DEVELOPMENT OF BASELINE 2006 EMISSIONS FROM OIL AND GAS ACTIVITY IN THE DENVER-JULESBURG BASIN

Prepared for
Colorado Department of Public Health and
Environment Air Pollution Control Division

Prepared by
Amnon Bar-Ilan
John Grant
Ron Friesen
Alison K. Pollack
ENVIRON International Corporation
773 San Marin Drive, Suite 2115
Novato, CA 94998

Doug Henderer
Daniel Pring
Buys & Associates
300 E. Mineral Ave., Suite 10
Littleton, CO 80122

Kathleen Sgamma
Independent Petroleum Association of Mountain States (IPAMS)
410 17th Street, Suite 1920
Denver, CO 80202

April 30, 2008

TABLE OF CONTENTS

Page

TABLES

FIGURES

INTRODUCTION

The Independent Petroleum Association of Mountain States (IPAMS) is sponsoring the development of a Phase III regional oil and gas emission inventory for the inter-Mountain West jointly with the Western Regional Air Partnership (WRAP), to build on the WRAP Phase I and Phase II inventory projects. This effort is focused on creating a comprehensive criteria pollutant emissions inventory for all activities associated with oil and gas field operations in the basins throughout the study region for year 2006 as well as future projection years; that includes all point and area sources related to the oil and gas industry.

The initial region of interest for the emission inventory is the Denver-Julesburg (D-J) Basin, which includes the 8-hour ozone nonattainment area under the jurisdiction of the Air Pollution Control Division (APCD) of the Colorado Department of Public Health and Environment (CDPHE). The 2006 baseline inventory consists of two primary categories: sources subject to Air Pollution Emission Notice (APEN) reporting requirements, and sources exempt from APEN reporting, which are collectively termed "unpermitted" sources in this document. This document describes the methodologies by which the 2006 inventory was constructed. This methodology is specific to the D-J Basin and will have additions and changes for other basins in the Phase III project. For each source category, a basic description is given of the methodology used to estimate emissions from a single source or from all sources belonging to companies that participated in the survey effort ("participating companies"), and a description of how those emissions were scaled up to the county and basin-wide level.

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"), the State of Colorado's database of permitted sources including APENs sources and Regulation 7 reports, and detailed survey responses of oil and gas activity from several major participating companies that operate in the D-J Basin. Some additional data sources were also used, including American Petroleum Institute (API) technical literature, the US Environmental Protection Agency's (EPA) AP-42 emissions factor technical guidance, the US EPA's NONROAD emissions model, and the US EPA's Natural Gas Star program technical guidance.

Temporal and Geographic Scope

This inventory considers a base year of 2006 for purposes of estimating emissions, consistent with the year for which episodic air quality modeling will be conducted for the upcoming Denver metropolitan area 8-hour ozone SIP modeling effort. All data requested from participating companies were for these companies' activities in the calendar year 2006. Similarly, all well count and production data for the basin obtained from the IHS database were for the calendar year 2006. 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 D-J Basin, whose boundaries as defined by the US Geological Survey (USGS) were used. The USGS boundaries for the D-J Basin were intersected with the State of Colorado boundaries so that only the portion of the D-J Basin within Colorado

was considered for this inventory. The following counties were wholly contained within the boundaries of the D-J Basin in this inventory:

- Adams
- Arapahoe
- Boulder
- Broomfield
- Crowley
- Denver
- Douglas
- Elbert
- El Paso
- Fremont
- Jefferson
- Kit Carson
- Larimer
- Lincoln
- Logan
- Morgan
- Phillips
- Pueblo
- Sedgwick
- Teller
- Washington
- Weld
- Yuma

Figure 1 shows the boundaries of the D-J Basin, with the 2006 well locations extracted from the IHS database overlaid.

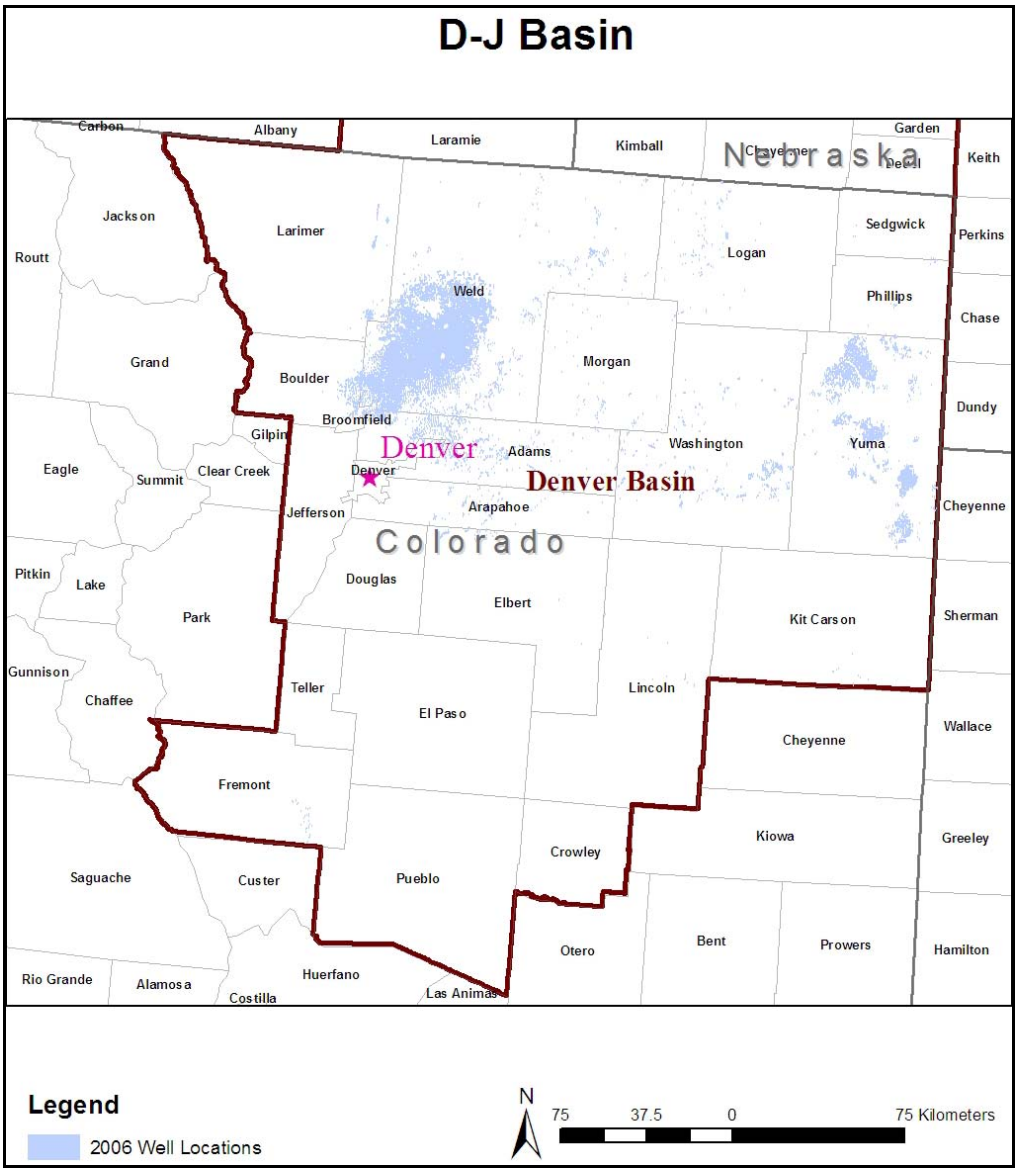

Figure 1. D-J Basin boundaries overlaid and 2006 oil and gas well locations.

Well Count and Production Data

Oil and gas related activity data across the entire D-J Basin were obtained from the IHS Enerdeq database queried via online interface. The IHS database uses data from the Colorado Oil and Gas Conservation Commission (COGCC) as a source of information for Colorado oil and gas activity. Two types of data were queried from the Enerdeq database: production data and well data. Production data includes information relevant to producing wells in the basin while well data includes information relevant to drilling activity ("spuds") and completions in the basin.

Production data were obtained for the counties that make up the D-J Basin in the form of PowerTools input files. PowerTools is an IHS application which, given PowerTools inputs queried from an IHS database, analyzes, integrates, and summarizes production data in an ACCESS database. The D-J Basin PowerTools input files were loaded into the PowerTools application. From ACCESS database created by PowerTools, extractions of the following data relevant to the emissions inventory development were made:

1. 2006 active wells, i.e. wells that reported any oil or gas production in 2006.
2. 2006 oil, gas, and water production by well.

