# AIR EMISSIONS INVENTORY ESTIMATES for a REPRESENTATIVE OIL and GAS WELL in the WESTERN UNITED STATES

March 25, 2013

KLEINFELDER

A Report Prepared for:

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# 1 EXECUTIVE SUMMARY

The Bureau of Land Management National Operations Center (BLM NOC) retained the Kleinfelder Team (which consists of staff from Kleinfelder, Inc. and ENVIRON International Corporation) to prepare an emissions inventory estimate of criteria pollutants, greenhouse gases (GHG), and key hazardous air pollutants (HAPs) for a representative oil and gas well in the western United States (US). The emissions inventory is designed to be used by BLM staff, such as NEPA planners, air resource specialists, and natural resource specialists, to evaluate emissions from small, which for purposes of this inventory is approximately five wells or less, oil and gas projects.

Defining a "representative" oil and gas well for the entire western US is extremely challenging as there are numerous variables, even within a single basin and sub basin that can materially affect the emissions. Such variables include oil and gas composition, difficulty drilling the geologic formation, oil and gas production rate, equipment at the well site, emission controls, produced water that may be associated with oil and gas production, among many others. Accordingly, to develop such an inventory, five different well types (three natural gas wells and two oil wells) representative of five different major oil and gas basins in the western US were evaluated. Figure 1-1, located at the end of this section, shows the major oil and gas producing basins in the western US. In order to develop the emission inventories, information that is not proprietary, not draft, and not pre-decisional was reviewed for the five selected basins plus other oil and gas developments in the western US. The information sources are discussed in Section 2 of this report. The characteristics of the five basins selected are similar to a large portion of the oil and gas produced in the western United States. The five well types and key characteristics are shown Table 1-1 on the next page.

An Excel workbook that provides the detailed and summary of the emission estimates was prepared. The Workbook is interactive, allowing the user to choose one of the five well types based on basin characteristics for the project of interest. Once the well type is selected, the Excel Workbook is automatically populated with the key variables. The electronic version of the Excel Workbook is included as Appendix A. Appendices B through F include printouts of the Excel Workbook for each of the five well types. Table 1-2 presents the summary emission inventory estimate results. Except for sulfur dioxide ($SO_2$), ethylbenzene, and nitrous oxide

($N_2O$), the values in Table 1-2 are rounded to one decimal place. Global warming potential (GWP) is rounded to a whole number. The number of significant figures shown in Table 1-2 varies as the quantity of individual pollutants is highly variable. For example, $SO_2$ emissions are reported to only one significant figure because the emissions are on the order of one ten thousandth of a ton per year. But GWP is reported to 5 significant figures because emissions are in the thousands of tons per year.

**TABLE 1-1**
**CHARACTERISTICS OF SELECTED REPRESENTATIVE BASINS**

| Product | Basin | Key Characteristics |
|---|---|---|
| Gas well | Uinta/Piceance | Deep wells which may include shale, dry gas, moderate condensate production |
| Gas well | Upper Green River | Deep wells, multiple devices per well, high condensate production, wet gas |
| Gas well | San Juan | Shallow wells, low amounts of condensate production, dry gas |
| Oil well | Williston | Shale formation, very deep wells, long horizontal drilling, high amounts of associated gas, associated gas flared |
| Oil well | Denver | Shallow wells, lower amounts of associated gas, associated gas sent to a sales line |

**TABLE 1-2**
**SUMMARY OF EMISSION ESTIMATES FOR A SINGLE OIL OR GAS WELL**

| Well Type: | Gas | Gas | Gas | Oil | Oil |
|---|---|---|---|---|---|
| **Pollutant** | **Uinta/ Piceance** (tpy) | **Upper Green River** (tpy) | **San Juan** (tpy) | **Williston** (tpy) | **Denver** (tpy) |
| NOx | 15.6 | 14.6 | 5.6 | 15.6 | 6.3 |
| CO | 3.8 | 3.9 | 3.1 | 8.0 | 3.4 |
| VOC | 3.4 | 5.2 | 5.3 | 17.6 | 6.7 |
| $SO_2$ | 0.0004 | 0.0004 | 0.001 | 0.001 | 0.001 |
| $PM_{10}$ | 6.9 | 6.7 | 6.8 | 6.9 | 6.6 |
| $PM_{2.5}$ | 0.8 | 0.8 | 0.5 | 0.8 | 0.5 |
| | | | | | |
| $CO_2$ | 2,552.1 | 2,882.1 | 651.9 | 3,156.4 | 1,049.0 |
| $CH_4$ | 12.2 | 14.1 | 6.1 | 16.6 | 1.8 |
| $N_2O$ | 0.05 | 0.05 | 0.04 | 0.6 | 0.04 |
| GWP | 2,825 | 3,194 | 791 | 3,682 | 1,099 |
| | | | | | |
| Benzene | 1.4 | 1.5 | 1.4 | 1.5 | 1.4 |
| Toluene | 1.0 | 1.2 | 1.0 | 1.0 | 1.0 |
| Ethylbenzene | 0.00003 | 0.01 | 0.0008 | 0.0008 | 0.0006 |
| Xylene | 0.6 | 0.7 | 0.6 | 0.6 | 0.6 |
| n-Hexane | 7.5 | 7.5 | 7.5 | 7.9 | 7.5 |
| Total HAPs | 10.4 | 10.9 | 10.5 | 11.0 | 10.5 |

Note: Sums may not precisely total due to round off differences. A value of 0.00 indicates that pollutant is not emitted or emitted in de minimis amounts. If there is a non-zero value, at least one significant figure is reported. Greenhouse gas emissions are in terms of short tons $CO_2$, $CH_4$, and $N_2O$. Global Warming Potential (GWP) is in terms of short tons of $CO_2$ equivalent ($CO_2e$), using a GWP of 1 for $CO_2$, 21 for $CH_4$, and 310 for $N_2O$.

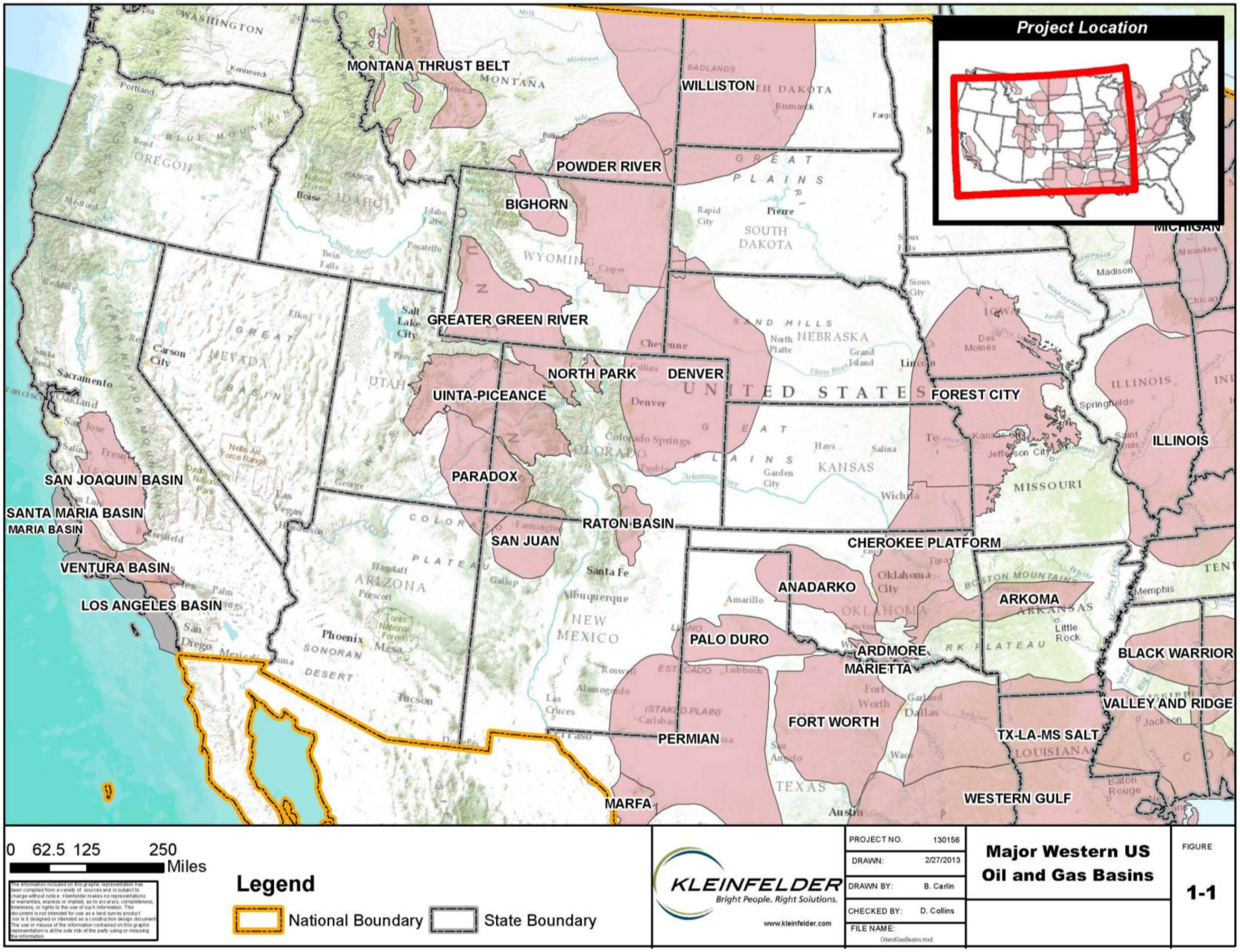
Emission estimates can be calculated as annual average emissions, worst-case single year emissions, or some other scenario. The various methods of representing emissions are problematic since a project could involve simultaneous construction and development (drilling and fracturing) and operation (production) in the same location, which is further complicated since well production is not a constant. Therefore, the worst-case emission estimate is to assume that construction, development, and operation occur simultaneously as shown in Table 1-2. If the user is interested in maximum operation-only emissions, then the tables in Section 3.3 of this report can be consulted where emissions from the three activities are reported separately.

As discussed in Sections 3.2.5 and 3.2.6 of this report, the emission calculations do not account for the fact that over time oil and gas well production rates decrease, i.e., the decline curve or decline factor. If one wanted a life-time average emission rate for production operations, a decline factor would have to be applied to the emission estimates in the tables of this report. To estimate lifetime average emissions, one can assume that operational emissions are linearly related to production and thus a linear application of the decline factor to the emissions can be used (i.e., if the decline factor is 50 percent, the lifetime average emissions would be 50 percent of those presented herein for operation). Note that the decline factor is not applied to construction or drilling emissions.

The electronic version of the Excel Workbook in Appendix A allows the user to enter project-specific variables that will over-ride the default values incorporated into the Workbook. Project variables are entered into a single “Constants and References” tab in the Workbook, and the changes automatically populate the remaining tabs and calculations. (The user should not enter the over-ridden value directly into the individual emission calculation sheets, but rather into the “Constants and References” sheet.)

In this document, the emission estimates are reported as a single value for each pollutant and well type rather than a range of values. However, Section 3 presents the range of key parameters evaluated and the basis for the selected single parameter. If the user wants to consider a range of emission estimates for a specific project, the range of key parameters shown in Section 3 or any other range of parameters can be entered into the Excel Workbook and a range of emission estimates easily generated.

The remaining sections of this report describe the methodology, references, and regulatory analyses used to develop the emission estimates in Section 2. Section 3 presents the parameters selected and results of the emission inventories. Sections 4 and 5 present conclusions and limitations. Section 6 provides a list of references used in the study.

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|---|---|
| PROJECT NO. | 130156 |
| DRAWN: | 2/27/2013 |
| DRAWN BY: | B. Carlin |
| CHECKED BY: | D. Collins |
| FILE NAME: | OilandGasBasins.mxd |

**Major Western US Oil and Gas Basins**

FIGURE **1-1**

## 2 EMISSION INVENTORY ESTIMATING METHODOLOGY AND REFERENCES

In order to develop the emission inventory estimates for representative oil and gas wells, an eight step process was used. The steps are as follows:

1. Identify active oil and gas basins in the western US.
2. In concert with BLM (Mr. Dave Maxwell of the National Operations Center), select those basins within which there are significant BLM lands and BLM interest in developing emissions inventories.
3. Identify basins that have significant oil and gas development and are representative of the BLM basins of interest.
4. Obtain National Environmental Protection Act (NEPA) Environmental Impact Statements (EISs) and Environmental Analyses (EAs), Resource Management Plans (RMPs), site-specific air permit applications, and other information that provide parameters and emission inventories for the basins selected, including reviewing the literature related to emission estimating techniques, such as United States Environmental Protection Agency (USEPA) publications.
5. From the literature and experience with development in the selected basins, select a representative collection of parameters necessary for estimating emissions for each basin.
6. Select appropriate emission estimating techniques and develop an Excel Workbook of emission estimates.
7. Evaluate the uncontrolled emission estimates against current federal and state regulations that could affect the emissions, and incorporate those emission controls required by regulations into the Excel Workbook as applicable.
8. Perform quality control/quality assurance checks on the Excel Workbook.

These steps will be further discussed in the following subsections.

### 2.1. SELECTION OF BASINS OF INTEREST AND REPRESENTATIVE BASINS

Most of the active oil and gas development in the western US occurs in the states of Alaska, California, Montana, North Dakota, Wyoming, Utah, Colorado, Nebraska, New Mexico, Texas, Oklahoma, and Kansas. In concert with BLM (Mr. Dave Maxwell of the National Operations Center), it was decided that neither California nor Alaska would be included in the project and that the focus would be only on conventional and shale oil and gas (e.g., coal bed methane was excluded). There is relatively little active oil and gas BLM land in California and Alaska has its own program for developing emission inventories and thus were excluded. It was also decided that Texas, Oklahoma, and Kansas would be excluded as well-specific information for wells in these basins tends to be proprietary to the operators. Although some information is available from state permit applications for wells, many of the activities that occur do not need a state permit or do not need a complete emissions inventory. Thus complete information for emissions inventories is not readily available. In addition, there is relatively less BLM controlled oil and gas lands in these Basins. Although the inventory can probably be used with relative confidence in Texas, Oklahoma, Kansas, or California if needed, it should not be used in Alaska because of the unique environment in that area.

For the remaining states, the major producing basins within which there is a relatively large amount of public land are the Williston, Upper Green River, Uinta, Piceance, Denver, San Juan, and Permian basins. These basins are responsible for a large portion of the oil and gas production in the western US that occurs on public lands. The Uinta and Piceance Basins are next to each other and have similar oil and gas geologic formation and production characteristics. Therefore, for purposes of the emission inventories, the Uinta and Piceance Basins were combined. The Permian Basin is also a major producing basin in southeast New Mexico and west Texas. Although this is a major basin, most of the development in Texas is on non-BLM land, and in New Mexico, BLM has already developed an emissions calculator for the Permian Basin. Therefore, the Permian basin was also excluded from this study. A map of the key oil and gas basins is shown in Figure 1-1 and a more detailed map is available from the US Energy Information Administration (EIA, 2013).

Therefore, the basins that were evaluated for this study are the Williston, Upper Green River, Uinta/Piceance, Denver, and San Juan. The Williston and Denver Basins are primarily oil plays, while the Upper Green River, Uinta/Piceance, and San Juan Basins are primarily natural gas plays. This does not mean that there could not be oil wells in the Upper Green River, Uinta/Piceance, or San Juan Basins or gas wells in the Williston and Denver Basins. But for purposes of the emission inventories, the representative wells were selected based on the primary play of that basin.

The key characteristics of the basins that are relevant for purposes of the emissions inventory are as follows. These characteristics are extremely generalized and actual conditions vary widely even within the same basin.

- Uinta/Piceance. Gas wells in this basin may or may not be drilled into a shale formation, but tend to be deep wells (on the order of 15,000 feet), are difficult to drill, and drill rigs are on a single well pad for a relatively long duration. There is not much water present in the gas, so no dehydrators are normally required at the well site. The gas wells produce a moderate amount of condensate (light oil). Equipment at the well site tends to be simple, with a single separator and a condensate tank. Although there are compressors used in the Basin to move gas to market, the compressors are not at well sites and are not included in the emission inventories.

- Upper Green River. Gas wells in the Upper Green River Basin also tend to be deep (on the order of 15,000 feet) but are drilled into non-shale formations. The gas tends to have more condensate (oil) present than either the San Juan or Uinta/Piceance Basins. There is more water vapor present in the gas from this Basin than others, so there normally is a dehydrator at each well site. The well sites also usually contain a separator and line heater. Wells are drilled at a relatively high density. There are gas compressors in the Basin used to move the gas to market. However, these compressors are not located at a well site.

- San Juan. Some gas wells in the San Juan basin may contain relatively high volumes of liquid water and thus pumpjack engines may be present (to remove the water) even though the wells are gas wells. San Juan gas wells produce relatively little condensate, thus there may not be any condensate tanks present. The wells tend to be shallow (on the order of 5,000 feet) and there is a minimal amount of equipment on site. For purposes of this study, the emission inventory includes a pumpjack engine and a condensate tank, even though they may not be present at all San Juan well types. As is the case for the Upper Green River Basin, gas compressors are used in the Basin, but are not generally located at a well site.

- Williston. Oil wells in the Williston Basin tend to be very deep (on the order of 15,000 to 18,000 feet), and are drilled into a shale formation that is difficult to drill, thus drill rigs are on site for a relatively long time. Horizontal drilling in the Williston Basin can be very long, on the order of a mile or more away from the well pad. The Williston formation is relatively very thin, and thus precise drilling is required. There is a relatively large amount of gas associated with the oil wells, and the gas may be flared in a flare pit for a period of time before it can be sent to a sales line.

- Denver. The Denver Basin is the easiest to drill, with relatively shallow wells (on the order of 5,000 feet deep) in non-shale formations. There are relatively low amounts of gas associated with the oil wells and that gas is sent to a sales line. The Denver Basin oil tends to be lighter than the Williston Basin.

Note that the oil and gas wells in these basins tend to be sweet wells (i.e., there is no or very little hydrogen sulfide associated with the wells). However, any of the wells in any of the basins could be sour wells with relatively large amounts of hydrogen sulfide ($H_2S$). For purposes of the emissions inventory, it was assumed that the wells were all sweet wells with no $H_2S$. However, if it is known that the project-specific wells are not sweet wells, then a project-specific $H_2S$ concentration can be input in the Excel Workbook and the Workbook will calculate potential $H_2S$ emissions. If the amount of $H_2S$ is significant, the project may be required to install $H_2S$ emission controls (e.g., a sweetening unit). The effectiveness of a sweetening unit and emissions from it are beyond the scope of this study, but would have to be accounted for in an emissions inventory if present. Since $H_2S$ can be an important issue, the Excel Workbook will calculate emissions of it, even though it is not a criteria pollutant or a HAP. The Excel Workbook also accounts for emissions of $SO_2$ from combustion of gas if the gas contains $H_2S$.

## 2.2. LITERATURE AND REFERENCES

Once the basins were selected, several sources of information were consulted in order to determine representative emission calculation parameters. Generally accepted emission estimating techniques published by the USEPA were used for the emission calculations. However, those techniques require a number of parameters in order to yield emissions. The parameters were obtained from NEPA documents, RMPs, air permits to construct, and professional judgment. USEPA publications are peer reviewed and generally accepted for emission estimating techniques. On the other hand, individual parameters needed to calculate the emissions are not generally available in peer reviewed literature, but are detailed in the NEPA documents, RMPs, and permits to construct. Those major documents used for this study, although not from scientific peer reviewed journals, were subjected to extensive stakeholder, state, and cooperating agency reviews. Therefore, those publications are suitable as the source of key oil and gas parameters needed for calculating emissions. Section 3 of this report discusses the key parameters and the source of the parameters selected, and Section 6 presents a list of references. The key sources of information for each of the basins are summarized below:

- Uinta/Piceance: Greater Natural Buttes EIS (BLM, 2012a), GASCO EIS (BLM, 2011b), White River RMP (BLM, 2012b), and the Colorado River Valley RMP (BLM, 2011a).
- Upper Green River: Jonah Infill EIS (BLM, 2006), Supplemental FEIS for the Pinedale Anticline (BLM, 2008), Wyoming air permits to construct
- San Juan: Farmington RMP (BLM, 2003)
- Williston. North Dakota air permits to construct and experience with the basin.
- Denver: Colorado air permits to construct and experience with the basin

As indicated, the above references are not the only literature sources used to select representative parameters, and the parameters in these sources were not used without judgment. In other words, the parameters contained in the above publications were evaluated and a representative value chosen based on professional judgment. No attempt was made to perform a statistical analysis of the parameters or choose an average or median from the references. The focus was on selecting representative parameters typical for the well type, not an average, or a conservative "worst case" value. The results of the parameter selection and the basis for the selection are discussed in Section 3 of this report. The equations and emission models used to estimate emissions are shown in the Appendices. The equations and models are those promulgated by the USEPA in such publications as AP-42, *Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources* (USEPA, 2013).

The specific references examined and the source of those references is listed below. Each of the key references has been assigned an abbreviation which is shown below in quotes, and which is used throughout the remainder of this report. The specific information obtained and used from each reference is discussed in Section 3 of this report.

- “NDDEQ”: Well site air quality permit to construct applications filed and approved for Helis Oil and Gas Company, LLC (3 sites), Prima Exploration, Inc. (2 sites), Samuel Gary Jr. and Associates, Inc. (2 sites) and G3 Operating, Inc. (3 sites). Available through a public records request to the North Dakota Department of Environmental Quality.
- “CDPHE”: Ten well site air quality permits to construct applications filed and approved for Bayswater Exploration and Production, LLC. Available through a public records request to the Colorado Department of Health and Environment Air Pollution Control Division.
- “WYDEQ”: Well site air quality permit to construct applications filed and approved for Helis Oil and Gas Company, LLC (4 sites), Enduro Operating, LLC (2 sites), and Samson Oil and Gas Ltd. (6 sites) Available through a public records request to the Wyoming Department of Environmental Quality Air Quality Division.
- “Farmington RMP”: Farmington Resource Management Plan and Final Environmental Impact Statement, March 2003 (BLM, 2003).
- “White River”: White River Field Office Oil and Gas Resource Management Plan Amendment / Environmental Impact Statement Air Resources Technical Support Document, June 2012 (BLM, 2012b).
- “Jonah”: Final Air Quality Technical Support Document for the Jonah Infill Drilling Project Environmental Impact Statement, January, 2006 (BLM, 2006).
- “Pinedale”: Supplemental Final Environmental Impact Statement for the Pinedale Anticline Project Area, June, 2008 (BLM, 2008).
- “CRV”: Final Colorado River Valley Field Office Resource Management Plan Revision, Air Resources Technical Support Document, Revised August 2011 (BLM, 2011a).
- “GNB”. Greater Natural Buttes Final Environmental Impact Statement, FES 12-8, March 2012 (BLM, 2012a).
- “GASCO”: Final Environmental Impact Statement (EIS) for the GASCO Uinta Basin Natural Gas Development Project, 2011 (BLM, 2011b).

Note that the above documents are mostly BLM publications. Although other publications were also evaluated, such as EISs published by the Bureau of Indian Affairs (BIA 2012a, BIA 2012b), because most of the public lands with oil and gas resources are in the western US and are controlled by BLM, the BLM EIS and RMP publications tend to be the most detailed and useful for this study.

The above publications and references provided project-specific detail and calculations for individual well activities, and thus were the most useful. There are other publications and information sources that were also reviewed, such as the Western Regional Air Partnership (WRAP) emissions databases (WRAP, 2013), the West-wide Jumpstart Air Quality Modeling Study (WRAP, 2013), the USEPA National Emissions Inventory (USEPA, 2013), and the USEPA Greenhouse Gas Reporting Program (GHGRP) emissions inventories (USEPA, 2011). However, these databases and information sources provide emissions on a facility-wide, company-wide, or regional basis and do not provide individual well-specific information suitable for use in the emissions inventories which are the subject of this study. On the other hand, the information in those databases were evaluated and compared to the emission estimating techniques and parameters used in this study as an overall confirmation that the individual well inventories are consistent with the facility and company-wide data and that consistent emission estimating techniques were used.

In addition to the above publications and permit applications, state regulations for the western US that could affect the emission inventories were also reviewed. This review is discussed in Section 2.5 of this report.

## 2.3. EMISSION CALCULATIONS

The parameters selected from the above references and professional judgment were then input into an Excel Workbook in order to calculate the emissions for each of the five representative basins. The Excel Workbook is contained in Appendix A, hard copies for each basin are shown in Appendices B through F, and a discussion of the key parameters and reason for selection is presented in Section 3 of this report. The Appendices also present the equations, emission models, and emission factors used to calculate the emissions and details for each of the individual emitting activities.

## 2.4. QUALITY CONTROL/QUALITY ASSURANCE OF THE EMISSION CALCULATIONS

As the Appendices show, the emission calculations involve a large number of activities, a large number of emission estimating techniques and parameters, and the parameters vary by well type. Quality Control/Quality Assurance (QC/QA) of the spreadsheets was conducted through independent (i.e., Kleinfelder Team staff who were not involved in the initial calculations) review of the estimating techniques, the parameters chosen, application of the parameters, and the emission calculations. The equations in the Excel Workbook were subjected to hand-calculation to confirm the value calculated electronically. Visual inspection was used to confirm population of the variables from the "Constants and References" tab of the Workbook throughout the appropriate equations. Selection of emission parameters for each well type was reviewed by engineers familiar with oil and gas operations but who were not involved in the initial selection. Finally, the emission totals were compared to other emission totals from other publications and projects to confirm representativeness.

## 2.5. STATE AND FEDERAL REGULATIONS

The final step was to evaluate state and federal regulations that could affect the emission calculations for isolated wells which are the subject of this study. For example, the new New Source Performance Standard (NSPS) for oil and gas production (40 CFR Part 60 Subpart OOOO) requires emission controls on condensate/oil tanks if the uncontrolled emissions are greater than 6 tons per year. In parallel with the NSPS, there are also National Emission Standards for Hazardous Air Pollutants (NESHAPs) that could apply to oil and gas wells, e.g., 40 CFR 63 Subpart HH.

The regulations evaluated and how they affect the emission calculations are summarized below. Only those portions of the regulations that could change the emissions inventory for the situation where there are a few isolated wells are noted. There are numerous federal and state regulatory requirements that could apply to large stationary and mobile sources or groups of sources, but it is beyond the scope of this study to present all of those regulatory requirements.

### 2.5.1. Federal NSPS

The primary federal regulation that affects individual wells is the NSPS for the Oil and Gas Sector (40 CFR 60 Subpart OOOO). Subpart OOOO (and 40 CFR 60 Subpart VVa which is referenced by Subpart OOOO as a requirement) could affect well emissions through the following requirements:

- The NSPS requires control of flowback emissions (associated natural gas) that could occur during the hydraulic fracturing process. Therefore, in this study it was assumed that hydraulic fracturing flowback emissions during well development would be controlled to the 95 percent level. However Subpart OOOO does not require control of flowback emissions during workovers, and thus no control during workovers was assumed.

- All storage tanks for oil or condensate are required to be controlled with a minimum of 95 percent efficiency if the uncontrolled VOC emissions are more than 6 tons per year. For the wells evaluated in this study, the storage tank VOC emissions from wells in all of the Basins except the San Juan were assumed to have uncontrolled emissions greater than 6 tons per year, and were controlled. (As discussed in Section 2.4.3, storage tanks in the Denver Basin are required to be controlled with a minimum of 70 percent efficiency even if uncontrolled emissions are less than 6 tons per year. However, in this study, uncontrolled VOC emissions for the Denver Basin oil well are greater than 6 tons per year, and the Subpart OOOO requirement of 95 percent control was applied to the Denver Basin well type).
- The NSPS requires, beginning October 15, 2013, that all pneumatic controllers on new wells emit less than 6 standard cubic feet per hour (scf/hr) of natural gas (generally termed "low bleed" pneumatics) unless high bleed pneumatic controllers are required for safety or other justifiable operational requirements. Accordingly, for purposes of the emission inventory, it was assumed that all pneumatic controllers were low-bleed. Other pneumatic devices (e.g. dump valves and pumps) do not have the low bleed requirement.

The second NSPS affecting emissions from single well sites is the NSPS for stationary spark ignition reciprocating engines, 40 CFR 60 Subpart JJJJ. This NSPS only applies to the pumpjack engines in the emissions inventory as the other engines are either not stationary or are diesel-fueled compression ignition engines. (Subpart JJJJ also applies to reciprocating compressor engines, but as discussed, the emissions inventories do not include compressors since compressors are not located at individual well sites). The NSPS requires engines manufactured after July 1, 2008 to meet emission limits of 2.8 grams per horsepower hour (g/bhp-hr) $NO_x$ and 4.8 g/bhp-hr CO for engines less than 100 horsepower (the pumpjack engines are smaller than 100 horsepower). For purposes of this study, it was assumed that the pumpjack engines would be model year 2008 or later and thus will meet the Subpart JJJJ emission limits.

In addition to the NSPS, there are federal regulations (40 CFR 89 and 40 CFR 1039) that require manufacturers of diesel-fueled engines used on the drill rig and drill platform to meet certain emission limits. The emission limits differ according to the size and year of manufacturer of the engine, with the most stringent limits being for engines manufactured after 2015 (i.e., large Tier 4 engines). However, older model year engines can continue to be used after 2015. For purposes of the emission inventories, it was assumed that drill rig engines would meet Tier 2 emission limits, i.e., limits for engines manufactured after 2001 for the smaller engines and after 2006 for the large drill rig engines over 750 horsepower. It was assumed that the remainder of the engines would not meet any specific emission limits (i.e., so-called Tier 0 engines). The emission limits on engines are complex and a complete description of the limits and alternatives is beyond the scope of this study. The engine emission limits also affect construction equipment and other tailpipe emissions; however, those emission limits are built into the USEPA NONROAD emission model used to select emission factors for that type of equipment.

### 2.5.2. Federal NESHAP

Federal NESHAPs can apply to major and non-major sources of hazardous air pollutants (HAPs). The individual wells in this study are not major sources of HAPs, and thus only the non-major provisions of the NESHAP apply (non-major sources of HAPs are termed "area sources"). There are two NESHAP provisions that apply to single well site area sources: Subpart HH and Subpart ZZZZ. For area sources, Subpart HH only applies to dehydrators that process more than 3 million cubic feet per day of natural gas or have benzene emissions greater than 1 ton per year. It was assumed that all of the gas wells in this study produce 4 million cubic feet per day of natural gas, and thus it was assumed that dehydrators, if present, would be controlled to a minimum of 95 percent efficiency.

40 CFR 63 Subpart ZZZZ applies to both stationary spark ignition and stationary compression ignition engines, called reciprocating internal combustion engines (RICE). For this study, the only stationary RICE is the pumpjack engine, (because compressors are not included in the inventory), and in that case, for the small pumpjack engines, compliance with Subpart ZZZZ is met by complying with Subpart JJJJ as discussed previously.

### 2.5.3. State Regulations

The key state regulations that could affect the emission inventory are summarized below. As in the case with the federal regulations, the following is not a complete list of all of the compliance obligations that individual well sites may have to meet, but rather only a brief summary of those regulations that could meaningfully affect the emission calculations. State requirements must be at least as stringent as Federal requirements, and in some cases are more stringent. For completeness, even when the state requirements are not more stringent than the federal requirements, the requirements are summarized below. Section 6 of this report identifies where the regulations discussed for each state can be obtained.

Montana

Montana requires sites where uncontrolled emissions from oil or condensate tanks or loading operations have the potential to emit VOCs greater than 15 tons per year to be controlled. The Federal 40 CFR 60 Subpart OOOO requires controls at 6 tons per year. For purposes of this emissions inventory, all of the oil or condensate tanks in all of the basins except for the San Juan Basin were assumed to have uncontrolled emissions greater than 6 tons per year, and thus emission controls were included in the emissions inventory for the Williston Basin well type. Montana regulations require submerged filling during loading operations, but this type of emission control has been included in all of the emission inventories because it is standard practice.

Montana requires stationary internal combustion engines over 85 horsepower to install oxidation catalytic reduction (or similar controls) to reduce emissions of NOx and CO (Montana Regulation ARM Title 17, Chapter 8, Subchapter 16, Section 1603(e) and (f)). However, the stationary engines at the well sites, i.e., the pump jack engines, are smaller than 85 horsepower, so no additional controls were included in the emission inventory.

North Dakota

North Dakota requires all sites with the potential to emit 20 tons per year or greater of VOCs from the storage tanks, including produced water tanks, to control vapors from the tanks by at least 98 percent control efficiency. For those sites where the vapors from storage tanks have the potential to emit less than 20 tons per year of VOCs, the tanks at those sites need to be controlled by at least 90 percent control efficiency. However, the Federal 40 CFR 60 Subpart OOOO requires 95 percent control at 6 tons per year, and thus 95 percent emission controls for wells in the Williston Basin were included in the emissions inventory.

North Dakota also requires vapors from dehydrator still vents that exceed the following emission levels to be routed to a control device: greater than or equal to 5.0 tons per year of any combination of HAPs or greater than or equal to 15.0 tons per year of VOCs. The dehydrators in this study do not have that level of emissions, thus no controls were included in the emission inventories.

As is the case in Montana, splash loading is not permitted in North Dakota, and submerged filling was assumed in the emission inventories.

<u>South Dakota</u>

No specific regulations are currently established that affect the emission inventories for well sites in South Dakota.

<u>Wyoming</u>

Due to the extensive oil and gas development in Wyoming over a number of years, there are a number of Wyoming state regulations that could affect the emission inventories. The requirements vary by location within the oil and gas basins.

For the Jonah-Pinedale Anticline Development (JPAD) Area, the following are required:

- Tank flashing: 98 percent control on all new and modified tanks if uncontrolled emissions are greater than 8 tons per year. Because this level of control is only for the JPAD, which is a subset of the Upper Green River Basin, it was assumed that only 95 percent control would apply to the Upper Green River Basin well type as that yields an upper bound emission estimate.
- Dehydration units: 98 percent control on all new and modified dehydrators. This level of control was included in the emissions inventory for the Upper Green River well type.
- Pneumatic pumps: 98 percent control requirement or closed loop system on all new natural gas operated pumps (heat trace or other pumps) or existing pumps at modified facilities. Pneumatic pumps (as opposed to pneumatic controllers) are not always

required for wells in the Upper Green River Basin, and more modern wells are using solar-powered pumps. However, for purposes of the emissions inventory, because control on pneumatic pumps is for the JPAD, which is a subset of the Upper Green River Basin, it was assumed that pneumatic pumps would be controlled. The San Juan and Uinta/Piceance gas well types also have pneumatic pumps, but no controls are required nor included in the emissions inventory.

- Pneumatic controllers: All new (post 2010) natural gas operated pneumatic controllers must be low or no bleed. Low bleed pneumatic controllers were assumed for the emissions inventory for the Upper Green River well type as well as the other two gas-well basins. Note that there are other pneumatic devices (e.g., dump valves) which are not required to be low bleed.
- Completions: Green completion permits required for all completions with goal of achieving 98 percent control of venting emissions or use of Best Management Practices (BMPs) where feasible. It was assumed for the emission inventory that there would be no BMP feasible for single well sites in a small project (i.e., less than 5 wells, which is the focus of this study), and, therefore, no controls were included.
- Well blowdowns: Well blowdowns are associated with non-routine maintenance activities (e.g., depressurization of a well to affect repair) and are not included in the emissions inventory. However, Wyoming regulations require the use of BMPs (e.g., limiting the duration of venting) to minimize emissions to the extent practical.
- Produced water tanks: 98 percent control requirement on all new and modified tanks in the JPAD area (a Wyoming specific requirement only for the JPAD area) if the VOC emissions are over 8 tons per year. However, when the potential emissions from the produced water tanks are calculated, none of the single well sites have this level of emissions and no control is included in the emissions inventory.

For the Concentrated Development Area (Carbon, Fremont, Lincoln, Natrona, Sublette (non-JPAD), Sweetwater, and Uinta Counties) the requirements are essentially the same as the JPAD area except that the controls must be in place for one year and then can be removed if emissions are less than 8 tons per year. However, the Subpart OOOO NSPS requires control at 6 tons per year. Therefore, for purposes of the emission inventory, none of the controls were removed.

The Wyoming statewide requirements, i.e., counties not in the JPAD or Concentrated Development Area, are similar to the JPAD requirements, although the thresholds are less stringent and there are no requirements on well completions or produced water tanks. The JPAD requirements on completions and produced water tanks did not affect the emissions inventories; therefore, there is no difference between statewide requirements and JPAD requirements with regard to the emission inventories in this study.

Colorado

The Colorado Department of Public Health, Air Pollution Control Division, also has extensive regulatory requirements for oil and gas wells, depending on the area within which the well is located.

In the Front Range, Denver-Julesburg Basin (i.e., the North Front Range 8-hour ozone non-attainment area), the following are required:

- Tanks at the well site must achieve a minimum of 70 percent control during the non-ozone season and 90 percent control during the ozone season. However, for purposes of the emission inventory, uncontrolled VOC emissions were assumed greater than 6 tons per year. Thus 40 CFR 60 Subpart OOOO requires 95 percent control, and that level of control was applied.
- Pneumatic controllers installed after Feb. 1 2009 are required to meet the definition of a low-bleed controller. Subpart OOOO also requires low bleed controllers. However, for purposes of this study, it was assumed that there were no pneumatic controllers (low bleed or otherwise) present at the Denver Basin wells, as such devices are not normally present for oil wells. (No pneumatic devices were included for the Williston oil well type either).

The following are statewide requirements in Colorado:

- New and existing condensate tanks emitting 20 tons VOC per year or more are required to control emissions by 95 percent. Although none of the well sites in this study exceed that threshold, the federal threshold is 6 tons per year and 95 percent control was assumed.

- New and existing glycol dehydrators emitting more than 15 tons VOC per year or more are required to control, but none of the well sites in this study exceed that threshold.

In addition to the Air Pollution Control Division, the Colorado Oil and Gas Conservation Commission (COGCC) also has regulations that require emission controls on tanks and dehydrators with uncontrolled emissions over 5 tons per year, no or low-bleed pneumatics where feasible, and BMPs or green completions. As noted, tank controls and low-bleed pneumatic controllers are included in the emission inventories, but no BMPs that affect emissions were included, and it was assumed that associated gas entered the sales line.

Utah

There are no specific requirements for single well-site sources that would affect the emission inventories.

New Mexico

There are no specific requirements for single well-site sources that would affect the emission inventories.

Arizona

There are no specific requirements for single well-site sources that would affect the emission inventories, other than dust control requirements. Dust control has been included in the emissions inventories of this study.

Nevada

There are no specific requirements for single well-site sources that would affect the emission inventories.

Idaho

There are no specific requirements for single well-site sources that would affect the emission inventories.

Washington

There are no specific requirements for single well-site sources that would affect the emission inventories.

Oregon

There are no specific requirements for single well-site sources that would affect the emission inventories.

# 3 EMISSION INVENTORY ESTIMATE RESULTS

The emission inventories for the five representative basins are presented in Appendices A through F. The following sub-sections of this report discuss the activities included and excluded from the emission inventories and the results of the inventories by activity and pollutant.

## 3.1. EMISSION ACTIVITIES

The emission inventories include the following general activities. The specific detailed activities and equations for calculating emissions are shown in the Appendices. The general activities are as follows:

Construction (access road, pipeline, well pad)

- Fugitive dust from access road and well pad construction, interim and final reclamation, and construction heavy equipment
- Fugitive dust from pipeline construction
- Tailpipe and fugitive dust emissions from light duty vehicles (e.g., pickup trucks for construction workers), construction heavy equipment, and heavy duty trucks such as tanker trucks
- Wind erosion from disturbed surfaces

Development (drilling/completion/workovers)

- Tailpipe emission from engines used on the drill rig platform to install the conductor pipe
- Tailpipe emissions from engines associated with drilling the well, including drill rig, air compressors, electrical generators, and dozer and other heavy equipment engines
- Tailpipe emissions from hydraulic fracturing pump and associated engines (i.e., well completions)
- Well cementing emissions
- Well workover emissions
- Hydraulic fracturing flowback emissions
- Tailpipe and fugitive dust emissions from worker and delivery/transport vehicles

Operation (production of natural gas and oil)

- Well production emissions from heaters, pneumatic controllers, pumpjack engines, plus fugitive emissions (i.e., leaks from valves, flanges, open ended lines, etc.) at the well site
- Storage tank and loading emissions, including tailpipe and fugitive dust emissions from tanker trucks and other vehicles servicing the well
- Well-site dehydrators
- Tailpipe and fugitive dust emissions from worker and delivery/transport vehicles

Reclamation (included as part of Construction)

- Interim reclamation fugitive dust and tailpipe emissions, which are included as part of the well pad construction by adding vehicles and the duration of activities
- Final reclamation fugitive dust and tailpipe emissions, which are included as part of the well pad construction by adding vehicles and the duration of activities

No emission estimates were included for pipeline natural gas compressors and dehydrators not located at the well site, although pipeline compression and possibly pipeline dehydration will be required somewhere along a pipeline leading to a central gathering station and for moving the gas to market. But these emissions are not at a single well site.

Combustion emissions from flares that may be used to control potential emissions from storage tanks or dehydrators were included in the emissions inventory (as well as un-combusted VOCs and GHGs were included). If there is $H_2S$ present in the flared gas, flare combustion can create $SO_2$. For purposes of this study it was assumed that the wells did not contain meaningful amounts of $H_2S$, so no $SO_2$ emissions from flares were included. However, if the user of the inventory has information that there is meaningful amounts of $H_2S$ present at a project, the user can enter the $H_2S$ content of the gas and the Excel Workbook will calculate both the $H_2S$ and $SO_2$ emissions resulting from combustion of gas containing $H_2S$. On the other hand, oil wells in the Williston Basin produce a large amount of associated gas, and that gas is flared in flare pits or other flare devices. The amount of associated gas can be considerable in the Williston Basin, thus the emissions inventory for the Williston Basin well type includes combustion emissions from flared associated gas.

Road maintenance emissions were not included in the emissions inventory, because this study focuses on projects that contain a small number of wells, typically wildcat or delineation wells.

In that that case, there may or may not be road maintenance activities and such activities are not at individual wells.

