Development of Baseline 2011 and Future Year 2015 Emissions from Oil and Gas Activity in the Great Plains Basin

Final Report

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CONTENTS

EXECUTIVE SUMMARY **1**

Report Outline 5

1.0 INTRODUCTION **6**

1.1 Baseline 2011 Inventory 6

1.2 Future Year 2015 Inventory 6

1.3 Temporal and Geographic Scope 7

1.4 Well Count and Production Data 9

2.0 2011 MIDSTREAM SOURCES **13**

2.1 Permit Data for Midstream Facilities from State Agencies 13

2.2 Permit Data from EPA Region 8 13

2.2.1 Title V 13

2.2.2 Tribal Minor Source Reporting 13

3.0 2011 WELL SITE SOURCES **14**

3.1 Surveyed Sources 14

4.0 2011 WELL SITE SOURCES EMISSION CALCULATION METHODOLOGIES **16**

4.1 Drilling and Completion Phase 16

4.1.1 Drill Rigs 16

4.1.2 Fracing Engines 17

4.1.3 Initial Completions 19

4.2 Production Phase 20

4.2.1 CBM Pump Engines 20

4.2.2 Amine Units 20

4.2.3 Recompletion Venting and Refracing Engines 20

4.2.4 Oil, Condensate, and Water Tanks 20

4.2.5 Casinghead Gas 22

4.2.6 Oil and Gas Well Truck Loading 22

4.2.7 Artificial Lift Engines 23

4.2.8 Fugitive Components 24

4.2.9 Heaters 25

4.2.10 Pneumatic Devices 27

4.2.11 Pneumatic (Gas Actuated) Pumps 28

4.2.12 Dehydrators 29
4.2.13 Workover Rigs 30
4.2.14 Compressor Engines 31
4.2.15 Miscellaneous Engines 32
4.2.16 Well Blowdowns 33
4.2.17 Compressor Start-ups and Shutdown 34
4.2.18 Compressor Fugitive Leaks 35
4.2.19 Flaring 36

5.0 2015 FORECAST 39

5.1 Geographic Grouping 39
5.2 Parameters Forecasted 39
5.3 Projection Methodologies for the Great Plains Basin 42
5.3.1 Western Great Plains Counties 42
5.3.2 Central Great Plains Counties 49
5.3.3 Phillips County 56
5.3.4 Other Counties 63
5.4 Scaling Factor Development and Uncontrolled 2015 Emissions 70
5.5 Controlled 2015 Emissions 73
5.5.1 Nonroad Diesel Engine Standards and Fuel Sulfur Standards 74
5.5.2 New Source Performance Standards for Pneumatic Devices, Tanks, and Engines 74
5.5.3 New Source Performance Standards and Montana Regulations for Well Completions 75
5.5.4 Summary of Controls 75
5.5.5 Projection Uncertainties 76

6.0 SUMMARY RESULTS 77

6.1 Base Year 2011 77
6.2 Future Year 2015 87

7.0 REFERENCES 97

APPENDICES

Appendix A. Oil and Gas Activity by Mineral Designation

Appendix B. Survey-based Well Site Source Input Factors

TABLES

Table ES-1. Summary of emissions from oil and gas operations in the Great Plains Basin. 3

Table ES-2. Summary of emissions from oil and gas operations by mineral ownership designation in the Great Plains Basin. 4

Table ES-3. Comparison of the Great Plains Basin emissions for 2011 and 2015. 4

Table ES-4. Comparison of production characteristics of the Great Plains Basin for 2011 and 2015. 4

Table 1-1. 2011 well count by well type and by county for the Great Plains Basin (counties without oil and gas production are not shown). 11

Table 1-2. 2011 production by production type and by county for the Great Plains Basin (counties without oil and gas production are not shown). 11

Table 1-3. 2011 spud counts by county for the Great Plains Basin (counties without oil and gas production are not shown). 12

Table 5-1. Scaling parameter for each oil and gas source category considered in this inventory. 40

Table 5-2. Scaling factors for parameters used in the projection analysis for all counties in the Great Plains Basin. 72

Table 5-3. Summary of federal and state “on-the-books” regulations affecting the oil and gas source categories considered in this inventory. 73

Table 5-4. 2015 oil and gas activity growth. 75

Table 5-5. Controls summary by emission category. 75

Table 6-1. 2011 emissions of all criteria pollutants by county for the Great Plains Basin. 84

Table 6-2. 2011 NOx emissions [ton/yr] by source category for the Great Plains Basin. 85

Table 6-3. 2011 VOC emissions [ton/yr] by source category for the Great Plains Basin. 86

Table 6-4. 2015 emissions of all criteria pollutants by county for the Great Plains Basin. 94

Table 6-5. 2015 NOx emissions [tons/year] by county and by source category for the Great Plains Basin. 95

Table 6-6. 2015 VOC emissions [tons/year] by county and by source category for the Great Plains Basin. 96

FIGURES

Figure 1-1. Great Plains Basin boundaries overlaid with 2011 oil and gas well locations by well type. 8

Figure 1-2. Great Plains Basin boundaries overlaid with 2011 oil and gas well locations by mineral designation. 9

Figure 5-1. Oil well count historical data (from the IHS database) for Western Great Plains Counties in the Great Plains Basin and projections to 2015. 43

Figure 5-2. Gas well count historical data (from the IHS database) for Western Great Plains Counties in the Great Plains Basin and projections to 2015. 44

Figure 5-3. Spud count historical data (from the IHS database) for Western Great Plains Counties in the Great Plains Basin and projections to 2015. 45

Figure 5-4. Associated gas production historical data (from the IHS database) for Western Great Plains Counties in the Great Plains Basin and projections to 2015. 46

Figure 5-5. Primary gas production historical data (from the IHS database) for Western Great Plains Counties in the Great Plains Basin and projections to 2015. 47

Figure 5-6. Oil production historical data (from the IHS database) for Western Great Plains Counties in the Great Plains Basin and projections to 2015. 48

Figure 5-7. Condensate production historical data (from the IHS database) for the Western Great Plains Counties in the Great Plains Basin and projections to 2015. 49

Figure 5-8. Oil well count historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. 50

Figure 5-9. Gas well count historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. 51

Figure 5-10. Spud count historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. 52

Figure 5-11. Associated gas production historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. 53

Figure 5-12. Primary gas production historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. 54

Figure 5-13. Oil production historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. 55

Figure 5-14. Condensate production historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. 56

Figure 5-15. Oil well count historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. 57

Figure 5-16. Gas well count historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. 58

Figure 5-17. Oil Well spud count historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. 59

Figure 5-18. Associated gas production historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. 60

Figure 5-19. Primary gas production historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. 61

Figure 5-20. Oil production historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. 62

Figure 5-21. Condensate production historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. 63

Figure 5-22. Oil well count historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. 64

Figure 5-23. Gas well count historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. 65

Figure 5-24. Spud count historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. 66

Figure 5-25. Associated gas production historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. 67

Figure 5-26. Primary gas production historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. 68

Figure 5-27. Oil production historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. 69

Figure 5-28. Condensate production historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. 70

Figure 6-1. 2011 NOx emissions by source category and by county in the Great Plains Basin. 78

Figure 6-2. 2011 NOx emissions by mineral designation in the Great Plains Basin. 79

Figure 6-3. 2011 VOC emissions by source category and by county in the Great Plains Basin. 80

Figure 6-4. 2011 VOC emissions by mineral designation in the Great Plains Basin. 81

Figure 6-5. Great Plains Basin NOx emissions proportional contributions by source category. 82

Figure 6-6. Great Plains Basin VOC emissions proportional contributions by source category. 83

Figure 6-7. 2015 NOx emissions by source category and by county in the Great Plains Basin. 88

Figure 6-8. 2015 NOx emissions by mineral designation in the Great Plains Basin. 89

Figure 6-9. 2015 VOC emissions by source category and by county in the Great Plains Basin. 90

Figure 6-10. 2015 VOC emissions by source category and by county in the Great Plains Basin. 91

Figure 6-11. 2015 NOx emissions contributions by source category in the Great Plains Basin. 92

Figure 6-12. 2015 VOC emissions contributions by source category in the Great Plains Basin. 93

ACRONYMS AND ABBREVIATIONS

API	American Petroleum Institute
ARM	Administrative Rules of Montana
bbl	Barrel
BCF	Billion cubic feet
BIA	Bureau of Indian Affairs
BLM	United States Bureau of Land Management
BSFC	Brake-specific fuel consumption
BTU	British thermal unit
CBM	Coal-bed methane
CO	Carbon monoxide
E&P	Exploration and production
EPA	United States Environmental Protection Agency
H_2S	Hydrogen sulfide
MCF	Thousand cubic feet
MMSCF	Million standard cubic feet
MT	Montana
MTDEQ	Montana Department of Environmental Quality
NAICS	North American Industry Classification System
NGL	Natural gas liquid
NOx	Nitrogen oxides
NSPS	New Source Performance Standards
O&G	Oil and Gas
PM	Particulate matter
PTE	Potential to emit
SCC	Source classification code
scf	Standard cubic foot
SIC	Standard industrial classification
SOx	Sulfur oxides
tons/yr	Short tons per year

tpy	Short tons per year
US	United States
USFS	United States Forest Service
USGS	United States Geological Survey
VOCs	Volatile organic compounds
VRU	Vapor recovery unit
WESTAR	Western States Air Resources Council
WRAP	Western Regional Air Partnership

EXECUTIVE SUMMARY

This study provides an analysis of the criteria pollutant emissions for oil and gas exploration and production operations in the Great Plains Basin (also called the North-Central Montana Basin) in Montana. This analysis is being sponsored by the United States Bureau of Land Management (BLM), Montana-Dakotas State Office, jointly with the Western Regional Air Partnership (WRAP). This effort is the first of its kind to develop basin-wide emissions based on well site data provided directly by oil and gas companies that operate in the Great Plains Basin; midstream source data was also gathered from state and federal agencies for inclusion in the inventory.

The primary source of information for Great Plains well site emissions was a survey outreach effort to the oil and gas producers in the basin. For midstream emission sources, detailed permit data from the Montana Department of Environmental Quality (MTDEQ) and United States Environmental Protection Agency (EPA) was gathered. Survey forms consisting of an Excel spreadsheet requesting data on 23 discrete source categories was forwarded to major participating operators in the Great Plains Basin. For each source category, data was requested separately for oil wells and gas wells. All data requested from participating companies were for these companies' activities in the calendar year 2011. Well count and production data for the basin were obtained from a commercially available database of oil and gas data maintained by IHS Corporation ("the IHS database"). As with the emissions estimates, the focus of the IHS database was calendar year 2011.

The companies participating in the survey process for the Great Plains Basin represented approximately 44% of well ownership in the basin, 51% of gas production in the basin, and 41% of oil production in the basin. While a higher surveyed producer representation in the surveys would have allowed for greater confidence in emissions, the representation available allowed for development of the most accurate inventory to-date for this basin. Source categories for which no data was obtained and which were therefore excluded from the study include amine units, coal bed methane (CBM) pump engines, truck loading at gas and natural gas liquids (NGL) processing plants, water disposal pits, and saltwater disposal engines. 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 or other databases that were analyzed, and therefore a reasonable estimate of basin-wide pipeline fugitive emissions could not be derived.

The Great Plains Basin was defined as consisting of Toole, Pondera, Glacier, Blaine, Hill, Liberty, Phillips, Cascade, Yellowstone, Golden Valley, Fergus, Rosebud, Teton, Musselshell, Petroleum, and Chouteau Counties in Montana. The Great Plains Basin had approximately 1.84 million barrels of oil production and 36.3 billion cubic feet (BCF) of gas production in 2011. The Great Plains Basin in 2011 consisted of 6,737 active oil and gas wells with gas wells accounting for about two-thirds of the well count and the remaining one-third of the well count accounted for by oil wells. Over 98% of gas production in the Great Plains Basin in 2011 was from primary gas from gas wells and over 98% of the oil production in the Great Plains Basin in 2011 was from oil wells. There is minimal CBM gas production in the Great Plains Basin in 2011.

The total emissions of nitrogen oxides (NOx) in the Great Plains Basin were 1,753 tons in 2011 while total emissions of volatile organic compounds (VOCs) in the Great Plains Basin were 5,311 tons in 2011. Overall, compressor engines accounted for approximately 66% of NOx emissions basin-wide, including wellhead and midstream compressor engines, with miscellaneous engines, drill rigs, fracing engines, and heaters accounting for approximately 29% of NOx emissions basin-wide. Flashing emissions from oil storage tanks accounted for approximately 33% of basin-wide VOC emissions while water tank losses accounted for approximately 21% of basin-wide VOC emissions.

Approximately 47% of NOx emissions were derived from the survey data, with the remaining approximately 53% of NOx emissions being derived from permit data for primarily midstream sources from MTDEQ. 92% of VOC emissions were derived from the survey data, with only 8% being derived from permit data.

Great Plains Basin oil and gas 2011 emissions were projected to future year 2015. The 2015 calendar year was chosen because at the time of inventory development, it represented a year two years in the future; a more distant projection year was not chosen because of the greater uncertainty associated with a longer time period with farther future projection years.

2015 projections for the Great Plains Basin were estimated by projecting oil and gas activity parameters from 2011 to 2015 based on historical trends in oil and gas activity. Regional differences in oil and gas activity were factored into the projection methodology by making projections for discrete subregions in the Great Plains Basin. On-the-books regulations were also analyzed to account for any additional emission control in future year 2015.

The total emissions of NOx in the Great Plains Basin were 1,408 tons in 2015 while total emissions of VOCs in the Great Plains Basin were 5,443 tons in 2015. Overall, compressor engines accounted for approximately 71% of basin-wide NOx emissions in 2015, including wellhead and midstream compressor engines, miscellaneous engines accounted for approximately 11% of NOx basin-wide emissions in 2015, and heaters accounted for 7% of basin-wide heater emissions in 2015. Flashing emissions from oil storage tanks accounted for approximately 35% of basin-wide VOC emissions while water tank losses accounted for approximately 23% of basin-wide VOC emissions.

Table ES-1 and Table ES-2 contain summaries of the total emissions from oil and gas operations in the Great Plains Basin by county and by mineral ownership designation, respectively. In addition to NOx and VOCs, emissions of carbon monoxide (CO), particulate matter (PM), and sulfur oxides (SOx) are reported.

Table ES-1. Summary of emissions from oil and gas operations in the Great Plains Basin.

County	NOx [tons/yr]	VOC [tons/yr]	CO [tons/yr]	SOx [tons/yr]	PM [tons/yr]
2011 Emissions					
Blaine, MT	685	544	163	0	7
Cascade, MT	0	127	0	0	0
Chouteau, MT	6	14	3	0	0
Fergus, MT	0	1	0	0	0
Glacier, MT	230	967	180	0	7
Golden Valley, MT	0	14	0	0	1
Hill, MT	52	119	55	0	1
Liberty, MT	41	353	30	0	1
Musselshell, MT	10	368	9	0	0
Petroleum, MT	8	103	6	0	0
Phillips, MT	149	235	111	0	3
Pondera, MT	86	337	42	0	2
Rosebud, MT	42	499	16	0	1
Teton, MT	18	151	15	0	1
Toole, MT	421	1,424	254	0	14
Yellowstone, MT	5	56	6	0	0
Total	**1,753**	**5,311**	**891**	**2**	**38**
2015 Emissions					
Blaine, MT	552	542	133	0	6
Cascade, MT	0	103	0	0	0
Chouteau, MT	5	13	3	0	0
Fergus, MT	0	1	0	0	0
Glacier, MT	167	953	149	0	5
Golden Valley, MT	0	11	0	0	1
Hill, MT	46	107	47	0	1
Liberty, MT	31	339	26	0	1
Musselshell, MT	11	466	9	0	0
Petroleum, MT	8	126	6	0	0
Phillips, MT	133	196	97	0	3
Pondera, MT	75	329	39	0	1
Rosebud, MT	36	606	16	0	1
Teton, MT	18	182	16	0	1
Toole, MT	319	1,403	216	0	9
Yellowstone, MT	6	67	6	0	0
Total	**1,408**	**5,443**	**765**	**1**	**28**

[a] – numbers in the table may not sum exactly to the total value listed due to rounding

Table ES-2. Summary of emissions from oil and gas operations by mineral ownership designation in the Great Plains Basin.

County	NOx [tons/yr]	VOC [tons/yr]	CO [tons/yr]	SOx [tons/yr]	PM [tons/yr]
2011 Emissions					
Tribal	116	490	64	0	5
Private/State	1,538	4,273	760	1	31
BLM	99	548	67	0	2
US Forest Service	0	0	0	0	0
Total	**1,753**	**5,311**	**891**	**2**	**38**
2015 Emissions					
Tribal	66	488	47	0	2
Private/State	1,244	4,399	651	1	23
BLM	98	556	67	0	2
US Forest Service	0	0	0	0	0
Total	**1,408**	**5,443**	**765**	**1**	**28**

[a] – numbers in the table may not sum exactly to the total value listed due to rounding

Table ES-3 below shows a summary of the 2011 and 2015 emissions inventory results. This table is intended for comparison purposes and therefore should be considered in conjunction with Table ES-4, which shows a summary of the production and well count characteristics for the 2015 and 2011 emission inventories. As these two tables show, oil and gas activity remain relatively constant, and subsequent emissions remain relatively constant from 2011 to 2015.

Table ES-3. Comparison of the Great Plains Basin emissions for 2011 and 2015.

Basin	Emissions (tons/yr)				
	NOx	VOC	CO	SOx	PM
2011 Great Plains Basin	1,753	5,311	891	2	38
2015 Great Plains Basin	1,408	5,443	765	1	28

Table ES-4. Comparison of production characteristics of the Great Plains Basin for 2011 and 2015.

Basin	Well Count	Oil/Condensate Production (bbl)			Gas Production (MCF)	Spud Counts
		Total	Oil Well Oil	Gas Well Condensate		
2011 Great Plains Basin	6,737	1,844,978	1,822,325	22,653	36,283,590	41
2015 Great Plains Basin	6,706	1,945,065	1,926,931	18,134	29,482,019	19

Report Outline

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

- Chapter 1.0 is an executive summary and briefly describes the methodology and key study results
- Chapter 2.0 describes the development of 2011 midstream emissions
- Chapter 3.0 describes the development of 2011 well site emissions
- Chapter 4.0 describes the calculation methodology for estimating 2011 emissions from well site sources
- Chapter 6.0: describes the 2015 emissions forecast methodology
- Chapter 7.0: presents summaries in graphical and tabular formats of base year 2011 and future year 2015 emissions

1.0 INTRODUCTION

The BLM is sponsoring the development of a regional oil and gas emission inventory for the Great Plains Basin jointly with the Western Regional Air Partnership (WRAP). This effort represents the first attempt to compile a comprehensive emissions inventory for the Great Plains based on local data. This effort is focused on creating a comprehensive criteria pollutant emissions inventory for activities associated with oil and gas field operations in the Great Plains Basin for a baseline year of 2011 as well as a future projection year of 2015; that includes all point and area sources related to the oil and gas industry.

1.1 Baseline 2011 Inventory

The inventory presented in this analysis is for the Great Plains Basin in Montana. The 2011 baseline inventory consists of three primary categories: (1) sources that were permitted by the State of Montana; (2) sources that were permitted by the EPA (for tribal land), including both Part 71 major sources and Tribal Minor New Source Review sources; and (3) sources that were either exempt from any permitting or for which data was collected from surveys of major companies operating in the Great Plains Basin, which are collectively termed "survey-based" sources in this document. This document describes the methodologies by which the 2011 inventory was constructed. 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 well site source category, a basic description is given of the methodology used to estimate emissions based on representative inputs from the survey effort.

In general, the inventory was developed using a combination of well count and production activity from a commercially available database of oil and gas data maintained by IHS Corporation ("the IHS database"), extensive data on large sources from state and EPA permits, and detailed survey responses of oil and gas activity from a number of major participating companies that operate in the Great Plains Basin. Some additional data sources were also used, including the EPA's AP-42 emissions factor technical guidance (EPA, 1995), the EPA's NONROAD emissions model (EPA, 2009), and the EPA's Natural Gas Star program technical guidance (EPA, 2008).

1.2 Future Year 2015 Inventory

The methodology used to develop the 2015 projections for the Great Plains Basin is described below in subsections:

- Geographic grouping of data – regional differences in production or activity are factored into the projection methodology by geographic region;
- Projected parameters – basic oil and gas activity parameters are projected forward to 2015 for purposes of developing scaling factors: well counts by type (i.e. oil, gas, and total), gas production by well type (i.e. primary gas production from gas wells, associated gas production from oil wells, and total gas production), liquid hydrocarbon

production by well type (i.e. oil production from oil wells, condensate production from gas wells, and total liquid hydrocarbon production), spud counts by well type (i.e., oil well spuds, gas well spuds, and total spuds) and total gas processed;

- Scaling factors and developing uncontrolled emissions projections – the projected parameters are used to develop scaling factors (incorporating geographic groupings), and these scaling factors are applied to the 2011 baseline emissions;
- Application of "on-the-books" regulations and control measures – existing regulations are summarized for their impacts on the future year emissions and applied to adjust the uncontrolled 2015 inventory.

1.3 Temporal and Geographic Scope

This inventory considers a base year of 2011 for purposes of estimating emissions. All data requested from participating companies were for these companies' activities in the calendar year 2011. Similarly, all base year well count and production data for the basin obtained from the IHS database were for the calendar year 2011. Emissions from all source categories are assumed to be uniformly distributed throughout the year except for heaters and pneumatic pumps, which are assigned seasonality fractions as they are typically used primarily in winter.

The geographic scope of this inventory is the Great Plains Basin in Central Montana. For the purposes of this study, the boundaries for the Great Plains Basin were modified from those of the US Geological Survey (USGS) (USGS, 2008) to wholly include Glacier, Pondera, Teton, Cascade, and Rosebud Counties. Lewis and Clark and Meagher Counties were dropped from the basin due to lack of oil and gas activity while Carbon County was dropped as it is included in the WRAP Phase III Powder River Basin[1]. The geographic scope of the analysis also considers activities by mineral ownership: BLM, United States Forest Service (USFS), Bureau of Indian Affairs (BIA) and state or private fee land.

Figure 1-1 and Figure 1-2 show the boundaries of the Great Plains Basin, with the 2011 well locations extracted from the IHS database overlaid. Figure 1-1 presents wells by type and Figure 1-2 presents wells by mineral designation.

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

Great Plains Basin - 2011 Wells

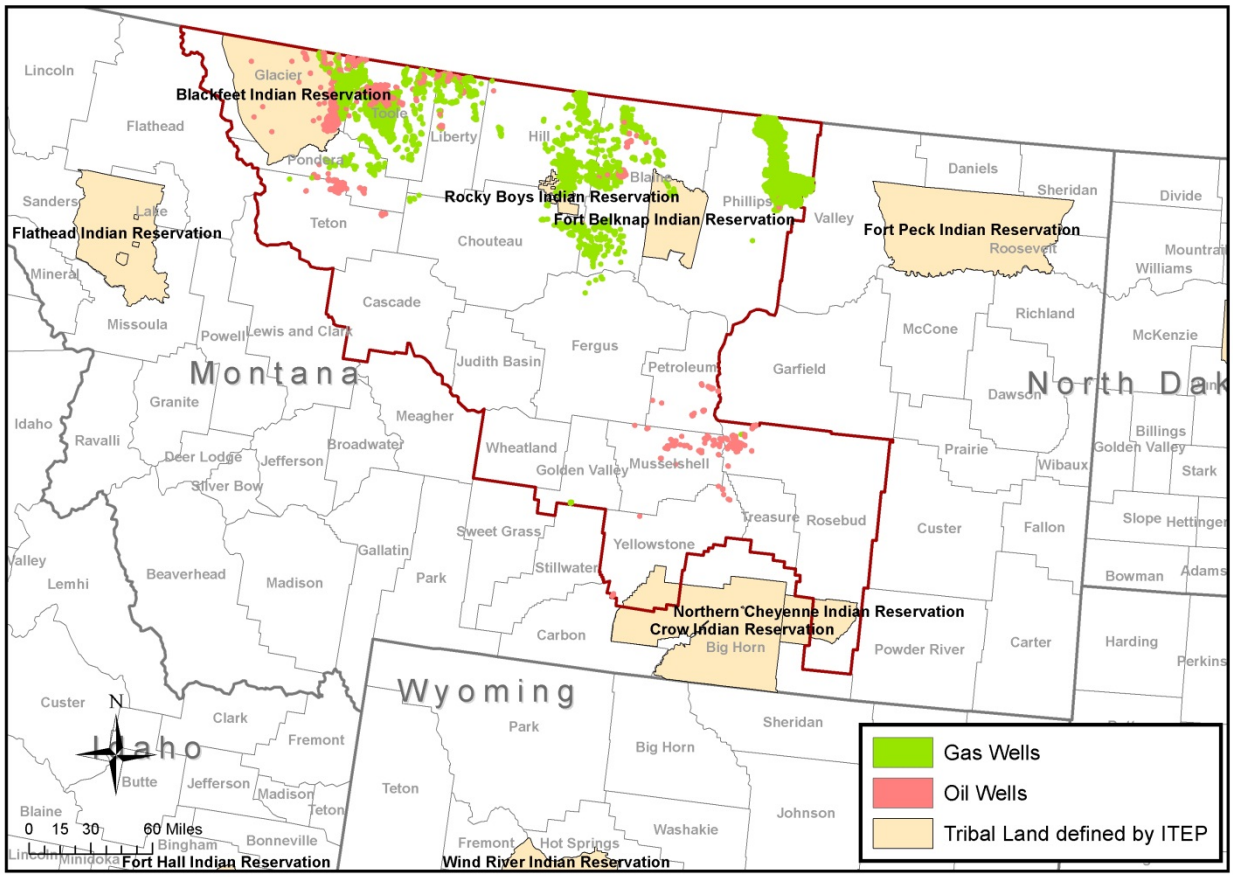

Figure 1-1. Great Plains Basin boundaries overlaid with 2011 oil and gas well locations by well type.[2]

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

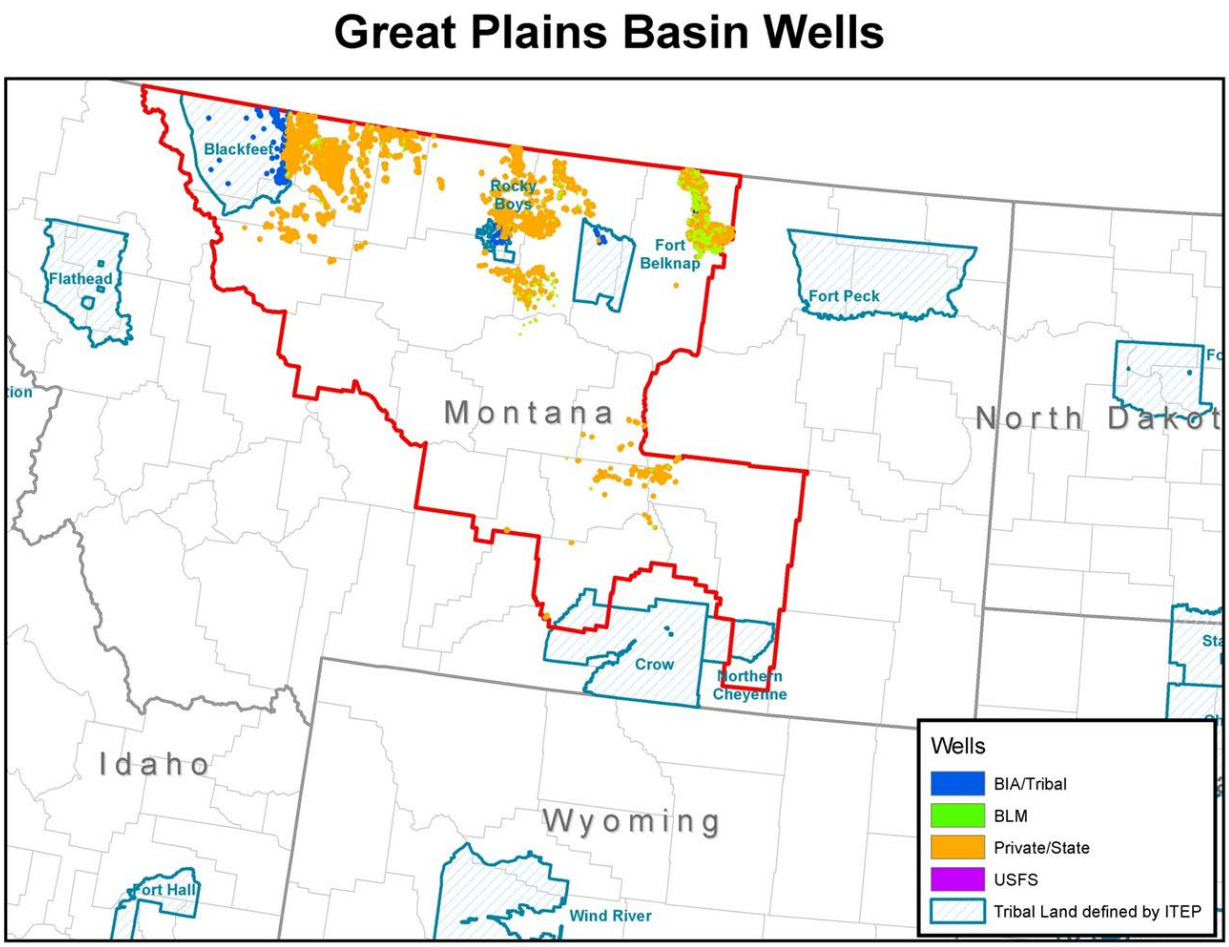

Figure 1-2. Great Plains Basin boundaries overlaid with 2011 oil and gas well locations by mineral designation.[3]

1.4 Well Count and Production Data

Oil and gas related activity data across the entire Great Plains Basin were obtained from the IHS Enerdeq database queried via online interface. The IHS database uses data from the Montana Board of Oil and Gas as sources of information for oil and gas activity. This data is also available directly through database querying tools maintained by the Montana Board of Oil and Gas, however it was determined that the IHS database is more accurate and complete than these state databases and therefore was chosen as the basis for production 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.

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

Production data were obtained for all counties in the Great Plains Basin 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, 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 Great Plains Basin 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 2011 were identified by indication that the spud occurred within 2011. 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.

The well counts by well type are presented in Table 1-1, and the oil, gas and water production by county are presented in Table 1-2. The spuds by county are presented in Table 1-3. Appendix A presents similar oil and gas activity tables by mineral designation. Because of the minimal number of coal-bed methane (CBM) wells in the basin (one CBM well total) and minimal volume of CBM gas produced in the basin (negligible gas production in 2011), CBM wells and production are lumped together with other gas wells.

Table 1-1. 2011 well count by well type and by county for the Great Plains Basin (counties without oil and gas production are not shown).

County	Well Count	
	Gas Wells	Oil Wells
Blaine, MT	749	64
Chouteau, MT	116	1
Fergus, MT	7	0
Glacier, MT	239	550
Golden Valley, MT	4	0
Hill, MT	599	2
Liberty, MT	190	104
Musselshell, MT	0	63
Petroleum, MT	0	41
Phillips, MT	1,651	2
Pondera, MT	89	223
Rosebud, MT	1	83
Teton, MT	4	108
Toole, MT	813	1,005
Yellowstone, MT	0	29
Total	**4,462**	**2,275**

Table 1-2. 2011 production by production type and by county for the Great Plains Basin (counties without oil and gas production are not shown).

County	Liquid Hydrocarbon Production		Gas Production		Produced Water (bbl)
	Condensate (bbl)	Oil (bbl)	Primary Gas (mcf)	Associated Gas (mcf)	
Blaine, MT	0	275,428	8,208,735	37,410	2,155,785
Chouteau, MT	0	0	1,063,921	2,340	6,631
Fergus, MT	0	0	29,743	0	1,480
Glacier, MT	252	410,844	1,330,962	154,236	6,424,105
Golden Valley, MT	0	0	186,062	0	0
Hill, MT	527	516	6,890,235	3,339	128,702
Liberty, MT	11,658	187,337	1,317,419	54,706	1,244,380
Musselshell, MT	0	147,518	0	7,183	7,608,162
Petroleum, MT	0	24,708	0	4,008	2,274,279
Phillips, MT	0	0	13,584,083	6,497	640,648
Pondera, MT	642	129,151	242,191	0	3,224,903
Rosebud, MT	6,469	219,108	0	12,013	7,529,891
Teton, MT	80	58,035	891	1	1,458,121
Toole, MT	3,025	355,592	2,876,254	271,361	12,632,845
Yellowstone, MT	0	14,088	0	0	966,082
Total	**22,653**	**1,822,325**	**35,730,496**	**553,094**	**46,296,014**

Table 1-3. 2011 spud counts by county for the Great Plains Basin (counties without oil and gas production are not shown).

County	Spuds
Blaine, MT	4
Chouteau, MT	0
Fergus, MT	0
Glacier, MT	10
Golden Valley, MT	0
Hill, MT	0
Liberty, MT	4
Musselshell, MT	1
Petroleum, MT	8
Phillips, MT	2
Pondera, MT	1
Rosebud, MT	4
Teton, MT	1
Toole, MT	6
Yellowstone, MT	0
Total	**41**

2.0 2011 MIDSTREAM SOURCES

Permitted midstream sources in the Great Plains Basin analysis refer to two types of sources for which data was gathered: (1) Title V or major sources in use in midstream, gas gathering applications from permit data from the MTDEQ; and (2) Part 71 major sources on tribal land from EPA Region 8. The two data source types are described below. In general, these permitted sources were used to supplement the emissions associated with well-site sources which were derived from survey data and tribal minor source registrations. Most permitted emissions used in this inventory were for midstream facilities which were not included in the exploration and production (E&P) sector surveys described in the next section. Although the MTDEQ registers production-site equipment, this study used the detailed survey of operators to estimate emissions from these sources rather than permit data for individual production sites due to the availability of the data and the resources available for processing this data.

2.1 Permit Data for Midstream Facilities from State Agencies

Similar to the WRAP Phase III emissions inventories[4], midstream companies were generally not participants in the survey process conducted in the Great Plains Basin, with the exception of some gas and oil producers who may also own and operate midstream facilities. Because MTDEQ permits large midstream sources on non-tribal land, it was determined that these permit databases would be the most comprehensive source of data on midstream facilities such as gas plants, compressor stations and associated equipment. Requests were made to the MTDEQ to query their database of permitted facilities to identify midstream oil and gas sources in the Great Plains Basin using a combination of NAICS (SIC) and SCC codes corresponding to onshore oil and gas sources. This query was focused on facilities and to the extent possible excluded production sites. It is noted that MTDEQ requires registration of production sites including registration of equipment at the sites, but discussions with MTDEQ indicated that this information was not considered readily available for use in the inventory.

2.2 Permit Data from EPA Region 8

2.2.1 Title V

Title V and Part 71 permits were requested from EPA Region 8 covering the Great Plains Basin, primarily for the Blackfeet, Rocky Boys and Fort Belknap Indian Reservations. Data provided by EPA did not indicate any midstream sources in the Great Plains Basin meeting the Title V emission thresholds.

2.2.2 Tribal Minor Source Reporting

Tribal minor source registration emissions were also requested from EPA Region 8 covering the Great Plains Basin, primarily for the Blackfeet, Rocky Boys and Fort Belknap Indian Reservations. Data provided by EPA indicated that no midstream sources had reported emissions as part of minor source reporting. Of the Indian Reservations in the Great Plains Basin, the Blackfeet Indian Reservation has the largest number of oil and gas wells (approximately 314 wells). At the time that this inventory was developed, sufficient tribal minor source registration data was not available for the Blackfeet Indian Reservation to develop well site emissions specific to that reservation.

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

3.0 2011 WELL SITE SOURCES

Emissions from well site sources were estimated based primarily on a survey effort that was conducted to develop basin-wide representative data for well site emission sources. Detailed inventory methodologies for each of the source categories are presented in Section 4.0. Emission estimates were generally made by extending representative emissions per well or per unit of production developed from the survey data to the entire basin by scaling by the appropriate oil and gas surrogate. Similarly, emissions by mineral designation were estimated by scaling basin-wide emissions by the oil and gas activity surrogate appropriate to each source category.

3.1 Surveyed Sources

A survey spreadsheet was forwarded to participating operators in the Great Plains Basin. The requested specific data related to the following 23 source categories:

- Drill Rigs
- Fracing Engines
- Completion Engines
- Initial Completion Venting
- Oil and Condensate Tanks
- Well Truck Loading
- Artificial Lift Engines
- Casinghead Flaring
- Fugitive
- Heaters
- Pneumatic Devices
- Pneumatic Pumps
- Dehydrators
- Workover Rigs
- Refracing Engines
- Recompletion Venting
- Other Flaring
- Miscellaneous Engines
- Well Blowdown (liquids unloading)
- Wellsite Compressor Engines
- Compressor Start-ups and Shutdown
- Water Tanks
- Water Disposal Pits

The companies participating in the survey process for the Great Plains Basin represented approximately 44% of well ownership in the basin, 51% of gas production in the basin, and 41% of oil production in the basin. Although these percentages did not meet the study's target ownership rate of 70% of oil and gas production, the percentage of oil and gas activity that was captured in the survey process allow for good representation of oil and gas operations in the basin.

Insufficient survey data was obtained to estimate emissions for certain source categories. These source categories were therefore excluded from the study and include amine units, CBM pump engines, truck loading at gas and NGL processing plants, water disposal pits, and saltwater disposal engines. Finally, 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 to tractably estimate basin-wide pipeline fugitive emissions.

It should be noted that the emission estimates calculated for survey-based 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 the survey responses. However the level of detail of the surveys and the extent of participation in the survey effort allow for emissions estimates of survey-based sources which represent a first-of-its-kind inventory for the Great Plains Basin.

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), and flash gas associated with oil tanks. These composition analyses were averaged to derive basin-wide gas composition averages for oil wells by associated gas production, for gas wells by primary gas production, and for oil tank flash gas based on oil production. The average composition analyses were used to determine the average basin-wide VOC volume and mass fractions of the vented gas by type (i.e. associated gas, primary gas, and oil tank flash gas). It is noted that due to lack of survey data, condensate tank flash gas compositions were taken from Friesen et.al (2009a).

Survey data was aggregated together at the basin-wide level 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. Aggregated input data for various emission source category calculations is provided in Appendix B.

4.0 2011 WELL SITE SOURCES EMISSION CALCULATION METHODOLOGIES

Described below are the methods used to calculated emissions from well site sources. The methodologies presented were applied for both oil wells and gas wells, as oil wells and gas wells were treated separately in the emission inventory analysis. Input factors used to estimate emissions for all well-site sources basin-wide are presented in Appendix B.