The production data are available by API number. 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.

In an attempt to validate the IHS well count and production data, comparisons were made to summary data for 2006 provided by COGCC. It was found that while IHS Enerdeq oil, gas, and water production agreed to within 1% with COGCC provided summary data, active well counts differed considerably between IHS data and COGCC summary data. Upon further analysis of the COGCC database, it was discovered that the difference in well counts was due to the way in which unique wells were identified. If unique wells are simply identified by unique 14-digit API numbers, a much higher well count is estimated compared to if unique wells are identified by the first 10 digits of the API number. Furthermore, discussions with COGCC indicated that production reports were received for some wells although the well did not produce any oil or gas. However, since the production report was received, COGCC classified this as an active well. If the first 10 digits of the API number only are used, and only wells with non-zero production of oil or gas are counted, well counts are consistent between the COGCC and IHS databases. Table 1 shows basin-wide well count estimates from the COGCC and IHS Enerdeq database.

Table 1. Comparison of active well count in Denver-Julesburg Basin.

Database	Identifier	Well Count
COGCC	API # (all digits)	21,847
COGCC	API # (first 10 digits and only active wells)	16,783
IHS Enerdeq	API # (first 10 digits and only active wells)	16,774

Well data were also obtained from the IHS Enerdeq database for the counties that make up the Denver Julesburg 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 2006 were identified by indication that the spud occurred within 2006. 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 and oil, gas and water production by county for the basin are presented in Table 2, and the spuds by county are presented in Table 3.

Table 2. 2006 well count and oil, gas and water production by county for the D-J Basin.

County	Well Count	Oil Production [bbl]	Gas Production [mcf]	Water Production [bbl]
Adams	889	406,823	6,738,398	628,171
Arapahoe	103	56,018	376,623	179,392
Boulder	232	132,523	2,373,186	62,787
Broomfield	58	31,798	635,433	14,664
Crowley	0	0	0	0
Denver	34	14,674	242,598	1,189
Elbert	60	38,296	196,974	155,302
El Paso	0	0	0	0
Fremont	37	50,074	0	0
Jefferson	0	0	0	0
Kit Carson	12	21,227	344,013	201,133
Larimer	135	116,755	212,406	3,854,032
Lincoln	12	78,112	27,203	729,088
Logan	112	207,829	260,466	6,081,895
Morgan	66	92,186	290,210	2,821,974
Phillips	19	0	555,029	127,347
Pueblo	0	0	0	0
Sedgwick	3	1,295	50,202	48,177
Teller	0	0	0	0
Washington	457	660,357	2,220,766	21,455,978
Weld	11,861	12,334,121	182,996,149	7,022,304
Yuma	2,684	0	37,111,123	3,375,324
TOTAL	**16,774**	**14,242,088**	**234,630,779**	**46,758,757**

Table 3. 2006 spud counts by county for the D-J Basin.

County	Total Number of Spuds in 2006
Adams	7
Arapahoe	3
Boulder	9
Crowley	0
Denver	7
Elbert	1
El Paso	0
Fremont	2
Jefferson	0
Kit Carson	2
Larimer	0
Lincoln	1
Logan	9
Morgan	1
Phillips	3
Pueblo	0
Sedgwick	0
Teller	0
Washington	23
Weld	877
Yuma	555
TOTAL	1500

Development of Spatial Allocation Surrogates

Updated spatial allocation surrogates for oil and gas emissions were developed using the 2006 IHS data. Surrogates were developed for the following Denver CAMx modeling domain:

04 km
Origin (-940, -292)
NX = 119, NY = 119

Latitude and longitude coordinates for oil and gas wells and drilling events were obtained from the IHS database. All data were obtained only for the portion of the D-J basin within Colorado. The locations of all wells in the D-J basin are shown in Figure 1. The oil and gas production surrogates were based on production data at known well locations, while the drilling surrogate was based solely on the number and location of wells drilled.

The creation of the surrogates took place in several steps, and relied on the use of ArcView GIS software.

1. All wells and drill rigs were labeled with the appropriate grid cell IJ values.
2. For each individual well, the oil, gas and water production values were divided by the total oil, gas and water production values corresponding to the county in which the well was located. This division resulted in determination of the fraction of a county's total production taking place at each well. In the case of the drilling surrogate, the number of drilling events, rather than the production values, was used.
3. For each unique grid cell/county combination with wells, each well's production fractions were summed to create the surrogate value.

Figures 2-4 depict the 4km domain spatial surrogate values.

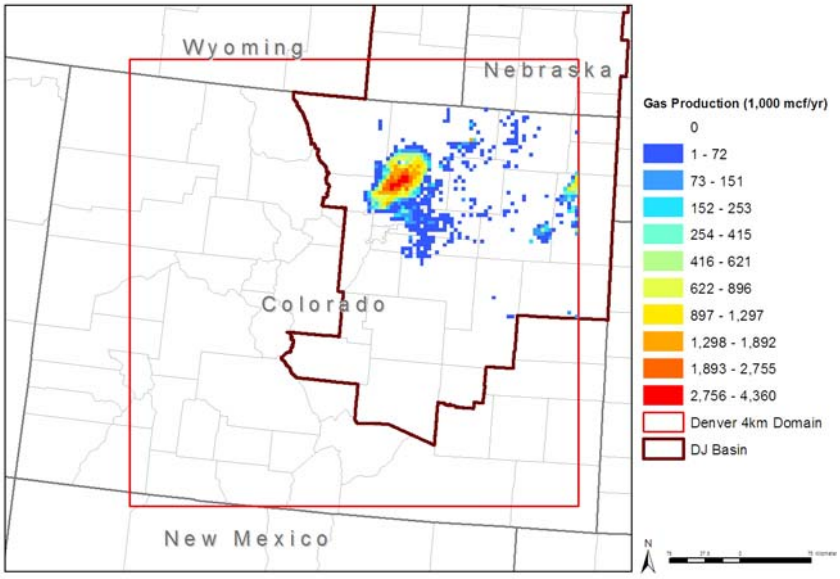

Figure 2. D-J Basin gas production spatial surrogate values for the 4km domain.

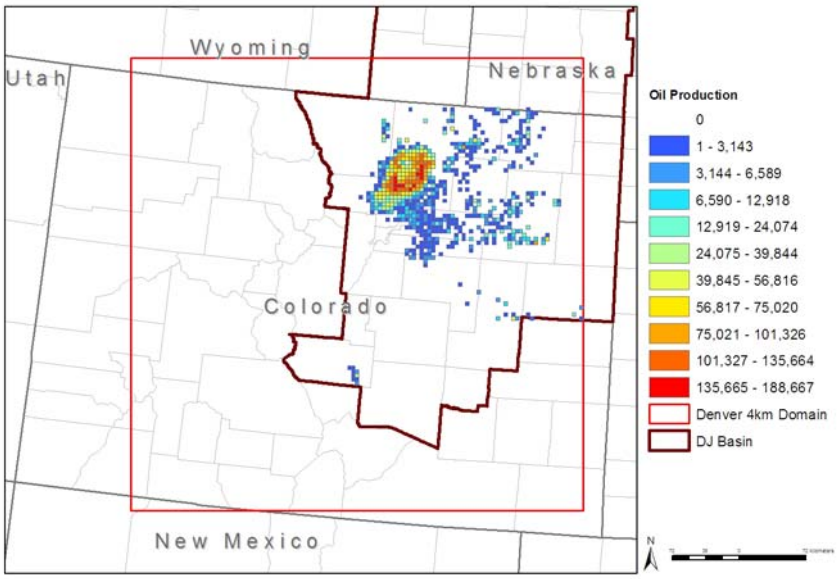

Figure 3. D-J Basin oil production spatial surrogate values for the 4km domain.

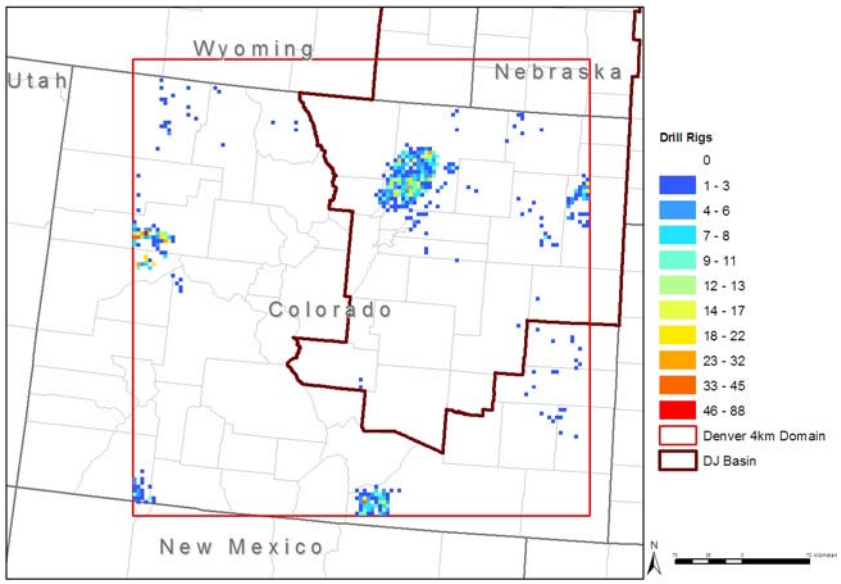

Figure 4. D-J Basin drilling locations spatial surrogate values for the 4km domain.