Some of the well sites in the San Juan Basin will have compressors located at the well head, but these compressors typically serve a group of gas wells even when located at a well site. However, for the wells which are the focus of this study (i.e., approximately five or fewer isolated wells), it is not likely that there would be well site compressor engines utilized. Therefore, no such engines were included in the emissions inventory, although field compression for a large group of wells somewhere in a large well field will be required in order to move the gas to market.

Two potential sources of VOC emissions are associated with liquids unloading (blowdowns) and working/breathing losses from storage tanks or mobile tanks. Working/breathing losses are much smaller than flashing emissions. The emissions inventory of this study was developed as a stand-alone document (and Excel Workbook) that could be used without additional emission estimating techniques. In order to calculate working and breathing losses, the USEPA TANKS emissions model would need to be used on a case by case basis. Working and breathing emissions are much smaller than flashing emissions and working and breathing losses could not be included without the user having to separately run the TANKS model (USEPA, 2012) on a case by case basis; therefore they have not been included in the inventory. Liquid unloading blowdowns are associated with a central facility. For the isolated few well scenario of this study, liquid unloading blowdowns would not likely be present and have thus not been included. Although unloading and working/breathing emissions can be meaningful when emissions from a large well field with thousands of wells are considered, in the case of the isolated wells which are the subject of this study, they are de minimis.

There may also be VOC emissions from drilling mud pits caused by hydrocarbons that may come up from the well during drilling. No emission factors were found in the references evaluated for this study, including no USEPA emission factors for this source. Accordingly, potential emissions from mud pits have not been included in the emission inventory.

The main activities producing meaningful amounts of HAPs typically associated with oil and gas drilling and production have been included in the emissions inventory. These HAPs are benzene, toluene, ethylbenzene, xylene (BTEX) and n-hexane. Tailpipe emissions of hazardous air pollutants from drill rig, hydraulic pump and similar engines and tailpipe emissions of HAPs from on-road and off-road equipment have not been included as those emissions tend to be much smaller than HAPs associated with the oil and gas products. Some of the HAPs associated with tailpipe emissions are acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde. These tailpipe emissions combined would constitute less than 0.3% of CO emissions, or on the order of 0.0008 tons per year in this emissions inventory. The percentage of tailpipe HAPs was derived from the I-15 Corridor Utah County to Salt Lake County FEIS, Table 3.8-8 (USDOT FHWA, 2008). Note that ethylbenzene emissions from oil and gas activities included in the emissions inventory are also relatively small, but ethylbenzene is one of the BTEX compounds associated with oil and gas production and it has been included in the emission inventory. Furthermore, some gas can contain larger amounts of benzene than the gas profiles used for the inventories in this study. If it is known that larger amounts of benzene are present, the project-specific gas composition can be entered into the Excel Workbook of Appendix A and the emissions will be automatically calculated.

In the Appendices, where a value of 0.00 appears, that indicates that there were no or de minimis emissions of that specific pollutant for that well type. If there are non-zero emissions, then at least one significant figure was reported. The number of significant figures shown in the Appendices varies as the quantity of individual pollutants is highly variable. For example, $SO_2$ emissions are reported to only one significant figure because the emissions are on the order of one ten thousandth of a ton per year. In the spreadsheets, the emission summaries are reported to two decimal places because in order to show a 0.00 value, two decimal places must appear in the Excel Workbook.

## 3.2. SELECTION OF PARAMETERS FOR EMISSION CALCULATIONS

The equations used to calculate the emissions for each of the above activities are shown on the spreadsheets in the Appendices. The equations use a combination of physical constants (e.g., conversion from meters to feet), variables required by the emission equations (e.g., moisture content of soil being moved), and well-specific parameters. The well-specific parameters are those parameters that were chosen to represent the five different well types that are the focus of this study. The basis for the physical constants, variables, and well-specific parameters are contained in the spreadsheets. The basis for most of the parameters are typical values based on professional judgment (e.g., 4 days to construct a well pad) and are generally used in all of the references discussed in Section 2.2 of this report. However, some of the well-specific parameters are more critical to the emissions estimates and required additional investigation and judgment for selection. The critical well-specific parameters and the basis for selection are as follows. The terminology used for the references (e.g., “NDDEQ”) is that presented in Section 2.2.

### 3.2.1. Vehicle Tailpipe and Fugitive Dust Emissions

Emissions associated with vehicle travel are a function of the emission factors (e.g., pounds per vehicle mile traveled, lb/VMT) and the number of miles traveled. The VMT is a function of the location and spacing of the wells, number and type of equipment and supply deliveries, number of workers, duration and magnitude of hydraulic fracturing, size of trucks bringing supplies (especially water) to the well, oil and condensate production rate of the well, size of the tanker trucks pumping the stock tanks, and numerous other variables. For purposes of the emission inventory, typical vehicle traffic counts and distances were used for wells drilled where there is relatively little hydraulic fracturing fluid needed. If project specific information is available for calculating project specific VMT (e.g., it is know that very large amounts of water will be needed for hydraulic fracturing), that information can be entered into the Workbook.

### 3.2.2. Drill Rig Engine Size

Drill rig and hydraulic fracturing pump engine horsepower vary widely among various inventories and studies, depending on the specific engines used by the drilling and production company and how quickly the drilling company intends to complete a well. GNB uses a drill rig engine of 1,476 horsepower (hp) and a completion rig of 475 hp. Jonah used 2,100 hp total for three engines when vertical drilling and 2,600 hp when horizontal drilling. Pinedale drill rig engines range from 3,640 to 4,040 hp. CRV used 2,952 hp for drill rig engines. For purposes of this emission inventory, the following drill rig engine sizes were assumed:

- Uinta/Piceance Drill Rig Engine 2,950 hp (i.e., the CRV value)
- Upper Green River Drill Rig Engine 2,100 hp (i.e., the Jonah value)
- San Juan Drill Rig Engine 2,100 hp (i.e., the Jonah value)
- Williston Drill Rig Engine 2,100 hp (i.e., the Jonah value)
- Denver Drill Rig Engine 2,950 hp (i.e., the CRV value)

The horsepower for other engines involved in drilling, hydraulic fracturing, and workovers (e.g., electrical generators, pump engines) are detailed in the Appendices. As shown in the

Appendices, hydraulic fracturing pump engines can also be relatively large, on the order of 1,500 horsepower.

The various reference documents either assume no load factor or variable load factors. For example, GNB used 65 percent load and 65 percent utilization for an overall load factor of 42 percent. For purposes of the emission inventory, two different load factors were used, depending on the operation and the engine. The 42 percent overall load factor was used for all engines except horizontal drilling and hydraulic fracturing pump engines. For those engines, a load factor of 59 percent was used, (90 percent load and 65 percent utilization), based on professional judgment, to reflect the fact that horizontal drilling and hydraulic fracturing are more power-intensive activities.

### 3.2.3. Drill Rig Engine Emission Limits

As discussed in Section 2.4.1, there are federal requirements for engine manufacturers to meet certain emission limits based on the "Tier" of the engine and date of manufacture. Various agency and EIS Records of Decision require more modern engines than federally required. For example, GNB required a minimum of Tier 2 engines, one of the alternatives evaluated in White River required Tier 4 engines, and Jonah required Tier 4 engines to be phased in between 2008 and 2015. Engines greater than 750 horsepower manufactured between 2011 and 2014 are required to meet interim Tier 4 emission limits while engines manufactured from 2015 and later are required to meet final Tier 4 emission limits. Turnover of the drill rig engine fleet to Tier 4 engines is dependent on individual rig operators; however, for purposes of the emissions inventory, Tier 2 engines were assumed. This provides a reasonable upper bound for the emissions from drill rig engines.

### 3.2.4. Hydraulic Fracturing Flowback Emissions

During hydraulic fracturing of the formation, the fracturing fluid is returned to the surface. This is termed "frac flowback." The flowback can contain a meaningful amount of associated natural gas from the formation. In some cases, all of the associated gas is captured and either flared or sent to a sales line. When the flowback gas is completely captured and sent to a sales line, it is called a "green completion". In other cases the associated gas is either flared or simply released to the atmosphere.

GNB assumed that all wells would be green completions with no flowback emissions. Jonah assumed that the flowback gas would be vented uncontrolled for 4 hours and flared for 80 hours with a total gas flowback amount of 35 thousand standard cubic feet (scf). CRV assumed that one-half the flowback gas would be vented uncontrolled and one-half flared, with a total flow of 1 million scf per well. Based on these references, for purposes of the emission inventory the CRV value of 1 million scf was used. The amount of flowback gas is highly variable and a function of the individual well, although for this study a constant value of 1 million scf was used. But as is the case with all variables, a different value can be input into the Excel Workbook if project-specific information is known. Consistent with 40 CFR Subpart OOOO and other regulations, it was assumed that all of the flowback gas was flared with 95 percent control.

### 3.2.5. Gas Production Rate, Decline Factor, and Dehydrator Emissions for Gas Wells

The gas production rate (standard cubic per day or scfd) of natural gas from an individual gas well is used to calculate potential dehydrator emissions. The anticipated production rate may be known, but the actual rate often varies greatly from the expected rate. For purposes of the emissions inventory, only the Upper Green River Basin well type has a dehydrator present.

Farmington RMP used an initial gas production rate of 55,584 Mscfd (55.6 MMscfd) per well but then applies a decline factor of 50 percent for the average life of the well (i.e., average production of 27.8 MMscfd). Pinedale used a gas production rate of 4,000 Mscfd (4.0 MMscfd) per well.

Both gas and oil wells initially produce much more on a daily basis than later in the life of the well. This is the decline factor or decline curve. Many of the reference documents do not specify a decline curve, either assuming that the initial production rate would remain constant or specifying an average production rate for the “life of the well”, basically an average production rate over a period of 10 to 20 years. For purposes of the emission inventory in this study, no decline factor was built in to the emission estimates because the project-specific production rate is not known, and thus a decline factor is meaningless. Thus, the emission inventories provide an upper bound estimate of emissions based on the production rate specified.

Accordingly, a 4.0 MMscfd gas production rate was used for the Upper Green River Basin well type dehydrator emission calculation.

Depending upon the size of the dehydrator and the potential uncontrolled emission rate, emission controls on the dehydrator potential VOC emissions may be required. Pinedale assumed that all well site dehydrators were controlled at 95 percent. White River assumed dehydrator control for one of the alternatives. For purposes of this study, only wells in the Upper Green River Basin will have well-site dehydrators. Pinedale assumed 95 percent control; therefore the emission inventory also assumes 95 percent control on well-site dehydrators.

### 3.2.6. Oil and Condensate Production Rate and Decline Factor at Gas and Oil Wells

One of the key variables in determining emissions from storage tanks is the oil production rate for oil wells, the condensate production rate for gas wells, and the decline factor. Natural gas wells often have hydrocarbon liquids associated with the produced gas, and these liquids are termed condensate. Likewise, oil wells can have associated natural gas produced with the oil. For this study, the term "produced gas" is used for the natural gas produced from gas wells, the term "associated gas" is used for the natural gas associated (or produced) with oil wells, and the term "flash gas" is used for the vapor that is released from oil or condensate in storage tanks.

NDDEQ assumes an oil production rate of 250 barrels per day (bbl/d) for the first 30 days of production at oil wells. GNB assumed 10 bbl/d of condensate production for the first year, 3 bbl/d condensate production for the second and following years for gas wells. Jonah used a constant 25.3 bbl/d condensate production rate for gas wells. Pinedale used 30 bbl/d condensate for gas wells. San Juan Basin gas wells have relatively little to no condensate. Therefore, for purposes of this emissions inventory, the following oil and condensate production rates were assumed:

- Uinta/Piceance Gas Well … 10 bbl condensate per day
- Upper Green River Gas Well … 30 bbl condensate per day
- San Juan Gas Well … 5 bbl condensate per day
- Williston Oil … 150 bbl oil per day
- Denver Oil … 125 bbl oil per day

NDDEQ uses an assumed decline factor of 0.6 (i.e., the average annual production rate in terms of bbl/d after the first 30 days will be 60 percent of the daily production during the first 30 days). GNB used a decline factor of 0.7 after the first year, Farmington RMP uses a 0.5 decline factor, Jonah used a factor of 0.7, and Pinedale used a factor of 0.335. For purposes of the emission inventory, no decline factor was built in to the emission estimates because the project-specific production rate is not known, and thus a decline factor is meaningless. Thus, the emission inventories provide an upper bound estimate of emissions based on the production rate specified. If a project-specific production rate and/or decline factor is known, that data can be entered in to the spreadsheets to change the emission estimates.

#### 3.2.7. Flash Gas to Oil Ratio for Gas and Oil Wells

The amount of vapor released in oil or condensate storage tanks is a function of the flash gas to oil ratio (Flash GOR). Flash GOR is also highly variable, even among different wells in the same basin. For purposes of the emissions inventory, the following Flash GORs were used for the gas and oil wells based on professional judgment:

- Uinta/Piceance Gas Well Flash GOR …100 standard cubic foot of gas per barrel of condensate (scf/bbl)
- Upper Green River Gas Well Flash GOR …98 scf/bbl of condensate
- San Juan Gas Well Flash GOR … 75 scf/bbl of condensate
- Williston Oil Well Flash GOR … 98 scf/bbl of oil
- Denver Oil Well Flash GOR … 45 scf/bbl of oil

#### 3.2.8. Well Gas-to-Oil Ratio for Oil Wells

Even though oil wells are developed to produce oil, they also have natural gas associated with them that comes from the geologic formation. This gas is termed "casing gas," "associated gas," or "produced gas." The amount of associated gas is determined by the Well Gas-to-Oil Ratio (Well GOR).

In the Denver Basin, there is sufficient pipeline infrastructure that associated gas produced with Denver oil wells is normally either used on-site or piped to a sales line essentially as soon as the well is completed. Therefore, in the Denver Basin, it was assumed that there are no emissions from the associated gas.

On the other hand, in the Williston Basin, there is insufficient natural gas infrastructure available, and the associated gas can be vented, flared, used at the well site, sent to a sales line, or a combination. For purposes of this study, it was assumed that all of the associated gas from

Williston Basin oil wells was flared for a period of 3 months, after which it was assumed that the associated gas would be sent to a sales line. Accordingly, there are emissions from associated gas for a period of 3 months. The emissions result from combustion of the associated gas plus un-combusted associated gas (95 percent of the gas was assumed to be combusted with 5 percent passing through the flare un-combusted). The amount of associated gas flared was calculated from the assumed oil production rate of 150 bbl/day and a Well GOR of 1,100 scf/bbl of oil produced, or 165 Mscf of associated gas per day. The Well GOR value assumed for this study is based on professional judgment, and the Excel Workbook allows the user to enter a different value if known.

#### 3.2.9. Produced Gas, Associated Gas, and Flash Gas Composition

As discussed previously, it was assumed that all five well types have oil/condensate storage tanks on site. The largest source of emissions from the storage tanks is the flash gas. The flash gas composition determines potential VOC, GHG and HAPs emissions. For this study, the flash gas composition was varied for each basin. The source of the flash gas compositions used in the study is as follows:

- Uinta/Piceance gas well … liquids analysis of the condensate used in filed and approved Utah permit applications and the E&P Tanks emissions model
- Upper Green River gas well … liquids analysis of the condensate used in the Wyoming Pinedale Tri-Annual Emissions Reporting default values and the E&P Tanks emissions model.
- San Juan gas well … liquids analysis of the condensate used in filed and approved permit applications for Colorado and the E&P Tanks emissions model (same as the Denver Basin oil well)
- Williston oil well … liquids analysis of oil used in filed and approved emission reporting efforts in North Dakota
- Denver oil well … liquids analysis of the condensate used in filed and approved permit applications for Colorado and the E&P Tanks emissions model

For produced and associated gas composition, the CRV provided a detailed gas composition table, and that composition was used for all five basins. If project specific gas composition data are available, they can be entered into the Excel Workbook and the composition will flow through the calculations. The associated/produced gas composition data are used in the emission calculations for fugitive emissions, pneumatic device emissions, venting, workover, and frac flowback emissions, plus emissions from flaring of associated gas in the Williston Basin.

### 3.2.10. Emissions from Produced Water

Some oil and gas wells have a meaningful amount of water associated with them. The produced water, which is stored in tanks, can contain VOCs that are emitted to the atmosphere. In order to calculate emissions from produced water, a produced water production rate needs to be known and then a known emission factor, or the USEPA TANKS emissions model could be used. For purposes of the emission inventories the TANKS model was not run because of the goal to have a stand-alone spreadsheet as discussed earlier with respect to working/breathing losses. Rather than running the TANKS model on a case by case basis, CDPHE published an emission factor (lb VOC per bbl of produced water) for produced water, which is 0.262 lb VOC per bbl for the Denver Basin and 0.178 lb VOC per bbl for some of the Colorado counties in the Piceance Basin. Due to the lack of other emission rates for produced water tanks, and to provide a reasonable upper bound estimate of emissions, each of the produced water tank emissions from each basin were calculated using the single CDPHE emission factor of 0.262 lb VOC per bbl.

To determine the amount of produced water, the PI/Dwights oil and gas production database was accessed through IHS Enerdeq (IHS, 2013) and an average produced water rate per well per year (rounded to the nearest thousand barrels) was calculated for all wells in the basin. The resulting produced water rates are as follows:

- Uinta/Piceance …4,000 bbl water per well per year (bbl/well/yr)
- Upper Green River …3,000 bbl/well/yr
- San Juan … 800 bbl/well/yr
- Williston … 36,000 bbl/well/yr
- Denver … 11,000 bbl/well/yr

The amount of produced water is highly variable within a basin and depends on the specific well. For example, the range of produced water values for gas wells in the San Juan Basin is from zero to over 160,000 bbl/well/yr according to the PI/Dwights database.

### 3.2.11. Pneumatic Controllers

Pneumatic controllers are used at the well sites to open and close valves, operate pumps, and other purposes. Pneumatic controllers can emit natural gas containing VOCs as part of the operation. Pneumatic controllers are classified as high bleed, intermittent bleed, low bleed, and no bleed. High and low bleed controllers emit a small stream of gas continuously. Intermittent bleed controllers emit on an occasional basis, however the frequency of bleeding is generally not known. Accordingly, emission inventories usually assume either high, low, or no bleed controllers.

The number and type of pneumatic controllers varies depending on the needs of the well field and the operating company's standard practices. For purposes of the emission inventories it was assumed that all gas wells have pneumatic controllers (in addition to pneumatic pumps and other pneumatic devices) and the pneumatic controllers are all low bleed. This is consistent with the 40 CFR Subpart OOOO regulatory requirements discussed previously. No pneumatic controllers, pumps, or other pneumatic devices were assumed present for the oil wells in the Williston or Denver Basins.

### 3.2.12. Pumpjack Engines

Pumpjack engines are generally natural gas fueled and are relatively small, on the order of 65 to 95 horsepower. The Farmington RMP assumed a 95 hp engine; other EISs assume smaller engines and/or a 95 hp engine but use a load factor that results in an effective continuous horsepower that is much lower than the engine rating. For purposes of the emission inventory, it was assumed that all of the pumpjack engines would be 65 hp, with a load factor of 0.54, or an effective continuous hp of 35. These values were chosen based on professional judgment.

### 3.2.13. Fugitive Emissions (Equipment Leaks)

Well site equipment processes and transfers gases and light oils with meaningful amounts of VOCs. Therefore, fugitive emissions from equipment leaks must be accounted for and were included in the emission inventories. USEPA emission factors for leaks from valves, connectors (flanges), open ended lines, and pressure relief valves as published in 40 CFR 98 Subpart W were used. Although 40 CFR 98 Subpart W is for greenhouse gas (GHG) emissions, it includes emission factors for the amount of fugitive gas emissions at oil and gas well sites; and these emission factors can be used to estimate not only GHG emissions but also HAPs and VOC emissions based on the gas composition. Thus the Subpart W emission factors were used. Typical counts for each type of leaking device at the well sites were input based on professional judgment. If other project specific information is available, equipment counts can be over-ridden in the spreadsheets. The emission factors assume no leak detection and repair (LDAR) program is implemented. If some sort of LDAR or inspection program is implemented, the emission factors should be adjusted accordingly. (LDAR may be required by 40 CFR 60 Subpart OOOO at some well sites on some of the equipment).

## 3.3. EMISSION INVENTORY RESULTS

Tables 3-1 through 3-5 show the emissions totals for each well type by activity. Except for sulfur dioxide, ethylbenzene, and nitrous oxide, the values in the Tables are rounded to one decimal place. Global warming potential (GWP) is rounded to a whole number.

Note that the tables report “total HAPs”; however, the total is based on only the five HAPs listed. There are trace amounts of other HAPs associated with oil and gas well development and production, but the amounts of those other HAPs are much, much smaller than the five key HAPs listed (the trace HAPs add less than a tenth of a percent to the total HAPs). There are three other HAPs emitted in meaningful quantities that are often associated with oil and gas production: formaldehyde, acetaldehyde, and acrolein. However, the main source of these HAPs are large natural gas compression engines at central gathering stations or field compression stations, which are not included in this study.

The Global Warming Potential (GWP) shown in the tables is calculated using a GWP of 1.0 for carbon dioxide, 21 for methane, and 310 for nitrous oxide. The individual greenhouse gas emissions are in terms of short tons for the individual greenhouse gas. The GWP is in terms of short tons of carbon dioxide equivalent ($CO_2e$).

As noted in Section 3.1, Construction emissions include emissions from interim and final reclamation of the well pad. Tables 3-1 through 3-5 are on the following pages.

**Table 3-1**
**Emission Estimates by Activity for a Natural Gas Well in the Uinta/Piceance Basin**

| Pollutant | Construction (tpy) | Development (tpy) | Operation (tpy) | Total (tpy) |
|---|---|---|---|---|
| $NO_x$ | 0.5 | 14.8 | 0.4 | 15.6 |
| CO | 0.3 | 3.2 | 0.4 | 3.8 |
| VOC | 0.04 | 0.7 | 2.6 | 3.4 |
| $SO_2$ | 0.0001 | 0.0002 | 0.0001 | 0.0004 |
| $PM_{10}$ | 2.0 | 4.9 | 0.04 | 6.9 |
| $PM_{2.5}$ | 0.06 | 0.5 | 0.2 | 0.8 |
| | | | | |
| $CO_2$ | 33.8 | 2,127.7 | 390.6 | 2,552.1 |
| $CH_4$ | 0.001 | 1.1 | 11.1 | 12.2 |
| $N_2O$ | 0.0003 | 0.05 | 0.0008 | 0.05 |
| GWP | 34 | 2,165 | 624 | 2,825 |
| | | | | |
| Benzene | 0.00 | 1.4 | 0.04 | 1.4 |
| Toluene | 0.00 | 1.0 | 0.02 | 1.0 |
| Ethylbenzene | 0.00 | 0.00 | 0.00003 | 0.00003 |
| Xylene | 0.00 | 0.6 | 0.01 | 0.6 |
| n-Hexane | 0.00 | 7.3 | 0.19 | 7.5 |
| Total HAPs | 0.00 | 10.2 | 0.25 | 10.4 |

Note: Sums may not precisely total due to round off differences. A value of 0.00 indicates that pollutant is not emitted or emitted in de minimis amounts. If there is a non-zero value, at least one significant figure is reported.

**Table 3-2**
**Emission Estimates by Activity for a Natural Gas Well in the Upper Green River Basin**

| Pollutant | Construction (tpy) | Development (tpy) | Operation (tpy) | Total (tpy) |
|---|---|---|---|---|
| $NO_x$ | 0.5 | 13.2 | 0.9 | 14.6 |
| CO | 0.3 | 2.9 | 0.8 | 3.9 |
| VOC | 0.04 | 0.7 | 4.4 | 5.2 |
| $SO_2$ | 0.0001 | 0.0002 | 0.0001 | 0.004 |
| $PM_{10}$ | 1.9 | 4.7 | 0.08 | 6.7 |
| $PM_{2.5}$ | 0.06 | 0.4 | 0.3 | 0.8 |
| | | | | |
| $CO_2$ | 33.8 | 1,900.3 | 948.0 | 2,882.1 |
| $CH_4$ | 0.001 | 1.1 | 13.0 | 14.1 |
| $N_2O$ | 0.0003 | 0.05 | 0.002 | 0.05 |
| GWP | 34 | 1,937 | 1,222 | 3,194 |
| | | | | |
| Benzene | 0.00 | 1.4 | 0.1 | 1.5 |
| Toluene | 0.00 | 1.0 | 0.2 | 1.2 |
| Ethylbenzene | 0.00 | 0.00 | 0.01 | 0.01 |
| Xylene | 0.00 | 0.6 | 0.2 | 0.7 |
| n-Hexane | 0.00 | 7.3 | 0.2 | 7.5 |
| Total HAPs | 0.00 | 10.2 | 0.7 | 10.9 |

Note: Sums may not precisely total due to round off differences. A value of 0.00 indicates that pollutant is not emitted or emitted in de minimis amounts. If there is a non-zero value, at least one significant figure is reported.

**Table 3-3**
**Emission Estimates by Activity for a Natural Gas Well in the San Juan Basin**

| Pollutant | Construction (tpy) | Development (tpy) | Operation (tpy) | Total (tpy) |
|---|---|---|---|---|
| $NO_x$ | 0.5 | 4.0 | 1.1 | 5.6 |
| CO | 0.3 | 1.1 | 1.8 | 3.1 |
| VOC | 0.04 | 0.3 | 5.0 | 5.3 |
| $SO_2$ | 0.0001 | 0.0002 | 0.0008 | 0.001 |
| $PM_{10}$ | 2.1 | 4.7 | 0.08 | 6.8 |
| $PM_{2.5}$ | 0.06 | 0.1 | 0.3 | 0.5 |
| | | | | |
| $CO_2$ | 33.8 | 561.6 | 56.4 | 651.9 |
| $CH_4$ | 0.001 | 1.1 | 5.0 | 6.1 |
| $N_2O$ | 0.0003 | 0.04 | 0.0004 | 0.04 |
| GWP | 34 | 595 | 161 | 791 |
| | | | | |
| Benzene | 0.00 | 1.4 | 0.03 | 1.4 |
| Toluene | 0.00 | 1.0 | 0.02 | 1.0 |
| Ethylbenzene | 0.00 | 0.00 | 0.0008 | 0.0008 |
| Xylene | 0.00 | 0.6 | 0.01 | 0.6 |
| n-Hexane | 0.00 | 7.3 | 0.2 | 7.5 |
| Total HAPs | 0.00 | 10.2 | 0.3 | 10.5 |

Note: Sums may not precisely total due to round off differences. A value of 0.00 indicates that pollutant is not emitted or emitted in de minimis amounts. If there is a non-zero value, at least one significant figure is reported.

**Table 3-4**
**Emission Estimates by Activity for an Oil Well in the Williston Basin**

| Pollutant | Construction (tpy) | Development (tpy) | Operation (tpy) | Total (tpy) |
|---|---|---|---|---|
| $NO_x$ | 0.5 | 13.2 | 1.8 | 15.6 |
| CO | 0.3 | 2.9 | 4.9 | 8.0 |
| VOC | 0.04 | 0.7 | 16.8 | 17.6 |
| $SO_2$ | 0.0001 | 0.0002 | 0.0008 | 0.001 |
| $PM_{10}$ | 2.0 | 4.8 | 0.1 | 6.9 |
| $PM_{2.5}$ | 0.06 | 0.4 | 0.3 | 0.8 |
| | | | | |
| $CO_2$ | 33.8 | 1,900.3 | 1,222.3 | 3,156.4 |
| $CH_4$ | 0.001 | 1.1 | 15.4 | 16.6 |
| $N_2O$ | 0.0003 | 0.05 | 0.5 | 0.6 |
| GWP | 34 | 1,922 | 1,700 | 3,682 |
| | | | | |
| Benzene | 0.00 | 1.4 | 0.2 | 1.5 |
| Toluene | 0.00 | 1.0 | 0.02 | 1.0 |
| Ethylbenzene | 0.00 | 0.00 | 0.0008 | 0.0008 |
| Xylene | 0.00 | 0.6 | 0.01 | 0.6 |
| n-Hexane | 0.00 | 7.3 | 0.6 | 7.9 |
| Total HAPs | 0.00 | 10.2 | 0.9 | 11.0 |

Note: Sums may not precisely total due to round off differences. A value of 0.00 indicates that pollutant is not emitted or emitted in de minimis amounts. If there is a non-zero value, at least one significant figure is reported.

**Table 3-5**
**Emission Estimates by Activity for an Oil Well in the Denver Basin**

| **Pollutant** | **Construction** (tpy) | **Development** (tpy) | **Operation** (tpy) | **Total** (tpy) |
|---|---|---|---|---|
| $NO_x$ | 0.5 | 4.5 | 1.3 | 6.3 |
| CO | 0.3 | 1.2 | 2.0 | 3.4 |
| VOC | 0.04 | 0.3 | 6.4 | 6.7 |
| $SO_2$ | 0.0001 | 0.0002 | 0.008 | 0.001 |
| $PM_{10}$ | 2.0 | 4.5 | 0.1 | 6.6 |
| $PM_{2.5}$ | 0.06 | 0.2 | 0.3 | 0.5 |
| | | | | |
| $CO_2$ | 33.8 | 623.7 | 391.5 | 1,050.0 |
| $CH_4$ | 0.001 | 1.1 | 0.7 | 1.8 |
| $N_2O$ | 0.0003 | 0.04 | 0.001 | 0.04 |
| GWP | 34 | 657 | 406 | 1,099 |
| | | | | |
| Benzene | 0.00 | 1.4 | 0.06 | 1.4 |
| Toluene | 0.00 | 1.0 | 0.01 | 1.0 |
| Ethylbenzene | 0.00 | 0.00 | 0.0006 | 0.0006 |
| Xylene | 0.00 | 0.6 | 0.004 | 0.6 |
| n-Hexane | 0.00 | 7.3 | 0.2 | 7.5 |
| Total HAPs | 0.00 | 10.2 | 0.4 | 10.5 |

Note: Sums may not precisely total due to round off differences. A value of 0.00 indicates that pollutant is not emitted or emitted in de minimis amounts. If there is a non-zero value, at least one significant figure is reported.

# 4 CONCLUSION

Five different emission estimate inventories were developed to represent typical oil and gas well emissions in the western US. California, Texas, Oklahoma, Kansas, and Alaska were not included in the study due to relatively little BLM land with oil and gas development in those states, those states have their own program for estimating emissions, and/or the unique environment of Alaska. The five well types chosen for analysis were natural gas wells from the Uinta/Piceance, Upper Green River, and San Juan Basins and oil wells from the Williston and Denver Basins. These Basins are responsible for a large portion of the oil and gas produced in the western United States. Characteristics of these basins as they affect emission estimates were described so that a user of the emission inventory can select a representative well type for development in other basins or sub-basins in the western US. The emission inventories focus on projects where there are a small number of wells, generally termed wildcat or delineation wells.

The emission estimates are suitable for use to estimate emissions from a small number of wells, and should not normally be extrapolated to large well fields with multiple wells. The inventories are based on generally accepted emission estimating techniques published by the USEPA. However, these techniques require a large number of case-specific parameters in order to estimate emissions. Typical parameters for each of the Basins studied were used to calculate the emissions, but there is a wide range of possible values, and project-specific information should be used whenever available.

Electronic and hard copy emission inventories were created. The electronic version of the emission spreadsheets can be modified by the user by overriding key parameters with project-specific data if available. Emissions were calculated for the criteria pollutants associated with oil and gas development, greenhouse gases (including calculation of global warming potential), and the five hazardous air pollutants that are emitted in meaningful amounts and traditionally associated with emissions from a single oil or gas well: hexane, benzene, toluene, ethylbenzene, and xylene.

The emission inventories can be easily modified to account for project-specific information that may be available. If no project-specific information is available, the emission inventories provide typical values for the selected basins and the inventories can be extrapolated to other basins in the western US as needed. If project-specific variables are entered into the Excel Workbook, the variables should be entered in the “Constants and References” tab and the entered variables will be automatically populated into the emission estimating equations in the Workbook. If a range of emission estimates are needed instead of a single value, a range of emission estimates can be created by entering a range of parameters in the Excel Workbook.

# 5 LIMITATIONS

This work was performed in a manner consistent with that level of care and skill ordinarily exercised by other members of Kleinfelder's profession practicing in the same locality, under similar conditions and at the date the services are provided. Our conclusions, opinions, and recommendations are based on a limited number of observations and data. It is possible that conditions could vary between or beyond the data evaluated. Kleinfelder makes no other representation, guarantee, or warranty, express or implied, regarding the services, communication (oral or written), report, opinion, or instrument of service provided. This report may be used only by the client and only for the purposes stated for this specific engagement within a reasonable time from its issuance.

The work performed was based on the scope of work requested by the client. Kleinfelder offers various levels of investigative and engineering services to suit the varying needs of different clients. It should be recognized that definition and evaluation of environmental conditions are a difficult and inexact science. Judgments leading to conclusions and recommendations are generally made with incomplete knowledge of the facility and conditions present due to the limitations of data. Although risk can never be eliminated, more detailed and extensive studies yield more information, which may help understand and manage the level of risk. Since detailed study and analysis involves greater expense, our clients participate in determining levels of service that provide adequate information for their purposes at acceptable levels of risk. More extensive studies should be performed to reduce uncertainties. Acceptance of this report will indicate that the client has reviewed the document and determined that it does not need or want a greater level of service than provided.

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# APPENDIX A

# ELECTRONIC VERSION OF EMISSIONS INVENTORIES

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Location Selection:**

| **Geography:** | **Well Type:** |
|---|---|
| Uinta/Piceance Basin | Natural Gas |

- Choose geography/basin, and well type will automatically fill
  < Choose Uinta/Piceance Basin for deep gas wells with little condensate
  < Choose Upper Green River Basin for deep gas wells with dehydrators and higher condensate
  < Choose San Juan Basin for shallow gas wells with little to no condensate
  < Choose Williston Basin for deep oil wells with high gas
  < Choose Denver Basin for shallow oil wells with low gas

If the user wants to change any specifications, do so within the "Constants and References" tab, as all other tabs connect to it.

| | Total Emissions (Tons per Year) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Pollutant:** | $NO_X$ | CO | VOC | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ | $CH_4$ | $N_2O$ |
| **Construction Phase:** | 0.47 | 0.29 | 0.04 | 0.0001 | 1.99 | 0.06 | 33.84 | 0.001 | 0.0003 |
| **Development Phase:** | 14.77 | 3.15 | 0.74 | 0.0002 | 4.89 | 0.49 | 2127.69 | 1.12 | 0.0516 |
| **Operation Phase:** | 0.39 | 0.36 | 2.62 | 0.0001 | 0.04 | 0.23 | 390.55 | 11.09 | 0.0008 |
| **Total:** | 15.63 | 3.80 | 3.40 | 0.0004 | 6.93 | 0.78 | 2552.08 | 12.21 | 0.0526 |

| | Total Emissions (Tons per Year) | | | | | |
|---|---|---|---|---|---|---|
| **Pollutant:** | Benzene | Toluene | Ethylbenzene | Xylene | n-Hexane | HAPs |
| **Construction Phase:** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Development Phase:** | 1.36 | 0.95 | 0.0000 | 0.55 | 7.31 | 10.18 |
| **Operation Phase:** | 0.03 | 0.01 | 0.00003 | 0.009 | 0.16 | 0.21 |
| **Total:** | 1.39 | 0.97 | 0.00003 | 0.56 | 7.46 | 10.39 |

**$CO_2$ equivalent (Global Warming Potential)**

**Total TPY:** 2824.87

$CO_2$ equivalent conversions:

| | |
|---|---|
| $CO_2$ | 1.00 |
| $CH_4$ | 21.00 |
| $N_2O$ | 310.00 |

**$H_2S$ Emissions**

**Total TPY:** 0.00

* If $H_2S$ in gas, input value in "Gas Stream Molar Ratios" tab, and potential emissions will calculate here. Current assumption is no $H_2S$ in gas stream.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Road Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 4 | Days/Location | (Typical Value) |
| | 48.0 | Dozer Hours/Location | (Typical Value) |
| | 48.0 | Backhoe Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |

$PM_{10}$ Multiplier: 0.75 * $PM_{15}$ (AP-42 Table 11.9-1, 7/98)

$PM_{2.5}$ Multiplier: 0.105 * TSP (AP-42 Table 11.9-1, 7/98)

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98 & 7/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content }\%)^{1.2} * (\text{soil moisture content }\%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content }\%)^{1.5} * (\text{soil moisture content }\%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions** [a] | | **Backhoe Emissions** [a] | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0473 | 1.97 | 0.0473 | 0.0946 |
| **$PM_{15}$** | 0.50 | 0.0120 | 0.50 | 0.0120 | 0.0241 |
| **$PM_{10}$** | 0.38 | 0.0090 | 0.38 | 0.0090 | 0.0181 |
| **$PM_{2.5}$** | 0.21 | 0.0050 | 0.05 | 0.0013 | 0.0062 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Road Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Grading Length: | 6.00 | miles | (Typical Value) |
| Construction Schedule: | 3 | Days/Location | (Typical Value) |
| | 12 | Hours/Day | (Typical Value) |
| | 36 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | |
| Average Grader Speed: | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 16.12 lbs TSP/Location**

**Emissions = 7.71 lbs $PM_{15}$/Location**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 16.12 | 0.45 | 8.06E-03 |
| **$PM_{15}$** | 7.71 | 0.21 | 3.86E-03 |
| **$PM_{10}$** | 4.63 | 0.13 | 2.31E-03 |
| **$PM_{2.5}$** | 0.50 | 0.01 | 2.50E-04 |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Well Pad Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | | |
|---|---|---|---|---|
| Construction Schedule: | 7 | Days/Location | | (Typical Value) |
| | 10 | Hours/Day | | (Typical Value) |
| | 70 | Hours/Location | (Dozer) | (Typical Value) |
| | 70 | Hours/Location | (Back Hoe) | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | | AP-42 Table 11.9-3, 7/98 |

$PM_{10}$ Multiplier: $0.75 * PM_{15}$ (AP-42 Table 11.9-1, 7/98)

$PM_{2.5}$ Multiplier: 0.105 * TSP (AP-42 Table 11.9-1, 7/98)

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content }\%)^{1.2} * (\text{soil moisture content }\%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content }\%)^{1.5} * (\text{soil moisture content }\%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions [a]** | | **Backhoe Emissions [a]** | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0690 | 1.97 | 0.0690 | 0.14 |
| **$PM_{15}$** | 0.50 | 0.0176 | 0.50 | 0.0176 | 0.04 |
| **$PM_{10}$** | 0.38 | 0.0132 | 0.38 | 0.0132 | 0.03 |
| **$PM_{2.5}$** | 0.21 | 0.0072 | 0.21 | 0.0072 | 0.01 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| Kleinfelder, Inc.<br>Wellsite Emissions | Base Location: Uinta/Piceance Basin<br>Well Type: Natural Gas |
|---|---|

**Construction Phase**

**Well Pad Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 4.0 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 40 | Hours/Location | (Typical Value) |
| Watering Control Efficiency | 50 | Percent (%) | (Typical Value) |
| Average Grader Speed | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| Distance Graded | 2.84 | Miles/Location | (Typical Value) |
| $PM_{10}$ Multiplier | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs) = $0.040 * (\text{Mean Vehicle Speed})^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = $0.051 * (\text{Mean Vehicle Speed})^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 7.63 lbs TSP/well pad**

**Emissions = 3.65 lbs $PM_{15}$/well pad**

| | Grader Construction Emissions | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 7.63 | 0.19 | 0.0038 |
| **$PM_{15}$** | 3.65 | 0.09 | 0.0018 |
| **$PM_{10}$** | 2.19 | 0.05 | 0.0011 |
| **$PM_{2.5}$** | 0.24 | 0.01 | 0.0001 |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Pipeline Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 7.0 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.75 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.105 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 7/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content }\%)^{1.2} * (\text{soil moisture content }\%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content }\%)^{1.5} * (\text{soil moisture content }\%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions [a]** | | **Backhoe Emissions [a]** | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0690 | 1.97 | 0.0690 | 0.14 |
| **$PM_{15}$** | 0.50 | 0.0176 | 0.50 | 0.0176 | 0.04 |
| **$PM_{10}$** | 0.38 | 0.0132 | 0.38 | 0.0132 | 0.03 |
| **$PM_{2.5}$** | 0.21 | 0.0072 | 0.21 | 0.0072 | 0.01 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Pipeline Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Distance Graded: | 12.50 | Miles/Location | (Typical Value) |
| Construction Schedule: | 7 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Mean Vehicle Speed: | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 7/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 33.58 lbs TSP/well**

**Emissions = 16.07 lbs $PM_{15}$/well**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 33.58 | 0.48 | 0.0168 |
| **$PM_{15}$** | 16.07 | 0.23 | 0.0080 |
| **$PM_{10}$** | 9.64 | 0.14 | 0.0048 |
| **$PM_{2.5}$** | 1.04 | 0.01 | 0.0005 |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Roadway Construction Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Heavy Diesel Truck Trips: | | | | | |
| Road Construction: | 7 | Trips | | | |
| Well Pad Construction: | 8 | Trips | Total Trips: | 21 | Trips |
| Pipeline Construction: | 6 | Trips | | | |
| Light Duty Pickup Truck Trips: | | | | | |
| Road Construction: | 16 | Trips | | | |
| Well Pad Construction: | 28 | Trips | Total Trips: | 100 | Trips |
| Pipeline Construction: | 56 | Trips | | | |

* All assumptions above are based on typical industry values

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (lb/mile) * \# Trips * Trip Distance (miles)}}{\text{2000 (lb/tons)}}$$

| Construction Vehicles | Heavy Haul Trucks | | Light Duty Pickups | | Total |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 3.12E-02 | 7.39E-03 | 1.48E-02 | 4.60E-02 |
| **CO** | 1.98E-02 | 8.32E-03 | 7.26E-02 | 1.45E-01 | 1.54E-01 |
| **VOC** | 3.16E-03 | 1.33E-03 | 3.54E-03 | 7.08E-03 | 8.41E-03 |
| **SO2** | 4.57E-05 | 1.92E-05 | 2.83E-05 | 5.66E-05 | 7.58E-05 |
| **PM10** | 4.22E-03 | 1.77E-03 | 1.94E-04 | 3.88E-04 | 2.16E-03 |
| **PM2.5** | 4.09E-03 | 1.72E-03 | 1.79E-04 | 3.58E-04 | 2.08E-03 |
| **CO2** | 1.88 | 0.79 | 1.13 | 2.25 | 3.04 |
| **CH4** | 7.61E-05 | 3.19E-05 | 4.56E-05 | 9.13E-05 | 1.23E-04 |
| **N2O** | 1.52E-05 | 6.39E-06 | 9.13E-06 | 1.83E-05 | 2.46E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Construction Heavy Equipment Tailpipe Emissions**

