# San Juan and Permian Basin 2014 Oil and Gas Emission Inventory Inputs
# Final Report

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November 2016

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## EXECUTIVE SUMMARY

This study provides emission inventory inputs necessary to develop criteria air pollutant (CAP) and greenhouse gas (GHG) emissions from oil and gas exploration, production, and midstream operations in the Greater San Juan Basin in Colorado and New Mexico and the portion of the Permian Basin in New Mexico. This analysis is being sponsored by the United States (US) Bureau of Land Management (BLM), New Mexico State Office, jointly with the Western Regional Air Partnership (WRAP). The results of this effort will be used in the next phase of the project to develop base year 2014 and future year emission inventories for the Greater San Juan and Permian basins to create the most accurate emission inventory that has been compiled to-date for each basin.

The primary sources of information used to develop oil and gas exploration and production well site emission inventory input factors were a survey outreach effort in the Greater San Juan Basin and a literature review in the Permian Basin. For midstream emission sources, detailed permit data was collected from the New Mexico Environment Department (NMED); Colorado Department of Public Health and Environment (CDPHE); and the US Environmental Protection Agency (EPA) Region 6, Region 8, and Region 9. Two survey forms were distributed to Greater San Juan basin operators to gather information on oil and gas exploration and production wellsite sources; the first form leveraged operators' Greenhouse Gas Reporting Protocol (GHGRP) Subpart W submissions to collect data from eight discrete source categories and the second form collected data on 12 additional source categories for which GHGRP data was insufficient to develop emission inventory inputs. Permian Basin wellsite input factors were developed based on data from other available studies and/or reporting because conducting a survey in the Permian Basin was not expected to yield adequate operator participation. The Permian Basin literature review focused on gathering data from two sources: the Texas Commission on Environmental Quality (TCEQ) oil and gas emission inventory and publically available GHGRP data.

The companies participating in the survey process for the Greater San Juan Basin represent approximately 53% of well ownership in the basin, 58% of gas production in the basin, and 53% of oil production in the basin. In order to increase operator representation for the development of accurate wellsite exploration and production input factors, Ramboll Environ compiled company specific GHGRP data for companies representing 13% of well ownership, 14% of gas production ownership, and 38% of oil production ownership that did not submit a survey. The combined operator representation from survey responses and the GHGRP data compilation is 65% of well ownership, 72% of gas production ownership, and 81% of oil production ownership. The percentage of oil and gas activity that was captured in the survey process and GHGRP data compilation allow for good representation of oil and gas operations in the basin.

Per stakeholder input, survey data was not collected for certain wellsite source categories because data was not expected to be available: amine units, truck loading at gas and natural gas liquid (NGL) processing plants and water disposal pits. This study does not consider fugitive emissions from oil and gas pipelines from well heads to the main compressor stations. Accurate

quantitative information on the length of pipeline in the basin was not available from sources queried as part of this effort.

In the next phase of this work, wellsite exploration and production emissions in the Greater San Juan and Permian basins will be estimated by combining the input factors developed from survey, literature review, and GHGRP data with county level 2014 oil and gas activity input factors. 2014 oil and gas activity, including spud count, well count and production by well type were obtained from a commercially available database of oil and gas data maintained by IHS Corporation ("the IHS database").

The Greater San Juan Basin was defined consistent with the EPA GHGRP San Juan Basin definition, including the counties of Archuleta and La Plata in Colorado and Cibola, Los Alamos, McKinley, Rio Arriba, San Juan, Sandoval, and Valencia in New Mexico. In 2014, the Greater San Juan Basin consisted of close to 25,000 active oil and gas wells which produced over one billion cubic feet of natural gas per year. Greater San Juan Basin gas production accounts for about one-third of combined Colorado and New Mexico gas production and about 3% of national on-shore gas production. Notably, there were only 126 wells spudded in the Greater San Juan Basin in 2014. Historic Greater San Juan Basin spud counts have been much higher; for example, there were 976[1] spuds in the Greater San Juan Basin in 2006 (Bar-Ilan et al., 2009a; 2009c).

The portion of the Permian Basin in New Mexico was defined consistent with the EPA GHGRP Permian Basin definition, including the counties of Chaves, Eddy, Roosevelt, and Lea. In 2014, the portion of the Permian Basin in New Mexico consisted of over 28,000 active oil and gas wells which produced over 117 million barrels of oil. The portion of the Permian Basin in New Mexico accounted for approximately 95% of oil production in New Mexico and approximately 4% of national on-shore oil production in 2014. There were over 1,000 wells spudded in the Permian Basin in 2014.

The contents of the report by Chapter are summarized as follows:

- Chapter 1.0 is an introduction that describes the methodology and oil and gas activity inputs;
- Chapter 2.0 describes the development of 2014 midstream emission inventory inputs;
- Chapter 3.0 describes the development of Greater San Juan Basin 2014 wellsite exploration and production emission inventory inputs;
- Chapter 4.0 describes the development of Permian Basin 2014 wellsite exploration and production emission inventory inputs;
- Chapter 5.0: presents recommendations for the next phase of this work.

[1] 919 wells spudded in the South San Juan Basin in 2006 (Bar-Ilan et al., 2009a) and 57 wells spudded in the North San Juan Basin in 2006 (Bar-Ilan et al., 2009c) for a total of 976 wells spudded in the Greater San Juan Basin in 2006.

# 1.0 INTRODUCTION

The BLM is sponsoring the development of a regional oil and gas emission inventory for the Greater San Juan Basin (in New Mexico and Colorado) and the Permian Basin (in New Mexico) jointly with the WRAP. The Greater San Juan Basin inventory will be an update to the WRAP Phase III South San Juan and North San Juan baseline (2006) and future emission inventories (Bar-Ilan et al., 2009a; 2009b; 2009c) and forecast updates for the WestJump Air Quality Modeling Study (AQMS; Bar-Ilan et al., 2012) and the Intermountain West Data Warehouse (IWDW; Parikh et al., 2015). The Permian Basin inventory will be an update to the WestJump AQMS Permian Basin baseline (2008) inventory (Bar-Ilan et al., 2013).

Described in this report is the effort to develop a comprehensive set of inputs for developing criteria air pollutant and greenhouse gas emissions base year 2014 inventory for activities associated with oil and gas exploration, production, and midstream operations in the Greater San Juan and Permian basins.

## 1.1 Emission Inventory Input Data

The inventory inputs presented in this analysis are for the Greater San Juan Basin in Colorado and New Mexico and the portion of the Permian Basin in New Mexico[2].

The inventory inputs can be grouped into three categories: (1) midstream point source facilities that were permitted by the State of New Mexico, State of Colorado, or EPA (for tribal land) and (2) wellsite sources for which data was collected from surveys of major companies operating in the Greater San Juan Basin and gathered from existing studies in both the Permian basin, (3) oil and gas activity data obtained from IHS Enerdeq.

This document describes the methodologies by which the 2014 inventory inputs were developed for both the Greater San Juan and Permian basins. For midstream sources which were based on state and federal permitting databases, the source of emissions and any important assumptions for these emissions are described. For each wellsite source, the basis of the inputs for each source category is described.

Well count and production activity from a commercially available database of oil and gas data maintained by IHS Corporation ("the IHS database") have been compiled to develop emissions per unit of oil and gas activity wellsite source category inputs.

Additional data sources used to develop the inventory inputs include, GHGRP data[3], Colorado Air Resources Management Modeling Study wellsite inputs (ENVIRON et al., 2015), the US EPA's

[2] The Texas Commission on Environmental Quality (TCEQ) has developed emission inventories for the portion of the Permian Basin in Texas.
[3] https://ghgdata.epa.gov/ghgp/main.do

AP-42 emissions factor technical guidance (EPA, 1995), and the US EPA's MOVES emissions model (EPA, 2015).

## 1.2 Temporal and Geographical Scope

The inventory inputs were developed for base year 2014. All midstream facility data gathered from state and federal agencies and wellsite survey data requested from participating companies were for activities in the calendar year 2014. Similarly, all well count and production data obtained from the IHS database were for the calendar year 2014.

The geographic scope of the inventory inputs is the Greater San Juan Basin in north-western New Mexico and south-western Colorado and the portion of the Permian Basin in New Mexico. For the purposes of this study, the boundaries for the Greater San Juan Basin are based on the American Association of Petroleum Geologists[4] (AAPG) San Juan Basin consistent with EPA GHGRP, including Archuleta and La Plata counties in Colorado and Cibola, Los Alamos, McKinley, Rio Arriba, San Juan, Sandoval, and Valencia counties in New Mexico. The Permian Basin in this study is limited to the portion of the Permian Basin in south-eastern New Mexico as defined by the AAPG[4], including Chavez, Eddy, Lea, and Roosevelt counties. The geographic scope of the analysis also considers activities by mineral estate ownership: Federal, Bureau of Indian Affairs (BIA or tribal), and state/private fee land.

Figure 1-1 through Figure 1-4 show the boundaries of the Greater San Juan and Permian basins, with 2014 well locations extracted from the IHS database overlaid. Figure 1-1 presents wells by type and Figure 1-2 present wells by mineral designation for the Greater San Juan Basin. Figure 1-3 presents wells by type and Figure 1-4 present wells by mineral designation for the Permian Basin.

[4] http://ngmdb.usgs.gov/Geolex/stratres/provinces

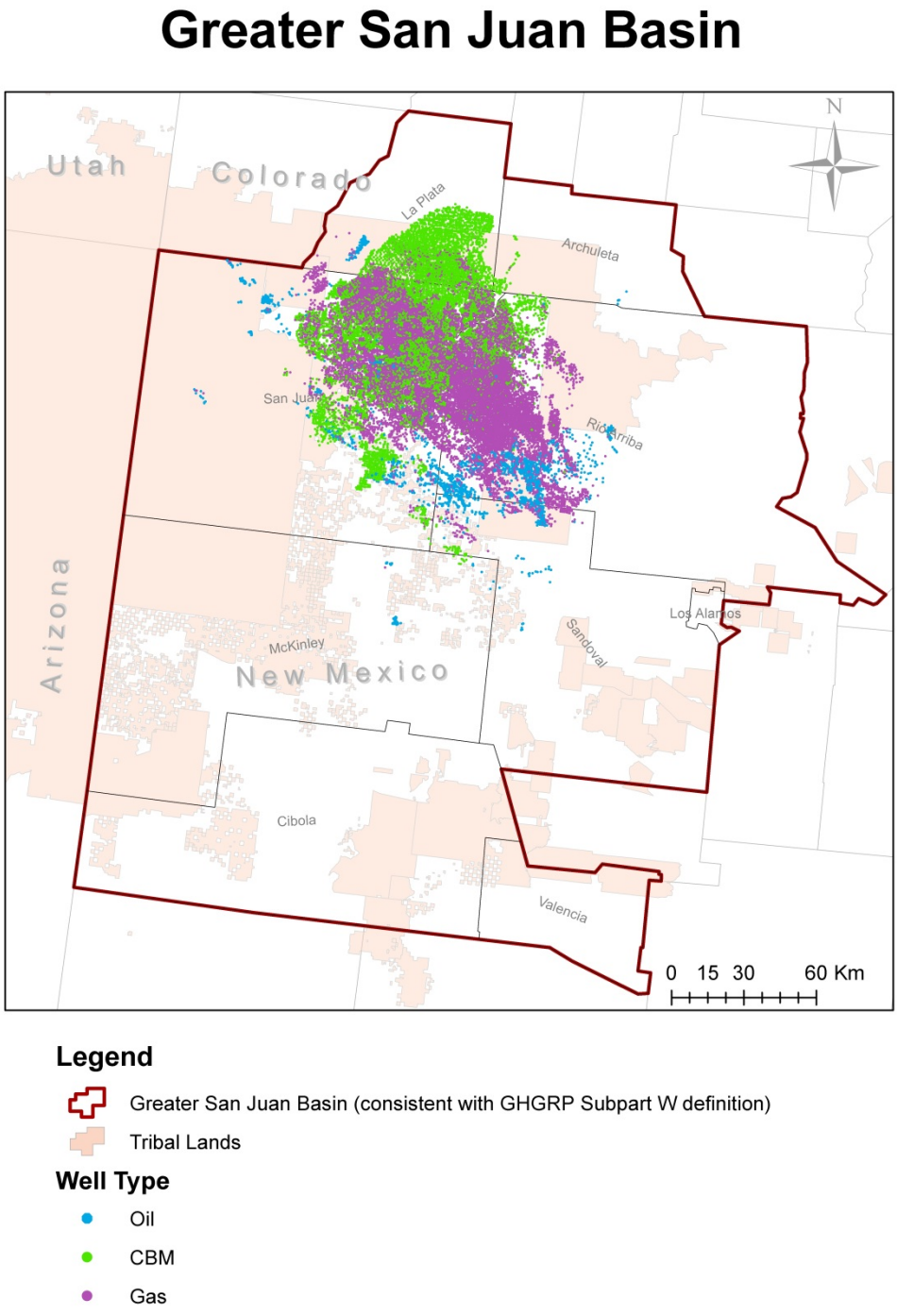



**Figure 1-1. Greater San Juan Basin boundaries overlaid with 2014 oil and gas well locations by well type.**[5]

[5] Includes data supplied by IHS Inc., its subsidiary and affiliated companies; Copyright (2011) all rights reserved.