Sources Subject to APEN Reporting and Condensate Tanks Subject to Regulation 7

On October 31, 2007 a request was made to the APCD for the 2006 Colorado APEN database for all oil and gas related emission sources covered by the following SCC and SIC codes:

- All of the SCCs 202002*, 310*, 404003* (where * indicates all sub-SCCs for the SCC)
- And only those with the following SICs: 13*, 492*, 4612.

APEN data for the D-J basin were extracted and sorted by operator. Company specific APEN source data were forwarded to participating operators for a completeness review that included the following three issues:

1) Source Categories that were missing from the APEN database,
2) Specific sources missing from the database, and
3) Sources within the database known to be no longer operating.

Following the completeness review and the addition or deletion of sources as appropriate, emission rates were reviewed. Emission rates were updated to reflect 2006 actual emissions in cases where supporting data were available. Actual emission updates provided by operators followed the APCD calculation methodologies from existing permits or required Operation and Maintenance Plans. The APCD methodologies are used to update Annual Emission Calculations (Minor Sources) and 12-Month Rolling Emission Totals (Synthetic Minor and Major Sources). Documentation of these changes, and a QA/QC review of updated emissions for APEN sources accompany this document.

A separate request was made to APCD for a copy of the 2006 Regulation 7 atmospheric storage tank reports for year 2006. Within the Ozone Control Area, data from the Regulation 7 reports was utilized in place of the APEN data to represent stock tank emissions as the Regulation 7 reports best reflected actual emissions. The Regulation 7 reports for condensate tanks were in

the form of monthly reports of condensate throughput for each tank, and emissions for each tank, for all companies operating condensate tanks subject to Regulation 7 in the ozone non-attainment area. A macro was written in EXCEL to process the reports in such a way that monthly condensate throughput (bbl) and emissions (lb-VOC) could be extracted and summed. Confirmation was obtained that CDPHE's annual Regulation 7 condensate tank emissions summary for 2006 was in reasonable agreement with the extracted emissions from the monthly Regulation 7 reports.

GIS analysis was used to intersect the boundary of the ozone non-attainment area with the latitude/longitude coordinates of all APENs sources. Those sources falling within the ozone non-attainment area were filtered to remove any sources that were condensate tanks, based on SCC and SCC description. For purposes of summing all permitted oil and gas sources' emissions in the D-J Basin, emissions from the remaining APENs sources (excluding condensate tanks in the ozone non-attainment area) were added to the summary emissions from all Regulation 7 condensate tank reports.

APEN Exempt Sources

Survey forms consisting of 11 Excel spreadsheets (attached) were forwarded to participating operators in the D-J basin. Each spreadsheet contained a request for specific data related to one of the following APEN exempt source categories:

- Well blowdowns
- Well completions
- Drilling rigs
- Exempt engines
- Fugitive emissions
- Heaters
- Gas composition analysis for the basin
- Pneumatic devices
- Pneumatic pumps
- Water tanks
- Workover rigs

The companies participating in the survey process for the D-J Basin represented 50% of well ownership in the basin, 63% of gas production in the basin, and 58% of oil production in the basin. This represented a sufficiently large percentage of oil and gas activity in the basin that it was felt that the responses obtained from the participating companies would be representative of all oil and gas operations in the basin.

In addition to the source categories listed above, emissions from three additional APEN exempt source categories were estimated based on additional information requests from the participating companies:

- APEN exempt atmospheric storage tanks
- Truck loading activities
- Flaring from condensate tanks

Detailed inventory methodologies for each of the source categories follow. Extrapolation of these data was necessary to account for emissions from all oil and gas activity in the basin. The extrapolation methodology to obtain county-level and basin-wide emissions for each source category is described below, but is largely based on scaling by the proportional representation of the respondents of basin-wide well count or oil or gas production, as appropriate.

For emissions from those source categories that relied on estimates of volume of gas vented or leaked, such as well blowdowns, completions, and fugitive emissions, gas composition analyses were requested from all participating companies. These composition analyses were averaged to derive a single basin-wide produced gas composition analysis. The average composition analysis was used to determine the average VOC volume and mass fractions of the vented gas basin-wide.

It should be noted that the emission estimates calculated for APEN exempt sources rely on data that is not as rigorously documented as permitted sources. Much of the data provided for the APEN exempt 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 unpermitted sources which are an improvement on the previous WRAP Phase I and Phase II emissions inventory efforts for the D-J Basin.

APEN Exempt Emission Calculation Methodologies

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 a laboratory analysis to estimate emissions according to Equations 1 and 2:

Equation (1) $V_{vented} \times f = V_{vented,TOTAL}$

where:

V_{vented} is the volume of vented gas per blowdown [mscf/event]
f is the frequency of blowdowns [events/year]
$V_{vented,TOTAL}$ is the total volume of vented gas from the participating companies [mscf/year]

Equation (2) $E_{blowdown} = V_{vented,TOTAL} \times 1000 \times MW_{VOC} \times R \times Y_{VOC}$

where:

$E_{blowdown}$ is the total VOC emissions from blowdowns conducted by the participating companies [lb-VOC/yr]
MW_{VOC} is the molecular weight of the VOC [lb/lb-mol]
R is the universal gas constant [lb-mol/379scf]
Y 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

The total VOC emissions from all blowdowns reported by participating companies was scaled by the proportional production ownership of the participating companies according to Equation 3:

Equation (3) $$E_{blowdown,TOTAL} = E_{blowdown} \times {P_{TOTAL}}/{P}$$

where:

$E_{blowdown,TOTAL}$ are the total emissions basin-wide from blowdowns [tons/year]
$E_{blowdown}$ are the blowdown emissions from the participating companies [tons/year]
P_{TOTAL} is the total gas production in the basin in 2006 [mscf]
P is the total gas production in the basin in 2006 by the participating companies [mscf]

County-level emissions were estimated by allocating the total basin-wide blowdown emissions into each county according to the fraction of total 2006 gas production occurring in that county.

Well Completions and Recompletions

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 data received from the participating companies indicated that completion flaring does not occur in the D-J Basin, however any Best Management Practices (BMP) for initial completions or re-completions were incorporated into the data provided.

The calculation methodology for completion emissions is identical to the method for blowdown emissions, and follows Equations 4 and 5:

Equation (4) $$V_{vented} \times f = V_{vented,TOTAL}$$

where:

V_{vented} is the volume of vented gas per initial completion or re-completion [mscf/event]
f is the frequency of completions [events/year]
$V_{vented,TOTAL}$ is the total volume of vented gas from completions for participating companies [mscf/year]

Equation (5) $$E_{completion} = V_{vented,TOTAL} \times 1000 \times MW_{VOC} \times R \times Y_{VOC}$$

where:

$E_{completions}$ is the total VOC emissions from completions conducted by all participating companies [lb-VOC/yr]
MW_{VOC} is the molecular weight of the VOC [lb/lb-mol]
R is the universal gas constant [lb-mol/379scf]
Y 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

The total VOC emissions from all completions reported by participating companies was scaled by the total number of completions in the basin to the number of completions conducted by the participating companies according to Equation 6:

Equation (6) $$E_{completion,TOTAL} = E_{completion} \times C_{TOTAL} / C$$

where:

$E_{completion,TOTAL}$ are the total emissions basin-wide from completions [tons/year]
$E_{completion}$ are the completion emissions from the participating companies [tons/year]
C_{TOTAL} is the total number of completions in the basin in 2006
C is the total number of completions in the basin in 2006 by the participating companies.

County-level emissions were estimated by allocating the total basin-wide completion emissions into each county according to the fraction of total 2006 completions that occurred in each county.