**Assumptions:**

Fuel and Engine:

| | | | |
|---|---|---|---|
| Brake Specific Fuel Consumption, Avg. (BSFC) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel Higher Heating Value (HHV) | 0.138 | mmBtu/Gallon | (Typical Value) |

Trackhoe:

| | | | |
|---|---|---|---|
| Working Hours | 188 | Total Hours | (Typical Value) |
| Rated Horsepower | 100 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Tractors/Loaders/Backhoes) | |

Dozer:

| | | | |
|---|---|---|---|
| Working Hours | 188 | Total Hours | (Typical Value) |
| Rated Horsepower | 140 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Crawler Tractor/Dozers) | |

Grader:

| | | | |
|---|---|---|---|
| Working Hours | 130 | Total Hours | (Typical Value) |
| Rated Horsepower | 250 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Graders) | |

| | | | |
|---|---|---|---|
| Total Horsepower Hours: | 45795.8 | Hp-hrs | (Sum of all horsepower above) |
| Total Fuel Usage: | 2737.79 | Gallons Diesel Fuel | |

**Equations:**

Total Fuel Usage: ((btu-hp-hr * hp-hrs) / Mmbtu-gal) / 1,000,000

$$\text{Emissions (tons/year/pad)} = \frac{\text{Emission Factor (g/mile) * Trip Distance (miles) * Load Factor}}{\text{453.6 (g/lb) * 2000 (lb/tons)}}$$

| Heavy Const. Vehicles | Backhoe | | | Dozer | | | Grader | | |
|---|---|---|---|---|---|---|---|---|---|
| | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) |
| **NOx** | 8.38 | 1.09E+00 | 1.02E-01 | 8.38 | 1.53E+00 | 1.43E-01 | 8.38 | 2.72E+00 | 1.77E-01 |
| **CO** | 2.7 | 3.51E-01 | 3.30E-02 | 2.7 | 4.92E-01 | 4.62E-02 | 2.7 | 8.78E-01 | 5.71E-02 |
| **VOC** [b] | 0.68 | 8.84E-02 | 8.31E-03 | 0.68 | 1.24E-01 | 1.16E-02 | 0.68 | 2.21E-01 | 1.44E-02 |
| **$PM_{10}$** | 0.39 | 5.07E-02 | 4.77E-03 | 0.39 | 7.10E-02 | 6.68E-03 | 0.39 | 1.27E-01 | 8.24E-03 |
| **$PM_{2.5}$** | 0.39 | 5.07E-02 | 4.77E-03 | 0.39 | 7.10E-02 | 6.68E-03 | 0.39 | 1.27E-01 | 8.24E-03 |

| Heavy Const. Vehicles | Total Emissions [c] (tons/yr) |
|---|---|
| **NOx** | 0.42 |
| **CO** | 0.14 |
| **VOC** | 0.03 |
| **$PM_{10}$** | 0.02 |
| **$PM_{2.5}$** | 0.02 |

**Greenhouse Gas Emissions:**

| | Diesel EF kg/mmbtu | Emissions lbs | Emissions Tons |
|---|---|---|---|
| $CO_2$ | 73.96 | 61604.19 | 30.80 |
| $CH_4$ | 0.003 | 2.50 | 0.0012 |
| $N_2O$ | 0.0006 | 0.50 | 0.0002 |

a From Table A-4 of Exhaust and Crankcase Emission Factors for NONROAD Engine Modeling - Compression Ignition, EPA-420-R-10-018, July 2010.
b Emission Factor represents total Hydrocarbon Emissions
c Converted from emission factor for Distillate Fuel Oil #2 (diesel) as listed in Table C-1 to Subpart C of Part 98 - Default Emission Factors and High Heat Values for Various Types of Fuel.
Listed Factor:

73.96 kg $CO_2$/mmBtu
393 hp-hr = mmBtu
188.2 g $CO_2$/hp-hr

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Wind Erosion Fugitive Dust**

**Assumptions:**

Threshold Friction Velocity ($U_t$) 1.02 m/s (2.28 mph) for well pads (AP-42 Table 13.2.5-2 Overburden - Western Surface Coal Mine)
1.33 m/s (2.97 mph) for roads (AP-42 Table 13.2.5-2 Roadbed material)

Initial Disturbance Area

| | | | |
|---|---|---|---|
| Total Access Road/ROW Area Per Location: | 976,800 | Square Meters | (Typical Value) |
| Total Well Pad Area Disturbed Per Location: | 50,000 | Square Meters | (Typical Value) |
| Total Area Disturbed Per Location: | 1,026,800 | Square Meters | (Typical Value) |
| Exposed Surface Type | Flat | | |
| Meteorological Data | 2002 Grand Junction (obtained from NCDC website) | | |
| Fastest Mile Wind Speed: | 45 | miles/hour | (Typical Value) |
| Fastest Mile Wind Speed ($U_{10}^{+}$) | 20.12 | meters/sec (45 mph) reported as fastest 2-minute wind speed for Grand Junction (2002) | |
| Number soil of disturbances | 1.00 | for well pads (Assumption, disturbance at construction and reclamation) constant for dirt roads | |

**Equations (AP-42 13.2.5.2 Industrial Wind Erosion)**

Friction Velocity $U^* = 0.053\ U_{10}^{+}$

Erosion Potential P (g/m$^2$/period) = $58*(U^*-U_t^*)^2 + 25*(U^*-U_t^*)$ for $U^*>U_t^*$, $P = 0$ for $U^*< U_t^*$

Emissions (tons/year) = Erosion Potential(g/m$^2$/period)*Disturbed Area(m$^2$)*Disturbances/year*(k)/(453.6 g/lb)/2000 lbs/ton/Develop Period

| **Particle Size Multiplier (k)** | | |
|---|---|---|
| **30 µm** | **<10 µm** | **<2.5 µm** |
| 1.0 | 0.5 | 0.075 |

| **Maxium $U_{10}^{+}$ Wind Speed (m/s)** | **Maximum U* Friction Velocity m/s** | **Well $U_t^*$ Threshold Velocity[a] m/s** | **Well Pad Erosion Potential g/m$^2$** | **Road $U_t^*$ Threshold Velocity[a] m/s** | **Road Erosion Potential g/m$^2$** |
|---|---|---|---|---|---|
| 20.12 | 1.07 | 1.02 | 1.28 | 1.33 | 0.00 |

**Wind Erosion Emissions**

| **Particulate Species** | **Well Pad (tons/year)** | **Roads/Pipelines (tons/year)** |
|---|---|---|
| TSP | 7.05E-02 | 0.00E+00 |
| $PM_{10}$ | 3.52E-02 | 0.00E+00 |
| $PM_{2.5}$ | 5.28E-03 | 0.00E+00 |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction, Development, and Production Phase**

**Construction, Development, and Operations Traffic Fugitive Dust Emissions**

**Assumptions:**

| | |
|---|---|
| Round Trip Miles | 40 |
| Round Trip (Paved) Miles | 16 |
| Round Trip (Un-Paved) Miles | 24 |
| Precipitation Days (P) | 45 |

Unpaved Calculation AP-42, Chapter 13.2.2
November 2006

E ($PM_{10}$) / VMT = 1.5 * $(S/12)^{0.9}$ * $(W/3)^{0.45}$ * (365-p)/365)

E ($PM_{2.5}$) / VMT = 0.15 * $(S/12)^{0.9}$ + $(W/3)^{0.45}$ * (365-p)/365)

Silt Content (S) 8.5 AP 42 13.2.2-1 Mean Silt Content Construction Sites

Paved Calculation AP-42, Chapter 13.2.1
January 2011

E ($PM_{10}$) / VMT = 0.0022 * $(sL)^{0.91}$ * $(W)^{1.02}$ * (1-(P/(365*4))

E ($PM_{2.5}$) / VMT = 0.00054 * $(sL)^{0.91}$ * $(W)^{1.02}$ * (1-(P/(365*4))

Silt Loading (sL) 0.6 AP-42 Table 13.2.1-2 baseline low volume roads

**Construction Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | $PM_{10}$ (lb/VMT) | $PM_{10}$ (lbs) | $PM_{10}$ (Tons) | $PM_{2.5}$ (lb/VMT) | $PM_{2.5}$ (lbs) | $PM_{2.5}$ (Tons) |
|---|---|---|---|---|---|---|---|---|
| Heavy Duty Haul Trucks | 80,000 | 21 | 3.09 | 1558.9 | 0.8 | 0.3 | 155.9 | 0.1 |
| Light Duty Pickup Trucks | 5,000 | 100 | 0.89 | 2131.8 | 1.1 | 0.1 | 213.2 | 0.1 |
| **Total:** | | | | **3690.67** | **1.85** | | **369.07** | **0.18** |

**Paved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| Heavy Duty Haul Trucks | 80,000 | 21 | 0.0576 | 19.4 | 0.0097 | 0.014 | 4.8 | 0.0024 |
| Light Duty Pickup Trucks | 5,000 | 100 | 0.0034 | 5.5 | 0.0027 | 0.001 | 1.3 | 0.0007 |
| **Total:** | | | | **24.8** | **0.0** | | **6.1** | **0.0** |

**Development Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | $PM_{10}$ (lb/VMT) | $PM_{10}$ (lbs) | $PM_{10}$ (Tons) | $PM_{2.5}$ (lb/VMT) | $PM_{2.5}$ (lbs) | $PM_{2.5}$ (Tons) |
|---|---|---|---|---|---|---|---|---|
| Light Duty Pickup Trucks: | 5,000 | 84 | 0.89 | 1790.7 | 0.9 | 0.1 | 179.1 | 0.1 |
| Light Duty Haul Trucks | 7,500 | 11 | 1.07 | 281.4 | 0.1 | 0.1 | 28.1 | 0.0 |
| Heavy Duty Haul Trucks | 80,000 | 67 | 3.09 | 4973.6 | 2.5 | 0.3 | 497.4 | 0.2 |
| Water Trucks | 70,000 | 24 | 2.91 | 1677.7 | 0.8 | 0.3 | 167.8 | 0.1 |
| **Total:** | | | | **8723.41** | **4.36** | | **872.34** | **0.44** |

**Paved Calculations:**

| **Vehicle Type** | **Average Weight (lbs)** | **Vehicle Round Trips** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Light Duty Pickup Trucks:** | 5000 | 84 | 0.00 | 4.6 | 0.0 | 0.0 | 1.1 | 0.0006 |
| **Light Duty Haul Trucks** | 7500 | 11 | 0.01 | 0.9 | 0.0 | 0.0 | 0.2 | 0.0001 |
| **Heavy Duty Haul Trucks** | 80000 | 67 | 0.06 | 61.8 | 0.0 | 0.0 | 15.2 | 0.0076 |
| **Water Trucks** | 70,000 | 24 | 0.05 | 19.3 | 0.0 | 0.0 | 4.7 | 0.0024 |
| **Total:** | | | | **86.6** | **0.0** | | **21.2** | **0.0** |

**Production Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| Light Duty Pickup Trucks: | 5,000 | 50 | 0.89 | 1065.89 | 0.53 | 0.0888 | 106.59 | 0.0533 |
| Light Duty Haul Trucks | 7,500 | 0 | 1.07 | 0.00 | 0.00 | 0.1066 | 0.00 | 0.0000 |
| Heavy Duty Haul Trucks | 80,000 | 2 | 3.09 | 148.47 | 0.07 | 0.3093 | 14.85 | 0.0074 |
| Water Trucks | 70,000 | 40 | 2.91 | 2796.14 | 1.40 | 0.2913 | 279.61 | 0.1398 |
| **Total:** | | | | **4010.50** | **2.01** | | **401.05** | **0.20** |

**Paved Calculations:**

| **Vehicle Type** | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| **Light Duty Pickup Trucks:** | 5,000 | 50 | 0.00 | 2.73 | 0.0014 | 0.0008 | 0.67 | 0.0003 |
| **Light Duty Haul Trucks** | 7,500 | 0 | 0.01 | 0.00 | 0.0000 | 0.0013 | 0.00 | 0.0000 |
| **Heavy Duty Haul Trucks** | 80,000 | 2 | 0.06 | 1.84 | 0.0009 | 0.0141 | 0.45 | 0.0002 |
| **Water Trucks** | 70,000 | 40 | 0.05 | 32.18 | 0.0161 | 0.0123 | 7.90 | 0.0039 |
| **Total:** | | | | **36.75** | **0.02** | | **9.02** | **0.00** |

| | | | |
|---|---|---|---|
| **Annual Total** | | **Unpaved Roads $PM_{10}$ (tons)** 8.21 | **Unpaved Roads $PM_{2.5}$ (tons)** 0.8 |
| | | **Paved Roads $PM_{10}$** 0.1 | **Paved Roads $PM_{2.5}$** 0.0 |
| | **Total:** | **8.3** | **0.8** |

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Development Phase**
**Drill Rig Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 18 | (Typical Value) |
| Hours of Operation | 432 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

| Engine | HP [a] | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Vertical Drill Rig Engine | 475 | 0.42 | 144 | 28728 |
| Horizontal Drill Rig Engine 1 | 2,950 | 0.59 | 288 | 501264 |
| Horizontal Drill Rig Engine 2 | 2,950 | 0.59 | 432 | 751896 |
| Drill Rig Generator | 350 | 0.42 | 432 | 63504 |
| Trailers Generator | 150 | 0.42 | 432 | 27216 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor Booster | 650 | 0.42 | 144 | 39312 |
| Forklift | 120 | 0.42 | 144 | 7257.6 |
| Aerial Lift | 50 | 0.42 | 16 | 336 |
| Frontend loader | 150 | 0.42 | 16 | 1008 |
| Dozer | 175 | 0.42 | 9 | 661.5 |
| Total HP | 10,220 | | | |

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 2090751.53 | 1045.38 |
| CH4 | 0.003 | 84.81 | 0.04 |
| N2O | 0.0006 | 16.96 | 0.01 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

Total: 1,554,239 Hp-hrs

Fuel Usage: 92,916 Gallons of Diesel Total Fuel Usage: (btu/hp-hr * hp-hrs) * gal/btu

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu) | Xylenes (lb/mmBtu) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Drill Rig Engine | 28728 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Horizontal Drill Rig Engine 1 | 501264 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Horizontal Drill Rig Engine 2 | 751896 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Drill Rig Generator | 63504 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Trailers Generator | 27216 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor Booster | 39312 | 1.3272 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Forklift | 7257.6 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Aerial Lift | 336 | 5.0000 | 6.9000 | 0.8000 | 0.7760 | 1.27E-05 | 1.8000 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frontend loader | 1008 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Dozer | 661.5 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Drill Rig Engine | | 0.02420 | 0.12984 | 0.00417 | 0.00404 | 4.02E-07 | 0.00518 | 0.00009 | 0.00003 | 0.00002 |
| Horizontal Drill Rig Engine 1 | | 0.42226 | 2.26545 | 0.07272 | 0.07053 | 7.02E-06 | 0.09040 | 0.00160 | 0.00058 | 0.00040 |
| Horizontal Drill Rig Engine 2 | | 0.63339 | 3.39817 | 0.10907 | 0.10580 | 1.05E-05 | 0.13560 | 0.00241 | 0.00087 | 0.00060 |
| Drill Rig Generator | | 0.18900 | 0.58661 | 0.02814 | 0.02730 | 8.89E-07 | 0.04760 | 0.00020 | 0.00007 | 0.00005 |
| Trailers Generator | | 0.08100 | 0.25140 | 0.01206 | 0.01170 | 3.81E-07 | 0.02040 | 0.00009 | 0.00003 | 0.00002 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor Booster | | 0.05751 | 0.17767 | 0.00570 | 0.00553 | 5.50E-07 | 0.00709 | 0.00013 | 0.00005 | 0.00003 |
| Forklift | | 0.02160 | 0.06704 | 0.00322 | 0.00312 | 1.02E-07 | 0.00544 | 0.00002 | 0.00001 | 0.00001 |
| Aerial Lift | | 0.00185 | 0.00256 | 0.00030 | 0.00029 | 4.70E-09 | 0.00067 | 0.00000 | 0.00000 | 0.00000 |
| Frontend loader | | 0.00300 | 0.00931 | 0.00045 | 0.00043 | 1.41E-08 | 0.00076 | 0.00000 | 0.00000 | 0.00000 |
| Dozer | | 0.00197 | 0.00611 | 0.00029 | 0.00028 | 9.26E-09 | 0.00050 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **1.55935** | **7.52998** | **0.25541** | **0.24775** | **0.00002** | **0.33762** | **0.00498** | **0.00180** | **0.00124** |

**Emission Factors**

- Drill rig emission factors based on Tier II engines
- All other engine emission factors based on Tier 0 engines (typical values)
- HAP emission factors from AP-42 Volume I, Large Stationary Diesel Engines Table 3.4-3

**Calculations:**

ton/year: (Total hp-hr * g/hp-hr) * lb-gram / lb-ton

*** Drill rig horsepower developed based on:**

1 Williston Basin: 2,100 from Jonah, Wyoming RMP
2 San Juan Basin: 2,100 from River Valley RMP
3 Upper Green River Basin: 2,100 from Jonah, Wyoming RMP
4 Denver Basin: 2,950 from River Valley RMP
5 Uintah Basin: 2,952 from River Valley RMP

Note, runtime for each drilling event is based on research and industry experience dependent upon each basin.

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Development Phase**
**Conductor Pipe Set Emissions**

**Assumptions:**

| Parameter | Value |
|---|---|
| Days of Operation | 2 |
| Hours of Operation | 24 |
| Diesel Fuel Sulfur Content | 0.000015 |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

Workovers:

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Rig Engine | 350 | 0.42 | 24 | 3528 |
| Rig Generator | 50 | 0.42 | 24 | 504 |

Total Horsepower: 400

Total: 4,032 Hp-hrs

Fuel Usage: 241 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

**Greenhouse Gases:**

| | Diesel EF Kg/mmBtu | Emissions lbs/Location | Emissions Tons/Location |
|---|---|---|---|
| $CO_2$ | 73.96 | 5423.82 | 2.71 |
| $CH_4$ | 0.003 | 0.22 | 0.00 |
| $N_2O$ | 0.0006 | 0.04 | 0.00 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu | Xylenes (lb/mmBtu |
|---|---|---|---|---|---|---|---|---|---|---|
| Rig Engine | 3528 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 0.0008 | 0.0003 | 0.0002 |
| Rig Generator | 504 | 5.0000 | 6.9000 | 0.8000 | 0.7760 | 1.27E-05 | 1.8000 | 0.0008 | 0.0003 | 0.0002 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Rig Engine | | 0.00328 | 0.01686 | 0.00051 | 0.00050 | 0.00000 | 0.00064 | 0.00001 | 0.00000 | 0.00000 |
| Rig Generator | | 0.00278 | 0.00383 | 0.00044 | 0.00043 | 0.00000 | 0.00100 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.00605** | **0.02069** | **0.00096** | **0.00093** | **0.00000** | **0.00164** | **0.00001** | **0.00000** | **0.00000** |

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

* Rig engine emission rates are based on a Tier II engine and rig generator emission rates are based on a Tier 0 engine.
* All days, hours, and HP values above are based on typical industry values

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Development Phase**
**Well Fracturing Engine Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 7 | (Typical Value) |
| Hours of Operation | 168 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Blenders | 500 | 0.42 | 4 | 840 |
| Auxilary Pump | 200 | 0.42 | 4 | 336 |
| Auxilary Pump | 200 | 0.42 | 8 | 672 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Generator | 150 | 0.42 | 168 | 10584 |

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 2018564.31 | 1009.28 |
| CH4 | 0.003 | 81.88 | 0.04 |
| N2O | 0.0006 | 16.38 | 0.01 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

Total: 1,500,576 Hp-hrs

Fuel Usage: 89,708 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu) | Xylenes (lb/mmBtu) |
|---|---|---|---|---|---|---|---|---|---|---|
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Blenders | 840 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Auxilary Pump | 336 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Auxilary Pump | 672 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Generator | 10584 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Blenders | | 0.00078 | 0.00401 | 0.00012 | 0.00012 | 1.18E-08 | 0.00015 | 0.00000 | 0.00000 | 0.00000 |
| Auxilary Pump | | 0.00100 | 0.00310 | 0.00015 | 0.00014 | 4.70E-09 | 0.00025 | 0.00000 | 0.00000 | 0.00000 |
| Auxilary Pump | | 0.00200 | 0.00621 | 0.00030 | 0.00029 | 9.41E-09 | 0.00050 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Generator | | 0.04072 | 0.09683 | 0.00842 | 0.00817 | 1.48E-07 | 0.01155 | 0.00003 | 0.00001 | 0.00001 |
| | **Total:** | **1.30213** | **6.84201** | **0.22574** | **0.21897** | **0.00002** | **0.28205** | **0.00480** | **0.00174** | **0.00119** |

**Emission Factors**

- Frac pump emission factors based on Tier II engines (typical values)
- All other engine emission factors based on Tier 0 engines (typical values)

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Development Phase**

**Hydraulic Fracturing Flowback Emissions**

**Assumptions:**

| | | | |
|---|---|---|---|
| **Estimated Frac flowback Rate:** | 10,000 | Scf/hr | |
| **Combustion Efficiency:** | 95.00 | Percent (%) | |
| **Event Duration:** | 100.00 | Hours | |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* Venting duration based on research and industry knowledge; please see report for additional information.
* Venting control based on Subpart OOOO requirements of 95% minimum control.
Control efficiency can be deleted if applicable.

**Equations:**

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf/lb-mol)) * hrs/yr
** Multiply above equation by 0.02 if including 98% control efficiency

**Un-combusted Componet Emissions:**

| Component | Mole % [a] | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 444.86 | 18.81 | 0.94 |
| Ethane | 5.7920 | 30.1 | 28.96 | 2.29 | 0.11 |
| Propane | 1.3650 | 44.1 | 6.83 | 0.79 | 0.04 |
| i-Butane | 0.3700 | 58.1 | 1.85 | 0.28 | 0.01 |
| n-Butane | 0.2610 | 58.1 | 1.31 | 0.20 | 0.01 |
| i-Pentane | 0.1550 | 72.2 | 0.78 | 0.15 | 0.01 |
| n-Pentane | 0.1020 | 72.2 | 0.51 | 0.10 | 0.00 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 0.73 | 0.17 | 0.01 |
| Heptanes | 0.0930 | 100.2 | 0.47 | 0.12 | 0.01 |
| Octanes | 0.0440 | 114.2 | 0.22 | 0.07 | 0.00 |
| Nonanes | 0.0160 | 128.3 | 0.08 | 0.03 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 0.03 | 0.01 | 0.00 |
| Benzene | 0.0270 | 78.1 | 0.14 | 0.03 | 0.00 |
| Toluene | 0.0190 | 92.1 | 0.10 | 0.02 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 0.06 | 0.02 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 0.73 | 0.17 | 0.01 |
| Nitrogen | 0.0940 | 28.0 | 9.40 | 0.69 | 0.03 |
| Carbon Dioxide | 2.5280 | 44.0 | 252.80 | 29.32 | 1.47 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |
| **VOC Subtotal** | 2.7600 | 1492.8 | 13.80 | 2.14 | 0.11 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 1.02 | 0.23 | 0.01 |
| **Total** | 100.1460 | 1645.0 | 749.82 | 53.26 | 2.66 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 8452.34 | 980.23 | 49.01 |
| C2 | 5.79 | 550.24 | 63.81 | 3.19 |
| C3 | 1.37 | 129.68 | 15.04 | 0.75 |
| C4 | 0.63 | 59.95 | 6.95 | 0.35 |
| C5+ | 0.76 | 72.58 | 8.42 | 0.42 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **53.72** | **Tons/Event** |
| **$N_2O$ Emissions:** | **1.13E-04** | **Tons/Event** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.37 | 3.80 | 0.19 | AP-42 CH13.5-1 |
| NOx | 0.068 | 0.70 | 0.03 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.00 | *Based on $H2_S$ 34 mol weight and $SO_2$ 64 mol weight |

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Development Phase**
**Workover Cementing Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 2 | (Typical Value) |
| Hours of Operation | 24 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8500 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

Workovers/Cementing:

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Coil Tubing Unit | 550 | 0.42 | 24 | 5544 |
| Circulation Pump | 450 | 0.42 | 24 | 4536 |
| Cement Pump Trucks | 500 | 0.42 | 8 | 1680 |

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| $CO_2$ | 73.96 | 16298.85 | 8.15 |
| $CH_4$ | 0.003 | 0.66 | 0.00 |
| $N_2O$ | 0.0006 | 0.13 | 0.00 |

Total Horsepower: 1,500 (Typical Value)

Total: 11,760 Hp-hrs

Fuel Usage: 724 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Formaldehyde (lb/mmBtu) | Toulene (lb/mmBtu | Xylenes (lb/mmBtu |
|---|---|---|---|---|---|---|---|---|---|---|
| Coil Tubing Unit | 5544 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 0.1636 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |
| Circulation Pump | 4536 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 0.1636 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |
| Cement Pump Trucks | 1680 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 0.6800 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Formaldehyde (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Coil Tubing Unit | | 0.00515 | 0.02649 | 0.00080 | 0.00078 | 0.00100 | 0.00002 | 0.00000 | 0.00001 | 0.00000 |
| Circulation Pump | | 0.00421 | 0.02168 | 0.00066 | 0.00064 | 0.00082 | 0.00001 | 0.00000 | 0.00001 | 0.00000 |
| Cement Pump Trucks | | 0.00500 | 0.01552 | 0.00074 | 0.00072 | 0.00126 | 0.00001 | 0.00000 | 0.00000 | 0.00000 |
| | | | | | | | | | | |
| | **Total:** | **0.01436** | **0.06369** | **0.00221** | **0.00214** | **0.00308** | **0.00004** | **0.00000** | **0.00001** | **0.00001** |

**Emission Factors**

- Engine emission factors based on Tier II engines (typical values)

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Development Phase**

**Well Venting During Workover Events**

**Assumptions:**

Significant gas venting only occurs on natural gas wells.

| | | | |
|---|---|---|---|
| **Estimated Venting Rate:** | 5,000 | Scf/Event | (Typical Value) |
| **Combustion Efficiency:** | 0.00 | Percent (%) | |
| **Event Quantity:** | 1.00 | Event | - Assumed one event |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* Vented quantity based on research and industry knowledge; please see report for additional information.

**Equations:**

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf-lb-mol))

** Multiply above equation by 0.02 if including 98% control efficiency

| Component | Mole % | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Event |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 4448.60 | 188.07 | 0.0940 |
| Ethane | 5.7920 | 30.1 | 289.60 | 22.95 | 0.0115 |
| Propane | 1.3650 | 44.1 | 68.25 | 7.93 | 0.0040 |
| i-Butane | 0.3700 | 58.1 | 18.50 | 2.83 | 0.0014 |
| n-Butane | 0.2610 | 58.1 | 13.05 | 2.00 | 0.0010 |
| i-Pentane | 0.1550 | 72.2 | 7.75 | 1.47 | 0.0007 |
| n-Pentane | 0.1020 | 72.2 | 5.10 | 0.97 | 0.0005 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.0000 |
| Hexanes | 0.1460 | 86.2 | 7.30 | 1.66 | 0.0008 |
| Heptanes | 0.0930 | 100.2 | 4.65 | 1.23 | 0.0006 |
| Octanes | 0.0440 | 114.2 | 2.20 | 0.66 | 0.0003 |
| Nonanes | 0.0160 | 128.3 | 0.80 | 0.27 | 0.0001 |
| Decanes + | 0.0050 | 142.3 | 0.25 | 0.09 | 0.0000 |
| Benzene | 0.0270 | 78.1 | 1.35 | 0.28 | 0.0001 |
| Toluene | 0.0190 | 92.1 | 0.95 | 0.23 | 0.0001 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.0000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.0000 |
| Xylenes | 0.0110 | 106.2 | 0.55 | 0.15 | 0.0001 |
| n-Hexane | 0.1460 | 86.2 | 7.30 | 1.66 | 0.0008 |
| Nitrogen | 0.0940 | 28.0 | 4.70 | 0.35 | 0.0002 |
| Carbon Dioxide | 2.5280 | 44.0 | 126.40 | 14.66 | 0.0073 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.0000 |

| | | | | | |
|---|---|---|---|---|---|
| **VOC Subtotal** | 2.7600 | 1492.8 | 138.00 | 21.44 | 0.0107 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 10.15 | 2.32 | 0.0012 |
| **Total** | 100.1460 | 1645.0 | 5007.30 | 247.46 | 0.1237 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed thatthe representative average gas analyses used by the River Valley RMP. was a good representative analyses of general gas wells.

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 0.00 | 0.00 | 0.00 |
| C2 | 5.79 | 0.00 | 0.00 | 0.00 |
| C3 | 1.37 | 0.00 | 0.00 | 0.00 |
| C4 | 0.63 | 0.00 | 0.00 | 0.00 |
| C5+ | 0.76 | 0.00 | 0.00 | 0.00 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **0.00** | **Tons/Event** |
| **$N_2O$ Emissions:** | **5.67E-07** | **Tons/Event** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.00 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| NOx | 0.000 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.000 | *Based on $H2_S$ 34 mol weight and $SO_2$ 64 mol weight |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Development Phase**

**Wellsite Development Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Light Duty Pickup Trucks: | 84 | Trips/Location | | | |
| Light Duty Haul Trucks | 11 | Trips/Location | Total Trips: | 95 | Trips |
| Heavy Duty Haul Trucks | 67 | Trips/Location | | | |
| Water Trucks | 24 | Trips/Location | Total Trips: | 91 | Trips |

* Miles and number of trips based on research and industry knowledge; please see report for additional information.

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (lb/mile) * \# Trips * Trip Distance (miles)}}{\text{2000 (lb/tons)}}$$

| **Construction Vehicles** | **Heavy Haul Trucks** | | **Light Duty Pickups** | | **Total** |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 1.35E-01 | 1.98E-02 | 1.41E-01 | 2.77E-01 |
| **CO** | 1.98E-02 | 3.60E-02 | 3.16E-03 | 3.76E-02 | 7.37E-02 |
| **VOC** | 3.16E-03 | 5.75E-03 | 4.57E-05 | 6.00E-03 | 1.18E-02 |
| **SO2** | 4.57E-05 | 8.32E-05 | 4.22E-03 | 8.68E-05 | 1.70E-04 |
| **PM10** | 4.22E-03 | 7.68E-03 | 4.09E-03 | 8.02E-03 | 1.57E-02 |
| **PM2.5** | 4.09E-03 | 7.44E-03 | 1.88E+00 | 7.77E-03 | 1.52E-02 |
| **CO2** | 1.88E+00 | 3.41E+00 | 7.61E-05 | 3.56E+00 | 6.98E+00 |
| **CH4** | 7.61E-05 | 1.38E-04 | 1.52E-05 | 1.45E-04 | 2.83E-04 |
| **N2O** | 1.52E-05 | 2.77E-05 | 0.00E+00 | 2.89E-05 | 5.66E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite for calendar year 2012.

c Assumes maximum development scenario

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Development Phase**

**Wellhead Gas Combustion**

**Wellhead gas combustion only for Williston Basin wells, due to the regularity of of pit flares combusting all gas coming from the wellhead. If gas being captured, change scf/hr value or hours of event value.

**Assumptions:**

| | | | |
|---|---|---|---|
| **Estimated Gas Flow Rate:** | 0 | Scf/hr | |
| **Combustion Efficiency:** | 0.00 | Percent (%) | |
| **Event Duration:** | 0.00 | Hours | - Estimated 3 months before sales line |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* It is assumed that all produced natural gas is sent to a sales line after the well is completed.

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf/lb-mol)) * hrs/yr
** Multiply above equation by 0.05 if including 95% control efficiency

**Combusted Componet Emissions:**

| Component | Mole % [a] | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 0.00 | 0.00 | 0.00 |
| Ethane | 5.7920 | 30.1 | 0.00 | 0.00 | 0.00 |
| Propane | 1.3650 | 44.1 | 0.00 | 0.00 | 0.00 |
| i-Butane | 0.3700 | 58.1 | 0.00 | 0.00 | 0.00 |
| n-Butane | 0.2610 | 58.1 | 0.00 | 0.00 | 0.00 |
| i-Pentane | 0.1550 | 72.2 | 0.00 | 0.00 | 0.00 |
| n-Pentane | 0.1020 | 72.2 | 0.00 | 0.00 | 0.00 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 0.00 | 0.00 | 0.00 |
| Heptanes | 0.0930 | 100.2 | 0.00 | 0.00 | 0.00 |
| Octanes | 0.0440 | 114.2 | 0.00 | 0.00 | 0.00 |
| Nonanes | 0.0160 | 128.3 | 0.00 | 0.00 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 0.00 | 0.00 | 0.00 |
| Benzene | 0.0270 | 78.1 | 0.00 | 0.00 | 0.00 |
| Toluene | 0.0190 | 92.1 | 0.00 | 0.00 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 0.00 | 0.00 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 0.00 | 0.00 | 0.00 |
| Nitrogen | 0.0940 | 28.0 | 0.00 | 0.00 | 0.00 |
| Carbon Dioxide | 2.5280 | 44.0 | 0.00 | 0.00 | 0.00 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |
| **VOC Subtotal** | 2.7600 | 1492.8 | 0.00 | 0.00 | 0.00 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 0.00 | 0.00 | 0.00 |
| **Total** | 100.1460 | 1645.0 | 0.00 | 0.00 | 0.00 |

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 0.00 | 0.00 | 0.00 |
| C2 | 5.79 | 0.00 | 0.00 | 0.00 |
| C3 | 1.37 | 0.00 | 0.00 | 0.00 |
| C4 | 0.63 | 0.00 | 0.00 | 0.00 |
| C5+ | 0.76 | 0.00 | 0.00 | 0.00 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **0.00** | **Tons/Year** |
| **$N_2O$ Emissions:** | **0.00E+00** | **Tons/Year** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.00 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| NOx | 0.000 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.00 | *Based on $H_2S$ 34 mol weight and $SO_2$ 64 mol weight |

| Kleinfelder, Inc.<br>Wellsite Emissions | | Base Location: Uinta/Piceance Basin<br>Well Type: Natural Gas |
|---|---|---|

**Production Phase**

**Production Equipment Fugitive Component Emissions**

**Assumptions:**

Components Counts:

| | Fugitive Components | | | | |
|---|---|---|---|---|---|
| **Component *** | Valves | Connectors | OE Lines | PR Valves | |
| **Count** | 59 | 193 | 8 | 3 | 0 |
| **Emissions Factor (scf/hr) [b]** | 0.121 | 0.017 | 0.031 | 0.193 | 0.000 |

* Fugitive component counts for natural gas wells from Subpart W, Table W-1B
* Fugitive component counts for oil wells from Subpart W, Table W-1C

Annual Equipment Run Time: 8760 Hours/Year 379.49 Scf/lb-mol

| Component | Mole % [a] | Mole Weight lb/lb-mol | Emissions Scf/Year [b] | Emissions lbs/Year | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 87,658.5 | 3,705.8 | 1.85 |
| Ethane | 5.7920 | 30.1 | 5,706.5 | 452.2 | 0.23 |
| Propane | 1.3650 | 44.1 | 1,344.8 | 156.3 | 0.08 |
| i-Butane | 0.3700 | 58.1 | 364.5 | 55.8 | 0.03 |
| n-Butane | 0.2610 | 58.1 | 257.1 | 39.4 | 0.02 |
| i-Pentane | 0.1550 | 72.2 | 152.7 | 29.0 | 0.01 |
| n-Pentane | 0.1020 | 72.2 | 100.5 | 19.1 | 0.01 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 143.8 | 32.7 | 0.02 |
| Heptanes | 0.0930 | 100.2 | 91.6 | 24.2 | 0.01 |
| Octanes | 0.0440 | 114.2 | 43.4 | 13.0 | 0.01 |
| Nonanes | 0.0160 | 128.3 | 15.8 | 5.3 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 4.9 | 1.8 | 0.00 |
| Benzene | 0.0270 | 78.1 | 26.6 | 5.5 | 0.00 |
| Toluene | 0.0190 | 92.1 | 18.7 | 4.5 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 10.8 | 3.0 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 143.8 | 32.7 | 0.02 |
| Nitrogen | 0.0940 | 28.0 | 92.6 | 6.8 | 0.00 |
| Carbon Dioxide | 2.5280 | 44.0 | 2,490.7 | 288.8 | 0.14 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| VOC Subtotal | 2.7600 | | | 422.43 | 0.21 |
| HAPS Subtotal | 0.2030 | | | 45.72 | 0.02 |
| Total | 100.1460 | | | 4876.06 | 2.44 |

**Calculation**

lb/hr = (Mol % * SumSCF/yr) / scf/lb-mol

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

[b] Fugitive emission factors from Subpart W, Table W-1A

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Production Phase**
**Process Heater Emissions**

**Wellsite Heater Inventory:**

| | Heating Value (Mbtu/hr) | Fuel Consumption (MMScf/yr) | |
|---|---|---|---|
| **Separator Heater** | **750** | **6.44** | * Heater treater size based on industry standard |

**Annual Run Time:** **8760** **Hours/Year**
**Fuel Gas Heat Value:** **1,020** **Btu/scf (Standard heating value from AP-42)**

**Equations:**

Fuel Consumption (MMscf/yr) = $\frac{\text{Heater Size (MBtu/hr) * 1,000 (Btu/MBtu) * Hours of Operation (hrs/yr)}}{\text{Fuel Heat Value (Btu/scf) * 1,000,000 (scf/MMscf)}}$

NOx/CO/TOC Emissions (tons/yr) = $\frac{\text{AP-42 E.Factor (lbs/MMscf) * Fuel Consumption (MMscf/yr) * Fuel heating Value (Btu/scf)}}{\text{2,000 (lbs/ton) * 1,020 (Btu/scf - Standard Fuel Heating Value)}}$

| | Emission Factor (lb/MMscf) | Separator Heater Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) [e] |
|---|---|---|---|---|---|---|
| *Criteria Pollutants & VOC* | | | | | | |
| NOx [a] | 100 | 0.3221 | 0.0000 | 0.0000 | 0.0000 | 0.3221 |
| CO [a] | 84.0 | 0.2705 | 0.0000 | 0.0000 | 0.0000 | 0.2705 |
| VOC | 5.5 | 0.0177 | 0.0000 | 0.0000 | 0.0000 | 0.0177 |
| $SO_2$ [b] | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| TSP [c] | 7.60 | 0.0245 | 0.0000 | 0.0000 | 0.0000 | 0.0245 |
| $PM_{10}$ [c] | 7.60 | 0.0245 | 0.0000 | 0.0000 | 0.0000 | 0.0245 |
| $PM_{2.5}$ [c] | 7.60 | 0.0245 | 0.0000 | 0.0000 | 0.0000 | 0.0245 |
| *Hazardous Air Pollutants* | | | | | | |
| Benzene [d] | 2.10E-03 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Toluene [d] | 3.40E-03 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Hexane [d] | 1.80 | 0.0058 | 0.0000 | 0.0000 | 0.0000 | 0.0058 |
| Formaldehyde [d] | 7.50E-02 | 0.0002 | 0.0000 | 0.0000 | 0.0000 | 0.0002 |
| *Greenhouse Gases* | | | | | | |
| $CO_2$ [f] | 120,162 | 386.9918 | 0.0000 | 0.0000 | 0.0000 | 386.9918 |
| $CH_4$ [f] | 2.27 | 0.0073 | 0.0000 | 0.0000 | 0.0000 | 0.0073 |
| $N_2O$ [f] | 0.23 | 0.0007 | 0.0000 | 0.0000 | 0.0000 | 0.0007 |

a AP-42 Table 1.4-1, Emission Factors for Natural Gas Combustion, 7/98
b Assumes produced gas contains no sulfur
c AP-42 Table 1.4-2, Emission Factors for Natural Gas Combustion, 7/98 (All Particulates are $PM_{1.0}$)
d AP-42 Table 1.4-3, Emission Factors for Organic Compounds from Natural Gas Combustion, 7/98
e Assumes maximum development scenario
f Subpart W - Part 98.233(z)(1) indicates the use of Table C-1 and Table C-2 for fuel combustion of stationary and portable equipment. Table C-1 provides an EF for natural gas combustion of 53.02 kg $CO_2$/mmBtu. Table C-2 provides an EF for natural gas combustion for $CH_4$ as 1.0E-03 kg/MMBtu and for $N_2O$ as 1.0E-04 kg/MMBtu.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Atmospheric Oil Tank Flashing Emissions**

**Assumptions:**

| | | | |
|---|---|---|---|
| Production Estimate: | 10 | barrels/day | |
| Production Days: | 365 | Days/Year | |
| Flasing Gas-to-Oil Ratio: | 100 | Scf/bbl | 379.49 Scf/lb-mol |
| Control Efficiency: | 95 | Percent (%) | |

**Flashing Gas Composition:**

| Component | Mole % | Mole Weight (lb/lb-mol) | Emissions (Uncontrolled) Scf/Year | Emissions (Uncontrolled) lbs/Year | Emissions (Uncontrolled) Tons/Year | Emissions (Controlled) Tons/Year |
|---|---|---|---|---|---|---|
| Methane | 44.8625 | 16.043 | 163748.125 | 6922.4780 | 3.4612 | 0.1731 |
| Ethane | 15.2687 | 30.07 | 55730.755 | 4415.9894 | 2.2080 | 0.1104 |
| Propane | 20.0892 | 44.097 | 73325.58 | 8520.4830 | 4.2602 | 0.2130 |
| i-Butane | 4.7308 | 58.123 | 17267.42 | 2644.6922 | 1.3223 | 0.0661 |
| n-Butane | 7.4972 | 58.123 | 27364.78 | 4191.2122 | 2.0956 | 0.1048 |
| i-Pentane | 2.2617 | 72.150 | 8255.205 | 1569.5092 | 0.7848 | 0.0392 |
| n-Pentane | 1.7732 | 72.150 | 6472.18 | 1230.5141 | 0.6153 | 0.0308 |
| Other Pentanes | 0.0000 | 70.100 | 0 | 0.0000 | 0.0000 | 0.0000 |
| Hexanes | 0.6780 | 86.177 | 2474.7 | 561.9706 | 0.2810 | 0.0140 |
| Heptanes | 0.6823 | 100.204 | 2490.395 | 657.5866 | 0.3288 | 0.0164 |
| Octanes | 0.1688 | 114.231 | 616.12 | 185.4594 | 0.0927 | 0.0046 |
| Nonanes | 0.0186 | 128.258 | 67.89 | 22.9451 | 0.0115 | 0.0006 |
| Decanes + | 0.0081 | 142.285 | 29.565 | 11.0850 | 0.0055 | 0.0003 |
| Benzene | 0.1117 | 78.120 | 407.705 | 83.9282 | 0.0420 | 0.0021 |
| Toluene | 0.0525 | 92.130 | 191.625 | 46.5214 | 0.0233 | 0.0012 |
| Ethylbenzene | 0.0013 | 106.160 | 4.745 | 1.3274 | 0.0007 | 0.0000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.120 | 0 | 0.0000 | 0.0000 | 0.0000 |
| Xylenes | 0.0077 | 106.160 | 28.105 | 7.8622 | 0.0039 | 0.0002 |
| n-Hexane | 0.5041 | 86.177 | 1839.965 | 417.8309 | 0.2089 | 0.0104 |
| Nitrogen | 0.1776 | 28.013 | 648.24 | 47.8515 | 0.0239 | 0.0012 |
| Carbon Dioxide | 1.1062 | 44.010 | 4037.63 | 468.2497 | 0.2341 | 0.0117 |
| Hydrogen Sulfide | 0.0000 | 34.080 | 0 | 0.0000 | 0.0000 | 0.0000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| VOC Subtotal | 38.59 | | | | 10.08 | 0.50 |
| HAPS Subtotal | 0.68 | | | | 0.28 | 0.01 |
| **Total** | **100.0002** | | | | **16.0037** | **0.8002** |

**Calculation:**

Scf/yr = (Mol% * scf/bbl * bbl/day * days/yr) / 100

lb/yr = (scf/yr * mol wt.) / scf/lb-mol

*** Production and gas to oil ratio based on basin specific differences. Please see "Gas Stream Molar Ratios" tab and report for additional information.**

| Kleinfelder, Inc.<br>Wellsite Emissions | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Wellsite Produced Water Tanks Venting**

**Assumptions:**

| | | |
|---|---|---|
| Average Estimated Water Production: | 4000 | Barrels Per Year |
| Number of Water Tanks: | 1 | Tanks |
| VOC Emissions Factor: | 0.2620 | lbs/bbl |
| n-Hexane Emission Factor: | 0.0220 | lbs/bbl |
| Benzene Emission Factor: | 0.0070 | lbs/bbl |

**Calculations:**

| | | |
|---|---|---|
| VOC Emissions: | 0.524 | Tons/Year |
| Hexane Emissions: | 0.044 | Tons/Year |
| Benzene Emissions: | 0.014 | Tons/Year |

* Production conservatively based on estimated industry single well average
* Emission factors based on only known lb/bbl factor, which was developed by the Colorado Department of Health and Environment (PS Memo 09-02).