4.1 Drilling and Completion Phase

4.1.1 Drill Rigs

Methodology

The participating companies provided data on drill rig engine usage in their operations. Emission calculations for drill rig engines are based on engine parameters including horsepower, hours of operation per spud and brake-horsepower-based emissions factors.

The basic methodology for estimating emissions from a drill rig engine is shown in Equation 1:

$$E_{drilling,engine} = \frac{EF_i \times HP \times LF \times t_{drilling}}{907{,}185} \qquad \text{(Equation 1)}$$

where:

$E_{drilling,engine}$ is the emissions from one engine on the drilling rig for drilling one well [ton/engine/spud]
EF_i is the emissions factor for the engine for pollutant *i* [g/hp-hr]
HP is the horsepower of the engine [hp]
LF is the load factor of the engine
$t_{drilling}$ is the actual on-time of the engine for a typical drilling event in the basin [hr/spud]
907,185 is the mass units conversion factor [g/ton]

A single drill rig may contain more than one engine, depending on the rig configuration. The total emissions from drilling one well are thus the sum of emissions from each engine, according to Equation 2:

$$E_{drilling} = \sum_i E_{drilling,engine,i} \qquad \text{(Equation 2)}$$

where:

$E_{drilling}$ is the total emissions from drilling one well [tons/spud]
$E_{drilling,engine,i}$ is the total emissions from engine *i* from drilling one well [tons/engine/spud]

It should be noted that SO_2 emissions were estimated using the brake-specific fuel consumption (BSFC) of the engine, as obtained from the EPA's NONROAD model (EPA, 2009) for a similarly sized drill/bore rig engine, and the 2011 sulfur content of the off-road diesel fuel (32 ppm) as obtained from the EPA Suggested Nationwide Fuel Properties (EPA, 2009). The EPA NONROAD

model guidance was used to determine the fraction of fuel sulfur that would go to forming PM emissions – for drilling rig engines this was only 2.2% of sulfur content. It was assumed that the remaining sulfur in the fuel would be emitted as SO_2.

Emissions factors for all other pollutants were obtained from the EPA's NONROAD model (EPA, 2009) for other oil field equipment (SCC 2270010010).

Extrapolation to Basin-Wide Emissions

Drilling emissions were scaled up to the basin level by multiplying the per spud drilling emissions by the number of spuds according to Equation 3:

$$E_{drilling,TOTAL} = E_{drilling} \times S_{TOTAL} \qquad \text{(Equation 3)}$$

where:

$E_{drilling,TOTAL}$ is the total emissions in the basin from drilling activity [tons/year]
$E_{drilling}$ is the average emissions per spud [tons/year/spud]
S_{TOTAL} is the total number of spuds that occurred in the basin in 2011

County-level emissions were estimated by allocating the total basin-wide drill rig emissions into each county according to the fraction of total 2011 spuds that occurred in each county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 spuds that occurred in each mineral designation in that county.

4.1.2 Fracing Engines

Methodology

Representative data from the participating companies was not available on fracing engine usage, therefore, representative data from the Williston Basin (ENVIRON, 2014) was used. Similar to drilling engines, emission calculations for fracing engines are based on engine parameters including horsepower, hours of operation per spud and brake-horsepower-based emissions factors.

The basic methodology for estimating emissions from a fracing engine is shown in Equation 4:

$$E_{fracing,engine} = \frac{EF_i \times HP \times LF \times t_{fracing}}{907{,}185} \qquad \text{(Equation 4)}$$

where:

$E_{fracing,engine}$ is the emissions from one engine in the fracing setup [ton/engine/spud]
EF_i is the emissions factor for the engine for pollutant *i* [g/hp-hr]
HP is the horsepower of the engine [hp]
LF is the load factor of the engine
$t_{fracing}$ is the actual on-time of the engine for a typical fracing event in the basin [hr/spud]

907,185 is the mass units conversion factor [g/ton]

A single fracing setup typically contains multiple engines. The total emissions from fracing one well are thus the sum of emissions from each engine, according to Equation 5:

$$E_{fracing} = \sum_i E_{fracing,engine,i} \qquad \text{(Equation 5)}$$

where:

$E_{fracing}$ is the total emissions from fracing one well [tons/spud]
$E_{fracing,engine,i}$ is the total emissions from engine *i* from fracing one well [tons/engine/spud]

It should be noted that SO_2 emissions were estimated using the BSFC of the engine, as obtained from the EPA's NONROAD model (EPA, 2009) for a similarly sized fracing engine, and the 2011 sulfur content of the off-road diesel fuel (32 ppm) as obtained from the EPA Suggested Nationwide Fuel Properties (EPA, 2009). The EPA NONROAD model guidance was used to determine the fraction of fuel sulfur that would go to forming PM emissions – for drilling rig engines this was only 2.2% of sulfur content. It was assumed that the remaining sulfur in the fuel would be emitted as SO_2.

Emissions factors for all other pollutants were obtained from the EPA's NONROAD model (EPA, 2009) for other oil field equipment (SCC 2270010010).

Extrapolation to Basin-Wide Emissions

Fracing emissions were scaled up to the basin level by multiplying the per fracing event emissions by the number of spuds according to Equation 6. It was assumed that all spuds were fracked.

$$E_{fracing,TOTAL} = E_{fracing} \times S_{TOTAL} \qquad \text{(Equation 6)}$$

where:

$E_{fracing,TOTAL}$ is the total emissions in the basin from fracing activity [tons/year]
$E_{fracing}$ is the total emissions per spud [tons/year/spud]
S_{TOTAL} is the total number of spuds that occurred in the basin in 2011

County-level emissions were estimated by allocating the total basin-wide fracing engine emissions into each county according to the fraction of total 2011 spuds that occurred in each county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 spuds that occurred in each mineral designation in that county.

4.1.3 Initial Completions

Methodology

Emissions from well completions were estimated on the basis of the volume of gas vented during completion and the average VOC content of that gas, obtained from the gas composition analyses. The "well completion" source category refers to initial completions of wells after drilling.

The emission calculations accounted for green completions and conventional completions and applied the ideal gas law and gas characteristics defined from laboratory analyses to estimate emissions according to Equations 7 and 8:

$$V_{vented,TOTAL} = V_{vented,green} \times f_{green} + V_{vented,conv} \times f_{conv} \qquad \text{(Equation 7)}$$

where:

$V_{vented,TOTAL}$ is the average volume of vented gas per well [mscf/spud]
$V_{vented,green}$ is the average volume of vented gas per well from a green completion [mscf/spud]
f_{green} is the fraction of completions that are green completions [%]
$V_{vented,conv}$ is the average volume of vented gas per well from a conventional completion [mscf/spud]
f_{conv} is the fraction of completions that are conventional completions [%]

$$E_{completion} = \left[\frac{P \times V_{vented,TOTAL} \times 1000 \times MW_{VOC}}{R \times T} \times Y_{VOC} \right] \times \left[\left(1 - C_{eff}\right) \times F + \left(1 - F\right) \right] \qquad \text{(Equation 8)}$$

where:

$E_{completion}$ is the VOC emissions from a representative well completion [lb/spud]
MW_{VOC} is the molecular weight of the VOC [lb/lb-mol]
R is the universal gas constant [scf-atm/K-lb-mol]
Y_{VOC} is the volume fraction of VOC in the vented gas
C_{eff} is the flaring control efficiency
F is the fraction of vented volume per completion that is flared
1,000 is the volume units conversion factor [scf/mscf]
T is the temperature [K]
P is the pressure in [atm]

The conversion from volume of gas vented to mass of VOC produced was evaluated at standard temperature and pressure.

Extrapolation to Basin-Wide Emissions

The total VOC emissions per spud were scaled to the entire basin by the total number of completions in the basin according to Equation 9:

$$E_{completion,TOTAL} = E_{completion} \times S_{TOTAL} / 2000 \quad \text{(Equation 9)}$$

where:

$E_{completion,TOTAL}$ are the total emissions basin-wide from completions [tons/year]
$E_{completions}$ is the VOC emissions from a representative completion [lb/year/spud]
S_{TOTAL} is the total number of spuds in the basin [spuds]
2,000 is the mass units conversion factor [lb/ton]

County-level emissions from completions were estimated by allocating the total basin-wide completion emissions into each county according to the fraction of 2011 spuds occurring in that county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 spuds that occurred in each mineral designation in that county.

4.2 Production Phase

4.2.1 CBM Pump Engines

As noted above, there is minimal CBM activity in the Great Plains Basin and producers responding to the surveys did not indicate any usage of CBM pump engines at gas wells in the Great Plains Basin. Insufficient data was gathered to estimate emissions for this source category.

4.2.2 Amine Units

The production companies surveyed as part of this work indicated minimal or no usage of amine units in field operations. Insufficient data was gathered to estimate emissions for this source category. It is possible that some amine units or other acid gas removal systems are in use at large gas processing facilities included with midstream sources and their vented emissions would be counted with the facility total VOC emissions for purposes of the inventory.

4.2.3 Recompletion Venting and Refracing Engines

Insufficient data was gathered to estimate emissions for these source categories.

4.2.4 Oil, Condensate, and Water Tanks

<u>Methodology</u>

Emission factors and controls for oil tanks in the Great Plains Basin were estimated from company surveys for oil tanks and water tanks; insufficient survey-based data was available for condensate tanks, therefore, condensate emission factor and control assumption were taken from Friesen et.al (2009).

The basin-wide emissions from oil, condensate, and water tanks are the summation of emissions in each county for oil, condensate, and water tanks respectively. For each county, condensate, water, and oil tank emissions were derived from production-based emission factors and IHS estimates of condensate, water, and oil production, respectively. Oil and gas

wells were identified based on IHS database well designation as either an oil or gas well. Emission factors from water tanks (0.18 lb VOC/bbl) and oil tanks (1.94 lb VOC/bbl) were estimated from survey-based data; the condensate tank emission factor (7.00 lb VOC/bbl) was taken from Friesen et.al (2009) due to lack of survey-based data.

Company surveys indicated no controls for oil tanks in 2011. The fraction of condensate tank throughput controlled by flare was estimated to be 9% as described in Bar-Ilan et.al (2013). Company surveys indicated that 73% of produced water was sent directly to pipeline and would not have water tank associated emissions. Survey-based data indicated that water tanks were uncontrolled in 2011.

County-level oil, water, and condensate tank emissions were estimated as per Equation 10:

$$E_{\tan ks-county} = \frac{P \times EF}{2000} * \left[UC + (1 - FC_{flare}) * CE_{flare} + (1 - FC_{EC}) * CE_{EC} + (1 - FC_{VRU}) * CE_{VRU} \right] \quad \text{(Equation 10)}$$

where:

$E_{tanks\text{-}county}$ is the county-level emissions from oil, condensate, or water tanks [tons/year]
EF is the VOC emissions factor for oil, condensate, or water tanks [lb-VOC/bbl]
P is the oil production of oil, condensate, or water tanks that is sent to tanks [bbl/year]
UC is the fraction of oil, condensate, or water production that is uncontrolled [%]
FC_{flare} is the fraction of oil, condensate, or water production controlled by flare [%]
CE_{flare} is the control efficiency of the flare [%]
FC_{EC} is the fraction of oil, condensate, or water production controlled by enclosed combustor [%]
CE_{EC} is the control efficiency of the enclosed combustor [%]
FC_{VRU} is the fraction of oil, condensate, or water production controlled by VRU [%]
CE_{VRU} is the control efficiency of the VRU [%]

Extrapolation to Basin-Wide Emissions

Emissions were estimated for basin-wide oil, condensate, and water tanks according to Equations 11:

$$E_{\tan ks} = \sum \left(E_{,\tan ks-county} \right)_i \quad \text{(Equation 11)}$$

where:

E_{tanks} is the basin-wide emissions from oil, condensate, or water tanks [tons/year]

Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 oil, condensate, or water production that occurred in each mineral designation in that county.

4.2.5 Casinghead Gas

Methodology

Casinghead gas venting and flaring emissions were estimated based on survey-based data. VOC emissions result from any casinghead gas that is vented to the atmosphere as well as from casinghead gas that is flared. According to operator surveys, 3.3% of casinghead gas is vented, 2.3% of casinghead gas is flared, and 94.4% of casinghead gas is sent to pipeline.

$$E_{casinghead} = \left[\frac{P \times V_{vented,TOTAL} \times 1000 \times MW_{VOC}}{R \times T} \times Y_{VOC} \right] \times \left[(1 - C_{eff}) \times F + (1 - F) \right] \quad \text{(Equation 12)}$$

where:

$E_{casinghead}$ is the VOC emissions from casinghead gas [lb/year]
$V_{vented,TOTAL}$ is the total volume of casinghead gas that is vented [mscf/year]
MW_{VOC} is the molecular weight of the VOC [lb/lb-mol]
R is the universal gas constant [scf-atm/K-lb-mol]
Y_{VOC} is the volume fraction of VOC in the vented gas
C_{eff} is the flaring control efficiency
F is the fraction of vented volume that is flared
1,000 is the volume units conversion factor [scf/mscf]
T is the temperature [K]
P is the pressure in [atm]

The conversion from volume of gas vented to mass of VOC produced was evaluated at standard temperature and pressure.

Extrapolation to Basin-Wide Emissions

The total VOC emissions from all casinghead gas venting and flaring as described in Equation 13 represent basin-wide casinghead VOC emissions. County-level emissions from casinghead gas were estimated by allocating the total basin-wide casinghead gas emissions into each county according to the fraction of 2011 associated gas production from oil wells occurring in that county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 associated gas production from oil wells that occurred in each mineral designation in that county.

4.2.6 Oil and Gas Well Truck Loading

Methodology

Based on surveyed producer responses and tribal minor source registrations, oil and gas well truck loading emissions were estimated based on loading losses per EPA AP-42, Section 5.2 methodology combined with IHS database statistics on the total produced oil and condensate volumes basin-wide (EPA, 1995). The loading loss rate was estimated based on EPA AP-42, Section 5.2 methodology, following Equation 13:

$$L = 12.46 \times \left(\frac{S \times V \times M}{T} \right) \qquad \text{(Equation 13)}$$

where:

L is the loading loss rate [lb/1000gal]
S is the saturation factor taken from AP-42 default values based on operating mode
V is the true vapor pressure of liquid loaded [psia]
M is the molecular weight of the vapor [lb/lb-mole]
T is the temperature of the bulk liquid [^{o}R]

Total truck loading emissions were then estimated by combining, separately for oil well and gas well truck loading, the calculated loading loss rate with the fraction of production sent directly to pipeline and the annual total volume of oil and condensate produced basin-wide as shown in Equation 14:

$$E_{loading} = L \times P \times (1 - F) \times \frac{42}{1000} \qquad \text{(Equation 14)}$$

where:

E is the truck loading emissions [lb/year]
L is the loading loss rate [lb/1000gal]
P is the hydrocarbon liquid produced [bbl/year]
F is the fraction of hydrocarbon liquid production that is sent directly to pipeline
42 is the volume-units conversion factor [gal/bbl]
1,000 is the volume-units conversion factor [gal/1000gal]

Extrapolation to Basin-Wide Emissions

The basic emission estimation methodology described in Equations 13 and 14 above accounts for total basin-wide emissions from truck loading losses.

County-level emissions were estimated by allocating the total basin-wide truck loading emissions into each county according to the fraction of oil or condensate production for each county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 oil or condensate production that occurred in each mineral designation in that county.

4.2.7 Artificial Lift Engines

Methodology

The participating companies and tribal minor source registrations provided data on artificial lift engine usage. Emission calculations for artificial lift engines are based on average artificial lift engine parameters including horsepower, and brake-horsepower-based emissions factors.

The basic methodology for estimating emissions from an artificial lift engine is shown in Equation 15:

$$E_{engine} = \frac{EF_i \times HP \times LF \times t_{annual}}{907{,}185} \qquad \text{(Equation 15)}$$

where:

E_{engine} are emissions from an artificial lift engine [ton/year/engine]
EF_i is the emissions factor of pollutant *i* [g/hp-hr]
HP is the horsepower of the engine [hp]
LF is the load factor of the engine
t_{annual} is the annual number of hours the engine is used [hr/year]
907,185 is the mass-units conversion factor [g/ton]

Emission factors were provided in operator surveys and in tribal minor source registrations. Based on the survey data which showed that all artificial lift engines in the basin were natural gas-fired engines, it is assumed that sour gas containing hydrogen sulfide (H_2S) would not be used for direct combustion in engines; therefore SO_2 emissions were also assumed negligible from artificial lift engines powered by natural gas.

Extrapolation to Basin-Wide Emissions

Emissions from artificial lift engines were estimated based on representative artificial lift engine emissions as well as survey-based and registration-based estimates of (1) the fraction of wells served by an artificial lift engine and (2) the fraction of artificial lift engines that are electrified according to Equation 16:

$$E_{engine,TOTAL} = E_{engine} \times C \times F \times W_{Oil,TOTAL} \qquad \text{(Equation 16)}$$

where:

$E_{engine,TOTAL}$ is the total emissions from artificial lift engines in the basin [ton/year]
E_{engine} are emissions from an artificial lift engine [ton/year/engine]
C is the fraction of artificial lift engines that are not electric
F is the fraction of oil wells that are served by an artificial lift engine
$W_{TOTAL,Oil}$ is the total count of oil wells in the basin

County-level emissions were estimated by allocating the total basin-wide artificial lift engine emissions into each county according to the fraction of total 2011 oil wells located in each county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 active oil wells that occurred in each mineral designation in that county.

4.2.8 Fugitive Components

Methodology

Fugitive emissions from well sites were estimated using AP-42 emissions factors (EPA, 1995) and fugitive component counts provided in the survey responses and tribal minor source

registration data. The participating companies provided representative component counts for oil wells and gas wells in the basin by component type and by the type of service to which the component applies – gas, light liquid, heavy liquid, or water. As noted above, due to the minimal CBM gas production in the Great Plains Basin, CBM fugitive emissions were not estimated.

Fugitive VOC emissions for a representative well were estimated according to Equation 17:

$$E_{fugitive} = \sum_i EF_i \times N_i \times t_{annual} \times Y \times \frac{1}{C_1} \qquad \text{(Equation 17)}$$

where:

$E_{fugitive}$ is the fugitive VOC emissions [ton-VOC/year]
EF_i is the emission factor of TOC [kg/hr/source] for component and service type *i*
N_i is the number of devices per oil well or per gas well for component and service type *i*
Y is the ratio of VOC to TOC in the vented gas
C_1 is 907.185 kg/ton

The conversion from volume of gas vented to mass of VOC produced was evaluated at standard temperature and pressure.

Extrapolation to Basin-Wide Emissions

Basin-wide fugitive emissions are estimated by multiplying the emissions per oil well and per gas well emissions by the number of oil wells and gas wells in the basin, according to Equation 18:

$$E_{fugitive,\ TOTAL} = E_{fugitive} \times W_{TOTAL} \qquad \text{(Equation 18)}$$

where:

$E_{fugitive,TOTAL}$ is the total fugitive emissions in the basin [ton/year]
$E_{fugitive}$ is the fugitive VOC emissions per well [ton-VOC/year]
W_{TOTAL} is the total number of wells in the basin

County-level emissions were estimated by allocating the basin-wide fugitive emissions from oil wells or gas wells into each county according to the fraction of 2011 oil well count or gas well count occurring in that county. Emissions by mineral designation for gas wells or oil wells were estimated in each county by allocating the county total gas well or oil well emissions into each mineral designation according to the fraction of total 2011 active oil wells or gas wells that occurred in each mineral designation in that county.

4.2.9 Heaters

Methodology

This source category refers to separator and/or tank heaters as well as dehydrator reboilers located at well sites. Heater emissions were calculated on the basis of the emissions factor of

the heater, and the annual flow rate of gas to the heater. The annual gas flow rate was calculated from the British Thermal Unit (BTU) rating of the heater and the local BTU content of the gas. Participating companies' survey data and tribal minor source registrations indicated that heaters were natural-gas fired. AP-42 emission factors for an uncontrolled small boiler for natural gas fuel were used for specific pollutants (EPA, 1995). Note that heaters were not assumed to be operated continuously and data on the annual hours of operation and the cycling fraction of the heaters were requested in the surveys.

The basic methodology for estimating emissions from heaters at a single well is shown in Equation 19:

$$E_{heater} = EF_{heater} \times Q_{heater} \times \frac{1}{\mathrm{HV}_{\mathrm{local}}} \times t_{annual} \times hc \times N_{heater} / 2000 \qquad \text{(Equation 19)}$$

where:

E_{heater} is the heater emissions per representative well [tons/well/year]
EF_{heater} is the emission factor for a heater for a given pollutant [lb/million scf]
Q_{heater} is the heater MMBTU/hr rating [$\mathrm{MMBTU}_{\mathrm{rated}}$/hr]
HV_{local} is the local natural gas heating value [$\mathrm{BTU}_{\mathrm{local}}$/scf]
t_{annual} is the annual hours of operation [hr/year]
hc is a heater cycling fraction to account for the fraction of operating hours that the heater is firing
N_{heater} is the number of heaters per well
2,000 is the mass-units conversion factor [lb/ton]

Extrapolation to Basin-Wide Emissions

Basin-wide heater emissions were estimated according to Equation 20:

$$E_{heater,TOTAL} = E_{heater} \times W_{TOTAL} \qquad \text{(Equation 20)}$$

where:

$E_{heater,TOTAL}$ is the total heater emissions in the basin [ton/year]
E_{heater} is the heater emissions per representative well [tons/well/year]
W_{TOTAL} is the total number of oil wells or gas wells in the basin

County-level emissions were estimated by allocating the basin-wide heater emissions from oil wells or gas wells into each county according to the fraction of 2011 oil well count or gas well count occurring in that county. Emissions by mineral designation for gas wells or oil wells were estimated in each county by allocating the county total gas well or oil well emissions into each mineral designation according to the fraction of total 2011 active oil wells or gas wells that occurred in each mineral designation in that county.

4.2.10 Pneumatic Devices

Methodology

Pneumatic device emissions were estimated based on the numbers, types of pneumatic devices, and bleed rates by device type provided by participating companies for representative oil wells and gas wells.

The methodology for estimating the emissions from pneumatic devices at a representative oil well or gas well is shown in Equations 21-22:

$$V_{vented,TOTAL} = \dot{V}_i \times N_i \times t_{annual} \qquad \text{(Equation 21)}$$

where:

$V_{vented,TOTAL}$ is the volume of vented gas from all pneumatic devices at a representative well [mscf/well/year]
$\dot{V}_i$ is the volumetric bleed rate from device *i* [mscf/hr/device]
N_i is the total number of device *i* per representative well [devices/well]
t_{annual} is the number of hours per year that devices were operating [hr/year]

$$E_{pneumatic} = \left[\frac{P \times V_{vented,TOTAL} \times 1000 \times MW_{VOC}}{R \times T} \times Y_{VOC} \right] \qquad \text{(Equation 22)}$$

where:

$E_{pneumatic}$ is the total conventional well pneumatic device VOC emissions per representative well [lb-VOC/well/year]
MW_{VOC} is the molecular weight of the VOC for vented gas [lb/lb-mol]
R is the universal gas constant [scf-atm/K-lb-mol]
Y_{VOC} is the volume fraction of VOC in the vented gas
1,000 is the volume-units conversion factor [scf/mscf]
T is the temperature [K]
P is the pressure in [atm]

The conversion from volume of gas vented to mass of VOC produced was evaluated at standard temperature and pressure.

Extrapolation to Basin-Wide Emissions

Basin-wide pneumatic device emissions were estimated according to Equation 23:

$$E_{pneumatic,TOTAL} = \frac{E_{pneumatic}}{2000} \times W_{TOTAL} \qquad \text{(Equation 23)}$$

where:

$E_{pneumatic,TOTAL}$ is the total pneumatic device emissions in the basin from oil wells or gas wells [ton/year]
$E_{pneumatic}$ is the pneumatic device VOC emissions per representative well [lb-VOC/year]
W_{TOTAL} is the total number of wells in the basin
2,000 is the mass-units conversion factor [lb/ton]

County-level emissions were estimated by allocating the total basin-wide oil well or gas well pneumatic emissions into each county according to the fraction of oil well count or gas well count occurring in that county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 oil well counts or gas well counts that occurred in each mineral designation in that county.

4.2.11 Pneumatic (Gas Actuated) Pumps

Methodology

Participating companies provided data on gas actuated pumps at oil wells in the Great Plains Basin. The data indicated negligible usage of heat trace pneumatic pumps and limited usage of chemical injection pneumatic pumps. Survey-based data was not available for gas well pneumatic pump usage. For gas well pneumatic pumps, Uinta Basin estimates (Friesen et.al, 2009) of pneumatic pump emissions per well were multiplied by the number of gas wells in the Great Plains Basin and scaled to the county-level and to mineral designations based on active gas well counts.

The volume of gas vented from heat trace and chemical injection pumps for a representative oil well and gas well were estimated according to Equation 24 and Equation 25 below

$$V_{vented,heattrace} = V_{ht} \times t \times n / 365 \qquad \text{(Equation 24)}$$

where:
$V_{vented,heattrace}$ is the total volume of vented gas per well [mscf/well/year]
V_{ht} is the volume of vented gas per pump, daily [mscf/pump/day]
t is the annually operating hours [hours/year]
365 is the time-unit conversion [days/year]
n is the fraction of wells that have heat trace pumps

$$V_{vented,chemical} = V_{CIP} \times G \times n \qquad \text{(Equation 25)}$$

where:
$V_{vented,chemical}$ is the total volume of vented gas per well [mscf/well/year]
V_{cip} is the volume of vented gas per gallon of chemical pumped [mscf/gallon]
G is the gallons of chemical pumped, annually [gallon/year]
n is the fraction of wells that have heat trace pumps

VOC emissions from pneumatic pumps were estimated according to Equation 26:

$$E_{pump} = \left[\frac{P \times \left(V_{vented,heattrace} + V_{vented,chemical}\right) \times 1000 \times MW_{VOC}}{R \times T} \times Y_{VOC} \right] \quad \text{(Equation 26)}$$

where:

E_{pump} is the gas-actuated pump VOC emissions per well [lb-VOC/well/year]
MW_{VOC} is the molecular weight of the VOC for the vented gas [lb/lb-mol]
R is the universal gas constant [scf-atm/K-lb-mol]
Y_{VOC} is the volume fraction of VOC in the vented gas
1,000 is the volume-units conversion factor [scf/mscf]
T is the temperature [K]
P is the pressure in [atm]

The conversion from volume of gas vented to mass of VOC produced was evaluated at standard temperature and pressure.

Extrapolation to Basin-Wide Emissions

Basin-wide gas-actuated pump emissions were estimated according to Equation 27:

$$E_{pump,TOTAL} = \frac{E_{pump}}{2000} \times W_{TOTAL} \quad \text{(Equation 27)}$$

where:

$E_{pump,TOTAL}$ is the total pneumatic pump emissions in the basin [ton/year]
E_{pump} is the gas-actuated pump VOC emissions for a representative well [lb-VOC/well/year]
W_{TOTAL} is the total number of wells in the basin
2,000 is the mass-units conversion factor [lb/ton]

County-level emissions were estimated by allocating the total basin-wide gas-actuated pump emissions into each county according to the fraction of total 2011 oil well counts or gas well counts that are located in each county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 oil well counts or gas well counts that occurred in each mineral designation in that county.

4.2.12 Dehydrators

Dehydrator emissions were calculated from two distinct sources: still vent emissions and reboiler emissions. Emissions from reboilers were estimated in the heaters source category as described in Section 4.2.9. Still vent emissions were estimated based on survey data from participating companies according to Equation 28.

$$E_{dehy,TOTAL} = \left[\frac{R}{2000} \times P_{TOTAL} \right] \times \left[\left(1 - C_{eff}\right) \times F + \left(1 - F\right) \right] \quad \text{(Equation 28)}$$

where:

$E_{dehy,TOTAL}$ are the total VOC emissions basin-wide from oil well or gas well dehydrators [tons/year]
R is the average dehydrator VOC emission rate [lb/mmscf]
P_{TOTAL} is the total gas production in the basin in 2011 from oil wells or gas wells [mmscf]
C_{eff} is the flaring control efficiency
F is the fraction of dehydrator emissions that are controlled by flare
2000 is a unit conversion constant [lb/ton]

Extrapolation to Basin-Wide Emissions

The total VOC emissions from all dehydrator still vents as described in Equation 28 already represent basin-wide dehydration VOC emissions. County-level emissions from dehydration were estimated by allocating the total basin-wide dehydration emissions from into each county according to the fraction of 2011 gas production from oil wells or gas wells occurring in that county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 gas production from oil wells or gas wells that occurred in each mineral designation in that county.

4.2.13 Workover Rigs

Methodology

The participating companies provided data on workover rig engine usage in their oil well and gas well operations.

The basic methodology for estimating emissions from a workover rig is shown in Equation 29:

$$E_{workover,rig} = \frac{EF_i \times HP \times LF \times t_{workover}}{907{,}185} \qquad \text{(Equation 29)}$$

where:

$E_{workover,rig}$ is the emissions from one engine on the workover rig for one well workover [ton/workover]
EF_i is the emissions factor for the engine for pollutant *i* [g/hp-hr]
HP is the horsepower of the engine [hp]
LF is the load factor of the engine
$t_{drilling}$ is the actual on-time of the engine for a typical workover event in the basin [hr/workover]
907,185 is the mass units conversion factor [g/ton]

It should be noted that SO_2 emissions were estimated using the BSFC of the engine, as obtained from the EPA's NONROAD model (EPA, 2009) for a similarly sized drill/bore rig engine, and the 2011 sulfur content of the off-road diesel fuel (32 ppm) as obtained from the EPA Suggested Nationwide Fuel Properties (EPA, 2009). The EPA NONROAD model guidance was used to determine the fraction of fuel sulfur that would go to forming PM emissions – for drilling rig engines this was only 2.2% of sulfur content. It was assumed that the remaining sulfur in the fuel would be emitted as SO_2.

Emissions factors for all other pollutants were obtained from the EPA's NONROAD model (EPA, 2009) for other oil field equipment (SCC 2270010010).

Extrapolation to Basin-Wide Emissions

Well workover emissions were scaled up to the basin level by multiplying the per workover event emissions by the well workover frequency and the number of active wells according to Equation 30:

$$E_{workover,TOTAL} = E_{workover} \times f \times W_{TOTAL} \qquad \text{(Equation 30)}$$

where:

$E_{drilling,TOTAL}$ is the total emissions in the basin from well workover activity [tons/year]
$E_{drilling}$ is the total emissions per workover [tons/workover]
f is the annual oil well workover frequency [workovers/well/year]
W_{TOTAL} is the total number of wells in the basin in 2011 [wells]

County-level workover emissions were estimated by allocating the total basin-wide oil well or gas well workover rig emissions into each county according to the fraction of total 2011 oil wells or gas wells that occurred in each county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 oil well counts or gas well counts that occurred in each mineral designation in that county.

4.2.14 Compressor Engines

Methodology

Survey data was provided by participating companies for compressor engine characteristics and operation at gas wells. Based on survey data provided, it was assumed that there was no usage of lateral compressors in the Great Plains Basin in 2011. For compressor engines at gas wells, Uinta Basin estimates (Friesen et.al, 2009) of compressor engine characteristics and usage were used because this data was not available from survey data. Large central compressor engines were assumed to be part of midstream point sources, as described above under permitted sources. It was assumed that all wellhead compressor engines are natural-gas fired.

Emission calculations for compressor engines follow a similar methodology as for artificial lift engines. Emission factors and load factors for the compressor engines were directly obtained from the survey respondents and tribal minor sources registration data.

The basic methodology for estimating emissions from compressor engines on a per well basis is shown in Equation 31:

$$E_{engine} = \frac{EF_i \times HP \times LF \times t_{annual} \times n}{907{,}185} \qquad \text{(Equation 31)}$$

where:

E_{engine} are emissions from a compressor engine [ton/year/well]
EF_i is the emissions factor of pollutant *i* [g/hp-hr]
HP is the horsepower of the engine [hp]
LF is the load factor of the engine
t_{annual} is the annual number of hours the engine is used [hr/year]
n is the number of compressor engines per well [engines/well]
907,185 is the mass units conversion factor [g/ton]

It was assumed that gas-fired engines would not use gas high in H_2S content due to operational issues; therefore SO_2 emissions were assumed negligible from these engines.

Extrapolation to Basin-Wide Emissions

Emissions from a representative oil well and gas well estimated per Equation 31 were scaled to the basin-level according to Equation 32:

$$E_{engine,TOTAL} = E_{engine} \times W_{TOTAL} \qquad \text{(Equation 32)}$$

where:

$E_{engine,TOTAL}$ is the total emissions from compressor engines in the basin [ton/year]
E_{engine} is the emissions from compressor engines at a representative well [ton/well/year]
W_{TOTAL} is the total number of wells in the basin [wells]

County-level emissions were estimated by allocating the total basin-wide compressor engine emissions into each county according to the fraction of total 2011 oil well counts or gas well counts that are located in each county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 oil well counts or gas well counts that occurred in each mineral designation in that county.

4.2.15 Miscellaneous Engines

Methodology:

Survey data was not available to characterize miscellaneous engine usage at oil and gas well sites. Uinta Basin (Friesen et.al, 2009) estimates of emissions per well were assumed for gas wells and oil wells. Emission per well were multiplied by the number of gas wells in the Great Plains Basin to estimate basin-wide emissions.

Extrapolation to Basin-Wide Emissions

The total emissions from miscellaneous engines were estimated as described above. County-level emissions were estimated by allocating the total basin-wide miscellaneous engine emissions into each county according to the fraction of total oil well counts or gas well counts that are located in each county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the

fraction of total 2011 oil well counts or gas well counts that occurred in each mineral designation in that county.

4.2.16 Well Blowdowns

Methodology

Emissions from well blowdowns were calculated using the estimated volume of gas vented during blowdown events, the frequency of the blowdowns, and the VOC content of the vented gas as documented by representative compositional analyses.

The calculations applied the ideal gas law and gas characteristics defined from laboratory analyses to estimate emissions according to Equations 33 to 34:

$$V_{vented,TOTAL} = V_{vented} \times f \times n \qquad \text{(Equation 33)}$$

where:

$V_{vented,TOTAL}$ is the total volume of vented gas per well [mscf/well/year]
V_{vented} is the volume of vented gas per blowdown [mscf/event]
f is the frequency of blowdowns [events/well/year]
n is the fraction of wells that conduct blowdowns

$$E_{blowdown} = \left[\frac{P \times V_{vented,TOTAL} \times 1000 \times MW_{VOC}}{R \times T} \times Y_{VOC} \right] \times \left[\left(1 - C_{eff}\right) \times F + \left(1 - F\right) \right] \qquad \text{(Equation 34)}$$

where:

$E_{blowdown}$ is the total VOC emissions from blowdowns per representative well [lb/well/year]
MW_{VOC} is the molecular weight of the VOC [lb/lb-mol]
R is the universal gas constant [scf-atm/K-lb-mol]
Y_{VOC} is the volume fraction of VOC in the vented gas
1000 is a volume-unit conversion (scf/mscf)
T is the temperature [K]
P is the pressure in [atm]

The conversion from volume of gas vented to mass of VOC produced was evaluated at standard temperature and pressure.

Extrapolation to Basin-Wide Emissions

The total VOC emissions from conventional well blowdowns were estimated by scaling representative well emissions to the entire basin according to Equation 35:

$$E_{blowdown,TOTAL} = E_{blowdown} \times W_{TOTAL} \qquad \text{(Equation 35)}$$

where:

$E_{blowdown,TOTAL}$ are the total emissions basin-wide from blowdowns [tons/year]

$E_{blowdown}$ are the blowdown VOC emissions per well [tons/well/year]
W_{TOTAL} is the total well count in the basin [wells]

County-level emissions from blowdowns were estimated by allocating the total basin-wide blowdown emissions from oil wells or gas wells into each county according to the fraction of oil well counts or gas well counts in that county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total oil well counts or gas well counts that occurred in each mineral designation in that county.

4.2.17 Compressor Start-ups and Shutdown

Methodology

Compressor engine startups and shutdowns refer to the emissions associated with venting of gas contained in compressor engines when they are restarted or shut down for maintenance, repairs or any other routine or non-routine reason. Emissions from compressor engine startups and shutdowns were calculated separately using the estimated volume of gas vented during compressor engine startup and shutdown events, the frequency of the startup and shutdown events, the number of compressor engines, and the VOC content of the vented gas as documented by representative compositional analyses. This source category does not consider combustion-related emissions associated with compressor start-ups and shutdowns. Surveyed producer data was for volumes of gas vented from compressor startups and shutdowns were used to estimate emissions for this source.

The calculations applied the ideal gas law and gas composition to estimate emissions according to Equations 36 to 37:

$$V_{vented,TOTAL} = V_{vented} \times n \times f \qquad \text{(Equation 36)}$$

where:

$V_{vented,TOTAL}$ is the volume of vented gas per well [mscf/well/year]
V_{vented} is the average volume of vented gas per startup or shutdown [mscf/event/engine]
n is the number of compressor engines per well [engines/well]
f is the frequency of startup or shutdown [events/year]

$$E_S = \left[\frac{P \times V_{vented,TOTAL} \times 1000 \times MW_{VOC}}{R \times T} \times Y_{VOC} \right] \qquad \text{(Equation 37)}$$

where:

E_S is the total VOC emissions from well compressor engine startups or shutdowns conducted per well [lb-VOC/well/year]
MW_{VOC} is the molecular weight of the VOC for vented gas [lb/lb-mol]
R is the universal gas constant [scf-atm/K-lb-mol]
Y_{VOC} is the volume fraction of VOC in the vented gas

1000 is a volume-unit conversion (scf/mscf)
T is the temperature [K]
P is the pressure in [atm]

The conversion from volume of gas vented to mass of VOC produced was evaluated at standard temperature and pressure.

Extrapolation to Basin-Wide Emissions

The total VOC emissions from a representative well were scaled by the total number of wells in the Great Plains Basin according to Equation 38:

$$E_{S,TOTAL} = E_S \times W_{TOTAL} \qquad \text{(Equation 38)}$$

where:

$E_{S,TOTAL}$ are the total emissions basin-wide from compressor engine startup or shutdown at conventional wells [tons/year]
E_S are the compressor engine startup or shutdown emissions from the participating companies at conventional wells [tons/well/year]
W_{TOTAL} is the total well count [wells]

County-level emissions were estimated by allocating the total basin-wide compressor startup and shutdown emissions from oil wells or gas wells into each county according to the fraction of oil wells or gas wells in that county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 oil well counts or gas well counts that occurred in each mineral designation in that county.