Drill Rigs – Drilling Operations

Methodology

The participating companies were surveyed for information on drilling rigs operating in 2006 in the D-J Basin. Because many drill rigs are operated by contractors to the oil and gas producers, data were not always available to the level of detail requested in the surveys. Some of the companies surveyed were able to provide exact configurations for all rigs used in their operations, while others were able to provide information on only one or several representative rigs. In all cases, complete information for every parameter needed to estimate drilling rig emissions was not available, and in these cases engineering analysis was used to fill in missing information. Because the nature of the survey responses for drilling rigs varied so much by company, the methodology used was to first estimate each company's total drilling rig emissions given the nature of the data available for that company, and then to sum the emissions and scale up to the basin level.

In general, the emissions for an individual rig engine were estimated according to Equation 7:

Equation (7) $$E_{drilling,engine} = \frac{EF_i \times HP \times LF \times t_{drilling}}{907{,}185}$$

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]

A single drilling rig may contain from 3 – 7 or more engines, including draw works, mud pump, and generator engines. The total emissions from drilling one well are thus the sum of emissions from each engine, according to Equation 8:

Equation (8) $$E_{drilling} = \sum_i E_{drilling,engine,i}$$

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 US EPA's NONROAD model for a similarly sized drill/bore rig engine, and the 2006 sulfur content of the off-road diesel fuel as obtained from communication with CDPHE. The off-road diesel fuel sulfur content was assumed to be 500ppm. 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 were either provided by the survey respondent or were obtained from the US EPA's NONROAD model. For emissions factors taken from the NONROAD model, in cases where it was not possible to ascertain the engine's technology type, uncontrolled, undeteriorated drill/bore rig engines of the same size class were assumed. When a producer supplied emission factors for some, but not all pollutants, the technology type of the engine was estimated based on the supplied emission factors and emissions factors from the NONROAD model were taken for the estimated technology type for drill/bore rig engines of the same size class. This allowed the calculations to incorporate information about specific rig engines when it was available, and defaulted to the NONROAD model where this information was not available. Load factors were similarly estimated by using respondent information where such detailed information was available, or by using the NONROAD model or the WRAP Phase II analysis where they were not available.

The resulting rig configurations included engines of several Tier models, several different counts of number of engines per rig, and differing load factors for the different engines on a rig.

Extrapolation to Basin-Wide Emissions

Due to the variability in the type of information provided by the participating companies, it was decided to sum the drilling emissions for each company separately using the data and assumptions for that company, and then to sum all participating companies' drilling emissions and scale this to the basin-wide drilling emissions. Participating companies' drilling emissions were estimated using the emissions from drilling one well using that company's representative rig or rigs, and then multiplying by the number of spuds drilled by that company in 2006. If more than one representative rig was provided, all spuds drilled by that company were divided evenly among the representative rigs. In the case of one respondent, all of that company's rigs were detailed including the total hours of usage during the year for all rigs. This was used to sum the company's drilling emissions, rather than the number of spuds.

The basin-wide drilling emissions were derived by scaling up the combined participating companies' drilling emissions according to Equation 9:

Equation (9) $$E_{drilling,TOTAL} = E_{drilling} \times \frac{S_{TOTAL}}{S}$$

where:

$E_{drilling,TOTAL}$ is the total emissions in the basin from drilling activity [tons/yr]
$E_{drilling}$ is the total emissions in the basin from drilling activity conducted by the participating companies (summed as described above) [tons/yr]
S_{TOTAL} is the total number of spuds that occurred in the basin in 2006
S is the total number of spuds in the basin in 2006 drilled by the participating companies

County-level emissions were estimated by allocating the total basin-wide drilling rig emissions into each county according to the fraction of total 2006 spuds that occurred in each county.

Workover Rigs

Methodology:

Participating companies' survey responses were used to derive a representative configuration of a workover rig, and the estimated duration of use of the workover rig for a typical well workover in the basin. Workover rigs are typically smaller in total horsepower than drilling rigs and usually consist of only one engine. For the D-J Basin, the survey responses indicated that the representative workover rig consisted of one Detroit Diesel Series 60 engine of approximately 475 hp. It was assumed that this engine was a baseline, uncontrolled, undeteriorated diesel engine for purposes of estimating its emissions factors. This was considered a reasonably conservative assumption, since some workover rig engines may be newer engines (Tier 1 or better), but some may not be recently maintained or rebuilt. Emissions factors were taken from the EPA NONROAD model for baseline, undeteriorated drill/bore rig engines of the same size class. The average load factor for a workover rig engine was obtained from the WRAP Phase II survey effort, since the participating companies were not able to provide detailed information on the load factors.

The basic methodology for estimating the emissions from a workover rig follows Equation 10:

Equation (10) $$E_{workover,engine} = \frac{EF_i \times HP \times LF \times t_{workover}}{907{,}185}$$

where:

$E_{workover,engine}$ is the emissions from one workover [ton/workover]
EF_i is the emissions factor of the workover rig engine of pollutant *i* [g/hp-hr]
HP is the horsepower of the workover rig engine [hp]
LF is the average load factor of the workover rig engine
$t_{workover}$ is the average duration of a workover event [hr/workover]

It should be noted that SO_2 emissions were estimated using the BSFC of the engine, as obtained from the US EPA's NONROAD model for a similarly sized drill/bore rig engine, and the 2006 sulfur content of the off-road diesel fuel as obtained from communication with CDPHE. The off-road diesel fuel sulfur content was assumed to be 500ppm. The EPA NONROAD model guidance was used to determine the fraction of fuel sulfur that would go to forming PM emissions – for workover rig engines this was 2.2% of sulfur content. It was assumed that the remaining sulfur in the fuel would be emitted as SO_2.

Extrapolation to Basin-Wide Emissions

The total workover rig emissions for the participating companies were derived by multiplying the per-workover emissions above for each pollutant by the total number of workovers conducted by the participating companies. This was then scaled up by the ratio of total well count in the basin to wells owned by the participating companies, following Equation 11:

Equation (11) $$E_{workover,TOTAL} = E_{workover} \times W_{TOTAL} / W$$

where:

$E_{workover,TOTAL}$ are the total emissions basin-wide from workovers [tons/year]
$E_{workover}$ are the total workover rig emissions from the participating companies [tons/year]
W_{TOTAL} is the total number of wells in the basin
W is the number of wells owned by the participating companies

County-level emissions were estimated by allocating the total basin-wide workover rig emissions into each county according to the fraction of total 2006 well counts that are located in each county.

APEN Exempt Engines

Methodology:

The participating companies provided a complete inventory of all APEN exempt engines in use in their operations. Emission calculations for APEN exempt engines follow a similar methodology as for drilling rig or workover rig engines.

The basic methodology for estimating emissions from an exempt engine is shown in Equation 12:

Equation (12) $$E_{engine} = \frac{EF_i \times HP \times LF \times t_{annual}}{907{,}185}$$

where:

E_{engine} are emissions from an exempt 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/yr]

Note that, similar to drilling rig and workover rig engines, SO_2 emissions are estimated using the BSFC of the engine, and the assumed sulfur content of the fuel, assuming that all sulfur emissions are in the form of SO_2. For natural gas-fired exempt engines, gas composition analyses indicate no sulfur present in the natural gas; therefore SO_2 emissions are negligible from these engines.

Extrapolation to Basin-Wide Emissions

Emissions from all exempt engines from the participating companies were summed. The total emissions from all participating companies were scaled by the ratio of total well count in the basin to wells owned by the participating companies according to Equation 13:

Equation (13) $$E_{engine,TOTAL} = E_{engine} \frac{W_{TOTAL}}{W}$$

where:

$E_{engine,TOTAL}$ is the total emissions from exempt engines in the basin [ton/yr]
E_{engine} is the total emissions from exempt engines owned by the participating companies [ton/yr]
W_{TOTAL} is the total number of wells in the basin
W is the number of wells owned by the participating companies

County-level emissions were estimated by allocating the total basin-wide exempt engine emissions into each county according to the fraction of total 2006 well counts that are located in each county.

Fugitive Leaks

Methodology

Fugitive emissions from well sites were estimated using AP-42 emissions factors and equipment counts provided in the survey responses. The participating companies provided total equipment counts for all of their operations in the basin by type of equipment and by the type of service to which the equipment applies – gas, light liquid, heavy liquid, or water.