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Truck Loading Emissions**

**AP - 42, Chapter 5.2** $\mathbf{L_L = 12.46 \times S \times P \times M / T}$

$L_L$ = Loading Loss Emission Factor (lbs VOC/1000 gal loaded)

S = Saturation Factor

P = True Vapor Pressure of the Loaded Liquid (psia)

M = Vapor Molecular Weight of the Loaded Liquid (lbs/lbmol)

T = Temperature of Loaded Liquid (ºR)

**VOC Emissions (tpy) =**

$$\frac{L_L \text{ (lbs VOC/1000 gal)} * 42 \text{ gal/bbl} * 365 \text{ days/year} * \text{production (bbl/day)}}{1000 \text{ gal} * 2000 \text{ lbs/ton}}$$

| S[1] | P (psia)[2] | M (lb/lbmol)[3] | T (ºF)[4] | T (ºR) | $L_L$ (lb/1000 gal) | Production (bbl/day) | VOC (tpy) |
|---|---|---|---|---|---|---|---|
| 0.6 | 4.20 | 66.00 | 50.00 | 509.67 | 4.07 | 10.0 | **0.31** |

Notes:

1. Saturation factor from AP-42, Table 5.2-1 (Submerged loading: dedicated normal service)
2. True vapor pressure is estimated from AP-42, Table 7.1-2 assuming an average daily temperature of either 40 or 50 deg F and an RVP of 10.0.
3. Molecular weight liquid vapor is estimated from AP-42, Table 7.1-2 assuming an RVP of 10.0.
4. Temperature based on the annual average temperature for basin location (either 40 or 50 degrees F based on options provided in AP-42 Table 7.1-2

| Kleinfelder, Inc. Wellsite Emissions | Base Location: Uinta/Piceance Basin Well Type: Natural Gas |
|---|---|

**Production Phase**

**Pumpjack Unit Emissions**

**Assumptions:**

***Pumpjack engines only included at oil wells***

| | | |
|---|---|---|
| Pumpjack Horsepower Rating: | 0.0 | Horsepower |
| Load Factor: | 0.54 | |
| Brake Specific Fuel Consumption: | 0 | Btu/hp-hr |
| Annual Operation: | 8,760 | Hours/Year |

**Equations:**

$$\text{Emissions (lbs/hr)} = \frac{\text{Emission Factor (g/hp-hr)} * \text{Power (hp)}}{453.6 \text{ g/lb}}$$

| Pollutant | Emission Factor [a] (lb/MMBtu) | Emission Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) |
|---|---|---|---|---|
| *Criteria Pollutants & VOC* | | | | |
| **NOx** | | 2.80 | 0.00 | 0.0000 |
| **CO** | | 4.80 | 0.00 | 0.0000 |
| **VOC** | 0.12 | - | 0.0000 | 0.0000 |
| **$PM_{10}$** [b] | 4.83E-02 | - | 0.00E+00 | 0.00E+00 |
| **$PM_{2.5}$** [b] | 4.83E-02 | - | 0.00E+00 | 0.00E+00 |
| **$SO_2$** | 5.88E-04 | - | 0.0000 | 0.0000 |
| *Hazardous Air Pollutants* | | | | |
| **Benzene** | 1.94E-03 | - | 0.00E+00 | 0.00E+00 |
| **Toluene** | 9.63E-04 | - | 0.00E+00 | 0.00E+00 |
| **Ethylbenzene** | 1.08E-04 | - | 0.00E+00 | 0.00E+00 |
| **Xylenes** | 2.68E-04 | - | 0.00E+00 | 0.00E+00 |
| **Formaldehyde** | 5.52E-02 | - | 0.0000 | 0.0000 |
| **n-Hexane** | 4.45E-04 | - | 0.00E+00 | 0.00E+00 |
| *Greenhouse Gases* | | | | |
| **$CO_2$** [c] | 117 | - | 0.00 | 0 |
| **$CH_4$** | 0.002 | - | 0.0000 | 0.0000 |
| **$N_2O$** | 0.0002 | - | 0.0000 | 0.0000 |

a AP-42 Table 3.2-3 Uncontrolled Emission Factors for 4-Stroke Rich-Burn Engines, 7/00; and Subpart JJJJ for NOX and CO emission rates.

b PM = sum of PM filterable and PM condensable

c Subpart W - Part 98.233(z)(1) indicates the use of Table C-1 and Table C-2 for fuel combustion of stationary and portable equipment. Table C-1 provides an EF for natural gas combustion of 53.02 kg $CO_2$/mmBtu. Table C-2 provides an EF for natural gas combustion for $CH_4$ as 1.0E-03 kg/MMBtu and for $N_2O$ as 1.0E-04 kg/MMBtu.

- Network website for the 1999 National-Scale Air Toxics Assessment at http://www.epa.gov/ttn/atw/nata1999/nsata99.html

# Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

Production Phase

Wellsite Dehydrator Emissions

**Assumptions:**

Number of Dehy Units: 0 Units

**Calculations:**

Calculations and specifications derived from Pinedale Anticline Final SEIS
GRI-GLYCalc 4.0 operated with: 4 MMSCFD, 0.32 gpm glycol flow, average representative gas analysis, and 95% control efficiency

**Emissions:**

| Species | Total Project Emissions (tons/year) |
|---|---|
| **Total VOC** | 0.000 |
| *Hazardous Air Pollutants* | |
| **Benzene** | 0.000 |
| **Toluene** | 0.000 |
| **Ethylbenzene** | 0.000 |
| **Xylenes** | 0.000 |
| **n-Hexane** | 0.000 |
| *Greenhouse Gases* | |
| $CO_2$ | 0.000 |
| $CH_4$ [a] | 0.000 |
| $N_2O$ | 0.000 |

Note, no greenhouse gas emissions included for dehydrator in Pinedale EIS

| **Kleinfelder, Inc.** **Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin **Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Roadway Construction Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Light Duty Pickup Trucks: | 50 | Trips/Location | | | |
| Light Duty Haul Trucks | 0 | Trips/Location | Total Trips: | 50 | Trips |
| Heavy Duty Haul Trucks | 2 | Trips/Location | | | |
| Water Trucks | 40 | Trips/Location | Total Trips: | 42 | Trips |

* Miles and number of trips based on research and industry knowledge; please see report for additional information.

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (g/mile)} * \text{\# Trips} * \text{Trip Distance (miles)}}{\text{2000 (lb/tons)}}$$

| **Construction Vehicles** | **Heavy Haul Trucks** | | **Light Duty Pickups** | | **Total** |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 6.25E-02 | 7.39E-03 | 7.39E-03 | 6.99E-02 |
| **CO** | 1.98E-02 | 1.66E-02 | 7.26E-02 | 7.26E-02 | 8.92E-02 |
| **VOC** | 3.16E-03 | 2.65E-03 | 3.54E-03 | 3.54E-03 | 6.19E-03 |
| **SO2** | 4.57E-05 | 3.84E-05 | 2.83E-05 | 2.83E-05 | 6.67E-05 |
| **PM10** | 4.22E-03 | 3.54E-03 | 1.94E-04 | 1.94E-04 | 3.74E-03 |
| **PM2.5** | 4.09E-03 | 3.44E-03 | 1.79E-04 | 1.79E-04 | 3.61E-03 |
| **CO2** | 1.88E+00 | 1.58E+00 | 1.13E+00 | 1.13E+00 | 2.70E+00 |
| **CH4** | 7.61E-05 | 6.39E-05 | 4.56E-05 | 4.56E-05 | 1.10E-04 |
| **N2O** | 1.52E-05 | 1.28E-05 | 9.13E-06 | 9.13E-06 | 2.19E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

c Assumes maximum development scenario

| Kleinfelder, Inc.<br>Wellsite Emissions | Base Location: Uinta/Piceance Basin<br>Well Type: Natural Gas |
|---|---|

**Production Phase**

**Pneumatic Device Emissions**

**Wellsite Pneumatic Inventory:**

| | | Classification | Quantity | Emission Factor (Scf/hr/unit) |
|---|---|---|---|---|
| **Devices:** | Dump Valve | Intermittent Bleed | 2 | 13.50 |
| | Pneumatic Controller | Low Bleed | 1 | 1.39 |
| | | | 0 | 0.00 |
| **Pumps:** | Chemical Pump | Pneumatic Pump | 1 | |
| | Sandpiper | Pneumatic Pump | 1 | 13.30 |

Annual Equipment Run Time: 8760 Hours/Year — 379.49 Scf/lb-mol

Pneumatic Device Control: [b] 0 Percent

* Low bleed and intermittent bleed emission factors (scf/hr) based on Subpart W, Table W-1A
* Quantity of devices based on typical industry values

| Component | Mole % | Mole Weight lb/lb-mol | Dump Valve Tons/Year | Pneumatic Controller Tons/Year | (None) Tons/Year | Pneumatic Pumps Tons/Year | Total Tons/Year |
|---|---|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 4.448 | 0.229 | 0.000 | 4.382 | 9.059 |
| Ethane | 5.7920 | 30.1 | 0.543 | 0.028 | 0.000 | 0.535 | 1.105 |
| Propane | 1.3650 | 44.1 | 0.188 | 0.010 | 0.000 | 0.185 | 0.382 |
| i-Butane | 0.3700 | 58.1 | 0.067 | 0.003 | 0.000 | 0.066 | 0.136 |
| n-Butane | 0.2610 | 58.1 | 0.047 | 0.002 | 0.000 | 0.047 | 0.096 |
| i-Pentane | 0.1550 | 72.2 | 0.035 | 0.002 | 0.000 | 0.034 | 0.071 |
| n-Pentane | 0.1020 | 72.2 | 0.023 | 0.001 | 0.000 | 0.023 | 0.047 |
| Other Pentanes | 0.0000 | 70.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Hexanes | 0.1460 | 86.2 | 0.039 | 0.002 | 0.000 | 0.039 | 0.080 |
| Heptanes | 0.0930 | 100.2 | 0.029 | 0.001 | 0.000 | 0.029 | 0.059 |
| Octanes | 0.0440 | 114.2 | 0.016 | 0.001 | 0.000 | 0.015 | 0.032 |
| Nonanes | 0.0160 | 128.3 | 0.006 | 0.000 | 0.000 | 0.006 | 0.013 |
| Decanes + | 0.0050 | 142.3 | 0.002 | 0.000 | 0.000 | 0.002 | 0.005 |
| Benzene | 0.0270 | 78.1 | 0.007 | 0.000 | 0.000 | 0.006 | 0.013 |
| Toluene | 0.0190 | 92.1 | 0.005 | 0.000 | 0.000 | 0.005 | 0.011 |
| Ethylbenzene | 0.0000 | 106.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Xylenes | 0.0110 | 106.2 | 0.004 | 0.000 | 0.000 | 0.004 | 0.007 |
| n-Hexane | 0.1460 | 86.2 | 0.039 | 0.002 | 0.000 | 0.039 | 0.080 |
| Nitrogen | 0.0940 | 28.0 | 0.008 | 0.000 | 0.000 | 0.008 | 0.017 |
| Carbon Dioxide | 2.5280 | 44.0 | 0.347 | 0.018 | 0.000 | 0.342 | 0.706 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **VOC Subtotal** | 2.8 | 1492.8 | 0.51 | 0.03 | 0.00 | 0.50 | 1.03 |
| **HAPS Subtotal** | 0.2 | 546.9 | 0.05 | 0.00 | 0.00 | 0.05 | 0.11 |
| **Total** | 100.1 | 1645.0 | 5.85 | 0.30 | 0.00 | 5.77 | 11.92 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

[b] 98% control input is a result of the Wyoming Department of Environment Quality requirement, and only pertains to the Upper Green River Basin.

# APPENDIX B

# EMISSION INVENTORY FOR THE UINTA/PICEANCE BASIN GAS WELL

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Location Selection:**

| **Geography:** | **Well Type:** |
|---|---|
| Uinta/Piceance Basin | Natural Gas |

- Choose geography/basin, and well type will automatically fill
  - < Choose Uinta/Piceance Basin for deep gas wells with little condensate
  - < Choose Upper Green River Basin for deep gas wells with dehydrators and higher condensate
  - < Choose San Juan Basin for shallow gas wells with little to no condensate
  - < Choose Williston Basin for deep oil wells with high gas
  - < Choose Denver Basin for shallow oil wells with low gas

If the user wants to change any specifications, do so within the "Constants and References" tab, as all other tabs connect to it.

| | **Total Emissions (Tons per Year)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Pollutant:** | **$NO_X$** | **CO** | **VOC** | **$SO_2$** | **$PM_{10}$** | **$PM_{2.5}$** | **$CO_2$** | **$CH_4$** | **$N_2O$** |
| **Construction Phase:** | 0.47 | 0.29 | 0.04 | 0.0001 | 1.99 | 0.06 | 33.84 | 0.001 | 0.0003 |
| **Development Phase:** | 14.77 | 3.15 | 0.74 | 0.0002 | 4.89 | 0.49 | 2127.69 | 1.12 | 0.0516 |
| **Operation Phase:** | 0.39 | 0.36 | 2.62 | 0.0001 | 0.04 | 0.23 | 390.55 | 11.09 | 0.0008 |
| **Total:** | 15.63 | 3.80 | 3.40 | 0.0004 | 6.93 | 0.78 | 2552.08 | 12.21 | 0.0526 |

| | **Total Emissions (Tons per Year)** | | | | | |
|---|---|---|---|---|---|---|
| **Pollutant:** | **Benzene** | **Toluene** | **Ethylbenzene** | **Xylene** | **n-Hexane** | **HAPs** |
| **Construction Phase:** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Development Phase:** | 1.36 | 0.95 | 0.0000 | 0.55 | 7.31 | 10.18 |
| **Operation Phase:** | 0.03 | 0.01 | 0.00003 | 0.009 | 0.16 | 0.21 |
| **Total:** | 1.39 | 0.97 | 0.00003 | 0.56 | 7.46 | 10.39 |

| **$CO_2$ equivalent (Global Warming Potential)** | |
|---|---|
| **Total TPY:** | **2824.87** |
| $CO_2$ equivalent conversions: | |
| $CO_2$ | 1.00 |
| $CH_4$ | 21.00 |
| $N_2O$ | 310.00 |

| **$H_2S$ Emissions** | |
|---|---|
| **Total TPY:** | **0.00** |

* If $H_2S$ in gas, input value in "Gas Stream Molar Ratios" tab, and potential emissions will calculate here. Current assumption is no $H_2S$ in gas stream.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Road Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 4 | Days/Location | (Typical Value) |
| | 48.0 | Dozer Hours/Location | (Typical Value) |
| | 48.0 | Backhoe Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |

$PM_{10}$ Multiplier: $0.75 * PM_{15}$ (AP-42 Table 11.9-1, 7/98)

$PM_{2.5}$ Multiplier: 0.105 * TSP (AP-42 Table 11.9-1, 7/98)

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98 & 7/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content } \%)^{1.2} * (\text{soil moisture content } \%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content } \%)^{1.5} * (\text{soil moisture content } \%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions [a]** | | **Backhoe Emissions [a]** | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0473 | 1.97 | 0.0473 | 0.0946 |
| **$PM_{15}$** | 0.50 | 0.0120 | 0.50 | 0.0120 | 0.0241 |
| **$PM_{10}$** | 0.38 | 0.0090 | 0.38 | 0.0090 | 0.0181 |
| **$PM_{2.5}$** | 0.21 | 0.0050 | 0.05 | 0.0013 | 0.0062 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Road Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Grading Length: | 6.00 | miles | (Typical Value) |
| Construction Schedule: | 3 | Days/Location | (Typical Value) |
| | 12 | Hours/Day | (Typical Value) |
| | 36 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | |
| Average Grader Speed: | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 16.12 lbs TSP/Location**

**Emissions = 7.71 lbs $PM_{15}$/Location**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 16.12 | 0.45 | 8.06E-03 |
| **$PM_{15}$** | 7.71 | 0.21 | 3.86E-03 |
| **$PM_{10}$** | 4.63 | 0.13 | 2.31E-03 |
| **$PM_{2.5}$** | 0.50 | 0.01 | 2.50E-04 |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Well Pad Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | | |
|---|---|---|---|---|
| Construction Schedule: | 7 | Days/Location | | (Typical Value) |
| | 10 | Hours/Day | | (Typical Value) |
| | 70 | Hours/Location | (Dozer) | (Typical Value) |
| | 70 | Hours/Location | (Back Hoe) | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.75 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | | |
| $PM_{2.5}$ Multiplier: | 0.105 * TSP | (AP-42 Table 11.9-1, 7/98) | | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs/hr) = 5.7 * (soil silt content %)$^{1.2}$ * (soil moisture content %)$^{-1.3}$* Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = 1.0 * (soil silt content %)$^{1.5}$ * (soil moisture content %)$^{-1.4}$ * Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions [a]** | | **Backhoe Emissions [a]** | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0690 | 1.97 | 0.0690 | 0.14 |
| **$PM_{15}$** | 0.50 | 0.0176 | 0.50 | 0.0176 | 0.04 |
| **$PM_{10}$** | 0.38 | 0.0132 | 0.38 | 0.0132 | 0.03 |
| **$PM_{2.5}$** | 0.21 | 0.0072 | 0.21 | 0.0072 | 0.01 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

## Kleinfelder, Inc.

**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Construction Phase**

**Well Pad Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 4.0 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 40 | Hours/Location | (Typical Value) |
| Watering Control Efficiency | 50 | Percent (%) | (Typical Value) |
| Average Grader Speed | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| Distance Graded | 2.84 | Miles/Location | (Typical Value) |
| $PM_{10}$ Multiplier | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 7.63 lbs TSP/well pad**

**Emissions = 3.65 lbs $PM_{15}$/well pad**

| | Grader Construction Emissions | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 7.63 | 0.19 | 0.0038 |
| **$PM_{15}$** | 3.65 | 0.09 | 0.0018 |
| **$PM_{10}$** | 2.19 | 0.05 | 0.0011 |
| **$PM_{2.5}$** | 0.24 | 0.01 | 0.0001 |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Pipeline Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 7.0 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.75 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.105 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 7/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content }\%)^{1.2} * (\text{soil moisture content }\%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content }\%)^{1.5} * (\text{soil moisture content }\%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions [a]** | | **Backhoe Emissions [a]** | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0690 | 1.97 | 0.0690 | 0.14 |
| **$PM_{15}$** | 0.50 | 0.0176 | 0.50 | 0.0176 | 0.04 |
| **$PM_{10}$** | 0.38 | 0.0132 | 0.38 | 0.0132 | 0.03 |
| **$PM_{2.5}$** | 0.21 | 0.0072 | 0.21 | 0.0072 | 0.01 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Pipeline Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Distance Graded: | 12.50 | Miles/Location | (Typical Value) |
| Construction Schedule: | 7 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Mean Vehicle Speed: | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 7/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 33.58 lbs TSP/well**

**Emissions = 16.07 lbs $PM_{15}$/well**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 33.58 | 0.48 | 0.0168 |
| **$PM_{15}$** | 16.07 | 0.23 | 0.0080 |
| **$PM_{10}$** | 9.64 | 0.14 | 0.0048 |
| **$PM_{2.5}$** | 1.04 | 0.01 | 0.0005 |

| **Kleinfelder, Inc.** | **Base Location:** Uinta/Piceance Basin |
|---|---|
| **Wellsite Emissions** | **Well Type:** Natural Gas |

**Construction Phase**

**Roadway Construction Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Heavy Diesel Truck Trips: | | | | | |
| Road Construction: | 7 | Trips | | | |
| Well Pad Construction: | 8 | Trips | Total Trips: | 21 | Trips |
| Pipeline Construction: | 6 | Trips | | | |
| Light Duty Pickup Truck Trips: | | | | | |
| Road Construction: | 16 | Trips | | | |
| Well Pad Construction: | 28 | Trips | Total Trips: | 100 | Trips |
| Pipeline Construction: | 56 | Trips | | | |

* All assumptions above are based on typical industry values

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (lb/mile) * \# Trips * Trip Distance (miles)}}{\text{2000 (lb/tons)}}$$

| **Construction Vehicles** | **Heavy Haul Trucks** | | **Light Duty Pickups** | | **Total** |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 3.12E-02 | 7.39E-03 | 1.48E-02 | 4.60E-02 |
| **CO** | 1.98E-02 | 8.32E-03 | 7.26E-02 | 1.45E-01 | 1.54E-01 |
| **VOC** | 3.16E-03 | 1.33E-03 | 3.54E-03 | 7.08E-03 | 8.41E-03 |
| **SO2** | 4.57E-05 | 1.92E-05 | 2.83E-05 | 5.66E-05 | 7.58E-05 |
| **PM10** | 4.22E-03 | 1.77E-03 | 1.94E-04 | 3.88E-04 | 2.16E-03 |
| **PM2.5** | 4.09E-03 | 1.72E-03 | 1.79E-04 | 3.58E-04 | 2.08E-03 |
| **CO2** | 1.88 | 0.79 | 1.13 | 2.25 | 3.04 |
| **CH4** | 7.61E-05 | 3.19E-05 | 4.56E-05 | 9.13E-05 | 1.23E-04 |
| **N2O** | 1.52E-05 | 6.39E-06 | 9.13E-06 | 1.83E-05 | 2.46E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

| Kleinfelder, Inc.<br>Wellsite Emissions | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Construction Heavy Equipment Tailpipe Emissions**

**Assumptions:**

Fuel and Engine:

| | | | |
|---|---|---|---|
| Brake Specific Fuel Consumption, Avg. (BSFC) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel Higher Heating Value (HHV) | 0.138 | mmBtu/Gallon | (Typical Value) |

Trackhoe:

| | | | |
|---|---|---|---|
| Working Hours | 188 | Total Hours | (Typical Value) |
| Rated Horsepower | 100 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Tractors/Loaders/Backhoes) | |

Dozer:

| | | | |
|---|---|---|---|
| Working Hours | 188 | Total Hours | (Typical Value) |
| Rated Horsepower | 140 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Crawler Tractor/Dozers) | |

Grader:

| | | | |
|---|---|---|---|
| Working Hours | 130 | Total Hours | (Typical Value) |
| Rated Horsepower | 250 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Graders) | |

| | | | |
|---|---|---|---|
| Total Horsepower Hours: | 45795.8 | Hp-hrs | (Sum of all horsepower above) |
| Total Fuel Usage: | 2737.79 | Gallons Diesel Fuel | |

**Equations:**

Total Fuel Usage: ((btu-hp-hr * hp-hrs) / Mmbtu-gal) / 1,000,000

$$\text{Emissions (tons/year/pad)} = \frac{\text{Emission Factor (g/mile) * Trip Distance (miles) * Load Factor}}{\text{453.6 (g/lb) * 2000 (lb/tons)}}$$

| Heavy Const. Vehicles | Backhoe | | | Dozer | | | Grader | | |
|---|---|---|---|---|---|---|---|---|---|
| | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) |
| **NOx** | 8.38 | 1.09E+00 | 1.02E-01 | 8.38 | 1.53E+00 | 1.43E-01 | 8.38 | 2.72E+00 | 1.77E-01 |
| **CO** | 2.7 | 3.51E-01 | 3.30E-02 | 2.7 | 4.92E-01 | 4.62E-02 | 2.7 | 8.78E-01 | 5.71E-02 |
| **VOC** [b] | 0.68 | 8.84E-02 | 8.31E-03 | 0.68 | 1.24E-01 | 1.16E-02 | 0.68 | 2.21E-01 | 1.44E-02 |
| **$PM_{10}$** | 0.39 | 5.07E-02 | 4.77E-03 | 0.39 | 7.10E-02 | 6.68E-03 | 0.39 | 1.27E-01 | 8.24E-03 |
| **$PM_{2.5}$** | 0.39 | 5.07E-02 | 4.77E-03 | 0.39 | 7.10E-02 | 6.68E-03 | 0.39 | 1.27E-01 | 8.24E-03 |

| Heavy Const. Vehicles | Total Emissions [c] (tons/yr) |
|---|---|
| **NOx** | 0.42 |
| **CO** | 0.14 |
| **VOC** | 0.03 |
| **$PM_{10}$** | 0.02 |
| **$PM_{2.5}$** | 0.02 |

**Greenhouse Gas Emissions:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | kg/mmbtu | lbs | Tons |
| $CO_2$ | 73.96 | 61604.19 | 30.80 |
| $CH_4$ | 0.003 | 2.50 | 0.0012 |
| $N_2O$ | 0.0006 | 0.50 | 0.0002 |

a From Table A-4 of Exhaust and Crankcase Emission Factors for NONROAD Engine Modeling - Compression Ignition, EPA-420-R-10-018, July 2010.

b Emission Factor represents total Hydrocarbon Emissions

c Converted from emission factor for Distillate Fuel Oil #2 (diesel) as listed in Table C-1 to Subpart C of Part 98 - Default Emission Factors and High Heat Values for Various Types of Fuel.

Listed Factor:

| | |
|---|---|
| 73.96 | kg $CO_2$/mmBtu |
| 393 | hp-hr = mmBtu |
| 188.2 | g $CO_2$/hp-hr |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Wind Erosion Fugitive Dust**

**Assumptions:**

Threshold Friction Velocity ($U_t$) 1.02 m/s (2.28 mph) for well pads (AP-42 Table 13.2.5-2 Overburden - Western Surface Coal Mine)
1.33 m/s (2.97 mph) for roads (AP-42 Table 13.2.5-2 Roadbed material)

Initial Disturbance Area

| | | | |
|---|---|---|---|
| Total Access Road/ROW Area Per Location: | 976,800 | Square Meters | (Typical Value) |
| Total Well Pad Area Disturbed Per Location: | 50,000 | Square Meters | (Typical Value) |
| Total Area Disturbed Per Location: | 1,026,800 | Square Meters | (Typical Value) |
| Exposed Surface Type | Flat | | |
| Meteorological Data | 2002 Grand Junction (obtained from NCDC website) | | |
| Fastest Mile Wind Speed: | 45 | miles/hour | (Typical Value) |
| Fastest Mile Wind Speed ($U_{10}^{+}$) | 20.12 | meters/sec (45 mph) reported as fastest 2-minute wind speed for Grand Junction (2002) | |
| Number soil of disturbances | 1.00 | for well pads (Assumption, disturbance at construction and reclamation) constant for dirt roads | |

**Equations (AP-42 13.2.5.2 Industrial Wind Erosion)**

Friction Velocity $U^* = 0.053\ U_{10}^{+}$

Erosion Potential $P\ (g/m^2/period) = 58*(U^*-U_t^*)^2 + 25*(U^*-U_t^*)$ for $U^*>U_t^*$, $P = 0$ for $U^*< U_t^*$

Emissions (tons/year) = Erosion Potential(g/m²/period)*Disturbed Area(m²)*Disturbances/year*(k)/(453.6 g/lb)/2000 lbs/ton/Develop Period

| **Particle Size Multiplier (k)** | | |
|---|---|---|
| **30 µm** | **<10 µm** | **<2.5 µm** |
| 1.0 | 0.5 | 0.075 |

| **Maxium $U_{10}^{+}$ Wind Speed (m/s)** | **Maximum U* Friction Velocity m/s** | **Well $U_t$* Threshold Velocity[a] m/s** | **Well Pad Erosion Potential $g/m^2$** | **Road $U_t$* Threshold Velocity[a] m/s** | **Road Erosion Potential $g/m^2$** |
|---|---|---|---|---|---|
| 20.12 | 1.07 | 1.02 | 1.28 | 1.33 | 0.00 |

**Wind Erosion Emissions**

| **Particulate Species** | **Well Pad (tons/year)** | **Roads/Pipelines (tons/year)** |
|---|---|---|
| TSP | 7.05E-02 | 0.00E+00 |
| $PM_{10}$ | 3.52E-02 | 0.00E+00 |
| $PM_{2.5}$ | 5.28E-03 | 0.00E+00 |

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Construction, Development, and Production Phase**
**Construction, Development, and Operations Traffic Fugitive Dust Emissions**

**Assumptions:**

| | |
|---|---|
| Round Trip Miles | 40 |
| Round Trip (Paved) Miles | 16 |
| Round Trip (Un-Paved) Miles | 24 |
| Precipitation Days (P) | 45 |

Unpaved Calculation AP-42, Chapter 13.2.2
November 2006

$E (PM_{10}) / VMT = 1.5 * (S/12)^{0.9} * (W/3)^{0.45} * (365\text{-}p)/365)$
$E (PM_{2.5}) / VMT = 0.15 * (S/12)^{0.9} + (W/3)^{0.45} * (365\text{-}p)/365)$

Silt Content (S) 8.5 AP 42 13.2.2-1 Mean Silt Content Construction Sites

Paved Calculation AP-42, Chapter 13.2.1
January 2011

$E (PM_{10}) / VMT = 0.0022 * (sL)^{0.91} * (W)^{1.02} * (1\text{-}(P/(365*4))$
$E (PM_{2.5}) / VMT = 0.00054 * (sL)^{0.91} * (W)^{1.02} * (1\text{-}(P/(365*4))$

Silt Loading (sL) 0.6 AP-42 Table 13.2.1-2 baseline low volume roads

**Construction Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | $PM_{10}$ (lb/VMT) | $PM_{10}$ (lbs) | $PM_{10}$ (Tons) | $PM_{2.5}$ (lb/VMT) | $PM_{2.5}$ (lbs) | $PM_{2.5}$ (Tons) |
|---|---|---|---|---|---|---|---|---|
| Heavy Duty Haul Trucks | 80,000 | 21 | 3.09 | 1558.9 | 0.8 | 0.3 | 155.9 | 0.1 |
| Light Duty Pickup Trucks | 5,000 | 100 | 0.89 | 2131.8 | 1.1 | 0.1 | 213.2 | 0.1 |
| **Total:** | | | | **3690.67** | **1.85** | | **369.07** | **0.18** |

**Paved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| Heavy Duty Haul Trucks | 80,000 | 21 | 0.0576 | 19.4 | 0.0097 | 0.014 | 4.8 | 0.0024 |
| Light Duty Pickup Trucks | 5,000 | 100 | 0.0034 | 5.5 | 0.0027 | 0.001 | 1.3 | 0.0007 |
| **Total:** | | | | **24.8** | **0.0** | | **6.1** | **0.0** |

**Development Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | $PM_{10}$ (lb/VMT) | $PM_{10}$ (lbs) | $PM_{10}$ (Tons) | $PM_{2.5}$ (lb/VMT) | $PM_{2.5}$ (lbs) | $PM_{2.5}$ (Tons) |
|---|---|---|---|---|---|---|---|---|
| Light Duty Pickup Trucks: | 5,000 | 84 | 0.89 | 1790.7 | 0.9 | 0.1 | 179.1 | 0.1 |
| Light Duty Haul Trucks | 7,500 | 11 | 1.07 | 281.4 | 0.1 | 0.1 | 28.1 | 0.0 |
| Heavy Duty Haul Trucks | 80,000 | 67 | 3.09 | 4973.6 | 2.5 | 0.3 | 497.4 | 0.2 |
| Water Trucks | 70,000 | 24 | 2.91 | 1677.7 | 0.8 | 0.3 | 167.8 | 0.1 |
| **Total:** | | | | **8723.41** | **4.36** | | **872.34** | **0.44** |

**Paved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Light Duty Pickup Trucks:** | 5000 | 84 | 0.00 | 4.6 | 0.0 | 0.0 | 1.1 | 0.0006 |
| **Light Duty Haul Trucks** | 7500 | 11 | 0.01 | 0.9 | 0.0 | 0.0 | 0.2 | 0.0001 |
| **Heavy Duty Haul Trucks** | 80000 | 67 | 0.06 | 61.8 | 0.0 | 0.0 | 15.2 | 0.0076 |
| **Water Trucks** | 70,000 | 24 | 0.05 | 19.3 | 0.0 | 0.0 | 4.7 | 0.0024 |
| **Total:** | | | | **86.6** | **0.0** | | **21.2** | **0.0** |

**Production Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| Light Duty Pickup Trucks: | 5,000 | 50 | 0.89 | 1065.89 | 0.53 | 0.0888 | 106.59 | 0.0533 |
| Light Duty Haul Trucks | 7,500 | 0 | 1.07 | 0.00 | 0.00 | 0.1066 | 0.00 | 0.0000 |
| Heavy Duty Haul Trucks | 80,000 | 2 | 3.09 | 148.47 | 0.07 | 0.3093 | 14.85 | 0.0074 |
| Water Trucks | 70,000 | 40 | 2.91 | 2796.14 | 1.40 | 0.2913 | 279.61 | 0.1398 |
| **Total:** | | | | **4010.50** | **2.01** | | **401.05** | **0.20** |

**Paved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| **Light Duty Pickup Trucks:** | 5,000 | 50 | 0.00 | 2.73 | 0.0014 | 0.0008 | 0.67 | 0.0003 |
| **Light Duty Haul Trucks** | 7,500 | 0 | 0.01 | 0.00 | 0.0000 | 0.0013 | 0.00 | 0.0000 |
| **Heavy Duty Haul Trucks** | 80,000 | 2 | 0.06 | 1.84 | 0.0009 | 0.0141 | 0.45 | 0.0002 |
| **Water Trucks** | 70,000 | 40 | 0.05 | 32.18 | 0.0161 | 0.0123 | 7.90 | 0.0039 |
| **Total:** | | | | **36.75** | **0.02** | | **9.02** | **0.00** |

**Annual Total**

| | $PM_{10}$ (tons) | $PM_{2.5}$ (tons) |
|---|---|---|
| **Unpaved Roads** | **8.21** | **0.8** |
| **Paved Roads** | **0.1** | **0.0** |
| **Total:** | **8.3** | **0.8** |

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Development Phase**
**Drill Rig Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 18 | (Typical Value) |
| Hours of Operation | 432 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

| Engine | HP [a] | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Vertical Drill Rig Engine | 475 | 0.42 | 144 | 28728 |
| Horizontal Drill Rig Engine 1 | 2,950 | 0.59 | 288 | 501264 |
| Horizontal Drill Rig Engine 2 | 2,950 | 0.59 | 432 | 751896 |
| Drill Rig Generator | 350 | 0.42 | 432 | 63504 |
| Trailers Generator | 150 | 0.42 | 432 | 27216 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor Booster | 650 | 0.42 | 144 | 39312 |
| Forklift | 120 | 0.42 | 144 | 7257.6 |
| Aerial Lift | 50 | 0.42 | 16 | 336 |
| Frontend loader | 150 | 0.42 | 16 | 1008 |
| Dozer | 175 | 0.42 | 9 | 661.5 |
| Total HP | 10,220 | | | |

Total: 1,554,239 Hp-hrs

Fuel Usage: 92,916 Gallons of Diesel Total Fuel Usage: (btu/hp-hr * hp-hrs) * gal/btu

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| $CO_2$ | 73.96 | 2090751.53 | 1045.38 |
| $CH_4$ | 0.003 | 84.81 | 0.04 |
| $N_2O$ | 0.0006 | 16.96 | 0.01 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu) | Xylenes (lb/mmBtu) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Drill Rig Engine | 28728 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Horizontal Drill Rig Engine 1 | 501264 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Horizontal Drill Rig Engine 2 | 751896 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Drill Rig Generator | 63504 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Trailers Generator | 27216 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor Booster | 39312 | 1.3272 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Forklift | 7257.6 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Aerial Lift | 336 | 5.0000 | 6.9000 | 0.8000 | 0.7760 | 1.27E-05 | 1.8000 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frontend loader | 1008 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Dozer | 661.5 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Drill Rig Engine | | 0.02420 | 0.12984 | 0.00417 | 0.00404 | 4.02E-07 | 0.00518 | 0.00009 | 0.00003 | 0.00002 |
| Horizontal Drill Rig Engine 1 | | 0.42226 | 2.26545 | 0.07272 | 0.07053 | 7.02E-06 | 0.09040 | 0.00160 | 0.00058 | 0.00040 |
| Horizontal Drill Rig Engine 2 | | 0.63339 | 3.39817 | 0.10907 | 0.10580 | 1.05E-05 | 0.13560 | 0.00241 | 0.00087 | 0.00060 |
| Drill Rig Generator | | 0.18900 | 0.58661 | 0.02814 | 0.02730 | 8.89E-07 | 0.04760 | 0.00020 | 0.00007 | 0.00005 |
| Trailers Generator | | 0.08100 | 0.25140 | 0.01206 | 0.01170 | 3.81E-07 | 0.02040 | 0.00009 | 0.00003 | 0.00002 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor Booster | | 0.05751 | 0.17767 | 0.00570 | 0.00553 | 5.50E-07 | 0.00709 | 0.00013 | 0.00005 | 0.00003 |
| Forklift | | 0.02160 | 0.06704 | 0.00322 | 0.00312 | 1.02E-07 | 0.00544 | 0.00002 | 0.00001 | 0.00001 |
| Aerial Lift | | 0.00185 | 0.00256 | 0.00030 | 0.00029 | 4.70E-09 | 0.00067 | 0.00000 | 0.00000 | 0.00000 |
| Frontend loader | | 0.00300 | 0.00931 | 0.00045 | 0.00043 | 1.41E-08 | 0.00076 | 0.00000 | 0.00000 | 0.00000 |
| Dozer | | 0.00197 | 0.00611 | 0.00029 | 0.00028 | 9.26E-09 | 0.00050 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **1.55935** | **7.52998** | **0.25541** | **0.24775** | **0.00002** | **0.33762** | **0.00498** | **0.00180** | **0.00124** |

**Emission Factors**

- Drill rig emission factors based on Tier II engines
- All other engine emission factors based on Tier 0 engines (typical values)
- HAP emission factors from AP-42 Volume I, Large Stationary Diesel Engines Table 3.4-3

**Calculations:**

ton/year: (Total hp-hr * g/hp-hr) * lb-gram / lb-ton

*** Drill rig horsepower developed based on:**

1 Williston Basin: 2,100 from Jonah, Wyoming RMP
2 San Juan Basin: 2,100 from River Valley RMP
3 Upper Green River Basin: 2,100 from Jonah, Wyoming RMP
4 Denver Basin: 2,950 from River Valley RMP
5 Uintah Basin: 2,952 from River Valley RMP

Note, runtime for each drilling event is based on research and industry experience dependent upon each basin

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Development Phase**
**Conductor Pipe Set Emissions**

**Assumptions:**

| Parameter | Value |
|---|---|
| Days of Operation | 2 |
| Hours of Operation | 24 |
| Diesel Fuel Sulfur Content | 0.000015 |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

Workovers:

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Rig Engine | 350 | 0.42 | 24 | 3528 |
| Rig Generator | 50 | 0.42 | 24 | 504 |

Total Horsepower: 400

Total: 4,032 Hp-hrs

Fuel Usage: 241 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

**Greenhouse Gases:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 5423.82 | 2.71 |
| CH4 | 0.003 | 0.22 | 0.00 |
| N2O | 0.0006 | 0.04 | 0.00 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu | Xylenes (lb/mmBtu |
|---|---|---|---|---|---|---|---|---|---|---|
| Rig Engine | 3528 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 0.0008 | 0.0003 | 0.0002 |
| Rig Generator | 504 | 5.0000 | 6.9000 | 0.8000 | 0.7760 | 1.27E-05 | 1.8000 | 0.0008 | 0.0003 | 0.0002 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Rig Engine | | 0.00328 | 0.01686 | 0.00051 | 0.00050 | 0.00000 | 0.00064 | 0.00001 | 0.00000 | 0.00000 |
| Rig Generator | | 0.00278 | 0.00383 | 0.00044 | 0.00043 | 0.00000 | 0.00100 | 0.00000 | 0.00000 | 0.00000 |
| | | | | | | | | | | |
| | **Total:** | **0.00605** | **0.02069** | **0.00096** | **0.00093** | **0.00000** | **0.00164** | **0.00001** | **0.00000** | **0.00000** |

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

* Rig engine emission rates are based on a Tier II engine and rig generator emission rates are based on a Tier 0 engine.
* All days, hours, and HP values above are based on typical industry values

| Kleinfelder, Inc. Wellsite Emissions | Base Location: Uinta/Piceance Basin Well Type: Natural Gas |
|---|---|

**Development Phase**

**Well Fracturing Engine Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 7 | (Typical Value) |
| Hours of Operation | 168 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Blenders | 500 | 0.42 | 4 | 840 |
| Auxilary Pump | 200 | 0.42 | 4 | 336 |
| Auxilary Pump | 200 | 0.42 | 8 | 672 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Generator | 150 | 0.42 | 168 | 10584 |

Total: 1,500,576 Hp-hrs

Fuel Usage: 89,708 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 2018564.31 | 1009.28 |
| CH4 | 0.003 | 81.88 | 0.04 |
| N2O | 0.0006 | 16.38 | 0.01 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu) | Xylenes (lb/mmBtu) |
|---|---|---|---|---|---|---|---|---|---|---|
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Blenders | 840 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Auxilary Pump | 336 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Auxilary Pump | 672 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Generator | 10584 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Blenders | | 0.00078 | 0.00401 | 0.00012 | 0.00012 | 1.18E-08 | 0.00015 | 0.00000 | 0.00000 | 0.00000 |
| Auxilary Pump | | 0.00100 | 0.00310 | 0.00015 | 0.00014 | 4.70E-09 | 0.00025 | 0.00000 | 0.00000 | 0.00000 |
| Auxilary Pump | | 0.00200 | 0.00621 | 0.00030 | 0.00029 | 9.41E-09 | 0.00050 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Generator | | 0.04072 | 0.09683 | 0.00842 | 0.00817 | 1.48E-07 | 0.01155 | 0.00003 | 0.00001 | 0.00001 |
| | **Total:** | **1.30213** | **6.84201** | **0.22574** | **0.21897** | **0.00002** | **0.28205** | **0.00480** | **0.00174** | **0.00119** |

**Emission Factors**

- Frac pump emission factors based on Tier II engines (typical values)
- All other engine emission factors based on Tier 0 engines (typical values)

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Development Phase**

**Hydraulic Fracturing Flowback Emissions**

**Assumptions:**

| | | | |
|---|---|---|---|
| **Estimated Frac flowback Rate:** | 10,000 | Scf/hr | |
| **Combustion Efficiency:** | 95.00 | Percent (%) | |
| **Event Duration:** | 100.00 | Hours | |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* Venting duration based on research and industry knowledge; please see report for additional information.
* Venting control based on Subpart OOOO requirements of 95% minimum control.
Control efficiency can be deleted if applicable.