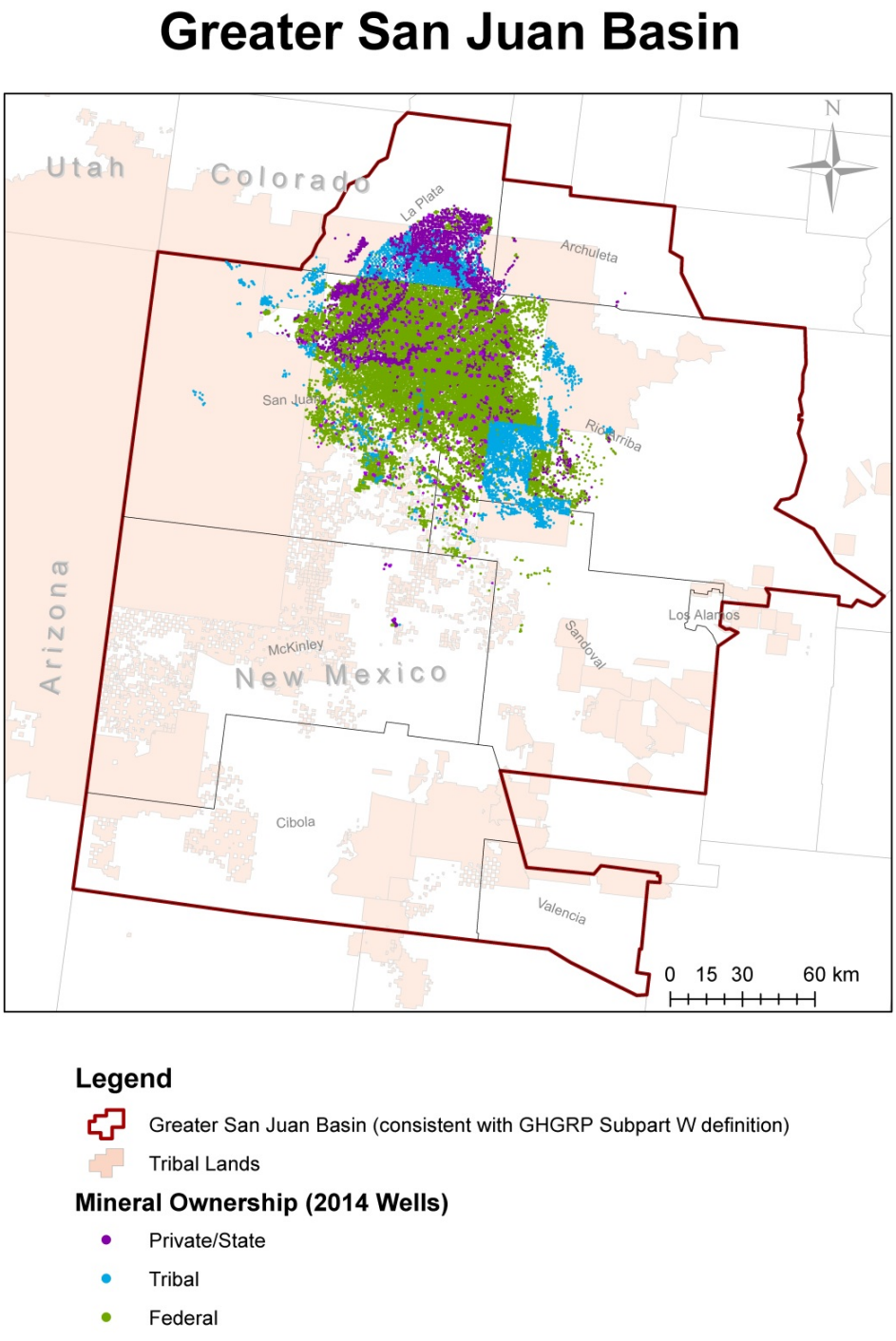



**Figure 1-2. Greater San Juan Basin boundaries overlaid with 2014 oil and gas well locations by mineral designation.[5]**

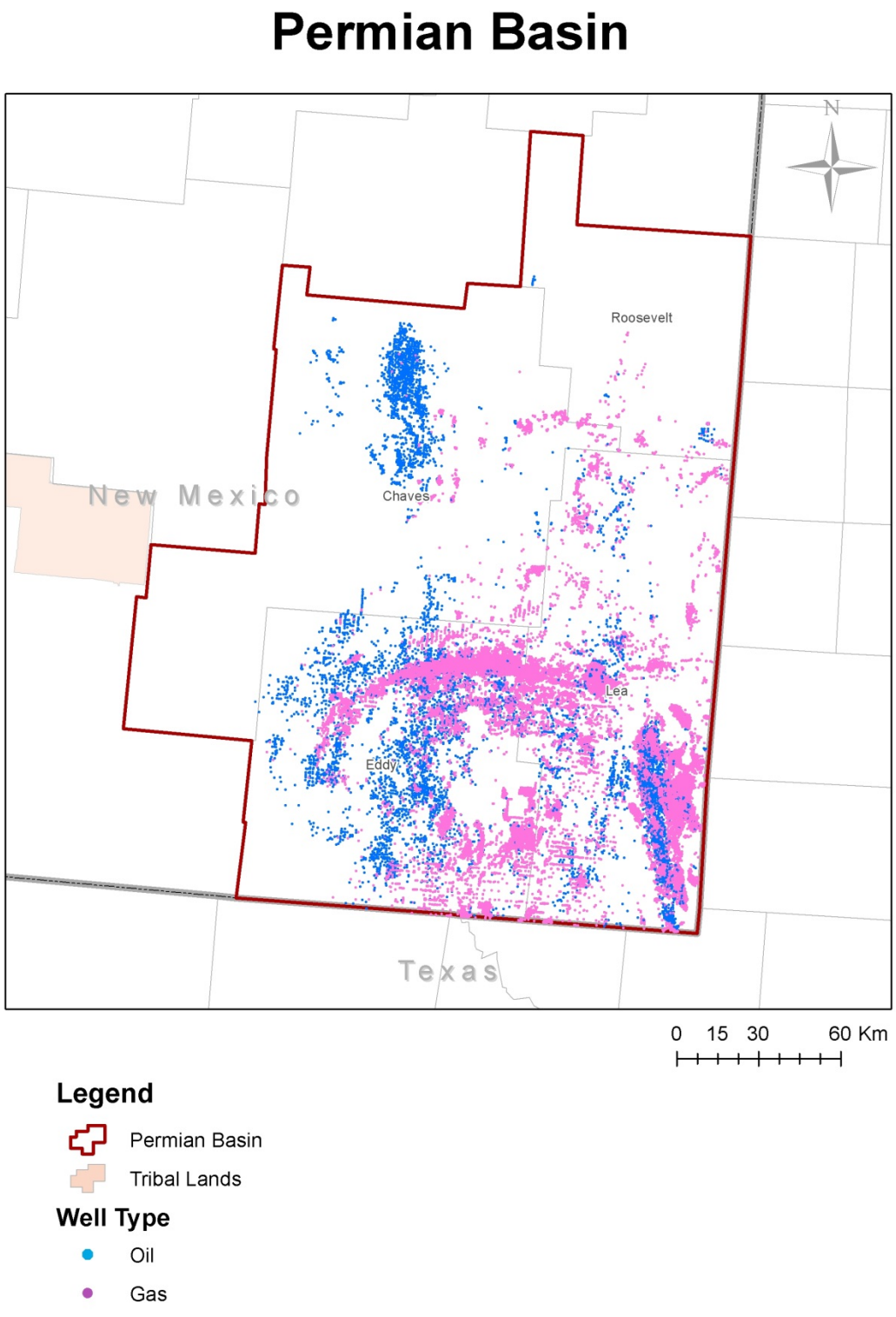



**Figure 1-3. Permian Basin boundaries overlaid with 2014 oil and gas well locations by well type.** [5]

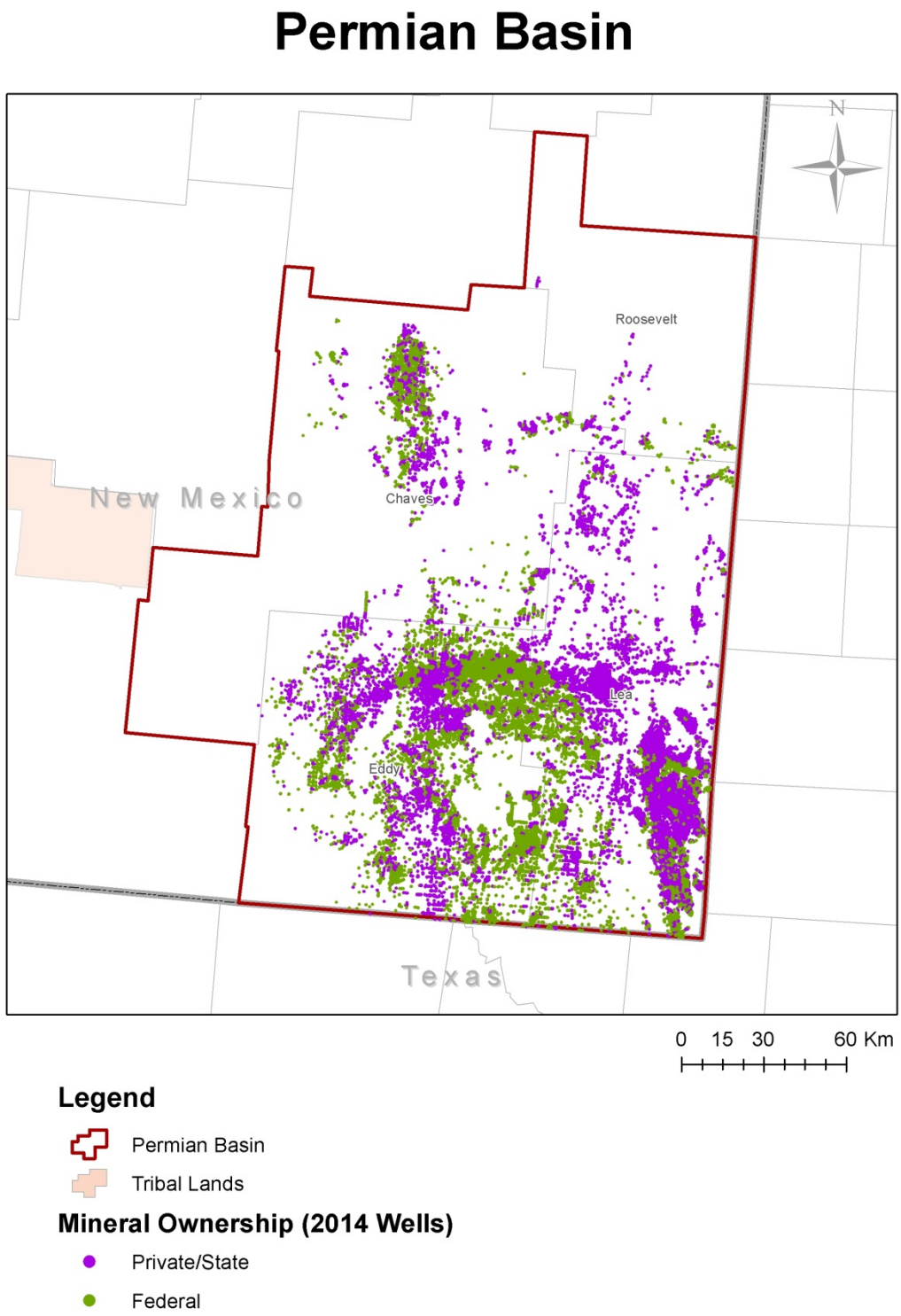



**Figure 1-4. Permian Basin boundaries overlaid with 2014 oil and gas well locations by mineral designation.** [5]

## 1.3 Well Count and Production Data

Oil and gas related activity data for the Greater San Juan and Permian basins were obtained from the IHS Enerdeq database queried via online interface. The IHS database uses data from each state's Oil and Gas Conservation Commission (OGCC or equivalent) as sources of information for oil and gas activity. This data is also available directly through database querying tools maintained by the respective agencies. It was determined that the IHS database is more accurate and complete than the state databases; the IHS database was also used to develop emission inventories in the WRAP Phase III, WestJump AQMS, and IWDW studies. Therefore, the IHS database was chosen as the basis for oil and gas activity statistics for this analysis. Two types of data were queried from the Enerdeq database: production data and well data. Production data includes information relevant to producing wells in the basin while well data includes information relevant to drilling activity ("spuds") and completions in the basin.