4.2.18 Compressor Fugitive Leaks

Methodology

This source category refers to leaking emissions of produced gas that escape through well site compressor engines. It must be noted that this source category refers only to compressor fugitive emissions for engines located at the well sites and that large midstream engine fugitives are not part of this analysis (fugitive emissions from permit-based sources would be included as part of the permit). Fugitive leaks from wellhead compressor seals were estimated per well based on Equation 39:

$$E_{compressor,\,fug} = \left(\frac{P \times V_{vented} \times t \times MW_{VOC}}{R \times T} \right) \times Y_{VOC} \times f \qquad \text{(Equation 39)}$$

where:

$E_{compressor,fug}$ are the VOC fugitive emissions from compressor seals [lb/well/yr]
V_{vented} is the volume of leaked gas per compressor [scf/compressor/day]
t is the annual days of operation for wellhead compressors [days/yr]

R is the universal gas constant [scf-atm/K-lb-mol]
MW_{VOC} is the molecular weight of the VOC for vented gas [lb/lb-mol]
f is the fraction of wells with wellhead compressors [compressors/well]
T is the temperature [K]
P is the pressure in [atm]
Y_{VOC} is the volume fraction of VOC in the vented gas

The conversion from volume of gas vented to mass of VOC produced was evaluated at standard temperature and pressure.

Extrapolation to Basin-Wide Emissions

Basin-wide compressor fugitive leak emissions are estimated according to Equation 40:

$$E_{fugitive,TOTAL} = E_{fugitive,j} \times N_{well} \qquad \text{(Equation 40)}$$

where:

$E_{fugitive,TOTAL}$ is the total basin-wide compressor fugitive leak emissions [ton/yr]
$E_{compressor,fug}$ are the per well VOC fugitive emissions from compressor seals [ton/well/yr]
N_{well} is the total number of active wells in the basin [wells]

County-level emissions were estimated by allocating the total basin-wide compressor fugitive leak emissions from oil wells or gas wells into each county according to the fraction of oil wells or gas wells in that county. Emissions by mineral designation were estimated in each county by allocating the county total emissions into each mineral designation according to the fraction of total 2011 oil well counts or gas well counts that occurred in each mineral designation in that county.

4.2.19 Flaring

Methodology

The basic methodology for estimating flaring emissions was similar among all the flaring categories. The AP-42 methodology (EPA, 1995) was applied, combining flared volumes with the heat content of the gas being flared and the appropriate AP-42 emission factor to determine the NOx and CO emissions. This basic AP-42 methodology is shown below in Equation 41:

$$E_{flare} = EF_i \times Q \times HV \qquad \text{(Equation 41)}$$

where:

E_{flare} is the basin-wide flaring emissions [lb]
EF_i is the emissions factor for pollutant i [lb/MMBtu]
Q is the volume of gas flared [MMscf]
HV is the heating value of the gas [BTU/scf]

SO_2 emissions were estimated for flaring activities where gas analyses indicated H_2S at measureable concentrations in the flared gas. The SO_2 flaring emission factor was estimated according to Equation 42:

$$EF_{SO2} = \left[\frac{P \times MW_{gas} \times W_{H2S}}{R \times T \times HV} \right] \times \left[\frac{MW_{SO2}}{MW_{H2S}} \right] \times 1{,}000{,}000 \qquad \text{(Equation 42)}$$

where:

EF_{SO2} is the emissions factor for pollutant *i* [lb/MMBtu]
P is the flared gas pressure [atm]
MW_{gas} is the flared gas molecular weight [lb/lb-mol]
W_{H2S} is the H_2S content of the gas as a weight fraction
R is the universal gas constant [scf-atm/K-lb-mol]
T is the flared gas temperature [K]
HV is the heating value of the flared gas [BTU/scf]
MW_{SO2} is the molecular weight of SO_2 [lb/lb-mol]
MW_{H2S} is the molecular weight of H_2S [lb/lb-mol]
1,000,000 is the volume-unit conversion [scf/MMscf]

The conversion from volume of gas vented to mass of SO_2 produced was evaluated at standard temperature and pressure.

The specific assumptions for each of the flaring categories are described below:

Oil Tank Flaring

Based on survey data, flaring activity at well site oil tanks was assumed negligible.

Condensate Tank Flaring

Condensate tanks flaring control estimates were based on survey data which indicated that 9% of condensate production was controlled by flare.

Casinghead Gas Flaring

In the Great Plains Basin, flaring of casinghead gas that is not sold was estimated as a unique source category. Survey data indicated that about 2.2% of casinghead gas would be flared.

Dehydrators

Based on survey data, flaring activity at well site dehydrators was assumed negligible.

Well Blowdowns

Based on survey data, flaring activity for well blowdowns was assumed negligible.

Initial Completions

Survey-based data indicated that green completions included negligible flaring and 5% of conventional completion volume was flared.

Other Flaring

Based on survey data, flaring activity for other events was assumed negligible.

5.0 2015 FORECAST

5.1 Geographic Grouping

The projections for 2015 have been conducted for three geographic groupings in the Great Plains Basin. These include:

- Western Great Plains Counties – this grouping represents an area in the basin that includes both oil and gas wells including Glacier, Liberty, Toole, and Pondera Counties;
- Central Great Plains Counties – this grouping represents an area in the basin that is primarily comprised of gas wells including Blaine, Hill, and Chateau Counties;
- Phillips County – this grouping represents only Phillips county with is comprised almost entirely of gas wells with minimal liquid hydrocarbon production;
- All Other Counties – this grouping contains primarily oil production areas outside of the three groupings listed above and includes all remaining counties in the basin;

As noted above, the geographic groupings were constructed to group similar production types.

5.2 Parameters Forecasted

The 2015 projections for oil and gas emissions in the Great Plains Basin rely on scaling the following parameters:

- Well counts by type (gas, oil, total)
- Spud counts by type (gas, oil, total)
- Gas production by type (primary, associated, total)
- Liquid Hydrocarbon production by type (oil, condensate, total)

These parameters are considered because each parameter applies to the emissions projections of one or more source categories. Note that the analysis uses data from the IHS database, which defines condensate production as liquid hydrocarbon production from wells which are classified as gas wells. Similarly, oil well oil production is defined as liquid hydrocarbon production from wells which are classified as oil wells. This is the distinction made between condensate and oil production. The majority of the liquid hydrocarbon production in the basin is in the form of primary oil.

The mapping of source category to projection parameter is shown below in Table 5-1.

Table 5-1. Scaling parameter for each oil and gas source category considered in this inventory.

Source	Type of Well	SCC	Description	Projection Parameter
Survey-based	Gas Wells	2310021603	Venting - blowdowns	Gas Well Well Count
Survey-based	Gas Wells	2310021603	Blowdown Flaring	Gas Well Well Count
Survey-based	Gas Wells	2310020600	Compressor engines	Gas Well Well Count
Survey-based	Gas Wells	2310021604	Compressor Engine Startup/Shutdown	Gas Well Well Count
Survey-based	Gas Wells	2310021506	Compressor Fugitives	Gas Well Well Count
Survey-based	Gas Wells	2310030220	Condensate tank	Gas Well Oil Production
Survey-based	Gas Wells	2310021011	Condensate tank flaring	Gas Well Oil Production
Survey-based	Gas Wells	2310021400	Dehydrator	Gas Well Gas Production
Survey-based	Gas Wells	2310021411	Dehydrator Flaring	Gas Well Gas Production
Survey-based	Gas Wells	2310000220	Drill rigs	Gas Well Spuds
Survey-based	Gas Wells	2310021000	Fracing	Gas Well Spuds
Survey-based	Gas Wells	2310021509	Survey-based Fugitives	Gas Well Well Count
Survey-based	Gas Wells	2310021100	Heaters	Gas Well Well Count
Survey-based	Gas Wells	2310021601	Venting - initial completions	Gas Well Spuds
Survey-based	Gas Wells	2310121701	Initial completion Flaring	Gas Well Spuds
Survey-based	Gas Wells	2310021700	Miscellaneous engines	Gas Well Well Count
Survey-based	Gas Wells	2310021300	Pneumatic devices	Gas Well Well Count
Survey-based	Gas Wells	2310021310	Pneumatic pumps	Gas Well Well Count
Survey-based	Gas Wells	2310021000	Refracing	Gas Well Well Count
Survey-based	Gas Wells	2310020800	Gas Well Truck Loading	Gas Well Oil Production
Survey-based	Gas Wells	2310000550	Water tank losses	Gas Well Water Production
Survey-based	Gas Wells	2310000550	Water Tank Flaring	Gas Well Water Production
Survey-based	Gas Wells	2310000230	Workover rigs	Gas Well Well Count
Survey-based	Gas Wells	2310021000	Other Venting	Gas Well Gas Production
Survey-based	Gas Wells	2310021000	Other Flaring	Gas Well Gas Production
Survey-based	Oil Wells	2310011600	Artificial Lift	Oil Well Well Count
Survey-based	Oil Wells	2310011000	Venting - blowdowns	Oil Well Well Count
Survey-based	Oil Wells	2310011000	Blowdown Flaring	Oil Well Well Count
Survey-based	Oil Wells	2310020600	Compressor engines	Oil Well Well Count
Survey-based	Oil Wells	2310011000	Compressor Engine Startup/Shutdown	Oil Well Well Count
Survey-based	Oil Wells	2310011506	Compressor Fugitives	Oil Well Well Count
Survey-based	Oil Wells	2310011450	Casinghead Gas Venting	Oil Well Gas Production
Survey-based	Oil Wells	2310011450	Casinghead Gas Flaring	Oil Well Gas Production
Survey-based	Oil Wells	2310011000	Dehydrator	Oil Well Gas Production
Survey-based	Oil Wells	2310011000	Dehydrator Flaring	Oil Well Gas Production
Survey-based	Oil Wells	2310000220	Drill rigs	Oil Well Spuds
Survey-based	Oil Wells	2310011000	Fracing	Oil Well Spuds

Source	Type of Well	SCC	Description	Projection Parameter
Survey-based	Oil Wells	2310010700	Survey-based Fugitives	Oil Well Well Count
Survey-based	Oil Wells	2310010100	Heaters	Oil Well Well Count
Survey-based	Oil Wells	2310111702	Venting - initial completions	Oil Well Spuds
Survey-based	Oil Wells	2310111701	Initial completion Flaring	Oil Well Spuds
Survey-based	Oil Wells	2310011000	Miscellaneous engines	Oil Well Well Count
Survey-based	Oil Wells	2310010200	Oil Tank	Oil Well Oil Production
Survey-based	Oil Wells	2310010200	Oil Tank Flaring	Oil Well Oil Production
Survey-based	Oil Wells	2310010300	Pneumatic devices	Oil Well Well Count
Survey-based	Oil Wells	2310111401	Pneumatic pumps	Oil Well Well Count
Survey-based	Oil Wells	2310011000	Refracing	Oil Well Well Count
Survey-based	Oil Wells	2310010800	Oil Well Truck Loading	Oil Well Oil Production
Survey-based	Oil Wells	2310000550	Water tank losses	Oil Well Water Production
Survey-based	Oil Wells	2310000550	Water Tank Flaring	Oil Well Water Production
Survey-based	Oil Wells	2310000230	Workover rigs	Oil Well Well Count
Survey-based	Oil Wells	2310011000	Other Venting	Oil Well Gas Production
Survey-based	Oil Wells	2310011000	Other Flaring	Oil Well Gas Production
MTDEQ Permitted Sources	All Wells	20200202	Compressor Engines	Total Gas Production
MTDEQ Permitted Sources	All Wells	31000404	Process Heaters	Total Gas Production
MTDEQ Permitted Sources	All Wells	31000227	Dehydrator	Total Gas Production
MTDEQ Permitted Sources	All Wells	20200254	Compressor Engines	Total Gas Production
MTDEQ Permitted Sources	All Wells	31000228	Dehydrator	Total Gas Production
MTDEQ Permitted Sources	All Wells	31000301	Dehydrator	Total Gas Production
MTDEQ Permitted Sources	All Wells	20200253	Compressor Engines	Total Gas Production
MTDEQ Permitted Sources	All Wells	31000207	Permitted Fugitives	Total Gas Production
MTDEQ Permitted Sources	All Wells	40400300	Permitted Tank Losses	Total Gas Production
MTDEQ Permitted Sources	All Wells	10500106	Process Heaters	Total Gas Production
MTDEQ Permitted Sources	All Wells	30502504	Natural Gas Production, Other Not Classified	Total Gas Production
MTDEQ Permitted Sources	All Wells	10200603	Process Heaters	Total Gas Production
MTDEQ Permitted Sources	All Wells	31000302	Dehydrator	Total Gas Production
MTDEQ Permitted Sources	All Wells	31000203	Compressor Engines	Total Gas Production
MTDEQ Permitted Sources	All Wells	31000220	Permitted Fugitives	Total Gas Production
MTDEQ Permitted Sources	All Wells	20100202	Compressor Engines	Total Gas Production
MTDEQ Permitted Sources	All Wells	20200201	Compressor Engines	Total Gas Production
MTDEQ Permitted Sources	All Wells	31000205	Natural Gas Production, Flares	Total Gas Production
MTDEQ Permitted Sources	All Wells	10101302	Other Heaters	Total Gas Production
MTDEQ Permitted Sources	All Wells	40400302	Permitted Tank Losses	Total Gas Production
MTDEQ Permitted Sources	All Wells	30501050	Natural Gas Production, Other Not Classified	Total Gas Production
MTDEQ Permitted Sources	All Wells	20300201	Other Engines	Total Gas Production

Source	Type of Well	SCC	Description	Projection Parameter
MTDEQ Permitted Sources	All Wells	40301132	Tank Evaporation	Total Gas Production
MTDEQ Permitted Sources	All Wells	40301152	Tank Evaporation	Total Gas Production
MTDEQ Permitted Sources	All Wells	40400151	Permitted Fugitives	Total Gas Production
MTDEQ Permitted Sources	All Wells	40400250	Permitted Tank Losses	Total Gas Production
MTDEQ Permitted Sources	All Wells	40400251	Valves, Flanges, and Pumps	Total Gas Production
MTDEQ Permitted Sources	All Wells	40301205	Other Evaporation	Total Gas Production
MTDEQ Permitted Sources	All Wells	30600801	Pipeline Valves and Flanges Fugitives	Total Gas Production
MTDEQ Permitted Sources	All Wells	31088801	Permitted Fugitives	Total Gas Production

5.3 Projection Methodologies for the Great Plains Basin

For the Great Plains Basin, the methodology for obtaining the 2015 value of each projection parameter is described below. Spud, well count and production projections for the basin were estimated by developing extrapolated trend lines from historical data, or conservatively holding well counts and production constant into the future if historic data indicated decline.

Additional annual data on oil and gas production and well counts was gathered from the IHS database for calendar year 2012 in order to better track recent trends. Therefore extrapolations and projections were made for the period 2013-2015, but it should be noted that projection factors represent the ratio of 2015 values of the parameters to 2011 values of the parameters.

5.3.1 Western Great Plains Counties

Oil Well Counts

Oil well counts in the Western Great Plains counties in the Great Plains Basin have been plotted for the years 2000–2012 below in Figure 5-1, including projections to 2015.

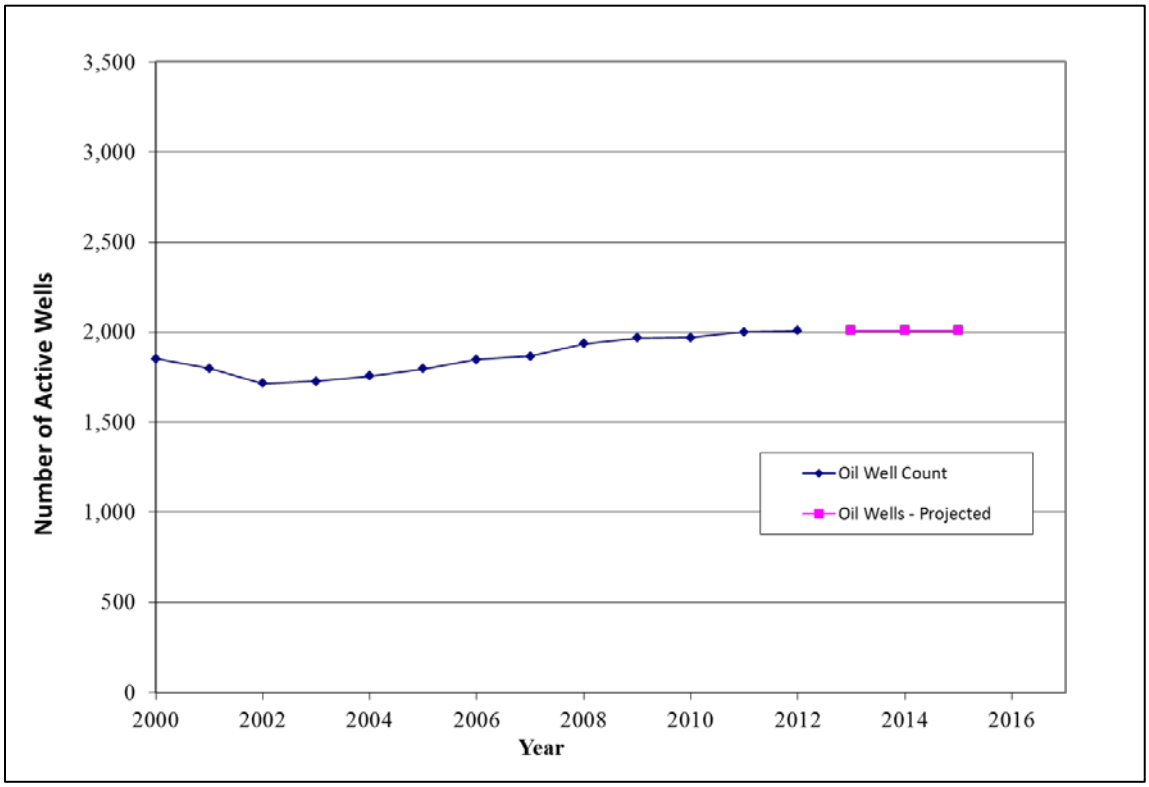

Figure 5-1. Oil well count historical data (from the IHS database) for Western Great Plains Counties in the Great Plains Basin and projections to 2015. [5]

From 2002 to 2012, oil well counts have been added at an average rate of approximately 29 wells per year; however, significantly slower growth is noted from 2009 to 2012. Oil well count projections were developed for the period 2013–2015 assuming that the oil well count remains at 2012 levels. This is consistent with relatively flat growth over the 2009 to 2012 period.

Gas Well Counts

Gas well counts in the Western Great Plains counties in the Great Plains Basin have been plotted for the years 2000–2012 below in Figure 5-2, including projections to 2015.

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

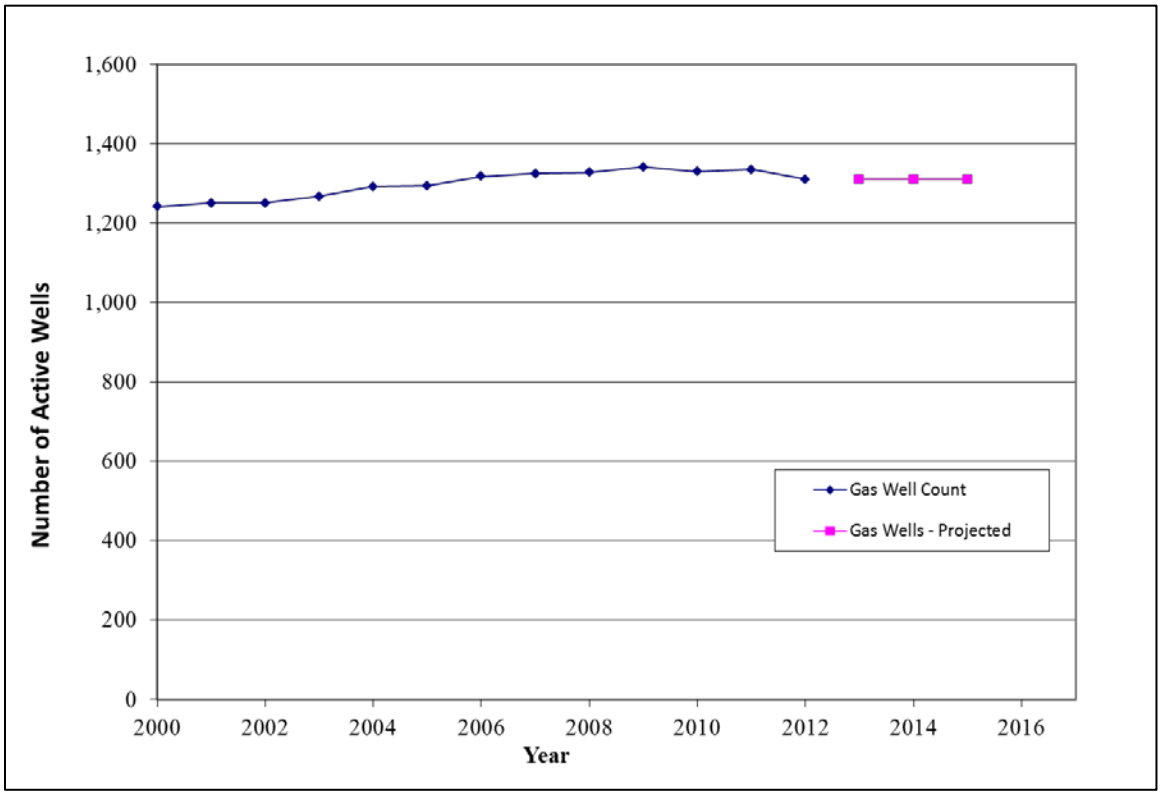

Figure 5-2. Gas well count historical data (from the IHS database) for Western Great Plains Counties in the Great Plains Basin and projections to 2015. [6]

Gas well count projections were developed for the period 2013–2015 assuming that the gas well count remains at 2012 levels. This is consistent with relatively flat growth over the 2006 to 2012 period.

Spud Counts

Spud counts in the Western Great Plains Counties in the Great Plains Basin have been plotted for the years 2000–2012 below in Figure 5-3, including projections to 2015. Spud counts by oil versus gas wells were estimated from IHS total spuds based on the number of oil and gas wells in each calendar year.

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

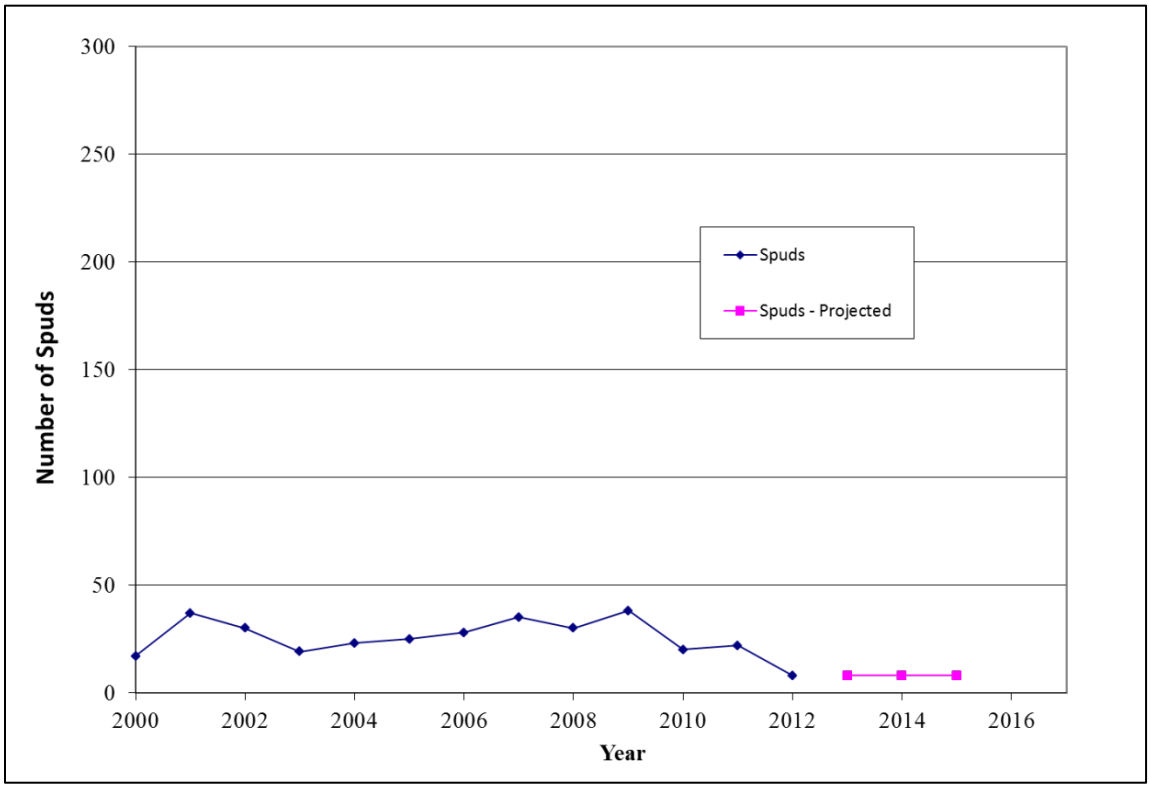

Figure 5-3. Spud count historical data (from the IHS database) for Western Great Plains Counties in the Great Plains Basin and projections to 2015. [7]

Historic spud counts in the Western Great Plains Counties, as obtained from the IHS database for the period 2000-2012 have fluctuated from 8 to 38 spuds, annually. Given the lack of a consistent trend in recent spud counts in the Western Great Plains Counties, the analysis assumed that the spud count would remain at 2012 levels in the period 2013-2015.

Associated Gas Production

Associated gas production (i.e. gas production from oil wells) in the Western Great Plains Counties in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-4, including projections to 2015.

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

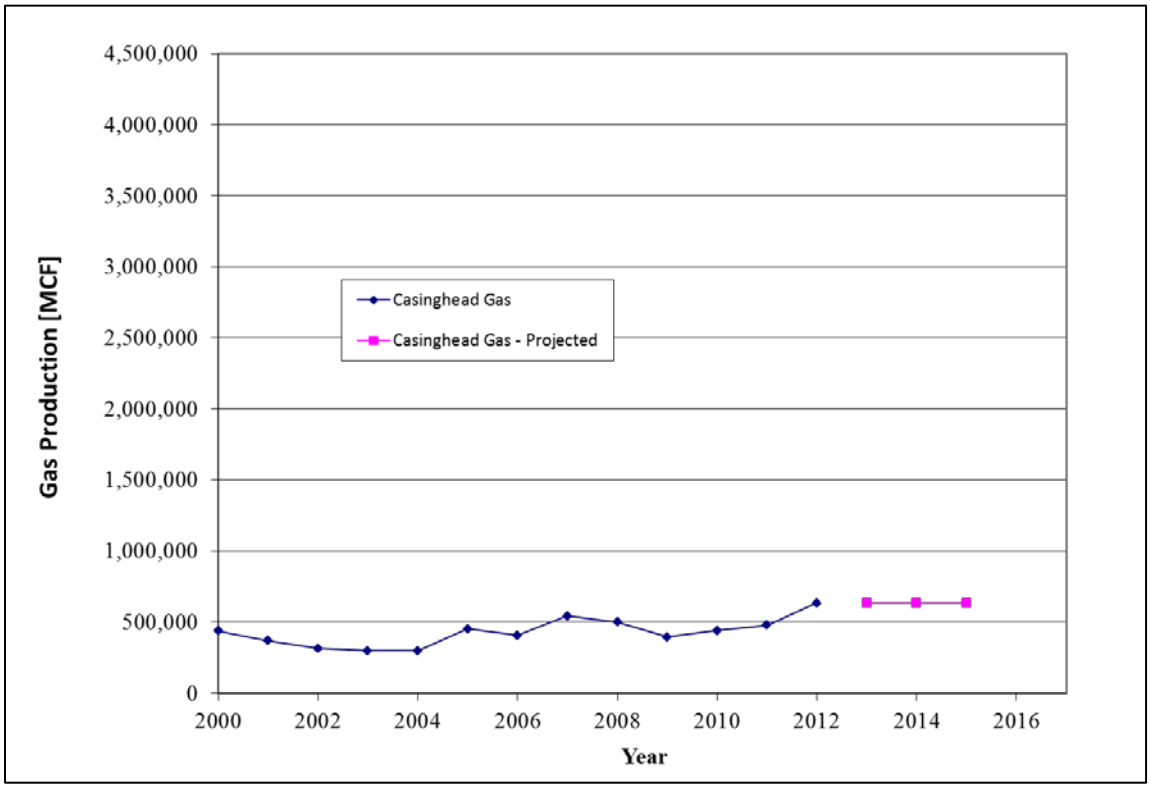

Figure 5-4. Associated gas production historical data (from the IHS database) for Western Great Plains Counties in the Great Plains Basin and projections to 2015. [8]

Associated gas production fluctuates from a minimum of 298 BCF to 634 BCF, annually over the 2000-2012 time period, with periods of both growth and decline. Given the lack of a consistent trend in recent associated gas production in the Western Great Plains Counties, the analysis assumed that the associated gas production would remain at 2012 levels in the period 2013-2015.

Primary Gas Production

Primary gas production (i.e. gas production from gas wells) in the Western Great Plains Counties in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-5, including projections to 2015.

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

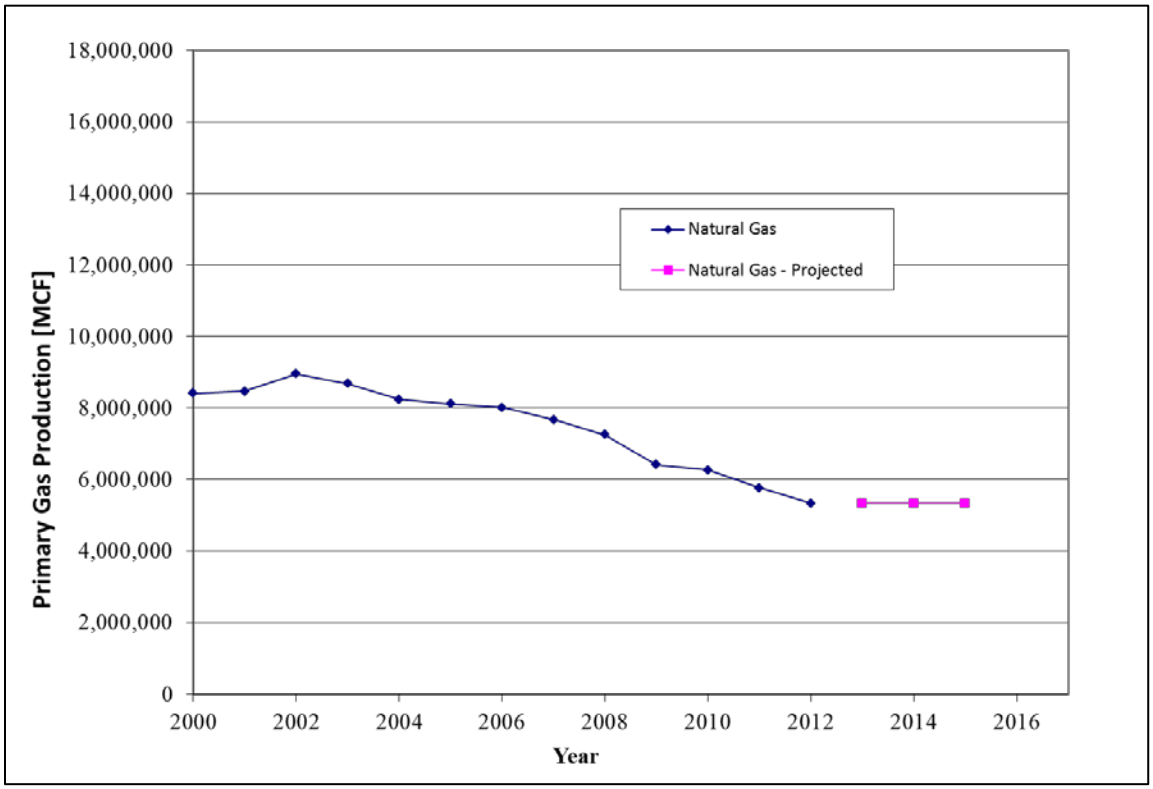

Figure 5-5. Primary gas production historical data (from the IHS database) for Western Great Plains Counties in the Great Plains Basin and projections to 2015. [9]

Primary gas production projections were developed for the period 2013–2015 assuming that the primary gas production remains at 2012 levels. This is conservative considering decreases in primary gas production over the 2002–2012 period.

Oil Well Oil Production

Oil well oil production in the Western Great Plains Counties in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-6, including projections to 2015.

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

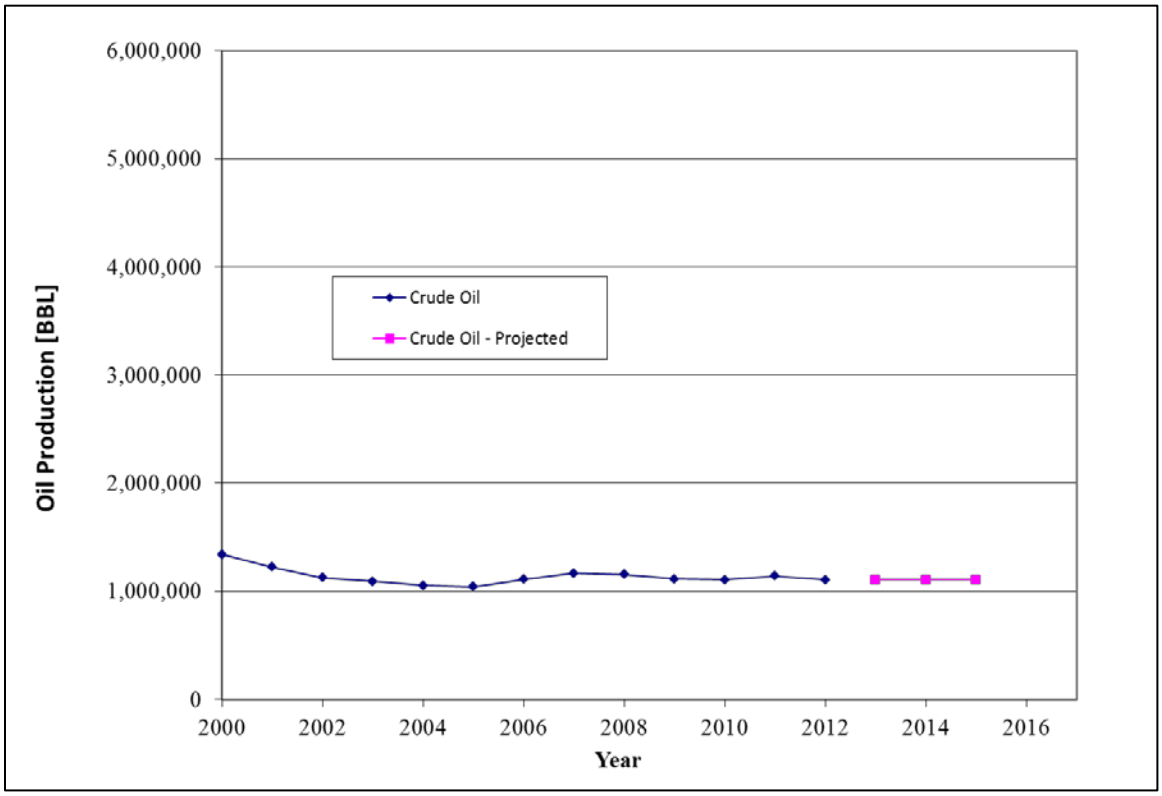

Figure 5-6. Oil production historical data (from the IHS database) for Western Great Plains Counties in the Great Plains Basin and projections to 2015. [10]

Oil production projections were developed for the period 2013–2015 assuming that oil production remains at 2012 levels. This is consistent with relatively flat growth over the 2006-2012 period.

Condensate Production

Condensate production in the Western Great Plains Counties in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-7, including projections to 2015.

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

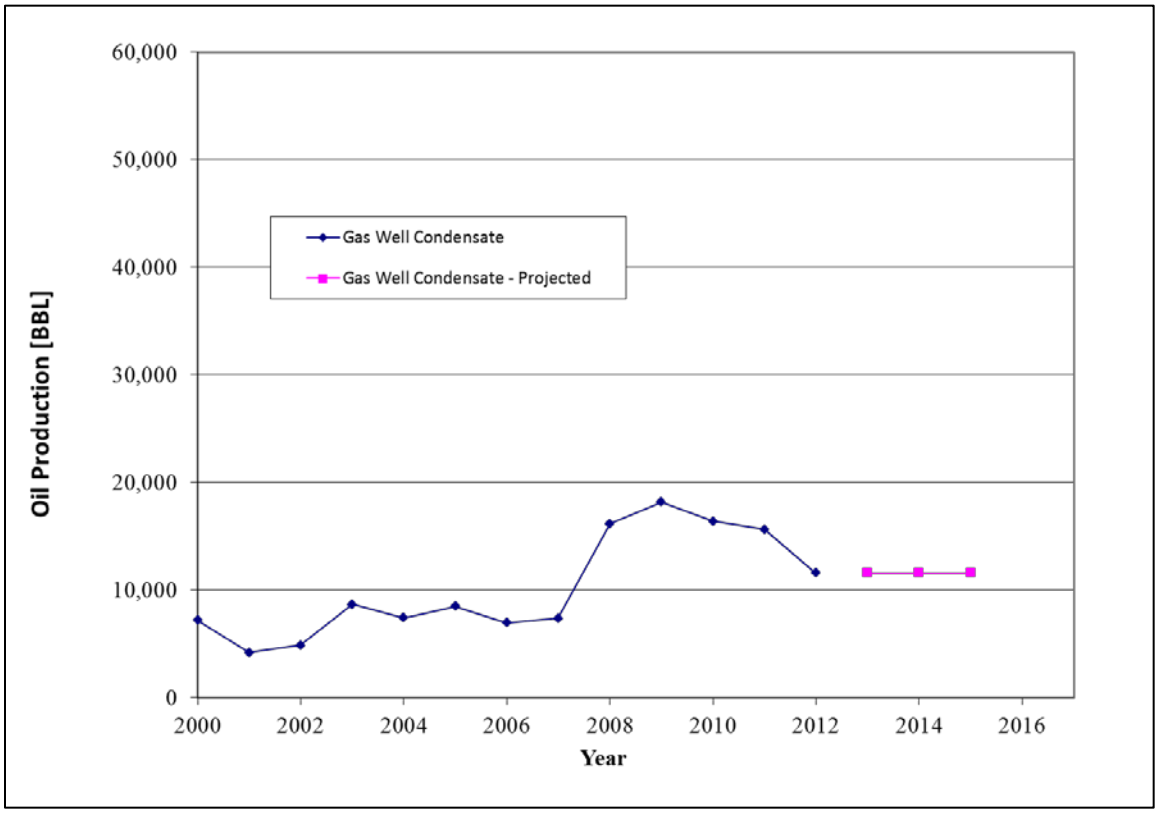

Figure 5-7. Condensate production historical data (from the IHS database) for the Western Great Plains Counties in the Great Plains Basin and projections to 2015. [11]

Condensate production in the Western Great Plains Counties is low relative to primary oil production. Condensate production projections were developed for the period 2013–2015 assuming that condensate production remains at 2012 levels. This is conservative given recent declines over the 2009-2012 period.

