

Method for Compiling Temporally and Spatially Aggregated Data on Hydraulic Fracturing—Treatments and Wells

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By Brian A. Varela and Tanya J. Gallegos

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
Volume		
barrel (bbl; petroleum, 1 barrel=42 gal)	0.1590	cubic meter (m ³)
quart (qt)	0.9464	liter (L)
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m ³)
gallon (gal)	3.785	cubic decimeter (dm ³)
million gallons (Mgal)	3,785	cubic meter (m ³)
cubic inch (in ³)	16.39	cubic centimeter (cm ³)
cubic inch (in ³)	0.01639	cubic decimeter (dm ³)
cubic inch (in ³)	0.01639	liter (L)
cubic foot (ft ³)	28.32	cubic decimeter (dm ³)
cubic foot (ft ³)	0.02832	cubic meter (m ³)
cubic yard (yd ³)	0.7646	cubic meter (m ³)
acre-foot (acre-ft)	1,233	cubic meter (m ³)
Mass		
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	metric ton (t)
ton, long (2,240 lb)	1.016	metric ton (t)

International System of Units to U.S. customary units

Multiply	By	To obtain
Volume		
cubic meter (m ³)	6.290	barrel (bbl; petroleum, 1 barrel = 42 gal)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
cubic meter (m ³)	264.2	gallon (gal)
cubic decimeter (dm ³)	0.2642	gallon (gal)
cubic meter (m ³)	0.0002642	million gallons (Mgal)
cubic decimeter (dm ³)	0.03531	cubic foot (ft ³)
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)
Mass		
kilogram (kg)	2.205	pound avoirdupois (lb)
metric ton (t)	1.102	ton, short (2,000 lb)
metric ton (t)	0.9842	ton, long (2,240 lb)

Abbreviations

API	American Petroleum Institute
BBL	barrel
CF	cubic feet
COMP_YEAR	completion year of well
CUM	cubic meters
FINAL_STATUS	code to identify well as either oil or gas well
GAL	gallon
GEO_PROV	geologic province of the well
HOLE_DIRECTION	short name of the orientation of the well borehole
HOLE_DIR_NAME	long name of the orientation of the well borehole
IHS	IHS Markit
JDBC	Java Database Connectivity
LAT	latitude
LB	pound
LON or LONG	longitude
MCF	thousand cubic feet
MS	Microsoft
PI_COMP_DATE	completion date of well
PIDM	Oracle IHS database (IHS Markit, 2019)
QT	quart
SPUD_DATE	date that well was spud
USGS	U.S. Geological Survey
UWI	unique well identifier

Method for Compiling Temporally and Spatially Aggregated Data on Hydraulic Fracturing—Treatments and Wells

By Brian A. Varela and Tanya J. Gallegos

Abstract

This report provides a step-by-step method for compiling hydraulic fracturing data in the United States (U.S.) from the IHS Markit, 2019, U.S. Well History and Production Relational Database (IHS Markit, 2019). Data on hydraulically fractured wells include their location (geologic province, State, county), well type (oil or gas), orientation (directional, horizontal, or vertical), spud date, completion date and the hydraulic fracturing treatments, treatment fluids types, treatment fluid volumes, additive types, agent types (“proppants”), and proppant amounts injected. This method also describes how to associate each unique well with the hydraulic fracturing treatments to provide an indication of the total amount of all treatment fluids injected into a well for hydraulic fracturing and the volume of each individual treatment fluid type injected.

Introduction

Hydraulic fracturing is a well stimulation technique applied to oil and gas wells to enhance the production of oil and gas from low permeability reservoirs (Coleman, 2009; Montgomery and Smith, 2010). The technique involves injecting treatment fluid(s) mixed with a propping agent or “proppant” (such as sand) into a well bore to fracture the host rock and create pathways for the oil and gas to flow to the well bore (Veatch, 1983a, b; Ground Water Protection Council and ALL Consulting, 2009; Montgomery and Smith, 2010). Treatment fluids contain a base fluid (such as water, gel, or oil) that is amended with various chemicals or additives, depending on the properties of the target hydrocarbon, reservoir, and the desired fracture geometry (Economides and Nolte, 2000; Elbel and Britt, 2000; Gulbis and Hodge, 2000; U.S. Environmental Protection Agency, 2004; Holditch, 2007). Hydraulic fracturing has historically been applied to wells of a vertical, directional, or horizontal orientation (Ground Water Protection Council and ALL Consulting, 2009). Data regarding these aspects of

hydraulically fractured wells and their treatments are found in the IHS Markit, 2019, U.S. Well History and Production Relational Database (IHS Markit, 2019). Several processing steps are needed to both extract the pertinent data and link the hydraulically fracturing wells to their associated hydraulic fracturing treatments.

Purpose

The purpose of this report is to provide a step-by-step method for compiling data from the IHS Markit, 2019, U.S. Well History and Production Relational Database (IHS Markit, 2019) in a consistent and repeatable manner to achieve data that describe the quantifiable aspects of hydraulic fracturing. The well data are compiled according to their location (geologic province, State, county), well type (oil or gas) and orientation (directional, horizontal, or vertical), spud date, and completion date. The wells are also associated with hydraulic fracturing treatments, treatment fluids type, treatment fluid volumes, additive types, agent types (“proppants”), and proppant amounts used for hydraulic fracturing as defined by IHS Markit (2019). Original data are proprietary and are not provided here but are available through IHS Markit (2019).

Data and Requirements

Data on Hydraulically Fractured Oil and Gas Wells

Data are from the IHS Markit (IHS), U.S. Well History and Production Relational Database (see <http://www.ihsenergy.com>) (IHS Markit, 2019). IHS currently offers two versions of this database, an online version (Enerdeq) and a local Oracle IHS database (PIDM) based on a PIDM data model (referred to as “PIDM” in this report) (IHS Markit, 2019). This report is written for the local Oracle version (based on PIDM Data Model 2.5.3 released February 2012) because it

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matches standards defined for petroleum industry databases (IHS Markit, 2019). Tabular data include the following:

- Tables WELL and WELL_TREATMENT
- Code tables R_FINAL_STATUS, R_ADDITIVE_TYPE, COUNTY, GEOLOGIC_PROV, PROPPANT_TYPE, PROVINCE_STATE, TREATMENT_FLUID, TREATMENT_TYPE, and WELL_PROFILE_TYPE.

Programs Used

- Microsoft (MS) Access 2010, released June 5, 2010 (see <https://products.office.com/en-US/>);
- Microsoft Excel 2010, released June 5, 2010 (see <https://products.office.com/en-US/>); and
- Java Development Kit (JDK) version 8, released March 2014 (see <https://www.oracle.com/technetwork/java/javase/downloads/jdk8-downloads-2133151.html>).

User Requirements

The user of the method described herein requires access to the IHS Markit (IHS), U.S. Well History and Production Relational Database (IHS Markit, 2019). The user also must have the ability to connect to an Oracle database directly using Java Database Connectivity (JDBC). The use of this method requires an understanding of programming, and specifically, the ability to compile and run a Java program. The user should also understand relational databases, most notably, the relationships between tables and the structure of the Oracle IHS database (PIDM) (IHS Markit, 2019). Finally, the user

should be proficient in Microsoft (MS) Office products such as Access, Excel, and Word.