Fugitive VOC emissions for an individual component were estimated similar to blowdown or completion emissions, according to Equations 14 and 15:

Equation (14) $V_{vented} \times N = V_{vented,TOTAL}$

where:

V_{vented} is the volume of fugitive gas leaked per component, for different service types [mscf/component]
N is the number of components of each service type
$V_{vented,TOTAL}$ is the total volume of vented gas from all components for all participating companies [mscf/year]

Equation (15) $E_{fugitive} = V_{vented,TOTAL} \times 1000 \times MW_{VOC} \times R \times Y_{VOC}$

where:

$E_{fugitive}$ is the fugitive VOC emissions for all participating companies [lb-VOC/yr]
MW_{VOC} is the molecular weight of the VOC [lb/lb-mol]
R is the universal gas constant [lb-mol/379scf]
Y 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 fugitive emissions are estimated by scaling the fugitive emissions from all participating companies by the ratio of the total number of wells in the basin to the number of wells owned by the participating companies, according to Equation 16:

Equation (16) $E_{fugitive,TOTAL} = E_{fugitive} \frac{W_{TOTAL}}{W}$

where:

$E_{fugitive,TOTAL}$ is the total emissions from fugitive leaks in the basin [ton/yr]
$E_{fugitive}$ is the fugitive emissions for all participating companies [lb-VOC/yr]
W_{TOTAL} is the total number of wells in the basin
W is the number of wells owned by the participating companies

County-level emissions were estimated by allocating the total basin-wide fugitive emissions into each county according to the fraction of total 2006 well counts that are located in each county.

Heater Treater, Separators, and Glycol Dehydrator Burners

Methodology

Heater (heater-treater, separator, tank heaters and glycol dehydrator burners) 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 BTU rating of the heater and the local BTU content of the gas. The AP-42 emission factors for an uncontrolled small boiler were used for specific pollutants.

The basic methodology for estimating emissions for a single heater is shown in Equation 17:

Equation (17) $$E_{heater} = EF_{heater} \times Q_{heater} \times \frac{HV_{local}}{HV_{rated}} \times t_{annual} \times hc$$

where:

E_{heater} is the emissions from a given heater
EF_{heater} is the emission factor for a heater for a given pollutant [lb/MMBTU]
Q_{heater} is the heater MMBTU/hr rating [$MMBTU_{rated}$/hr]
HV_{local} is the local natural gas heating value [$MMBTU_{local}$/scf]
HV_{rated} is the heating value for natural gas used to derive heater MMBTU rating, Q_{heater} [MMBTU/scf]
t_{annual} is the annual hours of operation [hr/yr]
hc is a heater cycling fraction to account for the fraction of operating hours that the heater is firing (if available)

Emissions for all heaters in the basin operated by the participating companies were estimated according to Equation 18:

Equation (18) $$E_{heater,companies} = E_{heater} \times N_{heater}$$

where:

$E_{heater,companies}$ is the total emissions from all heaters operated by participating companies [lb/yr]
E_{heater} is the emissions from a single heater [lb/yr/heater]
N_{heater} is the total number of heaters owned by the participating companies

The participating companies were requested to provide seasonal utilization rates to account for changes in usage throughout the year.

Extrapolation to Basin-Wide Emissions

Basin-wide heater emissions were estimated according to Equation 19:

Equation (19) $$E_{heater,TOTAL} = \frac{E_{heater,companies}}{2000} \times \frac{W_{TOTAL}}{W}$$

where:

$E_{heater,TOTAL}$ is the total heater emissions in the basin [ton/yr]
$E_{heater,companies}$ is the total emissions from all heaters operated by participating companies [lb/yr]
W_{TOTAL} is the total number of wells in the basin
W is the total number of wells in the basin owned by the participating companies

County-level emissions were estimated by allocating the total basin-wide heater emissions into each county according to the fraction of total 2006 well counts that are located in each county.

Pneumatic Control Devices

Methodology

Pneumatic device emissions were estimated by determining the numbers and types of pneumatic devices used at all wells in the basin owned by the participating companies. The bleed rates of these devices per unit of gas produced were determined by using guidance from the EPA's Natural Gas Star Program.

The methodology for estimating the emissions from all pneumatic devices owned by participating companies are shown in Equations 20 and 21:

Equation (20) $$V_{vented,TOTAL} = \dot{V}_i \times N_i \times t_{annual}$$

where:

$V_{vented,TOTAL}$ is the total volume of vented gas from all pneumatic devices for all participating companies [mscf/year]
$\dot{V}_i$ is the volumetric bleed rate from device i [mscf/hr/device]
N_i is the total number of device $\underline{i}$ owned by the participating companies
t_{annual} is the number of hours per year that devices were operating [hr/yr]

Equation (21) $$E_{pneumatic} = V_{vented,TOTAL} \times 1000 \times MW_{VOC} \times R \times Y_{VOC}$$

where:

$E_{pneumatic}$ is the pneumatic device VOC emissions for all participating companies [lb-VOC/yr]
MW_{VOC} is the molecular weight of the VOC [lb/lb-mol]
R is the universal gas constant [lb-mol/379scf]
Y 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 pneumatic device emissions were estimated according to Equation 22:

Equation (22) $$E_{pneumatic,TOTAL} = \frac{E_{pneumatic}}{2000} \times \frac{W_{TOTAL}}{W}$$

where:

$E_{pneumatic,TOTAL}$ is the total pneumatic device emissions in the basin [ton/yr]
$E_{pneumatic}$ is the pneumatic device VOC emissions for all participating companies [lb-VOC/yr]
W_{TOTAL} is the total number of wells in the basin
W is the total number of wells in the basin owned by the participating companies

County-level emissions were estimated by allocating the total basin-wide pneumatic device emissions into each county according to the fraction of total 2006 well counts that are located in each county.

Gas Actuated Pumps

Methodology

Participating companies provided data indicating either the average gas consumption rate per gallon of chemical or compound pumped, or the volume rate of gas consumption per day per pump.

If the gas consumption rate per pump per day was specified, this was multiplied by the number of pumps owned by the respondent and the total annual usage to derive total gas consumption from gas-actuated pumps for the respondent. If the gas consumption rate per gallon of chemical pumped was specified, this was multiplied by the total volume of chemical pumped by the respondent in the basin in 2006 to derive total gas consumption from gas-actuated pumps for the respondent.

VOC emissions were estimated similarly to pneumatic devices, following Equation 23:

Equation (23) $$E_{pump} = V_{vented,TOTAL} \times 1000 \times MW_{VOC} \times R \times Y_{VOC}$$

where:

E_{pump} is the gas-actuated pump VOC emissions for all participating companies [lb-VOC/yr]
$V_{vented,TOTAL}$ is the total volume of vented gas from all gas-actuated pumps for all participating companies [mscf/year]

MW_{VOC} is the molecular weight of the VOC [lb/lb-mol]
R is the universal gas constant [lb-mol/379scf]
Y is the volume fraction of VOC in the vented gas

The participating companies were requested to provide seasonal utilization rates to account for changes in usage throughout the year.

Extrapolation to Basin-Wide Emissions

Basin-wide gas-actuated pump emissions were estimated according to Equation 24:

Equation (24) $$E_{pump,TOTAL} = \frac{E_{pump}}{2000} \times \frac{W_{TOTAL}}{W}$$

where:
$E_{pump,TOTAL}$ is the total pneumatic pump emissions in the basin [ton/yr]
E_{pump} is the gas-actuated pump VOC emissions for all participating companies [lb-VOC/yr]
W_{TOTAL} is the total number of wells in the basin
W is the total number of wells in the basin owned by the participating companies

County-level emissions were estimated by allocating the total basin-wide gas-actuated pump emissions into each county according to the fraction of total 2006 well counts that are located in each county.

Produced Water Tanks

Methodology:

Compositional analyses were obtained for water samples collected from produced water tanks for input to the Tanks 4.0 program. Tanks 4.0 was used to estimate working and breathing losses based on the water composition analyses obtained from participating companies.

The average water production per well was derived as the ratio of total water production in the basin to the number of active wells. From this a conservative volumetric throughput of 120,000 gallons of water per wellsite was derived. This input to Tanks 4.0 produced an output emissions factor of 0.06 lb-VOC/year/wellsite.

Extrapolation to Basin-Wide Emissions

Basin-wide emissions were derived by multiplying the derived emissions factor per wellsite by the number of active wells in the basin, following Equation 25:

Equation (25) $E_{water-\tan ks} = \frac{EF_{water-\tan ks} W_{TOTAL}}{2000}$

where:

$E_{water\text{-}tanks,TOTAL}$ is the total breathing and working loss emissions of water tanks in the basin [tons/yr]

$EF_{water\text{-}tanks}$ is the breathing and working loss emissions factor for water tanks in the basin [lb-VOC/year/wellsite]

W_{TOTAL} is the total number of wells in the basin

County-level emissions were estimated by allocating the total basin-wide water tank emissions into each county according to the fraction of total 2006 well counts that are located in each county.