**Equations:**

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf/lb-mol)) * hrs/yr
** Multiply above equation by 0.02 if including 98% control efficiency

**Un-combusted Componet Emissions:**

| Component | Mole % [a] | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 444.86 | 18.81 | 0.94 |
| Ethane | 5.7920 | 30.1 | 28.96 | 2.29 | 0.11 |
| Propane | 1.3650 | 44.1 | 6.83 | 0.79 | 0.04 |
| i-Butane | 0.3700 | 58.1 | 1.85 | 0.28 | 0.01 |
| n-Butane | 0.2610 | 58.1 | 1.31 | 0.20 | 0.01 |
| i-Pentane | 0.1550 | 72.2 | 0.78 | 0.15 | 0.01 |
| n-Pentane | 0.1020 | 72.2 | 0.51 | 0.10 | 0.00 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 0.73 | 0.17 | 0.01 |
| Heptanes | 0.0930 | 100.2 | 0.47 | 0.12 | 0.01 |
| Octanes | 0.0440 | 114.2 | 0.22 | 0.07 | 0.00 |
| Nonanes | 0.0160 | 128.3 | 0.08 | 0.03 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 0.03 | 0.01 | 0.00 |
| Benzene | 0.0270 | 78.1 | 0.14 | 0.03 | 0.00 |
| Toluene | 0.0190 | 92.1 | 0.10 | 0.02 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 0.06 | 0.02 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 0.73 | 0.17 | 0.01 |
| Nitrogen | 0.0940 | 28.0 | 9.40 | 0.69 | 0.03 |
| Carbon Dioxide | 2.5280 | 44.0 | 252.80 | 29.32 | 1.47 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| **VOC Subtotal** | 2.7600 | 1492.8 | 13.80 | 2.14 | 0.11 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 1.02 | 0.23 | 0.01 |
| **Total** | 100.1460 | 1645.0 | 749.82 | 53.26 | 2.66 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 8452.34 | 980.23 | 49.01 |
| C2 | 5.79 | 550.24 | 63.81 | 3.19 |
| C3 | 1.37 | 129.68 | 15.04 | 0.75 |
| C4 | 0.63 | 59.95 | 6.95 | 0.35 |
| C5+ | 0.76 | 72.58 | 8.42 | 0.42 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **53.72** | **Tons/Event** |
| **$N_2O$ Emissions:** | **1.13E-04** | **Tons/Event** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.37 | 3.80 | 0.19 | AP-42 CH13.5-1 |
| NOx | 0.068 | 0.70 | 0.03 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.00 | *Based on $H2_S$ 34 mol weight and $SO_2$ 64 mol weight |

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Development Phase**
**Workover Cementing Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 2 | (Typical Value) |
| Hours of Operation | 24 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8500 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

Workovers/Cementing:

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Coil Tubing Unit | 550 | 0.42 | 24 | 5544 |
| Circulation Pump | 450 | 0.42 | 24 | 4536 |
| Cement Pump Trucks | 500 | 0.42 | 8 | 1680 |

**Greenhouse Gasses:**

| | Diesel EF Kg/mmBtu | Emissions lbs/Location | Emissions Tons/Location |
|---|---|---|---|
| CO2 | 73.96 | 16298.85 | 8.15 |
| CH4 | 0.003 | 0.66 | 0.00 |
| N2O | 0.0006 | 0.13 | 0.00 |

Total Horsepower: 1,500 (Typical Value)

Total: 11,760 Hp-hrs

Fuel Usage: 724 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Formaldehyde (lb/mmBtu) | Toulene (lb/mmBtu | Xylenes (lb/mmBtu |
|---|---|---|---|---|---|---|---|---|---|---|
| Coil Tubing Unit | 5544 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 0.1636 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |
| Circulation Pump | 4536 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 0.1636 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |
| Cement Pump Trucks | 1680 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 0.6800 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Formaldehyde (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Coil Tubing Unit | | 0.00515 | 0.02649 | 0.00080 | 0.00078 | 0.00100 | 0.00002 | 0.00000 | 0.00001 | 0.00000 |
| Circulation Pump | | 0.00421 | 0.02168 | 0.00066 | 0.00064 | 0.00082 | 0.00001 | 0.00000 | 0.00001 | 0.00000 |
| Cement Pump Trucks | | 0.00500 | 0.01552 | 0.00074 | 0.00072 | 0.00126 | 0.00001 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.01436** | **0.06369** | **0.00221** | **0.00214** | **0.00308** | **0.00004** | **0.00000** | **0.00001** | **0.00001** |

**Emission Factors**

- Engine emission factors based on Tier II engines (typical values)

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

| Kleinfelder, Inc. Wellsite Emissions | Base Location: Uinta/Piceance Basin; Well Type: Natural Gas |
|---|---|

**Development Phase**

**Well Venting During Workover Events**

**Assumptions:**

Significant gas venting only occurs on natural gas wells.

| | | | |
|---|---|---|---|
| **Estimated Venting Rate:** | 5,000 | Scf/Event | (Typical Value) |
| **Combustion Efficiency:** | 0.00 | Percent (%) | |
| **Event Quantity:** | 1.00 | Event | - Assumed one event |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* Vented quantity based on research and industry knowledge; please see report for additional information.

**Equations:**

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf-lb-mol))

** Multiply above equation by 0.02 if including 98% control efficiency

| Component | Mole % | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Event |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 4448.60 | 188.07 | 0.0940 |
| Ethane | 5.7920 | 30.1 | 289.60 | 22.95 | 0.0115 |
| Propane | 1.3650 | 44.1 | 68.25 | 7.93 | 0.0040 |
| i-Butane | 0.3700 | 58.1 | 18.50 | 2.83 | 0.0014 |
| n-Butane | 0.2610 | 58.1 | 13.05 | 2.00 | 0.0010 |
| i-Pentane | 0.1550 | 72.2 | 7.75 | 1.47 | 0.0007 |
| n-Pentane | 0.1020 | 72.2 | 5.10 | 0.97 | 0.0005 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.0000 |
| Hexanes | 0.1460 | 86.2 | 7.30 | 1.66 | 0.0008 |
| Heptanes | 0.0930 | 100.2 | 4.65 | 1.23 | 0.0006 |
| Octanes | 0.0440 | 114.2 | 2.20 | 0.66 | 0.0003 |
| Nonanes | 0.0160 | 128.3 | 0.80 | 0.27 | 0.0001 |
| Decanes + | 0.0050 | 142.3 | 0.25 | 0.09 | 0.0000 |
| Benzene | 0.0270 | 78.1 | 1.35 | 0.28 | 0.0001 |
| Toluene | 0.0190 | 92.1 | 0.95 | 0.23 | 0.0001 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.0000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.0000 |
| Xylenes | 0.0110 | 106.2 | 0.55 | 0.15 | 0.0001 |
| n-Hexane | 0.1460 | 86.2 | 7.30 | 1.66 | 0.0008 |
| Nitrogen | 0.0940 | 28.0 | 4.70 | 0.35 | 0.0002 |
| Carbon Dioxide | 2.5280 | 44.0 | 126.40 | 14.66 | 0.0073 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.0000 |

| | | | | | |
|---|---|---|---|---|---|
| **VOC Subtotal** | 2.7600 | 1492.8 | 138.00 | 21.44 | 0.0107 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 10.15 | 2.32 | 0.0012 |
| **Total** | 100.1460 | 1645.0 | 5007.30 | 247.46 | 0.1237 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed thatthe representative average gas analyses used by the River Valley RMP. was a good representative analyses of general gas wells.

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 0.00 | 0.00 | 0.00 |
| C2 | 5.79 | 0.00 | 0.00 | 0.00 |
| C3 | 1.37 | 0.00 | 0.00 | 0.00 |
| C4 | 0.63 | 0.00 | 0.00 | 0.00 |
| C5+ | 0.76 | 0.00 | 0.00 | 0.00 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **0.00** | **Tons/Event** |
| **$N_2O$ Emissions:** | **5.67E-07** | **Tons/Event** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.00 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| NOx | 0.000 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.000 | *Based on $H2_S$ 34 mol weight and $SO_2$ 64 mol weight |

**Kleinfelder, Inc.**

**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin

**Well Type:** Natural Gas

**Development Phase**

**Wellsite Development Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Light Duty Pickup Trucks: | 84 | Trips/Location | | | |
| Light Duty Haul Trucks | 11 | Trips/Location | Total Trips: | 95 | Trips |
| Heavy Duty Haul Trucks | 67 | Trips/Location | | | |
| Water Trucks | 24 | Trips/Location | Total Trips: | 91 | Trips |

* Miles and number of trips based on research and industry knowledge; please see report for additional information.

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (lb/mile)} * \text{\# Trips} * \text{Trip Distance (miles)}}{2000 \text{ (lb/tons)}}$$

| Construction Vehicles | Heavy Haul Trucks | | Light Duty Pickups | | Total |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 1.35E-01 | 1.98E-02 | 1.41E-01 | 2.77E-01 |
| **CO** | 1.98E-02 | 3.60E-02 | 3.16E-03 | 3.76E-02 | 7.37E-02 |
| **VOC** | 3.16E-03 | 5.75E-03 | 4.57E-05 | 6.00E-03 | 1.18E-02 |
| **SO2** | 4.57E-05 | 8.32E-05 | 4.22E-03 | 8.68E-05 | 1.70E-04 |
| **PM10** | 4.22E-03 | 7.68E-03 | 4.09E-03 | 8.02E-03 | 1.57E-02 |
| **PM2.5** | 4.09E-03 | 7.44E-03 | 1.88E+00 | 7.77E-03 | 1.52E-02 |
| **CO2** | 1.88E+00 | 3.41E+00 | 7.61E-05 | 3.56E+00 | 6.98E+00 |
| **CH4** | 7.61E-05 | 1.38E-04 | 1.52E-05 | 1.45E-04 | 2.83E-04 |
| **N2O** | 1.52E-05 | 2.77E-05 | 0.00E+00 | 2.89E-05 | 5.66E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite for calendar year 2012.

c Assumes maximum development scenario

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Development Phase**

**Wellhead Gas Combustion**

**Wellhead gas combustion only for Williston Basin wells, due to the regularity of of pit flares combusting all gas coming from the wellhead. If gas being captured, change scf/hr value or hours of event value.

**Assumptions:**

| | | | |
|---|---|---|---|
| **Estimated Gas Flow Rate:** | 0 | Scf/hr | |
| **Combustion Efficiency:** | 0.00 | Percent (%) | |
| **Event Duration:** | 0.00 | Hours | - Estimated 3 months before sales line |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* It is assumed that all produced natural gas is sent to a sales line after the well is completed.

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf/lb-mol)) * hrs/yr

** Multiply above equation by 0.05 if including 95% control efficiency

**Combusted Componet Emissions:**

| Component | Mole % [a] | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 0.00 | 0.00 | 0.00 |
| Ethane | 5.7920 | 30.1 | 0.00 | 0.00 | 0.00 |
| Propane | 1.3650 | 44.1 | 0.00 | 0.00 | 0.00 |
| i-Butane | 0.3700 | 58.1 | 0.00 | 0.00 | 0.00 |
| n-Butane | 0.2610 | 58.1 | 0.00 | 0.00 | 0.00 |
| i-Pentane | 0.1550 | 72.2 | 0.00 | 0.00 | 0.00 |
| n-Pentane | 0.1020 | 72.2 | 0.00 | 0.00 | 0.00 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 0.00 | 0.00 | 0.00 |
| Heptanes | 0.0930 | 100.2 | 0.00 | 0.00 | 0.00 |
| Octanes | 0.0440 | 114.2 | 0.00 | 0.00 | 0.00 |
| Nonanes | 0.0160 | 128.3 | 0.00 | 0.00 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 0.00 | 0.00 | 0.00 |
| Benzene | 0.0270 | 78.1 | 0.00 | 0.00 | 0.00 |
| Toluene | 0.0190 | 92.1 | 0.00 | 0.00 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 0.00 | 0.00 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 0.00 | 0.00 | 0.00 |
| Nitrogen | 0.0940 | 28.0 | 0.00 | 0.00 | 0.00 |
| Carbon Dioxide | 2.5280 | 44.0 | 0.00 | 0.00 | 0.00 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |
| **VOC Subtotal** | 2.7600 | 1492.8 | 0.00 | 0.00 | 0.00 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 0.00 | 0.00 | 0.00 |
| **Total** | 100.1460 | 1645.0 | 0.00 | 0.00 | 0.00 |

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 0.00 | 0.00 | 0.00 |
| C2 | 5.79 | 0.00 | 0.00 | 0.00 |
| C3 | 1.37 | 0.00 | 0.00 | 0.00 |
| C4 | 0.63 | 0.00 | 0.00 | 0.00 |
| C5+ | 0.76 | 0.00 | 0.00 | 0.00 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **0.00** | **Tons/Year** |
| **$N_2O$ Emissions:** | **0.00E+00** | **Tons/Year** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.00 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| NOx | 0.000 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.00 | *Based on $H_2S$ 34 mol weight and $SO_2$ 64 mol weight |

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Production Phase**

**Production Equipment Fugitive Component Emissions**

**Assumptions:**

Components Counts:

| | Fugitive Components | | | | |
|---|---|---|---|---|---|
| **Component *** | Valves | Connectors | OE Lines | PR Valves | |
| **Count** | 59 | 193 | 8 | 3 | 0 |
| **Emissions Factor (scf/hr)** [b] | 0.121 | 0.017 | 0.031 | 0.193 | 0.000 |

* Fugitive component counts for natural gas wells from Subpart W, Table W-1B
* Fugitive component counts for oil wells from Subpart W, Table W-1C

Annual Equipment Run Time: 8760 Hours/Year 379.49 Scf/lb-mol

| Component | Mole % [a] | Mole Weight lb/lb-mol | Emissions Scf/Year [b] | Emissions lbs/Year | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 87,658.5 | 3,705.8 | 1.85 |
| Ethane | 5.7920 | 30.1 | 5,706.5 | 452.2 | 0.23 |
| Propane | 1.3650 | 44.1 | 1,344.8 | 156.3 | 0.08 |
| i-Butane | 0.3700 | 58.1 | 364.5 | 55.8 | 0.03 |
| n-Butane | 0.2610 | 58.1 | 257.1 | 39.4 | 0.02 |
| i-Pentane | 0.1550 | 72.2 | 152.7 | 29.0 | 0.01 |
| n-Pentane | 0.1020 | 72.2 | 100.5 | 19.1 | 0.01 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 143.8 | 32.7 | 0.02 |
| Heptanes | 0.0930 | 100.2 | 91.6 | 24.2 | 0.01 |
| Octanes | 0.0440 | 114.2 | 43.4 | 13.0 | 0.01 |
| Nonanes | 0.0160 | 128.3 | 15.8 | 5.3 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 4.9 | 1.8 | 0.00 |
| Benzene | 0.0270 | 78.1 | 26.6 | 5.5 | 0.00 |
| Toluene | 0.0190 | 92.1 | 18.7 | 4.5 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 10.8 | 3.0 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 143.8 | 32.7 | 0.02 |
| Nitrogen | 0.0940 | 28.0 | 92.6 | 6.8 | 0.00 |
| Carbon Dioxide | 2.5280 | 44.0 | 2,490.7 | 288.8 | 0.14 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| VOC Subtotal | 2.7600 | | | 422.43 | 0.21 |
| HAPS Subtotal | 0.2030 | | | 45.72 | 0.02 |
| Total | 100.1460 | | | 4876.06 | 2.44 |

**Calculation**

lb/hr = (Mol % * SumSCF/yr) / scf/lb-mol

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

[b] Fugitive emission factors from Subpart W, Table W-1A

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Production Phase**
**Process Heater Emissions**

**Wellsite Heater Inventory:**

| | Heating Value (Mbtu/hr) | Fuel Consumption (MMScf/yr) | |
|---|---|---|---|
| **Separator Heater** | **750** | **6.44** | * Heater treater size based on industry standard |

**Annual Run Time:** **8760** **Hours/Year**
**Fuel Gas Heat Value:** **1,020** **Btu/scf (Standard heating value from AP-42)**

**Equations:**

$$\text{Fuel Consumption (MMscf/yr)} = \frac{\text{Heater Size (MBtu/hr)} * 1{,}000 \text{ (Btu/MBtu)} * \text{Hours of Operation (hrs/yr)}}{\text{Fuel Heat Value (Btu/scf)} * 1{,}000{,}000 \text{ (scf/MMscf)}}$$

$$\text{NOx/CO/TOC Emissions (tons/yr)} = \frac{\text{AP-42 E.Factor (lbs/MMscf)} * \text{Fuel Consumption (MMscf/yr)} * \text{Fuel heating Value (Btu/scf)}}{2{,}000 \text{ (lbs/ton)} * 1{,}020 \text{ (Btu/scf - Standard Fuel Heating Value)}}$$

| | Emission Factor (lb/MMscf) | Separator Heater Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) [e] |
|---|---|---|---|---|---|---|
| *Criteria Pollutants & VOC* | | | | | | |
| NOx [a] | 100 | 0.3221 | 0.0000 | 0.0000 | 0.0000 | 0.3221 |
| CO [a] | 84.0 | 0.2705 | 0.0000 | 0.0000 | 0.0000 | 0.2705 |
| VOC | 5.5 | 0.0177 | 0.0000 | 0.0000 | 0.0000 | 0.0177 |
| $SO_2$ [b] | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| TSP [c] | 7.60 | 0.0245 | 0.0000 | 0.0000 | 0.0000 | 0.0245 |
| $PM_{10}$ [c] | 7.60 | 0.0245 | 0.0000 | 0.0000 | 0.0000 | 0.0245 |
| $PM_{2.5}$ [c] | 7.60 | 0.0245 | 0.0000 | 0.0000 | 0.0000 | 0.0245 |
| *Hazardous Air Pollutants* | | | | | | |
| Benzene [d] | 2.10E-03 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Toluene [d] | 3.40E-03 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Hexane [d] | 1.80 | 0.0058 | 0.0000 | 0.0000 | 0.0000 | 0.0058 |
| Formaldehyde [d] | 7.50E-02 | 0.0002 | 0.0000 | 0.0000 | 0.0000 | 0.0002 |
| *Greenhouse Gases* | | | | | | |
| $CO_2$ [f] | 120,162 | 386.9918 | 0.0000 | 0.0000 | 0.0000 | 386.9918 |
| $CH_4$ [f] | 2.27 | 0.0073 | 0.0000 | 0.0000 | 0.0000 | 0.0073 |
| $N_2O$ [f] | 0.23 | 0.0007 | 0.0000 | 0.0000 | 0.0000 | 0.0007 |

a AP-42 Table 1.4-1, Emission Factors for Natural Gas Combustion, 7/98
b Assumes produced gas contains no sulfur
c AP-42 Table 1.4-2, Emission Factors for Natural Gas Combustion, 7/98 (All Particulates are $PM_{1.0}$)
d AP-42 Table 1.4-3, Emission Factors for Organic Compounds from Natural Gas Combustion, 7/98
e Assumes maximum development scenario
f Subpart W - Part 98.233(z)(1) indicates the use of Table C-1 and Table C-2 for fuel combustion of stationary and portable equipment. Table C-1 provides an EF for natural gas combustion of 53.02 kg $CO_2$/mmBtu. Table C-2 provides an EF for natural gas combustion for $CH_4$ as 1.0E-03 kg/MMBtu and for $N_2O$ as 1.0E-04 kg/MMBtu.

| Kleinfelder, Inc.<br>Wellsite Emissions | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Atmospheric Oil Tank Flashing Emissions**

**Assumptions:**

| | | | |
|---|---|---|---|
| Production Estimate: | 10 | barrels/day | |
| Production Days: | 365 | Days/Year | |
| Flasing Gas-to-Oil Ratio: | 100 | Scf/bbl | 379.49 Scf/lb-mol |
| Control Efficiency: | 95 | Percent (%) | |

**Flashing Gas Composition:**

| Component | Mole % | Mole Weight (lb/lb-mol) | Emissions (Uncontrolled) Scf/Year | Emissions (Uncontrolled) lbs/Year | Emissions (Uncontrolled) Tons/Year | Emissions (Controlled) Tons/Year |
|---|---|---|---|---|---|---|
| Methane | 44.8625 | 16.043 | 163748.125 | 6922.4780 | 3.4612 | 0.1731 |
| Ethane | 15.2687 | 30.07 | 55730.755 | 4415.9894 | 2.2080 | 0.1104 |
| Propane | 20.0892 | 44.097 | 73325.58 | 8520.4830 | 4.2602 | 0.2130 |
| i-Butane | 4.7308 | 58.123 | 17267.42 | 2644.6922 | 1.3223 | 0.0661 |
| n-Butane | 7.4972 | 58.123 | 27364.78 | 4191.2122 | 2.0956 | 0.1048 |
| i-Pentane | 2.2617 | 72.150 | 8255.205 | 1569.5092 | 0.7848 | 0.0392 |
| n-Pentane | 1.7732 | 72.150 | 6472.18 | 1230.5141 | 0.6153 | 0.0308 |
| Other Pentanes | 0.0000 | 70.100 | 0 | 0.0000 | 0.0000 | 0.0000 |
| Hexanes | 0.6780 | 86.177 | 2474.7 | 561.9706 | 0.2810 | 0.0140 |
| Heptanes | 0.6823 | 100.204 | 2490.395 | 657.5866 | 0.3288 | 0.0164 |
| Octanes | 0.1688 | 114.231 | 616.12 | 185.4594 | 0.0927 | 0.0046 |
| Nonanes | 0.0186 | 128.258 | 67.89 | 22.9451 | 0.0115 | 0.0006 |
| Decanes + | 0.0081 | 142.285 | 29.565 | 11.0850 | 0.0055 | 0.0003 |
| Benzene | 0.1117 | 78.120 | 407.705 | 83.9282 | 0.0420 | 0.0021 |
| Toluene | 0.0525 | 92.130 | 191.625 | 46.5214 | 0.0233 | 0.0012 |
| Ethylbenzene | 0.0013 | 106.160 | 4.745 | 1.3274 | 0.0007 | 0.0000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.120 | 0 | 0.0000 | 0.0000 | 0.0000 |
| Xylenes | 0.0077 | 106.160 | 28.105 | 7.8622 | 0.0039 | 0.0002 |
| n-Hexane | 0.5041 | 86.177 | 1839.965 | 417.8309 | 0.2089 | 0.0104 |
| Nitrogen | 0.1776 | 28.013 | 648.24 | 47.8515 | 0.0239 | 0.0012 |
| Carbon Dioxide | 1.1062 | 44.010 | 4037.63 | 468.2497 | 0.2341 | 0.0117 |
| Hydrogen Sulfide | 0.0000 | 34.080 | 0 | 0.0000 | 0.0000 | 0.0000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| VOC Subtotal | 38.59 | | | | 10.08 | 0.50 |
| HAPS Subtotal | 0.68 | | | | 0.28 | 0.01 |
| **Total** | **100.0002** | | | | **16.0037** | **0.8002** |

**Calculation:**

Scf/yr = (Mol% * scf/bbl * bbl/day * days/yr) / 100

lb/yr = (scf/yr * mol wt.) / scf/lb-mol

*** Production and gas to oil ratio based on basin specific differences. Please see "Gas Stream Molar Ratios" tab and report for additional information.**

| Kleinfelder, Inc.<br>Wellsite Emissions | Base Location: Uinta/Piceance Basin<br>Well Type: Natural Gas |
|---|---|

**Production Phase**

**Wellsite Produced Water Tanks Venting**

**Assumptions:**

| | | |
|---|---|---|
| Average Estimated Water Production: | 4000 | Barrels Per Year |
| Number of Water Tanks: | 1 | Tanks |
| VOC Emissions Factor: | 0.2620 | lbs/bbl |
| n-Hexane Emission Factor: | 0.0220 | lbs/bbl |
| Benzene Emission Factor: | 0.0070 | lbs/bbl |

**Calculations:**

| | | |
|---|---|---|
| VOC Emissions: | 0.524 | Tons/Year |
| Hexane Emissions: | 0.044 | Tons/Year |
| Benzene Emissions: | 0.014 | Tons/Year |

* Production conservatively based on estimated industry single well average
* Emission factors based on only known lb/bbl factor, which was developed by the Colorado Department of Health and Environment (PS Memo 09-02).

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Truck Loading Emissions**

**AP - 42, Chapter 5.2** $\mathbf{L_L = 12.46 \times S \times P \times M / T}$

$L_L$ = Loading Loss Emission Factor (lbs VOC/1000 gal loaded)
S = Saturation Factor
P = True Vapor Pressure of the Loaded Liquid (psia)
M = Vapor Molecular Weight of the Loaded Liquid (lbs/lbmol)
T = Temperature of Loaded Liquid (ºR)

**VOC Emissions (tpy) =**

$$\frac{L_L \text{ (lbs VOC/1000 gal)} * 42 \text{ gal/bbl} * 365 \text{ days/year} * \text{production (bbl/day)}}{1000 \text{ gal} * 2000 \text{ lbs/ton}}$$

| S[1] | P (psia)[2] | M (lb/lbmol)[3] | T (ºF)[4] | T (ºR) | $L_L$ (lb/1000 gal) | Production (bbl/day) | VOC (tpy) |
|---|---|---|---|---|---|---|---|
| 0.6 | 4.20 | 66.00 | 50.00 | 509.67 | 4.07 | 10.0 | **0.31** |

Notes:
1. Saturation factor from AP-42, Table 5.2-1 (Submerged loading: dedicated normal service)
2. True vapor pressure is estimated from AP-42, Table 7.1-2 assuming an average daily temperature of either 40 or 50 deg F and an RVP of 10.0.
3. Molecular weight liquid vapor is estimated from AP-42, Table 7.1-2 assuming an RVP of 10.0.
4. Temperature based on the annual average temperature for basin location (either 40 or 50 degrees F based on options provided in AP-42 Table 7.1-2

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Pumpjack Unit Emissions**

**Assumptions:**

***Pumpjack engines only included at oil wells***

| | | |
|---|---|---|
| Pumpjack Horsepower Rating: | 0.0 | Horsepower |
| Load Factor: | 0.54 | |
| Brake Specific Fuel Consumption: | 0 | Btu/hp-hr |
| Annual Operation: | 8,760 | Hours/Year |

**Equations:**

$$\text{Emissions (lbs/hr)} = \frac{\text{Emission Factor (g/hp-hr)} * \text{Power (hp)}}{453.6 \text{ g/lb}}$$

| Pollutant | Emission Factor [a] (lb/MMBtu) | Emission Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) |
|---|---|---|---|---|
| *Criteria Pollutants & VOC* | | | | |
| **NOx** | | 2.80 | 0.00 | 0.0000 |
| **CO** | | 4.80 | 0.00 | 0.0000 |
| **VOC** | 0.12 | - | 0.0000 | 0.0000 |
| **$PM_{10}$** [b] | 4.83E-02 | - | 0.00E+00 | 0.00E+00 |
| **$PM_{2.5}$** [b] | 4.83E-02 | - | 0.00E+00 | 0.00E+00 |
| **$SO_2$** | 5.88E-04 | - | 0.0000 | 0.0000 |
| *Hazardous Air Pollutants* | | | | |
| **Benzene** | 1.94E-03 | - | 0.00E+00 | 0.00E+00 |
| **Toluene** | 9.63E-04 | - | 0.00E+00 | 0.00E+00 |
| **Ethylbenzene** | 1.08E-04 | - | 0.00E+00 | 0.00E+00 |
| **Xylenes** | 2.68E-04 | - | 0.00E+00 | 0.00E+00 |
| **Formaldehyde** | 5.52E-02 | - | 0.0000 | 0.0000 |
| **n-Hexane** | 4.45E-04 | - | 0.00E+00 | 0.00E+00 |
| *Greenhouse Gases* | | | | |
| **$CO_2$** [c] | 117 | - | 0.00 | 0 |
| **$CH_4$** | 0.002 | - | 0.0000 | 0.0000 |
| **$N_2O$** | 0.0002 | - | 0.0000 | 0.0000 |

a AP-42 Table 3.2-3 Uncontrolled Emission Factors for 4-Stroke Rich-Burn Engines, 7/00; and Subpart JJJJ for NOX and CO emission rates.

b PM = sum of PM filterable and PM condensable

c Subpart W - Part 98.233(z)(1) indicates the use of Table C-1 and Table C-2 for fuel combustion of stationary and portable equipment. Table C-1 provides an EF for natural gas combustion of 53.02 kg $CO_2$/mmBtu. Table C-2 provides an EF for natural gas combustion for $CH_4$ as 1.0E-03 kg/MMBtu and for $N_2O$ as 1.0E-04 kg/MMBtu.

- Network website for the 1999 National-Scale Air Toxics Assessment at http://www.epa.gov/ttn/atw/nata1999/nsata99.html

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Uinta/Piceance Basin<br>**Well Type:** Natural Gas |
|---|---|

Production Phase

Wellsite Dehydrator Emissions

**Assumptions:**

Number of Dehy Units: 0 Units

**Calculations:**

Calculations and specifications derived from Pinedale Anticline Final SEIS
GRI-GLYCalc 4.0 operated with: 4 MMSCFD, 0.32 gpm glycol flow, average representative gas analysis, and 95% control efficiency

**Emissions:**

| **Species** | **Total Project Emissions (tons/year)** |
|---|---|
| **Total VOC** | 0.000 |
| *Hazardous Air Pollutants* | |
| **Benzene** | 0.000 |
| **Toluene** | 0.000 |
| **Ethylbenzene** | 0.000 |
| **Xylenes** | 0.000 |
| **n-Hexane** | 0.000 |
| *Greenhouse Gases* | |
| **$CO_2$** | 0.000 |
| **$CH_4$** [a] | 0.000 |
| **$N_2O$** | 0.000 |

Note, no greenhouse gas emissions included for dehydrator in Pinedale EIS

| Kleinfelder, Inc.<br>Wellsite Emissions | | Base Location: Uinta/Piceance Basin<br>Well Type: Natural Gas |
|---|---|---|

**Construction Phase**

**Roadway Construction Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Light Duty Pickup Trucks: | 50 | Trips/Location | | | |
| Light Duty Haul Trucks | 0 | Trips/Location | Total Trips: | 50 | Trips |
| Heavy Duty Haul Trucks | 2 | Trips/Location | | | |
| Water Trucks | 40 | Trips/Location | Total Trips: | 42 | Trips |

* Miles and number of trips based on research and industry knowledge; please see report for additional information.

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (g/mile)} * \text{\# Trips} * \text{Trip Distance (miles)}}{\text{2000 (lb/tons)}}$$

| Construction Vehicles | Heavy Haul Trucks | | Light Duty Pickups | | Total |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 6.25E-02 | 7.39E-03 | 7.39E-03 | 6.99E-02 |
| **CO** | 1.98E-02 | 1.66E-02 | 7.26E-02 | 7.26E-02 | 8.92E-02 |
| **VOC** | 3.16E-03 | 2.65E-03 | 3.54E-03 | 3.54E-03 | 6.19E-03 |
| **SO2** | 4.57E-05 | 3.84E-05 | 2.83E-05 | 2.83E-05 | 6.67E-05 |
| **PM10** | 4.22E-03 | 3.54E-03 | 1.94E-04 | 1.94E-04 | 3.74E-03 |
| **PM2.5** | 4.09E-03 | 3.44E-03 | 1.79E-04 | 1.79E-04 | 3.61E-03 |
| **CO2** | 1.88E+00 | 1.58E+00 | 1.13E+00 | 1.13E+00 | 2.70E+00 |
| **CH4** | 7.61E-05 | 6.39E-05 | 4.56E-05 | 4.56E-05 | 1.10E-04 |
| **N2O** | 1.52E-05 | 1.28E-05 | 9.13E-06 | 9.13E-06 | 2.19E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

c Assumes maximum development scenario

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Uinta/Piceance Basin
**Well Type:** Natural Gas

**Production Phase**
**Pneumatic Device Emissions**

**Wellsite Pneumatic Inventory:**

| | | Classification | Quantity | Emission Factor (Scf/hr/unit) |
|---|---|---|---|---|
| **Devices:** | Dump Valve | Intermittent Bleed | 2 | 13.50 |
| | Pneumatic Controller | Low Bleed | 1 | 1.39 |
| | | | 0 | 0.00 |
| **Pumps:** | Chemical Pump | Pneumatic Pump | 1 | |
| | Sandpiper | Pneumatic Pump | 1 | 13.30 |

Annual Equipment Run Time: 8760 Hours/Year

379.49 Scf/lb-mol

Pneumatic Device Control:[b] 0 Percent

* Low bleed and intermittent bleed emission factors (scf/hr) based on Subpart W, Table W-1A
* Quantity of devices based on typical industry values

| Component | Mole % | Mole Weight lb/lb-mol | Dump Valve Tons/Year | Pneumatic Controller Tons/Year | (None) Tons/Year | Pneumatic Pumps Tons/Year | Total Tons/Year |
|---|---|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 4.448 | 0.229 | 0.000 | 4.382 | 9.059 |
| Ethane | 5.7920 | 30.1 | 0.543 | 0.028 | 0.000 | 0.535 | 1.105 |
| Propane | 1.3650 | 44.1 | 0.188 | 0.010 | 0.000 | 0.185 | 0.382 |
| i-Butane | 0.3700 | 58.1 | 0.067 | 0.003 | 0.000 | 0.066 | 0.136 |
| n-Butane | 0.2610 | 58.1 | 0.047 | 0.002 | 0.000 | 0.047 | 0.096 |
| i-Pentane | 0.1550 | 72.2 | 0.035 | 0.002 | 0.000 | 0.034 | 0.071 |
| n-Pentane | 0.1020 | 72.2 | 0.023 | 0.001 | 0.000 | 0.023 | 0.047 |
| Other Pentanes | 0.0000 | 70.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Hexanes | 0.1460 | 86.2 | 0.039 | 0.002 | 0.000 | 0.039 | 0.080 |
| Heptanes | 0.0930 | 100.2 | 0.029 | 0.001 | 0.000 | 0.029 | 0.059 |
| Octanes | 0.0440 | 114.2 | 0.016 | 0.001 | 0.000 | 0.015 | 0.032 |
| Nonanes | 0.0160 | 128.3 | 0.006 | 0.000 | 0.000 | 0.006 | 0.013 |
| Decanes + | 0.0050 | 142.3 | 0.002 | 0.000 | 0.000 | 0.002 | 0.005 |
| Benzene | 0.0270 | 78.1 | 0.007 | 0.000 | 0.000 | 0.006 | 0.013 |
| Toluene | 0.0190 | 92.1 | 0.005 | 0.000 | 0.000 | 0.005 | 0.011 |
| Ethylbenzene | 0.0000 | 106.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Xylenes | 0.0110 | 106.2 | 0.004 | 0.000 | 0.000 | 0.004 | 0.007 |
| n-Hexane | 0.1460 | 86.2 | 0.039 | 0.002 | 0.000 | 0.039 | 0.080 |
| Nitrogen | 0.0940 | 28.0 | 0.008 | 0.000 | 0.000 | 0.008 | 0.017 |
| Carbon Dioxide | 2.5280 | 44.0 | 0.347 | 0.018 | 0.000 | 0.342 | 0.706 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **VOC Subtotal** | 2.8 | 1492.8 | 0.51 | 0.03 | 0.00 | 0.50 | 1.03 |
| **HAPS Subtotal** | 0.2 | 546.9 | 0.05 | 0.00 | 0.00 | 0.05 | 0.11 |
| **Total** | 100.1 | 1645.0 | 5.85 | 0.30 | 0.00 | 5.77 | 11.92 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

[b] 98% control input is a result of the Wyoming Department of Environment Quality requirement, and only pertains to the Upper Green River Basin.