Naming Conventions

Terms from the PIDM are set in all capital letters; PIDM table names are capitalized and underlined (for example, WELL_TREATMENT); schemas are capitalized, italicized, and underlined (for example, *PI_CODES*); IHS field names (column headings) are capitalized (for example, TRTM_UNIT); and table entries (values) are capitalized and italicized (for example, *GAL*) (table 1). Filenames created using this method are in quotation marks (for example, “fracworksheet.xlsx”). MS Access filenames are in bold and in quotes (for example, “**master tables.accdb**”), table names within MS Access database files are bold and underlined (for example, **Master Treatment**), query names within MS Access are italicized, bold and underlined (for example, **Treatments w codes**), field names within MS Access tables are all capitalized and bold (for example, **UWI**), and table entries within MS tables are all capitalized, bold, and italicized (for example, ***GAS WELL***). Also, when creating MS Access files, we use “[vintage year of PIDM]” and “[start date of compilation]” to indicate the year of the PIDM release and date that the data compilation was started, respectively. Since this process can be used for a single year or groups of multiple years, we use “[start year of interest – end year of interest]” when naming tables or queries and use “year(s) of interest” when referring to all the different groupings of years (for example, “for each year(s) of interest, create a new table called **Table Example-[start year of interest–end year of interest]**”). This is only a concern from step 5 onward. It should also be noted that users must modify many of the “checks” in the “fracworksheet.xlsx” file if this method is used to compile multiple year groupings.

Table 1. File naming conventions. [IHS, IHS Markit (IHS Markit, 2019); MS, Microsoft; PIDM, Oracle IHS database (IHS Markit, 2019)]

Item	Capitalized	Underlined	Italicized	Quotation marks	Bold	Example
Terms from PIDM	X					PIDM
IHS table name	X	X				<u>WELL_TREATMENT</u>
Schemas	X	X	X			<u>PI_CODES</u>
IHS field names (column headings)	X					TRTM_UNIT
Table entries (values)	X		X			<i>GAL</i>
Filenames				X		“fracworksheet.xlsx”
MS Access filenames				X	X	“ master tables.accdb ”
Table names within MS access		X			X	<u>Master Treatment</u>
Query names within MS Access		X	X		X	<u>Treatments_w_codes</u>
Field names within MS Access tables	X				X	UWI
Table entries within MS Access table	X		X		X	<i>GAS WELL</i>

Process Steps

Step 1: Convert treatment amounts

Use the Java program, “ConvertTreatments” (appendix 1) to convert the various treatment units (TRTM_UNIT) including *GAL* (gallon), *QT* (quart), *BBL* (barrel), *CF* (cubic feet) and *MCF* (thousand cubic feet) into *CUM* (cubic meters) as well as to convert proppant amounts (AGENT_UNIT) from *TON* (tons) into *LB* (pounds). Convert units for all records within the IHS WELL_TREATMENT table that have a value for either the treatment fluid amount (TRTM_AMOUNT) or the proppant amount (AGENT_AMOUNT). Only convert units that have a conversion factor in the PIDM (see appendix 2 for a list of IHS unit conversion factors) (IHS Markit, 2019); all other units will be ignored.

Step 2: Create files for data storage

- Create a new Microsoft (MS) Access file called “HydroFRAC-[vintage year of PIDM]-ConvertedTreatments-[start date of compilation].accdb”.
- From here forward “HydroFRAC-[vintage year of PIDM]-ConvertedTreatments-[start date of compilation].accdb” will be referred to as “converted treatments.accdb”.
- The output data could be stored in either a single MS Access file or in multiple MS Access files, depending on size limitations. If multiple files are used, then additional filenames should

be consecutively numbered and appended with the “file number of total number of files” (for example, “HydroFRAC-[vintage year of PIDM]-MasterTables-[start date of compilation]-1 of 2.accdb”).

- Create a MS Access file called “HydroFRAC-[vintage year of PIDM]-MasterTables-[start date of compilation].accdb”.
- From here forward “HydroFRAC-[vintage year of PIDM]-MasterTables-[start date of compilation].accdb” will be referred to as “master tables.accdb”.
- The output data could be stored in either a single MS Access file or in multiple MS Access files, depending on size limitations. If multiple files are used, then additional filenames should be consecutively numbered and appended with the “file number of total number of files” (for example, “HydroFRAC-[vintage year of PIDM]-MasterTables-[start date of compilation]-1 of 2.accdb”).
- Open a MS Excel file called “HydroFRAC-Template-Worksheet.xlsx” and save it as “HydroFRAC-[vintage year of PIDM]-Worksheet-[start date of compilation].xlsx”. Copy the template in appendix 2 into this Excel file. This file will be used to check the counts to assure that data have not been lost as specified throughout this report.
- From here forward, “HydroFRAC-[vintage year of PIDM]-Worksheet-[start date of compilation].xlsx” will be referred to as “fracworksheet.xlsx” file.

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- Create a text file called “README.txt”.
 - Use this file to record information about the various tables and files.
 - List information such as the data source, date of creation, name of person who created the file, methods/steps used to compile the data, list of field names, and what the data represent including the year(s) of compilation and any other definitions or explanations needed to document the origin, processing steps, methods, and quality.
- In the “fracworksheet.xlsx” file, record the number of records by treatment unit (TRTM_UNIT) and the number of records by proppant unit (AGENT_UNIT) (only of the *FRAC* or *REFRAC* treatment types) found in the original IHS WELL_TREATMENT table.
- Compare the counts of converted treatment fluid units (TRTM_UNIT) and converted proppant units (AGENT_UNIT). In the “fracworksheet.xlsx” file, explain discrepancies (if any) between original IHS WELL_TREATMENT and **usgs_treatment** tables.
- Differences in counts could arise because not all treatment fluid (TRTM_FLUID_TYPE) units (TRTM_UNIT) or proppant (AGENT_TYPE) units (AGENT_UNIT) are converted. Note the following:
 - Treatment fluid units (converted): *GAL*, *BBL*, *QT*, *CF*, and *MCF*;
 - Proppant units (converted): *LB* and *TON*;
 - Treatment fluid units (not converted): *NULL*, *LB*, *TON*, *HOLE*, *SACK*, and *FT*; and
 - Proppant units (not converted): *NULL* and *SACK*.

Step 3: Use Microsoft Access to store data from “converted treatments” database and from the PIDM

- Import the converted treatments comma separated values (.csv) file from the ConvertedTreatments Java program into MS Access “**converted treatments.accdb**” as a new table named JAVA_Converted_Treatments.
- Change the primary key for the JAVA_Converted_Treatments table to match the primary key of the IHS WELL_TREATMENT table UWI, SOURCE, TRTM_OBS_NO, TRTM_TYPE for consistency and record the total record count of JAVA_Converted_Treatments in the “fracworksheet.xlsx” file.
- Export only the TRTM_TYPE of *FRAC* and *REFRAC* converted records with codes to MS Access “**master tables.accdb**” and name the table JAVA_Converted_Treatments_FRAC_REFRAC.
- Connect MS Access to an Oracle IHS database (IHS Markit, 2019). MS Access could be linked to an Oracle IHS database (IHS Markit, 2019) using an Oracle Database Connectivity (ODBC) driver, however, a user could also connect using OraNet or other drivers depending on what database software is used. Link the WELL and WELL_TREATMENT tables from the PIDM into the “**master tables.accdb**”.
- Create a new **usgs_treatment** table in the “**master tables.accdb**” by merging the IHS WELL_TREATMENT with the converted treatment fluid amount (TRTM_AMOUNT) and proppant amount (AGENT_AMOUNT) from the JAVA_Converted_Treatments_FRAC_REFRAC table in the “**master tables.accdb**”.
- In the “fracworksheet.xlsx” file, record the number of records listed in the IHS WELL_TREATMENT and the **usgs_treatment** tables.
- Records are converted if either the treatment amount (TRTM_AMOUNT) or the proppant amount (AGENT_AMOUNT) has a value.
- Note that the counts for converted records from the **usgs_treatment** table will not likely match counts for TRTM_UNIT and AGENT UNIT from the IHS WELL_TREATMENT because a record could have a proppant amount and not a treatment fluid amount or vice versa.

Step 4: Create a master treatment table

- Record the count of *FRAC* and *REFRAC* records from the IHS WELL_TREATMENT table and the **usgs_treatment** table in the “fracworksheet.xlsx” file.
- It is possible that the count for *FRAC* and *REFRAC* records for IHS WELL_TREATMENT and **usgs_treatment** tables could be the same but highly unlikely since not all units are converted from WELL_TREATMENT. Furthermore, there are cases where a record can have a proppant amount (AGENT_AMOUNT) but not a treatment amount (TRTM_AMOUNT). It is more likely that the record count for **usgs_treatment** table will be less than the record count for IHS WELL_TREATMENT. There should never be more *FRAC* and *REFRAC* records in the **usgs_treatment** table than in the IHS WELL_TREATMENT table because the

usgs_treatment table is created from the IHS WELL_TREATMENT table.