Production data were obtained for all counties in the Greater San Juan and Permian Basins in the form of IHS "298" format data files. The "298" well data contain information regarding historical oil and gas production. The "298"well data were processed with a PERL script to arrive at a database of by American Petroleum Institute (API)-number, well type (oil, gas, or coalbed methane; CBM), annual gas production, oil production, and water production with latitude and longitude information.

The API number in the IHS database consists of 14 digits as follows:

- Digits 1 to 2: state identifier
- Digits 3 to 5: county identifier
- Digits 6 to 10: borehole identifier
- Digits 11 to 12: sidetracks
- Digits 13 to 14: event sequence code (recompletions)

Based on the expectation that the first 10 digits, which include geographic and borehole identifiers, would predict unique sets of well head equipment, the unique wells were identified by the first 10 digits of the API number.

Well data were also obtained from the IHS Enerdeq database for the counties that make up the Greater San Juan and Permian Basins in the form of "297" well data. The "297" well data contain information regarding spuds and completions. The "297"well data were processed with a PERL script to arrive at a database of by-API-number, spud and completion dates with latitude and longitude information. Drilling events in 2014 were identified by indication that the spud occurred within 2014. If the well API number indicated the well was a recompletion, it was not counted as a drilling event, though if the API number indicated the well was a sidetrack, it was counted as a drilling event.

Oil and gas activity by well type and mineral designation are shown in Table 1-1 and Table 1-2 for the Greater San Juan Basin and in Table 1-3 and Table 1-4 for the Permian Basin.

**Table 1-1. Greater San Juan Basin 2014 oil and gas activity by county (counties without oil and gas production are not shown).**

| County, State | Active Well Count | | | Liquid Hydrocarbon Production (Mbbl/yr) | | Gas Production (MMCF/yr) | | | Spuds |
|---|---|---|---|---|---|---|---|---|---|
| | Gas | Oil | CBM | Condensate | Oil | Natural Gas | Associated Gas | CBM | |
| Archuleta, CO | 3 | 6 | 93 | 0 | 2 | 609 | 0 | 15,011 | 1 |
| La Plata, CO | 858 | 80 | 2,154 | 7 | 23 | 22,962 | 40 | 311,200 | 19 |
| ***Colorado Subtotals*** | ***861*** | ***86*** | ***2,247*** | ***7*** | ***25*** | ***23,571*** | ***40*** | ***326,211*** | ***20*** |
| McKinley, NM | 2 | 112 | 8 | 17 | 51 | 0 | 0 | 181 | 0 |
| Rio Arriba, NM | 6,746 | 729 | 1,057 | 638 | 871 | 190,228 | 8,926 | 84,916 | 24 |
| Sandoval, NM | 149 | 203 | 33 | 42 | 1,849 | 565 | 7,889 | 1,162 | 26 |
| San Juan, NM | 8,289 | 595 | 3,753 | 950 | 1,618 | 212,426 | 6,978 | 197,307 | 52 |
| ***New Mexico Subtotals*** | ***15,186*** | ***1,639*** | ***4,851*** | ***1,647*** | ***4,389*** | ***403,219*** | ***23,793*** | ***283,566*** | ***102*** |
| **Basin-wide Totals** | **16,047** | **1,725** | **7,098** | **1,653** | **4,413** | **426,789** | **23,833** | **609,777** | **122** |

**Table 1-2. Greater San Juan Basin percent of 2014 oil and gas activity by mineral designation.**

| Mineral Designation | Active Well Count | | | Liquid Hydrocarbon Production | | Gas Production | | | Spuds |
|---|---|---|---|---|---|---|---|---|---|
| | Gas | Oil | CBM | Oil | Condensate | Natural Gas | Associated Gas | CBM | |
| Private/State | 18% | 19% | 34% | 22% | 14% | 19% | 18% | 45% | 25% |
| Tribal | 15% | 30% | 13% | 12% | 12% | 12% | 16% | 19% | 14% |
| Federal | 67% | 51% | 54% | 66% | 74% | 69% | 66% | 36% | 61% |

**Table 1-3. Permian Basin 2014 oil and gas activity by county (counties without oil and gas production are not shown).**

| County, State | Active Well Count | | Liquid Hydrocarbon Production (Mbbl/yr) | | Gas Production (MMCF/yr) | | Spuds |
|---|---|---|---|---|---|---|---|
| | Gas | Oil | Condensate | Oil | Natural Gas | Associated Gas | |
| Chaves, NM | 1,209 | 692 | 40 | 1,420 | 12,137 | 6,624 | 12 |
| Eddy, NM | 2,640 | 10,809 | 1,592 | 57,909 | 69,243 | 219,727 | 601 |
| Lea, NM | 2,073 | 10,961 | 996 | 55,079 | 35,560 | 160,000 | 471 |
| Roosevelt, NM | 35 | 149 | 16 | 205 | 1,065 | 1,508 | 5 |
| **Basin-wide Totals** | **5,957** | **22,611** | **2,644** | **114,613** | **118,006** | **387,858** | **1,089** |

**Table 1-4. Permian San Juan Basin percent of 2014 oil and gas activity by mineral designation.**

| Mineral Designation[1] | Active Well Count | | Liquid Hydrocarbon Production | | Gas Production | | Spuds |
|---|---|---|---|---|---|---|---|
| | Gas | Oil | Oil | Condensate | Natural Gas | Associated Gas | |
| Private/State | 56% | 54% | 52% | 48% | 56% | 49% | 55% |
| Federal | 44% | 46% | 48% | 52% | 44% | 51% | 45% |

[1] The Permian Basin did not include any oil and gas activity from tribal mineral estate.

## 2.0 MIDSTREAM PERMIT DATA

Permitted sources in this analysis refer primarily to larger sources in use in midstream, gas gathering and gas treatment applications that are generally treated in inventories as point sources. This includes large gas processing plants, major compressor stations, and other smaller compressor stations, including the associated equipment at these stations. Permitted midstream sources were obtained from several data sources:

1. Title V major sources in use in midstream, gas gathering applications from NMED permit data;
2. Major and minor sources in use in midstream applications from CDPHE permit data;
3. Title V major sources on tribal land from US EPA Region 6;
4. Title V major sources on tribal land from US EPA Region 9;
5. Midstream point source emissions from the 2014 National Emission Inventory (v1).

Facilities in attainment areas such as the Greater San Juan and Permian basins are required to obtain a Title V operating permit (Part 70 or Part 71 permit) if emissions exceed 100 tons per year for any criteria pollutant or 10 tons per year for any hazardous air pollutant. Minor sources on tribal land are registered under the Indian Country Minor New Source Review Rule which requires registration of existing and new minor sources on tribal land. Minor sources are defined in attainment areas as those sources which do not meet major permitting thresholds with the potential to emit more than:

- 10 tons per year of carbon monoxide (CO), nitrogen oxides ($NO_x$), sulfur dioxide ($SO_2$), or particulate matter (PM), or
- Five tons per year of volatile organic compounds (VOCs), or
- Five tons per year of particulate matter less than 10 microns ($PM_{10}$), or
- Three tons per year of particulate matter less than 2.5 microns ($PM_{2.5}$), or
- 0.1 tons per year of lead, or
- One ton per year of fluorides, or
- Two tons per year of hydrogen sulfide ($H_2S$)

It should be noted that all midstream emissions for the Permian Basin were obtained solely from the NMED database since the scope of this project is limited to the New Mexico counties of the Permian Basin which include no tribal land. The Greater San Juan and Permian basin permitted sources will be used to supplement the emissions associated with wellsite sources which will be estimated based on the analysis presented in Section 3.0 and Section 4.0. Most permitted emissions are midstream facilities not included in the exploration and production (E&P) sector described in Section 3.0 and Section 4.0. Although NMED and CDPHE register production-site equipment, this study has relied on the survey or literature review data to estimate emission inputs from these sources rather than permit data for individual production sites because (1) a comprehensive, readily available database of NMED registered wellsite

facilities is not available and (2) CDPHE registered wellsite facilities are not expected to capture a substantial fraction of wellsite emissions because most activity in the Greater San Juan Basin in Colorado is on tribal lands.

## 2.1 Permit Data for Midstream Facilities from the New Mexico Environmental Department

Similar to the WRAP Phase III emissions inventories[6], midstream companies were not participants in the survey process conducted in the Greater San Juan Basin. Because NMED permits midstream sources on non-tribal land in New Mexico, it was determined that the NMED permit database would be the most comprehensive source of data on midstream facilities such as gas plants, compressor stations and associated equipment on non-tribal land. Actual emissions data from applicable midstream Title V facilities are included in this report. For midstream sources with emissions that are not large enough to meet Title V thresholds, a request has been made for an extraction from the NMED's permit database, Tools for Environmental Management and Protection Organizations (TEMPO). It is anticipated that NMED staff will query the database using a specific combination of North American Industry Classification System (NAICS) codes pertaining to oil and gas source categories that will mitigate the retrieval of well-head compressors which was a concern in previous emission inventory efforts (Bar-Ilan et al., 2008; Bar-Ilan et al., 2012; Parikh et al. 2015). The inclusion of non-Title V midstream sources in the next phase of this study (emission inventory development) will enhance its quality relative to prior emission studies.

## 2.2 Permit Data for Midstream Facilities from the Colorado Department of Public Health and Environment

2014 permitted point sources data for oil and gas sources on non-tribal land in Colorado was obtained directly from Air Permit Emission Notices (APENs) collected by the CDPHE for the Greater San Juan Basin. The reporting threshold in Colorado for a point source is 2 tons per year (tpy) of any criteria pollutant in attainment areas such as the portion of the Greater San Juan Basin in Colorado, and because of this low permitting threshold the database of emissions for permitted sources in the APENs was considered a highly comprehensive source of data. Wellsite area sources were filtered out of the APENs database as wellsite inputs in the Greater San Juan basins will be determined from survey responses. APENs sources on tribal lands (as determined by the latitude/longitude coordinates for each source) were also excluded from the analysis to avoid double counting with tribal midstream emissions data. Since the oil and gas activity in the Greater San Juan Basin in Colorado is primarily on tribal lands, excluding wellsite APENs facilities is warranted.

[6] http://www.wrapair2.org/PhaseIII.aspx

## 2.3 Permit Data for Midstream Facilities from EPA Region 8

In consultation with the Southern Ute Indian Tribe Environmental Programs Division, midstream permitted emissions data for tribal lands in EPA Region 8 were taken from the 2014 NEI v1[7].

## 2.4 Permit Data for Midstream Facilities from EPA Region 6

Title V and the minor source permits for the Jicarilla Apache and Laguna Reservations were obtained from EPA Region 6 for the Greater San Juan Basin. The Region 6 minor source database contains wellsite and midstream source emissions. Based on the facility name, wellsite area sources were filtered out of the minor source permit data as wellsite inputs in this analysis will be determined from survey responses.

## 2.5 Permit Data for Midstream Facilities from EPA Region 9

The Navajo Nation Reservation minor source permits were obtained from EPA Region 9. Analysis of the minor source permit data indicated that all Navajo Nation Reservation minor source permits were located in Utah, thus they were excluded from this analysis. Emissions from Title V facilities on the Navajo Nation Reservation were obtained from the 2014 NEI v1.