# APPENDIX C

# EMISSION INVENTORY FOR THE UPPER GREEN RIVER BASIN GAS WELL

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Upper Green River Basin
**Well Type:** Natural Gas

**Location Selection:**

| **Geography:** | **Well Type:** |
|---|---|
| Upper Green River Basin | Natural Gas |

- Choose geography/basin, and well type will automatically fill
  < Choose Uinta/Piceance Basin for deep gas wells with little condensate
  < Choose Upper Green River Basin for deep gas wells with dehydrators and higher condensate
  < Choose San Juan Basin for shallow gas wells with little to no condensate
  < Choose Williston Basin for deep oil wells with high gas
  < Choose Denver Basin for shallow oil wells with low gas

If the user wants to change any specifications, do so within the "Constants and References" tab, as all other tabs connect to it.

| | Total Emissions (Tons per Year) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Pollutant:** | $NO_X$ | CO | VOC | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ | $CH_4$ | $N_2O$ |
| **Construction Phase:** | 0.47 | 0.29 | 0.04 | 0.0001 | 1.94 | 0.06 | 33.84 | 0.001 | 0.0003 |
| **Development Phase:** | 13.24 | 2.86 | 0.68 | 0.0002 | 4.70 | 0.44 | 1900.27 | 1.11 | 0.0498 |
| **Operation Phase:** | 0.86 | 0.75 | 4.43 | 0.0001 | 0.08 | 0.26 | 947.96 | 12.99 | 0.0018 |
| **Total:** | 14.57 | 3.90 | 5.16 | 0.0004 | 6.72 | 0.76 | 2882.07 | 14.10 | 0.0519 |

| | Total Emissions (Tons per Year) | | | | | |
|---|---|---|---|---|---|---|
| **Pollutant:** | Benzene | Toluene | Ethylbenzene | Xylene | n-Hexane | HAPs |
| **Construction Phase:** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Development Phase:** | 1.36 | 0.95 | 0.0000 | 0.55 | 7.31 | 10.18 |
| **Operation Phase:** | 0.11 | 0.22 | 0.01029 | 0.169 | 0.19 | 0.70 |
| **Total:** | 1.47 | 1.17 | 0.01029 | 0.72 | 7.50 | 10.87 |

**$CO_2$ equivalent (Global Warming Potential)**

**Total TPY:** **3194.19**

$CO_2$ equivalent conversions:
$CO_2$ 1.00
$CH_4$ 21.00
$N_2O$ 310.00

**$H_2S$ Emissions**

**Total TPY:** **0.00**

* If $H_2S$ in gas, input value in "Gas Stream Molar Ratios" tab, and potential emissions will calculate here. Current assumption is no $H_2S$ in gas stream.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Road Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 4 | Days/Location | (Typical Value) |
| | 48.0 | Dozer Hours/Location | (Typical Value) |
| | 48.0 | Backhoe Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |

$PM_{10}$ Multiplier: 0.75 * $PM_{15}$ (AP-42 Table 11.9-1, 7/98)

$PM_{2.5}$ Multiplier: 0.105 * TSP (AP-42 Table 11.9-1, 7/98)

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98 & 7/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content }\%)^{1.2} * (\text{soil moisture content }\%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content }\%)^{1.5} * (\text{soil moisture content }\%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions [a]** | | **Backhoe Emissions [a]** | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0473 | 1.97 | 0.0473 | 0.0946 |
| **$PM_{15}$** | 0.50 | 0.0120 | 0.50 | 0.0120 | 0.0241 |
| **$PM_{10}$** | 0.38 | 0.0090 | 0.38 | 0.0090 | 0.0181 |
| **$PM_{2.5}$** | 0.21 | 0.0050 | 0.05 | 0.0013 | 0.0062 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Road Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Grading Length: | 6.00 | miles | (Typical Value) |
| Construction Schedule: | 3 | Days/Location | (Typical Value) |
| | 12 | Hours/Day | (Typical Value) |
| | 36 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | |
| Average Grader Speed: | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 16.12 lbs TSP/Location**

**Emissions = 7.71 lbs $PM_{15}$/Location**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 16.12 | 0.45 | 8.06E-03 |
| **$PM_{15}$** | 7.71 | 0.21 | 3.86E-03 |
| **$PM_{10}$** | 4.63 | 0.13 | 2.31E-03 |
| **$PM_{2.5}$** | 0.50 | 0.01 | 2.50E-04 |

| **Kleinfelder, Inc.** | **Base Location:** Upper Green River Basin |
|---|---|
| **Wellsite Emissions** | **Well Type:** Natural Gas |

**Construction Phase**

**Well Pad Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | | |
|---|---|---|---|---|
| Construction Schedule: | 7 | Days/Location | | (Typical Value) |
| | 10 | Hours/Day | | (Typical Value) |
| | 70 | Hours/Location | (Dozer) | (Typical Value) |
| | 70 | Hours/Location | (Back Hoe) | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.75 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | | |
| $PM_{2.5}$ Multiplier: | 0.105 * TSP | (AP-42 Table 11.9-1, 7/98) | | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content } \%)^{1.2} * (\text{soil moisture content } \%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content } \%)^{1.5} * (\text{soil moisture content } \%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions [a]** | | **Backhoe Emissions [a]** | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0690 | 1.97 | 0.0690 | 0.14 |
| **$PM_{15}$** | 0.50 | 0.0176 | 0.50 | 0.0176 | 0.04 |
| **$PM_{10}$** | 0.38 | 0.0132 | 0.38 | 0.0132 | 0.03 |
| **$PM_{2.5}$** | 0.21 | 0.0072 | 0.21 | 0.0072 | 0.01 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Well Pad Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 4.0 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 40 | Hours/Location | (Typical Value) |
| Watering Control Efficiency | 50 | Percent (%) | (Typical Value) |
| Average Grader Speed | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| Distance Graded | 2.84 | Miles/Location | (Typical Value) |
| $PM_{10}$ Multiplier | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 7.63 lbs TSP/well pad**

**Emissions = 3.65 lbs $PM_{15}$/well pad**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 7.63 | 0.19 | 0.0038 |
| **$PM_{15}$** | 3.65 | 0.09 | 0.0018 |
| **$PM_{10}$** | 2.19 | 0.05 | 0.0011 |
| **$PM_{2.5}$** | 0.24 | 0.01 | 0.0001 |

| **Kleinfelder, Inc.** | **Base Location:** Upper Green River Basin |
|---|---|
| **Wellsite Emissions** | **Well Type:** Natural Gas |

**Construction Phase**

**Pipeline Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 7.0 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.75 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.105 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 7/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content }\%)^{1.2} * (\text{soil moisture content }\%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content }\%)^{1.5} * (\text{soil moisture content }\%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions [a]** | | **Backhoe Emissions [a]** | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0690 | 1.97 | 0.0690 | 0.14 |
| **$PM_{15}$** | 0.50 | 0.0176 | 0.50 | 0.0176 | 0.04 |
| **$PM_{10}$** | 0.38 | 0.0132 | 0.38 | 0.0132 | 0.03 |
| **$PM_{2.5}$** | 0.21 | 0.0072 | 0.21 | 0.0072 | 0.01 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.** <br> **Wellsite Emissions** | **Base Location:** Upper Green River Basin <br> **Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Pipeline Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Distance Graded: | 12.50 | Miles/Location | (Typical Value) |
| Construction Schedule: | 7 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Mean Vehicle Speed: | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 7/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 33.58 lbs TSP/well**

**Emissions = 16.07 lbs $PM_{15}$/well**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 33.58 | 0.48 | 0.0168 |
| **$PM_{15}$** | 16.07 | 0.23 | 0.0080 |
| **$PM_{10}$** | 9.64 | 0.14 | 0.0048 |
| **$PM_{2.5}$** | 1.04 | 0.01 | 0.0005 |

| Kleinfelder, Inc. Wellsite Emissions | Base Location: Upper Green River Basin<br>Well Type: Natural Gas |
|---|---|

**Construction Phase**

**Roadway Construction Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Heavy Diesel Truck Trips: | | | | | |
| Road Construction: | 7 | Trips | | | |
| Well Pad Construction: | 8 | Trips | Total Trips: | 21 | Trips |
| Pipeline Construction: | 6 | Trips | | | |
| Light Duty Pickup Truck Trips: | | | | | |
| Road Construction: | 16 | Trips | | | |
| Well Pad Construction: | 28 | Trips | Total Trips: | 100 | Trips |
| Pipeline Construction: | 56 | Trips | | | |

* All assumptions above are based on typical industry values

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (lb/mile)} * \text{\# Trips} * \text{Trip Distance (miles)}}{2000 \text{ (lb/tons)}}$$

| Construction Vehicles | Heavy Haul Trucks | | Light Duty Pickups | | Total |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 3.12E-02 | 7.39E-03 | 1.48E-02 | 4.60E-02 |
| **CO** | 1.98E-02 | 8.32E-03 | 7.26E-02 | 1.45E-01 | 1.54E-01 |
| **VOC** | 3.16E-03 | 1.33E-03 | 3.54E-03 | 7.08E-03 | 8.41E-03 |
| **SO2** | 4.57E-05 | 1.92E-05 | 2.83E-05 | 5.66E-05 | 7.58E-05 |
| **PM10** | 4.22E-03 | 1.77E-03 | 1.94E-04 | 3.88E-04 | 2.16E-03 |
| **PM2.5** | 4.09E-03 | 1.72E-03 | 1.79E-04 | 3.58E-04 | 2.08E-03 |
| **CO2** | 1.88 | 0.79 | 1.13 | 2.25 | 3.04 |
| **CH4** | 7.61E-05 | 3.19E-05 | 4.56E-05 | 9.13E-05 | 1.23E-04 |
| **N2O** | 1.52E-05 | 6.39E-06 | 9.13E-06 | 1.83E-05 | 2.46E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Construction Heavy Equipment Tailpipe Emissions**

**Assumptions:**

Fuel and Engine:

| | | | |
|---|---|---|---|
| Brake Specific Fuel Consumption, Avg. (BSFC) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel Higher Heating Value (HHV) | 0.138 | mmBtu/Gallon | (Typical Value) |

Trackhoe:

| | | | |
|---|---|---|---|
| Working Hours | 188 | Total Hours | (Typical Value) |
| Rated Horsepower | 100 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Tractors/Loaders/Backhoes) | |

Dozer:

| | | | |
|---|---|---|---|
| Working Hours | 188 | Total Hours | (Typical Value) |
| Rated Horsepower | 140 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Crawler Tractor/Dozers) | |

Grader:

| | | | |
|---|---|---|---|
| Working Hours | 130 | Total Hours | (Typical Value) |
| Rated Horsepower | 250 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Graders) | |

| | | | |
|---|---|---|---|
| Total Horsepower Hours: | 45795.8 | Hp-hrs | (Sum of all horsepower above) |
| Total Fuel Usage: | 2737.79 | Gallons Diesel Fuel | |

**Equations:**

Total Fuel Usage: ((btu-hp-hr * hp-hrs) / Mmbtu-gal) / 1,000,000

$$\text{Emissions (tons/year/pad)} = \frac{\text{Emission Factor (g/mile) * Trip Distance (miles) * Load Factor}}{\text{453.6 (g/lb) * 2000 (lb/tons)}}$$

| Heavy Const. Vehicles | Backhoe | | | Dozer | | | Grader | | |
|---|---|---|---|---|---|---|---|---|---|
| | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) |
| **NOx** | 8.38 | 1.09E+00 | 1.02E-01 | 8.38 | 1.53E+00 | 1.43E-01 | 8.38 | 2.72E+00 | 1.77E-01 |
| **CO** | 2.7 | 3.51E-01 | 3.30E-02 | 2.7 | 4.92E-01 | 4.62E-02 | 2.7 | 8.78E-01 | 5.71E-02 |
| **VOC [b]** | 0.68 | 8.84E-02 | 8.31E-03 | 0.68 | 1.24E-01 | 1.16E-02 | 0.68 | 2.21E-01 | 1.44E-02 |
| **$PM_{10}$** | 0.39 | 5.07E-02 | 4.77E-03 | 0.39 | 7.10E-02 | 6.68E-03 | 0.39 | 1.27E-01 | 8.24E-03 |
| **$PM_{2.5}$** | 0.39 | 5.07E-02 | 4.77E-03 | 0.39 | 7.10E-02 | 6.68E-03 | 0.39 | 1.27E-01 | 8.24E-03 |

| Heavy Const. Vehicles | Total Emissions [c] (tons/yr) |
|---|---|
| **NOx** | 0.42 |
| **CO** | 0.14 |
| **VOC** | 0.03 |
| **$PM_{10}$** | 0.02 |
| **$PM_{2.5}$** | 0.02 |

**Greenhouse Gas Emissions:**

| | Diesel EF kg/mmbtu | Emissions lbs | Emissions Tons |
|---|---|---|---|
| $CO_2$ | 73.96 | 61604.19 | 30.80 |
| $CH_4$ | 0.003 | 2.50 | 0.0012 |
| $N_2O$ | 0.0006 | 0.50 | 0.0002 |

a From Table A-4 of Exhaust and Crankcase Emission Factors for NONROAD Engine Modeling - Compression Ignition, EPA-420-R-10-018, July 2010.

b Emission Factor represents total Hydrocarbon Emissions

c Converted from emission factor for Distillate Fuel Oil #2 (diesel) as listed in Table C-1 to Subpart C of Part 98 - Default Emission Factors and High Heat Values for Various Types of Fuel.

Listed Factor:

73.96 kg $CO_2$/mmBtu
393 hp-hr = mmBtu
188.2 g $CO_2$/hp-hr

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Wind Erosion Fugitive Dust**

**Assumptions:**

Threshold Friction Velocity ($U_t$) 1.02 m/s (2.28 mph) for well pads (AP-42 Table 13.2.5-2 Overburden - Western Surface Coal Mine)
1.33 m/s (2.97 mph) for roads (AP-42 Table 13.2.5-2 Roadbed material)

Initial Disturbance Area

| | | | |
|---|---|---|---|
| Total Access Road/ROW Area Per Location: | 976,800 | Square Meters | (Typical Value) |
| Total Well Pad Area Disturbed Per Location: | 50,000 | Square Meters | (Typical Value) |
| Total Area Disturbed Per Location: | 1,026,800 | Square Meters | (Typical Value) |
| Exposed Surface Type | Flat | | |
| Meteorological Data | 2002 Grand Junction (obtained from NCDC website) | | |
| Fastest Mile Wind Speed: | 45 | miles/hour | (Typical Value) |
| Fastest Mile Wind Speed ($U_{10}^{+}$) | 20.12 | meters/sec (45 mph) reported as fastest 2-minute wind speed for Grand Junction (2002) | |
| Number soil of disturbances | 1.00 | for well pads (Assumption, disturbance at construction and reclamation) constant for dirt roads | |

**Equations (AP-42 13.2.5.2 Industrial Wind Erosion)**

Friction Velocity $U^* = 0.053\ U_{10}^{+}$

Erosion Potential P ($g/m^2$/period) = $58*(U^*-U_t^*)^2 + 25*(U^*-U_t^*)$ for $U^*>U_t^*$, $P = 0$ for $U^*< U_t^*$

Emissions (tons/year) = Erosion Potential($g/m^2$/period)*Disturbed Area($m^2$)*Disturbances/year*(k)/(453.6 g/lb)/2000 lbs/ton/Develop Period

| Particle Size Multiplier (k) | | |
|---|---|---|
| **30 µm** | **<10 µm** | **<2.5 µm** |
| 1.0 | 0.5 | 0.075 |

| Maxium $U_{10}^{+}$ Wind Speed (m/s) | Maximum U* Friction Velocity m/s | Well $U_t$* Threshold Velocity[a] m/s | Well Pad Erosion Potential $g/m^2$ | Road $U_t$* Threshold Velocity[a] m/s | Road Erosion Potential $g/m^2$ |
|---|---|---|---|---|---|
| 20.12 | 1.07 | 1.02 | 1.28 | 1.33 | 0.00 |

**Wind Erosion Emissions**

| Particulate Species | Well Pad (tons/year) | Roads/Pipelines (tons/year) |
|---|---|---|
| TSP | 7.05E-02 | 0.00E+00 |
| $PM_{10}$ | 3.52E-02 | 0.00E+00 |
| $PM_{2.5}$ | 5.28E-03 | 0.00E+00 |

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Upper Green River Basin
**Well Type:** Natural Gas

**Construction, Development, and Production Phase**
**Construction, Development, and Operations Traffic Fugitive Dust Emissions**

**Assumptions:**

| | |
|---|---|
| Round Trip Miles | 40 |
| Round Trip (Paved) Miles | 16 |
| Round Trip (Un-Paved) Miles | 24 |
| Precipitation Days (P) | 55 |

Unpaved Calculation AP-42, Chapter 13.2.2
November 2006

$E\ (PM_{10})\ /\ VMT = 1.5 * (S/12)^{0.9} * (W/3)^{0.45} * (365\text{-}p)/365)$
$E\ (PM_{2.5})\ /\ VMT = 0.15 * (S/12)^{0.9} + (W/3)^{0.45} * (365\text{-}p)/365)$

Silt Content (S) 8.5 AP 42 13.2.2-1 Mean Silt Content Construction Sites

Paved Calculation AP-42, Chapter 13.2.1
January 2011

$E\ (PM_{10})\ /\ VMT = 0.0022 * (sL)^{0.91} * (W)^{1.02} * (1-(P/(365*4))$
$E\ (PM_{2.5})\ /\ VMT = 0.00054 * (sL)^{0.91} * (W)^{1.02} * (1-(P/(365*4))$

Silt Loading (sL) 0.6 AP-42 Table 13.2.1-2 baseline low volume roads

**Unpaved Calculations:**

| **Construction Phase** | Vehicle Type | **Average Weight (lbs)** | **Vehicle Round Trips** | **$PM_{10}$ (lb/VMT)** | **$PM_{10}$ (lbs)** | **$PM_{10}$ (Tons)** | **$PM_{2.5}$ (lb/VMT)** | **$PM_{2.5}$ (lbs)** | **$PM_{2.5}$ (Tons)** |
|---|---|---|---|---|---|---|---|---|---|
| | Heavy Duty Haul Trucks | 80,000 | 21 | 3.00 | 1510.2 | 0.8 | 0.3 | 151.0 | 0.1 |
| | Light Duty Pickup Trucks | 5,000 | 100 | 0.86 | 2065.2 | 1.0 | 0.1 | 206.5 | 0.1 |
| | **Total:** | | | | **3575.33** | **1.79** | | **357.53** | **0.18** |

**Paved Calculations:**

| | Vehicle Type | **Average Weight (lbs)** | **Vehicle Round Trips** | **PM10 (lb/VMT)** | **PM10 (lbs)** | **PM10 (Tons)** | **PM2.5 (lb/VMT)** | **PM2.5 (lbs)** | **PM2.5 (Tons)** |
|---|---|---|---|---|---|---|---|---|---|
| | Heavy Duty Haul Trucks | 80,000 | 21 | 0.0572 | 19.2 | 0.0096 | 0.014 | 4.7 | 0.0024 |
| | Light Duty Pickup Trucks | 5,000 | 100 | 0.0034 | 5.4 | 0.0027 | 0.001 | 1.3 | 0.0007 |
| | **Total:** | | | | **24.6** | **0.0** | | **6.0** | **0.0** |

**Unpaved Calculations:**

| **Development Phase** | Vehicle Type | **Average Weight (lbs)** | **Vehicle Round Trips** | **$PM_{10}$ (lb/VMT)** | **$PM_{10}$ (lbs)** | **$PM_{10}$ (Tons)** | **$PM_{2.5}$ (lb/VMT)** | **$PM_{2.5}$ (lbs)** | **$PM_{2.5}$ (Tons)** |
|---|---|---|---|---|---|---|---|---|---|
| | Light Duty Pickup Trucks: | 5,000 | 84 | 0.86 | 1734.7 | 0.9 | 0.1 | 173.5 | 0.1 |
| | Light Duty Haul Trucks | 7,500 | 11 | 1.03 | 272.6 | 0.1 | 0.1 | 27.3 | 0.0 |
| | Heavy Duty Haul Trucks | 80,000 | 67 | 3.00 | 4818.2 | 2.4 | 0.3 | 481.8 | 0.2 |
| | Water Trucks | 70,000 | 24 | 2.82 | 1625.3 | 0.8 | 0.3 | 162.5 | 0.1 |
| | **Total:** | | | | **8450.81** | **4.23** | | **845.08** | **0.42** |

**Paved Calculations:**

| | **Vehicle Type** | **Average Weight (lbs)** | **Vehicle Round Trips** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Light Duty Pickup Trucks:** | 5000 | 84 | 0.00 | 4.5 | 0.0 | 0.0 | 1.1 | 0.0006 |
| | **Light Duty Haul Trucks** | 7500 | 11 | 0.01 | 0.9 | 0.0 | 0.0 | 0.2 | 0.0001 |
| | **Heavy Duty Haul Trucks** | 80000 | 67 | 0.06 | 61.3 | 0.0 | 0.0 | 15.1 | 0.0075 |
| | **Water Trucks** | 70,000 | 24 | 0.05 | 19.2 | 0.0 | 0.0 | 4.7 | 0.0024 |
| | **Total:** | | | | **85.9** | **0.0** | | **21.1** | **0.0** |

**Unpaved Calculations:**

| **Production Phase** | Vehicle Type | **Average Weight (lbs)** | **Vehicle Round Trips** | **PM10 (lb/VMT)** | **PM10 (lbs)** | **PM10 (Tons)** | **PM2.5 (lb/VMT)** | **PM2.5 (lbs)** | **PM2.5 (Tons)** |
|---|---|---|---|---|---|---|---|---|---|
| | Light Duty Pickup Trucks: | 5,000 | 50 | 0.86 | 1032.58 | 0.52 | 0.0860 | 103.26 | 0.0516 |
| | Light Duty Haul Trucks | 7,500 | 0 | 1.03 | 0.00 | 0.00 | 0.1033 | 0.00 | 0.0000 |
| | Heavy Duty Haul Trucks | 80,000 | 2 | 3.00 | 143.83 | 0.07 | 0.2996 | 14.38 | 0.0072 |
| | Water Trucks | 70,000 | 40 | 2.82 | 2708.76 | 1.35 | 0.2822 | 270.88 | 0.1354 |
| | **Total:** | | | | **3885.17** | **1.94** | | **388.52** | **0.19** |

**Paved Calculations:**

| | **Vehicle Type** | **Average Weight (lbs)** | **Vehicle Round Trips** | **PM10 (lb/VMT)** | **PM10 (lbs)** | **PM10 (Tons)** | **PM2.5 (lb/VMT)** | **PM2.5 (lbs)** | **PM2.5 (Tons)** |
|---|---|---|---|---|---|---|---|---|---|
| | **Light Duty Pickup Trucks:** | 5,000 | 50 | 0.00 | 2.71 | 0.0014 | 0.0008 | 0.66 | 0.0003 |
| | **Light Duty Haul Trucks** | 7,500 | 0 | 0.01 | 0.00 | 0.0000 | 0.0013 | 0.00 | 0.0000 |
| | **Heavy Duty Haul Trucks** | 80,000 | 2 | 0.06 | 1.83 | 0.0009 | 0.0140 | 0.45 | 0.0002 |
| | **Water Trucks** | 70,000 | 40 | 0.05 | 31.95 | 0.0160 | 0.0123 | 7.84 | 0.0039 |
| | **Total:** | | | | **36.49** | **0.02** | | **8.96** | **0.00** |

| **Annual Total** | | |
|---|---|---|
| | **Unpaved Roads $PM_{10}$ (tons)** | **Unpaved Roads $PM_{2.5}$ (tons)** |
| | **7.96** | **0.8** |
| | **Paved Roads $PM_{10}$** | **Paved Roads $PM_{2.5}$** |
| | **0.1** | **0.0** |
| **Total:** | **8.0** | **0.8** |

## Kleinfelder, Inc.

**Wellsite Emissions**

**Base Location:** Upper Green River Basin
**Well Type:** Natural Gas

**Development Phase**

**Drill Rig Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 18 | (Typical Value) |
| Hours of Operation | 432 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

| Engine | HP [a] | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Vertical Drill Rig Engine | 850 | 0.42 | 144 | 51408 |
| Horizontal Drill Rig Engine 1 | 2,100 | 0.59 | 288 | 356832 |
| Horizontal Drill Rig Engine 2 | 2,100 | 0.59 | 432 | 535248 |
| Drill Rig Generator | 350 | 0.42 | 432 | 63504 |
| Trailers Generator | 150 | 0.42 | 432 | 27216 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor Booster | 650 | 0.42 | 144 | 39312 |
| Forklift | 120 | 0.42 | 144 | 7257.6 |
| Aerial Lift | 50 | 0.42 | 16 | 336 |
| Frontend loader | 150 | 0.42 | 16 | 1008 |
| Dozer | 175 | 0.60 | 9 | 945 |
| Total HP | 8,895 | | | |

Total: 1,216,123 Hp-hrs

Fuel Usage: 72,703 Gallons of Diesel Total Fuel Usage: (btu/hp-hr * hp-hrs) * gal/btu

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| $CO_2$ | 73.96 | 1635919.59 | 817.96 |
| $CH_4$ | 0.003 | 66.36 | 0.03 |
| $N_2O$ | 0.0006 | 13.27 | 0.01 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu) | Xylenes (lb/mmBtu) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Drill Rig Engine | 51408 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Horizontal Drill Rig Engine 1 | 356832 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Horizontal Drill Rig Engine 2 | 535248 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Drill Rig Generator | 63504 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Trailers Generator | 27216 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor Booster | 39312 | 1.3272 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Forklift | 7257.6 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Aerial Lift | 336 | 5.0000 | 6.9000 | 0.8000 | 0.7760 | 1.27E-05 | 1.8000 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frontend loader | 1008 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Dozer | 945 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Drill Rig Engine | | 0.04331 | 0.23234 | 0.00746 | 0.00723 | 7.20E-07 | 0.00927 | 0.00016 | 0.00006 | 0.00004 |
| Horizontal Drill Rig Engine 1 | | 0.30059 | 1.61269 | 0.05176 | 0.05021 | 4.99E-06 | 0.06435 | 0.00114 | 0.00041 | 0.00028 |
| Horizontal Drill Rig Engine 2 | | 0.45089 | 2.41904 | 0.07765 | 0.07532 | 7.49E-06 | 0.09653 | 0.00171 | 0.00062 | 0.00043 |
| Drill Rig Generator | | 0.18900 | 0.58661 | 0.02814 | 0.02730 | 8.89E-07 | 0.04760 | 0.00020 | 0.00007 | 0.00005 |
| Trailers Generator | | 0.08100 | 0.25140 | 0.01206 | 0.01170 | 3.81E-07 | 0.02040 | 0.00009 | 0.00003 | 0.00002 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor Booster | | 0.05751 | 0.17767 | 0.00570 | 0.00553 | 5.50E-07 | 0.00709 | 0.00013 | 0.00005 | 0.00003 |
| Forklift | | 0.02160 | 0.06704 | 0.00322 | 0.00312 | 1.02E-07 | 0.00544 | 0.00002 | 0.00001 | 0.00001 |
| Aerial Lift | | 0.00185 | 0.00256 | 0.00030 | 0.00029 | 4.70E-09 | 0.00067 | 0.00000 | 0.00000 | 0.00000 |
| Frontend loader | | 0.00300 | 0.00931 | 0.00045 | 0.00043 | 1.41E-08 | 0.00076 | 0.00000 | 0.00000 | 0.00000 |
| Dozer | | 0.00281 | 0.00873 | 0.00042 | 0.00041 | 1.32E-08 | 0.00071 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **1.27513** | **6.00321** | **0.20645** | **0.20026** | **0.00002** | **0.27680** | **0.00389** | **0.00141** | **0.00097** |

**Emission Factors**

- Drill rig emission factors based on Tier II engines
- All other engine emission factors based on Tier 0 engines (typical values)
- HAP emission factors from AP-42 Volume I, Large Stationary Diesel Engines Table 3.4-3

**Calculations:**

ton/year: (Total hp-hr * g/hp-hr) * lb-gram / lb-ton

*** Drill rig horsepower developed based on:**

1 Williston Basin: 2,100 from Jonah, Wyoming RMP
2 San Juan Basin: 2,100 from River Valley RMI
3 Upper Green River Basin: 2,100 from Jonah, Wyoming RMP
4 Denver Basin: 2,950 from River Valley RMI
5 Uintah Basin: 2,952 from River Valley RMI

Note, runtime for each drilling event is based on research and industry experience dependent upon each basi

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|

**Development Phase**

**Conductor Pipe Set Emissions**

**Assumptions:**

| Parameter | Value |
|---|---|
| Days of Operation | 2 |
| Hours of Operation | 24 |
| Diesel Fuel Sulfur Content | 0.000015 |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

Workovers:

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Rig Engine | 350 | 0.42 | 24 | 3528 |
| Rig Generator | 50 | 0.42 | 24 | 504 |

Total Horsepower: 400

Total: 4,032 Hp-hrs

Fuel Usage: 241 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

**Greenhouse Gases:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 5423.82 | 2.71 |
| CH4 | 0.003 | 0.22 | 0.00 |
| N2O | 0.0006 | 0.04 | 0.00 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu | Xylenes (lb/mmBtu |
|---|---|---|---|---|---|---|---|---|---|---|
| Rig Engine | 3528 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 0.0008 | 0.0003 | 0.0002 |
| Rig Generator | 504 | 5.0000 | 6.9000 | 0.8000 | 0.7760 | 1.27E-05 | 1.8000 | 0.0008 | 0.0003 | 0.0002 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Rig Engine | | 0.00328 | 0.01686 | 0.00051 | 0.00050 | 0.00000 | 0.00064 | 0.00001 | 0.00000 | 0.00000 |
| Rig Generator | | 0.00278 | 0.00383 | 0.00044 | 0.00043 | 0.00000 | 0.00100 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.00605** | **0.02069** | **0.00096** | **0.00093** | **0.00000** | **0.00164** | **0.00001** | **0.00000** | **0.00000** |

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

* Rig engine emission rates are based on a Tier II engine and rig generator emission rates are based on a Tier 0 engine.
* All days, hours, and HP values above are based on typical industry values

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|

**Development Phase**

**Well Fracturing Engine Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 7 | (Typical Value) |
| Hours of Operation | 168 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Blenders | 500 | 0.42 | 4 | 840 |
| Auxilary Pump | 200 | 0.42 | 4 | 336 |
| Auxilary Pump | 200 | 0.42 | 8 | 672 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Generator | 150 | 0.42 | 168 | 10584 |

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 2018564.31 | 1009.28 |
| CH4 | 0.003 | 81.88 | 0.04 |
| N2O | 0.0006 | 16.38 | 0.01 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

Total: 1,500,576 Hp-hrs

Fuel Usage: 89,708 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu) | Xylenes (lb/mmBtu) |
|---|---|---|---|---|---|---|---|---|---|---|
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Blenders | 840 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Auxilary Pump | 336 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Auxilary Pump | 672 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Generator | 10584 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Blenders | | 0.00078 | 0.00401 | 0.00012 | 0.00012 | 1.18E-08 | 0.00015 | 0.00000 | 0.00000 | 0.00000 |
| Auxilary Pump | | 0.00100 | 0.00310 | 0.00015 | 0.00014 | 4.70E-09 | 0.00025 | 0.00000 | 0.00000 | 0.00000 |
| Auxilary Pump | | 0.00200 | 0.00621 | 0.00030 | 0.00029 | 9.41E-09 | 0.00050 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Generator | | 0.04072 | 0.09683 | 0.00842 | 0.00817 | 1.48E-07 | 0.01155 | 0.00003 | 0.00001 | 0.00001 |
| | **Total:** | **1.30213** | **6.84201** | **0.22574** | **0.21897** | **0.00002** | **0.28205** | **0.00480** | **0.00174** | **0.00119** |

**Emission Factors**

- Frac pump emission factors based on Tier II engines (typical values)
- All other engine emission factors based on Tier 0 engines (typical values)

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Upper Green River Basin
**Well Type:** Natural Gas

**Development Phase**
**Hydraulic Fracturing Flowback Emissions**

**Assumptions:**

| | | | |
|---|---|---|---|
| **Estimated Frac flowback Rate:** | 10,000 | Scf/hr | |
| **Combustion Efficiency:** | 95.00 | Percent (%) | |
| **Event Duration:** | 100.00 | Hours | |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* Venting duration based on research and industry knowledge; please see report for additional information.
* Venting control based on Subpart OOOO requirements of 95% minimum control.
Control efficiency can be deleted if applicable.

**Equations:**

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf/lb-mol)) * hrs/yr
** Multiply above equation by 0.02 if including 98% control efficiency

**Un-combusted Componet Emissions:**

| Component | Mole % [a] | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 444.86 | 18.81 | 0.94 |
| Ethane | 5.7920 | 30.1 | 28.96 | 2.29 | 0.11 |
| Propane | 1.3650 | 44.1 | 6.83 | 0.79 | 0.04 |
| i-Butane | 0.3700 | 58.1 | 1.85 | 0.28 | 0.01 |
| n-Butane | 0.2610 | 58.1 | 1.31 | 0.20 | 0.01 |
| i-Pentane | 0.1550 | 72.2 | 0.78 | 0.15 | 0.01 |
| n-Pentane | 0.1020 | 72.2 | 0.51 | 0.10 | 0.00 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 0.73 | 0.17 | 0.01 |
| Heptanes | 0.0930 | 100.2 | 0.47 | 0.12 | 0.01 |
| Octanes | 0.0440 | 114.2 | 0.22 | 0.07 | 0.00 |
| Nonanes | 0.0160 | 128.3 | 0.08 | 0.03 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 0.03 | 0.01 | 0.00 |
| Benzene | 0.0270 | 78.1 | 0.14 | 0.03 | 0.00 |
| Toluene | 0.0190 | 92.1 | 0.10 | 0.02 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 0.06 | 0.02 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 0.73 | 0.17 | 0.01 |
| Nitrogen | 0.0940 | 28.0 | 9.40 | 0.69 | 0.03 |
| Carbon Dioxide | 2.5280 | 44.0 | 252.80 | 29.32 | 1.47 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| **VOC Subtotal** | 2.7600 | 1492.8 | 13.80 | 2.14 | 0.11 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 1.02 | 0.23 | 0.01 |
| **Total** | 100.1460 | 1645.0 | 749.82 | 53.26 | 2.66 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 8452.34 | 980.23 | 49.01 |
| C2 | 5.79 | 550.24 | 63.81 | 3.19 |
| C3 | 1.37 | 129.68 | 15.04 | 0.75 |
| C4 | 0.63 | 59.95 | 6.95 | 0.35 |
| C5+ | 0.76 | 72.58 | 8.42 | 0.42 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **53.72** | **Tons/Event** |
| **$N_2O$ Emissions:** | **1.13E-04** | **Tons/Event** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.37 | 3.80 | 0.19 | AP-42 CH13.5-1 |
| NOx | 0.068 | 0.70 | 0.03 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.00 | *Based on $H2_S$ 34 mol weight and $SO_2$ 64 mol weight |

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Upper Green River Basin
**Well Type:** Natural Gas

**Development Phase**
**Workover Cementing Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 2 | (Typical Value) |
| Hours of Operation | 24 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8500 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

Workovers/Cementing:

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Coil Tubing Unit | 550 | 0.42 | 24 | 5544 |
| Circulation Pump | 450 | 0.42 | 24 | 4536 |
| Cement Pump Trucks | 500 | 0.42 | 8 | 1680 |

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 16298.85 | 8.15 |
| CH4 | 0.003 | 0.66 | 0.00 |
| N2O | 0.0006 | 0.13 | 0.00 |

Total Horsepower: 1,500 (Typical Value)

Total: 11,760 Hp-hrs

Fuel Usage: 724 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Formaldehyde (lb/mmBtu) | Toulene (lb/mmBtu | Xylenes (lb/mmBtu |
|---|---|---|---|---|---|---|---|---|---|---|
| Coil Tubing Unit | 5544 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 0.1636 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |
| Circulation Pump | 4536 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 0.1636 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |
| Cement Pump Trucks | 1680 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 0.6800 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Formaldehyde (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Coil Tubing Unit | | 0.00515 | 0.02649 | 0.00080 | 0.00078 | 0.00100 | 0.00002 | 0.00000 | 0.00001 | 0.00000 |
| Circulation Pump | | 0.00421 | 0.02168 | 0.00066 | 0.00064 | 0.00082 | 0.00001 | 0.00000 | 0.00001 | 0.00000 |
| Cement Pump Trucks | | 0.00500 | 0.01552 | 0.00074 | 0.00072 | 0.00126 | 0.00001 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.01436** | **0.06369** | **0.00221** | **0.00214** | **0.00308** | **0.00004** | **0.00000** | **0.00001** | **0.00001** |

**Emission Factors**

- Engine emission factors based on Tier II engines (typical values)

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|

**Development Phase**

**Well Venting During Workover Events**

**Assumptions:**

Significant gas venting only occurs on natural gas wells.

| | | | |
|---|---|---|---|
| **Estimated Venting Rate:** | 5,000 | Scf/Event | (Typical Value) |
| **Combustion Efficiency:** | 0.00 | Percent (%) | |
| **Event Quantity:** | 1.00 | Event | - Assumed one event |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* Vented quantity based on research and industry knowledge; please see report for additional information.

**Equations:**

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf-lb-mol))
** Multiply above equation by 0.02 if including 98% control efficiency

| Component | Mole % | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Event |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 4448.60 | 188.07 | 0.0940 |
| Ethane | 5.7920 | 30.1 | 289.60 | 22.95 | 0.0115 |
| Propane | 1.3650 | 44.1 | 68.25 | 7.93 | 0.0040 |
| i-Butane | 0.3700 | 58.1 | 18.50 | 2.83 | 0.0014 |
| n-Butane | 0.2610 | 58.1 | 13.05 | 2.00 | 0.0010 |
| i-Pentane | 0.1550 | 72.2 | 7.75 | 1.47 | 0.0007 |
| n-Pentane | 0.1020 | 72.2 | 5.10 | 0.97 | 0.0005 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.0000 |
| Hexanes | 0.1460 | 86.2 | 7.30 | 1.66 | 0.0008 |
| Heptanes | 0.0930 | 100.2 | 4.65 | 1.23 | 0.0006 |
| Octanes | 0.0440 | 114.2 | 2.20 | 0.66 | 0.0003 |
| Nonanes | 0.0160 | 128.3 | 0.80 | 0.27 | 0.0001 |
| Decanes + | 0.0050 | 142.3 | 0.25 | 0.09 | 0.0000 |
| Benzene | 0.0270 | 78.1 | 1.35 | 0.28 | 0.0001 |
| Toluene | 0.0190 | 92.1 | 0.95 | 0.23 | 0.0001 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.0000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.0000 |
| Xylenes | 0.0110 | 106.2 | 0.55 | 0.15 | 0.0001 |
| n-Hexane | 0.1460 | 86.2 | 7.30 | 1.66 | 0.0008 |
| Nitrogen | 0.0940 | 28.0 | 4.70 | 0.35 | 0.0002 |
| Carbon Dioxide | 2.5280 | 44.0 | 126.40 | 14.66 | 0.0073 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.0000 |

| | | | | | |
|---|---|---|---|---|---|
| **VOC Subtotal** | 2.7600 | 1492.8 | 138.00 | 21.44 | 0.0107 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 10.15 | 2.32 | 0.0012 |
| **Total** | 100.1460 | 1645.0 | 5007.30 | 247.46 | 0.1237 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed thatthe representative average gas analyses used by the River Valley RMP. was a good representative analyses of general gas wells.

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 0.00 | 0.00 | 0.00 |
| C2 | 5.79 | 0.00 | 0.00 | 0.00 |
| C3 | 1.37 | 0.00 | 0.00 | 0.00 |
| C4 | 0.63 | 0.00 | 0.00 | 0.00 |
| C5+ | 0.76 | 0.00 | 0.00 | 0.00 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **0.00** | **Tons/Event** |
| **$N_2O$ Emissions:** | **5.67E-07** | **Tons/Event** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.00 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| NOx | 0.000 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.000 | *Based on $H2_S$ 34 mol weight and $SO_2$ 64 mol weight |

| **Kleinfelder, Inc.** | **Base Location:** Upper Green River Basin |
|---|---|
| **Wellsite Emissions** | **Well Type:** Natural Gas |

**Development Phase**

**Wellsite Development Traffic Tailpipe Emissions**

**Assumptions:**

Average Round Trip Distance: 40.0 Miles/Trip Average

| | | | | | |
|---|---|---|---|---|---|
| Light Duty Pickup Trucks: | 84 | Trips/Location | | | |
| Light Duty Haul Trucks | 11 | Trips/Location | Total Trips: | 95 | Trips |
| Heavy Duty Haul Trucks | 67 | Trips/Location | | | |
| Water Trucks | 24 | Trips/Location | Total Trips: | 91 | Trips |

* Miles and number of trips based on research and industry knowledge; please see report for additional information.

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (lb/mile) * \# Trips * Trip Distance (miles)}}{\text{2000 (lb/tons)}}$$

| Construction Vehicles | Heavy Haul Trucks | | Light Duty Pickups | | Total |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 1.35E-01 | 1.98E-02 | 1.41E-01 | 2.77E-01 |
| **CO** | 1.98E-02 | 3.60E-02 | 3.16E-03 | 3.76E-02 | 7.37E-02 |
| **VOC** | 3.16E-03 | 5.75E-03 | 4.57E-05 | 6.00E-03 | 1.18E-02 |
| **SO2** | 4.57E-05 | 8.32E-05 | 4.22E-03 | 8.68E-05 | 1.70E-04 |
| **PM10** | 4.22E-03 | 7.68E-03 | 4.09E-03 | 8.02E-03 | 1.57E-02 |
| **PM2.5** | 4.09E-03 | 7.44E-03 | 1.88E+00 | 7.77E-03 | 1.52E-02 |
| **CO2** | 1.88E+00 | 3.41E+00 | 7.61E-05 | 3.56E+00 | 6.98E+00 |
| **CH4** | 7.61E-05 | 1.38E-04 | 1.52E-05 | 1.45E-04 | 2.83E-04 |
| **N2O** | 1.52E-05 | 2.77E-05 | 0.00E+00 | 2.89E-05 | 5.66E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite for calendar year 2012.

c Assumes maximum development scenario

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|

**Development Phase**

**Wellhead Gas Combustion**

**Wellhead gas combustion only for Williston Basin wells, due to the regularity of of pit flares combusting all gas coming from the wellhead. If gas being captured, change scf/hr value or hours of event value.

**Assumptions:**

| | | | |
|---|---|---|---|
| **Estimated Gas Flow Rate:** | 0 | Scf/hr | |
| **Combustion Efficiency:** | 0.00 | Percent (%) | |
| **Event Duration:** | 0.00 | Hours | - Estimated 3 months before sales line |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* It is assumed that all produced natural gas is sent to a sales line after the well is completed.