- Create a query called Treatments_w_codes in the “converted_treatments.accdb” to link code information from the IHS tables in the PI_CODES schema (R_ADDITIVE_TYPE, R_PROPPANT_TYPE, R_TREATMENT_FLUID, and R_TREATMENT_TYPE) to the usgs_treatment table to convert the IHS codes to full text. Note that PI_CODES is a schema that holds all the tables that convert “codes” to their actual value, therefore, the PI_CODES table converts “FRAC” to “Fracturing”.
- Make sure the joined IHS PI_CODES tables are specified to retain all converted records and only retain IHS PI_CODES records, when available.
- Include field names: UWI, SOURCE, TRTM_OBS_NO, TRTM_TYPE, TRTM_TYPE_NAME, TEST_TYPE, RUN_NO, TEST_NUMBER, TRTM_START_DATE, ADDITIVE_TYPE, ADDITIVE_TYPE_NAME, TRTM_FLUID_TYPE, TRTM_FLUID_TYPE_NAME, TRTM_AMOUNT, TRTM_UNIT, AGENT_TYPE, AGENT_NAME, AGENT_AMOUNT, and AGENT_UNIT.
- In the “fracworksheet.xlsx” file, record the number of records in the Treatments_w_codes query after linking the IHS PI_CODES.
- Verify that the number of Treatments_w_codes query records match the number of records in the usgs_treatment table. The number of records in the query should be the exact same as the number in the usgs_treatment table. This provides the following:
 - Verifies that records were not inadvertently removed because they did not have a code;
 - Verifies that codes are connected correctly and that the code name has been added (for example, FRAC [TRTM_TYPE] now has an additional column [TRTM_TYPE_NAME] in this case, “Fracturing”);
 - Checks that if a code is empty (for example, the ADDITIVE_TYPE is empty) then the entire record is not removed when records are joined.
- If the number of records in the Treatments_w_codes query agrees with the number of records in the usgs_treatment table, create a new table from the Treatments_w_codes query in the previous step that includes only the FRAC and REFRAC records with codes. Export the new table to the “master_tables.accdb” database file calling the new table Master Treatment table, within the “master_tables.accdb” file.
 - If the record counts do not agree, repeat step 4.
- Check that the Master Treatment table record count matches the FRAC and REFRAC count from the usgs_treatment table. Because the query from the previous step was used to create a new table called Master Treatment table within the “master_tables.accdb”, this step verifies that the Treatments_w_codes query and Master Treatment table both have the same number of FRAC and REFRAC records. Record counts should match before proceeding to the next step.
 - If the record counts do not match, delete the Master Treatment table and repeat step 4.
- Use the Master Treatment table to create a query called Unique UWIs using the “Group by” function to obtain the count of unique wells (UWIs) from the Master Treatment table.
- Record the count of unique wells (UWIs) from the Unique UWIs query to get all the well information for the UWIs in the Master Treatment table. The count is used to verify the number of wells after adding the well information.
- Record explanations and information regarding the Master Treatment table data in the README text file.

Step 5: Create master wells table(s)

Step 5a: Compile FRAC/REFRAC wells from the PIDM and check

- Using the Unique UWIs query from the previous step, create a new query called Unique UWIs_w_codes. Link the unique UWIs from the Unique UWIs query to the IHS WELL table and to the IHS database (IHS Markit, 2019) code tables schema (PI_CODES) to obtain the following well field names:
 - From IHS WELL table
 - SPUD_DATE, PI_COMP_DATE, COMP_YEAR, PI_SURFACE_LAT as LAT, PI_SURFACE_LONG as LON; and
 - From IHS code tables (PI_CODES)
 - PI_R_FINAL_STATUS.LONG_NAME as FINAL_STATUS, R_COUNTY.LONG_NAME as COUNTY, R_PROVINCE_STATE.LONG_NAME as STATE, R_GEOLOGIC_PROV.LONG_NAME as GEO_PROV, and R_WELL_PROFILE_TYP.LONG_NAME as HOLE_DIR_NAME.

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- When linking codes, keep all original records (UWIs from the Unique UWI query) and add only the IHS PI_CODES table field names that match.
 - Note that because of a technical issue with MS Access, the user must change the identifier for PI_SURFACE_LAT to LAT and PI_SURFACE_LONG to LON.
- In the “fracworksheet.xlsx” file, record the number of records in the Unique UWIs w codes query after linking the codes. Make sure that the number of unique UWIs in the Unique UWIs w codes query matches the count of unique UWIs from the Unique UWIs query.
- If the count of unique UWIs in the Unique UWIs query match the count from the Unique UWIs w codes query, use the Unique UWIs w codes query to create a new query called Master Well Table-All.
 - If the counts do not match, make sure the Unique UWIs query is correct following step 4 and repeat step 5a.
- Create another temporary query based on the Master Well Table-All query using the “Group By” and “Count” functions to get the counts by State:
 - “Group By” PROVINCE_STATE and “Count” UWI.
 - The difference between the count by State from the Master Well Table-All query and the count by State from Master Well Table-Land query is equal to the number of offshore wells.
- In “fracworksheet.xlsx” file, record the total number of wells listed in the Master Well Table-Land query. Check that the number of wells matches the counts from Master Well Table-All query by State (not including the offshore State codes).
 - If counts do not match, repeat step 5b.

Step 5b: Compile FRAC/REFRAC onshore wells and check

- Using the Master Well Table-All query create a temporary query to obtain the count of wells by State using SQL's (Structured Query Language) “Group By” and “Count” functions.
 - “Group By” PROVINCE_STATE and “Count” UWI.
 - Since the Master Well Table-All query contains all the unique UWIs that had a FRAC or REFRAC treatment, this step should provide a count of the FRAC or REFRAC wells by State.
 - In the “fracworksheet.xlsx” file, record the count of UWIs by State.
- Create another query called Master Well Table-Land [based on the Master Well Table-All query]. Remove all offshore wells by excluding entries with a PROVINCE_STATE value greater than 50.
 - The process uses IHS PROVINCE_STATE values to determine if a well is offshore or onshore. We assume onshore wells have a PROVINCE_STATE value that is equal to one of the 50 States in the United States and those wells without value or with a value that is not equal to one of the 50 States in the United States are assumed to be located offshore presumably in waters outside of the continental land mass.

Step 5c: Compile FRAC/REFRAC onshore wells completed during the years of interest and check

- Using the Master Well Table-Land query, create a temporary query to get the count of wells by State using the “Group By” and “Count” functions.
 - “Group By” COMP_YEAR and “Count” UWI.
 - Since the Master Well Table-Land query contains all the onshore unique UWIs that had a FRAC or REFRAC treatment, this step should provide a count of the FRAC or REFRAC wells by completion year.
 - In the “fracworksheet.xlsx” file, record the count of UWIs by COMP_YEAR listed in the temporary Master Well Table-Land query.
- From this point on, the user can compile data for various year(s) of interest by repeating each of the following steps for each grouping (“[start year of interest-end year of interest]” of completion year (for example, 2000, or 2000–2010).
 - Create query/queries from Master Well Table-Land query to obtain all wells by COMP_YEAR for the year(s) of interest and call the query/queries Master Well Table-Land-[start year of interest-end year of interest] query/queries.
 - Record the record count for each Master Well Table-Land-[start year of interest-end year of interest] query in the “fracworksheet.xlsx” file.
 - Compare the Master Well Table-Land-[start year of interest-end year of interest] query counts by COMP_YEAR for each range of year(s) of interest to the counts by COMP_YEAR from the Master Well Table-Land temporary query. Check that the

record counts by **COMP_YEAR** match for wells in year(s) of interest.