## 2.6 Greater San Juan Permit Data Emissions Summary

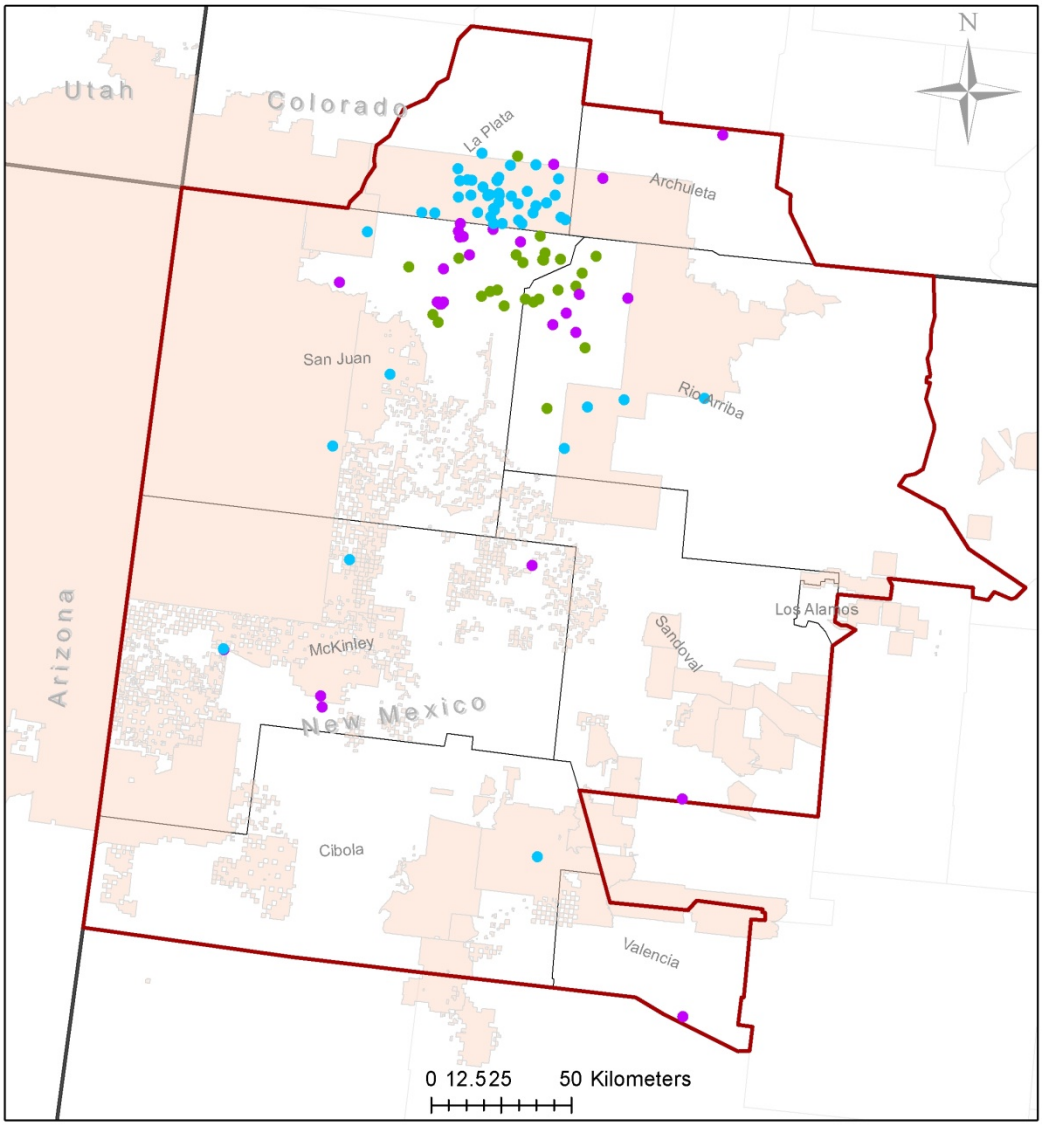
The Greater San Juan basin permitted emissions are summarized in Table 2-1. The majority of emissions are from the NMED permit source database. Figure 2-1 shows the facility locations by mineral designation; as described above tribal midstream facilities include both Title V/Part71 and minor sources (CDPHE also provided a small number of minor source midstream facilities) while BLM and private/state fee facilities provided by NMED only include Title V emissions because no minor facilities were able to be included from NMED's permit database. 40% of midstream NOx emissions are from sources on tribal land, 32% from sources on private/state fee land and remaining from the sources on federal land. For VOC, 45% of emissions are from the sources on federal land and 29% and 26% of VOC emissions are from the sources on tribal and private/state fee land respectively.

**Table 2-1. Summary of midstream permitted source emissions (tons/year) by data source for the Greater San Juan Basin.**

| Emission Data Source | Emissions (tons/yr) | | | | |
|---|---|---|---|---|---|
| | NOx | VOC | CO | $PM_{10}$ | $SO_2$ |
| NMED | 7,651 | 3,000 | 5,114 | 270 | 186 |
| CDPHE | 89 | 26 | 88 | 2 | 0 |
| EPA Region 6 | 618 | 377 | 257 | 4 | 0 |
| EPA Region 8 | 3,368 | 1,698 | 2,094 | 81 | 52 |
| EPA Region 9 | 9 | 8 | 7 | 0 | 0 |
| **Total** | **11,735** | **5,109** | **7,560** | **357** | **238** |

[7] https://www.epa.gov/air-emissions-inventories/2014-nei-data

# Greater San Juan Basin




**Legend**

- Greater San Juan Basin (consistent with GHGRP Subpart W definition)
- Tribal Lands

**Ownership**

- Federal
- Private/State
- Tribal

**Figure 2-1. Greater San Juan Basin boundaries overlaid with 2014 midstream facility point source locations.**

## 2.7 Permian Permit Data Emissions Summary

The Permian basin permitted emissions are summarized in Table 2-2. All permitted emissions are from the NMED permit source database. Figure 2-2 shows the facility locations by mineral designation. 89% of midstream NOx emissions are from sources on private/state fee land and 11% from sources on BLM land. 73% of midstream VOC emissions are from sources on private/state fee land and 27% from sources on BLM land.

**Table 2-2. Summary of midstream permitted source emissions (tons/year) for the Permian Basin.**

| Emission Data Source | Emissions (tons/yr) | | | | |
|---|---|---|---|---|---|
| | NOx | VOC | CO | $PM_{10}$ | $SO_2$ |
| NMED | 10,578 | 2,678 | 5,230 | 224 | 6,681 |
| **Total** | **10,578** | **2,678** | **5,230** | **224** | **6,681** |

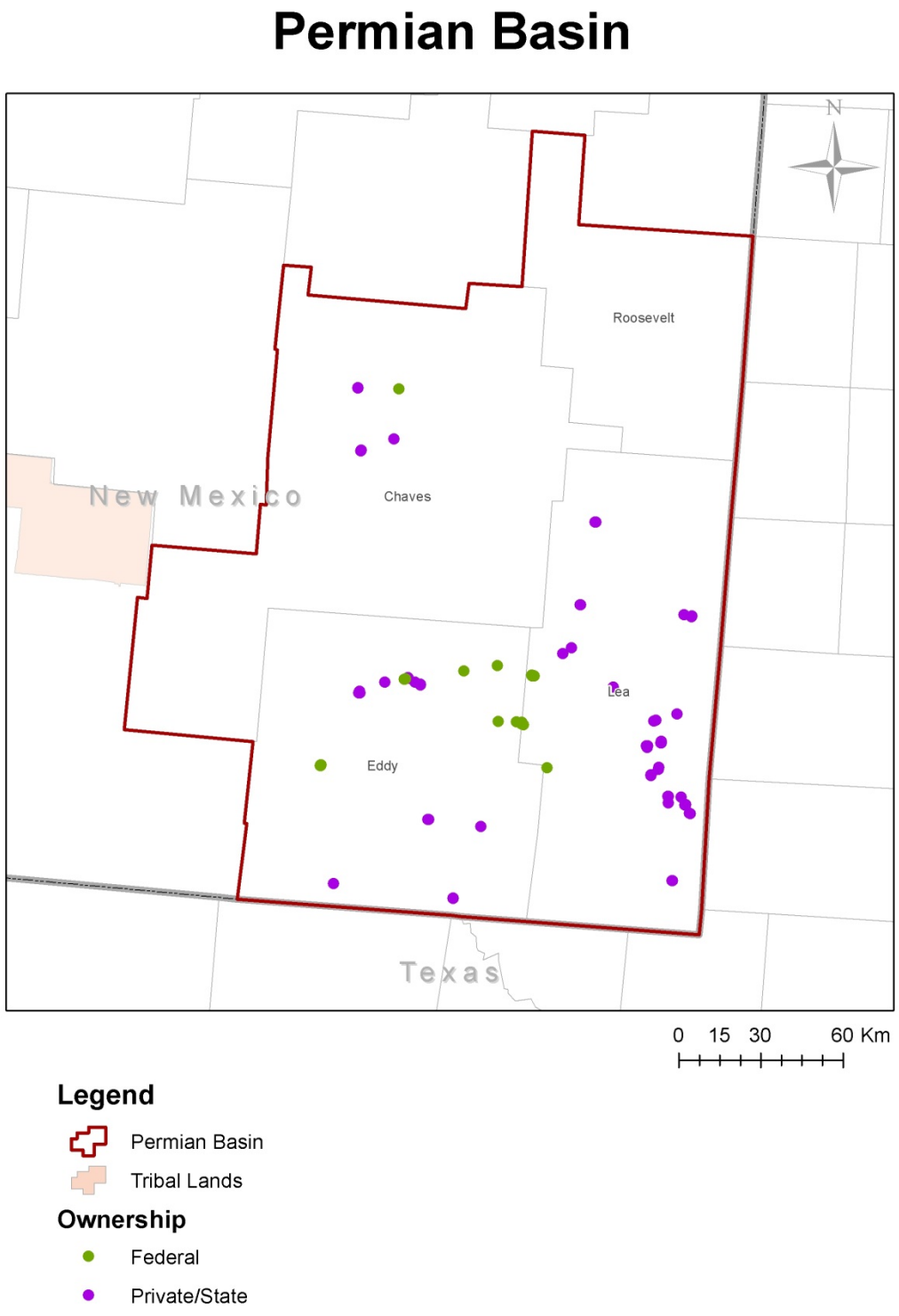



**Figure 2-2. Permian Basin boundaries overlaid with 2014 midstream facility point source locations.**

# 3.0 GREATER SAN JUAN BASIN WELLSITE INPUTS

Input factors to estimate emissions for the Greater San Juan Basin were derived primarily from operator surveys. Where gaps were identified for specific input parameters, they were filled with data collected for the Greater San Juan Basin from the EPA GHGRP data, the EPA 2011 NEI Oil and Gas Tool[8], and the Colorado Air Resources Management Modeling Study (ENVIRON et al., 2015)

## 3.1 Operator Survey

Two surveys were developed to query wellsite emission inventory inputs from operators of the Greater San Juan Basin. A survey was developed to request Subpart W submittals from operators along with other supplemental Subpart W data needed to develop wellsite inputs for wellsite sources reported under Subpart W. Additionally, a second survey was developed to gather wellsite emission inventory inputs for: (1) sources for which Subpart W data is insufficient; (2) sources which are not included in Subpart W; and (3) supporting data (e.g. gas compositions and simulation model input/output). Table 3-1 below shows each oil and gas source category for which data was requested along with the associated survey from which data was gathered.

**Table 3-1. Emission source categories by survey source.**

| Source Category | |
|---|---|
| **Non-Subpart W Survey** | **Subpart W Survey** |
| Drilling | Pneumatic Controllers |
| Fracing Engines | Pneumatic Pumps |
| Completion Venting | Dehydrators |
| Completion Engines | Casinghead Gas Venting/Flaring |
| Field Compressor Engines | Fugitive Components |
| Field Water Pump Engines | Liquid Unloading |
| Well Truck Loading | Condensate and Crude Oil Tanks |
| Artificial Lift Engines | Heaters |
| Workover Rigs | |
| Refracing Engines | |
| Miscellaneous Engines | |
| Water Tanks | |

The companies participating in the survey process for the Greater San Juan Basin represented approximately 53% of well ownership, 58% of gas production, and 53% of oil production. In order to increase operator representation, Ramboll Environ compiled company specific GHGRP data and gap filled source categories for which GHGRP data were not available for companies representing 13% of well ownership, 14% of gas production ownership, and 38% of oil production ownership to bring operator representation up to 65% of well ownership, 72% of

[8] ftp://ftp.epa.gov/EmisInventory/2011nei/doc/Tool_and_Report112614.zip

gas production ownership, and 81% of oil production ownership. The percentage of oil and gas activity that was captured in the survey process and based on company specific GHGRP data allow for good representation of oil and gas operations in the basin.

### 3.1.1 Gap Fill Data Sources

There are three data sources which were relied upon to create wellsite input factors to fill survey gaps (i.e. source categories for which operators were unable to provide survey data): (1) EPA GHGRP data and (2) Basin factors from the EPA Oil & Gas Emission Estimation Tool, and (3) Emission inventory input factors from ENVIRON et al. (2015) for source categories for which input factors were not available from the EPA Oil & Gas Emission Estimation Tool. GHGRP data gap filling was limited to two companies that did not complete a Subpart W survey. All of the wellsite input factors not able to be sourced from operator surveys or 2014 GHGRP data were filled with basin factors from the EPA Oil & Gas Emission Estimation Tool or ENVIRON et al. (2015).

#### 3.1.1.1 GHGRP Wellsite Data

EPA makes GHGRP supporting data available on the Envirofacts[9] and Facility Level Information on GreenHouse gases Tool (FLIGHT)[10]. The information available in the GHGRP supporting data depends on the reporting requirements for each source category; the reported data is not sufficient to derive a complete set of wellsite input factors for any source category. For example, pertinent information on compressor engines is limited to compressor engine counts and combustion GHG emissions whereas a criteria pollutant emission inventory requires information on engine type (rich or lean burn) and emission controls to estimate criteria pollutant emission rates. In general, available GHGRP data that is suggested for use to populate wellsite input factors is limited to event counts, equipment counts, and control prevalence. For parameters such as vented volumes, gas composition, engine horsepower, and engine emission rates, the EPA Oil and Gas Emission Estimation Tool estimates are used.

#### 3.1.1.2 EPA Oil and Gas Tool Data

For its 2011 NEI, EPA used the Oil & Gas Emission Estimation Tool to estimate oil and gas area source emissions for counties in which state/local/tribal agencies did not provide their own estimates of area source oil and gas emissions. The Oil & Gas Emission Estimation Tool was used in the 2011 NEI to estimate emissions throughout the Greater San Juan Basin.

