmapper.cr.usgs.gov/data/noga95/natl/spatial/doc/pr_natlg.htm*

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- Data in the original IHS database (IHS Energy, 2011) is largely collected and reported by others and, like any other database, is subject to error. Although criteria were applied to remove the obviously flawed or questionable data (such as latitudes and longitudes not associated with a U.S. state or HUC; wells with spud dates prior to the advent of hydraulic fracturing; volumes with irreconcilable units of measure), the culling of unrepresentative data is considered incomplete.
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- Although the dates of initial hydraulic fracturing treatments were not given, the approximate dates were derived by associating hydraulic fracturing with the well spud dates.
- The data evaluated herein from the original IHS database (IHS Energy, 2011) and resulting data series likely do not represent all hydraulically fractured wells or hydraulic fracturing treatments in the United States. Therefore, the number of wells and hydraulic fracturing treatments and their attributes listed in this data series may not be completely represented by the entries.
- Each individual well and individual treatment record within the original IHS database (IHS Energy, 2011) was not independently substantiated. Furthermore, the data have not been evaluated for depiction of trends on small scales (such as a well-by-well basis or by individual hydraulic fracturing treatment). However, the data (derived from the original IHS database [IHS Energy, 2011]) aggregated over time and (or) spatial areas in this data series were evaluated and found to be consistent with the literature (Gallegos and Varela, 2015). Therefore, these data are deemed sufficiently accurate to compute statistics that provide an indication of tendencies of hydraulic fracturing treatments and hydraulically fractured wells within geographically and geologically defined areas (for example, states, geologic provinces, HUCs) and over defined periods of years (for example, 1947–1952, 1953–1999, 2000–2010).
- HUC and Geologic Provinces boundaries may have changed over time.

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Montgomery, C.T., and Smith, M.B., 2010, Hydraulic fracturing—History of an enduring technology: Journal of Petroleum Technology, v. 62, no. 12, p. 26–32.

Appendix 1. Manufacturers of Products and Services Mentioned

Microsoft (makers of Office software, including Access and Excel)
One Microsoft Way
Redmond, WA 98052-6399
http://support.microsoft.com/contactus/

ESRI (Environmental Systems Research Institute, Inc.) (makers of ArcGIS and ArcVIEW)
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