5.3.2 Central Great Plains Counties

Oil Well Counts

Oil well counts in the Central Great Plains Counties in the Great Plains Basin have been plotted for the years 2000–2012 below in Figure 5-8, including projections to 2015.

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

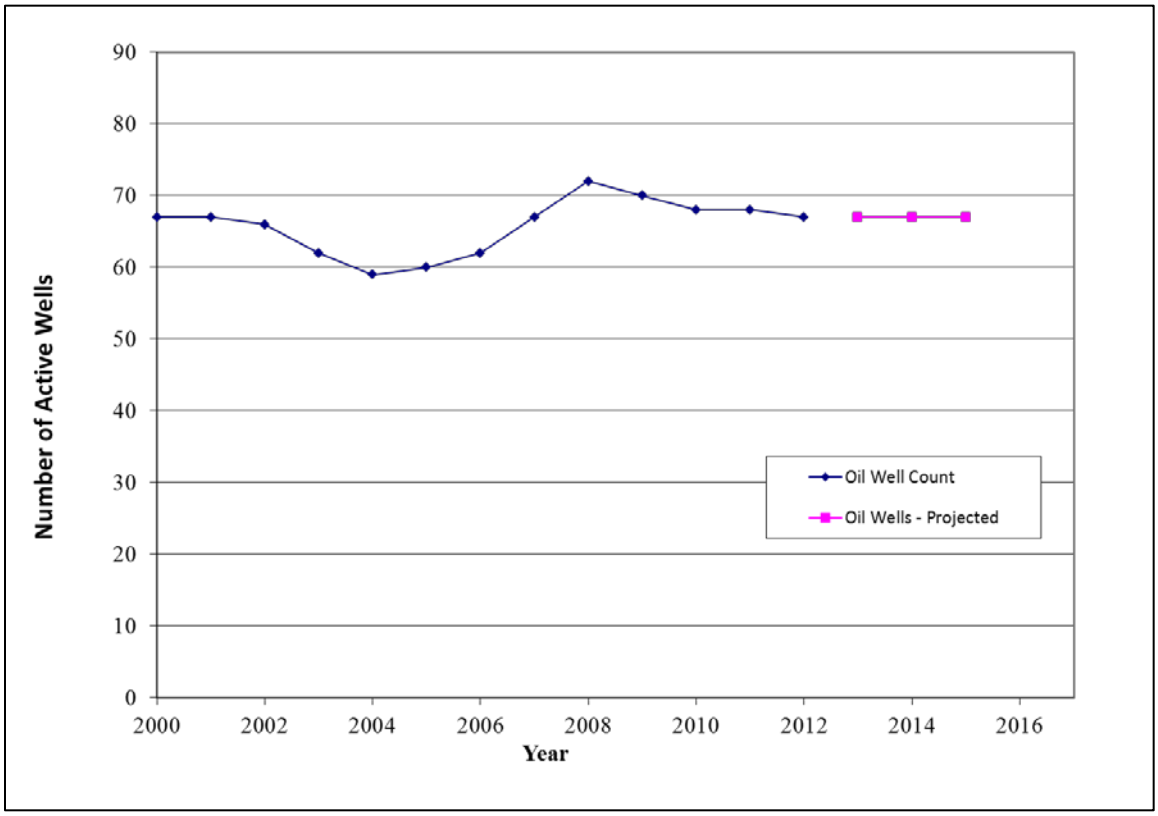

Figure 5-8. Oil well count historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. [12]

Oil well count in the Central Great Plains Counties is low relative to gas well count. Oil well count projections were developed for the period 2013–2015 assuming that oil well count remains at 2012 levels. This is conservative given recent declines over the 2008 to 2012 period.

Gas Well Counts

Gas well counts in the Central Great Plains Counties in the Great Plains Basin have been plotted for the years 2000–2012 below in Figure 5-9, including projections to 2015.

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

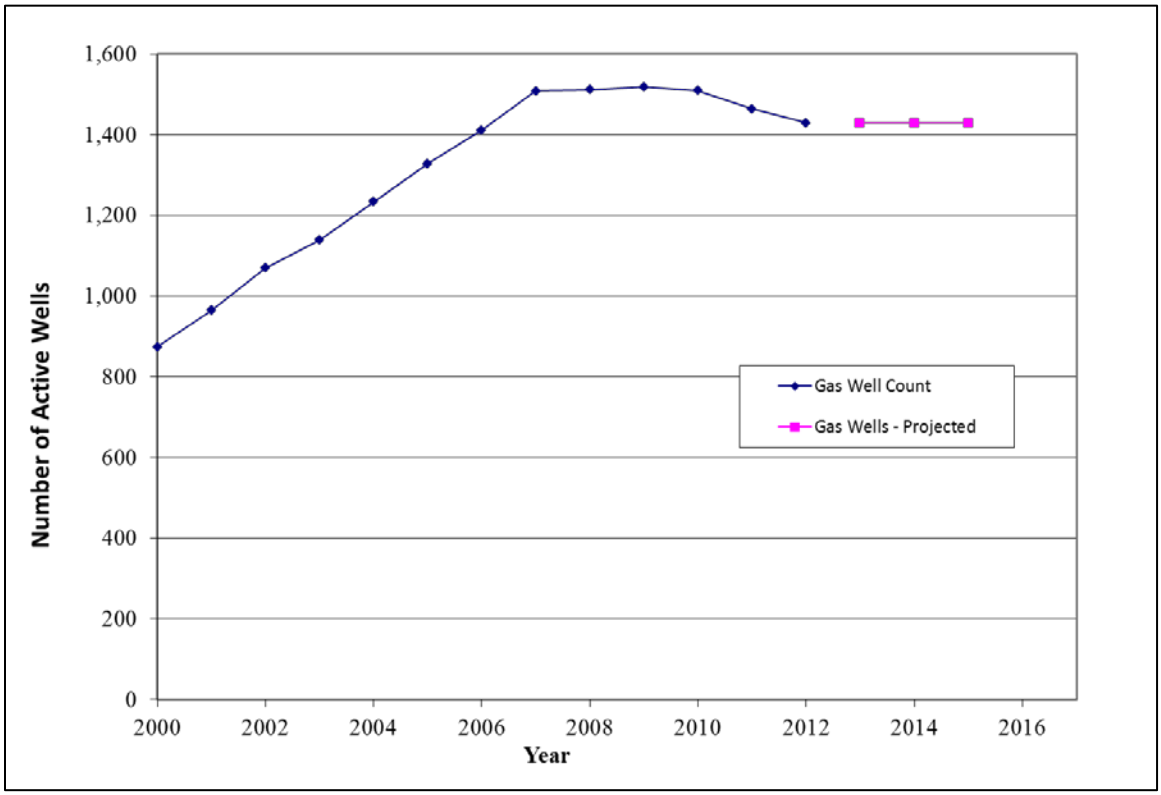

Figure 5-9. Gas well count historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. [13]

Gas well count projections were developed for the period 2013–2015 assuming that gas well count remains at 2012 levels. This is conservative given recent declines over the 2010-2012 period.

Spud Counts

Spud counts in the Central Great Plains Counties in the Great Plains Basin have been plotted for the years 2000–2012 below in Figure 5-10, including projections to 2015. Spud counts by oil versus gas wells were estimated from IHS total spuds based on the number of oil and gas wells in each calendar year.

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

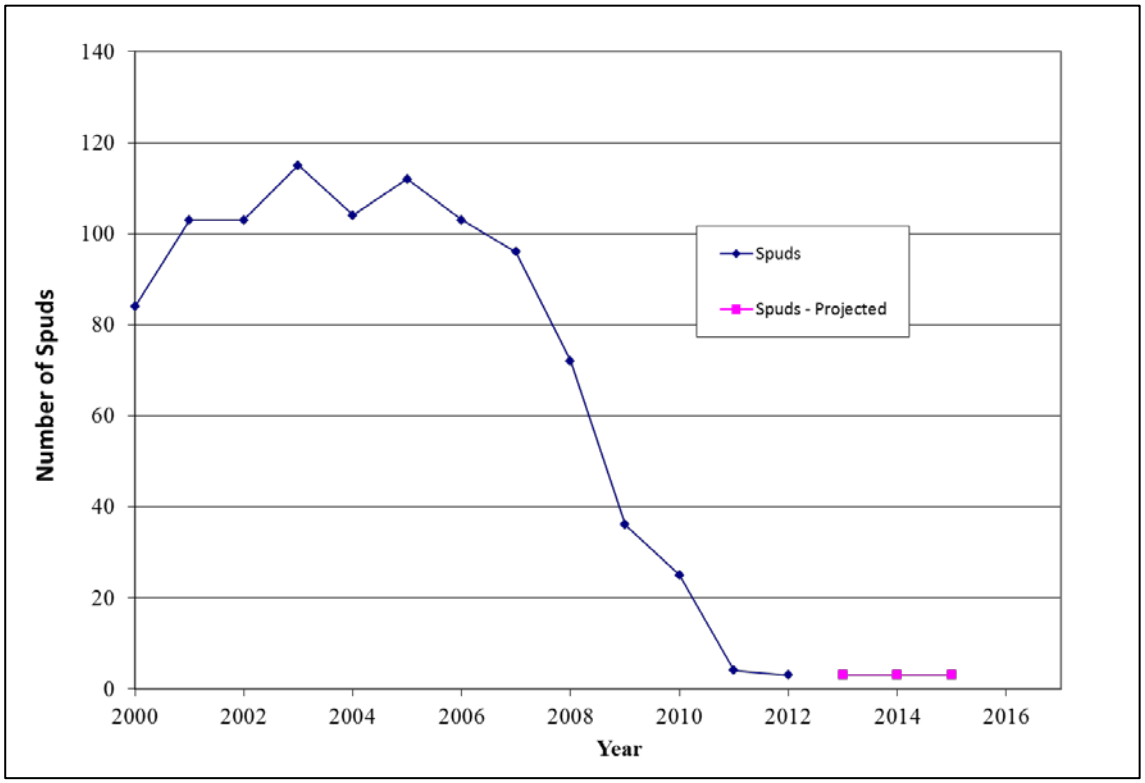

Figure 5-10. Spud count historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. [14]

Historic spud counts in the Central Great Plains Counties, as obtained from the IHS database for the period 2000-2012 show significant decreases over the 2005-2011 time period, with relatively flat growth from 2011-2012. Consistent with active oil and gas well count projections, it was assumed that future spud counts would remain at 2012 levels in the future.

Associated Gas Production

Associated gas production in the Central Great Plains Counties in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-11, including projections to 2015.

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

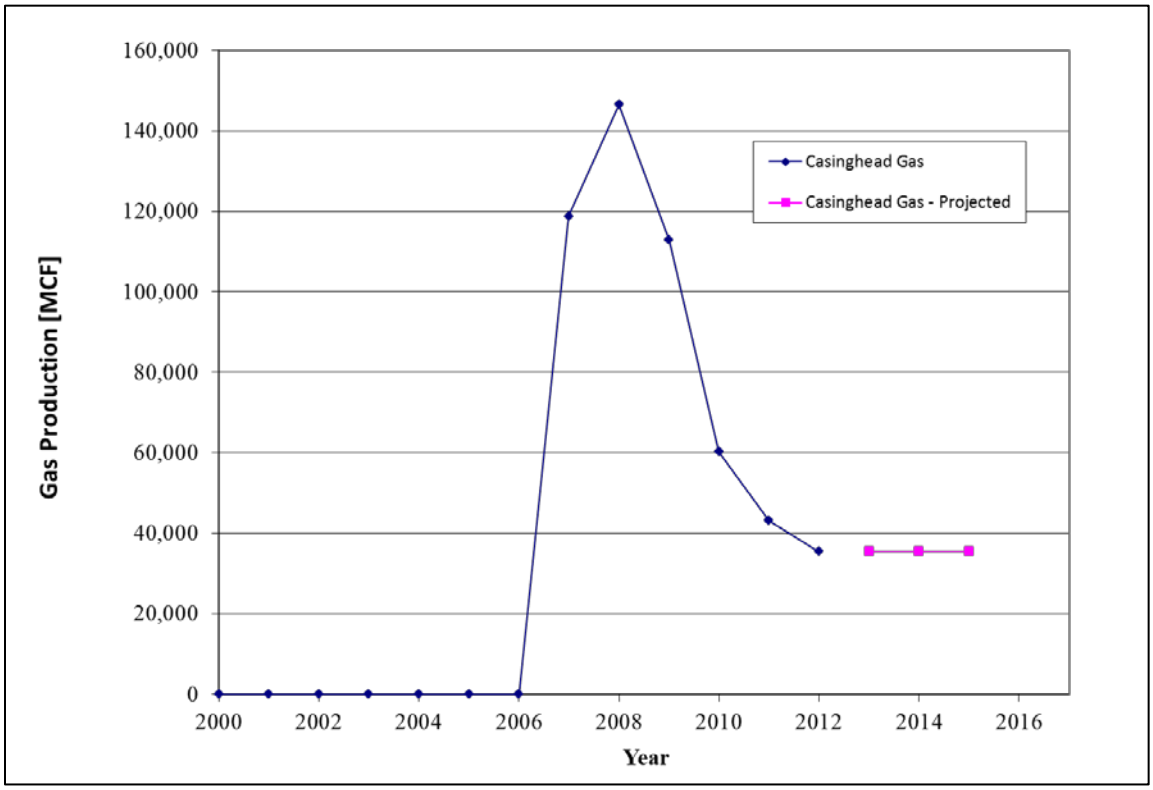

Figure 5-11. Associated gas production historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. [15]

Associated gas production in the Central Great Plains Counties is low relative to primary gas production. Associated gas production projections were developed for the period 2013–2015 assuming that associated gas production remains at 2012 levels. This is conservative given recent declines over the 2008 to 2012 period.

Primary Gas Production

Primary gas production in the Central Great Plains Counties in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-12, including projections to 2015.

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

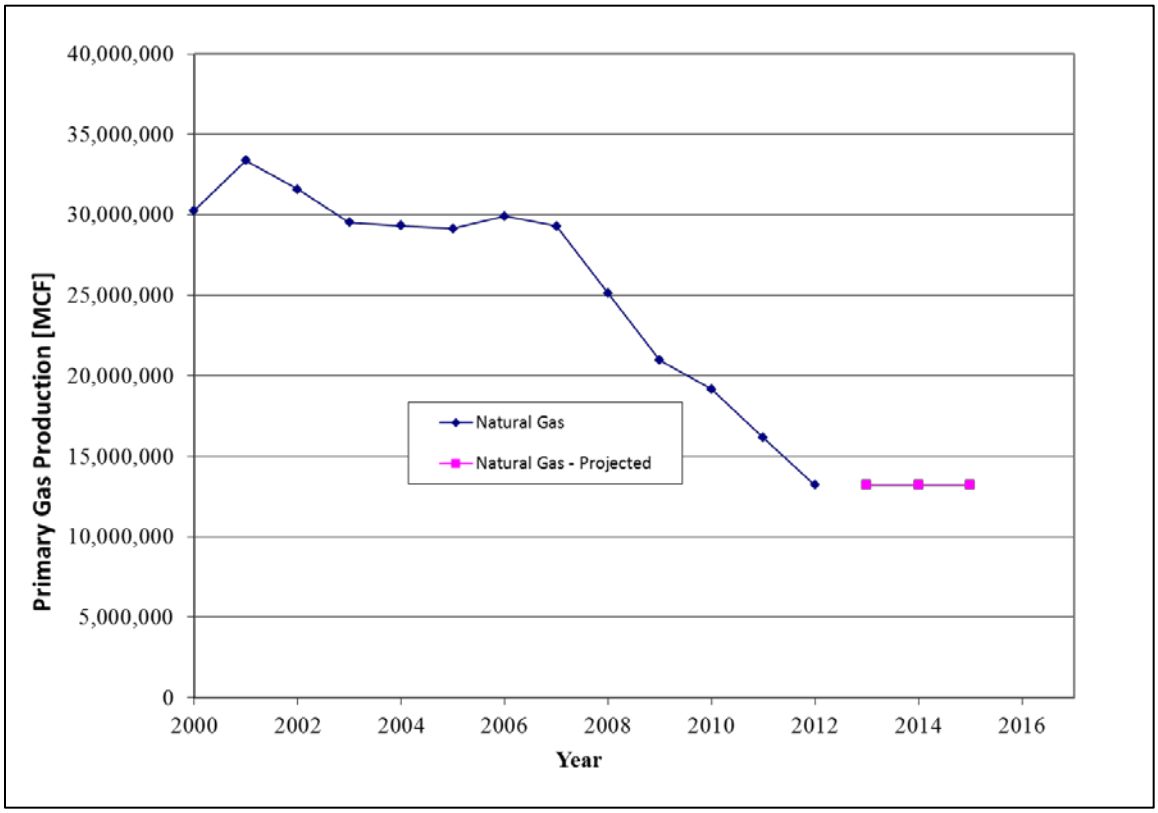

Figure 5-12. Primary gas production historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. [16]

Primary gas production projections were developed for the period 2013–2015 assuming that primary gas production remains at 2012 levels. This is conservative given recent declines over the 2007 to 2012 period.

Oil Well Oil Production

Oil well oil production in the Central Great Plains Counties in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-13, including projections to 2015.

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

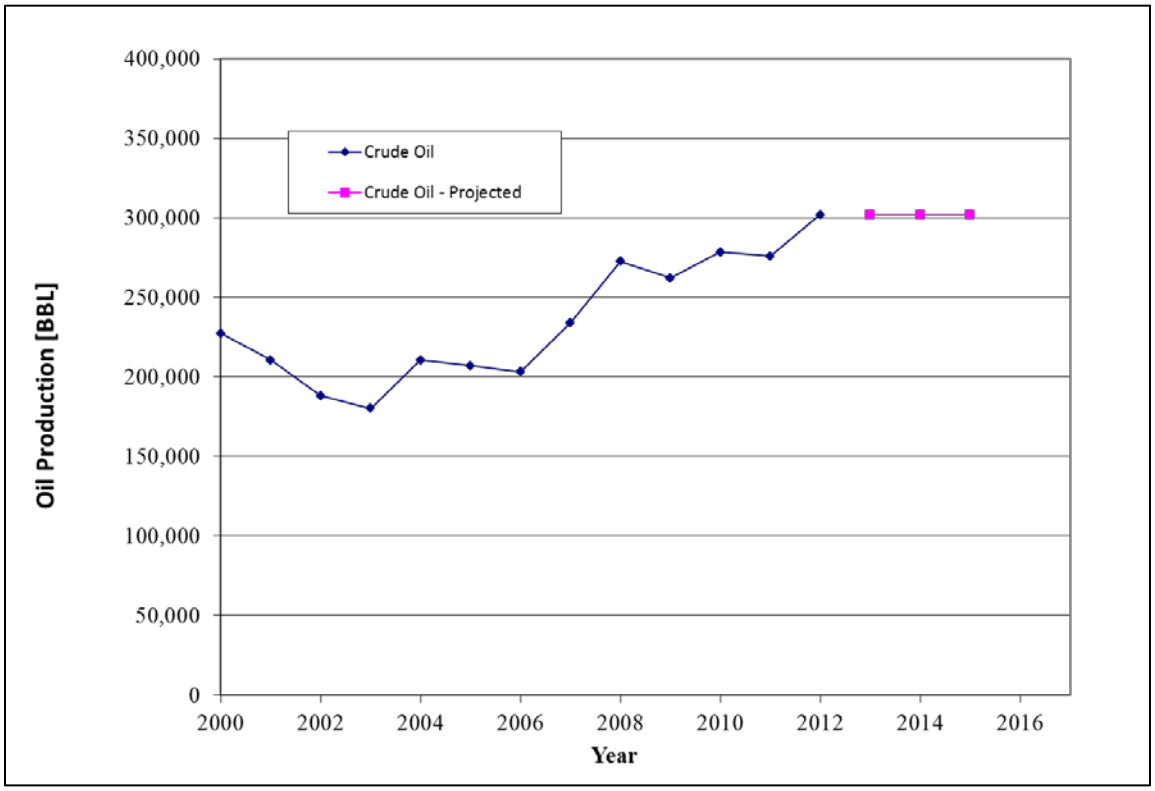

Figure 5-13. Oil production historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. [17]

Oil production in the Central Great Plains Counties in the Great Plains Basin from 2000-2012 show periods of growth and decline. Lacking consistent trends in oil production, it was assumed that oil production would remain at 2012 levels in the period 2013-2015.

Condensate Production

Condensate production in the Central Great Plains Counties in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-14, including projections to 2015.

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

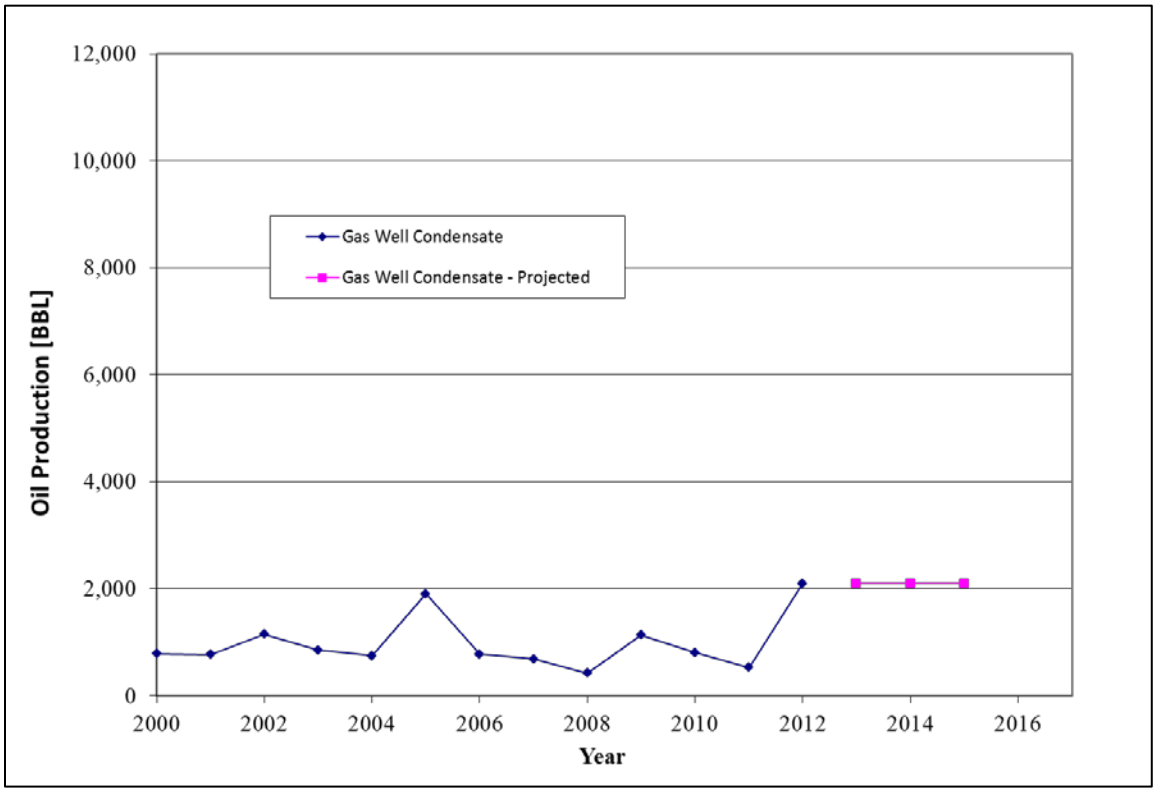

Figure 5-14. Condensate production historical data (from the IHS database) for Central Great Plains Counties in the Great Plains Basin and projections to 2015. [18]

Condensate production is very low in the Central Great Plains Counties. This analysis assumed that condensate production would remain at 2012 levels in the period 2013-2015.

5.3.3 Phillips County

Oil Well Counts

Oil well counts in Phillips County in the Great Plains Basin have been plotted for the years 2000–2012 below in Figure 5-15, including projections to 2015.

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

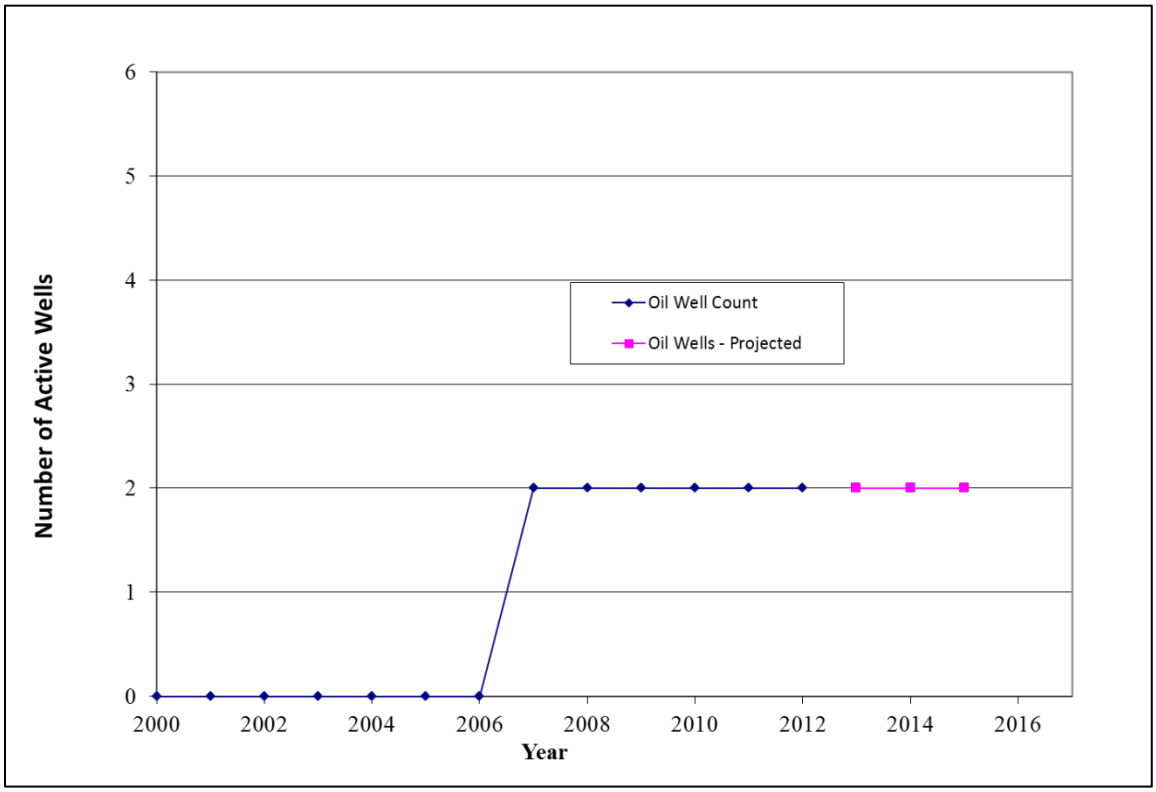

Figure 5-15. Oil well count historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. [19]

Active oil well counts in Phillips County are very low. This analysis assumed that 2012 active oil well counts would remain constant in the period 2013-2015.

Gas Well Counts

Gas well counts in Phillips County in the Great Plains Basin have been plotted for the years 2000–2012 below in Figure 5-16, including projections to 2015.

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

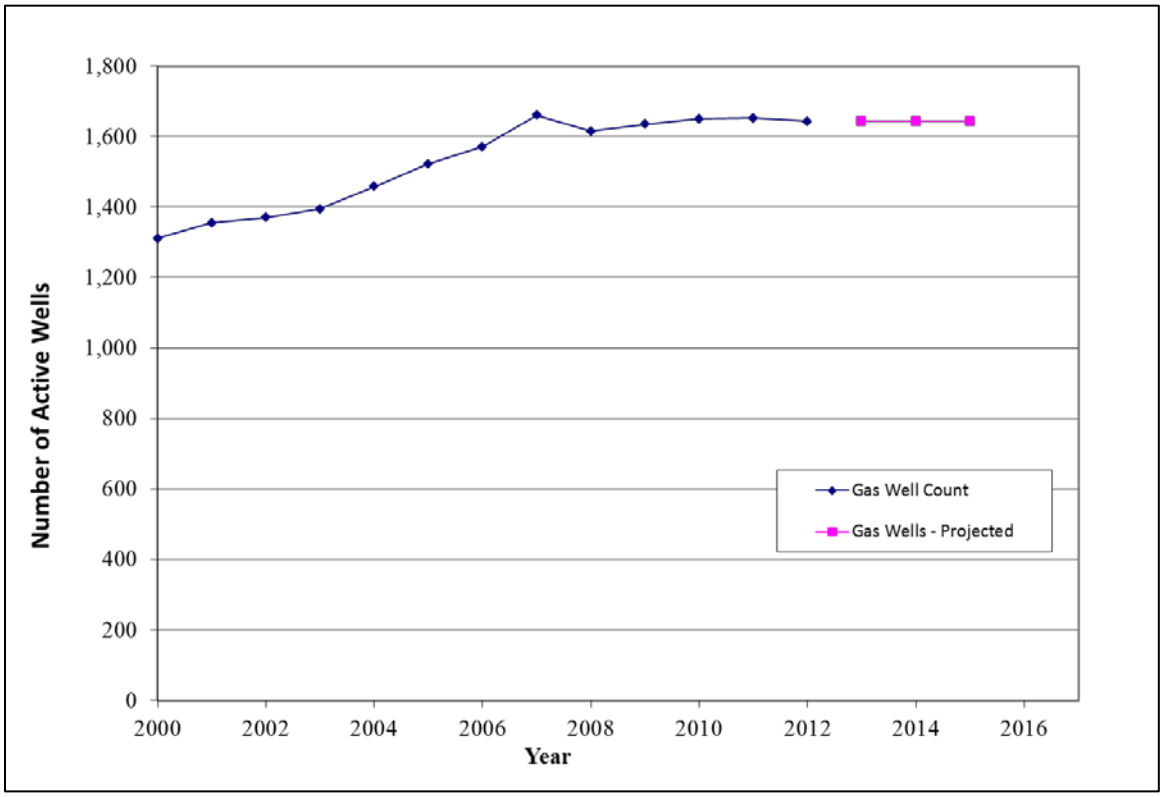

Figure 5-16. Gas well count historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. [20]

Active gas well counts in Phillips County show relatively steady increases from 2000-2007 and relatively flat growth over the 2008-2012 period. Consistent with the flat growth in the 2008–2012 period, this analysis assumed that 2012 active gas well counts would remain constant in the period 2013-2015.

Spud Counts

Spud counts in Phillips County in the Great Plains Basin have been plotted for the years 2000–2012 below in Figure 5-17, including projections to 2015. Spud counts by oil versus gas wells were estimated from IHS total spuds based on the number of oil and gas wells in each calendar year.

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

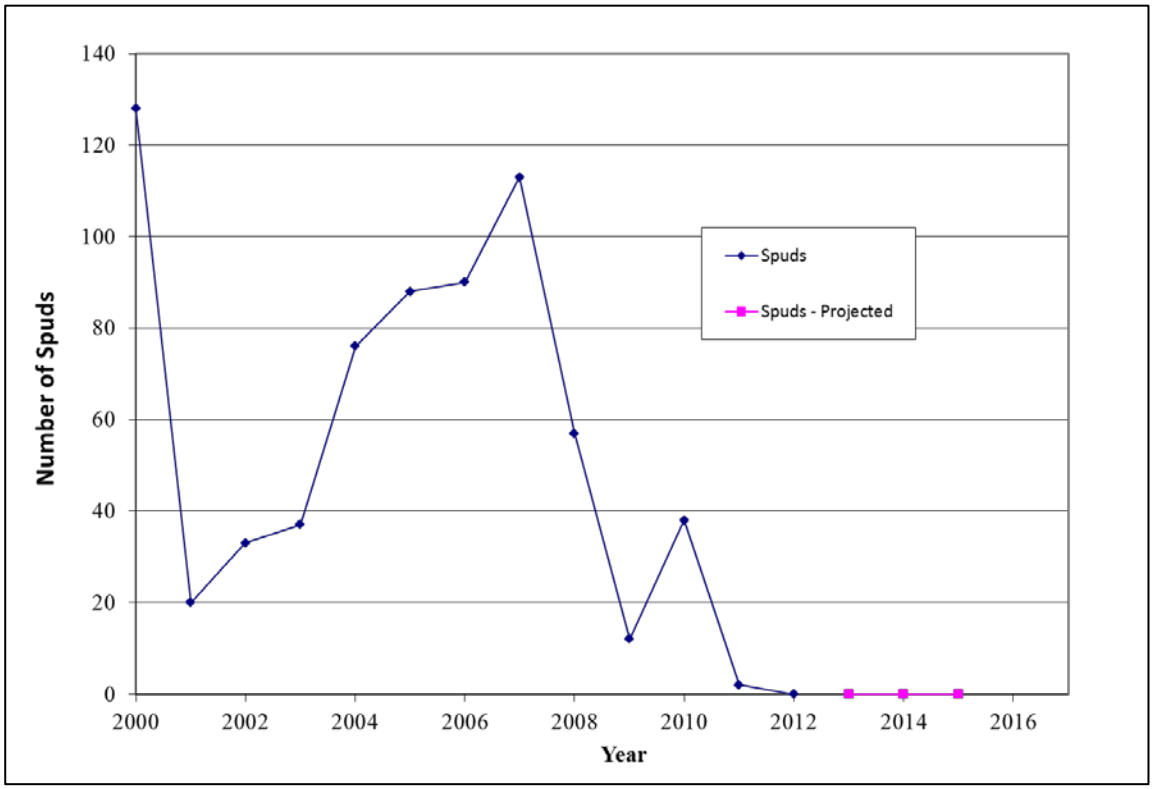

Figure 5-17. Oil Well spud count historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. [21]

Historic oil well and gas well spud counts in Phillips County, as obtained from the IHS database for the period 2000-2012 are erratic, making an extrapolation from historical data infeasible. Consistent with active oil and gas well count projections, it was assumed that future spud counts would remain at 2012 levels in the future.

Associated Gas Production

Associated gas production in Phillips County in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-18, including projections to 2015.

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

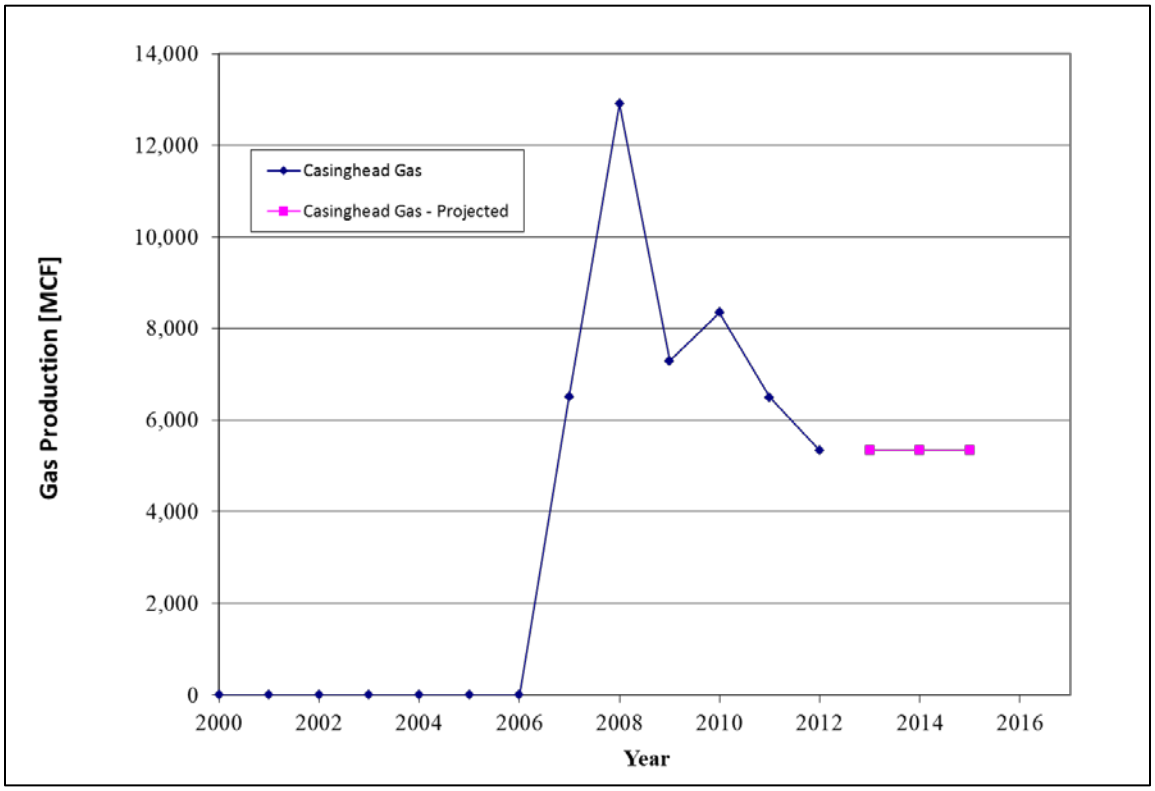

Figure 5-18. Associated gas production historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. [22]

Associated gas production in Phillips County is very low. This analysis assumed that 2012 associated gas production would remain constant in the period 2013-2015.

Primary Gas Production

Primary gas production in Phillips County in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-19, including projections to 2015.