The Tool calculates a comprehensive county-level criteria pollutant area source emission inventory based on county-level wellsite input factors and oil and gas activity data. The wellsite input factors in the Tool for the Greater San Juan Basin are based on Western Regional Air Partnership (WRAP) Phase III study[6] estimates that were provided to EPA by Ramboll Environ and WESTAR (Moore, 2013).

[9] http://www2.epa.gov/enviro/greenhouse-gas-overview
[10] http://ghgdata.epa.gov/ghgp/main.do

## 3.2 Input Factors

The Greater San Juan Basin input factors that were compiled from operator surveys, GHGRP data, EPA Oil and Gas Estimation Tool data, and ENVIRON et al. (2015) are shown in Appendix A. Survey data was aggregated together at the basin-wide level by well type to maintain the confidentiality of each company's data. Survey data was aggregated across all operators by the weighted average contribution of each company's data using the surrogate as the weighting factor. This methodology allows each company's survey data to impact the emissions from each source category in proportion to the company's ownership of the surrogate assigned to each category. The possibility of developing sub-basin level input factors was investigated; however, the survey data provided did not allow for protection of operator confidentiality for aggregate sub-basin level inputs.

For emissions from those source categories that relied on estimates of volume of gas vented or leaked, such as tank flashing, well blowdowns, completions, and fugitive emissions, gas composition analyses were requested from all participating companies for gas produced from oil wells (i.e. casinghead or associated gas), gas produced from gas wells (primary gas), gas produced from CBM wells (coalbed methane gas) and flash gas associated with oil, condensate, and water tanks. These composition analyses were averaged to derive representative basin-wide gas composition for oil wells by associated gas production, for gas wells by primary gas production, and for CBM wells by coalbed methane production. The average composition analyses are used to determine the average basin-wide VOC volume and mass fractions of the vented gas by type (see Table 3-2). Due to lack of survey data, oil, condensate, and water tank flash gas compositions were taken from (ENVIRON et al., 2015).

**Table 3-2. Gas composition input factors by well type.**

| Gas Composition Parameter | Associated Gas | Natural Gas | CBM | Condensate and Crude Oil Tanks | Water Tanks |
|---|---|---|---|---|---|
| Gas Molecular Weight (g/mol) | 20 | 20 | 16 | not available | not available |
| VOC Fraction (molar) | 3% | 6% | 1% | not available | not available |
| VOC/TOC (weight) | 9% | 16% | 2% | not available | not available |
| VOC Molecular Weight (g/mol) | 59 | 55 | 48 | 36 | 55 |
| Percent VOC (weight) | 7% | 15% | 2% | 58% | 5% |
| Percent CH4 (weight) | 65% | 64% | 84% | 9% | 84% |
| Percent CO2 (weight) | 12% | 5% | 5% | 2% | 1% |

## 3.3 Uncertainty

It should be noted that the input factor estimates for wellsite sources rely on data that is not as rigorously documented as permitted sources. Much of the data provided for these sources is based upon estimates and extrapolation from survey responses and other supporting data as described above. However, the level of detail of the surveys and other supporting data (e.g. GHGRP) and the extent of participation in the survey effort allow for representative input

factors to be developed for wellsite sources that are an improvement over previous studies for which input factors were developed for the 2006 timeframe (Bar-Ilan et al., 2009a; 2009c).

Per stakeholder input, survey data was not collected for certain wellsite source categories because data was not expected to be available: amine units, truck loading at gas and NGL processing plants, and water disposal pits. Finally, input factors for potential fugitive emissions from oil and gas pipelines from well heads to the main compressor stations were not estimated. Insufficient data was available on the components of pipelines or the complete extent of pipelines in the basins.

# 4.0 PERMIAN BASIN WELLSITE INPUTS

Permian Basin wellsite input factors were developed based on data available from other studies and/or reporting because conducting a survey in the Permian Basin was not expected to yield adequate operator participation. The possibility of conducting a survey in the Permian Basin was explored through outreach to some Permian Basin operators with assistance from BLM staff, but the operator responses indicated that a survey was not likely to be successful.

A literature review was performed to gather data on Permian Basin wellsite emission sources. Review of available literature indicated that there are two recent and applicable sources: (1) the TCEQ oil and gas emission inventory; and (2) data available as part of EPA Subpart W reporting for wellsite sources for the Permian Basin. These two sources are the subject of the review presented in this chapter. There are two more studies, a 2012 Central States Air Resources Agencies (CENSARA) study (ENVIRON, 2012) and a 2008 Central Regional Air Planning Association (CENRAP) study (Bar-Ilan et al., 2008), that include data for the Permian Basin, however Permian Basin wellsite inputs collected for these studies are primarily from data collected in calendar year 2008 and this data has been incorporated into or updated in the TCEQ Permian Basin oil and gas inventory.

## 4.1 Subpart W Greenhouse Gas Reporting Program (GHGRP)

A review of the Subpart W reporting (40 CFR 98, Subpart W) data was performed[11]. Owners or operators of facilities[12] that contain petroleum and natural gas systems and emit 25,000 metric tons or more of GHGs per year (expressed as carbon dioxide equivalents) are required to report GHG data to EPA. The Subpart W reporting is required for the following petroleum and natural gas industry segments:

1. Onshore petroleum and natural gas production
2. Offshore petroleum and natural gas production
3. Onshore natural gas processing plants
4. Onshore natural gas transmission compression
5. Underground natural gas storage
6. Liquefied natural gas (LNG) storage
7. Liquefied natural gas import and export equipment
8. Natural gas distribution

The purpose of the review of Subpart W data in this study is to develop representative wellsite emission inventory inputs, therefore, the literature review was performed on data available for the "Onshore petroleum and natural gas production" segment only. Table 4-1 identifies the source categories required to report under the Subpart W for this segment. The Subpart W data available on Envirofacts[9] and Facility Level Information on GreenHouse gases Tool (FLIGHT)[10]

[11] http://www.epa.gov/ghgreporting/reporters/subpart/w.html
[12] http://www2.epa.gov/sites/production/files/2015-08/documents/petroleumnaturalgassystems.pdf

provides GHG emissions with limited equipment/process-level data which are required to develop representative input factors.

**Table 4-1. Source categories required to report under the Subpart W for the onshore petroleum and natural gas production segment.**

| Source Type |
|---|
| Natural gas pneumatic device venting |
| Natural gas driven pneumatic pump venting |
| Acid gas removal vents |
| Dehydrator vents |
| Well venting for liquids unloading |
| Gas well venting during completions and workovers from hydraulic fracturing |
| Gas well venting during completions and workovers without hydraulic fracturing |
| Onshore production storage tanks |
| Well testing venting and flaring |
| Associated gas venting and flaring |
| Flare stack emissions |
| Centrifugal compressor venting |
| Reciprocating compressor venting |
| Population count and emissions factors |
| Enhanced Oil Recovery (EOR) injection pump blowdown |
| EOR hydrocarbon liquids dissolved $CO_2$ |
| Combustion emissions by following subpart W |

The Subpart W GHGRP submissions for all facilities[12] within the Permian Basin boundary[13], which includes counties in both western Texas and south-eastern New Mexico, were downloaded for calendar year 2014. 62 facilities submitted data for the Permian Basin, however, data from 17 facilities were not able to be used for this analysis for the following reasons:

- Seven facilities did not report their data due to undisclosed valid reasons.
- Four facilities have not met the EPA verification requirement.
- One facility's data was not accessible for download from the FLIGHT database.
- Five facilities did not have well count information available in their GHGRP submissions. Without well count, representative input factors were unable to be calculated.

For each facility, data were downloaded in ".txt" format and a macro was developed in MS EXCEL to efficiently compile data from each facility's file for analysis. It was concluded that there was publicly available data relevant to compiling basin-wide input factors for a limited number of source categories: pneumatic devices, pneumatic pumps, fugitives and wellhead compressor engines. Total equipment counts for each of these sources were compiled for 45

[13] http://www.ccdsupport.com/confluence/display/help/Subpart+W+Basin+and+County+Combinations

facilities. These 45 facilities represent 107,217 wells in the Permian Basin. Table 4-2 summarizes input factors developed for pneumatic devices, pneumatic pumps, fugitives and compressor engines based on the 2014 Subpart W data. It should be noted that the GHGRP does not provide data by well type for these sources. Additional data beyond what is made publicly available by EPA from the reporting operators would be required to make use of Subpart W data for sources not listed in Table 4-2.

**Table 4-2. Input factors developed using the GHGRP submissions for the Permian Basin.**

| Parameter | | Value | Unit |
|---|---|---|---|
| **Pneumatic Devices** | | | |
| Devices counts for oil and gas wells | High Bleed | 0.04 | number of devices per well |
| | Intermittent | 0.31 | |
| | Low Bleed | 0.24 | |
| EPA default bleed rate | High Bleed | 37.00 | scf/hr |
| | Intermittent | 13.50 | |
| | Low Bleed | 1.39 | |
| **Fugitives** | | | |
| Fugitives counts for gas and oil wells | Onshore, gas service - connector | 29.56 | number of components per well |
| | Onshore, gas service - open-ended line | 0.99 | |
| | Onshore, gas service - pressure relief valve | 0.43 | |
| | Onshore, gas service - valve | 9.15 | |
| | Onshore, light crude service - connector | 5.89 | |
| | Onshore, light crude service - flange | 9.72 | |
| | Onshore, light crude service - other | 0.79 | |
| | Onshore, light crude service - valve | 5.00 | |
| **Pneumatic Pumps** | | | |
| Number of pumps per well | | 0.03 | pumps/well |
| Vent rate for pumps | | 13.3 | scf/hr/pump |
| **Compressor Engines*** | | | |
| Number of compressor engines | | 0.02 | engines/well |

* For the compressor engines, the GHGRP does not provide sufficient information to develop engine activity i.e. average horsepower, load factor, hours of operation, etc.

## 4.2 Texas Oil and Gas Emission Inventory

The TCEQ has developed a 2012 oil and gas emission inventory based primarily on ERG (2010), but with some significant updates to source categories such as compressor engines, storage tanks, heaters, pneumatic devices, completions, etc. (TCEQ, 2015) as well as a 2014 emission inventory that updates the 2012 emission inventory (TCEQ, 2016). Table 4-3 lists the reports that provide emission estimation methodologies for each source category and the associated oil and gas activity surrogate used to develop emissions.

The TCEQ reports provide detailed wellsite input factor data used in development of the Texas oil and gas inventory. The input factor data in the TCEQ reports are based on a variety of

sources including oil and gas operator data, CENRAP study data (Bar-Ilan, et al., 2008), EPA Oil and Gas Tool V.2.0[14], EPA AP-42[15] factors, manufacturing specifications, etc. The input factors used in the TCEQ inventory to estimate Permian Basin oil and gas wellsite emissions are summarized in Table 4-4.

**Table 4-3. List of TCEQ reports reviewed for each wellsite source.**

| Wellsite Source | Associated Surrogate | Report |
|---|---|---|
| Artificial Lift Engines | Oil Well Counts | ERG (2010) |
| Well Blowdowns | Well Counts | |
| Dehydrators | Well Counts | |
| Oil and Condensate Loading | Oil Production and Condensate Production | |
| Fugitives | Well Counts | |
| Wellhead Compressor Engines | Gas Production | |
| Crude Oil Storage Tanks | Oil Production | |
| Pneumatic Pumps | Well Counts | |
| Fracturing | Spuds | |
| Completions | Spuds | |
| Produced Water | Water Production | ENVIRON (2010) |
| Drilling | Spuds | ERG (2011) |
| Condensate Tanks | Condensate Production | ERG (2012) |
| Heaters | Well Counts | ERG (2010, 2013) |
| Mud Degassing | Spuds | ERG (2014) |
| Pneumatic Device | Well Counts | TCEQ (2014) |

**Table 4-4. Input factors used in the TCEQ inventory for wellsite sources.**

| Parameter | | Value | Unit |
|---|---|---|---|
| **Artificial Lift Engines** | | | |
| Fraction of oil wells with artificial lift engines | | 96.70% | % |
| Fraction of artificial lift engines that are electrically operated | | 70.00% | % |
| Average horsepower of the engine | | 20.55 | hp |
| Average Fuel Consumption | | 0.21 | mmbtu/hp-hr |
| Load factor | | 71.00% | % |
| Annual number of hours | | 4,380 | hr/yr |
| Emission Factors | NOx | 14.75 | g/hp-hr |
| | VOC | 0.14 | |
| | CO | 7.37 | |
| | PM | 0.05 | |
| | SOx | <0.01 | |