APEN Exempt Atmospheric Storage Tanks

Methodology

A VOC emissions factor for APEN exempt storage tanks was derived by summing all uncontrolled emissions from Regulation 7 condensate tanks and dividing by the total production from these same tanks. The resulting emissions factor is 13.86 [lb-VOC/bbl], and assumes that no flares or other controls are in place for APEN exempt condensate tanks.

Extrapolation to Basin-Wide Emissions

Within the ozone non-attainment area, total production of condensate was obtained from the Regulation 7 reports, which were considered the most accurate estimate of condensate production in this area. GIS analysis was used to intersect the locations of all active wells in the basin with the boundaries of the ozone non-attainment area, in order to derive an estimate of the total condensate production in the area based on IHS data. The Regulation 7 production total was subtracted from the IHS total for the ozone non-attainment area to derive total condensate production handled by APEN exempt storage tanks, following Equation 26:

Equation (26) $P_{exempt,\tan ks,NAA} = P_{IHS,NAA} - P_{\mathrm{Re}g7,NAA}$

where:

$P_{exempt,tanks,NAA}$ is the production handled by APEN exempt storage tanks in the ozone non-attainment area [bbl]

$P_{IHS,NAA}$ is the total condensate production in the ozone non-attainment area extracted from the IHS database [bbl]

$P_{Reg7,NAA}$ is the total condensate production handled by permitted tanks in the ozone non-attainment area as derived from the Regulation 7 reports [bbl]

Outside of the ozone non-attainment area, a similar approach was used in which the total production handled by permitted storage tanks was estimated for the condensate tanks listed in the APENs database. This was subtracted from the total production in the basin outside of the

non-attainment area to derive total condensate production handled by APEN exempt storage tanks following Equation 27:

Equation (27) $$P_{exempt,\tan ks,outside} = P_{IHS,outside} - P_{APENs,outside}$$

where:

$P_{exempt,tanks,outside}$ is the production handled by APEN exempt storage tanks outside of the ozone non-attainment area [bbl]

$P_{IHS,outside}$ is the total condensate production outside of the ozone non-attainment area extracted from the IHS database [bbl]

$P_{APENs,outside}$ is the total condensate production handled by permitted tanks outside of the ozone non-attainment area as derived from the APENs permits for condensate tanks [bbl]

Total basin-wide VOC emissions from APEN exempt condensate tanks are estimated by Equations 28 and 29:

Equation (28) $$E_{exempt,\tan ks,NAA} = \frac{P_{exempt,\tan ks,NAA} \times EF_{exempt,\tan ks}}{2000}$$

and

Equation (29) $$E_{exempt,\tan ks,outside} = \frac{P_{exempt,\tan ks,outside} \times EF_{exempt,\tan ks}}{2000}$$

where:

$E_{exempt,tanks,NAA}$ is the basin-wide emissions from exempt tanks in the ozone non-attainment area [tons/yr]

$E_{exempt,tanks,outside}$ is the basin-wide emissions from exempt tanks outside of the ozone non-attainment area [tons/yr]

$EF_{exempt,tanks}$ is the derived VOC emissions factor for exempt tanks [lb-VOC/bbl]

County-level emissions were estimated by allocating the total basin-wide APEN exempt condensate tank emissions into each county according to the fraction of total 2006 condensate production that occurred in each county.

Well Site Land Farming

Methodology

Spill reports submitted to the COGCC in 2006 for any county within the boundaries of the D-J Basin were summarized to determine the type of material released (oil, methanol, or produced water), the volume of material released, and the volume of material recovered. All oil and methanol not recovered was conservatively assumed to completely volatilize and contribute to VOC emissions. Water spills were not considered in this analysis.

The above methodology may double count larger spills that were transported to landfarms and thus accounted for in the APEN process.

Extrapolation to Basin-Wide Emissions

Basin-wide emissions from spills were estimated according to Equation 30:

Equation (30) $$E_{spills} = \frac{V_{unrecovered,i} \times \rho_i}{2000}$$

where:

E_{spills} is the total basin-wide VOC emissions from spills
$V_{unrecovered,i}$ is the total volume of spilled material of substance *i* that was unrecovered
ρ_i is the liquid density of substance *i*

County-level spill emissions were estimated by summing the spill emissions for each county, as indicated by the spill report. Spills that occurred in 2006 were reported for only the following counties in the D-J Basin:

- Logan
- Morgan
- Washington
- Weld
- Yuma

Truck Loading

Methodology

Truck loading emissions were estimated based on loading losses per EPA AP-42, Section 5.2 methodology combined with condensate produced in the basin. As surveyed producers indicated that all condensate production in the basin was transported by truck, no correction was necessary to adjust condensate production to account for other modes of transport. Loading loss emissions were estimated based on EPA AP-42, Section 5.2 methodology, following Equation 31:

Equation (31) $$L = 12.46 \times \left(\frac{S \times V \times M}{T} \right)$$

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]

Truck loading emissions for participating companies were then estimated by combining the calculated loading loss rate with condensate production as shown in Equation 32:

Equation (32) $E_{loading} = L \times P \times \frac{42}{1000}$

where:

E is the truck loading emissions [lb/yr]
L is the loading loss rate [lb/1000gal]
P is the condensate production for the surveyed producers [bbl]

Extrapolation to Basin-Wide Emissions

Basin-wide truck loading emissions were estimated according to Equation 33:

Equation (33) $E_{loading,TOTAL} = \frac{E_{loading}}{2000} \times \frac{P_{TOTAL}}{P}$

where:

$E_{loading,,TOTAL}$ is the total truck loading emissions in the basin [ton/yr]
$E_{loading}$ is the truck loading pump VOC emissions for all participating companies [lb-VOC/yr]
P_{TOTAL} is the total condensate production in the basin
P is the condensate production for the surveyed producers [bbl]

County-level emissions were estimated by allocating the total basin-wide truck loading emissions into each county subject to Regulation 7 requirements according to the fraction of within-EAC condensate production for each county.

Flaring

Methodology

For this source category the AP-42 methodology was applied to estimate flare emissions associated with atmospheric storage tanks. Atmospheric storage tanks vent rates were combined with the heat content of the gas being flared and the appropriate AP-42 emission factor to determine the NOx and CO emissions. Per input from surveyed producers, it was assumed that no flaring occurred outside of the EAC, where condensate tanks are not subject to Regulation 7 control requirements.

Extrapolation to Basin-Wide Emissions

Surveyed producers indicated the use of only two control technologies to conform to Regulation 7 requirements: flaring and vapor recovery units (VRUs). Producers supplied production controlled by VRU which allowed for the calculation of production controlled by flaring according to Equation 34. Here it was assumed, conservatively that non surveyed producers used only flare control devices to control emissions from atmospheric storage tanks.

Equation (34) $P_{flare} = P_{Reg7,CNT} - P_{Reg7,VRU}$

where:

P_{flare} is the total condensate production handled by permitted tanks in the ozone non-attainment area and controlled by flares [bbl]
$P_{Reg7,CNT}$ is the total condensate production handled by permitted tanks in the ozone non-attainment area and controlled by any technology as estimated in regulation 7 summaries [bbl]
$P_{Reg7,VRU}$ is the total condensate production handled by permitted tanks in the ozone non-attainment area and controlled by VRUs as reported by participating companies [bbl]

Emissions were estimated according to AP-42 methodology, following Equation 35.

Equation (35) $E_{flare} = EF_i \times P_{flare} \times Q \times HV$

where:

E_{flare} is the basinwide flaring emissions [lb/yr]
EF_i is the emissions factor for pollutant *i* [lb/MMBtu]
Q is the condensate tank vent rate as supplied by participating companies [scf/bbl]
HV is the heating value of the gas as estimated by participating companies [BTU/scf]
P_{flare} is the total condensate production handled by permitted tanks in the ozone non-attainment area and controlled by flares [bbl]

County-level emissions were estimated by allocating the total basin-wide truck loading emissions into each county subject to Regulation 7 requirements according to the fraction of within EAC condensate production for each county.

Summary Results

Results from the combined permitted sources (APENs sources excluding condensate tanks in the ozone non-attainment area, and condensate tanks in the ozone non-attainment area from the Regulation 7 reports), and the combined unpermitted sources are presented below on a county level and as summaries for the entire D-J Basin as a series of pie charts and bar graphs. The quantitative emissions summaries are presented at the end of this document in table format.

Figure 5 shows that NOx emissions are primarily concentrated in Weld and Yuma counties, as evidenced by the areas of large concentrations of well locations, as shown in Figure 1. Figure 6 shows that VOC emissions are primarily concentrated in Weld county only. Production activity in Yuma county is mostly dry gas, and therefore a smaller proportion of total VOC emissions occur in Yuma county.