- If counts do not match, repeat step 5c.

Step 5d: Compile FRAC/REFRAC oil and gas onshore wells completed in the years of interest and check.

- Create a new query/queries for each Master Well Table-Land-[start year of interest-end year of interest] query and only include wells that have a **FINAL_STATUS** of either **OIL WELL** or **GAS WELL**. Name the query/queries as follows: Master Well Table-Land-OilGas-[start year of interest-end year of interest].
- Using the Master Well Table-Land-[start year of interest-end year of interest] queries for each year(s) of interest, record the counts of the **FINAL_STATUS** in the “fracworksheet.xlsx” file.
- Check that the count from the Master Well Table-Land-[start year of interest-end year of interest] queries of all **FINAL_STATUS** matches the Master Well Table-Land-OilGas-[start year of interest-end year of interest] queries for only the **FINAL_STATUS** of type **OIL WELL** and **GAS WELL**.
- If counts do not match, repeat step 5d.

Step 5e: Compile FRAC/REFRAC, horizontal, vertical, directional, oil and gas onshore wells completed for year(s) of interest.

- Within each Master Well Table-Land-OilGas-[start year of interest-end year of interest] query created and checked in the previous step containing **FRAC/REFRAC** wells, **OIL WELL**, and **GAS WELL** records for each year(s) of interest, count the **HOLE_DIRECTION** records and record this count in the “fracworksheet.xlsx” file.
- Create a new query/queries based on each Master Well Table-Land-OilGas-[start year of interest-end year of interest] query called Master Well Table-Land-OilGas-DHV-[start year of interest-end year of interest] query and only include wells that have a **HOLE_DIRECTION** of either **HORIZONTAL**, **DIRECTIONAL**, or **VERTICAL**.
- Verify that the counts of **HOLE_DIRECTION** records from each Master Well Table-Land-OilGas-DHV-[start year of interest-end year of interest]

interest] query match the count of records with a **HOLE_DIRECTION** of **HORIZONTAL**, **DIRECTIONAL**, or **VERTICAL** in the Master Well Table-Land-OilGas-[start year of interest-end year of interest] query.

- These counts should match because one is a subset of the other. This is a check to verify that errors were not made when querying only the vertical, directional, and horizontal wells.
- If counts do not match, repeat step 5e.

Step 5f: Create table(s) of FRAC/REFRAC horizontal, directional, oil and gas onshore wells completed in the year(s) of interest.

- For each Master Well Table-Land-OilGas-DHV-[start year of interest-end year of interest] query, record the number of records in the “fracworksheet.xlsx” file.
- Use each Master Well Table-Land-OilGas-DHV-[start year of interest-end year of interest] query/queries to create a table(s) called Master Well Table-[start year of interest-end year of interest].
- After creating each Master Well Table-[start year of interest-end year of interest] table, record the total number of records and check against the record count of the corresponding Master Well Table-Land-OilGas-DHV-[start year of interest-end year of interest] query.
- If counts do not match, repeat step 5f.
- Update the README text file with information about the various tables and files, such as data source, date of creation, name of the person who created the file, methods/steps used to compile the data, list of field names, and what the data represent including years of interest and any other definitions or explanations needed to document the origin, processing steps, methods, and (or) quality.

Step 6: Create master table(s)

- Link the well information to the treatment information to create a “Master Table”.
- Create a query called Master TableO-[start year of interest-end year of interest] based on each Master Well Table-[start year of interest-end year of interest] and link the Master Treatment table to each Master Well Table-[start year of interest-end year of interest] using the UWI.

8 Method for Compiling Temporally and Spatially Aggregated Data on Hydraulic Fracturing—Treatments and Wells

- This step results in a ***Master Table*** query that contains all the ***FRAC/REFRAC*** treatments for all onshore wells in the U.S. by State completed in the years of interest that have a **FINAL STATUS** of ***OIL WELL*** or ***GAS WELL*** and a **HOLE DIRECTION** of ***HORIZONTAL, DIRECTIONAL,*** or ***VERTICAL***.
- Check that data were not lost in the compilation.
 - In the “fracworksheet.xls” file, record the counts of the UWIs listed in the **Master Well Table-[start year of interest-end year of interest]**.
 - Using the ***Master TableO-[start year of interest-end year of interest]*** query/queries, create a temporary query for each year(s) of interest. Count the unique UWIs, which should match the number of wells (UWIs) from the **Master Well Table-[start year of interest-end year of interest]** of the same year(s) of interest.
 - If count does not match, repeat step 6.
 - If the count of unique wells (UWI) from the ***Master TableO-[start year of interest-end year of interest]*** query matches the count of UWIs from **Master Well Table-[start year of interest-end year of interest]**, make a table for each year(s) of interest and call the table(s) **Master Table-[start year of interest-end year of interest]**. Record the total number of records in each table in the “fracworksheet.xls” file. The record count from **Master Table-[start year of interest-end year of interest]** should match the corresponding record count from ***Master TableO-[start year of interest-end year of interest]***.
 - If records counts do not match, repeat step 6.
 - Include the field names: **UWI, SPUD_DATE, PI_COMP_DATE, COMP_YEAR, STATE, COUNTY, HOLE_DIRECTION, HOLE_DIR_NAME, GEO_PROV, FINAL_STATUS, LAT, LON, SOURCE, TRTM_OBS_NO, TRTM_TYPE, TRTM_TYPE_NAME, TEST_TYPE, RUN_NO, TEST_NUMBER, TRTM_START_DATE, ADDITIVE_TYPE, ADDITIVE_TYPE, NAME, TRTM_FLUID, TRTM_FLUID_NAME, TRTM_AMOUNT, TRTM_UNIT, AGENT_TYPE, AGENT_TYPE_NAME, AGENT_AMOUNT, and AGENT_UNIT.**
 - Update the README text file with information about the various tables and files, such as data source, date of creation, name of person who created the file, methods/steps used to compile the data, list of field names, and what the data represent including years of interest and any other definitions or explanations needed to

document the origin, processing steps, methods, and (or) quality.

Step 7: Check master table(s) counts

- Check that no records were lost between the query and table.
 - Open each **Master Table-[start year of interest-end year of interest]** table and go to the last record and record the total number of records in the “fracworksheet.xlsx” file.
 - Verify that the count of each **Master Table-[start year of interest-end year of interest]** matches the count from the corresponding ***Master TableO-[start year of interest-end year of interest]*** query. If this is not the case, then go back to last known correct check.
 - Verify and record in “fracworksheet.xlsx” file that each **Master Table-[start year of interest-end year of interest]** table only contains treatments of **TRTM_TYPE FRAC** or **REFRAC**, that the **FINAL_STATUS** only has ***OIL WELL*** or ***GAS WELL***, the **COMP_YEAR** only includes the years of interest, and the **HOLE_DIRECTION** contains only ***HORIZONTAL, DIRECTIONAL,*** or ***VERTICAL*** and onshore wells by State.
 - If the record counts do not match, repeat steps 4 to 7.

Step 8: Start the process to compile treatment totals

- For each **Master table-[start year of interest-end year of interest]**, create a temporary query that counts the treatment fluid amount units (**TRTM_AMT_UNIT**). Verify that there is only unit of **CUM** (cubic meters). Record the counts of records in the “fracworksheet.xlsx” file.
 - As mentioned in step 3, if there are **TRTM_AMT_UNIT** other than **CUM**, then a mistake has been made in the first step. The user must start the process from step 1 because the treatment units were not converted properly.
 - Some **TRTM_AMT_UNIT** entries could be blank in cases where the record had a proppant amount but not a treatment amount.
- For each **Master Table-[start year of interest-end year of interest]**, create a query called ***Treatments w values-[start year of interest-end year of interest]*** that

retains only the records that have a treatment amount (TRTM_AMT). Record the counts in the “fracworksheets.xlsx” file.