[14] EPA Oil and Gas Toll V2.0, November, 2014.
ftp://ftp.epa.gov/EmisInventory/2011nei/doc/Tool_and_Report112614.zip
[15] EPA AP-42. Emission Factors & AP42, Compilation of Air Pollutant Emission Factors.
http://www3.epa.gov/ttnchie1/ap42/

| Parameter | | | Value | Unit |
|---|---|---|---|---|
| **Well Blowdown**[16] | | | | |
| Volume of vented gas per blowdown | | | 50.00 | mcf/event/wellhead |
| Number of blowdowns per well | | | 5.00 | event/wellhead/yr |
| Number of blowdowns controlled by flares | | | 0.00[17] | - |
| **Dehydrators** | | | | |
| VOC Venting emission factors | | | 1.63 | lb/mmscf |
| Amount of produced gas flared | | | 13.40 | lbs flared/mmscf produced |
| Density of gas flared | | | 46,952 | lb/mmscf |
| Heat value of the gas flared | | | 1,209 | mmbtu/mmscf |
| Flaring Emission Factors | NOx | | 0.07 | lb/mmbtu |
| | CO | | 0.37 | lb/mmbtu |
| Glycol Regenerator Boilers Emission Factors | NOx | | 0.05 | lb/mmscf |
| | CO | | 0.11 | |
| **Heaters** | | | | |
| Average number of heaters per well | | | 0.37 | - |
| Average heater size | | | 0.53 | mmbtu/hr |
| Average hours of operation | | | 3,477 | hr/yr |
| Average fuel content | | | 1,359 | btu/scf |
| Emission Factors | NOx | | 58.20 | lb/mmscf |
| | VOC | | 5.50 | |
| | CO | | 84.00 | |
| | $PM_{10}$ | | 7.60 | |
| | $PM_{2.5}$ | | 7.60 | |
| | $H_2S$ mass fraction | Gas Wells | <0.01 | - |
| | | Oil Wells | 6.50 | - |
| **Pneumatic Devices** | | | | |
| No. of devices per well | Gas Wells | | 1.19 | - |
| | Oil Wells | | 0.43 | - |
| Weighted average bleed rate | Gas Wells | | 8.79 | scf/hr |
| | Oil Wells | | 5.24 | |
| VOC emission factor | Gas Wells | | 0.38 | tpy/well |
| | Oil Wells | | 0.19 | |
| **Fugitives** | | | | |
| Gas Wells -Fugitives | Valves | | 19.00 | number of components per well |
| | Pump Seals | | 2.00 | |
| | Others | | 10.00 | |
| | Connectors | | 43.00 | |
| | Flanges | | 29.00 | |
| | Open-ended lines | | 3.00 | |
| | VOC to TOC ratio | | 0.14 | - |
| Oil Wells -Fugitives | Valves | | 16.00 | number of components per well |
| | Pump Seals | | 2.00 | |
| | Others | | 10.00 | |

[16] Gas wells only per TCEQ (2016)

[17] Personal communication with the Bureau of Land Management (BLM) staff (Mary Uhl), November 12, 2015.

| Parameter | | Value | Unit |
|---|---|---|---|
| | Connectors | 58.00 | |
| | Flanges | 12.00 | |
| | Open-ended lines | 2.00 | |
| | VOC to TOC ratio | 0.14 | - |
| **Oil Tanks** | | | |
| VOC Emission Factor | | 1.60 | lb/bbl |
| Fraction of Production Controlled | | 0.00% | % |
| **Condensate Tanks** | | | |
| VOC Emission Factor | | 7.07 | lb/bbl |
| Fraction of Production Controlled | | 19.50% | % |
| **Oil Tank Loading** | | | |
| Mode of Operation | | Submerged loading: dedicated vapor balance /Splash loading: dedicated vapor balance service | - |
| Saturation Factor | | 1.00 | - |
| Temperature of the bulk liquid loaded | | From the National Weather Service and from several state/local monitoring sites by county | degrees Fahrenheit |
| True Pressure | | (0.057*temperature of liquid loaded(degrees Fahrenheit))-0.58 | psia |
| Molecular Weight of Crude RVP 5 | | 50.00 | lb/lb-mole |
| **Condensate Tank Loading** | | | |
| Mode of Operation | | Submerged loading: dedicated vapor balance /Splash loading: dedicated vapor balance service | - |
| Saturation Factor | | 1.00 | - |
| Temperature of the bulk liquid loaded | | From the National Weather Service and from several state/local monitoring sites by county | degrees Fahrenheit |
| True Pressure | | (0.077*temperature of liquid loaded(degrees Fahrenheit))-1.03 | psia |
| Molecular Weight of Gasoline RVP 7 | | 68.00 | lb/lb-mole |

| Parameter | | | Value | Unit |
|---|---|---|---|---|
| **Pneumatic Pumps** | | | | |
| Methane vent rate for gas wells using Kimray pumps | | | 1,041 | scf/mmscf |
| Gas pumped per gas well annually with Kimray pumps per unit throughput | | | 42.90 | mmscf/well/yr |
| Methane vent rate for gas wells using CIP pumps | | | 260.00 | scf/mmscf |
| Number of hours of operation of CIP pumps at gas wells | | | 8,760 | hr/yr |
| Number of CIP pumps per gas well | | | 0.14 | count/well |
| Methane vent rate for oil wells using CIP pumps | | | 248.00 | scf/mmscf |
| Number of hours of operation of CIP pumps at oil wells | | | 8,760 | hr/yr |
| Number of CIP pumps per oil well | | | 0.05 | count/well |
| Molecular weight of the gas emitted by gas-actuated pumps at gas wells | | | 21.56 | g/mol |
| VOC molar fraction of gas emitted by gas-actuated pumps at gas wells | | | 8.23% | % |
| Hydrogen sulfide molar fraction of gas emitted by gas-actuated pumps at gas wells | | | 0.00% | % |
| Carbon dioxide molar fraction of gas emitted by gas-actuated pumps at gas wells | | | 2.18% | % |
| Methane molar fraction of gas emitted by gas-actuated pumps at gas wells | | | 75.00% | % |
| Molecular weight of the VOC emitted by gas-actuated pumps at gas wells | | | 50.64 | g/mol |
| Molecular weight of the gas emitted by gas-actuated pumps at oil wells | | | 20.68 | g/mol |
| VOC molar fraction of gas emitted by gas-actuated pumps at oil wells | | | 7.06% | % |
| Hydrogen sulfide molar fraction of gas emitted by gas-actuated pumps at oil wells | | | 0.64% | % |
| Carbon dioxide molar fraction of gas emitted by gas-actuated pumps at oil wells | | | 2.08% | % |
| Methane molar fraction of gas emitted by gas-actuated pumps at oil wells | | | 80.62% | % |
| Molecular weight of the VOC emitted by gas-actuated pumps at oil wells | | | 53.22 | g/mol |
| Methane to VOC weight ratio of gas emitted by gas-actuated pumps at oil wells | | | 3.44 | - |
| Hydrogen sulfide to VOC weight ratio emitted by gas-actuated pumps at oil wells | | | 0.06 | - |
| Methane to VOC weight ratio of gas emitted by gas-actuated pumps at gas wells | | | 2.88 | - |
| Hydrogen sulfide to VOC weight ratio emitted by gas-actuated pumps at gas wells | | | 0.00% | % |
| **Drill Rigs (Vertical Wells Depth <= 7,000 ft)** | | | | |
| Mechanical Rig Type | Draw Works | No. of Engines | 1.60 | - |
| | | Average Age | 7.00 | yrs. |
| | | Horsepower | 442.00 | hp |
| | | Hours | 30.80 | hr/1000 ft drilled |
| | | Average Load | 51.80% | % |
| | Mud Pump | No. of Engines | 1.69 | - |
| | | Average Age | 6.00 | yrs. |
| | | Horsepower | 428.00 | hp |
| | | Hours | 29.40 | hr/1000 ft drilled |
| | | Average Load | 45.90% | % |

| Parameter | | | Value | Unit |
|---|---|---|---|---|
| | Generator | Number of Engines | 0.97 | - |
| | | Average Age | 4.00 | yrs. |
| | | Horsepower | 330.00 | hp |
| | | Hours | 28.30 | hr/1000 ft drilled |
| | | Average Load | 70.40% | % |
| **Drill Rigs (Vertical Wells Depth > 7,000 ft)** | | | | |
| Mechanical Rig Type | Draw Works | Number of Engines | 2.01 | - |
| | | Average Age | 25.00 | yrs. |
| | | Horsepower | 455.00 | hp |
| | | Hours | 35.90 | hr/1000 ft drilled |
| | | Average Load | 47.40% | % |
| | Mud Pump | Number of Engines | 1.62 | - |
| | | Average Age | 18.00 | yrs. |
| | | Horsepower | 761.00 | hp |
| | | Hours | 33.20 | hr/1000 ft drilled |
| | | Average Load | 46.00% | % |
| | Generator | Number of Engines | 2.00 | - |
| | | Average Age | 10.00 | yrs. |
| | | Horsepower | 407.00 | hp |
| | | Hours | 19.30 | hr/1000 ft drilled |
| | | Average Load | 78.70% | % |
| Electrical | | Number of Engines | 2.15 | - |
| | | Average Age | 2.00 | yrs. |
| | | Horsepower | 1,381 | hp |
| | | Hours | 62.60 | hr/1000 ft drilled |
| | | Average Load | 48.50% | % |
| **Drill Rigs (Horizontally Drilled)** | | | | |
| Mechanical Rig Type | Draw Works | No. of Engines | 2.00 | - |
| | | Average Age | 15.00 | yrs. |
| | | Horsepower | 483.00 | hp |
| | | Hours | 50.10 | hr/1000 ft drilled |
| | | Average Load | 41.10% | % |
| | Mud Pump | No. of Engines | 2.00 | - |
| | | Average Age | 6.00 | yrs. |
| | | Horsepower | 1,075 | hp |
| | | Hours | 36.40 | hr/1000 ft drilled |
| | | Average Load | 42.60% | % |
| | Generator | No. of Engines | 2.00 | - |
| | | Average Age | 10.00 | yrs. |
| | | Horsepower | 390.00 | hp |
| | | Hours | 26.80 | hr/1000 ft drilled |
| | | Average Load | 69.00% | % |
| Electrical | | Number of Engines | 2.03 | - |
| | | Average Age | 2.00 | yrs. |
| | | Horsepower | 1,346 | hp |
| | | Hours | 47.30 | hr/1000 ft drilled |
| | | Average Load | 52.50% | % |

| Parameter | | Value | Unit |
|---|---|---|---|
| **Produced Water** | | | |
| VOC Emission Factor | | 0.01 | lb/bbl |
| **Compressor Engines** | | | |
| Energy required per unit of gas production | | 3.21 | hp-hr/mmscf |
| Percent Workload | Generic | 6.21% | % |
| | 2-cycle lean burn 50 to 499 Hp | 7.14% | % |
| | 4-cycle lean burn 500+ hp | 28.60% | % |
| | 4-cycle rich burn < 50 hp | 0.60% | % |
| | 4-cycle rich burn 50 to 499 hp | 36.55% | % |
| | 4-cycle rich burn 500+ hp w/NSCR | 20.92% | % |
| Generic Emission Factors | NOx | 5.51 | g/bhp-hr |
| | VOC | 0.95 | |
| | CO | 1.86 | |
| | PM | 0.15 | |
| | SOx | <0.01 | |
| 2-cycle Lean Burn 50 to 499 hp Emission Factors | NOx | 8.47 | g/bhp-hr |
| | VOC | 0.81 | |
| | CO | 1.51 | |
| | PM | 0.15 | |
| | SOx | <0.01 | |
| 4-cycle Lean Burn 500+ hp Emission Factors | NOx | 1.66 | g/bhp-hr |
| | VOC | 0.51 | |
| | CO | 2.20 | |
| | PM | 0.01 | |
| | SOx | <0.01 | |
| 4-cycle Rich Burn < 50 hp Emission Factors | NOx | 12.95 | g/bhp-hr |
| | VOC | 0.05 | |
| | CO | 1.10 | |
| | PM | 0.03 | |
| | SOx | <0.01 | |
| 4-cycle Rich Burn 50 to 499 hp Emission Factors | NOx | 15.89 | g/bhp-hr |
| | VOC | 0.16 | |
| | CO | 7.70 | |
| | PM | 0.03 | |
| | SOx | <0.01 | |
| 4-cycle Rich Burn 500+ hp w/NSCR Emission Factors | NOx | 1.28 | g/bhp-hr |
| | VOC | 0.05 | |
| | CO | 0.85 | |
| | PM | 0.03 | |
| | SOx | <0.01 | |
| **Fracing Engines** | | | |
| Horsepower (HP) of a hydraulic fracture engine | | 1,258 | hp |
| Load factor of a hydraulic fracture engine | | 0.63 | - |
| Number of stages per fracturing event | | 5.75 | - |
| Number of hours per fracturing stage | | 1.50 | hp/stage |
| Number of fracturing engines used per fracturing event | | 3.50 | - |

| Parameter | Value | Unit |
|---|---|---|
| **Initial Completions** | | |
| Volume vented per completion | 0 | MCF/event |
| Fraction of completions controlled by flare | 0 | - |
| Fraction of completions controlled by green completion techniques | 0 | - |

## 4.3 Uncertainty

The findings of the literature review suggest that the TCEQ equipment/process-level wellsite input factors are the most complete and comprehensive available for most oil and gas wellsite sources in the Permian Basin while the GHGRP data are available to characterize input factors for a limited number of sources. For pneumatic pumps and fugitive leaks, we recommend that the GHGRP input factors summarized in Table 4-2 be used since these factors were developed based on actual data submitted to EPA by operators in the Permian Basin for the calendar year 2014 whereas the TCEQ data for these source categories is based on older data collected as part of Bar-Ilan et al. (2008). While limited GHGRP data is also available for pneumatic devices and compressor engines, due to the lack of pneumatic device data by well type and the lack of engine characteristics for compressor engines, we recommend that TCEQ data be used. We suggest that in the absence of New Mexico specific or complete GHGRP data, the TCEQ wellsite input factors, summarized in Table 4-4 be used to develop a New Mexico Permian Basin emission inventory for all wellsite sources except pneumatic pumps and fugitive leaks. The gas composition analysis for the Permian Basin would be obtained from the EPA Oil and Gas Tool V.2[14] since TCEQ does not have information on Permian Basin natural gas composition.