Figure 7 shows that compressor engines and drilling rigs combined account for almost 80% of NOx emissions. Similarly, Figure 8 shows that permitted and unpermitted condensate tanks and pneumatic devices account for approximately 81% of VOC emissions.

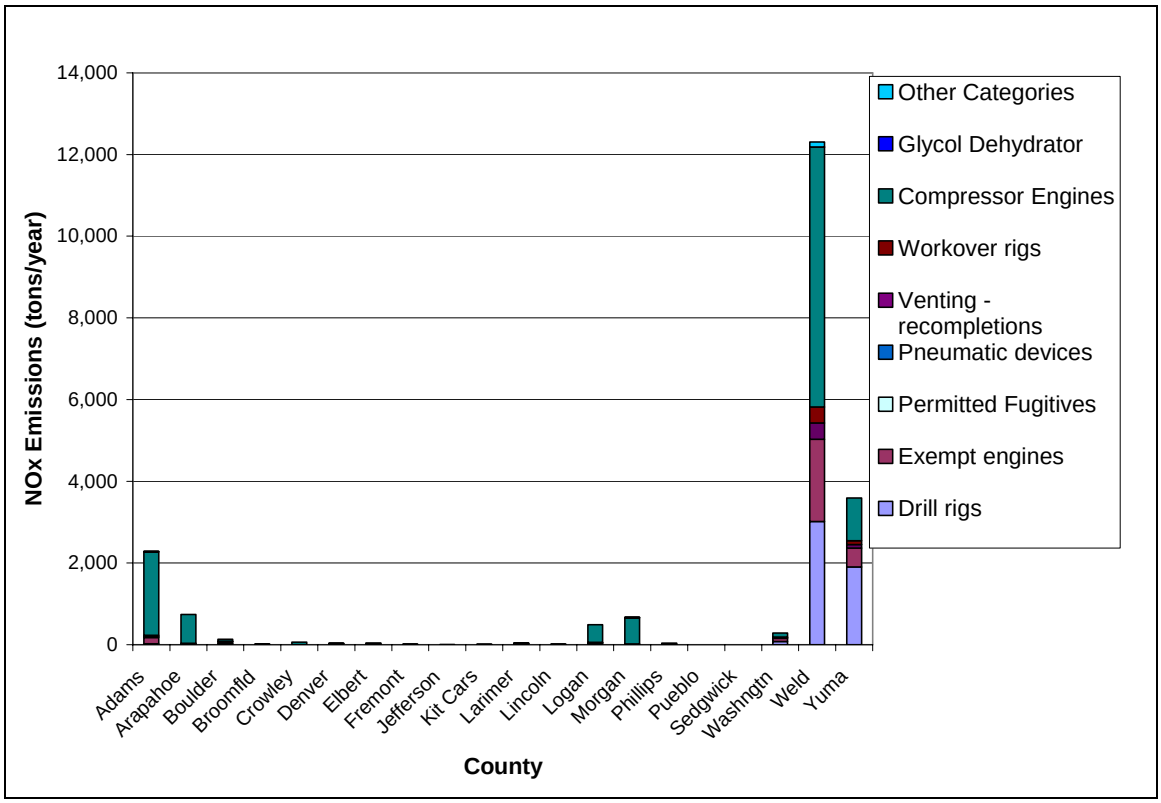

Figure 5. 2006 NOx emissions by source category and by county in the D-J Basin.

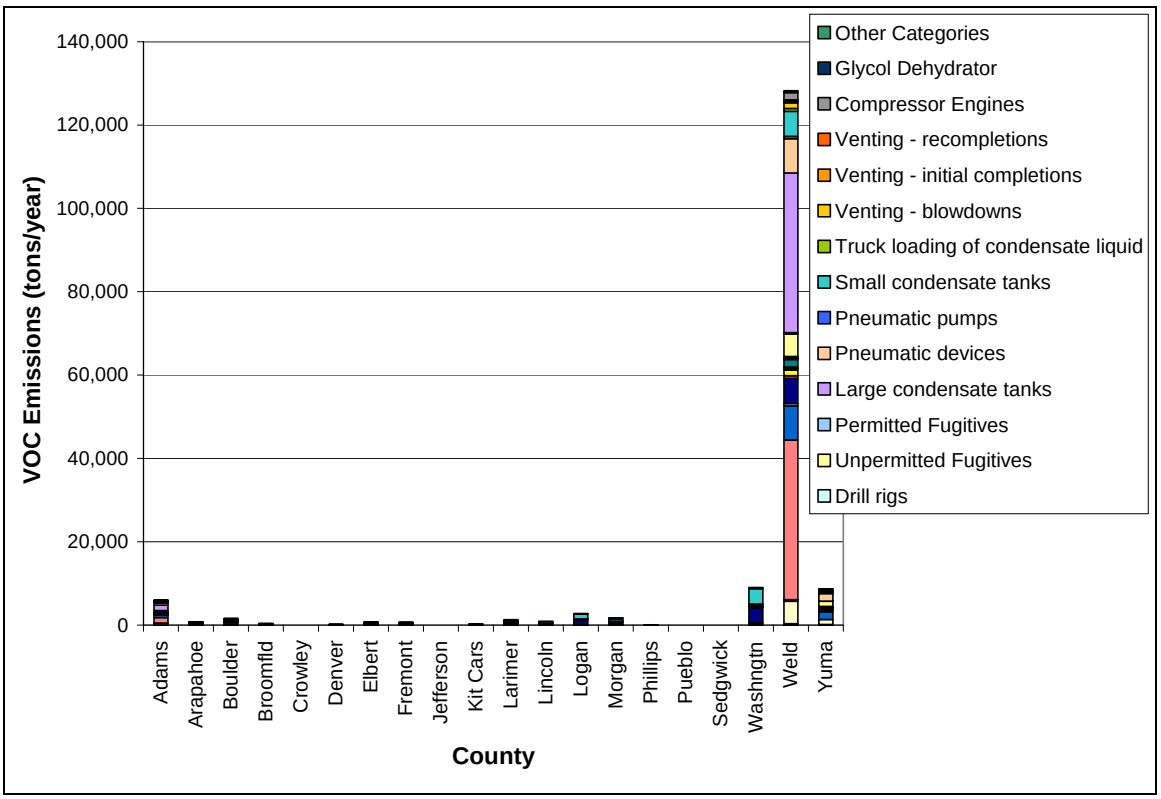

Figure 6. 2006 VOC emissions by source category and by county in the D-J Basin.

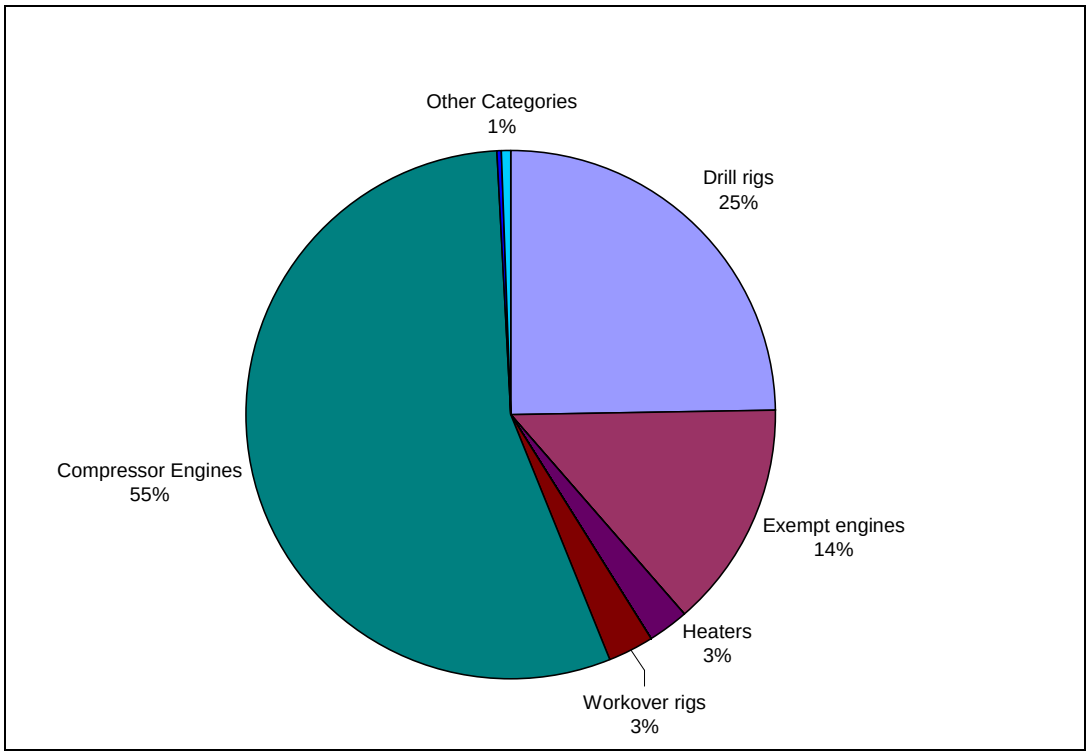

Figure 7. D-J Basin NOx emissions proportional contributions by source category.