- Check that the count of treatments with a treatment amount (TRTM_AMT) in each query matches the count of the treatment units TRTM_AMT_UNITS (in this case, this is equal to the count of CUM entries).
- If the counts match, use each Treatments w values-[start year of interest-end year of interest] query to make a new table called Master Table w TRTM_AMT-[start year of interest-end year of interest].
- Include field names: UWI, SPUD_DATE, PI_COMP_DATE, COMP_YEAR, STATE, COUNTY, HOLE_DIRECTION, HOLE_DIR_NAME, GEO_PROV, FINAL_STATUS, LAT, LON, SOURCE, TRTM_OBS_NO, TRTM_TYPE, TRTM_TYPE_NAME, TEST_TYPE, RUN_NO, TEST_NUMBER, TRTM_START_DATE, ADDITIVE_TYPE, ADDITIVE_TYPE_NAME, TRTM_FLUID_TYPE, TRTM_FLUID_TYPE_NAME, TRTM_AMOUNT, TRTM_UNIT, AGENT_TYPE, AGENT_TYPE_NAME, AGENT_AMOUNT, and AGENT_UNIT.
 - If counts do not match, then repeat step 8.
- Record the number of records of each Master Table w TRTM_AMT-[start year interest-end year interest] table in the “fracworksheets.xlsx” file.
- Update the README file with information on data source, date of creation, name of person who created the file, methods/steps used to compile the data, definition of columns and rows, and what the data represent including years of compilation and any other definitions or explanations needed to document the origin, processing steps, methods, and (or) any other notes that would reflect quality.

Step 9: Create master well treatment totals table(s)

- Create a new query called Unique wells w TRTM_AMT-[start year of interest-end year of interest] based on the Master Table w TRTM_AMT-[start year of interest-end year of interest] table. Apply the “Group By” function to the UWI to return a list of all unique wells. Record the total for each year(s) of interest table in “fracworksheets.xlsx” file.
- Create a query/queries called Q-Master Wells Treatment Totals-[start year of interest-end year of interest] for each Master Table w TRTM_AMT-[start year of interest-end year of interest].

- Include the well information (UWI, SPUD_YEAR, PI_COMP_DATE, COMP_YEAR, FINAL_STATUS, HOLE_DIRECTION, HOLE_DIR_NAME, STATE, COUNTY, GEO_PROV, LAT and LON).
- Include only the TRTM_AMT (treatment amount) and TRTM_UNIT (treatment unit) from the treatment information contained in the Master Table w TRTM_AMT-[start year of interest-end year of interest].
- Use the “Group By” function within the query, group by well information such that a single record is retrieved for every well. Use the “Sum” function to calculate the sum of the treatment amounts (TRTM_AMTs) resulting in a single treatment amount per well.
 - If the name of the column heading is not changed, the resulting query will name the column heading “SumOfTRTM_AMOUNT”. This might cause confusion because the next query also generates a “SumOfTRTM_AMOUNT” if the name is not changed as well.
 - It is recommended that the column be renamed “TOTAL_TRTM_AMOUNT”.

Record the record count in the “fracworksheets.xlsx” file.

- If the counts from the query/queries Q-Master Wells Treatment Totals-[start year of interest-end year of interest] match the totals from the Unique Wells w TRTM_AMT-[start year of interest-end year of interest] query, then using query Q-Master Well Treatment Totals-[start year of interest-end year of interest] create a new table called Master Well Treatment Totals-[start year of interest-end year of interest] for each year(s) of interest and record the record count in the “fracworksheets.xlsx” file.
- If the record counts do not match, then repeat step 9.
- Update the README text file to document the data source, date of creation, name of person who created the file, methods/steps used to compile the data, list of field names, and what the data represent including years of compilation and any other definitions or explanations needed to document the origin, processing steps, methods, and factors that could affect the data quality.

Step 10: Create a master well treatment total by fluid table(s)

- Create a new query (or queries) called Q-Well Treatment Totals by Fluid-[start year of interest-end year of

interest] based on the Master Table w TRTM_AMT-[start year of interest-end year of interest] table.

- Include the well information (UWI, SPUD_YEAR, PI_COMP_DATE, COMP_YEAR, FINAL_STATUS, HOLE_DIRECTION, HOLE_DIR_NAME, STATE, COUNTY, GEO_PROV, LAT and LON).
- Include the treatment information (TRTM_FLUID_TYPE, TRTM_FLUID_TYPE_NAME, and TRTM_AMT).
- In the Q-Well Treatment Totals by Fluid-[start year of interest-end year of interest] query, compute the total volume of each fluid type injected into each well by applying the “Group By” function to all well information, TRTM_FLUID_TYPE, and TRTM_FLUID_TYPE_NAME, and apply the “Sum” function to the TRTM_AMT.
 - If the name of the column heading is not changed, the resulting query will name the column heading “SumOfTRTM_AMOUNT”. This might cause confusion because the previous query also generated a “SumOfTRTM_AMOUNT” if the name was not changed.
 - It is recommended that this column be renamed “TOTAL_TRTM_FLUID_AMOUNT”.
- Create a new query/queries called Unique Wells Q-Well Treatment Totals by Fluid-[start year of interest-end year of interest] based on the Q-Well Treatment Totals by Fluid-[start year of interest-end year of interest] query and use the “Group By” function for only the UWI.
- Record the counts for each Q-Well Treatment Totals by Fluid-[start year of interest-end year of interest] and Unique Wells Q-Well Treatment Totals by Fluid-[start year of interest-end year of interest] and check that the Unique Well Q-Well Treatment Totals by Fluid-[start year of interest-end year of interest] count matches the Unique Wells w TRTM_AMT-[start year of interest-end year of interest] count from step 9.
- If counts do not match, repeat step 10.
- If counts match, create a new table(s) called Master Well Treatment Totals by Fluid-[start year of interest-end year of interest] for each year(s) of interest.
- Verify that the counts of records in the Q-Well Treatment Totals by Fluid-[start year of interest-end year of interest] query match the counts of records in the Master Well Treatment Total by Fluid-[start year of interest-end year of interest] table.

- If the counts do not match, then repeat step 10.

Step 11: Remove proprietary data

The proprietary information should be removed prior to public release of the data, in accordance with IHS Markit (IHS Markit, 2019) agreements.

- Remove all proprietary information considered proprietary by IHS Markit (IHS Markit, 2019) from all the MS databases (.acddb) and tables as well as from any text files created using this report. For example, proprietary information includes, but is not limited to the following: well identity information such as the UWI (or API), latitude (LAT), and longitude (LON) of the wells.
 - Note that this step only applies to the tables created by the user using this method. The original IHS tables are static and should retain the well identity information.
- Final data products derived from this method should be reviewed by IHS Markit prior to release in accordance with IHS Markit agreements (IHS Markit, 2019).

Summary

Completion of this procedure will result in the following MS Access files and tables within MS Access files:

- “HydroFRAC-[vintage year of PIDM]-ConvertedTreatments-[start date of compilation].acddb”;
- “HydroFRAC-[vintage year of PIDM]-MasterTables-[start date of compilation].acddb”;
- **Master Treatment Table;**
- **Master Well Table-[start year of interest-end year of interest]** for all year groupings;
- **Master Table-[start year of interest-end year of interest]** for all year groupings;
- **Master Table w TRTM_AMT-[start year of interest-end year of interest]** for all year groupings;
- **Master Well Treatment Totals-[start year of interest-end year of interest]** for all year groupings; and
- **Master Well Treatment Total by Fluid-[start year of interest-end year of interest]** for all year groupings.

A description of each of these tables is found in appendix 3. These data provide information about the treatment fluids, treatment fluid types, and treatment fluid amounts injected into wells for hydraulic fracturing. Data are organized by general well location (State, county, and geologic

province), by well orientation (horizontal, vertical, and directional), and well type (oil or gas). Data tables can be exported to MS Excel for further analysis.