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

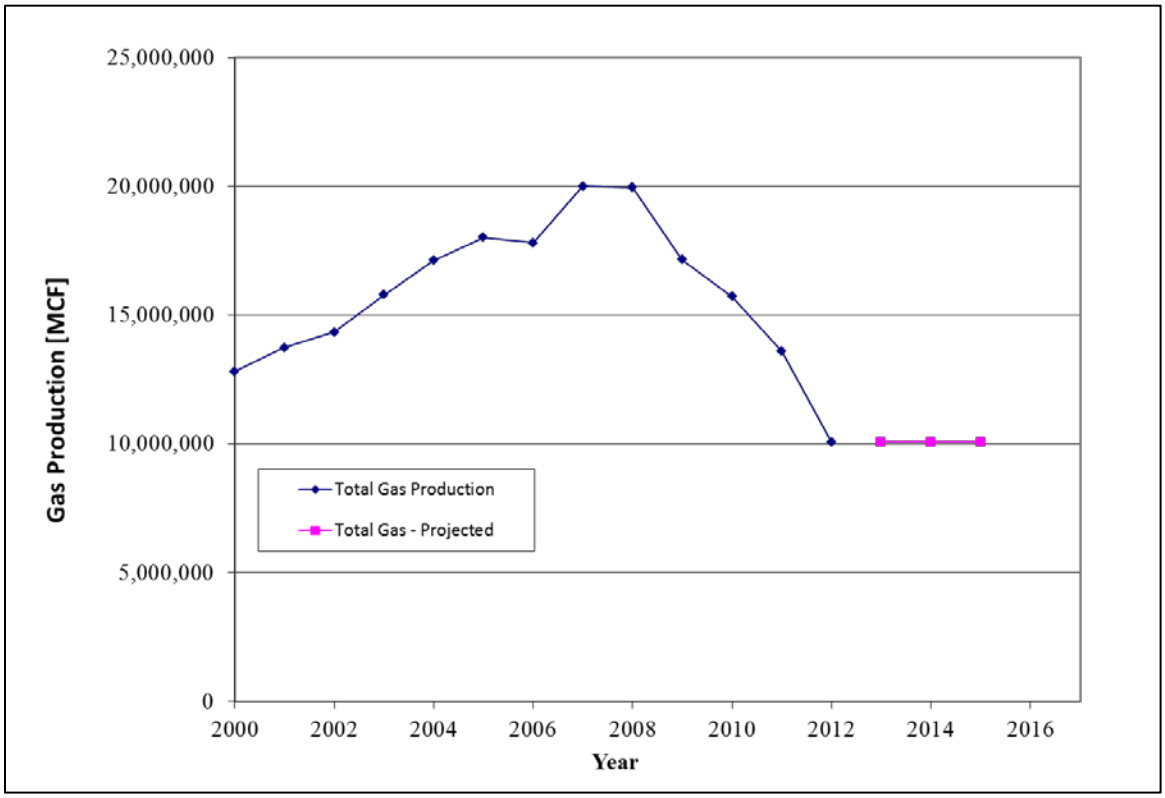

Figure 5-19. Primary gas production historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. [23]

Primary gas production in Phillips County was generally increasing during the 2000–2007 historical period. Data from 2008–2012 show a declining trend in primary gas production, and therefore this analysis conservatively assumed that primary gas production would remain at 2012 levels through the period 2013-2015.

Oil Well Oil Production

Oil well oil production in Phillips County in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-20, including projections to 2015.

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

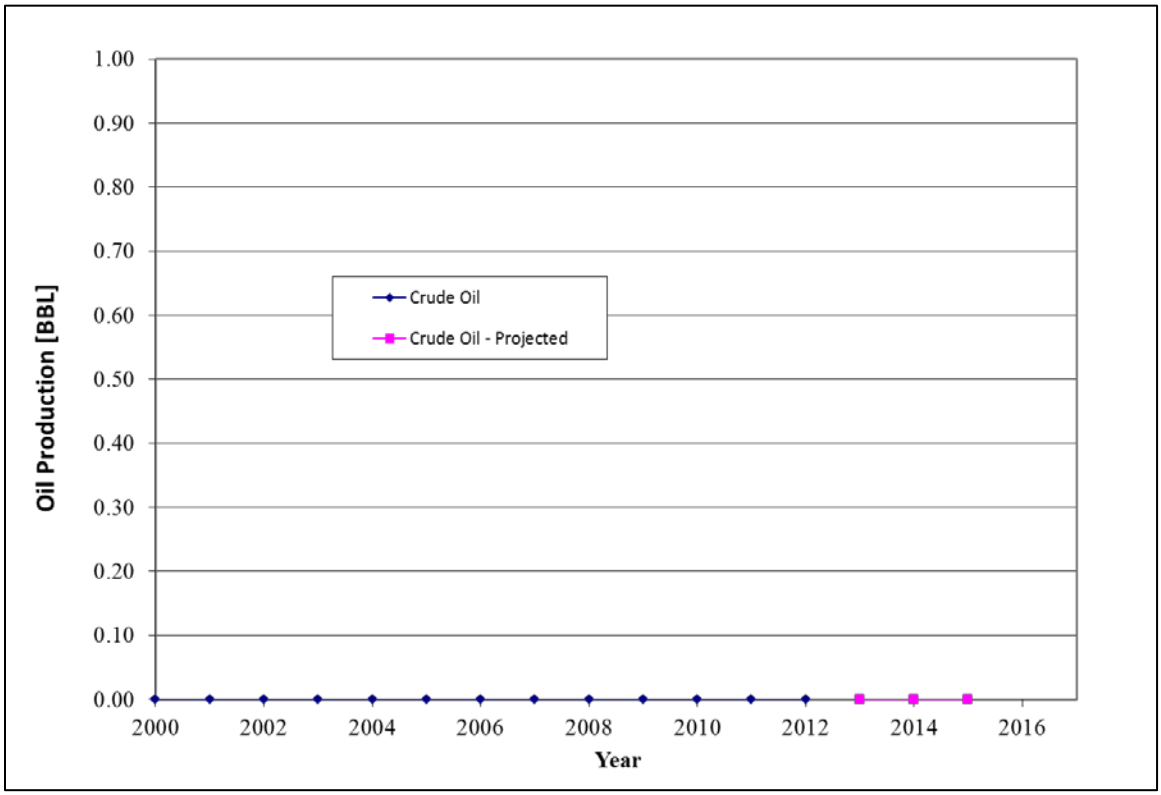

Figure 5-20. Oil production historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. [24]

Oil production in Phillips County is negligible. This analysis assumed that 2012 oil production would remain constant in the period 2013-2015.

Condensate Production

Condensate production in Phillips County in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-21, including projections to 2015.

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

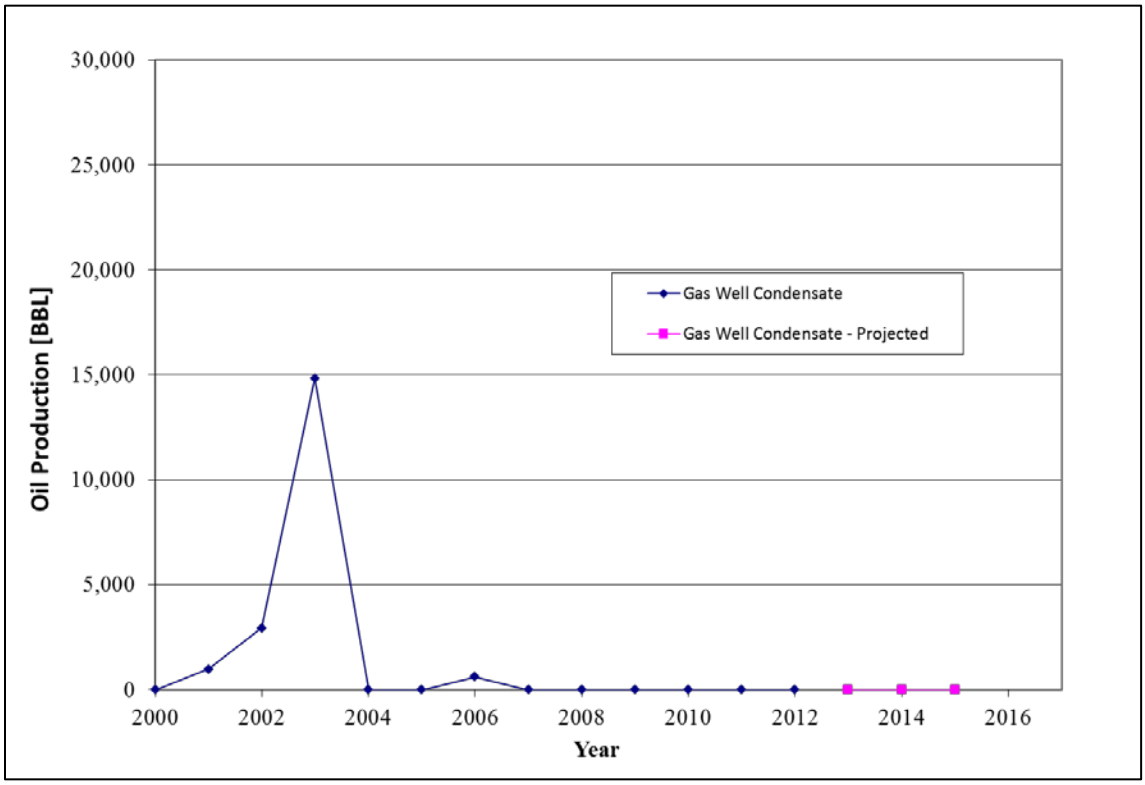

Figure 5-21. Condensate production historical data (from the IHS database) for Phillips County in the Great Plains Basin and projections to 2015. [25]

Condensate production in Phillips County is negligible. This analysis assumed that 2012 condensate production would remain constant in the period 2013-2015.

5.3.4 Other Counties

Oil Well Counts

Oil well counts in the "Other Counties" grouping in the Great Plains Basin have been plotted for the years 2000–2012 below in Figure 5-22, including projections to 2015.

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

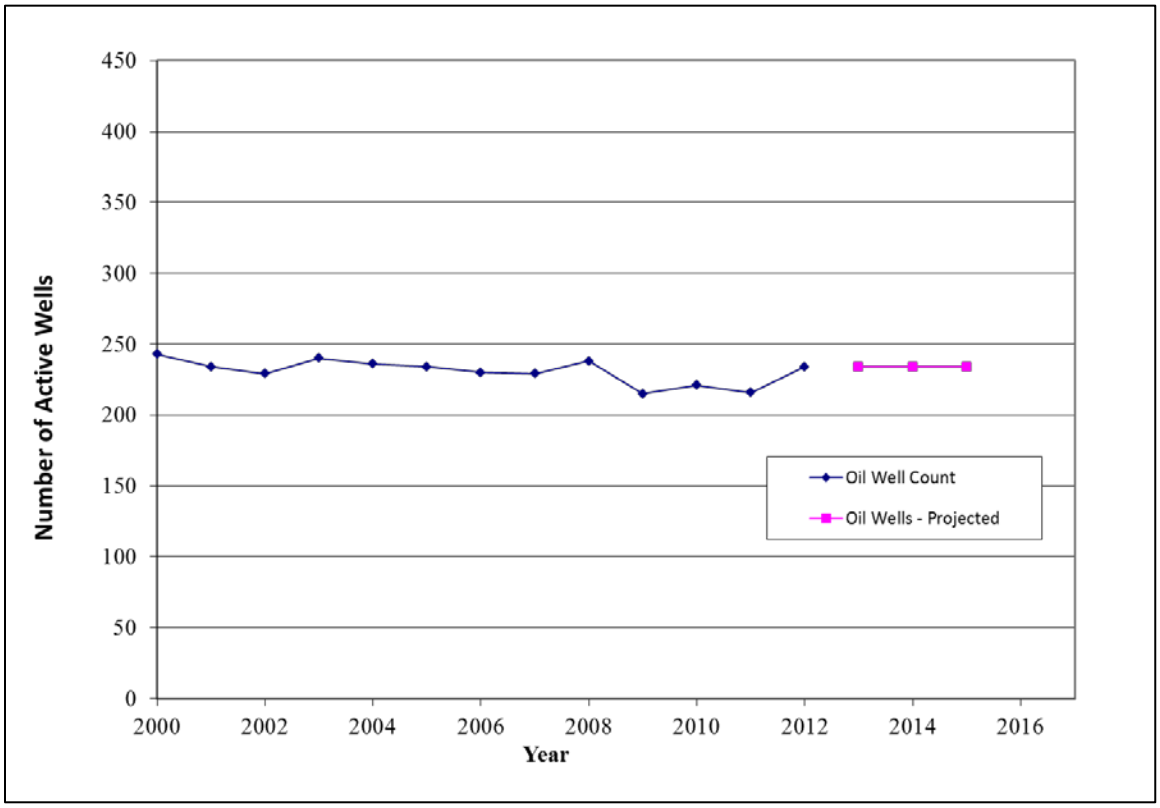

Figure 5-22. Oil well count historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. [26]

Oil well counts in the "Other Counties" grouping show relatively flat growth over the 2000-2012 period. This analysis assumed that oil well count would remain at 2012 levels in the period 2013-2015.

Gas Well Counts

Gas well counts in the "Other Counties" grouping in the Great Plains Basin have been plotted for the years 2000–2012 below in Figure 5-23, including projections to 2015.

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

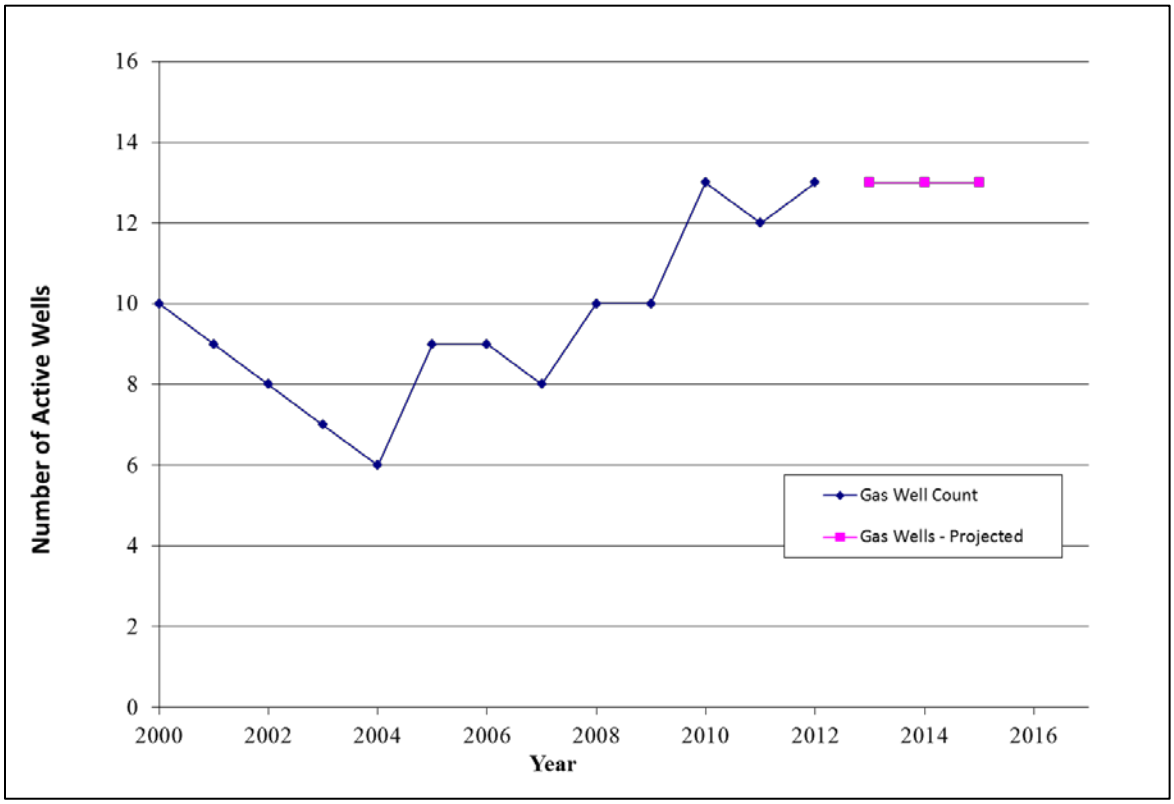

Figure 5-23. Gas well count historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. [27]

Gas well counts in the "Other Counties" grouping are small. This analysis assumed that gas well count would remain at 2012 levels in the period 2013-2015.

Spud Counts

Spud counts in the "Other Counties" grouping in the Great Plains Basin have been plotted for the years 2000–2012 below in Figure 5-24, including projections to 2015.

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

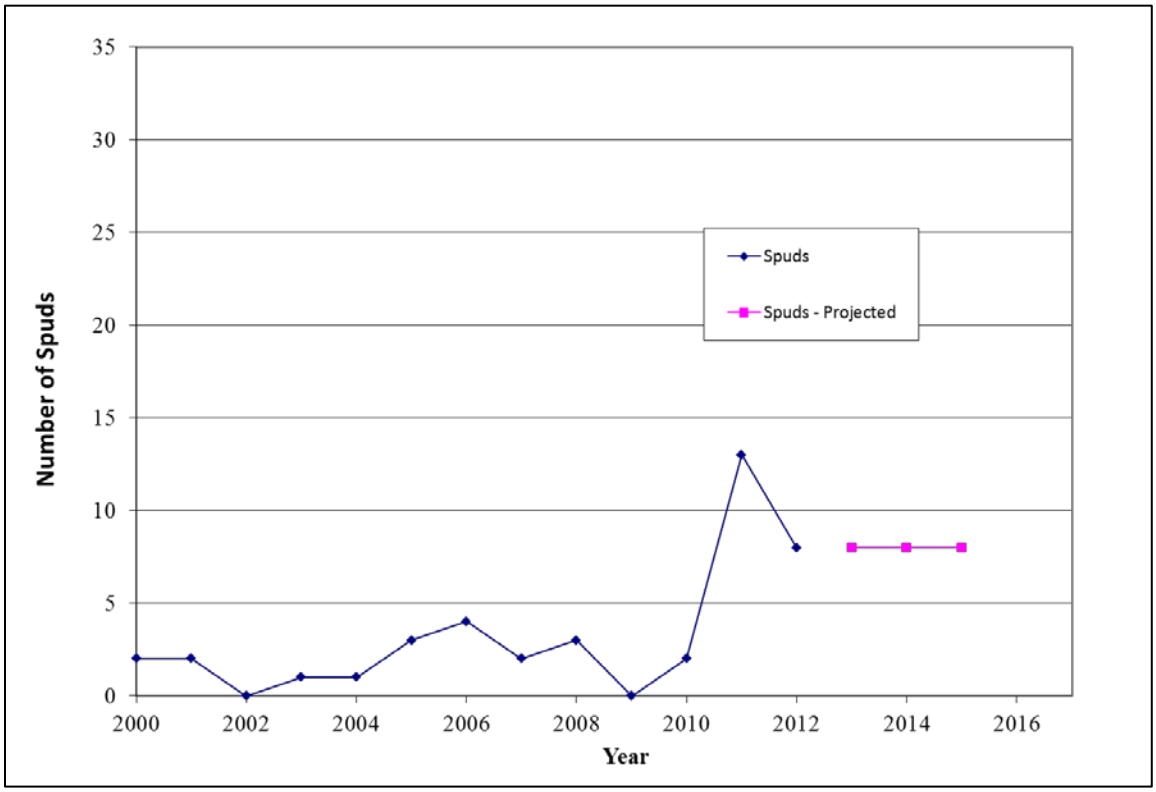

Figure 5-24. Spud count historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. [28]

Historic spud counts in the "Other Counties" grouping, as obtained from the IHS database for the period 2000-2012 range from zero spuds to 13 spuds. This analysis assumed that the spud count would remain at 2012 levels in the period 2013-2015.

Associated Gas Production

Associated gas production in the "Other Counties" grouping in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-25, including projections to 2015.

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

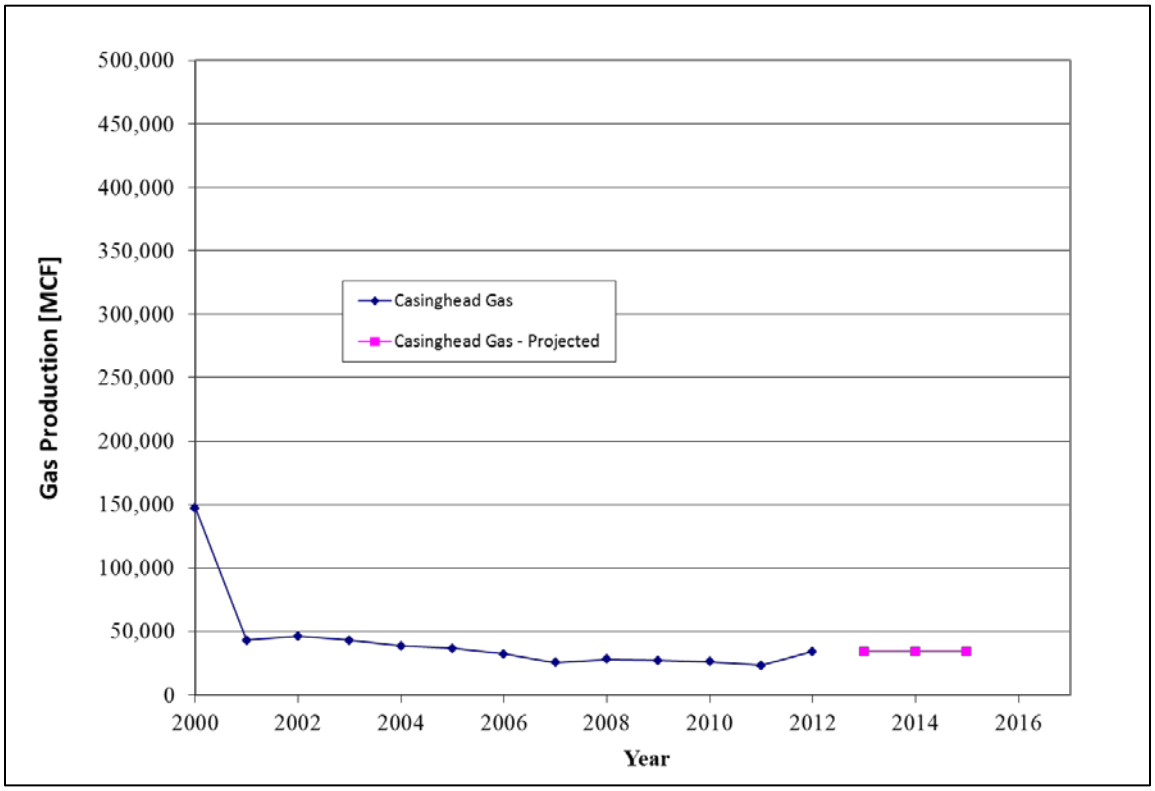

Figure 5-25. Associated gas production historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. [29]

Associated gas production in the "Other Counties" grouping has been relatively constant over the 2001-2012 period. This analysis assumed that associated gas production would remain at 2012 levels in the period 2013-2015.

Primary Gas Production

Primary gas production in the "Other Counties" grouping in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-26, including projections to 2015.

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

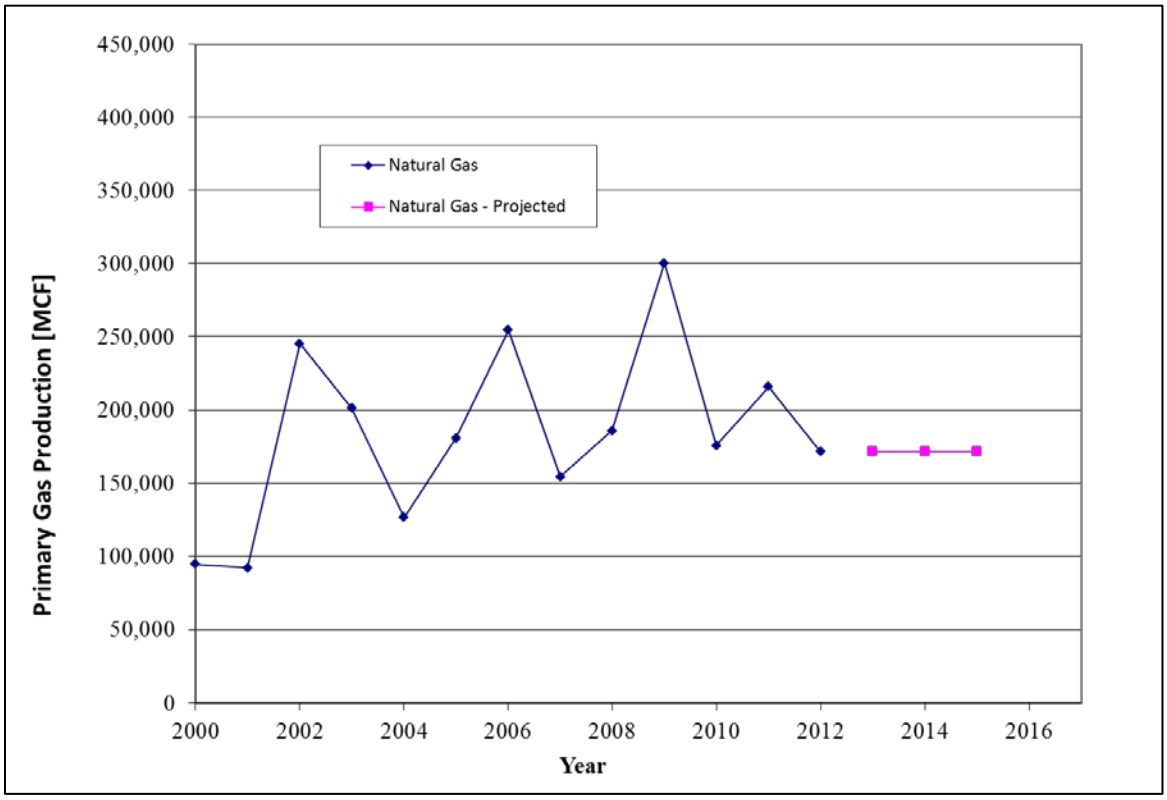

Figure 5-26. Primary gas production historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. [30]

Primary gas production in the "Other Counties" grouping shows erratic fluctuations in production over the 2000 to 2012 period. This analysis assumed that primary gas production would remain at 2012 levels through the period 2013-2015.

Oil Well Oil Production

Oil well oil production in the "Other Counties" grouping in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-27, including projections to 2015.

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

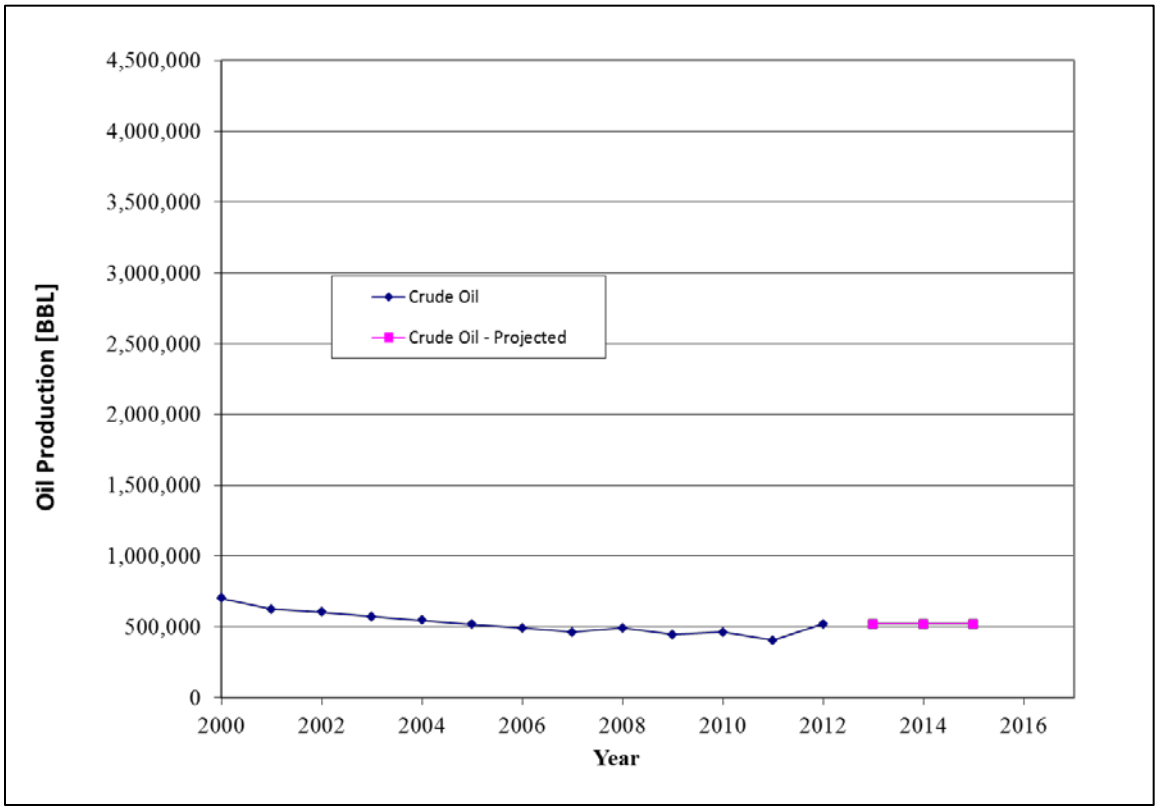

Figure 5-27. Oil production historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. [31]

Oil production in the "Other Counties" grouping shows a relatively consistent decline over the period 2000-2007, with relatively flat growth from 2007-2012. This analysis assumed that oil production would remain at 2012 levels through the period 2013-2015.

Condensate Production

Condensate production in the "Other Counties" grouping in the Great Plains Basin has been plotted for the years 2000–2012 below in Figure 5-28, including projections to 2015.

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

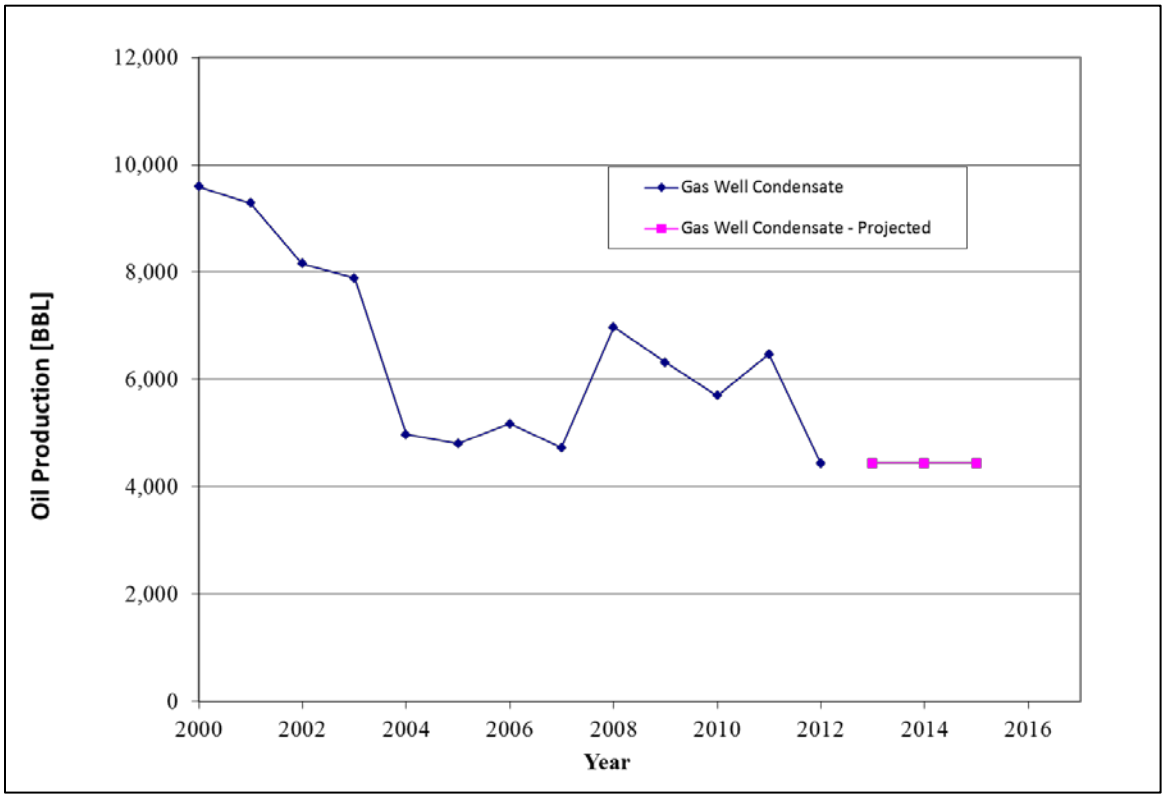

Figure 5-28. Condensate production historical data (from the IHS database) for Other Counties in the Great Plains Basin and projections to 2015. [32]

Condensate production in the "Other Counties" grouping is small relative to oil production. This analysis assumed that condensate production would remain at 2012 levels through the period 2013-2015.

5.4 Scaling Factor Development and Uncontrolled 2015 Emissions

Scaling factors were generated for the Great Plains Basin geographic groupings described above, for each parameter considered here:

- Well counts by type (gas, oil, total)
- Spud counts by type (gas, oil, total)
- Gas production by type (primary, associated, total)
- Liquid hydrocrabon production by type (oil production from oil wells, condensate, total)

It is noted that all geographic groupings (except Phillips County) are comprised of more than one county in which the scaling factors for each parameter are identical for all counties in the grouping. The ratio of the value of each of these parameters in 2015 to their values in 2011 is

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the scaling factor for that parameter for purposes of this projection. This is shown in Equation 43 below:

$$f_{i,j} = W_{i,j,2015} / W_{i,j,2011} \qquad \text{(Equation 43)}$$

where:

$f_{i,j}$ is the scaling factor for geographic grouping *j* in the Great Plains Basin for parameter *i* (oil or gas well count, spud count, associated or primary gas production, oil well oil production, and condensate production)

$W_{i,j,2011}$ is the value of parameter *i* in geographic grouping *j* in 2011

$W_{i,j,2015}$ is the projected value of parameter *i* in geographic grouping *j* in 2015

The scaling factor based on the appropriate parameter is selected for each source category as described in Table 5-1. The scaling factors for the eight parameters used in this analysis for each county in the Great Plains Basin are presented in Table 5-2 below.

Table 5-2. Scaling factors for parameters used in the projection analysis for all counties in the Great Plains Basin.

County	Well Counts			Spuds			Gas Production			Liquid Hydrocarbon Production		
	Oil Wells	Gas Wells	Total	Oil Wells	Gas Wells	Total	Associated Gas	Primary Gas	Total	Oil	Con-densate	Total
Blaine, MT	0.985	0.976	0.977	0.750	0.750	0.750	0.822	0.817	0.817	1.094	3.989	1.099
Cascade, MT	1.083	1.083	1.083	0.615	0.000	0.615	1.472	0.795	0.861	1.282	0.686	1.272
Chouteau, MT	0.985	0.976	0.977	0.750	0.750	0.750	0.822	0.817	0.817	1.094	3.989	1.099
Fergus, MT	1.083	1.083	1.083	0.615	0.000	0.615	1.472	0.795	0.861	1.282	0.686	1.272
Glacier, MT	1.004	0.981	0.995	0.364	0.364	0.364	1.327	0.925	0.955	0.969	0.741	0.966
Golden Valley, MT	1.083	1.083	1.083	0.615	0.000	0.615	1.472	0.795	0.861	1.282	0.686	1.272
Hill, MT	0.985	0.976	0.977	0.750	0.750	0.750	0.822	0.817	0.817	1.094	3.989	1.099
Liberty, MT	1.004	0.981	0.995	0.364	0.364	0.364	1.327	0.925	0.955	0.969	0.741	0.966
Musselshell, MT	1.083	1.083	1.083	0.615	0.000	0.615	1.472	0.795	0.861	1.282	0.686	1.272
Petroleum, MT	1.083	1.083	1.083	0.615	0.000	0.615	1.472	0.795	0.861	1.282	0.686	1.272
Phillips, MT	1.000	0.995	0.995	1.000	1.000	1.000	0.823	0.741	0.741	1.000	1.000	1.000
Pondera, MT	1.004	0.981	0.995	0.364	0.364	0.364	1.327	0.925	0.955	0.969	0.741	0.966
Rosebud, MT	1.083	1.083	1.083	0.615	0.000	0.615	1.472	0.795	0.861	1.282	0.686	1.272
Teton, MT	1.083	1.083	1.083	0.615	0.000	0.615	1.472	0.795	0.861	1.282	0.686	1.272
Toole, MT	1.004	0.981	0.995	0.364	0.364	0.364	1.327	0.925	0.955	0.969	0.741	0.966
Yellowstone, MT	1.083	1.083	1.083	0.615	0.000	0.615	1.472	0.795	0.861	1.282	0.686	1.272

5.5 Controlled 2015 Emissions

This methodology considered any "on-the-books" federal or state regulations that would affect the uncontrolled 2015 emissions projections described above. Table 5-3 below lists the "on-the-books" federal and state regulations that affect emissions source categories in the oil and gas industry, and the action taken to adjust the 2015 emissions inventory appropriately. In cases where an emissions source is regulated by both federal and state regulations, the more stringent of either the federal or state regulation was implemented. A more detailed description follows of the methodology used to address each of these regulations as they affected the uncontrolled 2015 Great Plains Basin emissions projections. The uncontrolled 2015 emissions were adjusted based on the proposed actions or control factors developed for each regulation described in Table 5-3 to account for how these regulations may affect any oil and gas source category considered in this inventory.

Table 5-3. Summary of federal and state "on-the-books" regulations affecting the oil and gas source categories considered in this inventory.

Source Category	Regulation	Enforcing Agency	Effective Date	Implementation in the 2015 Great Plains Basin Emissions Projections
Federal				
Drill Rig, Fracing Engines Workover Rigs	Nonroad engine Tier standards (1-4) (EPA, 2005)	US EPA	Phase in from 1996 - 2014	EPA NONROAD model used to create county-level control factors for the drill rig SCC to account for fleet turnover.
Drill Rig, Fracing Engines Workover Rigs	Nonroad diesel fuel sulfur standards (EPA, 2006)	US EPA	Phase in beginning in 2010	Assume 11 ppm sulfur in nonroad diesel fuel throughout Great Plains Basin. Control factors derived from EPA NONROAD model (see above).
All New Spark-Ignited Stationary Engines	New Source Performance Stds. (NSPS) (EPA, 2008; EPA, 2012)	US EPA	Phase in from 2008 - 2011	Effect on emissions assumed negligible considering little to no growth in oil and gas activity from 2011-2015
Pneumatic Controllers	New Source Performance Stds. Subpart OOOO (NSPS) (EPA, 2012)	US EPA	Beginning Sep. 2011	Effect on emissions assumed negligible considering little to no growth in oil and gas activity from 2011-2015
Condensate and Crude Oil Tanks	New Source Performance Stds. Subpart OOOO (NSPS) (EPA, 2012)	US EPA	Oct. 15, 2013	Effect on emissions assumed negligible considering little to no growth in oil and gas activity from 2011-2015
Gas Well Completions	New Source Performance Stds. Subpart OOOO (NSPS) (EPA, 2012)	US EPA	Oct. 2012 (low pressure) / Jan. 2015 (all other)	Insufficient information to estimate the impact of this regulation requiring reduced emission completions
Dehydrators	New Source Performance Stds. Subpart HH (NSPS) (EPA, 2012)	US EPA	Phase in from Oct. 2012-Oct. 2015	Insufficient information to estimate the impact of this regulation.
Gas Processing Plants	New Source Performance Stds. Subpart OOOO (NSPS) (EPA, 2012)	US EPA	Oct. 2013	Not enough information on detailed emissions at gas processing facilities; conservatively assumed that there would be no effect of this regulation on the 2015 inventory.
All Tribal Sources not meeting major source thresholds	Minor Source Reporting Requirements on Indian Tribal Land	US EPA	Phase-In Beginning Aug. 2011	No information was available to determine the future impacts of this regulation on emissions.