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf/lb-mol)) * hrs/yr
** Multiply above equation by 0.05 if including 95% control efficiency

**Combusted Componet Emissions:**

| Component | Mole % [a] | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 0.00 | 0.00 | 0.00 |
| Ethane | 5.7920 | 30.1 | 0.00 | 0.00 | 0.00 |
| Propane | 1.3650 | 44.1 | 0.00 | 0.00 | 0.00 |
| i-Butane | 0.3700 | 58.1 | 0.00 | 0.00 | 0.00 |
| n-Butane | 0.2610 | 58.1 | 0.00 | 0.00 | 0.00 |
| i-Pentane | 0.1550 | 72.2 | 0.00 | 0.00 | 0.00 |
| n-Pentane | 0.1020 | 72.2 | 0.00 | 0.00 | 0.00 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 0.00 | 0.00 | 0.00 |
| Heptanes | 0.0930 | 100.2 | 0.00 | 0.00 | 0.00 |
| Octanes | 0.0440 | 114.2 | 0.00 | 0.00 | 0.00 |
| Nonanes | 0.0160 | 128.3 | 0.00 | 0.00 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 0.00 | 0.00 | 0.00 |
| Benzene | 0.0270 | 78.1 | 0.00 | 0.00 | 0.00 |
| Toluene | 0.0190 | 92.1 | 0.00 | 0.00 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 0.00 | 0.00 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 0.00 | 0.00 | 0.00 |
| Nitrogen | 0.0940 | 28.0 | 0.00 | 0.00 | 0.00 |
| Carbon Dioxide | 2.5280 | 44.0 | 0.00 | 0.00 | 0.00 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| **VOC Subtotal** | 2.7600 | 1492.8 | 0.00 | 0.00 | 0.00 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 0.00 | 0.00 | 0.00 |
| **Total** | 100.1460 | 1645.0 | 0.00 | 0.00 | 0.00 |

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 0.00 | 0.00 | 0.00 |
| C2 | 5.79 | 0.00 | 0.00 | 0.00 |
| C3 | 1.37 | 0.00 | 0.00 | 0.00 |
| C4 | 0.63 | 0.00 | 0.00 | 0.00 |
| C5+ | 0.76 | 0.00 | 0.00 | 0.00 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **0.00** | **Tons/Year** |
| **$N_2O$ Emissions:** | **0.00E+00** | **Tons/Year** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.00 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| NOx | 0.000 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.00 | *Based on $H_2S$ 34 mol weight and $SO_2$ 64 mol weight |

| Kleinfelder, Inc.<br>Wellsite Emissions | | Base Location: Upper Green River Basin<br>Well Type: Natural Gas |
|---|---|---|

**Production Phase**

**Production Equipment Fugitive Component Emissions**

**Assumptions:**

Components Counts:

| | Fugitive Components | | | | |
|---|---|---|---|---|---|
| **Component *** | Valves | Connectors | OE Lines | PR Valves | |
| **Count** | 97 | 348 | 12 | 6 | 0 |
| **Emissions Factor (scf/hr) [b]** | 0.121 | 0.017 | 0.031 | 0.193 | 0.000 |

* Fugitive component counts for natural gas wells from Subpart W, Table W-1B
* Fugitive component counts for oil wells from Subpart W, Table W-1C

Annual Equipment Run Time: 8760 Hours/Year 379.49 Scf/lb-mol

| Component | Mole % [a] | Mole Weight lb/lb-mol | Emissions Scf/Year [b] | Emissions lbs/Year | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 149,511.3 | 6,320.6 | 3.16 |
| Ethane | 5.7920 | 30.1 | 9,733.1 | 771.2 | 0.39 |
| Propane | 1.3650 | 44.1 | 2,293.8 | 266.5 | 0.13 |
| i-Butane | 0.3700 | 58.1 | 621.8 | 95.2 | 0.05 |
| n-Butane | 0.2610 | 58.1 | 438.6 | 67.2 | 0.03 |
| i-Pentane | 0.1550 | 72.2 | 260.5 | 49.5 | 0.02 |
| n-Pentane | 0.1020 | 72.2 | 171.4 | 32.6 | 0.02 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 245.3 | 55.7 | 0.03 |
| Heptanes | 0.0930 | 100.2 | 156.3 | 41.3 | 0.02 |
| Octanes | 0.0440 | 114.2 | 73.9 | 22.3 | 0.01 |
| Nonanes | 0.0160 | 128.3 | 26.9 | 9.1 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 8.4 | 3.2 | 0.00 |
| Benzene | 0.0270 | 78.1 | 45.4 | 9.3 | 0.00 |
| Toluene | 0.0190 | 92.1 | 31.9 | 7.8 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 18.5 | 5.2 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 245.3 | 55.7 | 0.03 |
| Nitrogen | 0.0940 | 28.0 | 158.0 | 11.7 | 0.01 |
| Carbon Dioxide | 2.5280 | 44.0 | 4,248.1 | 492.7 | 0.25 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| VOC Subtotal | 2.7600 | | | 720.50 | 0.36 |
| HAPS Subtotal | 0.2030 | | | 77.98 | 0.04 |
| Total | 100.1460 | | | 8316.67 | 4.16 |

**Calculation**

lb/hr = (Mol % * SumSCF/yr) / scf/lb-mol

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

[b] Fugitive emission factors from Subpart W, Table W-1A

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Process Heater Emissions**

**Wellsite Heater Inventory:**

| | Heating Value (Mbtu/hr) | Fuel Consumption (MMScf/yr) | |
|---|---|---|---|
| **Separator Heater** | **750** | **6.44** | * Heater treater size based on industry standard |
| **Dehydrator Heater** | **500** | **4.29** | |
| **Glycol Reboiler** | **80** | **0.69** | |
| **Line Heater** | **500** | **4.29** | |

**Annual Run Time:** **8760** **Hours/Year**

**Fuel Gas Heat Value:** **1,020** **Btu/scf (Standard heating value from AP-42)**

**Equations:**

$$\text{Fuel Consumption (MMscf/yr)} = \frac{\text{Heater Size (MBtu/hr)} * 1{,}000 \text{ (Btu/MBtu)} * \text{Hours of Operation (hrs/yr)}}{\text{Fuel Heat Value (Btu/scf)} * 1{,}000{,}000 \text{ (scf/MMscf)}}$$

$$\text{NOx/CO/TOC Emissions (tons/yr)} = \frac{\text{AP-42 E.Factor (lbs/MMscf)} * \text{Fuel Consumption (MMscf/yr)} * \text{Fuel heating Value (Btu/scf)}}{2{,}000 \text{ (lbs/ton)} * 1{,}020 \text{ (Btu/scf - Standard Fuel Heating Value)}}$$

| | Emission Factor (lb/MMscf) | Separator Heater Total Emissions (Tons/Year) | Dehydrator Heater Total Emissions (Tons/Year) | Glycol Reboiler Total Emissions (Tons/Year) | Line Heater Total Emissions (Tons/Year) | Total Emissions (Tons/Year) [e] |
|---|---|---|---|---|---|---|
| *Criteria Pollutants & VOC* | | | | | | |
| NOx [a] | 100 | 0.3221 | 0.2147 | 0.0344 | 0.2147 | 0.7858 |
| CO [a] | 84.0 | 0.2705 | 0.1804 | 0.0289 | 0.1804 | 0.6601 |
| VOC | 5.5 | 0.0177 | 0.0118 | 0.0019 | 0.0118 | 0.0432 |
| $SO_2$ [b] | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| TSP [c] | 7.60 | 0.0245 | 0.0163 | 0.0026 | 0.0163 | 0.0597 |
| $PM_{10}$ [c] | 7.60 | 0.0245 | 0.0163 | 0.0026 | 0.0163 | 0.0597 |
| $PM_{2.5}$ [c] | 7.60 | 0.0245 | 0.0163 | 0.0026 | 0.0163 | 0.0597 |
| *Hazardous Air Pollutants* | | | | | | |
| Benzene [d] | 2.10E-03 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Toluene [d] | 3.40E-03 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Hexane [d] | 1.80 | 0.0058 | 0.0039 | 0.0006 | 0.0039 | 0.0141 |
| Formaldehyde [d] | 7.50E-02 | 0.0002 | 0.0002 | 0.0000 | 0.0002 | 0.0006 |
| *Greenhouse Gases* | | | | | | |
| $CO_2$ [f] | 120,162 | 386.9918 | 257.9945 | 41.2791 | 257.9945 | 944.2600 |
| $CH_4$ [f] | 2.27 | 0.0073 | 0.0049 | 0.0008 | 0.0049 | 0.0178 |
| $N_2O$ [f] | 0.23 | 0.0007 | 0.0005 | 0.0001 | 0.0005 | 0.0018 |

a AP-42 Table 1.4-1, Emission Factors for Natural Gas Combustion, 7/98
b Assumes produced gas contains no sulfur
c AP-42 Table 1.4-2, Emission Factors for Natural Gas Combustion, 7/98 (All Particulates are $PM_{1.0}$)
d AP-42 Table 1.4-3, Emission Factors for Organic Compounds from Natural Gas Combustion, 7/98
e Assumes maximum development scenario
f Subpart W - Part 98.233(z)(1) indicates the use of Table C-1 and Table C-2 for fuel combustion of stationary and portable equipment. Table C-1 provides an EF for natural gas combustion of 53.02 kg $CO_2$/mmBtu. Table C-2 provides an EF for natural gas combustion for $CH_4$ as 1.0E-03 kg/MMBtu and for $N_2O$ as 1.0E-04 kg/MMBtu.

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Upper Green River Basin
**Well Type:** Natural Gas

**Production Phase**

**Atmospheric Oil Tank Flashing Emissions**

**Assumptions:**

| | | | | |
|---|---|---|---|---|
| Production Estimate: | 30 | barrels/day | | |
| Production Days: | 365 | Days/Year | | |
| Flasing Gas-to-Oil Ratio: | 98 | Scf/bbl | 379.49 | Scf/lb-mol |
| Control Efficiency: | 95 | Percent (%) | | |

**Flashing Gas Composition:**

| Component | Mole % | Mole Weight (lb/lb-mol) | Emissions (Uncontrolled) Scf/Year | Emissions (Uncontrolled) lbs/Year | Emissions (Uncontrolled) Tons/Year | Emissions (Controlled) Tons/Year |
|---|---|---|---|---|---|---|
| Methane | 48.6355 | 16.043 | 521907.5505 | 22063.7246 | 11.0319 | 0.5516 |
| Ethane | 21.3989 | 30.07 | 229631.5959 | 18195.5311 | 9.0978 | 0.4549 |
| Propane | 14.9031 | 44.097 | 159925.1661 | 18583.4147 | 9.2917 | 0.4646 |
| i-Butane | 4.0847 | 58.123 | 43832.9157 | 6713.4854 | 3.3567 | 0.1678 |
| n-Butane | 3.6800 | 58.123 | 39490.08 | 6048.3331 | 3.0242 | 0.1512 |
| i-Pentane | 1.7781 | 72.150 | 19080.7911 | 3627.7084 | 1.8139 | 0.0907 |
| n-Pentane | 0.8467 | 72.150 | 9085.9377 | 1727.4511 | 0.8637 | 0.0432 |
| Other Pentanes | 0.0000 | 70.100 | 0 | 0.0000 | 0.0000 | 0.0000 |
| Hexanes | 1.3611 | 86.177 | 14605.9641 | 3316.8151 | 1.6584 | 0.0829 |
| Heptanes | 1.1842 | 100.204 | 12707.6502 | 3355.4438 | 1.6777 | 0.0839 |
| Octanes | 0.2217 | 114.231 | 2379.0627 | 716.1261 | 0.3581 | 0.0179 |
| Nonanes | 0.0693 | 128.258 | 743.6583 | 251.3377 | 0.1257 | 0.0063 |
| Decanes + | 0.0067 | 142.285 | 71.8977 | 26.9571 | 0.0135 | 0.0007 |
| Benzene | 0.1161 | 78.120 | 1245.8691 | 256.4687 | 0.1282 | 0.0064 |
| Toluene | 0.1927 | 92.130 | 2067.8637 | 502.0219 | 0.2510 | 0.0126 |
| Ethylbenzene | 0.0039 | 106.160 | 41.8509 | 11.7075 | 0.0059 | 0.0003 |
| 2,2,4 Trimethylpentane | 0.0351 | 78.120 | 376.6581 | 77.5370 | 0.0388 | 0.0019 |
| Xylenes | 0.1152 | 106.160 | 1236.2112 | 345.8225 | 0.1729 | 0.0086 |
| n-Hexane | 0.4064 | 86.177 | 4361.0784 | 990.3414 | 0.4952 | 0.0248 |
| Nitrogen | 0.0000 | 28.013 | 0 | 0.0000 | 0.0000 | 0.0000 |
| Carbon Dioxide | 0.9608 | 44.010 | 10310.3448 | 1195.7055 | 0.5979 | 0.0299 |
| Hydrogen Sulfide | 0.0000 | 34.080 | 0 | 0.0000 | 0.0000 | 0.0000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| VOC Subtotal | 29.01 | | | | 23.28 | 1.16 |
| HAPS Subtotal | 0.87 | | | | 1.09 | 0.05 |
| **Total** | **100.0002** | | | | **44.0030** | **2.2001** |

**Calculation:**

Scf/yr = (Mol% * scf/bbl * bbl/day * days/yr) / 100
lb/yr = (scf/yr * mol wt.) / scf/lb-mol

*** Production and gas to oil ratio based on basin specific differences. Please see "Gas Stream Molar Ratios" tab and report for additional information.**

| Kleinfelder, Inc.<br>Wellsite Emissions | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Wellsite Produced Water Tanks Venting**

**Assumptions:**

| | | |
|---|---|---|
| Average Estimated Water Production: | 3000 | Barrels Per Year |
| Number of Water Tanks: | 1 | Tanks |
| VOC Emissions Factor: | 0.2620 | lbs/bbl |
| n-Hexane Emission Factor: | 0.0220 | lbs/bbl |
| Benzene Emission Factor: | 0.0070 | lbs/bbl |

**Calculations:**

| | | |
|---|---|---|
| VOC Emissions: | 0.393 | Tons/Year |
| Hexane Emissions: | 0.033 | Tons/Year |
| Benzene Emissions: | 0.0105 | Tons/Year |

* Production conservatively based on estimated industry single well average
* Emission factors based on only known lb/bbl factor, which was developed by the Colorado Department of Health and Environment (PS Memo 09-02).

| Kleinfelder, Inc. Wellsite Emissions | Base Location: Upper Green River Basin Well Type: Natural Gas |
|---|---|

**Production Phase**

**Truck Loading Emissions**

**AP - 42, Chapter 5.2** $L_L = 12.46 \times S \times P \times M / T$

$L_L$ = Loading Loss Emission Factor (lbs VOC/1000 gal loaded)

S = Saturation Factor
P = True Vapor Pressure of the Loaded Liquid (psia)
M = Vapor Molecular Weight of the Loaded Liquid (lbs/lbmol)
T = Temperature of Loaded Liquid (ºR)

**VOC Emissions (tpy) =**

$$\frac{L_L \text{ (lbs VOC/1000 gal)} * 42 \text{ gal/bbl} * 365 \text{ days/year} * \text{production (bbl/day)}}{1000 \text{ gal} * 2000 \text{ lbs/ton}}$$

| S[1] | P (psia)[2] | M (lb/lbmol)[3] | T (ºF)[4] | T (ºR) | $L_L$ (lb/1000 gal) | Production (bbl/day) | VOC (tpy) |
|---|---|---|---|---|---|---|---|
| 0.6 | 3.40 | 66.00 | 40.00 | 499.67 | 3.36 | 30.0 | **0.77** |

Notes:
1. Saturation factor from AP-42, Table 5.2-1 (Submerged loading: dedicated normal service)
2. True vapor pressure is estimated from AP-42, Table 7.1-2 assuming an average daily temperature of either 40 or 50 deg F and an RVP of 10.0.
3. Molecular weight liquid vapor is estimated from AP-42, Table 7.1-2 assuming an RVP of 10.0.
4. Temperature based on the annual average temperature for basin location (either 40 or 50 degrees F based on options provided in AP-42 Table 7.1-2

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Pumpjack Unit Emissions**

**Assumptions:**

***Pumpjack engines only included at oil wells***

| | | |
|---|---|---|
| Pumpjack Horsepower Rating: | 0.0 | Horsepower |
| Load Factor: | 0.54 | |
| Brake Specific Fuel Consumption: | 0 | Btu/hp-hr |
| Annual Operation: | 8,760 | Hours/Year |

**Equations:**

$$\text{Emissions (lbs/hr)} = \frac{\text{Emission Factor (g/hp-hr)} * \text{Power (hp)}}{453.6 \text{ g/lb}}$$

| Pollutant | Emission Factor [a] (lb/MMBtu) | Emission Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) |
|---|---|---|---|---|
| *Criteria Pollutants & VOC* | | | | |
| **NOx** | | 2.80 | 0.00 | 0.0000 |
| **CO** | | 4.80 | 0.00 | 0.0000 |
| **VOC** | 0.12 | - | 0.0000 | 0.0000 |
| **$PM_{10}$** [b] | 4.83E-02 | - | 0.00E+00 | 0.00E+00 |
| **$PM_{2.5}$** [b] | 4.83E-02 | - | 0.00E+00 | 0.00E+00 |
| **$SO_2$** | 5.88E-04 | - | 0.0000 | 0.0000 |
| *Hazardous Air Pollutants* | | | | |
| **Benzene** | 1.94E-03 | - | 0.00E+00 | 0.00E+00 |
| **Toluene** | 9.63E-04 | - | 0.00E+00 | 0.00E+00 |
| **Ethylbenzene** | 1.08E-04 | - | 0.00E+00 | 0.00E+00 |
| **Xylenes** | 2.68E-04 | - | 0.00E+00 | 0.00E+00 |
| **Formaldehyde** | 5.52E-02 | - | 0.0000 | 0.0000 |
| **n-Hexane** | 4.45E-04 | - | 0.00E+00 | 0.00E+00 |
| *Greenhouse Gases* | | | | |
| **$CO_2$** [c] | 117 | - | 0.00 | 0 |
| **$CH_4$** | 0.002 | - | 0.0000 | 0.0000 |
| **$N_2O$** | 0.0002 | - | 0.0000 | 0.0000 |

a AP-42 Table 3.2-3 Uncontrolled Emission Factors for 4-Stroke Rich-Burn Engines, 7/00; and Subpart JJJJ for NOX and CO emission rates.

b PM = sum of PM filterable and PM condensable

c Subpart W - Part 98.233(z)(1) indicates the use of Table C-1 and Table C-2 for fuel combustion of stationary and portable equipment. Table C-1 provides an EF for natural gas combustion of 53.02 kg $CO_2$/mmBtu. Table C-2 provides an EF for natural gas combustion for $CH_4$ as 1.0E-03 kg/MMBtu and for $N_2O$ as 1.0E-04 kg/MMBtu.

- Network website for the 1999 National-Scale Air Toxics Assessment at http://www.epa.gov/ttn/atw/nata1999/nsata99.html

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|

Production Phase

Wellsite Dehydrator Emissions

**Assumptions:**

Number of Dehy Units: 1 Units

**Calculations:**

Calculations and specifications derived from Pinedale Anticline Final SEIS
GRI-GLYCalc 4.0 operated with: 4 MMSCFD, 0.32 gpm glycol flow, average representative gas analysis, and 95% control efficiency

**Emissions:**

| Species | Total Project Emissions (tons/year) |
|---|---|
| **Total VOC** | 0.630 |
| *Hazardous Air Pollutants* | |
| **Benzene** | 0.070 |
| **Toluene** | 0.190 |
| **Ethylbenzene** | 0.010 |
| **Xylenes** | 0.150 |
| **n-Hexane** | 0.010 |
| *Greenhouse Gases* | |
| **$CO_2$** | 0.000 |
| **$CH_4$ [a]** | 0.000 |
| **$N_2O$** | 0.000 |

Note, no greenhouse gas emissions included for dehydrator in Pinedale EIS

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | | **Base Location:** Upper Green River Basin<br>**Well Type:** Natural Gas |
|---|---|---|

**Construction Phase**

**Roadway Construction Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Light Duty Pickup Trucks: | 50 | Trips/Location | | | |
| Light Duty Haul Trucks | 0 | Trips/Location | Total Trips: | 50 | Trips |
| Heavy Duty Haul Trucks | 2 | Trips/Location | | | |
| Water Trucks | 40 | Trips/Location | Total Trips: | 42 | Trips |

* Miles and number of trips based on research and industry knowledge; please see report for additional information.

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (g/mile) * \# Trips * Trip Distance (miles)}}{\text{2000 (lb/tons)}}$$

| Construction Vehicles | Heavy Haul Trucks | | Light Duty Pickups | | Total |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 6.25E-02 | 7.39E-03 | 7.39E-03 | 6.99E-02 |
| **CO** | 1.98E-02 | 1.66E-02 | 7.26E-02 | 7.26E-02 | 8.92E-02 |
| **VOC** | 3.16E-03 | 2.65E-03 | 3.54E-03 | 3.54E-03 | 6.19E-03 |
| **SO2** | 4.57E-05 | 3.84E-05 | 2.83E-05 | 2.83E-05 | 6.67E-05 |
| **PM10** | 4.22E-03 | 3.54E-03 | 1.94E-04 | 1.94E-04 | 3.74E-03 |
| **PM2.5** | 4.09E-03 | 3.44E-03 | 1.79E-04 | 1.79E-04 | 3.61E-03 |
| **CO2** | 1.88E+00 | 1.58E+00 | 1.13E+00 | 1.13E+00 | 2.70E+00 |
| **CH4** | 7.61E-05 | 6.39E-05 | 4.56E-05 | 4.56E-05 | 1.10E-04 |
| **N2O** | 1.52E-05 | 1.28E-05 | 9.13E-06 | 9.13E-06 | 2.19E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

c Assumes maximum development scenario

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Upper Green River Basin
**Well Type:** Natural Gas

**Production Phase**
**Pneumatic Device Emissions**

**Wellsite Pneumatic Inventory:**

| | | Classification | Quantity | Emission Factor (Scf/hr/unit) |
|---|---|---|---|---|
| **Devices:** | Dump Valve | Intermittent Bleed | 4 | 13.50 |
| | Pneumatic Controller | Low Bleed | 1 | 1.39 |
| | | | 0 | 0.00 |
| **Pumps:** | Chemical Pump | Pneumatic Pump | 1 | |
| | Sandpiper | Pneumatic Pump | 1 | 13.30 |
| | Gycol Pump | Pneumatic Pump | 1 | |

Annual Equipment Run Time: 8760 Hours/Year — 379.49 Scf/lb-mol

Pneumatic Device Control:[b] 98 Percent

* Low bleed and intermittent bleed emission factors (scf/hr) based on Subpart W, Table W-1A
* Quantity of devices based on typical industry values

| Component | Mole % | Mole Weight lb/lb-mol | Dump Valve Tons/Year | Pneumatic Controller Tons/Year | (None) Tons/Year | Pneumatic Pumps Tons/Year | Total Tons/Year |
|---|---|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 8.896 | 0.229 | 0.000 | 0.131 | 9.257 |
| Ethane | 5.7920 | 30.1 | 1.085 | 0.028 | 0.000 | 0.016 | 1.129 |
| Propane | 1.3650 | 44.1 | 0.375 | 0.010 | 0.000 | 0.006 | 0.390 |
| i-Butane | 0.3700 | 58.1 | 0.134 | 0.003 | 0.000 | 0.002 | 0.139 |
| n-Butane | 0.2610 | 58.1 | 0.095 | 0.002 | 0.000 | 0.001 | 0.098 |
| i-Pentane | 0.1550 | 72.2 | 0.070 | 0.002 | 0.000 | 0.001 | 0.073 |
| n-Pentane | 0.1020 | 72.2 | 0.046 | 0.001 | 0.000 | 0.001 | 0.048 |
| Other Pentanes | 0.0000 | 70.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Hexanes | 0.1460 | 86.2 | 0.078 | 0.002 | 0.000 | 0.001 | 0.082 |
| Heptanes | 0.0930 | 100.2 | 0.058 | 0.001 | 0.000 | 0.001 | 0.060 |
| Octanes | 0.0440 | 114.2 | 0.031 | 0.001 | 0.000 | 0.000 | 0.033 |
| Nonanes | 0.0160 | 128.3 | 0.013 | 0.000 | 0.000 | 0.000 | 0.013 |
| Decanes + | 0.0050 | 142.3 | 0.004 | 0.000 | 0.000 | 0.000 | 0.005 |
| Benzene | 0.0270 | 78.1 | 0.013 | 0.000 | 0.000 | 0.000 | 0.014 |
| Toluene | 0.0190 | 92.1 | 0.011 | 0.000 | 0.000 | 0.000 | 0.011 |
| Ethylbenzene | 0.0000 | 106.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Xylenes | 0.0110 | 106.2 | 0.007 | 0.000 | 0.000 | 0.000 | 0.008 |
| n-Hexane | 0.1460 | 86.2 | 0.078 | 0.002 | 0.000 | 0.001 | 0.082 |
| Nitrogen | 0.0940 | 28.0 | 0.016 | 0.000 | 0.000 | 0.000 | 0.017 |
| Carbon Dioxide | 2.5280 | 44.0 | 0.693 | 0.018 | 0.000 | 0.010 | 0.722 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **VOC Subtotal** | 2.8 | 1492.8 | 1.01 | 0.03 | 0.00 | 0.01 | 1.06 |
| **HAPS Subtotal** | 0.2 | 546.9 | 0.11 | 0.00 | 0.00 | 0.00 | 0.11 |
| **Total** | 100.1 | 1645.0 | 11.71 | 0.30 | 0.00 | 0.17 | 12.18 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

[b] 98% control input is a result of the Wyoming Department of Environment Quality requirement, and only pertains to the Upper Green River Basin.

## APPENDIX D

## EMISSION INVENTORY FOR THE SAN JUAN BASIN GAS WELL

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** San Juan Basin
**Well Type:** Natural Gas

**Location Selection:**

| Geography: | Well Type: |
|---|---|
| San Juan Basin | Natural Gas |

- Choose geography/basin, and well type will automatically fill
  < Choose Uinta/Piceance Basin for deep gas wells with little condensate
  < Choose Upper Green River Basin for deep gas wells with dehydrators and higher condensate
  < Choose San Juan Basin for shallow gas wells with little to no condensate
  < Choose Williston Basin for deep oil wells with high gas
  < Choose Denver Basin for shallow oil wells with low gas

If the user wants to change any specifications, do so within the "Constants and References" tab, as all other tabs connect to it.

| | Total Emissions (Tons per Year) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Pollutant:** | $NO_X$ | CO | VOC | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | $CO_2$ | $CH_4$ | $N_2O$ |
| **Construction Phase:** | 0.47 | 0.29 | 0.04 | 0.0001 | 2.05 | 0.06 | 33.84 | 0.001 | 0.0003 |
| **Development Phase:** | 4.04 | 1.08 | 0.30 | 0.0002 | 4.67 | 0.14 | 561.61 | 1.05 | 0.0389 |
| **Operation Phase:** | 1.06 | 1.75 | 4.98 | 0.0008 | 0.08 | 0.27 | 56.44 | 4.99 | 0.0004 |
| **Total:** | 5.57 | 3.12 | 5.32 | 0.0010 | 6.81 | 0.48 | 651.89 | 6.05 | 0.0396 |

| | Total Emissions (Tons per Year) | | | | | |
|---|---|---|---|---|---|---|
| **Pollutant:** | Benzene | Toluene | Ethylbenzene | Xylene | n-Hexane | HAPs |
| **Construction Phase:** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Development Phase:** | 1.35 | 0.95 | 0.0000 | 0.55 | 7.31 | 10.17 |
| **Operation Phase:** | 0.03 | 0.02 | 0.00078 | 0.008 | 0.18 | 0.31 |
| **Total:** | 1.38 | 0.97 | 0.00078 | 0.56 | 7.49 | 10.48 |

| $CO_2$ equivalent (Global Warming Potential) | |
|---|---|
| **Total TPY:** | **791.23** |
| $CO_2$ equivalent conversions: | |
| $CO_2$ | 1.00 |
| $CH_4$ | 21.00 |
| $N_2O$ | 310.00 |

| $H_2S$ Emissions | |
|---|---|
| **Total TPY:** | **0.00** |

* If $H_2S$ in gas, input value in "Gas Stream Molar Ratios" tab, and potential emissions will calculate here. Current assumption is no $H_2S$ in gas stream.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Road Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 4 | Days/Location | (Typical Value) |
| | 48.0 | Dozer Hours/Location | (Typical Value) |
| | 48.0 | Backhoe Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |

$PM_{10}$ Multiplier: 0.75 * $PM_{15}$ (AP-42 Table 11.9-1, 7/98)

$PM_{2.5}$ Multiplier: 0.105 * TSP (AP-42 Table 11.9-1, 7/98)

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98 & 7/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content } \%)^{1.2} * (\text{soil moisture content } \%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content } \%)^{1.5} * (\text{soil moisture content } \%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions [a]** | | **Backhoe Emissions [a]** | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0473 | 1.97 | 0.0473 | 0.0946 |
| **$PM_{15}$** | 0.50 | 0.0120 | 0.50 | 0.0120 | 0.0241 |
| **$PM_{10}$** | 0.38 | 0.0090 | 0.38 | 0.0090 | 0.0181 |
| **$PM_{2.5}$** | 0.21 | 0.0050 | 0.05 | 0.0013 | 0.0062 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| Kleinfelder, Inc.<br>Wellsite Emissions | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Road Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Grading Length: | 6.00 | miles | (Typical Value) |
| Construction Schedule: | 3 | Days/Location | (Typical Value) |
| | 12 | Hours/Day | (Typical Value) |
| | 36 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | |
| Average Grader Speed: | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs) = $0.040 * (\text{Mean Vehicle Speed})^{2.5} * \text{Distance Graded} * \text{Control Efficiency}$

Emissions ($PM_{15}$ lbs) = $0.051 * (\text{Mean Vehicle Speed})^{2.0} * \text{Distance Graded} * \text{Control Efficiency}$

**Emissions = 16.12 lbs TSP/Location**

**Emissions = 7.71 lbs $PM_{15}$/Location**

| | Grader Construction Emissions | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 16.12 | 0.45 | 8.06E-03 |
| **$PM_{15}$** | 7.71 | 0.21 | 3.86E-03 |
| **$PM_{10}$** | 4.63 | 0.13 | 2.31E-03 |
| **$PM_{2.5}$** | 0.50 | 0.01 | 2.50E-04 |

# Kleinfelder, Inc.

**Wellsite Emissions**

**Base Location:** San Juan Basin
**Well Type:** Natural Gas

**Construction Phase**

**Well Pad Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | | |
|---|---|---|---|---|
| Construction Schedule: | 7 | Days/Location | | (Typical Value) |
| | 10 | Hours/Day | | (Typical Value) |
| | 70 | Hours/Location | (Dozer) | (Typical Value) |
| | 70 | Hours/Location | (Back Hoe) | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | | AP-42 Table 11.9-3, 7/98 |

$PM_{10}$ Multiplier: $0.75 * PM_{15}$ (AP-42 Table 11.9-1, 7/98)

$PM_{2.5}$ Multiplier: 0.105 * TSP (AP-42 Table 11.9-1, 7/98)

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content } \%)^{1.2} * (\text{soil moisture content } \%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content } \%)^{1.5} * (\text{soil moisture content } \%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | Dozer Emissions [a] | | Backhoe Emissions [a] | | Total |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0690 | 1.97 | 0.0690 | 0.14 |
| **$PM_{15}$** | 0.50 | 0.0176 | 0.50 | 0.0176 | 0.04 |
| **$PM_{10}$** | 0.38 | 0.0132 | 0.38 | 0.0132 | 0.03 |
| **$PM_{2.5}$** | 0.21 | 0.0072 | 0.21 | 0.0072 | 0.01 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Well Pad Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 4.0 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 40 | Hours/Location | (Typical Value) |
| Watering Control Efficiency | 50 | Percent (%) | (Typical Value) |
| Average Grader Speed | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| Distance Graded | 2.84 | Miles/Location | (Typical Value) |
| $PM_{10}$ Multiplier | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 7.63 lbs TSP/well pad**

**Emissions = 3.65 lbs $PM_{15}$/well pad**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 7.63 | 0.19 | 0.0038 |
| **$PM_{15}$** | 3.65 | 0.09 | 0.0018 |
| **$PM_{10}$** | 2.19 | 0.05 | 0.0011 |
| **$PM_{2.5}$** | 0.24 | 0.01 | 0.0001 |

# Kleinfelder, Inc.

## Wellsite Emissions

**Base Location:** San Juan Basin
**Well Type:** Natural Gas

**Construction Phase**

**Pipeline Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 7.0 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.75 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.105 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 7/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content } \%)^{1.2} * (\text{soil moisture content } \%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content } \%)^{1.5} * (\text{soil moisture content } \%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | Dozer Emissions [a] | | Backhoe Emissions [a] | | Total |
|---|---|---|---|---|---|
| | lbs/hr | Tons/Location | lbs/hr | Tons/Location | Tons/Location |
| **TSP** | 1.97 | 0.0690 | 1.97 | 0.0690 | 0.14 |
| **$PM_{15}$** | 0.50 | 0.0176 | 0.50 | 0.0176 | 0.04 |
| **$PM_{10}$** | 0.38 | 0.0132 | 0.38 | 0.0132 | 0.03 |
| **$PM_{2.5}$** | 0.21 | 0.0072 | 0.21 | 0.0072 | 0.01 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Pipeline Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Distance Graded: | 12.50 | Miles/Location | (Typical Value) |
| Construction Schedule: | 7 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Mean Vehicle Speed: | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for Bulldozing Overburden Emissions, Western Surface Coal Mining, 7/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 33.58 lbs TSP/well**

**Emissions = 16.07 lbs $PM_{15}$/well**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 33.58 | 0.48 | 0.0168 |
| **$PM_{15}$** | 16.07 | 0.23 | 0.0080 |
| **$PM_{10}$** | 9.64 | 0.14 | 0.0048 |
| **$PM_{2.5}$** | 1.04 | 0.01 | 0.0005 |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Roadway Construction Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Heavy Diesel Truck Trips: | | | | | |
| Road Construction: | 7 | Trips | | | |
| Well Pad Construction: | 8 | Trips | Total Trips: | 21 | Trips |
| Pipeline Construction: | 6 | Trips | | | |
| Light Duty Pickup Truck Trips: | | | | | |
| Road Construction: | 16 | Trips | | | |
| Well Pad Construction: | 28 | Trips | Total Trips: | 100 | Trips |
| Pipeline Construction: | 56 | Trips | | | |

* All assumptions above are based on typical industry values

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (lb/mile)} * \text{\# Trips} * \text{Trip Distance (miles)}}{2000 \text{ (lb/tons)}}$$

| **Construction Vehicles** | **Heavy Haul Trucks** | | **Light Duty Pickups** | | **Total** |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 3.12E-02 | 7.39E-03 | 1.48E-02 | 4.60E-02 |
| **CO** | 1.98E-02 | 8.32E-03 | 7.26E-02 | 1.45E-01 | 1.54E-01 |
| **VOC** | 3.16E-03 | 1.33E-03 | 3.54E-03 | 7.08E-03 | 8.41E-03 |
| **SO2** | 4.57E-05 | 1.92E-05 | 2.83E-05 | 5.66E-05 | 7.58E-05 |
| **PM10** | 4.22E-03 | 1.77E-03 | 1.94E-04 | 3.88E-04 | 2.16E-03 |
| **PM2.5** | 4.09E-03 | 1.72E-03 | 1.79E-04 | 3.58E-04 | 2.08E-03 |
| **CO2** | 1.88 | 0.79 | 1.13 | 2.25 | 3.04 |
| **CH4** | 7.61E-05 | 3.19E-05 | 4.56E-05 | 9.13E-05 | 1.23E-04 |
| **N2O** | 1.52E-05 | 6.39E-06 | 9.13E-06 | 1.83E-05 | 2.46E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

| **Kleinfelder, Inc.** | **Base Location:** San Juan Basin |
|---|---|
| **Wellsite Emissions** | **Well Type:** Natural Gas |

**Construction Phase**

**Construction Heavy Equipment Tailpipe Emissions**

**Assumptions:**

Fuel and Engine:

| | | | |
|---|---|---|---|
| Brake Specific Fuel Consumption, Avg. (BSFC) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel Higher Heating Value (HHV) | 0.138 | mmBtu/Gallon | (Typical Value) |

Trackhoe:

| | | |
|---|---|---|
| Working Hours | 188 | Total Hours (Typical Value) |
| Rated Horsepower | 100 | (Estimate) |
| Load Factor | 0.59 | (Default LF from NONROAD model for Tractors/Loaders/Backhoes) |

Dozer:

| | | |
|---|---|---|
| Working Hours | 188 | Total Hours (Typical Value) |
| Rated Horsepower | 140 | (Estimate) |
| Load Factor | 0.59 | (Default LF from NONROAD model for Crawler Tractor/Dozers) |

Grader:

| | | |
|---|---|---|
| Working Hours | 130 | Total Hours (Typical Value) |
| Rated Horsepower | 250 | (Estimate) |
| Load Factor | 0.59 | (Default LF from NONROAD model for Graders) |

| | | | |
|---|---|---|---|
| Total Horsepower Hours: | 45795.8 | Hp-hrs | (Sum of all horsepower above) |
| Total Fuel Usage: | 2737.79 | Gallons Diesel Fuel | |

**Equations:**

Total Fuel Usage: ((btu-hp-hr * hp-hrs) / Mmbtu-gal) / 1,000,000

$$\text{Emissions (tons/year/pad)} = \frac{\text{Emission Factor (g/mile) * Trip Distance (miles) * Load Factor}}{\text{453.6 (g/lb) * 2000 (lb/tons)}}$$

| Heavy Const. Vehicles | Backhoe | | | Dozer | | | Grader | | |
|---|---|---|---|---|---|---|---|---|---|
| | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) |
| **NOx** | 8.38 | 1.09E+00 | 1.02E-01 | 8.38 | 1.53E+00 | 1.43E-01 | 8.38 | 2.72E+00 | 1.77E-01 |
| **CO** | 2.7 | 3.51E-01 | 3.30E-02 | 2.7 | 4.92E-01 | 4.62E-02 | 2.7 | 8.78E-01 | 5.71E-02 |
| **VOC [b]** | 0.68 | 8.84E-02 | 8.31E-03 | 0.68 | 1.24E-01 | 1.16E-02 | 0.68 | 2.21E-01 | 1.44E-02 |
| **$PM_{10}$** | 0.39 | 5.07E-02 | 4.77E-03 | 0.39 | 7.10E-02 | 6.68E-03 | 0.39 | 1.27E-01 | 8.24E-03 |
| **$PM_{2.5}$** | 0.39 | 5.07E-02 | 4.77E-03 | 0.39 | 7.10E-02 | 6.68E-03 | 0.39 | 1.27E-01 | 8.24E-03 |

| Heavy Const. Vehicles | Total Emissions [c] (tons/yr) |
|---|---|
| **NOx** | 0.42 |
| **CO** | 0.14 |
| **VOC** | 0.03 |
| **$PM_{10}$** | 0.02 |
| **$PM_{2.5}$** | 0.02 |

**Greenhouse Gas Emissions:**

| | Diesel EF kg/mmbtu | Emissions lbs | Emissions Tons |
|---|---|---|---|
| $CO_2$ | 73.96 | 61604.19 | 30.80 |
| $CH_4$ | 0.003 | 2.50 | 0.0012 |
| $N_2O$ | 0.0006 | 0.50 | 0.0002 |

a From Table A-4 of Exhaust and Crankcase Emission Factors for NONROAD Engine Modeling - Compression Ignition, EPA-420-R-10-018, July 2010.

b Emission Factor represents total Hydrocarbon Emissions

c Converted from emission factor for Distillate Fuel Oil #2 (diesel) as listed in Table C-1 to Subpart C of Part 98 - Default Emission Factors and High Heat Values for Various Types of Fuel.