Acknowledgments

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Appendixes

Appendix 1. Java program, "ConvertTreatments"

Appendix 2. IHS Units Conversion Factors

Appendix 3. List of Tables Compiled

Appendix 4. The "fracworksheet.xlsx" File

Appendix 1. Java program, “ConvertTreatments”

```

import java.io.*;
import java.sql.*;
import java.util.Properties;
/**
 * ConvertTreatments_only_IHS_conv is meant to make a connection to our internal IHS oracle server
 *and go through the WELL_TREATMENT table for various treatment fluid units and proppant (agent)
 *units and convert to a common
 * unit only using the conversions found in the IHS PI_ADMIN.PPDM_UNIT_CONVERSION table. This
 *program writes info to a comma separated values (csv) file but only writes the records that had either a
 *treatment fluid amount or
 * an agent (proppant) amount.
 *
 * @author (Brian A Varela)
 * @version (11/14/2008)
 */
public class ConvertTreatments_only_IHS_conv
{
    /**
     * Constructor for objects of class ConvertTreatments
     */
    public ConvertTreatments_only_IHS_conv()
    {
    }

    /**
     * Most of the work is done in the main method. The main method sets up the connection to the
     *oracle database and gets the user input of which unit to convert to; either cubic meters or gallons for
     *the treatment fluid type
     * and pounds for the proppant amount. The main method also creates the output files and reads in
     *the input file. The only thing not done by the main method is the conversion
     *
     * @param type String used to hold the unit to be converted to; either CUM for cubic meters or GAL
     *for gallons
     * @param amount double used to hold the treatment fluid amount
     * @param agent_amt double used to hold the proppant amount
     */
    public static void main(String args[])
    {
        String type="";
        double amount=-1.0d, agent_amt=-1.0d;
        try{
            System.out.println("Program Starting...");

            //create connection to oracle
            String url = "jdbc:oracle:oci:@"
                +"(DESCRIPTION=(ADDRESS=(PROTOCOL=TCP)(HOST=igskaecgas020.cr.usgs.gov)(PORT=1521)))"

```

```

+”(CONNECT_DATA=(SID=propdb))”);
Driver driver = new oracle.jdbc.OracleDriver();
Properties props = new Properties();
Connection con = driver.connect( url, props );
con.setReadOnly(true);

BufferedReader in = new BufferedReader(new InputStreamReader(System.in));
while(type.equalsIgnoreCase(“GAL”) == false && type.equalsIgnoreCase(“CUM”) == false)
{
    System.out.println(“Which unit would you like to convert to: GAL or CUM?”);
    type = in.readLine();
}
in.close();
System.out.println(“OK Converting to “+type.toUpperCase());
type = type.toUpperCase();

PrintWriter out = new PrintWriter(new FileWriter(“Converted_WELL_TREATMENTS-”+
type.toUpperCase()+”.csv”));
out.println(“UWI,SOURCE,TRTM_OBS_NO,TRTM_TYPE,TEST_TYPE,RUN_NO,TEST_NUMBER,”+
“TRTM_START_DATE,ADDITIVE_TYPE,TRTM_FLUID_TYPE,TRTM_AMOUNT,TRTM_UNIT,AGENT_TYPE,”+
“AGENT_AMOUNT,AGENT_UNIT,ORIGINAL_TRTM_UNIT,ORIGINAL_AGENT_UNIT”);

PreparedStatement pstmt = con.prepareStatement(
“SELECT UWI, SOURCE, TRTM_OBS_NO, TRTM_TYPE, TEST_TYPE, RUN_NO,”+
“TEST_NUMBER, TRTM_START_DATE, ADDITIVE_TYPE, TRTM_FLUID_TYPE,”
“TRTM_AMOUNT, TRTM_UNIT, AGENT_TYPE, AGENT_AMOUNT, AGENT_UNIT “+
“FROM PIDM.WELL_TREATMENT “+
“WHERE TRTM_AMOUNT Is Not Null OR AGENT_AMOUNT is Not Null”);

ResultSet trtm = pstmt.executeQuery();

//loop through all treatments and figure out which have values and print out other information
//like UWI, SOURCE, TRTM_OBS_NO, etc.
while(trtm.next())
{
    if(trtm.getString(11) != null) //if treatment amount is not null convert and store in variable
//amount
    {
        amount = ConvertTrtmAmt(trtm.getString(11), trtm.getString(12), type);
    }

    if(trtm.getString(14) != null) //if proppant amount is not null convert and store in variable
//agent_amt
    {
        agent_amt = ConvertAgentAmt(trtm.getString(14), trtm.getString(15), “LB”);
    }

    if(amount != -1.0d || agent_amt != -1.0d) //if treatment amount or proppant amount is not
//null print record out and converted amount
    {
        for(int i=1; i<11; i++)

```

```

    {
        if(i==1)
        {
            out.print(trtm.getString(i));
        }
        else if(i == 8)
        {
            if(trtm.getString(i) == null)
            {
                out.print(",");
            }
            else
            {
                out.print(","+(trtm.getDate(i).getMonth()+1)+"/"+trtm.getDate(i).getDate()+"/"+(trtm.
getDate(i).getYear()+1900));
            }
        }
        else
        {
            if(trtm.getString(i) == null)
            {
                out.print(",");
            }
            else
            {
                out.print(","+trtm.getString(i));
            }
        }
    }

    if(amount != -1.0d && agent_amt != -1.0d) //if treatment amount and proppant amount is
//not null print record out and converted amount - legacy
    {
        out.print(","+amount+","+type);
        if(trtm.getString(13) != null)
        {
            out.print(","+trtm.getString(13));
        }
        else
        {
            out.print(",");
        }
        out.print(","+agent_amt+",LB,"+trtm.getString(12)+","+trtm.getString(15));
    }
    else if(amount != -1.0d)
    {
        out.print(","+amount+","+type);
        if(trtm.getString(13) != null)
        {
            out.print(","+trtm.getString(13));
        }
    }

```

```

        else
        {
            out.print(",");
        }
        out.print(",,"+trtm.getString(12));
        if(trtm.getString(15) != null)
        {
            out.print(", "+trtm.getString(15));
        }
        else
        {
            out.print(",");
        }
    }
else
{
    out.print(",");
    if(trtm.getString(13) != null)
    {
        out.print(", "+trtm.getString(13));
    }
    else
    {
        out.print(",");
    }
    out.print(", "+agent_amt+",LB");
    if(trtm.getString(12) != null)
    {
        out.print(", "+trtm.getString(12));
    }
    else
    {
        out.print(",");
    }
    out.print(", "+trtm.getString(15));
}

    out.println();
}

    amount=-1.0d;
    agent_amt=-1.0d;
}
//print program finished to terminal and quit program
System.out.println("Program Finished.");
trtm.close();
pstmt.close();
out.close();
System.exit(1);
}catch(Exception e){e.printStackTrace();}
}