We note that there is uncertainty in the input factors data for the following source categories:

- **Compressor engines:** Compressor engine emissions estimation methodology used in the TCEQ inventory for the Permian Basin does not explicitly provide compressor engine prevalence at wellsites. Typically, estimates of compressor engine prevalence and representative compressor engine activity are used to estimate compressor engine emissions. The GHGRP provides engine frequency but does not have information on engine characteristics and activity data.
- **Fugitive devices:** GHGRP data is not available at the well type level of detail, therefore the same fugitive device profile would be applied across all wells. TCEQ data is based on Bar-Ilan et al. (2008) which is dated and was not based on a robust sample of operator provided data for the Permian Basin.
- **Pneumatic pumps:** GHGRP data is not available to characterize Permian Basin pneumatic pump characteristics and activity; only pump count is available. TCEQ inventory data is based on the 2011 NEI Oil and Gas Tool which is based on Bar-Ilan et al. (2008). Bar-Ilan et al. (2008) is dated and was not based on a robust sample of operator provided data for the Permian Basin.

- **Artificial lift engines:** TCEQ inventory emissions were estimated as described in ERG (2010) based on Texas-wide assumptions rather than a survey of operators in the Permian Basin.
- **Well completion venting, blowdowns:** TCEQ inventory estimates are based on the 2011 NEI Oil and Gas Tool input factors which are based on Bar-Ilan et al. (2008). Bar-Ilan et al. (2008) is a dated study and was not based on a robust sample of operator provided data for the Permian Basin.
- **Dehydrators:** TCEQ inventory estimates are based on assumptions derived from point sources which are not specific to the Permian Basin and are not likely to have been located at wellsites.

The effects on emissions of the EPA New Source Performance Standard (NSPS) Subpart OOOO need to be accounted for in the emission inventories to be developed in the next phase of this work. NSPS Subpart OOOO requires controls on tanks emitting more than six tons of VOC per year that were new or modified after August 23, 2011 and the implementation of green completion technology for hydraulically fractured natural gas wells drilled after Aug. 23, 2011. EPA NSPS Subpart OOOO also requires the use of low-bleed pneumatic devices (i.e. pneumatic devices that are rated at 6 standard cubic-feet of gas per hour (scf/hr) or lower) from August 23, 2011 at new or modified wells. ERG (2014) has provided recommendations for incorporating the effects of the Subpart OOOO requirements into the inventory; a similar methodology should be applied to estimate the effects of controls in the next phase of this study when the New Mexico Permian Basin emission inventories are compiled.

In 2008, EPA published NSPS Subpart JJJJ that applies to new, modified and reconstructed stationary spark ignition (SI) internal combustion engines (ICE). NSPS Subpart JJJJ applies to stationary SI engines combusting any fuel (natural gas, gasoline, liquefied petroleum gas (LPG), compressed natural gas, landfill gas, digester gas, and any other applicable fuel). The NSPS Subpart JJJJ emission standards vary by horsepower range and by fuel type and apply to natural gas-fueled artificial lift and compressor engines. The data available in ERG (2010) indicated emission rates above NSPS standards for existing artificial lift engines and hence the NSPS JJJJ standards should be considered in the inventories to be developed during the next phase of this work. The TCEQ data for the compressor engines indicates that some compressor engines emission factors are lower than the NSPS JJJJ requirement and no additional control is required for those engines. For compressor engines with emission rates above the NSPS JJJJ threshold, control should be accounted for in the base year and future year emission inventory for the Permian Basin.

## 5.0 RECOMMENDATIONS

In the next phase of inventory development, the emission inventory inputs developed as described in this report will be used to prepare a comprehensive by county and SCC emission inventory for the Greater San Juan and Permian basins for a base year 2014 and forecasted to a future year. The inventories will be developed using the inventory input data described in this report for a 2014 baseline year and a midterm projected year.

In the next phase of this work, Permian Basin emission controls relative to NSPS OOOO and NSPS JJJJ requirements should be reviewed carefully so that to the extent possible, emissions control accurately reflect the implementation of such requirements for the 2014 base year and future year emission inventory. Oil and gas forecasts to develop future year emissions inventories for the Greater San Juan and Permian basins should also be carefully considered to capture, to the extent possible, the dynamic nature of oil and gas activity which is continually responding to both commodity prices and oil and gas exploration and production costs.

The accuracy of the emission inventory inputs developed in this study may be improved as follows:

- EPA could make all underlying data in GHGRP Subpart W reporting available (aggregate across companies by area in the case of confidentiality considerations) so that more source category inputs could be sourced from GHGRP Subpart W data;
- The accuracy of the inputs (produced gas compositions, tank flashing gas compositions, and equipment profiles and operations) could be enhanced with additional operator participation in the wellsite survey efforts.
- Operator participation in the Permian Basin to provide review of the wellsite input factors.
- It is expected that some compressor stations are missing from the current midstream permit data emissions because either these facilities do not meet state or federal reporting criteria or emissions estimates were not readily available from the state or federal agency. The inclusion of those sources through additional outreach and survey efforts would enhance inventory completeness.
- Input factors for potential fugitive emissions from oil and gas pipelines from well heads to the main compressor stations were not estimated. The collection of data on the extent of these pipelines so that fugitive emissions from them could be estimated would enhance inventory completeness.
- Per stakeholder input, survey data was not collected for certain wellsite source categories (amine units, truck loading at gas and NGL processing plants, and water disposal pits) because data was not expected to be available. The inclusion of these categories would enhance inventory completeness.

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# APPENDIX A

## Greater San Juan Basin Wellsite Emission Inventory Input Factors

# Appendix A. Greater San Juan Basin Wellsite Emission Inventory Input Factors

**Table A1. Greater San Juan Basin Input Factors.**

| Wellsite Emission Inventory Input Parameter | | Units | Input Factor | | |
|---|---|---|---|---|---|
| | | | Oil Wells | Gas Wells | CBM Wells |
| **Artificial Lift Engines** | | | | | |
| Percent of wells that have an artificial lift engine: | | unitless | 99% | NA | NA |
| Rated Horsepower: | | hp/well | 17 | | |
| Load Factor: | | unitless | 0.4 | | |
| Hours of Operation: | | hr/year | 7,106 | | |
| Fuel Type (Natural Gas, Gasoline, Diesel, Electric): | | unitless | Natural Gas | | |
| Natural Gas Engines: Percent that are Lean Burn: | | unitless | 0% | | |
| Natural Gas Engines: Percent that are Rich Burn: | | unitless | 100% | | |
| Percent of Artificial Lift Engines that are Electric: | | unitless | 0% | | |
| Emission Factors | NOx | g/bhp-hr | 8.3 | | |
| | CO | g/bhp-hr | 12.7 | | |
| | VOC | g/bhp-hr | 0.1 | | |
| | PM10 | g/bhp-hr | 0.1 | | |
| | SOx | g/bhp-hr | 0.0 | | |
| **Casinghead Flaring and Venting** | | | | | |
| Percent of Casinghead Gas To Pipeline | | unitless | 99.9% | NA | NA |
| Percent of Casinghead Gas Flared | | unitless | 0.0% | | |
| Percent of Casinghead Gas Vented to Atmosphere | | unitless | 0.1% | | |
| Heating Value | | Btu/SCF | 1,390 | | |
| **Condensate Tank** | | | | | |
| Combined Flashing, Working and Breathing VOC Emission Factor | | lb VOC/bbl | NA | 4.85 | NA |
| Fraction of Production Controlled | | unitless | | 0.0% | |
| Flare Control Efficiency | | unitless | | 98.0% | |
| Flaring Emission Factors | NOx | lb/MMBtu | | 0.07 | |
| | CO | lb/MMBtu | | 0.37 | |
| **Dehydrator Venting and Flaring** | | | | | |
| No. of Dehydrators | | no. per well | 0.01 | 0.01 | 0.01 |
| Dehydrator Uncontrolled VOC Emissions | | lb/MMscf | 21.6 | 21.6 | 21.6 |
| Percent of Dehydrators that are Uncontrolled | | unitless | 100% | 100% | 100% |

| Wellsite Emission Inventory Input Parameter | | Units | Input Factor | | |
|---|---|---|---|---|---|
| | | | Oil Wells | Gas Wells | CBM Wells |
| Percent of Dehydrators that are Controlled by Flare | | unitless | 0% | 0% | 0% |
| Percent of Dehydrators Controlled by Routing to System | | unitless | 0% | 0% | 0% |
| Flaring Control Efficiency | | unitless | NA | NA | NA |
| Heating Value of Gas | | Btu/SCF | 1,020 | 1,020 | 1,020 |
| Flaring Emission Factors | NOx | lb/MMBtu | NA | NA | NA |
| | CO | lb/MMBtu | NA | NA | NA |
| **Drill Rigs** | | | | | |
| Number of Engines | | no. of engines | 2.1 | 2.7 | 2.0 |
| Rated Horsepower | | hp/engine | 540 | 575 | 537 |
| Load Factor | | unitless | 0.63 | 0.63 | 0.63 |
| Hours of Operation | | hours/spud | 214 | 226 | 213 |
| Fuel Type (Natural Gas, Gasoline, Diesel, Electric) | | | Diesel | Diesel | Diesel |
| Emission Factors | NOx | g/bhp-hr | 4.61 | 4.61 | 4.61 |
| | CO | g/bhp-hr | 1.24 | 1.24 | 1.24 |
| | VOC | g/bhp-hr | 0.38 | 0.38 | 0.38 |
| | SOx | g/bhp-hr | 0.01 | 0.01 | 0.01 |
| | PM10 | g/bhp-hr | 0.24 | 0.24 | 0.24 |
| **Fracing Engines** | | | | | |
| Percent of spuds where fracing was performed | | unitless | 100% | 100% | 100% |
| Number of Engines | | no. of engines | 3.7 | 5.7 | 3.5 |
| Rated Horsepower | | hp/engine | 1,233 | 942 | 1,258 |
| Load Factor | | unitless | 0.6 | 0.6 | 0.6 |
| Hours of Operation | | hours/spud | 9.7 | 21.8 | 8.6 |
| Fuel Type (Natural Gas, Gasoline, Diesel, Electric) | | | Diesel | Diesel | Diesel |
| Emission Factors | NOx | g/bhp-hr | 6.1 | 6.1 | 6.1 |
| | CO | g/bhp-hr | 1.7 | 1.7 | 1.7 |
| | VOC | g/bhp-hr | 0.5 | 0.5 | 0.5 |
| | SOx | g/bhp-hr | 0.0 | 0.0 | 0.0 |
| | PM10 | g/bhp-hr | 0.3 | 0.3 | 0.3 |
| **Fugitive Components** | | | | | |
| hours of operation | | per year | 8760 | 8760 | 8760 |
| No. of devices per well | Onshore, gas service - valve | count/well | 47 | 81 | 80 |
| | Onshore, gas service - connector | count/well | 147 | 264 | 256 |