Source Category	Regulation	Enforcing Agency	Effective Date	Implementation in the 2015 Great Plains Basin Emissions Projections
State – Montana				
Well Completions	MT ARM 36.22.1221 Completion venting controls.	MTDEQ	1984	Not enough information was available in producer data; conservatively assume that there would be no effect of this regulation on the 2015 inventory.
Condensate and Crude Oil Tanks	MT ARM 17.8.1603(1)(b) VOC vapors from oil or condensate storage tanks with a PTE > 15 tpy must be controlled	MTDEQ	Jan 2006	Not enough information to make a 2015 specific analysis. Assumed that rates of control in 2015 are similar to rates of control in 2011 for VOC.
All VOC sources	MT ARM 17.8.1711(1)(a) VOC vapors from each piece of O&G well facility equipment with PTE >15 tpy, must be controlled	MTDEQ	Apr 2006	Not enough information to make a 2015 specific analysis. Assumed that rates of control in 2015 are similar to rates of control in 2011 for VOC sources not controlled per other regulations.
	MT ARM 17.8.1603(1)(a) VOC vapors must be captured and routed to a gas pipeline if within ½ mile to control device.	MTDEQ	Jan 2006	
	MT ARM 17.8.752 case by case BACT determination	MTDEQ	Dec 2002	
	MT ARM 17.8.1711(1)(a) VOC vapors from each piece of O&G well facility equipment, with a PTE > 15 tpy, must be controlled	MTDEQ	Apr 2006	
Truck loading	MT ARM 17.8.1711(1)(b) Submerged filling on all hydrocarbon liquid loading or unloading	MTDEQ	Apr 2006	Assumed submerged filling for all tank loading.

5.5.1 Nonroad Diesel Engine Standards and Fuel Sulfur Standards

The EPA NONROAD2005 model was run with fuel inputs based on the EPA guidance for NONROAD fuel properties (EPA, 2009a). The model outputs were used to develop county-level emissions per unit population for "other oil field equipment" (SCC 2270010010) for the calendar year 2011, and then separately for the calendar year 2015. These emissions per unit population reflect the predicted fleet mix of engines – for various tier standards from baseline uncontrolled engines through Tier IV engines – and are used as a representation of fleet turnover for drilling rigs, fracing engines, and workover rigs. The ratios of the per unit emissions in 2015 to those in 2011 for each county of interest were taken to be the control factors accounting for federal non-road tier standards and diesel fuel sulfur standards.

5.5.2 New Source Performance Standards for Pneumatic Devices, Tanks, and Engines

Based on the no growth assumptions over the 2013-2015 period, increases in oil and gas activity are small (see Table 5-4). Decreases in emissions from control of pneumatic devices, tanks, and engines were assumed negligible.

Table 5-4. 2015 oil and gas activity growth.

Parameter	Ratio of 2015 to 2011 oil and gas activity
Gas Production	
Primary Gas	81%
Associated Gas	129%
Total	**81%**
Oil Production	
Condensate	80%
Oil	106%
Total	**105%**
Active Well Count	
Gas Well Count	98%
Oil Well Count	101%
Total	**99%**
Spuds	
Spuds	46%

5.5.3 New Source Performance Standards and Montana Regulations for Well Completions

Both the New Source Performance Standards (NSPS) Subpart OOOO and the Administrative Rules of Montana (ARM) 36.22.1221 require controls on well completions in the form of either reduced emission completions (NSPS Subpart OOOO) or combustion controls on vented gas during completions. However insufficient information was available from the baseline 2011 survey data to accurately characterize the uncontrolled fraction of well completions or the uncontrolled VOC emissions from these completions, therefore it was not possible to implement these regulations in the 2015 midterm projections for the Great Plains Basin.

5.5.4 Summary of Controls

Table 5-5 presents a summary of emissions controls by source category.

Table 5-5. Controls summary by emission category.

Source Category	Well Type	2011 and 2015
Drill Rigs, Fracing Engines, Workover Rigs	oil wells	NONROAD default 2011 emission rates
	gas wells	
Initial Completions	oil wells	29% green completions, 71% conventional completions
	gas wells	29% green completions, 71% conventional completions
Condensate Tanks	gas wells	9% controlled by flare, 87% uncontrolled,
Oil Tanks	oil wells	100% uncontrolled, 0% controlled
Water Tanks	oil wells	100% uncontrolled, 0% controlled
	gas wells	
Oil Well Truck Loading	oil wells	0% of oil sent directly to pipeline, 100% submerged loading
Gas Well Truck Loading	gas wells	0% of condensate sent directly to pipeline, 100% submerged loading

Source Category	Well Type	2011 and 2015
Artificial Lift Engines	oil wells	Average emission rates greater than NSPS JJJJ standards based on survey-based data
Fugitive Components	oil wells	no control
	gas wells	
Heaters	oil wells	no control
	gas wells	
Pneumatic Devices	oil wells	0% high bleed, 73% intermediate bleed, and 37% low bleed
	gas wells	0% high bleed, 25% intermediate bleed, and 75% low bleed
Pneumatic Pumps	oil wells	uncontrolled
	gas wells	
Dehydrators	oil wells	uncontrolled
	gas wells	uncontrolled
Wellhead Compressor Engines	oil wells	survey-based data indicates that engines meet interim NSPS JJJJ emission standards
	gas wells	survey-based data indicates that engines meet interim NSPS JJJJ emission standards
Miscellaneous Engines	oil wells	emission rates based on Friesen et.al (2009)
	gas wells	emission rates based on Friesen et.al (2009)
Well Blowdowns	oil wells	uncontrolled
	gas wells	uncontrolled
Midstream Sources	not applicable	Based on assumed control and emission rates in MTDEQ and EPA permit databases

5.5.5 Projection Uncertainties

There is significant uncertainty associated with the 2015 future year emission estimates since development of the Great Plains Basin will depend on economic and environmental factors that are difficult to forecast. Some of the specific factors that make the projections uncertain are as follows:

- Uncertainty in forecasting spudding rates and number of active wells
- New practices developed that improve efficiencies (e.g. drilling time, multi-well pads, multi-well fracing, etc.)
- Effect of electrification of equipment (i.e. artificial lift or compressors)

Future updates to inventory forecasts may address some of these uncertainties if additional data is available on forecasted activities, on equipment usage and processes, and on basin-level industry trends. However, given the lack of detailed data to address these factors the uncertainty of the projections is noted.

6.0 SUMMARY RESULTS

6.1 Base Year 2011

Results from the combined permitted sources and the combined surveyed sources are presented below for the entire Great Plains Basin as a series of pie charts and bar graphs including county-level emissions, basin-wide emissions and emissions on tribal and non-tribal land. The quantitative emissions summaries are presented in Table 6-1 through Table 6-3. Detailed emissions by mineral designation are presented in Appendix A. A complete list of emissions for all counties is included in the summary emissions spreadsheets that accompany this report.

Figure 6-1 shows NOx emissions by county and source category in the Great Plains Basin. Figure 6-1 shows that NOx emissions are concentrated in Blaine (39%), Toole (24%), Glacier (13%), and Phillips (9%) Counties. These counties represent the counties with the highest total well count in the Great Plains Basin. Figure 6-2 shows NOx emissions by mineral estate in the Great Plains Basin. Approximately 88% of emissions are concentrated on private/state fee mineral estimate, with 6% on tribal, 7% on BLM, and 0% on USFS mineral estate, respectively.

Figure 6-3 shows that VOC emissions are more evenly distributed across the Great Plains Basin than NOx emissions with the largest contributions from Toole (27%), Glacier (18%), Blaine (10%), and Rosebud (9%) Counties. As shown in Figure 6-4, 80% of emissions are concentrated on private/state fee mineral estimate, with 9% on tribal, 10% on BLM, and 0% on USFS mineral estate.

Figure 6-5 shows that compressor engines are the single largest source categories of NOx emissions in the Great Plains Basin, accounting for approximately 66% of NOx emissions in 2011. Miscellaneous engines, drill rigs, fracing engines, and heaters together account for approximately 29% of NOx emissions. Figure 6-6 shows that oil tanks are the largest source of VOC emissions, contributing approximately 33% of basin-wide emissions. Notably, water tanks emission are the second largest source of VOC emissions, contributing approximately 21% of basin-wide emissions. Water tank emissions are large contributors to VOC emissions not because of high water production rates or high water tank emission factors; rather, VOC emissions from other sources (e.g. fugitive devices and pneumatic devices) are relatively low.

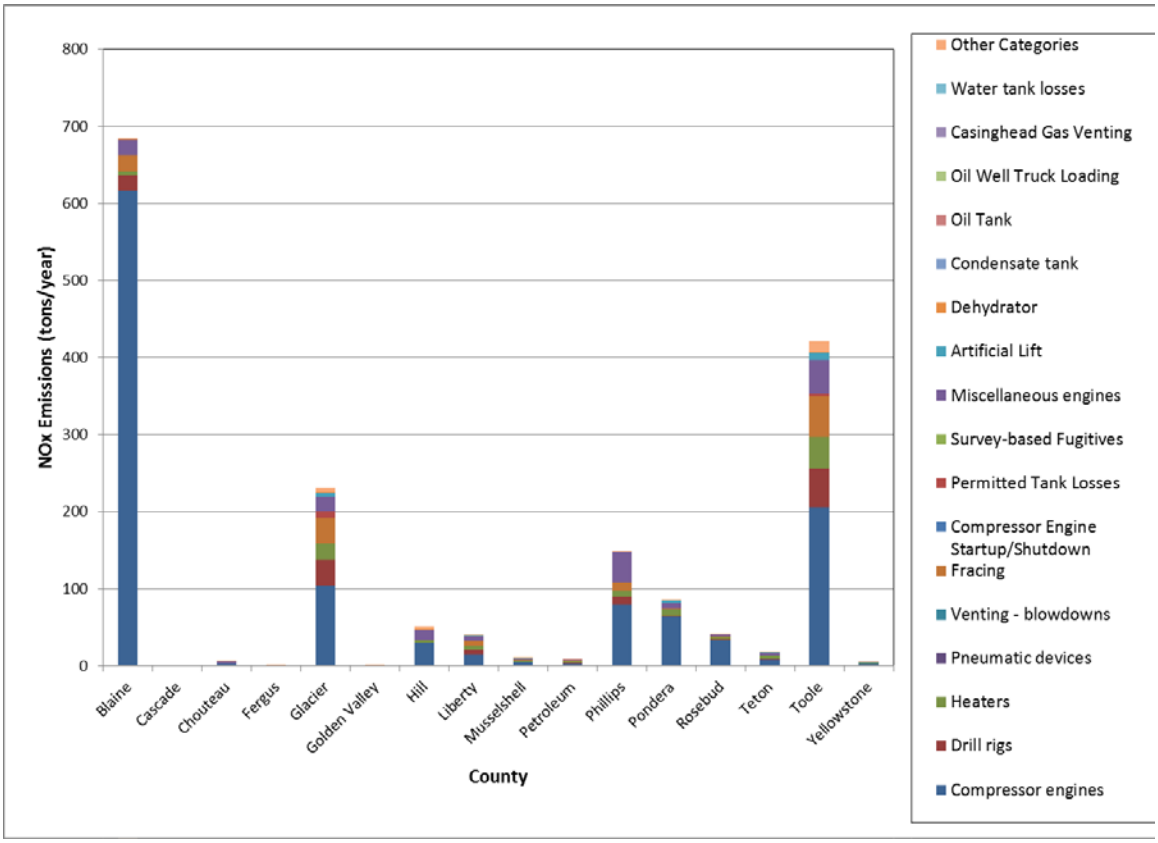

Figure 6-1. 2011 NOx emissions by source category and by county in the Great Plains Basin.

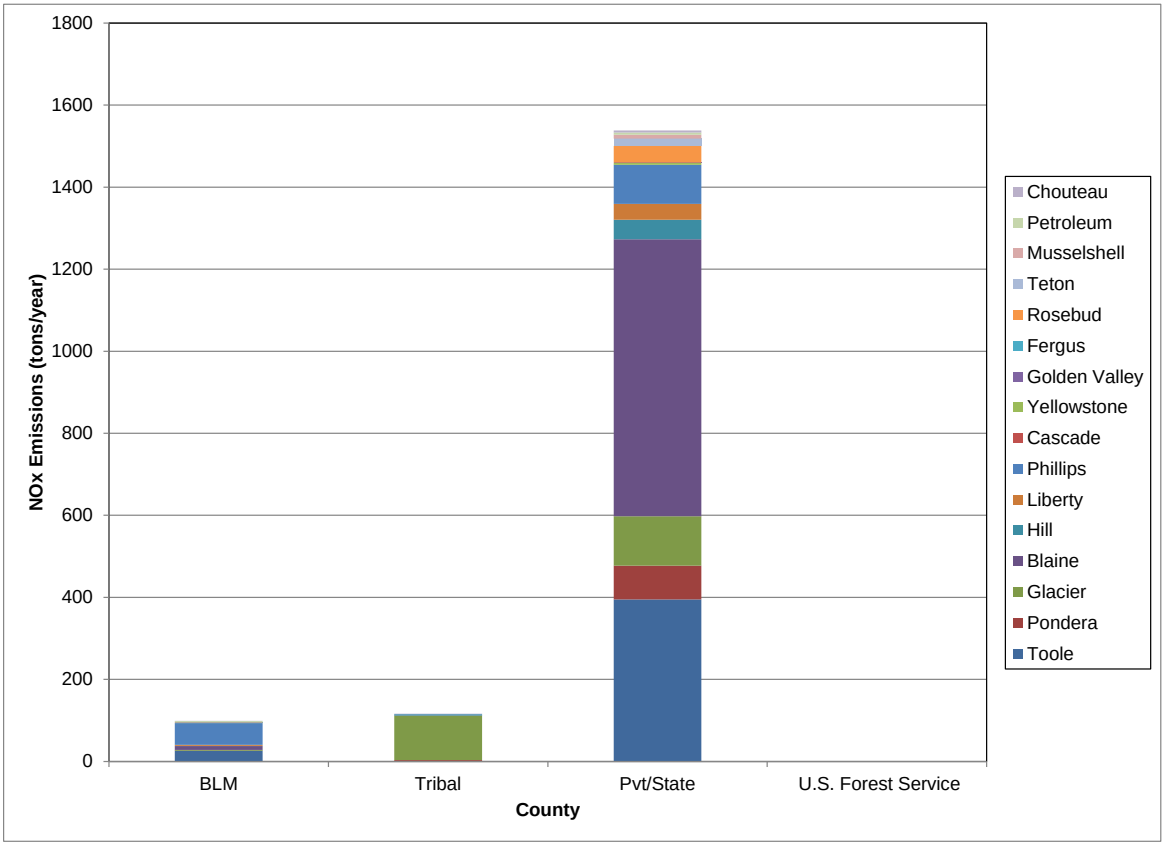

Figure 6-2. 2011 NOx emissions by mineral designation in the Great Plains Basin.

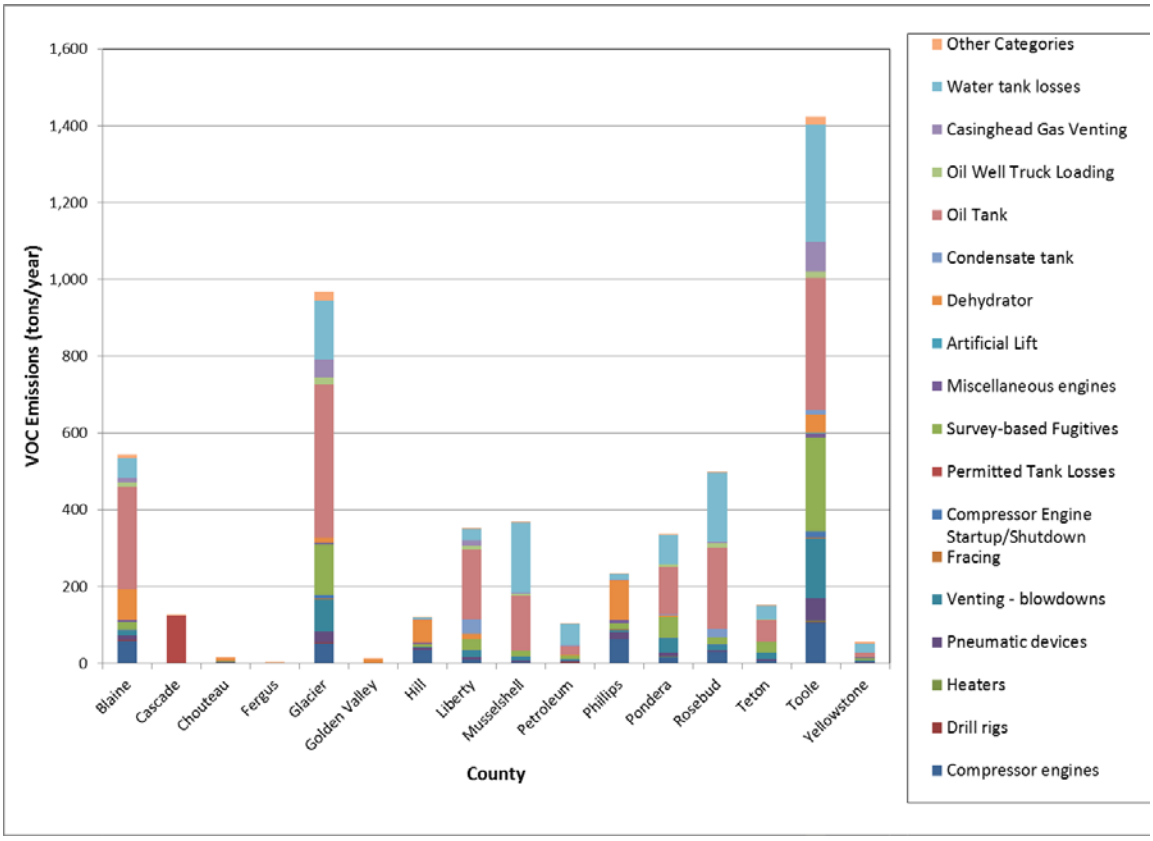

Figure 6-3. 2011 VOC emissions by source category and by county in the Great Plains Basin.

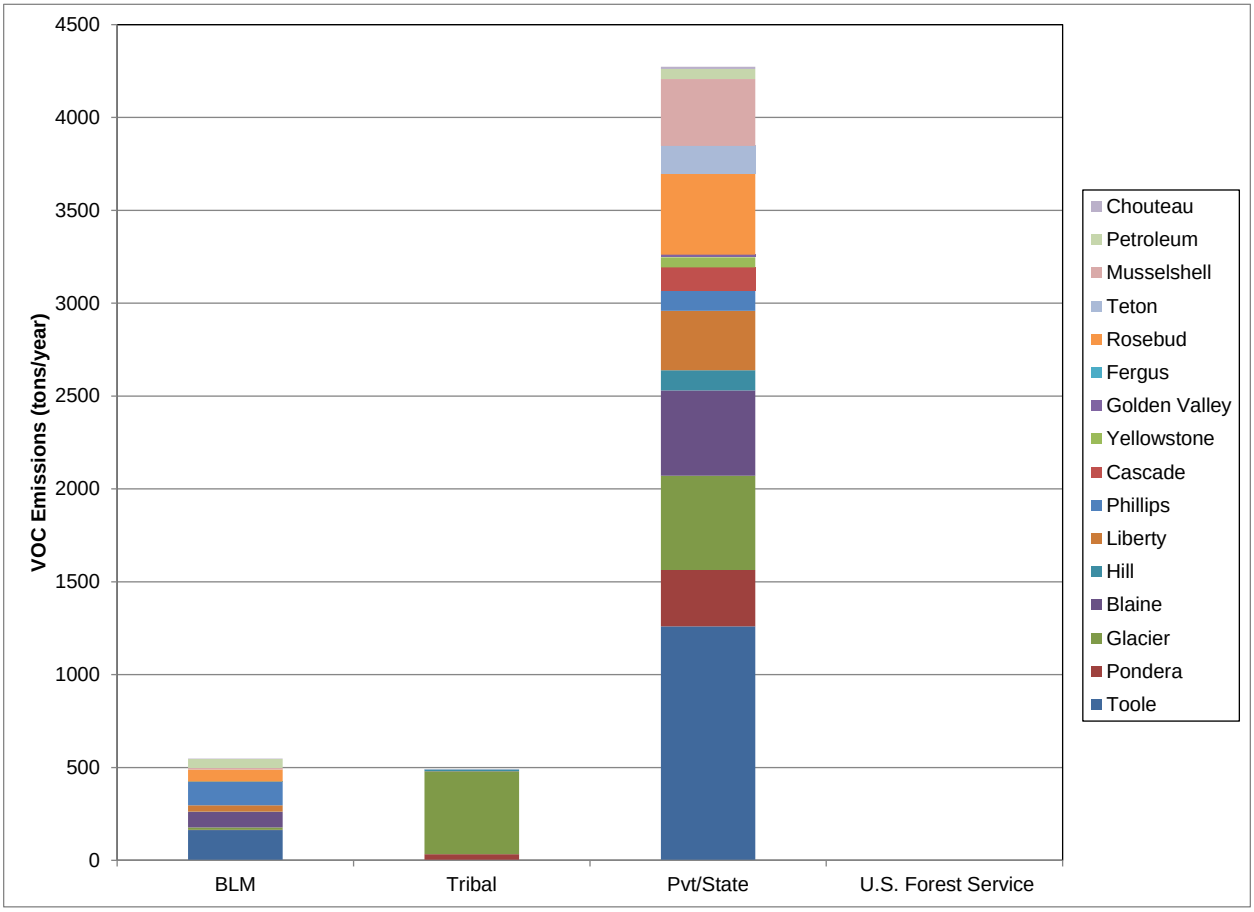

Figure 6-4. 2011 VOC emissions by mineral designation in the Great Plains Basin.

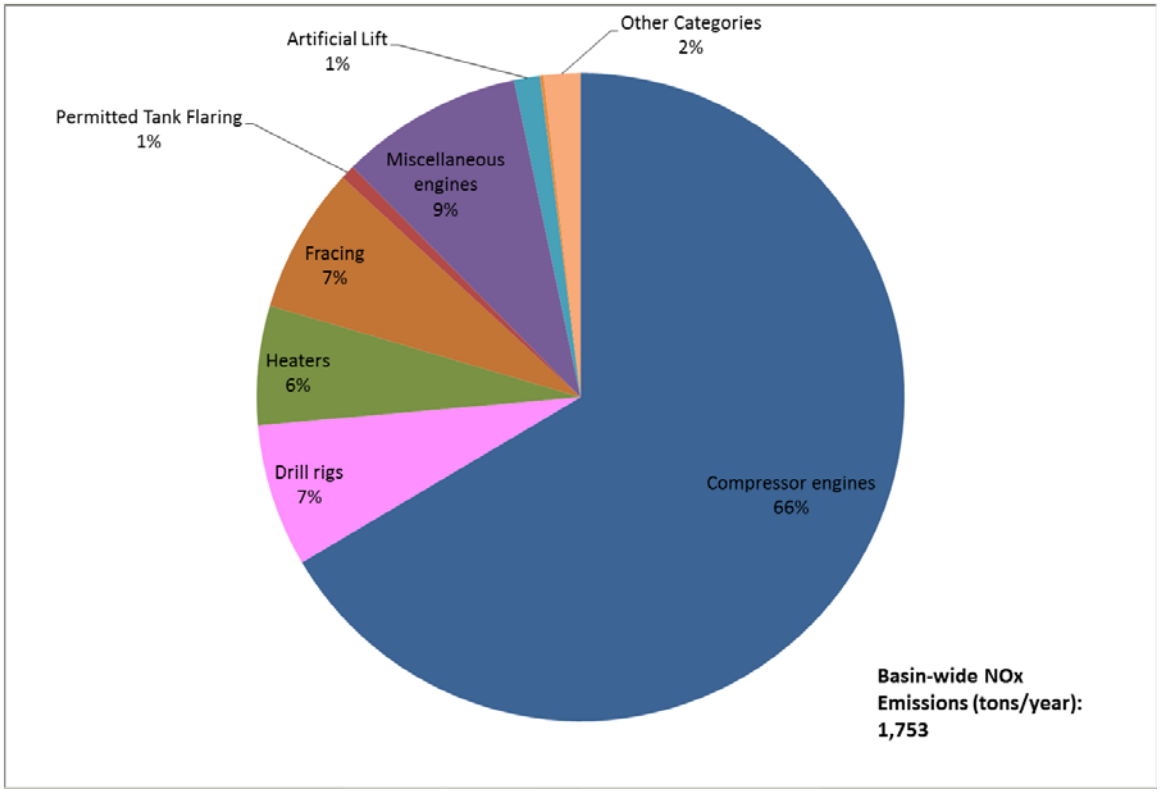

Figure 6-5. Great Plains Basin NOx emissions proportional contributions by source category.

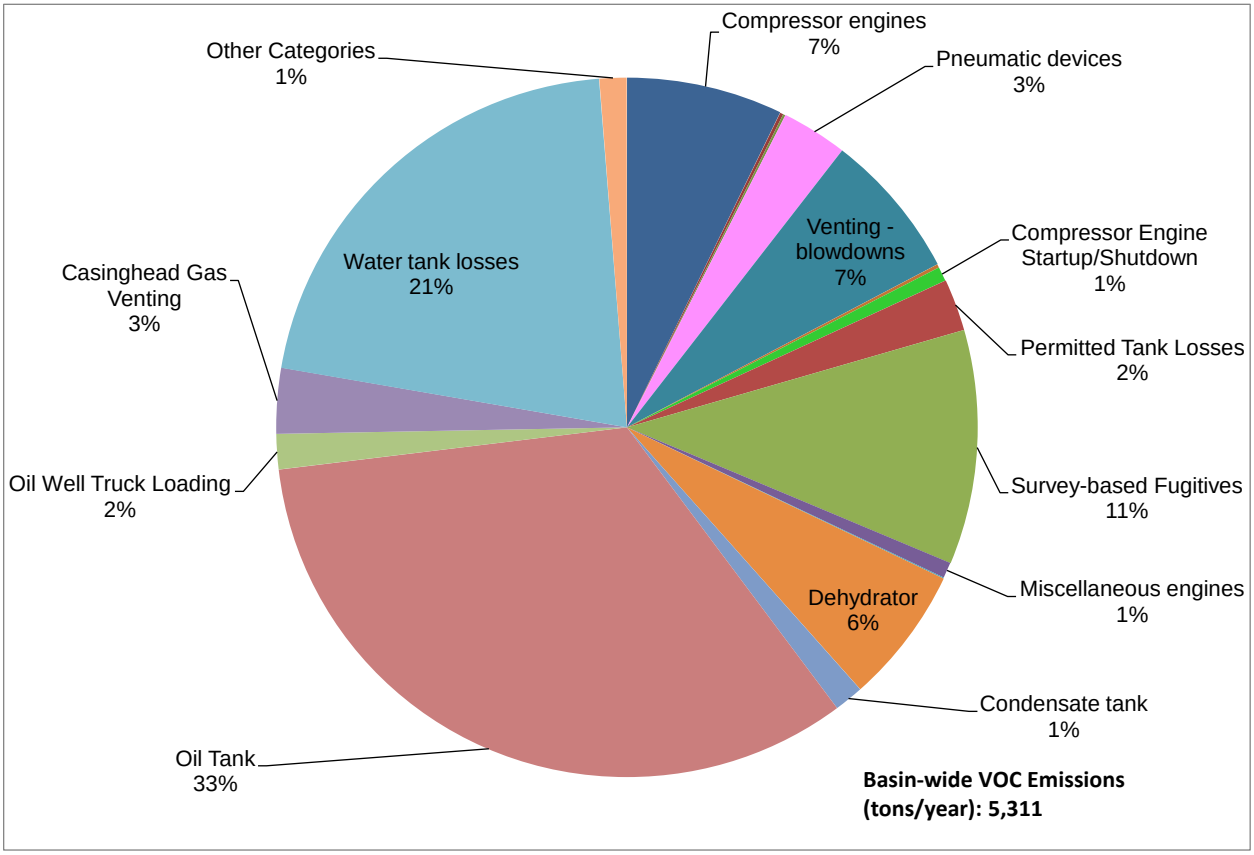

Figure 6-6. Great Plains Basin VOC emissions proportional contributions by source category.

Table 6-1. 2011 emissions of all criteria pollutants by county for the Great Plains Basin.

County	NOx [tons/yr]	VOC [tons/yr]	CO [tons/yr]	SOx [tons/yr]	PM [tons/yr]
Blaine, MT	685	544	163	0	7
Cascade, MT	0	127	0	0	0
Chouteau, MT	6	14	3	0	0
Fergus, MT	0	1	0	0	0
Glacier, MT	230	967	180	0	7
Golden Valley, MT	0	14	0	0	1
Hill, MT	52	119	55	0	1
Liberty, MT	41	353	30	0	1
Musselshell, MT	10	368	9	0	0
Petroleum, MT	8	103	6	0	0
Phillips, MT	149	235	111	0	3
Pondera, MT	86	337	42	0	2
Rosebud, MT	42	499	16	0	1
Teton, MT	18	151	15	0	1
Toole, MT	421	1,424	254	0	14
Yellowstone, MT	5	56	6	0	0
Total	**1,753**	**5,311**	**891**	**2**	**38**

Table 6-2. 2011 NOx emissions [ton/yr] by source category for the Great Plains Basin.

County	Compressor Engines	Drill rigs	Heaters	Fracing	Miscellaneous Engines	Artificial Lift	Dehydrator	Other Categories	Totals
Blaine, MT	616	20	6	21	19	1	1	2	685
Cascade, MT	0	0	0	0	0	0	0	0	0
Chouteau, MT	2	0	1	0	3	0	0	0	6
Fergus, MT	0	0	0	0	0	0	0	0	0
Glacier, MT	104	33	22	34	19	6	1	13	230
Golden Valley, MT	0	0	0	0	0	0	0	0	0
Hill, MT	30	0	3	0	14	0	0	4	52
Liberty, MT	14	6	5	6	7	1	0	1	41
Musselshell, MT	5	0	2	0	1	1	0	0	10
Petroleum, MT	3	1	2	1	1	0	0	0	8
Phillips, MT	79	11	7	11	39	0	0	2	149
Pondera, MT	63	1	9	1	7	2	0	2	86
Rosebud, MT	33	1	3	1	2	1	0	1	42
Teton, MT	8	0	4	0	3	1	0	1	18
Toole, MT	205	51	41	52	43	10	1	17	421
Yellowstone, MT	2	0	1	0	1	0	0	1	5
Total	**1,165**	**125**	**104**	**128**	**160**	**23**	**3**	**44**	**1,753**

Table 6-3. 2011 VOC emissions [ton/yr] by source category for the Great Plains Basin.

County	Compressor Engines	Pneumatic Devices	Venting - Blowdowns	Survey-based Fugitives	Dehydrator	Oil Tank	Casinghead Gas Venting	Water Tank Losses	Other Categories	Totals
Blaine, MT	59	11	13	22	78	267	11	52	32	544
Cascade, MT	0	0	0	0	0	0	0	0	127	127
Chouteau, MT	2	1	1	1	8	0	1	0	1	14
Fergus, MT	0	0	0	0	0	0	0	0	0	1
Glacier, MT	51	30	84	132	12	398	45	155	61	967
Golden Valley, MT	0	0	0	0	11	0	0	0	2	14
Hill, MT	34	7	3	6	59	1	1	3	6	119
Liberty, MT	9	7	16	26	14	182	16	30	53	353
Musselshell, MT	3	3	9	15	0	143	2	183	9	368
Petroleum, MT	2	2	6	10	0	24	1	55	3	103
Phillips, MT	62	18	7	15	103	0	2	15	13	235
Pondera, MT	17	12	34	53	2	125	0	78	16	337
Rosebud, MT	31	4	12	20	0	212	4	181	34	499
Teton, MT	6	5	16	25	0	56	0	35	6	151
Toole, MT	106	59	154	244	49	345	79	304	84	1,424
Yellowstone, MT	2	1	4	7	0	14	0	23	5	56
Total	**382**	**161**	**361**	**575**	**337**	**1,766**	**161**	**1,116**	**452**	**5,311**

6.2 Future Year 2015

The scaling factors were applied to the baseline 2011 inventory, and "on-the-books" regulations were applied to the uncontrolled 2015 emissions projections to generate the final 2015 emissions projections and results presented below. It should be noted that based on recent trends, oil and gas activity was held constant at 2012 levels to 2015. Detailed emissions by mineral designation are presented in Appendix A. A complete list of emissions for all counties is included in the summary emissions spreadsheets that accompany this report.

Figure 6-7 and Table 6-4 show that similar to 2011, NOx emissions are concentrated in Blaine (39%), Toole (23%), Glacier (12%), and Phillips (9%) Counties. Similar to 2011, NOx emissions are concentrated on private/state fee mineral estate (88%) as shown in Figure 6-8. Figure 6-9 and Table 6-4 show that the largest VOC emissions contributions are from Toole (26%) and Glacier (18%) Counties. NOx emissions are concentrated on private/state fee mineral estate (81%) as shown in Figure 6-10.

Consistent with the 2011 baseline emissions analysis, compressor engines are the single largest source categories of NOx emissions in the Great Plains Basin, accounting for approximately 71% of NOx emissions in 2015 as shown in Figure 6-11 and Table 6-5. It is noted that drilling emissions decline over time as expected from turnover of equipment to newer engines meeting more stringent emissions standards and as a result of decreased estimates of spud count in 2015 relative to 2011. Drilling represents a smaller fraction of basin-wide NOx in 2015 than in 2011. As a result of 2015 estimates of little to no growth in oil and gas activity relative to 2011, emissions control resulting from NSPS performance standards for stationary engines were assumed to have a negligible effect on emissions.

VOC emissions contributions in the 2015 inventory are similar to VOC contributions in the 2011 baseline inventory, with 35% of emissions from oil tanks and 23% of emissions from water tanks as shown in Figure 6-12 and Table 6-6. As a result of 2015 estimates of little to no growth in oil and gas activity relative to 2011, emissions control resulting from NSPS performance standards for pneumatic devices and tanks were assumed to have a negligible effect on emissions.

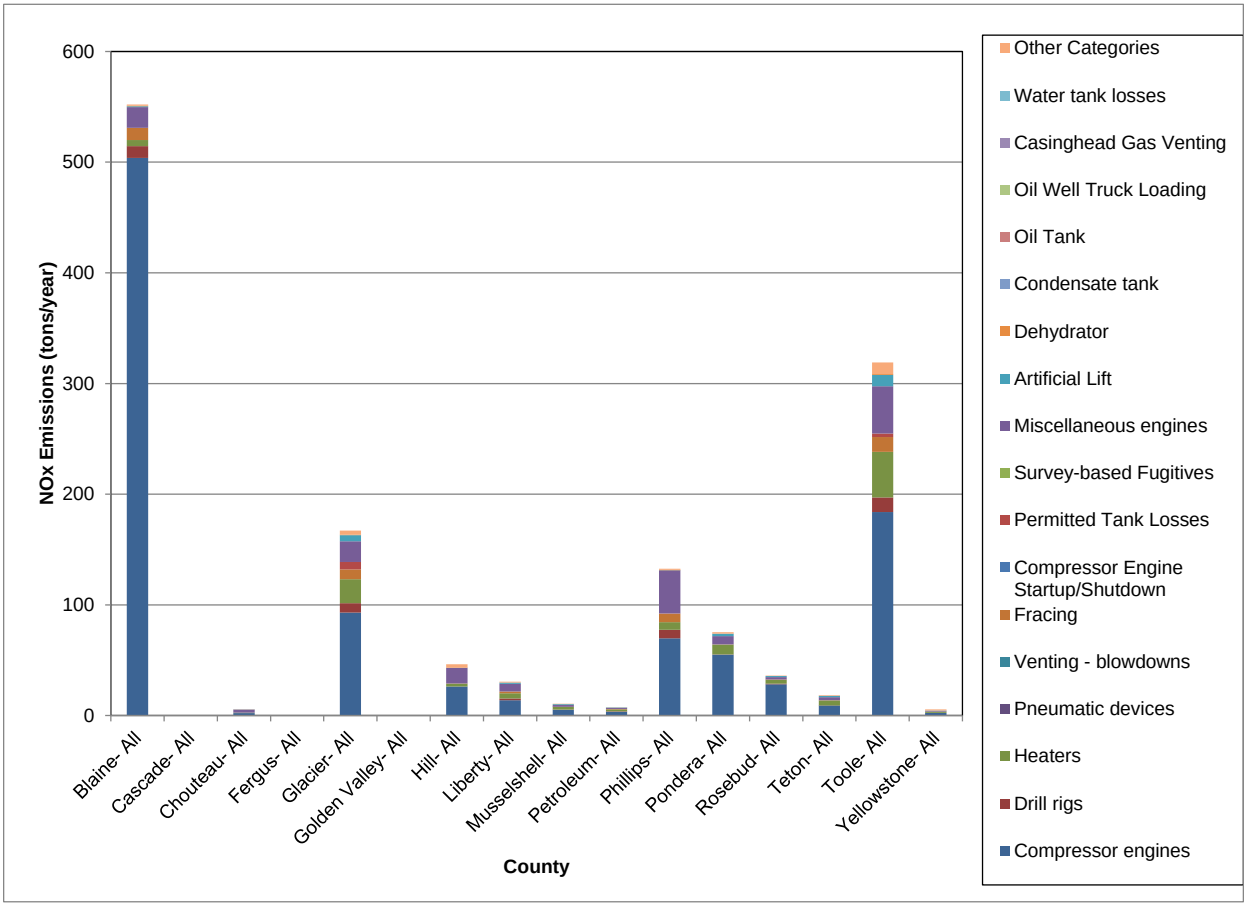

Figure 6-7. 2015 NOx emissions by source category and by county in the Great Plains Basin.