```


18 Method for Compiling Temporally and Spatially Aggregated Data on Hydraulic Fracturing—Treatments and Wells

```
/**
 * The ConvertTrtmAmt method is used to convert the treatment fluid amount into either gallons or
 *cubic meters determined by the user.
 *
 *
 * @param new_amt double to hold converted treatment fluid amount
 */
public static double ConvertTrtmAmt(String amount, String unit, String type)
{
    double new_amt=-1.0d;

    if(type == null)
    {}
    else if(type.equalsIgnoreCase("GAL")) //convert to gallons (GAL)
    {
        if(unit.equals("GAL"))
        {
            new_amt = new Double(amount);
        }
        else if(unit.equals("BBL"))
        {
            new_amt = new Double(amount) * 42.0d;
        }
        else if(unit.equals("QT"))
        {
            new_amt = new Double(amount) / 4.0d;
        }
        // else if(unit.equals("CF"))
        // {
        //     new_amt = new Double(amount) * 7.4805d;
        // }
        // else if(unit.equals("LB"))
        // {
        //     new_amt = new Double(amount)/8.345d;
        // }
        // else if(unit.equals("TON"))
        // {
        //     new_amt = new Double(amount) * 2000.0d;
        //     new_amt = new_amt/8.345d;
        // }
    }
    else //convert to Cubic Meters (CUM)
    {
        if(unit.equals("GAL"))
        {
            new_amt = new Double(amount) * .0037854d;
        }
        else if(unit.equals("BBL"))
        {
            new_amt = new Double(amount) * .158987d;
        }
    }
}
```

```

    }
    else if(unit.equals("QT"))
    {
        new_amt = new Double(amount) * .00094634d;
    }
    else if(unit.equals("CF"))
    {
        new_amt = new Double(amount) * .028317d;
    }
    else if(unit.equals("MCF"))
    {
        new_amt = new Double(amount) * 28.3168466d;
    }
}

return new_amt;
}

/**
 * The ConvertAgentAmt method is used to convert the agent (proppant) amount into pounds (LB).
 * This method takes a String of the amount, a String of the original unit, and a String type that indicates
 * the unit to convert to
 * in this case we only convert to pounds (LB).
 *
 *
 * @param agent_amt double used to hold the proppant amount
 */
public static double ConvertAgentAmt(String amount, String unit, String type)
{
    double agent_amt=-1.0d;
    if(unit == null)
    {}
    else if(unit.equalsIgnoreCase("LB"))
    {
        agent_amt = new Double(amount);
    }
    else
    {
        if(unit.equalsIgnoreCase("TON"))
        {
            agent_amt = new Double(amount) * 2000.0d;
        }
    }
}

return agent_amt;
}
}

```

Appendix 2. IHS Units Conversion Factors

Table 2.1. IHS Markit (IHS Markit, 2019) unit conversion factors.

[Abbreviations: BBL, barrel; CF, cubic feet; CUM, cubic meters; GAL, gallon; LBS, pounds; MCF, thousand cubic feet; QT, quart]

From unit	To unit	Conversion
Treatment fluid		
GAL	CUM	$\text{GAL} \times 0.0037854$
BBL	CUM	$\text{BBL} \times 0.158987$
QT	CUM	$\text{QT} \times 0.0009464$
CF	CUM	$\text{CF} \times 0.028317$
MCF	CUM	$\text{MCF} \times 28.3168466$
Agent (proppant)		
TON	LBS	$\text{TON} \times 2000$

Appendix 3. List of Tables Compiled

Master Treatment Table

- Methods/steps used to compile data: Steps 1, 2 and 3.
- Field names: SOURCE, TRTM_OBS_NO, TRTM_TYPE, TRTM_TYPE_NAME, TEST_TYPE, RUN_NO, TEST_NUMBER, TRTM_START_DATE, ADDITIVE_TYPE, ADDITIVE_TYPE_NAME, TRTM_FLUID_TYPE, TRTM_FLUID_TYPE_NAME, TRTM_AMOUNT, TRTM_UNIT, AGENT_TYPE, AGENT_NAME, AGENT_AMOUNT, and AGENT_UNIT.
- Data represented: All hydraulic fracturing or refracturing treatments (coded as FRAC or REFRAC) listed in the PIDM with proppant (AGENT) amounts converted to pounds and treatment fluid amounts converted to cubic meters (CUM).

Master Well Table-[start year of interest-end year of interest]

- Method/step used to compile data: Step 5.
- Field names: SPUD_DATE, PI_COMP_DATE, COMP_YEAR, STATE, COUNTY, HOLE_DIRECTION, HOLE_DIRECTION_NAME, GEO_PROV, and FINAL_STATUS.
- Data represented: Data represents all horizontal, directional, or vertical oil and gas wells that were hydraulically fractured or refractured and completed during the years of interest.

Master Table-[start year of interest-end year of interest]

- Methods/steps used to compile data: Steps 6 and 7.
- Field names: SPUD_DATE, PI_COMP_DATE, COMP_YEAR, STATE, COUNTY, HOLE_DIRECTION, HOLE_DIRECTION_NAME, GEO_PROV, FINAL_STATUS, SOURCE, TRTM_OBS_NO, TRTM_TYPE, TRTM_TYPE_NAME, TEST_TYPE, RUN_NO, TEST_NUMBER, TRTM_START_DATE, ADDITIVE_TYPE, ADDITIVE_TYPE_NAME, TRTM_FLUID_TYPE, TRTM_FLUID_TYPE_NAME, TRTM_AMOUNT,

TRTM_UNIT, AGENT_TYPE, AGENT_TYPE_NAME, AGENT_AMOUNT, and AGENT_UNIT.

- Data represented: All hydraulic fracturing or refracturing treatments applied to directional, horizontal, and vertical oil and gas wells completed during the year(s) of interest and associated with a State code. Each row represents a single treatment such that one well could have multiple treatments (more than one row per well).

Master Table w TRTM_AMT-[start year of interest-end year of interest]

- Methods/steps used to compile data: Steps 8 and 9.
- Field names: SPUD_DATE, PI_COMP_DATE, COMP_YEAR, STATE, COUNTY, HOLE_DIRECTION, HOLE_DIRECTION_NAME, GEO_PROV, FINAL_STATUS, SOURCE, TRTM_OBS_NO, TRTM_TYPE, TRTM_TYPE_NAME, TEST_TYPE, RUN_NO, TEST_NUMBER, TRTM_START_DATE, ADDITIVE_TYPE, ADDITIVE_TYPE_NAME, TRTM_FLUID_TYPE, TRTM_FLUID_TYPE_NAME, TRTM_AMOUNT, TRTM_UNIT, AGENT_TYPE, AGENT_TYPE_NAME, AGENT_AMOUNT, and AGENT_UNIT.
- Data represented: Same as **Master Table** except this table contains only the records that report a treatment amount for a given treatment type. Each row represents a single treatment and associated treatment amount such that one well could have multiple treatments (more than one row per well).

Master Well Treatment Totals-[start year of interest-end year of interest]

- Methods/steps used to compile data: Steps 8 and 9.
- Field names: SPUD_DATE, PI_COMP_DATE, COMP_YEAR, STATE, COUNTY, HOLE_DIRECTION, HOLE_DIRECTION_NAME, GEO_PROV, FINAL_STATUS, TOTAL_TRTM_AMOUNT, and TRTM_UNIT.
- Data represented: Same as **Master Table w TRTM_AMT** except these records contain only a single sum of all treatment amounts applied to a given well, regardless of treatment fluid type. Each row represents a

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single total treatment amount such that one well could only have one entry (one row per well).

Master Well Treatment Total by Fluid-[start year of interest-end year of interest]

- Data source: IHS PIDM (internal Oracle database) (IHS Markit, 2019).
- Methods/steps used to compile data: Steps 8 and 10.
- Field names: SPUD_DATE, PI_COMP_DATE, COMP_YEAR, STATE, COUNTY, HOLE_DIRECTION, HOLE_DIRECTION_NAME, GEO_PROV, FINAL_STATUS, TRTM_FLUID_TYPE, TRTM_FLUID_TYPE_NAME, TOTAL_TRTM_FLUID_AMOUNT, and TRTM_UNIT.
- Data represented: Same as Master Table w TRTM_AMT except each record represents the sum of all the treatment amounts of a given treatment type applied to a given well such that one well could have multiple entries (more than one row per well).

Appendix 4. The "fracworksheet.xlsx" File

The following series of tables are used to document the record counts at various steps throughout the data compilation process.

Table 4.1. Step 3 count of treatment records.

Step 3	
	Count
Count of records in the IHS WELL_TREATMENT table:	
Count of records in the USGS TREATMENT table:	
Count of records in the JAVA Converted Treatments table*:	
<i>* Converted Treatments contains some treatments that had NULL treatment fluid amount but had a proppant amount, and some Converted Treatments contains some treatments that had a NULL proppant amount but had a treatment fluid amount (this explains why the converted treatment units or converted proppant numbers may not match the converted treatment table size).</i>	

Table 4.2. Step 3 count of TRTM_UNIT records.