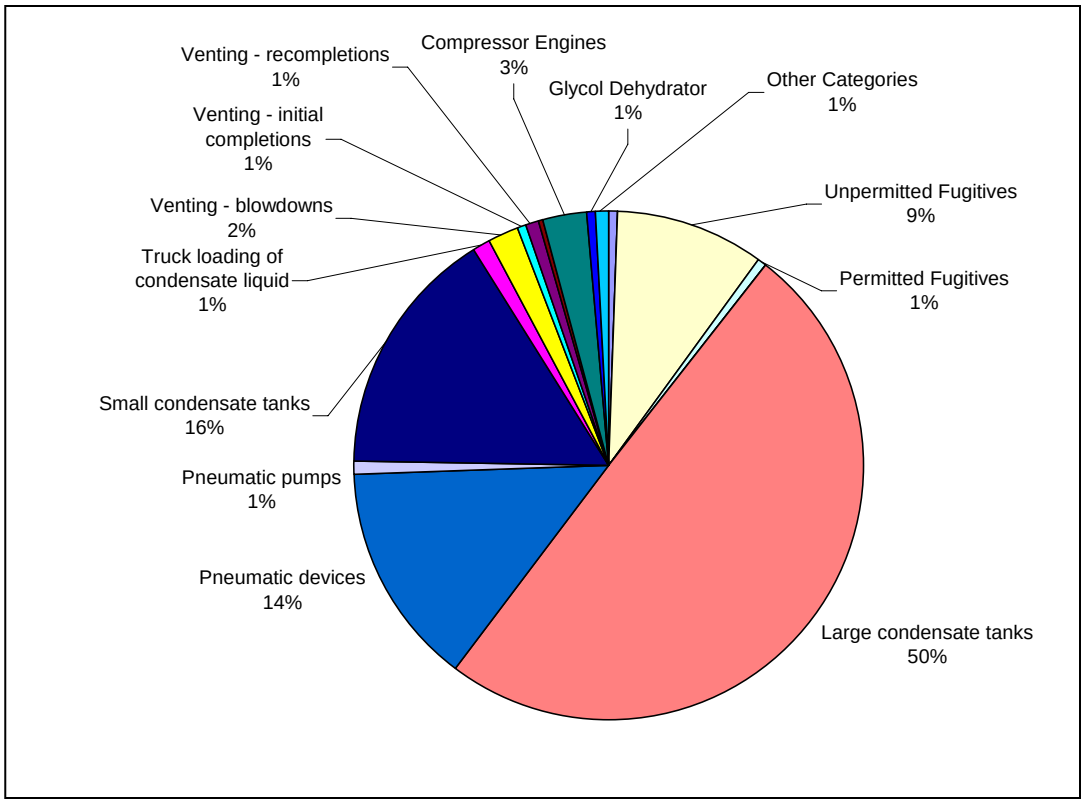

Figure 8. D-J Basin VOC emissions proportional contributions by source category.

Table 4. 2006 emissions of all criteria pollutants by county for the D-J Basin.

County	NOx [tons/yr]	VOC [tons/yr]	CO [tons/yr]	SOx [tons/yr]	PM [tons/yr]
Adams	2,286	3,005	939	13	19
Arapahoe	742	408	253	0	4
Boulder	129	803	76	1	4
Broomfield	14	193	10	0	0
Crowley	63	1	85	0	1
Denver	32	103	19	0	2
Douglas	0	0	0	0	0
Elbert	43	363	27	0	1
El Paso	0	0	0	0	0
Fremont	16	329	9	0	1
Jefferson	6	0	10	0	0
Kit Carson	10	139	6	0	1
Larimer	37	651	23	0	1
Lincoln	14	462	11	0	0
Logan	491	1,382	183	2	9
Morgan	672	883	672	132	4
Phillips	40	47	26	0	1
Pueblo	0	0	0	0	0
Sedgwick	1	11	0	0	0
Teller	0	0	0	0	0
Washington	284	4,509	207	1	9
Weld	12,310	64,111	8,393	51	421
Yuma	3,592	4,359	1,993	24	158
Totals	**20,783**	**81,758**	**12,941**	**226**	**636**

Table 5. 2006 NOx emissions by county and by source category for the D-J Basin**.**

County	Drill rigs	Exempt engines	Heaters	Workover Rigs	Compressor Engines	Glycol Dehydrator	Other Categories	Totals
Adams	24	151	30	29	2,041	0	11	**2,286**
Arapahoe	10	18	4	3	707	0	0	**742**
Boulder	31	40	8	8	43	0	1	**130**
Broomfield	0	10	2	2	0	0	0	**14**
Crowley	0	0	0	0	63	0	0	**63**
Denver	24	6	1	1	0	0	0	**32**
Douglas	0	0	0	0	0	0	0	**0**
Elbert	3	10	2	2	26	0	0	**43**
El Paso	0	0	0	0	0	0	0	**0**
Fremont	7	6	1	1	0	0	0	**16**
Jefferson	0	0	0	0	6	0	0	**6**
Kit Carson	7	2	0	0	0	0	0	**10**
Larimer	0	23	5	5	5	0	0	**37**
Lincoln	3	2	0	0	8	0	0	**15**
Logan	31	19	4	4	44	0	0	**491**
Morgan	3	11	2	2	638	8	7	**672**
Phillips	10	3	1	1	26	0	0	**40**
Pueblo	0	0	0	0	0	0	0	**0**
Sedgwick	0	1	0	0	0	0	0	**1**
Teller	0	0	0	0	0	0	0	**0**
Washington	79	78	15	15	97	0	0	**284**
Weld	3,012	2,018	400	391	6,363	5	122	**12,310**
Yuma	1,906	457	90	89	1,050	0	0	**3,592**
Totals	**5,152**	**2,854**	**565**	**553**	**11,506**	**13**	**141**	**20,783**

Table 6. 2006 VOC emissions by county and by source category for the D-J Basin.

County	Drill rigs	Unpermitted Fugitives	Permitted Fugitives	Large condensate tanks	Pneumatic devices	Pneumatic pumps	Small condensate tanks	Truck loading of condensate liquid	Venting – blowdowns	Venting - initial completions	Venting - recompletions	Compressor Engines	Glycol Dehydrator	Other Categories	Totals
Adams	2	401	84	1,279	614	44	174	23	50	2	3	212	44	75	3,005
Arapahoe	1	46	18	176	70	5	24	3	3	1	1	17	22	19	408
Boulder	2	105	0	417	172	12	57	7	18	3	4	3	0	4	803
Broomfield	0	26	0	100	43	3	14	2	5	0	0	0	0	1	193
Crowley	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Denver	2	15	0	46	23	2	6	1	2	2	3	0	0	1	103
Douglas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elbert	0	27	0	0	41	3	214	2	2	0	0	1	0	72	363
El Paso	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fremont	1	17	0	0	25	2	280	3	0	1	1	0	0	1	329
Jefferson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kit Carson	1	5	0	0	8	1	118	1	3	1	1	0	0	0	139
Larimer	0	61	0	269	92	7	211	7	2	0	0	0	0	2	651
Lincoln	0	5	0	0	8	1	436	4	0	0	0	0	0	7	462
Logan	2	51	0	0	77	6	1,160	12	2	3	4	45	9	13	1,382
Morgan	0	30	4	0	45	3	514	5	2	0	0	147	54	77	883
Phillips	1	9	0	0	13	1	0	0	4	1	1	8	9	0	47
Pueblo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sedgwick	0	1.4	0	0	2	0	7	0	0	0	0	0	0	0	11
Teller	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Washington	6	206	0	0	312	23	3,684	37	17	8	10	13	8	185	4,509
Weld	209	5348	354	38,349	8,164	591	5,977	693	1,360	292	394	1,773	240	367	64,111
Yuma	132	1210	0	0	1,834	134	0	0	276	185	249	172	121	47	4,359
Totals	**357**	**7564**	**460**	**40,636**	**11,545**	**836**	**12,874**	**800**	**1,744**	**500**	**674**	**2,393**	**506**	**869**	**81,758**