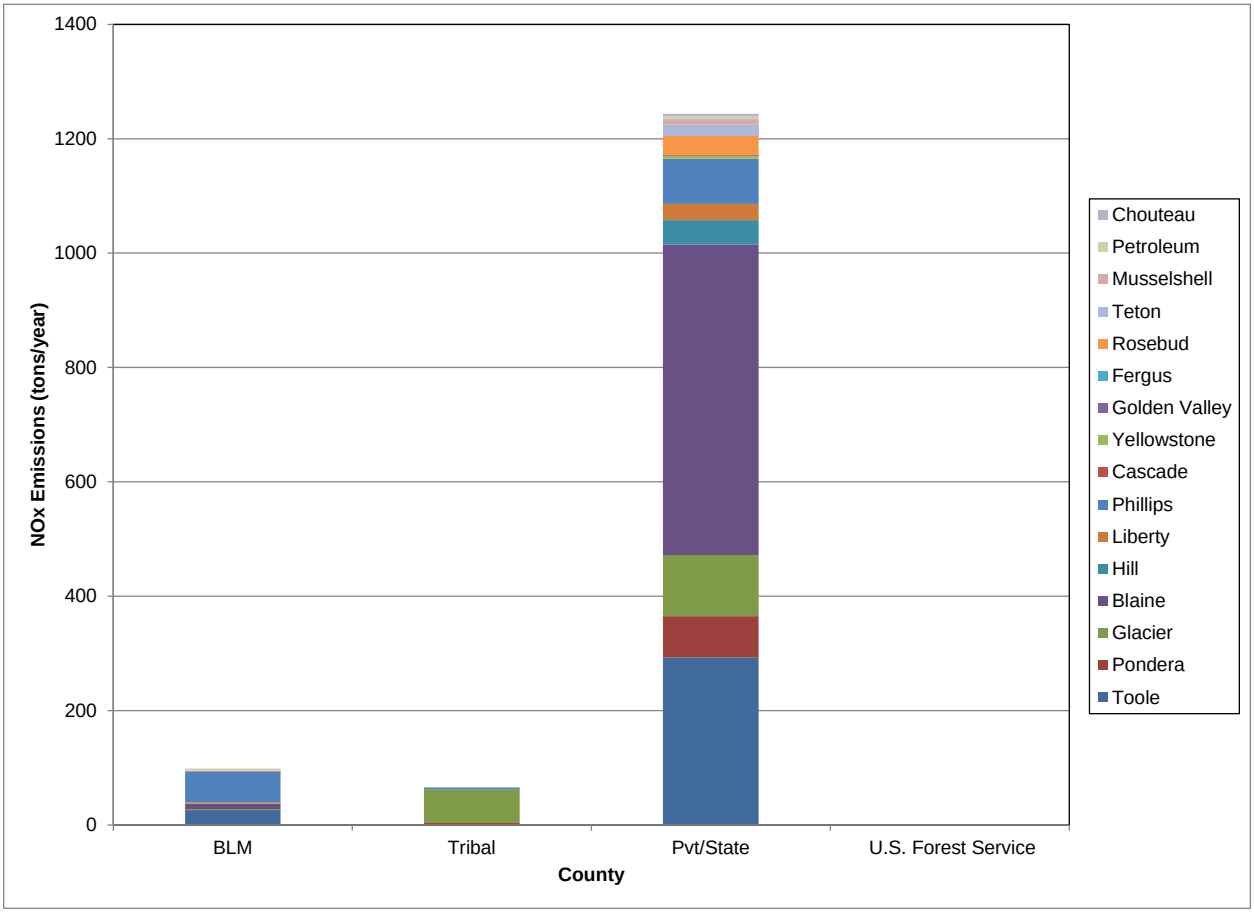

Figure 6-8. 2015 NOx emissions by mineral designation in the Great Plains Basin.

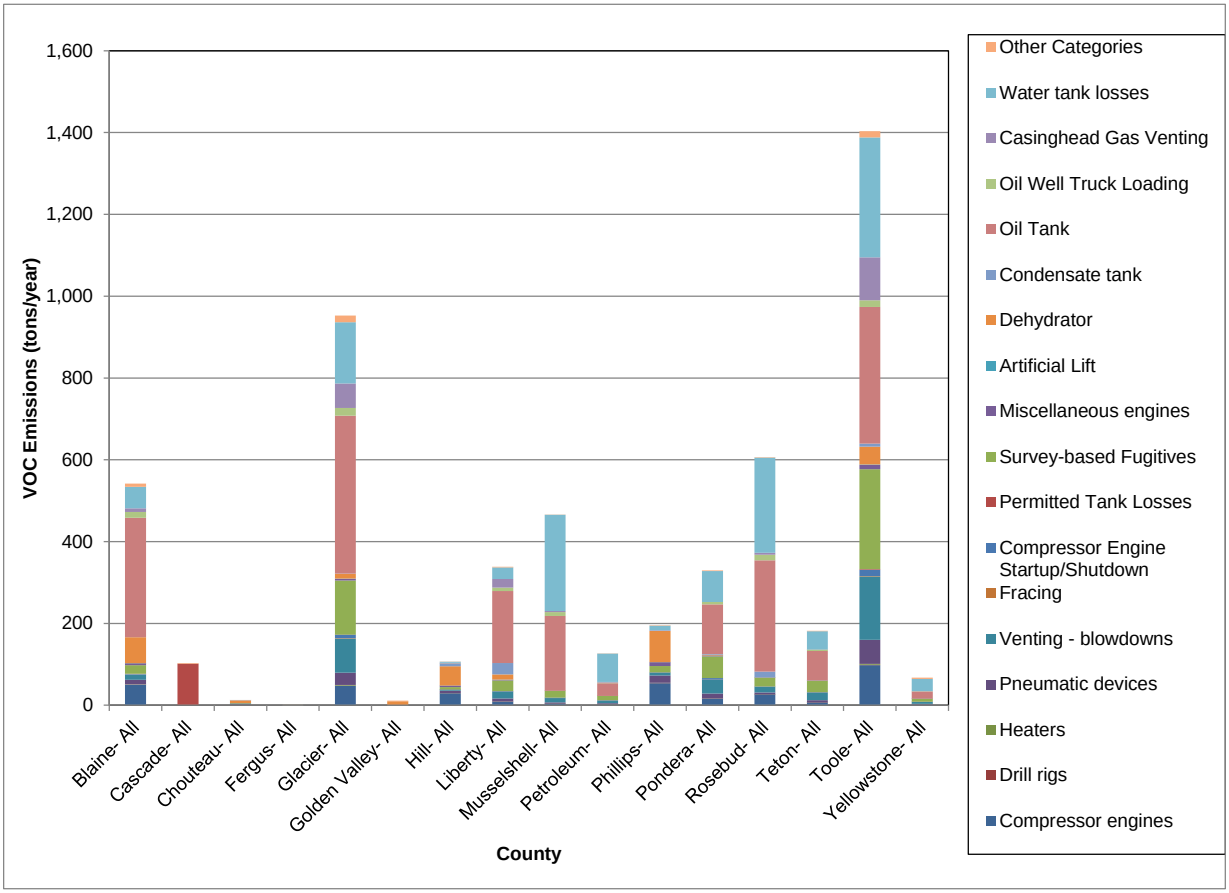

Figure 6-9. 2015 VOC emissions by source category and by county in the Great Plains Basin.

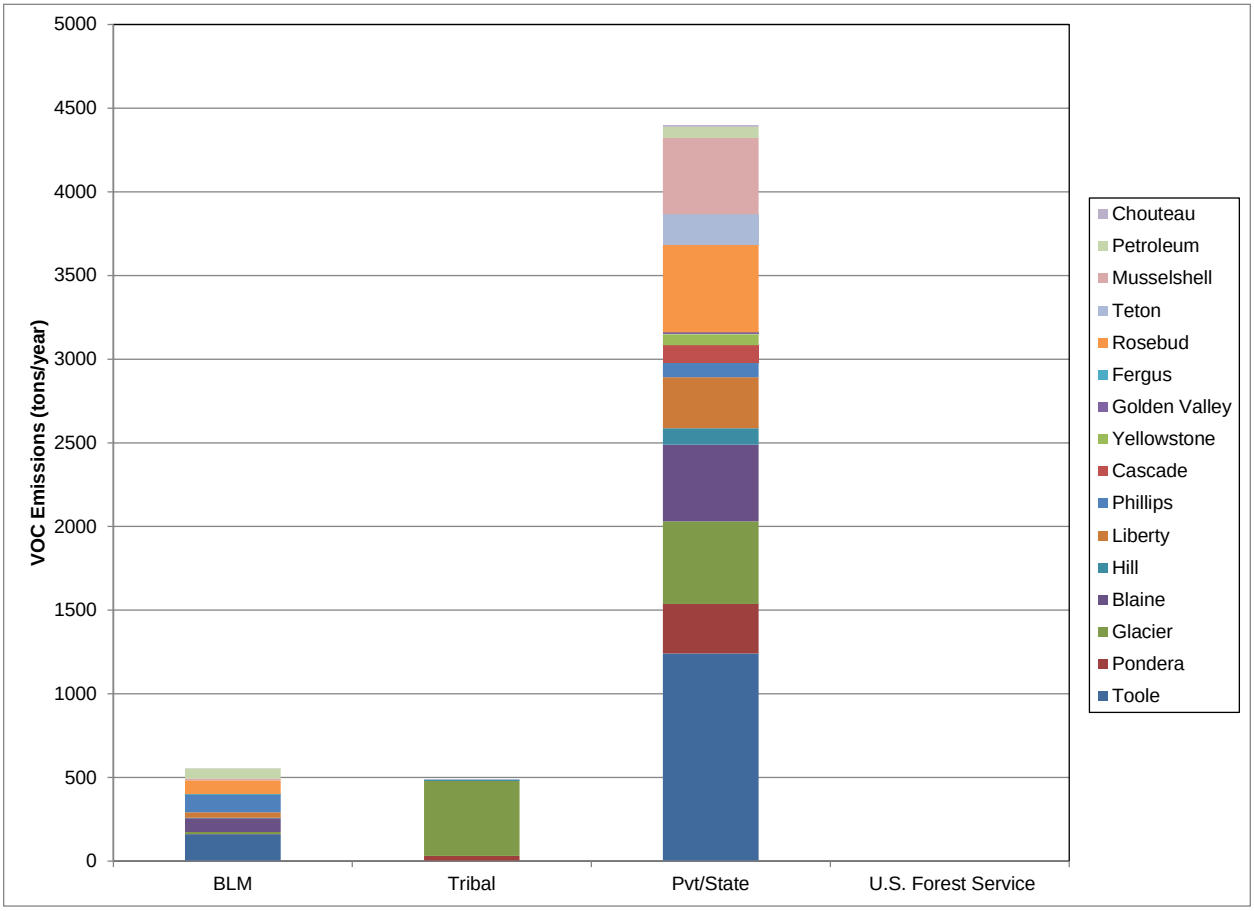

Figure 6-10. 2015 VOC emissions by source category and by county in the Great Plains Basin.

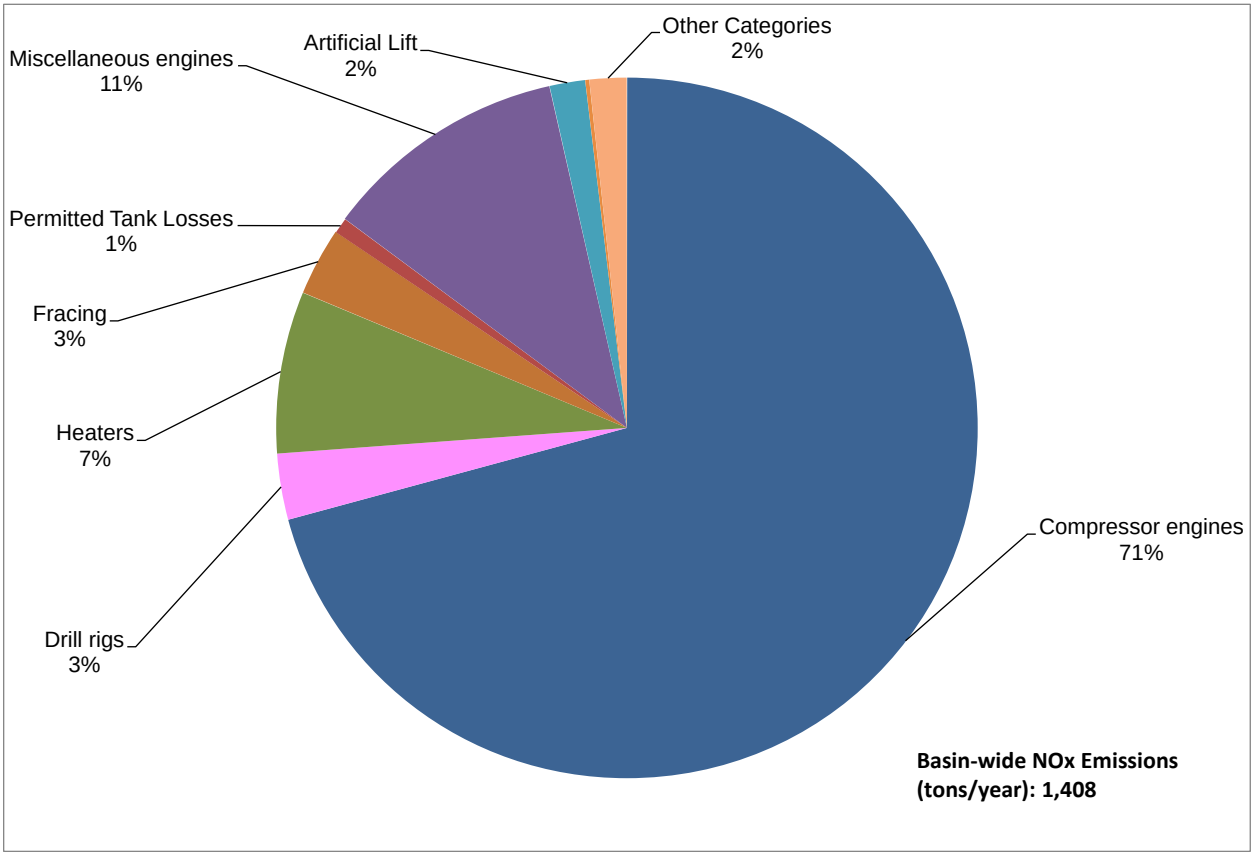

Figure 6-11. 2015 NOx emissions contributions by source category in the Great Plains Basin.

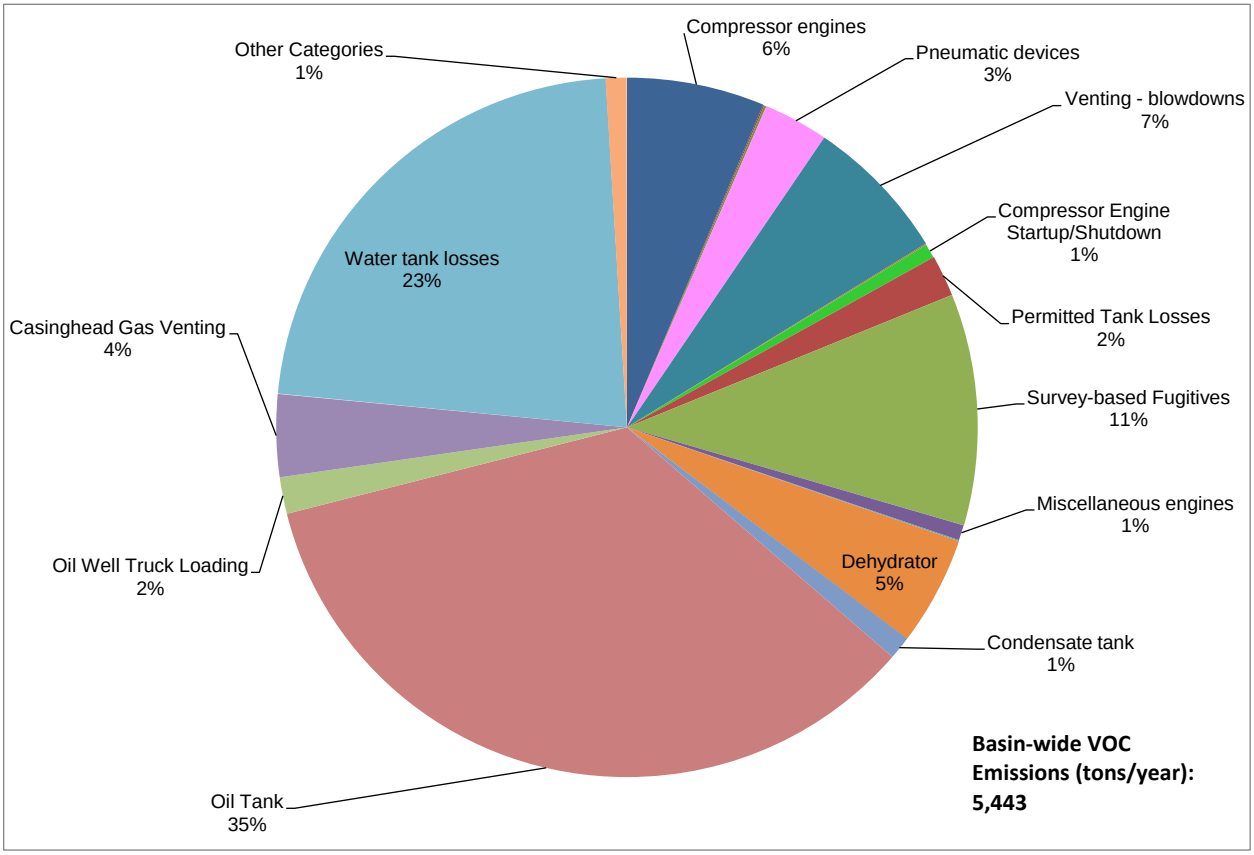

Figure 6-12. 2015 VOC emissions contributions by source category in the Great Plains Basin.

Table 6-4. 2015 emissions of all criteria pollutants by county for the Great Plains Basin.

County	NOx [tons/yr]	VOC [tons/yr]	CO [tons/yr]	SOx [tons/yr]	PM [tons/yr]
Blaine, MT	552	542	133	0	6
Cascade, MT	0	103	0	0	0
Chouteau, MT	5	13	3	0	0
Fergus, MT	0	1	0	0	0
Glacier, MT	167	953	149	0	5
Golden Valley, MT	0	11	0	0	1
Hill, MT	46	107	47	0	1
Liberty, MT	31	339	26	0	1
Musselshell, MT	11	466	9	0	0
Petroleum, MT	8	126	6	0	0
Phillips, MT	133	196	97	0	3
Pondera, MT	75	329	39	0	1
Rosebud, MT	36	606	16	0	1
Teton, MT	18	182	16	0	1
Toole, MT	319	1,403	216	0	9
Yellowstone, MT	6	67	6	0	0
Total	**1,408**	**5,443**	**765**	**1**	**28**

Table 6-5. 2015 NOx emissions [tons/year] by county and by source category for the Great Plains Basin.

County	Compressor Engines	Drill rigs	Heaters	Fracing	Miscellaneous Engines	Artificial Lift	Dehydrator	Other Categories	Totals
Blaine, MT	504	11	5	11	19	1	0	1	552
Cascade, MT	0	0	0	0	0	0	0	0	0
Chouteau, MT	2	0	1	0	3	0	0	0	5
Fergus, MT	0	0	0	0	0	0	0	0	0
Glacier, MT	93	9	22	9	19	6	1	10	167
Golden Valley, MT	0	0	0	0	0	0	0	0	0
Hill, MT	26	0	3	0	14	0	0	3	46
Liberty, MT	14	2	5	2	7	1	0	1	31
Musselshell, MT	5	0	3	0	2	1	0	0	11
Petroleum, MT	3	0	2	0	1	0	0	0	8
Phillips, MT	70	8	7	8	39	0	0	1	133
Pondera, MT	55	0	9	0	7	2	0	1	75
Rosebud, MT	28	0	3	0	2	1	0	1	36
Teton, MT	9	0	4	0	3	1	0	1	18
Toole, MT	184	13	41	13	43	10	1	13	319
Yellowstone, MT	2	0	1	0	1	0	0	1	6
Total	**996**	**43**	**105**	**44**	**159**	**23**	**3**	**34**	**1,408**

Table 6-6. 2015 VOC emissions [tons/year] by county and by source category for the Great Plains Basin.

County	Compressor Engines	Pneumatic Devices	Venting - Blowdowns	Survey-based Fugitives	Dehydrator	Oil Tank	Casinghead Gas Venting	Water Tank Losses	Other Categories	Totals
Blaine, MT	50	11	13	21	64	292	9	52	30	542
Cascade, MT	0	0	0	0	0	0	0	0	103	103
Chouteau, MT	1	1	1	1	6	0	1	0	1	13
Fergus, MT	0	0	0	0	0	0	0	0	0	1
Glacier, MT	47	30	84	132	12	386	60	150	52	953
Golden Valley, MT	0	0	0	0	9	0	0	0	2	11
Hill, MT	29	6	3	6	48	1	1	3	11	107
Liberty, MT	9	7	16	26	13	176	21	28	42	339
Musselshell, MT	4	3	10	16	0	183	3	235	11	466
Petroleum, MT	2	2	7	10	0	31	2	69	3	126
Phillips, MT	54	18	7	15	76	0	2	11	13	196
Pondera, MT	16	12	34	53	2	121	0	75	15	329
Rosebud, MT	26	4	14	21	0	272	5	233	31	606
Teton, MT	6	6	18	28	0	72	0	45	7	182
Toole, MT	98	59	155	245	44	334	105	293	71	1,403
Yellowstone, MT	2	2	5	7	0	18	0	30	5	67
Total	**345**	**162**	**365**	**582**	**274**	**1,886**	**208**	**1,225**	**395**	**5,443**

7.0 REFERENCES

ENVIRON, 2014. "Development of Baseline 2011 and Future Year 2015 Emissions from Oil and Gas Activity in the Williston Basin." Prepared for Bureau of Land Management and Western States Air Resources Council. Prepared by ENVIRON International Corporation, Novato, CA.

EPA, 2009. NONROAD2008a Model. United States Environmental Protection Agency Assessment and Standards Division, Office of Transportation and Air Quality. Available Online: http://www.epa.gov/otaq/nonrdmdl.htm

EPA, 2009a. Suggested Nationwide Average Fuel Properties. United States Environmental Protection Agency Assessment and Standards Division, Office of Transportation and Air Quality. Available Online: http://www.epa.gov/otaq/models/nonrdmdl/nonrdmdl2008/420b09018.pdf

EPA, 2008. EPA Natural Gas Star Program, US Environmental Protection Agency, Research Triangle Park, NC, 2008; EPA430-F-08-011. http://www.epa.gov/gasstar/

EPA, 1995. "AP 42, Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources"; January. http://www.epa.gov/ttn/chief/ap42/

Friesen, R., R. Parikh, J. Grant, A. Bar-Ilan, A. Pollack, D. Henderer, D. Pring, K. Sgamma, P. Schlagel, 2009. "Development of Baseline 2006 Emissions from Oil and Gas Activity in the Uinta Basin." Prepared for Western Governors' Association. Prepared by ENVIRON International Corporation, Novato, CA. http://www.wrapair.org/forums/ogwg/documents/2009-03_06_Baseline_Emissions_Uinta_Basin_Technical_Memo_03-25.pdf

USGS, 2008. "National Oil and Gas Assessment: Supporting Data" United States Geological Survey, Reston, VA. http://energy.cr.usgs.gov/oilgas/noga/data.html

APPENDIX A

Oil and Gas Activity and Emissions by Mineral Designation

Appendix A. Oil and Gas Activity by Mineral Designation

Table A-1. Great Plains Basin 2011 well count by mineral designation and by county.

County	Well Count			
	Private/State	BLM	US Forest Service	Tribal
Blaine, MT	636	169	0	8
Chouteau, MT	100	16	0	1
Fergus, MT	0	7	0	0
Glacier, MT	484	12	0	293
Golden Valley, MT	4	0	0	0
Hill, MT	525	15	0	61
Liberty, MT	267	27	0	0
Musselshell, MT	58	5	0	0
Petroleum, MT	24	17	0	0
Phillips, MT	506	1,130	0	17
Pondera, MT	287	4	0	21
Rosebud, MT	78	6	0	0
Teton, MT	112	0	0	0
Toole, MT	1,623	195	0	0
Yellowstone, MT	28	1	0	0
Total	**4,732**	**1,604**	**0**	**401**

Table A-2. Great Plains Basin 2011 liquid hydrocarbon production (bbl/yr) by mineral designation and by county.

County	Liquid Hydrocarbon Production (bbl/yr)			
	Private/State	BLM	US Forest Service	Tribal
Blaine, MT	236,547	38,881	0	0
Chouteau, MT	0	0	0	0
Fergus, MT	0	0	0	0
Glacier, MT	204,155	5,799	0	201,142
Golden Valley, MT	0	0	0	0
Hill, MT	1,043	0	0	0
Liberty, MT	176,662	22,333	0	0
Musselshell, MT	142,944	4,574	0	0
Petroleum, MT	14,075	10,633	0	0
Phillips, MT	0	0	0	0
Pondera, MT	108,971	570	0	20,252
Rosebud, MT	182,706	42,871	0	0
Teton, MT	58,115	0	0	0
Toole, MT	319,453	39,164	0	0
Yellowstone, MT	13,877	211	0	0
Total	**1,458,548**	**165,036**	**0**	**221,394**

Table A-3. Great Plains Basin 2011 gas production (MCF/yr) by mineral designation and by county.

County	Gas Production (MCF/yr)			
	Private/State	BLM	US Forest Service	Tribal
Blaine, MT	5,935,815	2,280,689	0	29,641
Chouteau, MT	928,771	134,995	0	2,495
Fergus, MT	0	29,743	0	0
Glacier, MT	1,162,419	9,138	0	313,641
Golden Valley, MT	186,062	0	0	0
Hill, MT	5,940,252	164,539	0	788,783
Liberty, MT	1,322,235	49,890	0	0
Musselshell, MT	7,183	0	0	0
Petroleum, MT	4,008	0	0	0
Phillips, MT	4,758,858	8,790,802	0	40,920
Pondera, MT	240,660	1,531	0	0
Rosebud, MT	9,935	2,078	0	0
Teton, MT	892	0	0	0
Toole, MT	2,964,241	183,374	0	0
Yellowstone, MT	0	0	0	0
Total	**23,461,331**	**11,646,779**	**0**	**1,175,480**

Table A-4. Great Plains Basin 2011 produced water production (bbl/yr) by mineral designation and by county.

County	Produced Water Production (bbl/yr)			
	Private/State	BLM	US Forest Service	Tribal
Blaine, MT	1,786,271	369,514	0	0
Chouteau, MT	5,323	1,308	0	0
Fergus, MT	0	1,480	0	0
Glacier, MT	4,121,084	34,641	0	2,268,380
Golden Valley, MT	0	0	0	0
Hill, MT	125,600	2,921	0	181
Liberty, MT	1,205,380	39,000	0	0
Musselshell, MT	7,572,247	35,915	0	0
Petroleum, MT	1,075,597	1,198,682	0	0
Phillips, MT	173,898	466,724	0	26
Pondera, MT	3,160,767	570	0	63,566
Rosebud, MT	6,804,296	725,595	0	0
Teton, MT	1,458,121	0	0	0
Toole, MT	11,291,847	1,340,998	0	0
Yellowstone, MT	936,052	30,030	0	0
Total	**39,716,483**	**4,247,378**	**0**	**2,332,153**

Table A-5. Great Plains Basin 2011 spud counts by mineral designation and by county.

County	Spud Count			
	Private/State	BLM	US Forest Service	Tribal
Blaine, MT	4	0	0	0
Chouteau, MT	0	0	0	0
Fergus, MT	0	0	0	0
Glacier, MT	0	0	0	10
Golden Valley, MT	0	0	0	0
Hill, MT	0	0	0	0
Liberty, MT	4	0	0	0
Musselshell, MT	1	0	0	0
Petroleum, MT	8	0	0	0
Phillips, MT	2	0	0	0
Pondera, MT	1	0	0	0
Rosebud, MT	4	0	0	0
Teton, MT	1	0	0	0
Toole, MT	6	0	0	0
Yellowstone, MT	0	0	0	0
Total	**31**	**0**	**0**	**10**

Table A-6. Great Plains Basin 2011 emissions of all criteria pollutants by county and by mineral designation.

	Tribal Emissions [tons/yr]					Private/State Emissions [tons/yr]					BLM Emissions [tons/yr]					US Forest Service Emissions [tons/yr]				
County	**NOx**	**VOC**	**CO**	**SOx**	**PM**	**NOx**	**VOC**	**CO**	**Sox**	**PM**	**NOx**	**VOC**	**CO**	**SOx**	**PM**	**NOx**	**VOC**	**CO**	**SOx**	**PM**
Blaine, MT	0	1	0	0	0	675	459	157	0	7	9	84	6	0	0	0	0	0	0	0
Cascade, MT	0	0	0	0	0	0	127	0	0	0	0	0	0	0	0	0	0	0	0	0
Chouteau, MT	0	0	0	0	0	5	13	3	0	0	1	2	0	0	0	0	0	0	0	0
Fergus, MT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Glacier, MT	108	447	59	0	5	120	508	120	0	3	2	12	1	0	0	0	0	0	0	0
Golden Valley, MT	0	0	0	0	0	0	14	0	0	1	0	0	0	0	0	0	0	0	0	0
Hill, MT	3	8	2	0	0	48	108	53	0	1	1	2	0	0	0	0	0	0	0	0
Liberty, MT	0	0	0	0	0	39	320	29	0	1	2	33	2	0	0	0	0	0	0	0
Musselshell, MT	0	0	0	0	0	9	360	8	0	0	1	8	1	0	0	0	0	0	0	0
Petroleum, MT	0	0	0	0	0	6	54	4	0	0	3	49	2	0	0	0	0	0	0	0
Phillips, MT	1	1	0	0	0	95	107	80	0	2	53	126	30	0	1	0	0	0	0	0
Pondera, MT	3	33	3	0	0	82	303	38	0	1	0	1	0	0	0	0	0	0	0	0
Rosebud, MT	0	0	0	0	0	41	434	16	0	1	1	65	1	0	0	0	0	0	0	0
Teton, MT	0	0	0	0	0	18	151	15	0	1	0	0	0	0	0	0	0	0	0	0
Toole, MT	0	0	0	0	0	395	1,260	232	0	13	26	163	22	0	1	0	0	0	0	0
Yellowstone, MT	0	0	0	0	0	5	55	6	0	0	0	1	0	0	0	0	0	0	0	0
Total	**116**	**490**	**64**	**0**	**5**	**1,538**	**4,273**	**760**	**1**	**31**	**99**	**548**	**67**	**0**	**2**	**0**	**0**	**0**	**0**	**0**

Table A-7. Great Plains Basin 2011 NOx emissions [tons/year] by source category and by mineral designation.

County	Compressor Engines	Drill rigs	Heaters	Fracing	Miscellaneous Engines	Artificial Lift	Dehydrator	Other Categories	Totals
Blaine , MT; BLM	4	0	1	0	4	0	0	0	9
Cascade , MT; BLM	0	0	0	0	0	0	0	0	0
Chouteau , MT; BLM	0	0	0	0	0	0	0	0	1
Fergus , MT; BLM	0	0	0	0	0	0	0	0	0
Glacier , MT; BLM	1	0	0	0	0	0	0	0	2
Golden Valley , MT; BLM	0	0	0	0	0	0	0	0	0
Hill , MT; BLM	0	0	0	0	0	0	0	0	1
Liberty , MT; BLM	1	0	0	0	1	0	0	0	2
Musselshell , MT; BLM	0	0	0	0	0	0	0	0	1
Petroleum , MT; BLM	1	0	1	0	0	0	0	0	3
Phillips , MT; BLM	21	0	5	0	27	0	0	1	53
Pondera , MT; BLM	0	0	0	0	0	0	0	0	0
Rosebud , MT; BLM	0	0	0	0	0	0	0	0	1
Teton , MT; BLM	0	0	0	0	0	0	0	0	0
Toole , MT; BLM	13	0	6	0	5	2	0	1	26
Yellowstone , MT; BLM	0	0	0	0	0	0	0	0	0
Blaine , MT; Tribal	0	0	0	0	0	0	0	0	0
Cascade , MT; Tribal	0	0	0	0	0	0	0	0	0
Chouteau , MT; Tribal	0	0	0	0	0	0	0	0	0
Fergus , MT; Tribal	0	0	0	0	0	0	0	0	0
Glacier , MT; Tribal	20	33	10	34	7	3	0	2	108
Golden Valley , MT; Tribal	0	0	0	0	0	0	0	0	0
Hill , MT; Tribal	1	0	0	0	1	0	0	0	3
Liberty , MT; Tribal	0	0	0	0	0	0	0	0	0
Musselshell , MT; Tribal	0	0	0	0	0	0	0	0	0
Petroleum , MT; Tribal	0	0	0	0	0	0	0	0	0
Phillips , MT; Tribal	0	0	0	0	0	0	0	0	1
Pondera , MT; Tribal	2	0	1	0	0	0	0	0	3
Rosebud , MT; Tribal	0	0	0	0	0	0	0	0	0
Teton , MT; Tribal	0	0	0	0	0	0	0	0	0
Toole , MT; Tribal	0	0	0	0	0	0	0	0	0
Yellowstone , MT; Tribal	0	0	0	0	0	0	0	0	0
Blaine , MT; Private/State	612	20	4	21	15	1	1	1	675
Cascade , MT; Private/State	0	0	0	0	0	0	0	0	0
Chouteau , MT; Private/State	2	0	0	0	2	0	0	0	5
Fergus , MT; Private/State	0	0	0	0	0	0	0	0	0
Glacier , MT; Private/State	83	0	12	0	11	3	1	11	120

County	Compressor Engines	Drill rigs	Heaters	Fracing	Miscellaneous Engines	Artificial Lift	Dehydrator	Other Categories	Totals
Golden Valley , MT; Private/State	0	0	0	0	0	0	0	0	0
Hill , MT; Private/State	29	0	2	0	12	0	0	4	48
Liberty , MT; Private/State	13	6	4	6	6	1	0	1	39
Musselshell , MT; Private/State	4	0	2	0	1	1	0	0	9
Petroleum , MT; Private/State	2	1	1	1	1	0	0	0	6
Phillips , MT; Private/State	58	11	2	11	12	0	0	1	95
Pondera , MT; Private/State	62	1	8	1	7	2	0	2	82
Rosebud , MT; Private/State	32	1	3	1	2	1	0	1	41
Teton , MT; Private/State	8	0	4	0	3	1	0	1	18
Toole , MT; Private/State	192	51	35	52	39	9	1	16	395
Yellowstone , MT; Private/State	2	0	1	0	1	0	0	1	5
Blaine , MT; USFS	0	0	0	0	0	0	0	0	0
Cascade , MT; USFS	0	0	0	0	0	0	0	0	0
Chouteau , MT; USFS	0	0	0	0	0	0	0	0	0
Fergus , MT; USFS	0	0	0	0	0	0	0	0	0
Glacier , MT; USFS	0	0	0	0	0	0	0	0	0
Golden Valley , MT; USFS	0	0	0	0	0	0	0	0	0
Hill , MT; USFS	0	0	0	0	0	0	0	0	0
Liberty , MT; USFS	0	0	0	0	0	0	0	0	0
Musselshell , MT; USFS	0	0	0	0	0	0	0	0	0
Petroleum , MT; USFS	0	0	0	0	0	0	0	0	0
Phillips , MT; USFS	0	0	0	0	0	0	0	0	0
Pondera , MT; USFS	0	0	0	0	0	0	0	0	0
Rosebud , MT; USFS	0	0	0	0	0	0	0	0	0
Teton , MT; USFS	0	0	0	0	0	0	0	0	0
Toole , MT; USFS	0	0	0	0	0	0	0	0	0
Yellowstone , MT; USFS	0	0	0	0	0	0	0	0	0
Total	**1,165**	**125**	**104**	**128**	**160**	**23**	**3**	**44**	**1,753**

Table A-8. Great Plains Basin 2011 VOC emissions [tons/year] by source category and by mineral designation.

County	Compressor Engines	Pneumatic Devices	Venting - Blowdowns	Survey-based Fugitives	Dehydrator	Oil Tank	Casinghead Gas Venting	Water Tank Losses	Other Categories	Totals
Blaine , MT; BLM	3	2	3	5	17	38	0	9	8	84
Cascade , MT; BLM	0	0	0	0	0	0	0	0	0	0
Chouteau , MT; BLM	0	0	0	0	1	0	0	0	0	2
Fergus , MT; BLM	0	0	0	0	0	0	0	0	0	1
Glacier , MT; BLM	1	1	2	2	0	6	0	1	1	12
Golden Valley , MT; BLM	0	0	0	0	0	0	0	0	0	0
Hill , MT; BLM	0	0	0	0	1	0	0	0	0	2
Liberty , MT; BLM	1	1	2	2	0	22	0	1	5	33
Musselshell , MT; BLM	0	0	1	1	0	4	0	1	0	8
Petroleum , MT; BLM	1	1	3	4	0	10	0	29	1	49
Phillips , MT; BLM	14	12	5	10	65	0	0	11	8	126
Pondera , MT; BLM	0	0	0	0	0	1	0	0	0	1
Rosebud , MT; BLM	0	0	1	1	0	42	0	17	3	65
Teton , MT; BLM	0	0	0	0	0	0	0	0	0	0
Toole , MT; BLM	9	8	24	37	1	37	0	32	15	163
Yellowstone , MT; BLM	0	0	0	0	0	0	0	1	0	1
Blaine , MT; Tribal	0	0	0	0	0	0	0	0	0	1
Cascade , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Chouteau , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Fergus , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Glacier , MT; Tribal	14	13	38	60	3	195	0	55	68	447
Golden Valley , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Hill , MT; Tribal	1	1	0	1	6	0	0	0	0	8
Liberty , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Musselshell , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Petroleum , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Phillips , MT; Tribal	0	0	0	0	0	0	0	0	0	1
Pondera , MT; Tribal	1	1	3	5	0	20	0	2	2	33
Rosebud , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Teton , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Toole , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Yellowstone , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Blaine , MT; Private/State	56	9	10	17	61	229	0	43	34	459
Cascade , MT; Private/State	0	0	0	0	0	0	0	0	127	127
Chouteau , MT; Private/State	1	1	1	1	7	0	0	0	1	13
Fergus , MT; Private/State	0	0	0	0	0	0	0	0	0	0

County	Compressor Engines	Pneumatic Devices	Venting - Blowdowns	Survey-based Fugitives	Dehydrator	Oil Tank	Casinghead Gas Venting	Water Tank Losses	Other Categories	Totals
Glacier , MT; Private/State	36	16	44	69	9	198	0	99	37	508
Golden Valley , MT; Private/State	0	0	0	0	11	0	0	0	2	14
Hill , MT; Private/State	33	6	2	5	51	1	0	3	7	108
Liberty , MT; Private/State	8	7	15	24	14	160	0	29	64	320
Musselshell , MT; Private/State	3	3	9	14	0	139	0	182	11	360
Petroleum , MT; Private/State	1	1	4	6	0	14	0	26	3	54
Phillips , MT; Private/State	47	6	2	5	37	0	0	4	7	107
Pondera , MT; Private/State	16	11	31	48	2	105	0	76	14	303
Rosebud , MT; Private/State	31	4	12	18	0	171	0	164	35	434
Teton , MT; Private/State	6	5	16	25	0	56	0	35	6	151
Toole , MT; Private/State	97	51	131	207	48	308	0	272	148	1,260
Yellowstone , MT; Private/State	2	1	4	7	0	13	0	23	5	55
Blaine , MT; USFS	0	0	0	0	0	0	0	0	0	0
Cascade , MT; USFS	0	0	0	0	0	0	0	0	0	0
Chouteau , MT; USFS	0	0	0	0	0	0	0	0	0	0
Fergus , MT; USFS	0	0	0	0	0	0	0	0	0	0
Glacier , MT; USFS	0	0	0	0	0	0	0	0	0	0
Golden Valley , MT; USFS	0	0	0	0	0	0	0	0	0	0
Hill , MT; USFS	0	0	0	0	0	0	0	0	0	0
Liberty , MT; USFS	0	0	0	0	0	0	0	0	0	0
Musselshell , MT; USFS	0	0	0	0	0	0	0	0	0	0
Petroleum , MT; USFS	0	0	0	0	0	0	0	0	0	0
Phillips , MT; USFS	0	0	0	0	0	0	0	0	0	0
Pondera , MT; USFS	0	0	0	0	0	0	0	0	0	0
Rosebud , MT; USFS	0	0	0	0	0	0	0	0	0	0
Teton , MT; USFS	0	0	0	0	0	0	0	0	0	0
Toole , MT; USFS	0	0	0	0	0	0	0	0	0	0
Yellowstone , MT; USFS	0	0	0	0	0	0	0	0	0	0
Total	**382**	**161**	**361**	**575**	**337**	**1,766**	**0**	**1,116**	**613**	**5,311**

Table A-9. Great Plains Basin 2015 emissions of all criteria pollutants by county and by mineral designation.