IHS Table - Count of TRTM_UNIT records			
TRTM_UNIT	CountOfUWI	Converted Treatment Units	Count
GAL		Converted (GAL, BBL, QT, CF, MCF)	
BBL		Not Converted (NULL, LB, TON, HOLE, SACK, FT)	
QT		Total	
CF			
MCF		Converted Proppant Units	
LB		Converted (LB, TON)	
TON		Not Converted (NULL, SACK)	
HOLE		Total	
SACK			
FT			
Total			

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Table 4.3. Step 3 count of AGENT_UNIT records.

IHS Table - Count of AGENT_UNIT records	
AGENT_UNIT	CountOfUWI
LB	
SACK	
TON	
Total	

Table 4.4. Step 4 FRAC and REFRAC treatment record counts.

Step 4	
Record Count of IHS - <u>WELL_TREATMENT</u> (FRAC or REFRAC):	
Record Count of Converted Treatments - <u>USGS_TREATMENT</u> (FRAC or REFRAC)*:	
Difference	
Record Count of Converted Treatments - <u>Treatments_w_codes</u> (FRAC or REFRAC) after linking codes:	
Record Count of <u>Master Treatment</u> Table (FRAC or REFRAC):	
Record Count of Unique UWIs from <u>Master Treatment</u> Table (FRAC or REFRAC):	
* <u>Converted Treatments</u> records contain records with a missing or NULL treatment fluid amount or a NULL proppant amount but not both. Since the <u>Converted Treatments</u> table doesn't contain all the original records along with the fact that the <u>Converted Treatment</u> table only contains the FRAC and REFRAC treatment records there will be an incalculable difference in record counts between the IHS <u>WELL_TREATMENT</u> table and the <u>Converted Treatments</u> table.	

Table 4.5. Step 5a unique UWI and Master Well Table-All record counts.

Step 5a	
Record Count of <u>Unique_UWIs_w_codes</u> count from <u>Master Treatment</u> Table (FRAC or REFRAC):	
Record Count of <u>Master Well Table-All</u> record Count:	

Table 4.6. Steps 5b, 5c, 5d, and 5e count by completion year.

Steps 5b, 5c, 5d, 5e	
Count by Completion Year - <i>Master_Well_Table-Land</i>	
COMP_YEAR*	CountOfUWI
start year of interest...	
...1889	
1891	
1895	
1896	
1897	
1899	
2011	
2012	
2013	
2014	
2015	
2016...	
end year of interest	
Total	
Before yyyy	
yyyy-yyyy	
*COMP_YEAR: Add a separate row for each completion year of interest for which data are compiled.	

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Table 4.7. Steps 5b, 5c, 5d, and 5e count by State.

Steps 5b, 5c, 5d, 5e	
Count by State - <i>Master_Well_Table-Land</i>	
STATE	CountOfUWI
ALABAMA	
ARIZONA	
ARKANSAS	
CALIFORNIA	
COLORADO	
FLORIDA	
GEORGIA	
IDAHO	
ILLINOIS	
INDIANA	
IOWA	
KANSAS	
KENTUCKY	
LOUISIANA	
MARYLAND	
MICHIGAN	
MISSISSIPPI	
MISSOURI	
MONTANA	
NEBRASKA	
NEVADA	
NEW MEXICO	
NEW YORK	
NORTH CAROLINA	
NORTH DAKOTA	
OHIO	
OKLAHOMA	
PENNSYLVANIA	
SOUTH DAKOTA	
TENNESSEE	

Steps 5b, 5c, 5d, 5e	
Count by State - <i>Master_Well_Table-Land</i>	
STATE	CountOfUWI
TEXAS	
UTAH	
VIRGINIA	
WASHINGTON	
WEST VIRGINIA	
WYOMING	
ALASKA	
NORTHERN GULF OF MEXICO	
Total	
OnShore	
OffShore	
Count After Removing Offshore Wells:	

Table 4.8. Steps 5b, 5c, 5d, and 5e count by Final Status.

Steps 5b, 5c, 5d, 5e	
Count by Final Status - <i>Master_Well_Table-Land-[start year of interest-end year of interest]</i>	
FINAL_STATUS	CountOfUWI
GAS WELL	
OIL WELL	
MULTIPLE COMPLETION, GAS	
DRY HOLE, TEMPORARILY ABANDONED	
INJ, SRV, CO2, STORAGE, WDW, PSEUDO ORIG, MINING BOREHOLE	
WATER INJECTION	
SALT WATER DISPOSAL	
MULTIPLE COMPLETION, OIL	
MULTIPLE COMPLETION, OIL AND GAS	
WATER SUPPLY WELL	
JUNKED AND ABANDONED WELL	
Total	
Oil and Gas Wells Only	

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Table 4.9. Steps 5b, 5c, 5d, and 5e count by HOLE_DIRECTION.

Steps 5b, 5c, 5d, 5e	
Count by HOLE_DIRECTION - <i>Master_Well_Table-Land-OilGas-[start year of interest-end year of interest]</i>	
HOLE_DIR_NAME	
VERTICAL	
HORIZONTAL	
DIRECTIONAL	
PINNATE	
Total	
Vertical, Horizontal and Directional Oil and Gas Wells only	

Table 4.10. Step 5f record counts for land-based oil and gas horizontal, directional and vertical wells.

Step 5f	
::Query::	
Record Count of <i>Master_Well_Table-Land-OilGas-DHV-[start year of interest-end year of interest]</i> :	
::Table::	
Record Count of Master Well Table-[start year of interest-end year of interest] :	

Table 4.11. Step 6 record counts for building **Master Table-[start year of interest-end year of interest]**.

Step 6	
Record Count of Master Well Table-[start year of interest-end year of interest] (<i>FRAC or REFRAC, Onshore, Oil or Gas Well, Horizontal Directional or Vertical</i>):	
::Query::	
Record Count of Unique UWIs from Master Table-[start year of interest-end year of interest]	
Record Count of <i>Master TableQ-[start year of interest-end year of interest]</i>	

Table 4.12. Step 7 record count of **Master Table-[start year of interest-end year of interest]**.

Step 7	
Record Count of Master Table-[start year of interest-end year of interest]	
Does Master Table-[start year of interest-end year of interest] Only Include Records of COMP_YEAR=start year of interest-end year of interest?	
Does Master Table-[start year of interest-end year of interest] Only Include Records of TRTM_TYPE=FRAC or REFRAC?	
Does Master Table-[start year of interest-end year of interest] Only Include Records of FINAL_STATUS=OIL WELL or GAS WELL?	
Does Master Table-[start year of interest-end year of interest] Only Include Records of HOLE_DIRECTION=HORIZONTAL or DIRECTIONAL or VERTICAL	

Table 4.13. Step 8 **Master Table-[start year of interest-end year of interest]** record count of TRTM_UNIT.

Step 8	
Master Table-[start year of interest-end year of interest] Record Count of TRTM_UNIT	
Does Master Table-[start year of interest-end year of interest] (temporary query) only include records with a treatment fluid amount in cubic meter units (CUM)?	
Record Count of Records for temporary query of Master Table-[start year of interest-end year of interest] of records with treatment fluid amount?	
Record Count of Treatments_w_values-[start year of interest-end year of interest] Query from Master Table[start year of interest-end year of interest] only with records that have a TRTM_AMOUNT?	
Record Count of Master Table w TRTM_AMT-[start year of interest-end year of interest]	

Table 4.14. Step 9 record counts of unique wells that had treatment amounts.

Step 9	
Record Count of Unique Wells w TRTM_AMT-[start year of interest-end year of interest]	
Record Count of Q-Master Wells Treatment Totals-[start year of interest-end year of interest]	

Table 4.15. Step 10 record counts of treatment totals by fluid.

Step 10	
Record Count of Q-Well Treatment Totals by Fluid-[start year of interest-end year of interest]	
Record Count of Unique Wells Q-Well Treatment Totals by Fluid-[start year of interest-end year of interest]	
Record Count of Master Well Treatment Totals by Fluid-[start year of interest-end year of interest]	