| Wellsite Emission Inventory Input Parameter | | Units | Input Factor | | |
|---|---|---|---|---|---|
| | | | Oil Wells | Gas Wells | CBM Wells |
| | Onshore, gas service - open-ended line | count/well | 6 | 10 | 9 |
| | Onshore, gas service - pressure relief valve | count/well | 2 | 4 | 4 |
| | Onshore, gas service - Other | count/well | 0 | 0 | 0 |
| | Onshore, light crude service - valve | count/well | 5 | 0 | 0 |
| | Onshore, light crude service - flange | count/well | 10 | 0 | 1 |
| | Onshore, light crude service - connector | count/well | 6 | 0 | 1 |
| | Onshore, light crude service - open-ended line | count/well | 0 | 0 | 0 |
| | Onshore, light crude service - pump | count/well | 0 | 0 | 0 |
| | Onshore, light crude service - other | count/well | 0 | 0 | 0 |
| | Onshore, heavy crude service - valve | count/well | 0 | 0 | 0 |
| | Onshore, heavy crude service - flange | count/well | 0 | 0 | 0 |
| | Onshore, heavy crude service - connector | count/well | 0 | 0 | 0 |
| | Onshore, heavy crude service - open-ended line | count/well | 0 | 0 | 0 |
| | Onshore, heavy crude service - other | count/well | 0 | 0 | 0 |
| | Onshore, water service - valve | count/well | 1 | 0 | 0 |
| | Onshore, water service - connector | count/well | 0 | 0 | 0 |
| | Onshore, water service - open-ended line | count/well | 0 | 0 | 0 |
| | Onshore, water service - pressure relief valve | count/well | 0 | 0 | 0 |
| | Onshore, water service - Other | count/well | 12 | 0 | 0 |
| **Heaters** | | | | | |
| Number of Heaters per well | | no. of heaters/well | 1.0 | 1.0 | 1.0 |
| Heater MMBtu Rating | | MMBtu/hr | 0.3 | 0.3 | 0.3 |
| Annual Heater Usage | | hrs | 2,763 | 2763 | 2763 |
| Heater Cycling (fraction of the time the heater is doing work when it is turned on) | | unitless | 0.9 | 0.9 | 0.9 |
| Heating Value | | Btu/SCF | 1,060 | 1,060 | 1,060 |
| Emission Factors | NOx | lb/MMscf | 100.0 | 100.0 | 100.0 |
| | VOC | lb/MMscf | 5.5 | 5.5 | 5.5 |
| | CO | lb/MMscf | 84.0 | 84.0 | 84.0 |
| | SOx | lb/MMscf | 0.0 | 0.0 | 0.0 |
| | PM | lb/MMscf | 7.6 | 7.6 | 7.6 |
| **Oil Tank Venting and Flaring** | | | | | |
| Percentage of Tanks that are Uncontrolled | | unitless | 100% | NA | NA |
| Percent of Tanks that are Controlled by Flare | | unitless | 0% | | |

| Wellsite Emission Inventory Input Parameter | | Units | Input Factor | | |
|---|---|---|---|---|---|
| | | | Oil Wells | Gas Wells | CBM Wells |
| Percent of Tanks that are Controlled by VRU | | unitless | 0% | | |
| Percent of Tanks that are Controlled by Enclosed Combustion Devices | | unitless | 0% | | |
| Flaring Control Efficiency | | unitless | 98% | | |
| Uncontrolled Combined Flashing, Working and Breathing VOC Emission Factor | | lb VOC/bbl | 4.8 | | |
| Flaring Emission Factors | NOx | lb/MMBtu | 0.1 | | |
| | CO | lb/MMBtu | 0.4 | | |
| **Pneumatic Controllers** | | | | | |
| Number of Devices per Well | High Bleed Devices | | 0.1 | 0.2 | 0.05 |
| | Intermittent Devices | | 1.1 | 2.7 | 2.2 |
| | Low Bleed Device | | 1.4 | 2.5 | 0.1 |
| Device Rate | High Bleed Devices | scf/hr | 37.3 | 37.3 | 37.3 |
| | Intermittent Devices | | 13.5 | 13.5 | 13.5 |
| | Low Bleed Device | | 1.4 | 1.4 | 1.4 |
| Annual Hours of Operation | | hrs/yr | 8,760 | 8,760 | 8,760 |
| **Pneumatic Pumps** | | | | | |
| Number of Pumps per Well | | | 0.02 | 1.4 | NA |
| Annual Hours of Operation: | | hr/year | 8,760 | 8,760 | |
| Population Emission Factors | | scf/hr/pump | 13.3 | 13.3 | |
| **Refracing Engines** | | | | | |
| Refracing Frequency | | | 0.05 | 0.05 | NA |
| Number of Engines | | no. of engines | 4.5 | 4.3 | |
| Total Rated Horsepower | | hp/engine | 1,521 | 1,514 | |
| Load Factor | | unitless | 1.0 | 1.0 | |
| Hours of Operation | | hours/refrac | 2.9 | 2.9 | |
| Fuel Type (Natural Gas, Gasoline, Diesel, Electric) | | | Diesel | Diesel | |
| Emission Factors | NOx | g/bhp-hr | 6.1 | 6.1 | |
| | CO | g/bhp-hr | 1.7 | 1.7 | |
| | VOC | g/bhp-hr | 0.5 | 0.5 | |
| | SOx | g/bhp-hr | 0.0 | 0.0 | |
| | PM10 | g/bhp-hr | 0.3 | 0.3 | |
| **Workover Rigs** | | | | | |
| Workover Frequency | | unitless | 0.1 | 0.1 | 0.1 |
| Total Rated Horsepower (hp) | | hp/workover | 666 | 656 | 459 |

| Wellsite Emission Inventory Input Parameter | | Units | Input Factor | | |
|---|---|---|---|---|---|
| | | | Oil Wells | Gas Wells | CBM Wells |
| Load Factor | | unitless | 0.4 | 0.4 | 0.4 |
| Hours of Operation | | hours/year | 46.0 | 47.4 | 18.6 |
| Fuel Type (Natural Gas, Gasoline, Diesel, Electric) | | | Diesel | Diesel | Diesel |
| Emission Factors | NOx | g/bhp-hr | 4.8 | 4.8 | 4.8 |
| | CO | g/bhp-hr | 1.6 | 1.6 | 1.6 |
| | VOC | g/bhp-hr | 0.3 | 0.3 | 0.3 |
| | SOx | g/bhp-hr | 0.0 | 0.0 | 0.0 |
| | PM10 | g/bhp-hr | 0.2 | 0.2 | 0.2 |
| **Wellsite Truck Loading** | | | | | |
| Fraction of Total Oil Production Sent Directly to Pipeline, Not Subject to Wellsite Loading | | unitless | 0% | 0% | NA |
| True vapor pressure of liquid loaded | | psi | 3.4 | 5.2 | |
| Temperature of Liquid Loaded | | °R | 540 | 540 | |
| Molecular Weight of Liquid Loaded (lb/lb-mole) | | lb/lb-mole | 50 | 50 | |
| Fraction of Tanks Mode of operation: Submerged Loading of a Clean cargo tank | | unitless | 0% | 0% | |
| Fraction Of Tanks Mode of operation: submerged loading: dedicated vapor balance service | | unitless | 1% | 4% | |
| Fraction of Tanks Mode of operation: submerged loading: dedicated normal service | | unitless | 99% | 96% | |
| Saturation Factor for Submerged Loading of a Clean cargo tank | | unitless | 0% | 0% | |
| Saturation Factor for submerged loading: dedicated vapor balance service | | unitless | 0.6 | 0.6 | |
| Saturation Factor for submerged loading: submerged loading: dedicated normal service | | unitless | 1.0 | 1.0 | |
| **Water Tank Venting and Flaring** | | | | | |
| Directly to a Wellsite Tank | | unitless | 100% | 100% | 100% |
| Directly to Pipeline to Injection Well | | unitless | 0% | 0% | 0% |
| Directly to Pipeline to Water Disposal Pit | | unitless | 0% | 0% | 0% |
| Other (please specify) | | unitless | 0% | 0% | 0% |
| Percent of Tanks that are Uncontrolled | | unitless | 100% | 100% | 100% |
| Percent of Tanks that are Controlled by Flare | | unitless | 0% | 0% | 0% |
| Percent of Tanks that are Controlled by VRU | | unitless | 0% | 0% | 0% |
| Percent of Tanks that are Controlled by Enclosed Combustion Devices | | unitless | 0% | 0% | 0% |
| Flaring Control Efficiency | | unitless | NA | NA | NA |
| VRU Control Efficiency | | unitless | NA | NA | NA |

| Wellsite Emission Inventory Input Parameter | | Units | Input Factor | | |
|---|---|---|---|---|---|
| | | | Oil Wells | Gas Wells | CBM Wells |
| Uncontrolled VOC Emission Factor | | lb/bbl | 0.01 | 0.01 | 0.01 |
| **Liquid Unloading** | | | | | |
| Percentage of Wells Vented for Liquid Unloading | | | 1% | 45% | 9% |
| Fraction of Liquid Unloading controlled | | % | 0% | 0% | 0% |
| Average Natural Gas Volume per Event | | MCF/event | 59 | 3,209 | 617 |
| Number of Unloading Vented to the Atmosphere per well | | no. of events per well | 1.0 | 31.9 | 2.1 |
| **Initial Completion Venting and Flaring** | | | | | |
| Flaring Control Efficiency | | unitless | 85% | 85% | NA |
| Number of Completion Events per Spud | | | 0.5 | 0.9 | 1.0 |
| Volume of Gas Vented to Atmosphere per Event (MCF/event) | | | 1,877 | 626 | 598 |
| Volume of Gas Sent to Flare per Event (MCF/event) | | | 9,112 | 3,243 | 2,278 |
| Volume of Gas Sent to Closed-loop System per Event (MCF/event) | | | 0.0 | 0.0 | 0.0 |
| Flaring Emission Factors | NOx | lb/MMBtu | 0.1 | 0.1 | NA |
| | CO | lb/MMBtu | 0.4 | 0.4 | NA |
| **Lateral Compressor Engines** | | | | | |
| Number of Wells per Typical Lateral Compressor Engine | | | NA | 111 | 111 |
| Rated Horsepower | | hp | | 444 | 670 |
| Load Factor | | unitless | | 0.7 | 0.7 |
| Hours of Operation | | hours/engine/year | | 7,776 | 7,828 |
| Fuel Type (Natural Gas, Gasoline, Diesel, Electric) | | | | Natural Gas | Natural Gas |
| Natural Gas Engines: Percent that are Lean Burn | | unitless | | 48% | 57% |
| Natural Gas Engines: Percent that are Rich Burn | | unitless | | 52% | 43% |
| Percent of Engines with Control | | | | 29% | 33% |
| Type of Engine Emission Control (if applicable) | | | | NSCR | NSCR/OC |
| Emission Factors | NOx | g/bhp-hr | | 5.4 | 5.0 |
| | CO | g/bhp-hr | | 7.1 | 6.5 |
| | VOC | g/bhp-hr | | 0.3 | 0.3 |
| | PM10 | g/bhp-hr | | 0.1 | 0.1 |
| | SOx | g/bhp-hr | | 0.0 | 0.0 |
| **Water Pump Engines** | | | | | |
| Number of Water Pump Engines Per well | | no. per well | 0.06 | 0.06 | 1.00 |
| Percentage of Wells that have Electric Water Pump Engines | | | 0% | 4% | 5% |

| Wellsite Emission Inventory Input Parameter | | Units | Input Factor | | |
|---|---|---|---|---|---|
| | | | Oil Wells | Gas Wells | CBM Wells |
| Total Rated Horsepower (hp) | | hp/well | 136 | 142 | 34 |
| Load Factor | | unitless | 0.4 | 0.5 | 0.5 |
| Hours of Operation | | hours/year | 2,810 | 2,920 | 8,760 |
| Fuel Type (Natural Gas, Gasoline, Diesel, Electric) | | | Natural Gas | Natural Gas | Natural Gas |
| Emission Factors | NOx | g/bhp-hr | 1.0 | 1.0 | 1.0 |
| | CO | g/bhp-hr | 1.9 | 2.0 | 2.0 |
| | VOC | g/bhp-hr | 0.7 | 0.7 | 0.7 |
| | SOx | g/bhp-hr | 0.0 | 0.0 | 0.0 |
| | PM10 | g/bhp-hr | 0.0 | 0.0 | 0.0 |
| **Wellhead Compressor Engines** | | | | | |
| Percentage of wells that have a wellhead compressor engine | | % | NA | 94% | 94% |
| Rated Horsepower | | hp | | 110 | 109 |
| Load Factor | | unitless | | 0.75 | 0.75 |
| Hours of Operation | | hours/engine/year | | 8,262 | 8,288 |
| Fuel Type (Natural Gas, Gasoline, Diesel, Electric) | | | | Natural Gas | Natural Gas |
| Natural Gas Engines: Percent that are Lean Burn | | unitless | | 10% | 9% |
| Natural Gas Engines: Percent that are Rich Burn | | unitless | | 90% | 91% |
| Percent of Engines with Control | | | | 0 | 0 |
| Type of Engine Emission Control (if applicable) | | | | NSCR | NSCR |
| Emission Factors | NOx | g/bhp-hr | | 7.4 | 7.1 |
| | CO | g/bhp-hr | | 11.2 | 10.8 |
| | VOC | g/bhp-hr | | 0.1 | 0.1 |
| | PM10 | g/bhp-hr | | 0.1 | 0.1 |
| | SOx | g/bhp-hr | | 0.0 | 0.0 |