County	Tribal Emissions [tons/yr]					Private/State Emissions [tons/yr]					BLM Emissions [tons/yr]					US Forest Service Emissions [tons/yr]				
	NOx	VOC	CO	SOx	PM	NOx	VOC	CO	Sox	PM	NOx	VOC	CO	SOx	PM	NOx	VOC	CO	SOx	PM
Blaine, MT	0	1	0	0	0	543	458	127	0	5	9	83	6	0	0	0	0	0	0	0
Cascade, MT	0	0	0	0	0	0	103	0	0	0	0	0	0	0	0	0	0	0	0	0
Chouteau, MT	0	0	0	0	0	5	11	3	0	0	1	2	0	0	0	0	0	0	0	0
Fergus, MT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Glacier, MT	58	447	42	0	2	107	493	105	0	2	2	12	1	0	0	0	0	0	0	0
Golden Valley, MT	0	0	0	0	0	0	11	0	0	1	0	0	0	0	0	0	0	0	0	0
Hill, MT	3	7	2	0	0	43	98	45	0	1	1	2	0	0	0	0	0	0	0	0
Liberty, MT	0	0	0	0	0	28	305	24	0	1	2	34	2	0	0	0	0	0	0	0
Musselshell, MT	0	0	0	0	0	10	456	9	0	0	1	10	1	0	0	0	0	0	0	0
Petroleum, MT	0	0	0	0	0	5	66	4	0	0	3	60	2	0	0	0	0	0	0	0
Phillips, MT	1	1	0	0	0	79	88	67	0	1	53	106	30	0	1	0	0	0	0	0
Pondera, MT	3	32	3	0	0	72	296	36	0	1	0	1	0	0	0	0	0	0	0	0
Rosebud, MT	0	0	0	0	0	35	524	15	0	1	1	83	1	0	0	0	0	0	0	0
Teton, MT	0	0	0	0	0	18	182	16	0	1	0	0	0	0	0	0	0	0	0	0
Toole, MT	0	0	0	0	0	293	1,242	194	0	9	26	161	22	0	1	0	0	0	0	0
Yellowstone, MT	0	0	0	0	0	5	66	6	0	0	0	2	0	0	0	0	0	0	0	0
Total	**66**	**488**	**47**	**0**	**2**	**1,244**	**4,399**	**651**	**1**	**23**	**98**	**556**	**67**	**0**	**2**	**0**	**0**	**0**	**0**	**0**

Table A-10. Great Plains Basin 2015 NOx emissions [tons/year] by source category and by mineral designation.

County	Compressor Engines	Drill rigs	Heaters	Fracing	Miscellaneous engines	Artificial Lift	Dehydrator	Other Categories	Totals
Blaine , MT; BLM	4	0	1	0	4	0	0	0	9
Cascade , MT; BLM	0	0	0	0	0	0	0	0	0
Chouteau , MT; BLM	0	0	0	0	0	0	0	0	1
Fergus , MT; BLM	0	0	0	0	0	0	0	0	0
Glacier , MT; BLM	1	0	0	0	0	0	0	0	2
Golden Valley , MT; BLM	0	0	0	0	0	0	0	0	0
Hill , MT; BLM	0	0	0	0	0	0	0	0	1
Liberty , MT; BLM	1	0	0	0	1	0	0	0	2
Musselshell , MT; BLM	0	0	0	0	0	0	0	0	1
Petroleum , MT; BLM	1	0	1	0	0	0	0	0	3
Phillips , MT; BLM	21	0	5	0	27	0	0	1	53
Pondera , MT; BLM	0	0	0	0	0	0	0	0	0
Rosebud , MT; BLM	0	0	0	0	0	0	0	0	1
Teton , MT; BLM	0	0	0	0	0	0	0	0	0
Toole , MT; BLM	13	0	6	0	5	2	0	1	26
Yellowstone , MT; BLM	0	0	0	0	0	0	0	0	0
Blaine , MT; Tribal	0	0	0	0	0	0	0	0	0
Cascade , MT; Tribal	0	0	0	0	0	0	0	0	0
Chouteau , MT; Tribal	0	0	0	0	0	0	0	0	0
Fergus , MT; Tribal	0	0	0	0	0	0	0	0	0
Glacier , MT; Tribal	20	9	10	9	7	3	0	1	58
Golden Valley , MT; Tribal	0	0	0	0	0	0	0	0	0
Hill , MT; Tribal	1	0	0	0	1	0	0	0	3
Liberty , MT; Tribal	0	0	0	0	0	0	0	0	0
Musselshell , MT; Tribal	0	0	0	0	0	0	0	0	0
Petroleum , MT; Tribal	0	0	0	0	0	0	0	0	0
Phillips , MT; Tribal	0	0	0	0	0	0	0	0	1
Pondera , MT; Tribal	2	0	1	0	0	0	0	0	3
Rosebud , MT; Tribal	0	0	0	0	0	0	0	0	0
Teton , MT; Tribal	0	0	0	0	0	0	0	0	0
Toole , MT; Tribal	0	0	0	0	0	0	0	0	0
Yellowstone , MT; Tribal	0	0	0	0	0	0	0	0	0
Blaine , MT; Private/State	500	11	4	11	15	0	0	1	543
Cascade , MT; Private/State	0	0	0	0	0	0	0	0	0
Chouteau , MT; Private/State	2	0	0	0	2	0	0	0	5
Fergus , MT; Private/State	0	0	0	0	0	0	0	0	0
Glacier , MT; Private/State	72	0	12	0	11	3	1	9	107

County	Compressor Engines	Drill rigs	Heaters	Fracing	Miscellaneous engines	Artificial Lift	Dehydrator	Other Categories	Totals
Golden Valley , MT; Private/State	0	0	0	0	0	0	0	0	0
Hill , MT; Private/State	25	0	2	0	12	0	0	3	43
Liberty , MT; Private/State	13	2	4	2	6	1	0	1	28
Musselshell , MT; Private/State	5	0	2	0	1	1	0	0	10
Petroleum , MT; Private/State	2	0	1	0	1	0	0	0	5
Phillips , MT; Private/State	49	8	2	8	12	0	0	1	79
Pondera , MT; Private/State	53	0	8	0	7	2	0	1	72
Rosebud , MT; Private/State	28	0	3	0	2	1	0	0	35
Teton , MT; Private/State	9	0	4	0	3	1	0	1	18
Toole , MT; Private/State	171	13	35	13	38	9	1	13	293
Yellowstone , MT; Private/State	2	0	1	0	1	0	0	1	5
Blaine , MT; USFS	0	0	0	0	0	0	0	0	0
Cascade , MT; USFS	0	0	0	0	0	0	0	0	0
Chouteau , MT; USFS	0	0	0	0	0	0	0	0	0
Fergus , MT; USFS	0	0	0	0	0	0	0	0	0
Glacier , MT; USFS	0	0	0	0	0	0	0	0	0
Golden Valley , MT; USFS	0	0	0	0	0	0	0	0	0
Hill , MT; USFS	0	0	0	0	0	0	0	0	0
Liberty , MT; USFS	0	0	0	0	0	0	0	0	0
Musselshell , MT; USFS	0	0	0	0	0	0	0	0	0
Petroleum , MT; USFS	0	0	0	0	0	0	0	0	0
Phillips , MT; USFS	0	0	0	0	0	0	0	0	0
Pondera , MT; USFS	0	0	0	0	0	0	0	0	0
Rosebud , MT; USFS	0	0	0	0	0	0	0	0	0
Teton , MT; USFS	0	0	0	0	0	0	0	0	0
Toole , MT; USFS	0	0	0	0	0	0	0	0	0
Yellowstone , MT; USFS	0	0	0	0	0	0	0	0	0
Total	**996**	**43**	**105**	**44**	**159**	**23**	**3**	**34**	**1,408**

Table A-11. Great Plains Basin 2015 VOC emissions [tons/year] by source category and by mineral designation.

County	Compressor Engines	Pneumatic Devices	Venting - Blowdowns	Survey-based Fugitives	Dehydrator	Oil Tank	Casinghead Gas Venting	Water Tank Losses	Other Categories	Totals
Blaine , MT; BLM	3	2	3	4	14	41	0	8	7	83
Cascade , MT; BLM	0	0	0	0	0	0	0	0	0	0
Chouteau , MT; BLM	0	0	0	0	1	0	0	0	0	2
Fergus , MT; BLM	0	0	0	0	0	0	0	0	0	1
Glacier , MT; BLM	1	1	2	2	0	5	0	1	1	12
Golden Valley , MT; BLM	0	0	0	0	0	0	0	0	0	0
Hill , MT; BLM	0	0	0	0	1	0	0	0	0	2
Liberty , MT; BLM	1	1	2	2	0	21	0	1	6	34
Musselshell , MT; BLM	0	0	1	1	0	6	0	1	0	10
Petroleum , MT; BLM	1	1	3	4	0	13	0	37	1	60
Phillips , MT; BLM	14	12	5	10	48	0	0	8	8	106
Pondera , MT; BLM	0	0	0	0	0	1	0	0	0	1
Rosebud , MT; BLM	0	0	1	2	0	53	0	22	4	83
Teton , MT; BLM	0	0	0	0	0	0	0	0	0	0
Toole , MT; BLM	9	8	24	37	1	35	0	31	15	161
Yellowstone , MT; BLM	0	0	0	0	0	0	0	1	0	2
Blaine , MT; Tribal	0	0	0	0	0	0	0	0	0	1
Cascade , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Chouteau , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Fergus , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Glacier , MT; Tribal	14	13	39	61	3	189	0	53	75	447
Golden Valley , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Hill , MT; Tribal	1	1	0	1	5	0	0	0	0	7
Liberty , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Musselshell , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Petroleum , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Phillips , MT; Tribal	0	0	0	0	0	0	0	0	0	1
Pondera , MT; Tribal	1	1	3	5	0	19	0	1	2	32
Rosebud , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Teton , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Toole , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Yellowstone , MT; Tribal	0	0	0	0	0	0	0	0	0	0
Blaine , MT; Private/State	47	9	10	17	50	251	0	44	31	458
Cascade , MT; Private/State	0	0	0	0	0	0	0	0	103	103
Chouteau , MT; Private/State	1	1	1	1	6	0	0	0	1	11
Fergus , MT; Private/State	0	0	0	0	0	0	0	0	0	0

County	Compressor Engines	Pneumatic Devices	Venting - Blowdowns	Survey-based Fugitives	Dehydrator	Oil Tank	Casinghead Gas Venting	Water Tank Losses	Other Categories	Totals
Glacier , MT; Private/State	33	16	44	69	8	192	0	96	35	493
Golden Valley , MT; Private/State	0	0	0	0	9	0	0	0	2	11
Hill , MT; Private/State	28	6	2	5	42	1	0	2	11	98
Liberty , MT; Private/State	8	7	15	24	13	155	0	27	57	305
Musselshell , MT; Private/State	3	3	9	15	0	178	0	234	14	456
Petroleum , MT; Private/State	1	1	4	6	0	17	0	32	4	66
Phillips , MT; Private/State	39	6	2	5	28	0	0	3	6	88
Pondera , MT; Private/State	15	11	31	48	2	102	0	74	13	296
Rosebud , MT; Private/State	26	4	13	20	0	219	0	210	32	524
Teton , MT; Private/State	6	6	18	28	0	72	0	45	7	182
Toole , MT; Private/State	89	51	131	207	42	299	0	262	161	1,242
Yellowstone , MT; Private/State	2	2	5	7	0	17	0	29	5	66
Blaine , MT; USFS	0	0	0	0	0	0	0	0	0	0
Cascade , MT; USFS	0	0	0	0	0	0	0	0	0	0
Chouteau , MT; USFS	0	0	0	0	0	0	0	0	0	0
Fergus , MT; USFS	0	0	0	0	0	0	0	0	0	0
Glacier , MT; USFS	0	0	0	0	0	0	0	0	0	0
Golden Valley , MT; USFS	0	0	0	0	0	0	0	0	0	0
Hill , MT; USFS	0	0	0	0	0	0	0	0	0	0
Liberty , MT; USFS	0	0	0	0	0	0	0	0	0	0
Musselshell , MT; USFS	0	0	0	0	0	0	0	0	0	0
Petroleum , MT; USFS	0	0	0	0	0	0	0	0	0	0
Phillips , MT; USFS	0	0	0	0	0	0	0	0	0	0
Pondera , MT; USFS	0	0	0	0	0	0	0	0	0	0
Rosebud , MT; USFS	0	0	0	0	0	0	0	0	0	0
Teton , MT; USFS	0	0	0	0	0	0	0	0	0	0
Toole , MT; USFS	0	0	0	0	0	0	0	0	0	0
Yellowstone , MT; USFS	0	0	0	0	0	0	0	0	0	0
Total	**345**	**162**	**365**	**582**	**274**	**1,886**	**0**	**1,225**	**603**	**5,443**

APPENDIX B

Survey-based Well Site Source Input Factors

Appendix B. Survey-based Well Site Source Input Factors

Table B-1. Survey-based Well Site Source Input Factors.

Parameter	Oil Wells	Gas Wells	Unit	Source
Artificial Lift Engines				
Percent of wells that have an artificial lift engine	27%	-	unitless	Operator Surveys
Rated Horsepower	9	-	hp	Operator Surveys
Load Factor	75%	-	unitless	Operator Surveys
Hours of Operation	1248	-	hr/year	Operator Surveys
Fuel Type (Natural Gas, Gasoline, Diesel, Electric)	Natural Gas	-	unitless	Operator Surveys
Natural Gas Engines: Percent that are Lean Burn	100%	-	unitless	Operator Surveys
Natural Gas Engines: Percent that are Rich Burn	0%	-	unitless	Operator Surveys
Percent of Artificial Lift Engines that are Electric	66%	-	unitless	Operator Surveys
Nox EF	11.99	-	g/bhp-hr	EPA NONROAD2008a Model
CO EF	40.93	-	g/bhp-hr	EPA NONROAD2008a Model
VOC EF	1.28	-	g/bhp-hr	EPA NONROAD2008a Model
PM10 EF	0.05	-	g/bhp-hr	EPA NONROAD2008a Model
SOx EF	0.00	-	g/bhp-hr	
Blowdown Venting and Flaring				
Basinwide VOC Fraction (molar)	10%	0.37%	unitless	Operator Surveys
Basinwide VOC molecular weight	62	48	g/mol	Operator Surveys
Heating Value of Gas	1,043	978	BTU/SCF	Operator Surveys
Annual number of blowdowns	2	2	events/well/year	EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Total volume of gas vented per blowdown event	7.65	7.65	MCF/event	EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Fraction of Vented Gas Flared	0%	0%	unitless	EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Flare Destruction Efficiency	98%	98%	unitless	Assumed Value
Flaring NOx EF	0.068	0.068	lb/MMBtu	EPA AP-42, Table 13.5-1
Flaring CO EF	0.37	0.37	lb/MMBtu	EPA AP-42, Table 13.5-1
Compressor Engines				
Percentage of wells that have a lateral compressor engine	100.00%	26.87%	unitless	Gas wells - Operator Surveys, Oil Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)

Parameter	Oil Wells	Gas Wells	Unit	Source
Number of wells per typical lateral compressor engine	183	137	no. of wells	Gas wells - Operator Surveys, Oil Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Rated Horsepower	1239	851	hp	Gas wells - Operator Surveys, Oil Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Load Factor	90%	80%	unitless	Gas wells - Operator Surveys, Oil Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Hours of Operation	8016	8760	hours/engine/year	Gas wells - Operator Surveys, Oil Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Fuel Type (Natural Gas, Gasoline, Diesel, Electric)	Natural Gas	Natural Gas		Gas wells - Operator Surveys, Oil Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Natural Gas Engines: Percent that are Lean Burn	96%	59%	unitless	Gas wells - Operator Surveys, Oil Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Natural Gas Engines: Percent that are Rich Burn	4%	41%	unitless	Gas wells - Operator Surveys, Oil Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Nox EF	1.43	1.43	g/bhp-hr	Operator Surveys
CO EF	1.10	1.10	g/bhp-hr	Operator Surveys
VOC EF	1.00	1.00	g/bhp-hr	Operator Surveys
PM10 EF	0.04	0.04	g/bhp-hr	EPA AP-42 Table 3-2-2
SOx EF	0.00	0.00	g/bhp-hr	EPA AP-42 Table 3-2-2
Compressor Startup/Shutdown				
Startup: Average volume of gas used per event	24.32	24.32	MCF/year	Operator Surveys
Startup: Average no. of events per engine	6.84	6.84	events/engine/year	Operator Surveys
Startup: No. of engines	12	9	no. of engines	Operator Surveys
Startup: Total Startup or Shutdown Events	85	60	events/year	Operator Surveys
Shutdown: Average volume of gas used per event	24.32	24.32	MCF/year	Operator Surveys
Shutdown: Average no. of events per engine	6.84	6.84	events/engine/year	Operator Surveys
Shutdown: No. of engines	12	9	no. of engines	Operator Surveys
Shutdown: Total Startup or Shutdown Events	85	60	events/year	Operator Surveys
Basinwide VOC Fraction (molar)	10.31%	0.37%	unitless	Operator Surveys

Parameter	Oil Wells	Gas Wells	Unit	Source
Basinwide VOC molecular weight	61.97	47.51	g/mol	Operator Surveys
Compressor Fugitives				
Fugitive emission factor for reciprocating engines	9.48	9.48	Mcf/compressor CH4	EPA/GRI 1996 study: Methane Emissions from the Natural Gas Industry, Volume 8: Equipment Leaks
CH4 Mole fraction	70%	70%	unitless	EPA/GRI 1996 study: Methane Emissions from the Natural Gas Industry, Volume 8: Equipment Leaks
Number of Compressor Engines	12	9	engines	Operator Surveys
Basinwide VOC Fraction (molar)	23%	1%	unitless	Operator Surveys
Basinwide VOC molecular weight	62	48	g/mol	Operator Surveys
Casinghead Flaring and Venting				
Percent of Casinghead Gas To Pipeline	94.4%	-	unitless	Operator Surveys
Percent of Casinghead Gas Flared	2.3%	-	unitless	Operator Surveys
Percent of Casinghead Gas Vented to Atmosphere	3.3%	-	unitless	Operator Surveys
Heating Value	1043	-	Btu/SCF	Operator Surveys
Flare Destruction Efficiency	90%	-	unitless	Operator Surveys
Basinwide VOC Fraction (molar)	10%	-	unitless	Operator Surveys
Basinwide VOC molecular weight	62	-	g/mol	Operator Surveys
Flaring NOx EF	0.068	-	lb/MMBtu	EPA AP-42, Table 13.5-1
Flaring CO EF	0.37	-	lb/MMBtu	EPA AP-42, Table 13.5-1
Condensate Tank Flaring and Venting				
Fraction of condensate directed to tanks	-	100.00%	unitless	EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Fraction of condensate tanks with a flare	-	9.18%	unitless	EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Capture Efficiency of the flare	-	100.00%	unitless	EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Control Efficiency of the flare	-	98.00%	unitless	EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Emission factor of VOC per barrel (BBL) of condensate throughput	-	7.00	lb VOC/bbl	EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Basinwide VOC molecular weight	-	58	g/mol	Phase III 2006 Uinta Emission Inventory, WRAP Phase III (ENVIRON, 2008)
Basinwide VOC mol fraction	-	31%	unitless	Phase III 2006 Uinta Emission Inventory, WRAP Phase III (ENVIRON, 2008)

Parameter	Oil Wells	Gas Wells	Unit	Source
Flaring NOx EF	-	0.068	0.068	EPA AP-42, Table 13.5-1
Flaring CO EF	-	0.37	0.37	EPA AP-42, Table 13.5-1
Dehydrator Venting and Flaring				
No. of Dehydrators Per Well	0.001	0.002	no. or dehydrators/well	Gas wells - Operator Surveys, Oil Wells - EPA Oil and Gas Tool Inputs for South San Juan Basin (ENVIRON 2013)
Dehydrator Uncontrolled VOC Emissions	22	15	lb/MMscf	Gas wells - Operator Surveys, Oil Wells - EPA Oil and Gas Tool Inputs for South San Juan Basin (ENVIRON 2013)
Percent of Dehydrators that are Uncontrolled	100%	100%	unitless	Gas wells - Operator Surveys, Oil Wells - EPA Oil and Gas Tool Inputs for South San Juan Basin (ENVIRON 2013)
Percent of Dehydrators that are Controlled by Flare	0%	0%	unitless	Gas wells - Operator Surveys, Oil Wells - Assumed same as gas wells
Percent of Dehydrators Controlled by Routing to System	0%	0%	unitless	Gas wells - Operator Surveys, Oil Wells - Assumed same as gas wells
Flaring Control Efficiency	98%	98%	unitless	Assumed Value
Basinwide VOC molecular weight	68	68	g/mol	2011 Williston Basin Operator Surveys
Basinwide VOC molar fraction	20%	20%	unitless	2011 Williston Basin Operator Surveys
Heating Value of Gas	1651	1651	BTU/SCF	2011 Williston Basin Operator Surveys
Flaring NOx EF	0.068	0.068	lb/MMBtu	EPA AP-42, Table 13.5-1
Flaring CO EF	0.37	0.37	lb/MMBtu	EPA AP-42, Table 13.5-1
Drilling				
Number of Engines	7	7	no. of engines	Operator Surveys
Total Rated Horsepower	3260	3260	hp	Operator Surveys
Load Factor	81%	81%	unitless	Operator Surveys
Hours of Operation	193	193	hours/spud	Operator Surveys
Fuel Type (Natural Gas, Gasoline, Diesel, Electric)	Diesel	Diesel		Operator Surveys
EFs: NOx	4.35	4.35	g/bhp-hr	EPA NONROAD2008a Model
EFs: CO	1.56	1.56	g/bhp-hr	EPA NONROAD2008a Model
EFs: VOC	0.28	0.28	g/bhp-hr	EPA NONROAD2008a Model
EFs: SOx	0.004	0.004	g/bhp-hr	EPA NONROAD2008a Model
EFs: PM10	0.23	0.23	g/bhp-hr	EPA NONROAD2008a Model
Fracing				
Percent of spuds where fracing was performed	87%	87%	unitless	2011 Williston Basin Operator Surveys

Parameter	Oil Wells	Gas Wells	Unit	Source
Number of Engines	6	6	no. of engines	2011 Williston Basin Operator Surveys
Total Rated Horsepower	14169	14169	hp	2011 Williston Basin Operator Surveys
Load Factor	46%	46%	unitless	2011 Williston Basin Operator Surveys
Hours of Operation	50	50	hours/frac job	2011 Williston Basin Operator Surveys
Fuel Type (Natural Gas, Gasoline, Diesel, Electric)	Diesel	Diesel		2011 Williston Basin Operator Surveys
EFs: NOx	5.83	5.83	g/bhp-hr	EPA NONROAD2008a Model
EFs: CO	1.32	1.32	g/bhp-hr	EPA NONROAD2008a Model
EFs: VOC	0.37	0.37	g/bhp-hr	EPA NONROAD2008a Model
EFs: SOx	0.003	0.00	g/bhp-hr	EPA NONROAD2008a Model
EFs: PM10	0.23	0.23	g/bhp-hr	EPA NONROAD2008a Model
Number of Heaters per frac job	3.00	3.00	no. of heaters	2011 Williston Basin Operator Surveys
Heater MMBtu Rating	0.03	0.03	MMBtu/hr	2011 Williston Basin Operator Surveys
Heater Usage per frac job	50.00	50.00	hours/frac job	2011 Williston Basin Operator Surveys
Heater Cycling (fraction of the time the heater is doing work when it is turned on)	1.00	1.00	unitless	2011 Williston Basin Operator Surveys
Heating Value	90,500	90,500	BTU/gal propane	EPA AP-42 Emission Factor, Table 1.5-1
EFs: NOx	13	13	lb/10^3 gal	EPA AP-42 Emission Factor, Table 1.5-1
EFs: VOC	1	1	lb/10^3 gal	EPA AP-42 Emission Factor, Table 1.5-1
EFs: CO	8	8	lb/10^3 gal	EPA AP-42 Emission Factor, Table 1.5-1
EFs: SOx	0	0	lb/10^3 gal	EPA AP-42 Emission Factor, Table 1.5-1
EFs: PM10	1	1	lb/10^3 gal	EPA AP-42 Emission Factor, Table 1.5-1
Fugitives				
hours of operation	8760	8760	per year	Assumed Value
VOC/TOC ratio	35%	1%	unitless	Operator Surveys
No. of Devices per Well: valves - Gas	0.05	13.53	component count/well	Operator Surveys
No. of Devices per Well: pump seals - Gas	0.00	0.00	component count/well	Operator Surveys
No. of Devices per Well: others (please provide description) - Gas	0.06	0.53	component count/well	Operator Surveys
No. of Devices per Well: connectors - Gas	0.90	58.70	component count/well	Operator Surveys
No. of Devices per Well: flanges - Gas	0.15	0.82	component count/well	Operator Surveys

Parameter	Oil Wells	Gas Wells	Unit	Source
No. of Devices per Well: open-ended lines - Gas	0.03	1.15	component count/well	Operator Surveys
No. of Devices per Well: non-GAS DEVICES -	0.00	0.00	component count/well	Operator Surveys
No. of Devices per Well: valves - Heavy Oil	7.05	0.00	component count/well	Operator Surveys
No. of Devices per Well: valves - Light Oil	0.16	0.00	component count/well	Operator Surveys
No. of Devices per Well: valves - Water/Oil	0.00	0.00	component count/well	Operator Surveys
No. of Devices per Well: pump seals - Heavy Oil	0.87	0.00	component count/well	Operator Surveys
No. of Devices per Well: pump seals - Light Oil	0.05	0.00	component count/well	Operator Surveys
No. of Devices per Well: pump seals - Water/Oil	0.00	0.00	component count/well	Operator Surveys
No. of Devices per Well: others (please provide description) - Heavy Oil	4.86	0.00	component count/well	Operator Surveys
No. of Devices per Well: others (please provide description) - Light Oil	0.06	0.00	component count/well	Operator Surveys
No. of Devices per Well: others (please provide description) - Water/Oil	0.00	0.00	component count/well	Operator Surveys
No. of Devices per Well: connectors - Heavy Oil	4.19	0.00	component count/well	Operator Surveys
No. of Devices per Well: connectors - Light Oil	0.84	0.00	component count/well	Operator Surveys
No. of Devices per Well: connectors - Water/Oil	0.00	0.00	component count/well	Operator Surveys
No. of Devices per Well: flanges - Heavy Oil	5.55	0.00	component count/well	Operator Surveys
No. of Devices per Well: flanges - Light Oil	0.24	0.00	component count/well	Operator Surveys
No. of Devices per Well: flanges - Water/Oil	0.00	0.00	component count/well	Operator Surveys
No. of Devices per Well: open-ended lines - Heavy Oil	0.46	0.00	component count/well	Operator Surveys

Parameter	Oil Wells	Gas Wells	Unit	Source
No. of Devices per Well: open-ended lines - Light Oil	0.00	0.00	component count/well	Operator Surveys
Heaters				
Number of Heaters per well	0.31	0.24	no. of heaters/well	Operator Surveys
Heater MMBtu Rating	0.39	0.07	MMBtu/hr	Operator Surveys
Annual Heater Usage	7858	5158	hrs	Operator Surveys
Heater Cycling (fraction of the time the heater is doing work when it is turned on)	0.89	1.00	unitless	Operator Surveys
Heating Value	1135	982	Btu/SCF	Operator Surveys
EFs: NOx	100	100	lb/MMscf	EPA AP-42 Emission Factor, Table 1.4-1 and Table 1.4-2
EFs: VOC	6	6	lb/MMscf	EPA AP-42 Emission Factor, Table 1.4-1 and Table 1.4-3
EFs: CO	84	84	lb/MMscf	EPA AP-42 Emission Factor, Table 1.4-1 and Table 1.4-4
EFs: SOx	0	0	lb/MMscf	
EFs: PM	8	8	lb/MMscf	EPA AP-42 Emission Factor, Table 1.4-1 and Table 1.4-6
Initial Completion Venting and Flaring				
Flaring Control Efficiency	98%	98%	unitless	Assumed Value
Gas Molecular weight	27	17	g/mol	Operator Surveys
Basinwide VOC Fraction (molar)	10%	0%	unitless	Operator Surveys
Basinwide VOC molecular weight	62	48	g/mol	Operator Surveys
Green Completion: Percent of Completions By Type	29%	29%	unitless	EPA Oil and Gas Tool Inputs for Uinta Basin (ENIVRON 2013)
Green Completion: Total Volume of Gas Generated Per Completion (MCF/completion)	0	0	MCF/completion	EPA Oil and Gas Tool Inputs for Uinta Basin (ENIVRON 2013)
Green Completion: Volume of Gas Vented to Atmosphere Per Completion (MCF/completion)	0	0	MCF/completion	EPA Oil and Gas Tool Inputs for Uinta Basin (ENIVRON 2013)
Green Completion: Volume of Gas Flared Per Completion (MCF/completion)	0	0	MCF/completion	EPA Oil and Gas Tool Inputs for Uinta Basin (ENIVRON 2013)
Green Completion: Volume of Gas Controlled by Closed-loop System (MCF/completion)	-	-	MCF/completion	EPA Oil and Gas Tool Inputs for Uinta Basin (ENIVRON 2013)
Conventional Completion: Percent of Completions By Type	71%	71%	unitless	EPA Oil and Gas Tool Inputs for Uinta Basin (ENIVRON 2013)

Parameter	Oil Wells	Gas Wells	Unit	Source
Conventional Completion: Total Volume of Gas Generated Per Completion (MCF/completion)	120	120	MCF/completion	EPA Oil and Gas Tool Inputs for Uinta Basin (ENIVRON 2013)
Conventional Completion: Volume of Gas Vented to Atmosphere Per Completion (MCF/completion)	115	115	MCF/completion	EPA Oil and Gas Tool Inputs for Uinta Basin (ENIVRON 2013)
Conventional Completion: Volume of Gas Flared Per Completion (MCF/completion)	6	6	MCF/completion	EPA Oil and Gas Tool Inputs for Uinta Basin (ENIVRON 2013)
Conventional Completion: Volume of Gas Controlled by Closed-loop System (MCF/completion)	-	-	MCF/completion	EPA Oil and Gas Tool Inputs for Uinta Basin (ENIVRON 2013)
Miscellaneous Engines				
EFs: NOx	0.02	0.02	tons/well	2006 Uinta Emission Inventory, WRAP Phase III (ENVIRON, 2008)
EFs: VOC	0.01	0.01	tons/well	2006 Uinta Emission Inventory, WRAP Phase III (ENVIRON, 2008)
EFs: CO	0.01	0.01	tons/well	2006 Uinta Emission Inventory, WRAP Phase III (ENVIRON, 2008)
EFs: PM10	0.00	0.00	tons/well	2006 Uinta Emission Inventory, WRAP Phase III (ENVIRON, 2008)
EFs: SOx	0.00	0.00	tons/well	2006 Uinta Emission Inventory, WRAP Phase III (ENVIRON, 2008)
Oil Tank Venting and Flaring				
Percent of Tanks that are Uncontrolled	100%	-	unitless	Operator Surveys
Percent of Tanks that are Controlled by Flare	0%	-	unitless	Operator Surveys
Percent of Tanks that are Controlled by VRU	0%	-	unitless	Operator Surveys
Percent of Tanks that are Controlled by Encolosed Combustion Devices	0%	-	unitless	Operator Surveys
Flaring Control Efficiency	98%	-	unitless	Assumed Value
Uncontrolled Combined Flashing, Working and Breathing VOC Emission Factor	1.94	-	lb VOC/bbl	Operator Surveys
Pneumatic Devices				
Annual Hours of Operation	8760	8760	hrs	Assumed Value
Number of High Bleed Devices per Well	-	-	no. of devices	Operator Surveys
High Bleed Device Rate	N/A	N/A	scf/hr	Operator Surveys
Number of Intermittent Devices per Well	0.03	0.13	no. of devices	Device count -Oerator Surveys, Bleed Rate - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)

Parameter	Oil Wells	Gas Wells	Unit	Source
Intermittent Bleed Device Rate	23.66	23.66	scf/hr	Device count -Oerator Surveys, Bleed Rate - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Number of Low Devices per Well	0.01	0.38	no. of devices	Operator Surveys
Low Bleed Device Rate	6.00	6.00	scf/hr	Operator Surveys
Pneumatic Pump				
Methane vent rate for gas wells	-	911	SCF/Pump/day	Oil Wells- Operator Surveys, Gas Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Average pump hours of operation	-	8760	hr/year	Oil Wells- Operator Surveys, Gas Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Average number of pumps per well	0.04	0.72	count/well	Oil Wells- Operator Surveys, Gas Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
VOC Fraction (Weight)	-	1%	unitless	Operator Surveys
CH4 Fraction (Weight)	-	92%	unitless	Operator Surveys
Gas Usage (cf/gal chemical pumped)	42	-	scf/gal chemical pumped	Oil Wells- Operator Surveys, Gas Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Total Volume of Chemical Pumped per Year per Pump	360	-	gal/pump/year	Oil Wells- Operator Surveys, Gas Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Percent of Pumps that are Uncontrolled	100%	-	unitless	Oil Wells- Operator Surveys, Gas Wells - EPA Oil and Gas Tool Inputs for Uinta Basin (ENVIRON 2013)
Workover				
Workover Frequency	0.4	0.1	events/well/year	Operator Surveys
Number of Engines	1	1	no. of engines	Operator Surveys
Total Rated Horsepower Per Engine (hp)	488	427	hp	Operator Surveys
Load Factor	0.8	0.6	unitless	Operator Surveys
Hours of Operation	9.6	10.3	hours/workover	Operator Surveys
Fuel Type (Natural Gas, Gasoline, Diesel, Electric)	Diesel	Diesel		Operator Surveys
EFs: NOx	3.82	4.26	g/bhp-hr	EPA NONROAD2008a Model
EFs: CO	0.94	1.14	g/bhp-hr	EPA NONROAD2008a Model

Parameter	Oil Wells	Gas Wells	Unit	Source
EFs: VOC	0.12	0.21	g/bhp-hr	EPA NONROAD2008a Model
EFs: SOx	0.00	0.00	g/bhp-hr	EPA NONROAD2008a Model
EFs: PM10	0.17	0.17	g/bhp-hr	EPA NONROAD2008a Model
Well Truck Loading				
Fraction of Total Oil Production Sent Directly to Pipeline, Not Subject to Wellsite Loading	0%	0%	unitless	Oil Wells Operator Surveys Gas Wells EPA Oil and Gas Tool Inputs for Uinta Basin, 2013
True vapor pressure of liquid loaded	2.21	5.02	psi	Oil Wells Operator Surveys Gas Wells EPA Oil and Gas Tool Inputs for Uinta Basin, 2013
Temperature of Liquid Loaded	521	530	°R	Oil Wells Operator Surveys Gas Wells EPA Oil and Gas Tool Inputs for Uinta Basin, 2013
Molecular Weight of Liquid Loaded (lb/lb-mole)	50.0	59.7	lb/lb-mole	Oil Wells EPA AP-42, Table 7.1-2 Gas Wells EPA Oil and Gas Tool Inputs for Uinta Basin, 2013
Fraction of Tanks Mode of operation: Submerged Loading of a Clean cargo tank	25%	0%	unitless	Oil Wells Operator Surveys Gas Wells EPA Oil and Gas Tool Inputs for Uinta Basin, 2013
Fraction Of Tanks Mode of operation: submerged loading: dedicated vapor balance service	75%	0%	unitless	Oil Wells Operator Surveys Gas Wells EPA Oil and Gas Tool Inputs for Uinta Basin, 2013
Fraction of Tanks Mode of operation: submerged loading: dedicated normal service	0%	100%	unitless	Gas Wells EPA Oil and Gas Tool Inputs for Uinta Basin, 2013
Saturation Factor for Submerged Loading of a Clean cargo tank	0.60	-	unitless	EPA AP-42, Table 5.2-1
Saturation Factor for submerged loading: dedicated vapor balance service	1.00	-	unitless	EPA AP-42, Table 5.2-1
Saturation Factor for submerged loading: submerged loading: dedicated normal service	-	0.55	unitless	Gas Wells EPA Oil and Gas Tool Inputs for Uinta Basin, 2013
VOC Weight Fraction	95%	95%	unitless	Oil Wells EPA Oil and Gas Tool Inputs for Uinta Basin, 2013 Gas Wells EPA Oil and Gas Tool Inputs for Uinta Basin, 2013
Loading Losses	2.26	3.70	lb/1000 gallons	
Water Tank Venting and Flaring				
Directly to a Wellsite Tank	27%	27%	unitless	Operator Surveys

Parameter	Oil Wells	Gas Wells	Unit	Source
Directly to Pipeline to Injection Well	13%	13%	unitless	Operator Surveys
Directly to Pipeline to Water Disposal Pit	60%	60%	unitless	Operator Surveys
Other (please specify)	0%	0%	unitless	Operator Surveys
Percent of Tanks that are Uncontrolled	100%	100%	unitless	Operator Surveys
Percent of Tanks that are Controlled by Flare	0%	0%	unitless	Operator Surveys
Percent of Tanks that are Controlled by VRU	0%	0%	unitless	Operator Surveys
Percent of Tanks that are Controlled by Encolosed Combustion Devices	0%	0%	unitless	Operator Surveys
Flaring Control Efficiency	98%	98%	unitless	Assumed Value
VRU Control Efficiency	99%	99%	unitless	Assumed Value
Uncontrolled VOC Emission Factor	0.18	0.18	lb/bbl	Operator Surveys