Listed Factor:

73.96 kg $CO_2$/mmBtu
393 hp-hr = mmBtu
188.2 g $CO_2$/hp-hr

| **Kleinfelder, Inc.** **Wellsite Emissions** | **Base Location:** San Juan Basin **Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Wind Erosion Fugitive Dust**

**Assumptions:**

Threshold Friction Velocity ($U_t$) 1.02 m/s (2.28 mph) for well pads (AP-42 Table 13.2.5-2 Overburden - Western Surface Coal Mine)
1.33 m/s (2.97 mph) for roads (AP-42 Table 13.2.5-2 Roadbed material)

Initial Disturbance Area

| | | | |
|---|---|---|---|
| Total Access Road/ROW Area Per Location: | 976,800 | Square Meters | (Typical Value) |
| Total Well Pad Area Disturbed Per Location: | 50,000 | Square Meters | (Typical Value) |
| Total Area Disturbed Per Location: | 1,026,800 | Square Meters | (Typical Value) |
| Exposed Surface Type | Flat | | |
| Meteorological Data | 2002 Grand Junction (obtained from NCDC website) | | |
| Fastest Mile Wind Speed: | 45 | miles/hour | (Typical Value) |
| Fastest Mile Wind Speed ($U_{10}^{+}$) | 20.12 | meters/sec (45 mph) reported as fastest 2-minute wind speed for Grand Junction (2002) | |
| Number soil of disturbances | 1.00 | for well pads (Assumption, disturbance at construction and reclamation) constant for dirt roads | |

**Equations (AP-42 13.2.5.2 Industrial Wind Erosion)**

Friction Velocity $U^* = 0.053\ U_{10}^{+}$

Erosion Potential P (g/m$^2$/period) = $58*(U^*-U_t^*)^2 + 25*(U^*-U_t^*)$ for $U^*>U_t^*$, $P = 0$ for $U^*< U_t^*$

Emissions (tons/year) = Erosion Potential(g/m$^2$/period)*Disturbed Area(m$^2$)*Disturbances/year*(k)/(453.6 g/lb)/2000 lbs/ton/Develop Period

| **Particle Size Multiplier (k)** | | |
|---|---|---|
| **30 µm** | **<10 µm** | **<2.5 µm** |
| 1.0 | 0.5 | 0.075 |

| **Maxium $U_{10}^{+}$ Wind Speed (m/s)** | **Maximum U* Friction Velocity m/s** | **Well $U_t$* Threshold Velocity[a] m/s** | **Well Pad Erosion Potential g/m$^2$** | **Road $U_t$* Threshold Velocity[a] m/s** | **Road Erosion Potential g/m$^2$** |
|---|---|---|---|---|---|
| 20.12 | 1.07 | 1.02 | 1.28 | 1.33 | 0.00 |

**Wind Erosion Emissions**

| **Particulate Species** | **Well Pad (tons/year)** | **Roads/Pipelines (tons/year)** |
|---|---|---|
| TSP | 7.05E-02 | 0.00E+00 |
| $PM_{10}$ | 3.52E-02 | 0.00E+00 |
| $PM_{2.5}$ | 5.28E-03 | 0.00E+00 |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction, Development, and Production Phase**

**Construction, Development, and Operations Traffic Fugitive Dust Emissions**

**Assumptions:**

| | |
|---|---|
| Round Trip Miles | 40 |
| Round Trip (Paved) Miles | 16 |
| Round Trip (Un-Paved) Miles | 24 |
| Precipitation Days (P) | 35 |

Unpaved Calculation AP-42, Chapter 13.2.2
November 2006

$E (PM_{10}) / VMT = 1.5 * (S/12)^{0.9} * (W/3)^{0.45} * (365-p)/365)$

$E (PM_{2.5}) / VMT = 0.15 * (S/12)^{0.9} + (W/3)^{0.45} * (365-p)/365)$

Silt Content (S) 8.5 AP 42 13.2.2-1 Mean Silt Content Construction Sites

Paved Calculation AP-42, Chapter 13.2.1
January 2011

$E (PM_{10}) / VMT = 0.0022 * (sL)^{0.91} * (W)^{1.02} * (1-(P/(365*4))$

$E (PM_{2.5}) / VMT = 0.00054 * (sL)^{0.91} * (W)^{1.02} * (1-(P/(365*4))$

Silt Loading (sL) 0.6 AP-42 Table 13.2.1-2 baseline low volume roads

**Construction Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | $PM_{10}$ (lb/VMT) | $PM_{10}$ (lbs) | $PM_{10}$ (Tons) | $PM_{2.5}$ (lb/VMT) | $PM_{2.5}$ (lbs) | $PM_{2.5}$ (Tons) |
|---|---|---|---|---|---|---|---|---|
| Heavy Duty Haul Trucks | 80,000 | 21 | 3.19 | 1607.6 | 0.8 | 0.3 | 160.8 | 0.1 |
| Light Duty Pickup Trucks | 5,000 | 100 | 0.92 | 2198.4 | 1.1 | 0.1 | 219.8 | 0.1 |
| **Total:** | | | | **3806.00** | **1.90** | | **380.60** | **0.19** |

**Paved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| Heavy Duty Haul Trucks | 80,000 | 21 | 0.0580 | 19.5 | 0.0098 | 0.014 | 4.8 | 0.0024 |
| Light Duty Pickup Trucks | 5,000 | 100 | 0.0034 | 5.5 | 0.0027 | 0.001 | 1.3 | 0.0007 |
| **Total:** | | | | **25.0** | **0.0** | | **6.1** | **0.0** |

**Development Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | $PM_{10}$ (lb/VMT) | $PM_{10}$ (lbs) | $PM_{10}$ (Tons) | $PM_{2.5}$ (lb/VMT) | $PM_{2.5}$ (lbs) | $PM_{2.5}$ (Tons) |
|---|---|---|---|---|---|---|---|---|
| Light Duty Pickup Trucks: | 5,000 | 84 | 0.92 | 1846.7 | 0.9 | 0.1 | 184.7 | 0.1 |
| Light Duty Haul Trucks | 7,500 | 11 | 1.10 | 290.2 | 0.1 | 0.1 | 29.0 | 0.0 |
| Heavy Duty Haul Trucks | 80,000 | 67 | 3.19 | 5129.0 | 2.6 | 0.3 | 512.9 | 0.3 |
| Water Trucks | 70,000 | 24 | 3.00 | 1730.1 | 0.9 | 0.3 | 173.0 | 0.1 |
| **Total:** | | | | **8996.02** | **4.50** | | **899.60** | **0.45** |

**Paved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Light Duty Pickup Trucks:** | 5000 | 84 | 0.00 | 4.6 | 0.0 | 0.0 | 1.1 | 0.0006 |
| **Light Duty Haul Trucks** | 7500 | 11 | 0.01 | 0.9 | 0.0 | 0.0 | 0.2 | 0.0001 |
| **Heavy Duty Haul Trucks** | 80000 | 67 | 0.06 | 62.2 | 0.0 | 0.0 | 15.3 | 0.0076 |
| **Water Trucks** | 70,000 | 24 | 0.05 | 19.5 | 0.0 | 0.0 | 4.8 | 0.0024 |
| **Total:** | | | | **87.2** | **0.0** | | **21.4** | **0.0** |

**Production Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| Light Duty Pickup Trucks: | 5,000 | 50 | 0.92 | 1099.20 | 0.55 | 0.0916 | 109.92 | 0.0550 |
| Light Duty Haul Trucks | 7,500 | 0 | 1.10 | 0.00 | 0.00 | 0.1099 | 0.00 | 0.0000 |
| Heavy Duty Haul Trucks | 80,000 | 2 | 3.19 | 153.11 | 0.08 | 0.3190 | 15.31 | 0.0077 |
| Water Trucks | 70,000 | 40 | 3.00 | 2883.52 | 1.44 | 0.3004 | 288.35 | 0.1442 |
| **Total:** | | | | **4135.83** | **2.07** | | **413.58** | **0.21** |

**Paved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| **Light Duty Pickup Trucks:** | 5,000 | 50 | 0.00 | 2.75 | 0.0014 | 0.0008 | 0.67 | 0.0003 |
| **Light Duty Haul Trucks** | 7,500 | 0 | 0.01 | 0.00 | 0.0000 | 0.0013 | 0.00 | 0.0000 |
| **Heavy Duty Haul Trucks** | 80,000 | 2 | 0.06 | 1.86 | 0.0009 | 0.0142 | 0.46 | 0.0002 |
| **Water Trucks** | 70,000 | 40 | 0.05 | 32.42 | 0.0162 | 0.0124 | 7.96 | 0.0040 |
| **Total:** | | | | **37.02** | **0.02** | | **9.09** | **0.00** |

**Annual Total**

| | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|
| **Unpaved Roads (tons)** | **8.47** | **0.8** |
| **Paved Roads** | **0.1** | **0.0** |
| **Total:** | **8.5** | **0.9** |

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** San Juan Basin
**Well Type:** Natural Gas

**Development Phase**
**Drill Rig Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 12 | (Typical Value) |
| Hours of Operation | 288 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

| Engine | HP [a] | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Vertical Drill Rig Engine | 550 | 0.42 | 96 | 22176 |
| Horizontal Drill Rig Engine | 2,100 | 0.60 | 192 | 241920 |
| Drill Rig Generator | 350 | 0.42 | 288 | 42336 |
| Trailers Generator | 150 | 0.42 | 288 | 18144 |
| Air Compressor | 550 | 0.42 | 96 | 22176 |
| Air Compressor | 550 | 0.42 | 96 | 22176 |
| Air Compressor Booster | 650 | 0.42 | 96 | 26208 |
| Forklift | 120 | 0.42 | 96 | 4838.4 |
| Aerial Lift | 50 | 0.42 | 12 | 252 |
| Frontend loader | 150 | 0.42 | 12 | 756 |
| Dozer | 175 | 0.42 | 6 | 441 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| Total HP | 5,395 | | | |

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 539991.94 | 270.00 |
| CH4 | 0.003 | 21.90 | 0.01 |
| N2O | 0.0006 | 4.38 | 0.00 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

Total: 401,423 Hp-hrs

Fuel Usage: 23,998 Gallons of Diesel Total Fuel Usage: (btu/hp-hr * hp-hrs) * gal/btu

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu) | Xylenes (lb/mmBtu) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Drill Rig Engine | 22176 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Horizontal Drill Rig Engine | 241920 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Drill Rig Generator | 42336 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Trailers Generator | 18144 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 22176 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 22176 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor Booster | 26208 | 1.3272 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Forklift | 4838.4 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Aerial Lift | 252 | 3.4900 | 8.3800 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frontend loader | 756 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Dozer | 441 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Drill Rig Engine | | 0.02059 | 0.10597 | 0.00322 | 0.00312 | 3.10E-07 | 0.00400 | 0.00007 | 0.00003 | 0.00002 |
| Horizontal Drill Rig Engine | | 0.20379 | 1.09335 | 0.03509 | 0.03404 | 3.39E-06 | 0.04363 | 0.00077 | 0.00028 | 0.00019 |
| Drill Rig Generator | | 0.12600 | 0.39107 | 0.01876 | 0.01820 | 5.93E-07 | 0.03173 | 0.00014 | 0.00005 | 0.00003 |
| Trailers Generator | | 0.05400 | 0.16760 | 0.00804 | 0.00780 | 2.54E-07 | 0.01360 | 0.00006 | 0.00002 | 0.00001 |
| Air Compressor | | 0.02059 | 0.10597 | 0.00322 | 0.00312 | 3.10E-07 | 0.00400 | 0.00007 | 0.00003 | 0.00002 |
| Air Compressor | | 0.02059 | 0.10597 | 0.00322 | 0.00312 | 3.10E-07 | 0.00400 | 0.00007 | 0.00003 | 0.00002 |
| Air Compressor Booster | | 0.03834 | 0.11845 | 0.00380 | 0.00369 | 3.67E-07 | 0.00473 | 0.00008 | 0.00003 | 0.00002 |
| Forklift | | 0.01440 | 0.04469 | 0.00214 | 0.00208 | 6.77E-08 | 0.00363 | 0.00002 | 0.00001 | 0.00000 |
| Aerial Lift | | 0.00097 | 0.00233 | 0.00020 | 0.00019 | 3.53E-09 | 0.00028 | 0.00000 | 0.00000 | 0.00000 |
| Frontend loader | | 0.00225 | 0.00698 | 0.00034 | 0.00032 | 1.06E-08 | 0.00057 | 0.00000 | 0.00000 | 0.00000 |
| Dozer | | 0.00131 | 0.00407 | 0.00020 | 0.00019 | 6.17E-09 | 0.00033 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.50285** | **2.14646** | **0.07822** | **0.07588** | **0.00001** | **0.11048** | **0.00128** | **0.00047** | **0.00032** |

**Emission Factors**

- Drill rig emission factors based on Tier II engines
- All other engine emission factors based on Tier 0 engines (typical values)
- HAP emission factors from AP-42 Volume I, Large Stationary Diesel Engines Table 3.4-3

**Calculations:**

ton/year: (Total hp-hr * g/hp-hr) * lb-gram / lb-ton

*** Drill rig horsepower developed based on:**

1 Williston Basin: 2,100 from Jonah, Wyoming RMP
2 San Juan Basin: 2,100 from River Valley RMI
3 Upper Green River Basin: 2,100 from Jonah, Wyoming RMP
4 Denver Basin: 2,950 from River Valley RMI
5 Uintah Basin: 2,952 from River Valley RMI

Note, runtime for each drilling event is based on research and industry experience dependent upon each basi

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** San Juan Basin
**Well Type:** Natural Gas

**Development Phase**
**Conductor Pipe Set Emissions**

**Assumptions:**

| Parameter | Value |
|---|---|
| Days of Operation | 2 |
| Hours of Operation | 24 |
| Diesel Fuel Sulfur Content | 0.000015 |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

Workovers:

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Rig Engine | 350 | 0.42 | 24 | 3528 |
| Rig Generator | 50 | 0.42 | 24 | 504 |

Total Horsepower: 400

Total: 4,032 Hp-hrs

Fuel Usage: 241 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

**Greenhouse Gases:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 5423.82 | 2.71 |
| CH4 | 0.003 | 0.22 | 0.00 |
| N2O | 0.0006 | 0.04 | 0.00 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu | Xylenes (lb/mmBtu |
|---|---|---|---|---|---|---|---|---|---|---|
| Rig Engine | 3528 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 0.0008 | 0.0003 | 0.0002 |
| Rig Generator | 504 | 5.0000 | 6.9000 | 0.8000 | 0.7760 | 1.27E-05 | 1.8000 | 0.0008 | 0.0003 | 0.0002 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Rig Engine | | 0.00328 | 0.01686 | 0.00051 | 0.00050 | 0.00000 | 0.00064 | 0.00001 | 0.00000 | 0.00000 |
| Rig Generator | | 0.00278 | 0.00383 | 0.00044 | 0.00043 | 0.00000 | 0.00100 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.00605** | **0.02069** | **0.00096** | **0.00093** | **0.00000** | **0.00164** | **0.00001** | **0.00000** | **0.00000** |

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

* Rig engine emission rates are based on a Tier II engine and rig generator emission rates are based on a Tier 0 engine.
* All days, hours, and HP values above are based on typical industry values

| Kleinfelder, Inc. | |
|---|---|
| **Wellsite Emissions** | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |

**Development Phase**

**Well Fracturing Engine Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 3 | (Typical Value) |
| Hours of Operation | 72 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Frac Pump | 1,500 | 0.59 | 72 | 63720 |
| Frac Pump | 1,500 | 0.59 | 72 | 63720 |
| Frac Pump | 1,500 | 0.59 | 72 | 63720 |
| Frac Pump | 1,500 | 0.59 | 72 | 63720 |
| Frac Pump | 1,500 | 0.59 | 72 | 63720 |
| Blenders | 500 | 0.42 | 4 | 840 |
| Auxilary Pump | 200 | 0.42 | 4 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Generator | 150 | 0.42 | 72 | 4536 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 437166.20 | 218.58 |
| CH4 | 0.003 | 17.73 | 0.01 |
| N2O | 0.0006 | 3.55 | 0.00 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

Total: 324,984 Hp-hrs

Fuel Usage: 19,428 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu) | Xylenes (lb/mmBtu) |
|---|---|---|---|---|---|---|---|---|---|---|
| Frac Pump | 63720 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 63720 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 63720 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 63720 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 63720 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Blenders | 840 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Auxilary Pump | 336 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Generator | 4536 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Frac Pump | | 0.05368 | 0.28798 | 0.00924 | 0.00897 | 8.92E-07 | 0.01149 | 0.00020 | 0.00007 | 0.00005 |
| Frac Pump | | 0.05368 | 0.28798 | 0.00924 | 0.00897 | 8.92E-07 | 0.01149 | 0.00020 | 0.00007 | 0.00005 |
| Frac Pump | | 0.05368 | 0.28798 | 0.00924 | 0.00897 | 8.92E-07 | 0.01149 | 0.00020 | 0.00007 | 0.00005 |
| Frac Pump | | 0.05368 | 0.28798 | 0.00924 | 0.00897 | 8.92E-07 | 0.01149 | 0.00020 | 0.00007 | 0.00005 |
| Frac Pump | | 0.05368 | 0.28798 | 0.00924 | 0.00897 | 8.92E-07 | 0.01149 | 0.00020 | 0.00007 | 0.00005 |
| Blenders | | 0.00078 | 0.00401 | 0.00012 | 0.00012 | 1.18E-08 | 0.00015 | 0.00000 | 0.00000 | 0.00000 |
| Auxilary Pump | | 0.00100 | 0.00310 | 0.00015 | 0.00014 | 4.70E-09 | 0.00025 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Generator | | 0.01745 | 0.04150 | 0.00361 | 0.00350 | 6.35E-08 | 0.00495 | 0.00001 | 0.00001 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.29020** | **1.49467** | **0.05063** | **0.04911** | **0.00000** | **0.06354** | **0.00104** | **0.00038** | **0.00026** |

**Emission Factors**

- Frac pump emission factors based on Tier II engines (typical values)
- All other engine emission factors based on Tier 0 engines (typical values)

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Development Phase**

**Hydraulic Fracturing Flowback Emissions**

**Assumptions:**

| | | | |
|---|---|---|---|
| **Estimated Frac flowback Rate:** | 10,000 | Scf/hr | |
| **Combustion Efficiency:** | 95.00 | Percent (%) | |
| **Event Duration:** | 100.00 | Hours | |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* Venting duration based on research and industry knowledge; please see report for additional information.
* Venting control based on Subpart OOOO requirements of 95% minimum control.
Control efficiency can be deleted if applicable.

**Equations:**

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf/lb-mol)) * hrs/yr
** Multiply above equation by 0.02 if including 98% control efficiency

**Un-combusted Componet Emissions:**

| Component | Mole % [a] | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 444.86 | 18.81 | 0.94 |
| Ethane | 5.7920 | 30.1 | 28.96 | 2.29 | 0.11 |
| Propane | 1.3650 | 44.1 | 6.83 | 0.79 | 0.04 |
| i-Butane | 0.3700 | 58.1 | 1.85 | 0.28 | 0.01 |
| n-Butane | 0.2610 | 58.1 | 1.31 | 0.20 | 0.01 |
| i-Pentane | 0.1550 | 72.2 | 0.78 | 0.15 | 0.01 |
| n-Pentane | 0.1020 | 72.2 | 0.51 | 0.10 | 0.00 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 0.73 | 0.17 | 0.01 |
| Heptanes | 0.0930 | 100.2 | 0.47 | 0.12 | 0.01 |
| Octanes | 0.0440 | 114.2 | 0.22 | 0.07 | 0.00 |
| Nonanes | 0.0160 | 128.3 | 0.08 | 0.03 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 0.03 | 0.01 | 0.00 |
| Benzene | 0.0270 | 78.1 | 0.14 | 0.03 | 0.00 |
| Toluene | 0.0190 | 92.1 | 0.10 | 0.02 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 0.06 | 0.02 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 0.73 | 0.17 | 0.01 |
| Nitrogen | 0.0940 | 28.0 | 9.40 | 0.69 | 0.03 |
| Carbon Dioxide | 2.5280 | 44.0 | 252.80 | 29.32 | 1.47 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |
| **VOC Subtotal** | 2.7600 | 1492.8 | 13.80 | 2.14 | 0.11 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 1.02 | 0.23 | 0.01 |
| **Total** | 100.1460 | 1645.0 | 749.82 | 53.26 | 2.66 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 8452.34 | 980.23 | 49.01 |
| C2 | 5.79 | 550.24 | 63.81 | 3.19 |
| C3 | 1.37 | 129.68 | 15.04 | 0.75 |
| C4 | 0.63 | 59.95 | 6.95 | 0.35 |
| C5+ | 0.76 | 72.58 | 8.42 | 0.42 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **53.72** | **Tons/Event** |
| **$N_2O$ Emissions:** | **1.13E-04** | **Tons/Event** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.37 | 3.80 | 0.19 | AP-42 CH13.5-1 |
| NOx | 0.068 | 0.70 | 0.03 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.00 | *Based on $H2_S$ 34 mol weight and $SO_2$ 64 mol weight |

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** San Juan Basin
**Well Type:** Natural Gas

**Development Phase**
**Workover Cementing Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 2 | (Typical Value) |
| Hours of Operation | 24 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8500 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

Workovers/Cementing:

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Coil Tubing Unit | 550 | 0.42 | 24 | 5544 |
| Circulation Pump | 450 | 0.42 | 24 | 4536 |
| Cement Pump Trucks | 500 | 0.42 | 8 | 1680 |

Total Horsepower: 1,500 (Typical Value)

Total: 11,760 Hp-hrs

Fuel Usage: 724 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| $CO_2$ | 73.96 | 16298.85 | 8.15 |
| $CH_4$ | 0.003 | 0.66 | 0.00 |
| $N_2O$ | 0.0006 | 0.13 | 0.00 |

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Formaldehyde (lb/mmBtu) | Toulene (lb/mmBtu | Xylenes (lb/mmBtu |
|---|---|---|---|---|---|---|---|---|---|---|
| Coil Tubing Unit | 5544 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 0.1636 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |
| Circulation Pump | 4536 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 0.1636 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |
| Cement Pump Trucks | 1680 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 0.6800 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Formaldehyde (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Coil Tubing Unit | | 0.00515 | 0.02649 | 0.00080 | 0.00078 | 0.00100 | 0.00002 | 0.00000 | 0.00001 | 0.00000 |
| Circulation Pump | | 0.00421 | 0.02168 | 0.00066 | 0.00064 | 0.00082 | 0.00001 | 0.00000 | 0.00001 | 0.00000 |
| Cement Pump Trucks | | 0.00500 | 0.01552 | 0.00074 | 0.00072 | 0.00126 | 0.00001 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.01436** | **0.06369** | **0.00221** | **0.00214** | **0.00308** | **0.00004** | **0.00000** | **0.00001** | **0.00001** |

**Emission Factors**

- Engine emission factors based on Tier II engines (typical values)

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

## Kleinfelder, Inc.
### Wellsite Emissions

**Base Location:** San Juan Basin
**Well Type:** Natural Gas

**Development Phase**
**Well Venting During Workover Events**

**Assumptions:**

Significant gas venting only occurs on natural gas wells.

| | | | |
|---|---|---|---|
| **Estimated Venting Rate:** | 5,000 | Scf/Event | (Typical Value) |
| **Combustion Efficiency:** | 0.00 | Percent (%) | |
| **Event Quantity:** | 1.00 | Event | - Assumed one event |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* Vented quantity based on research and industry knowledge; please see report for additional information.

**Equations:**

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf-lb-mol))
** Multiply above equation by 0.02 if including 98% control efficiency

| Component | Mole % | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Event |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 4448.60 | 188.07 | 0.0940 |
| Ethane | 5.7920 | 30.1 | 289.60 | 22.95 | 0.0115 |
| Propane | 1.3650 | 44.1 | 68.25 | 7.93 | 0.0040 |
| i-Butane | 0.3700 | 58.1 | 18.50 | 2.83 | 0.0014 |
| n-Butane | 0.2610 | 58.1 | 13.05 | 2.00 | 0.0010 |
| i-Pentane | 0.1550 | 72.2 | 7.75 | 1.47 | 0.0007 |
| n-Pentane | 0.1020 | 72.2 | 5.10 | 0.97 | 0.0005 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.0000 |
| Hexanes | 0.1460 | 86.2 | 7.30 | 1.66 | 0.0008 |
| Heptanes | 0.0930 | 100.2 | 4.65 | 1.23 | 0.0006 |
| Octanes | 0.0440 | 114.2 | 2.20 | 0.66 | 0.0003 |
| Nonanes | 0.0160 | 128.3 | 0.80 | 0.27 | 0.0001 |
| Decanes + | 0.0050 | 142.3 | 0.25 | 0.09 | 0.0000 |
| Benzene | 0.0270 | 78.1 | 1.35 | 0.28 | 0.0001 |
| Toluene | 0.0190 | 92.1 | 0.95 | 0.23 | 0.0001 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.0000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.0000 |
| Xylenes | 0.0110 | 106.2 | 0.55 | 0.15 | 0.0001 |
| n-Hexane | 0.1460 | 86.2 | 7.30 | 1.66 | 0.0008 |
| Nitrogen | 0.0940 | 28.0 | 4.70 | 0.35 | 0.0002 |
| Carbon Dioxide | 2.5280 | 44.0 | 126.40 | 14.66 | 0.0073 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.0000 |

| | | | | | |
|---|---|---|---|---|---|
| **VOC Subtotal** | 2.7600 | 1492.8 | 138.00 | 21.44 | 0.0107 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 10.15 | 2.32 | 0.0012 |
| **Total** | 100.1460 | 1645.0 | 5007.30 | 247.46 | 0.1237 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed thatthe representative average gas analyses used by the River Valley RMP. was a good representative analyses of general gas wells.

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 0.00 | 0.00 | 0.00 |
| C2 | 5.79 | 0.00 | 0.00 | 0.00 |
| C3 | 1.37 | 0.00 | 0.00 | 0.00 |
| C4 | 0.63 | 0.00 | 0.00 | 0.00 |
| C5+ | 0.76 | 0.00 | 0.00 | 0.00 |

**$CO_2$ Total Emissions:** **0.00** **Tons/Event**
**$N_2O$ Emissions:** **5.67E-07** **Tons/Event**

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.00 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| NOx | 0.000 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.000 | *Based on $H2_S$ 34 mol weight and $SO_2$ 64 mol weight |

| Kleinfelder, Inc. | | Base Location: San Juan Basin |
|---|---|---|
| Wellsite Emissions | | Well Type: Natural Gas |

**Development Phase**

**Wellsite Development Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Light Duty Pickup Trucks: | 84 | Trips/Location | | | |
| Light Duty Haul Trucks | 11 | Trips/Location | Total Trips: | 95 | Trips |
| Heavy Duty Haul Trucks | 67 | Trips/Location | | | |
| Water Trucks | 24 | Trips/Location | Total Trips: | 91 | Trips |

* Miles and number of trips based on research and industry knowledge; please see report for additional information.

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (lb/mile)} * \text{\# Trips} * \text{Trip Distance (miles)}}{2000 \text{ (lb/tons)}}$$

| Construction Vehicles | Heavy Haul Trucks | | Light Duty Pickups | | Total |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 1.35E-01 | 1.98E-02 | 1.41E-01 | 2.77E-01 |
| **CO** | 1.98E-02 | 3.60E-02 | 3.16E-03 | 3.76E-02 | 7.37E-02 |
| **VOC** | 3.16E-03 | 5.75E-03 | 4.57E-05 | 6.00E-03 | 1.18E-02 |
| **SO2** | 4.57E-05 | 8.32E-05 | 4.22E-03 | 8.68E-05 | 1.70E-04 |
| **PM10** | 4.22E-03 | 7.68E-03 | 4.09E-03 | 8.02E-03 | 1.57E-02 |
| **PM2.5** | 4.09E-03 | 7.44E-03 | 1.88E+00 | 7.77E-03 | 1.52E-02 |
| **CO2** | 1.88E+00 | 3.41E+00 | 7.61E-05 | 3.56E+00 | 6.98E+00 |
| **CH4** | 7.61E-05 | 1.38E-04 | 1.52E-05 | 1.45E-04 | 2.83E-04 |
| **N2O** | 1.52E-05 | 2.77E-05 | 0.00E+00 | 2.89E-05 | 5.66E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite for calendar year 2012.

c Assumes maximum development scenario

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Development Phase**

**Wellhead Gas Combustion**

**Wellhead gas combustion only for Williston Basin wells, due to the regularity of of pit flares combusting all gas coming from the wellhead. If gas being captured, change scf/hr value or hours of event value.

**Assumptions:**

| | | | |
|---|---|---|---|
| **Estimated Gas Flow Rate:** | 0 | Scf/hr | |
| **Combustion Efficiency:** | 0.00 | Percent (%) | |
| **Event Duration:** | 0.00 | Hours | - Estimated 3 months before sales line |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* It is assumed that all produced natural gas is sent to a sales line after the well is completed.

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf/lb-mol)) * hrs/yr

** Multiply above equation by 0.05 if including 95% control efficiency

**Combusted Componet Emissions:**

| Component | Mole % [a] | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 0.00 | 0.00 | 0.00 |
| Ethane | 5.7920 | 30.1 | 0.00 | 0.00 | 0.00 |
| Propane | 1.3650 | 44.1 | 0.00 | 0.00 | 0.00 |
| i-Butane | 0.3700 | 58.1 | 0.00 | 0.00 | 0.00 |
| n-Butane | 0.2610 | 58.1 | 0.00 | 0.00 | 0.00 |
| i-Pentane | 0.1550 | 72.2 | 0.00 | 0.00 | 0.00 |
| n-Pentane | 0.1020 | 72.2 | 0.00 | 0.00 | 0.00 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 0.00 | 0.00 | 0.00 |
| Heptanes | 0.0930 | 100.2 | 0.00 | 0.00 | 0.00 |
| Octanes | 0.0440 | 114.2 | 0.00 | 0.00 | 0.00 |
| Nonanes | 0.0160 | 128.3 | 0.00 | 0.00 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 0.00 | 0.00 | 0.00 |
| Benzene | 0.0270 | 78.1 | 0.00 | 0.00 | 0.00 |
| Toluene | 0.0190 | 92.1 | 0.00 | 0.00 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 0.00 | 0.00 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 0.00 | 0.00 | 0.00 |
| Nitrogen | 0.0940 | 28.0 | 0.00 | 0.00 | 0.00 |
| Carbon Dioxide | 2.5280 | 44.0 | 0.00 | 0.00 | 0.00 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |
| **VOC Subtotal** | 2.7600 | 1492.8 | 0.00 | 0.00 | 0.00 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 0.00 | 0.00 | 0.00 |
| **Total** | 100.1460 | 1645.0 | 0.00 | 0.00 | 0.00 |

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 0.00 | 0.00 | 0.00 |
| C2 | 5.79 | 0.00 | 0.00 | 0.00 |
| C3 | 1.37 | 0.00 | 0.00 | 0.00 |
| C4 | 0.63 | 0.00 | 0.00 | 0.00 |
| C5+ | 0.76 | 0.00 | 0.00 | 0.00 |

**$CO_2$ Total Emissions:** **0.00** **Tons/Year**

**$N_2O$ Emissions:** **0.00E+00** **Tons/Year**

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.00 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| NOx | 0.000 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.00 | *Based on $H_2S$ 34 mol weight and $SO_2$ 64 mol weight |

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** San Juan Basin
**Well Type:** Natural Gas

**Production Phase**

**Production Equipment Fugitive Component Emissions**

**Assumptions:**

Components Counts:

| | Fugitive Components | | | | |
|---|---|---|---|---|---|
| **Component *** | Valves | Connectors | OE Lines | PR Valves | |
| **Count** | 59 | 193 | 8 | 3 | 0 |
| **Emissions Factor (scf/hr)** [b] | 0.121 | 0.017 | 0.031 | 0.193 | 0.000 |

* Fugitive component counts for natural gas wells from Subpart W, Table W-1B
* Fugitive component counts for oil wells from Subpart W, Table W-1C

Annual Equipment Run Time: 8760 Hours/Year 379.49 Scf/lb-mol

| Component | Mole % [a] | Mole Weight lb/lb-mol | Emissions Scf/Year [b] | Emissions lbs/Year | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 87,658.5 | 3,705.8 | 1.85 |
| Ethane | 5.7920 | 30.1 | 5,706.5 | 452.2 | 0.23 |
| Propane | 1.3650 | 44.1 | 1,344.8 | 156.3 | 0.08 |
| i-Butane | 0.3700 | 58.1 | 364.5 | 55.8 | 0.03 |
| n-Butane | 0.2610 | 58.1 | 257.1 | 39.4 | 0.02 |
| i-Pentane | 0.1550 | 72.2 | 152.7 | 29.0 | 0.01 |
| n-Pentane | 0.1020 | 72.2 | 100.5 | 19.1 | 0.01 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 143.8 | 32.7 | 0.02 |
| Heptanes | 0.0930 | 100.2 | 91.6 | 24.2 | 0.01 |
| Octanes | 0.0440 | 114.2 | 43.4 | 13.0 | 0.01 |
| Nonanes | 0.0160 | 128.3 | 15.8 | 5.3 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 4.9 | 1.8 | 0.00 |
| Benzene | 0.0270 | 78.1 | 26.6 | 5.5 | 0.00 |
| Toluene | 0.0190 | 92.1 | 18.7 | 4.5 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 10.8 | 3.0 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 143.8 | 32.7 | 0.02 |
| Nitrogen | 0.0940 | 28.0 | 92.6 | 6.8 | 0.00 |
| Carbon Dioxide | 2.5280 | 44.0 | 2,490.7 | 288.8 | 0.14 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| VOC Subtotal | 2.7600 | | | 422.43 | 0.21 |
| HAPS Subtotal | 0.2030 | | | 45.72 | 0.02 |
| Total | 100.1460 | | | 4876.06 | 2.44 |

**Calculation**

lb/hr = (Mol % * SumSCF/yr) / scf/lb-mol

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

[b] Fugitive emission factors from Subpart W, Table W-1A

## Kleinfelder, Inc.

**Wellsite Emissions**

**Base Location:** San Juan Basin
**Well Type:** Natural Gas

**Production Phase**

**Process Heater Emissions**

**Wellsite Heater Inventory:**

| | Heating Value (Mbtu/hr) | Fuel Consumption (MMScf/yr) | |
|---|---|---|---|
| **Separator Heater** | **100** | **0.86** | * Heater treater size based on industry standard |

**Annual Run Time:** **8760** **Hours/Year**
**Fuel Gas Heat Value:** **1,020** **Btu/scf (Standard heating value from AP-42)**

**Equations:**

$$\text{Fuel Consumption (MMscf/yr)} = \frac{\text{Heater Size (MBtu/hr)} * 1{,}000 \text{ (Btu/MBtu)} * \text{Hours of Operation (hrs/yr)}}{\text{Fuel Heat Value (Btu/scf)} * 1{,}000{,}000 \text{ (scf/MMscf)}}$$

$$\text{NOx/CO/TOC Emissions (tons/yr)} = \frac{\text{AP-42 E.Factor (lbs/MMscf)} * \text{Fuel Consumption (MMscf/yr)} * \text{Fuel heating Value (Btu/scf)}}{2{,}000 \text{ (lbs/ton)} * 1{,}020 \text{ (Btu/scf - Standard Fuel Heating Value)}}$$

| | Emission Factor (lb/MMscf) | Separator Heater Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) [e] |
|---|---|---|---|---|---|---|
| *Criteria Pollutants & VOC* | | | | | | |
| NOx [a] | 100 | 0.0429 | 0.0000 | 0.0000 | 0.0000 | 0.0429 |
| CO [a] | 84.0 | 0.0361 | 0.0000 | 0.0000 | 0.0000 | 0.0361 |
| VOC | 5.5 | 0.0024 | 0.0000 | 0.0000 | 0.0000 | 0.0024 |
| $SO_2$ [b] | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| TSP [c] | 7.60 | 0.0033 | 0.0000 | 0.0000 | 0.0000 | 0.0033 |
| $PM_{10}$ [c] | 7.60 | 0.0033 | 0.0000 | 0.0000 | 0.0000 | 0.0033 |
| $PM_{2.5}$ [c] | 7.60 | 0.0033 | 0.0000 | 0.0000 | 0.0000 | 0.0033 |
| *Hazardous Air Pollutants* | | | | | | |
| Benzene [d] | 2.10E-03 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Toluene [d] | 3.40E-03 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Hexane [d] | 1.80 | 0.0008 | 0.0000 | 0.0000 | 0.0000 | 0.0008 |
| Formaldehyde [d] | 7.50E-02 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| *Greenhouse Gases* | | | | | | |
| $CO_2$ [f] | 120,162 | 51.5989 | 0.0000 | 0.0000 | 0.0000 | 51.5989 |
| $CH_4$ [f] | 2.27 | 0.0010 | 0.0000 | 0.0000 | 0.0000 | 0.0010 |
| $N_2O$ [f] | 0.23 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0001 |

a AP-42 Table 1.4-1, Emission Factors for Natural Gas Combustion, 7/98
b Assumes produced gas contains no sulfur
c AP-42 Table 1.4-2, Emission Factors for Natural Gas Combustion, 7/98 (All Particulates are $PM_{1.0}$)
d AP-42 Table 1.4-3, Emission Factors for Organic Compounds from Natural Gas Combustion, 7/98
e Assumes maximum development scenario
f Subpart W - Part 98.233(z)(1) indicates the use of Table C-1 and Table C-2 for fuel combustion of stationary and portable equipment. Table C-1 provides an EF for natural gas combustion of 53.02 kg $CO_2$/mmBtu. Table C-2 provides an EF for natural gas combustion for $CH_4$ as 1.0E-03 kg/MMBtu and for $N_2O$ as 1.0E-04 kg/MMBtu.

| Kleinfelder, Inc.<br>Wellsite Emissions | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Atmospheric Oil Tank Flashing Emissions**

**Assumptions:**

| | | | | |
|---|---|---|---|---|
| Production Estimate: | 5 | barrels/day | | |
| Production Days: | 365 | Days/Year | | |
| Flasing Gas-to-Oil Ratio: | 75 | Scf/bbl | 379.49 | Scf/lb-mol |
| Control Efficiency: | 0 | Percent (%) | | |

**Flashing Gas Composition:**

| Component | Mole % | Mole Weight (lb/lb-mol) | Emissions (Uncontrolled) Scf/Year | Emissions (Uncontrolled) lbs/Year | Emissions (Uncontrolled) Tons/Year | Emissions (Controlled) Tons/Year |
|---|---|---|---|---|---|---|
| Methane | 23.6778 | 16.043 | 32408.98875 | 1370.0951 | 0.6850 | 0.6850 |
| Ethane | 31.6716 | 30.07 | 43350.5025 | 3435.0038 | 1.7175 | 1.7175 |
| Propane | 27.0752 | 44.097 | 37059.18 | 4306.3023 | 2.1532 | 2.1532 |
| i-Butane | 2.3870 | 58.123 | 3267.20625 | 500.4080 | 0.2502 | 0.2502 |
| n-Butane | 6.1325 | 58.123 | 8393.859375 | 1285.6104 | 0.6428 | 0.6428 |
| i-Pentane | 0.9352 | 72.150 | 1280.055 | 243.3686 | 0.1217 | 0.1217 |
| n-Pentane | 1.5003 | 72.150 | 2053.535625 | 390.4256 | 0.1952 | 0.1952 |
| Other Pentanes | 0.6754 | 70.100 | 924.5016563 | 170.7754 | 0.0854 | 0.0854 |
| Hexanes | 2.2516 | 86.177 | 3081.8775 | 699.8523 | 0.3499 | 0.3499 |
| Heptanes | 0.7869 | 100.204 | 1077.069375 | 284.3992 | 0.1422 | 0.1422 |
| Octanes | 0.1469 | 114.231 | 201.069375 | 60.5243 | 0.0303 | 0.0303 |
| Nonanes | 0.0463 | 128.258 | 63.373125 | 21.4185 | 0.0107 | 0.0107 |
| Decanes + | 0.0105 | 142.285 | 14.371875 | 5.3886 | 0.0027 | 0.0027 |
| Benzene | 0.1540 | 78.120 | 210.7875 | 43.3917 | 0.0217 | 0.0217 |
| Toluene | 0.0709 | 92.130 | 97.044375 | 23.5598 | 0.0118 | 0.0118 |
| Ethylbenzene | 0.0034 | 106.160 | 4.65375 | 1.3019 | 0.0007 | 0.0007 |
| 2,2,4 Trimethylpentane | 0.0253 | 78.120 | 34.629375 | 7.1286 | 0.0036 | 0.0036 |
| Xylenes | 0.0219 | 106.160 | 29.975625 | 8.3855 | 0.0042 | 0.0042 |
| n-Hexane | 0.9119 | 86.177 | 1248.163125 | 283.4408 | 0.1417 | 0.1417 |
| Nitrogen | 0.0000 | 28.013 | 0 | 0.0000 | 0.0000 | 0.0000 |
| Carbon Dioxide | 2.1907 | 44.010 | 2998.520625 | 347.7427 | 0.1739 | 0.1739 |
| Hydrogen Sulfide | 0.0000 | 34.080 | 0 | 0.0000 | 0.0000 | 0.0000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| VOC Subtotal | 43.14 | | | | 4.17 | 4.17 |
| HAPS Subtotal | 1.19 | | | | 0.18 | 0.18 |
| **Total** | **100.6753** | | | | **6.7443** | **6.7443** |

**Calculation:**

Scf/yr = (Mol% * scf/bbl * bbl/day * days/yr) / 100

lb/yr = (scf/yr * mol wt.) / scf/lb-mol

*** Production and gas to oil ratio based on basin specific differences. Please see "Gas Stream Molar Ratios" tab and report for additional information.**

| Kleinfelder, Inc.<br>Wellsite Emissions | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Wellsite Produced Water Tanks Venting**

**Assumptions:**

| | | |
|---|---|---|
| Average Estimated Water Production: | 800 | Barrels Per Year |
| Number of Water Tanks: | 0 | Tanks |
| VOC Emissions Factor: | 0.2620 | lbs/bbl |
| n-Hexane Emission Factor: | 0.0220 | lbs/bbl |
| Benzene Emission Factor: | 0.0070 | lbs/bbl |

**Calculations:**

| | | |
|---|---|---|
| VOC Emissions: | 0 | Tons/Year |
| Hexane Emissions: | 0 | Tons/Year |
| Benzene Emissions: | 0 | Tons/Year |

* Production conservatively based on estimated industry single well average
* Emission factors based on only known lb/bbl factor, which was developed by the Colorado Department of Health and Environment (PS Memo 09-02).

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Truck Loading Emissions**

**AP - 42, Chapter 5.2** $L_L = 12.46 \times S \times P \times M / T$

$L_L$ = Loading Loss Emission Factor (lbs VOC/1000 gal loaded)

S = Saturation Factor

P = True Vapor Pressure of the Loaded Liquid (psia)

M = Vapor Molecular Weight of the Loaded Liquid (lbs/lbmol)

T = Temperature of Loaded Liquid (ºR)

**VOC Emissions (tpy) =**

$$\frac{L_L \text{ (lbs VOC/1000 gal) * 42 gal/bbl * 365 days/year * production (bbl/day)}}{\text{1000 gal * 2000 lbs/ton}}$$

| S[1] | P (psia)[2] | M (lb/lbmol)[3] | T (ºF)[4] | T (ºR) | $L_L$ (lb/1000 gal) | Production (bbl/day) | VOC (tpy) |
|---|---|---|---|---|---|---|---|
| 0.6 | 4.20 | 66.00 | 50.00 | 509.67 | 4.07 | 5.0 | **0.16** |

Notes:
1. Saturation factor from AP-42, Table 5.2-1 (Submerged loading: dedicated normal service)
2. True vapor pressure is estimated from AP-42, Table 7.1-2 assuming an average daily temperature of either 40 or 50 deg F and an RVP of 10.0.
3. Molecular weight liquid vapor is estimated from AP-42, Table 7.1-2 assuming an RVP of 10.0.
4. Temperature based on the annual average temperature for basin location (either 40 or 50 degrees F based on options provided in AP-42 Table 7.1-2

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Pumpjack Unit Emissions**

**Assumptions:**

***Pumpjack engines only included at oil wells***

| | | |
|---|---|---|
| Pumpjack Horsepower Rating: | 65.0 | Horsepower |
| Load Factor: | 0.54 | |
| Brake Specific Fuel Consumption: | 8,000 | Btu/hp-hr |
| Annual Operation: | 8,760 | Hours/Year |

**Equations:**

$$\text{Emissions (lbs/hr)} = \frac{\text{Emission Factor (g/hp-hr)} * \text{Power (hp)}}{453.6 \text{ g/lb}}$$

| Pollutant | Emission Factor [a] (lb/MMBtu) | Emission Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) |
|---|---|---|---|---|
| *Criteria Pollutants & VOC* | | | | |
| **NOx** | | 2.80 | 0.22 | 0.9490 |
| **CO** | | 4.80 | 0.37 | 1.6269 |
| **VOC** | 0.12 | - | 0.0337 | 0.1476 |
| **$PM_{10}$** [b] | 4.83E-02 | - | 1.36E-02 | 5.94E-02 |
| **$PM_{2.5}$** [b] | 4.83E-02 | - | 1.36E-02 | 5.94E-02 |
| **$SO_2$** | 5.88E-04 | - | 0.0002 | 0.0007 |
| *Hazardous Air Pollutants* | | | | |
| **Benzene** | 1.94E-03 | - | 5.45E-04 | 2.39E-03 |
| **Toluene** | 9.63E-04 | - | 2.70E-04 | 1.18E-03 |
| **Ethylbenzene** | 1.08E-04 | - | 3.03E-05 | 1.33E-04 |
| **Xylenes** | 2.68E-04 | - | 7.53E-05 | 3.30E-04 |
| **Formaldehyde** | 5.52E-02 | - | 0.0155 | 0.0679 |
| **n-Hexane** | 4.45E-04 | - | 1.25E-04 | 5.47E-04 |
| *Greenhouse Gases* | | | | |
| **$CO_2$** [c] | 117 | - | 32.82 | 144 |
| **$CH_4$** | 0.002 | - | 0.0006 | 0.0027 |
| **$N_2O$** | 0.0002 | - | 0.0001 | 0.0003 |

a AP-42 Table 3.2-3 Uncontrolled Emission Factors for 4-Stroke Rich-Burn Engines, 7/00; and Subpart JJJJ for NOX and CO emission rates.

b PM = sum of PM filterable and PM condensable

c Subpart W - Part 98.233(z)(1) indicates the use of Table C-1 and Table C-2 for fuel combustion of stationary and portable equipment. Table C-1 provides an EF for natural gas combustion of 53.02 kg $CO_2$/mmBtu. Table C-2 provides an EF for natural gas combustion for $CH_4$ as 1.0E-03 kg/MMBtu and for $N_2O$ as 1.0E-04 kg/MMBtu.

- Network website for the 1999 National-Scale Air Toxics Assessment at http://www.epa.gov/ttn/atw/nata1999/nsata99.html

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

Production Phase

Wellsite Dehydrator Emissions

**Assumptions:**

Number of Dehy Units: 0 Units

**Calculations:**

Calculations and specifications derived from Pinedale Anticline Final SEIS

GRI-GLYCalc 4.0 operated with: 4 MMSCFD, 0.32 gpm glycol flow, average representative gas analysis, and 95% control efficiency

**Emissions:**

| Species | Total Project Emissions (tons/year) |
|---|---|
| **Total VOC** | 0.000 |
| *Hazardous Air Pollutants* | |
| **Benzene** | 0.000 |
| **Toluene** | 0.000 |
| **Ethylbenzene** | 0.000 |
| **Xylenes** | 0.000 |
| **n-Hexane** | 0.000 |
| *Greenhouse Gases* | |
| **$CO_2$** | 0.000 |
| **$CH_4$ [a]** | 0.000 |
| **$N_2O$** | 0.000 |

Note, no greenhouse gas emissions included for dehydrator in Pinedale EIS

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Construction Phase**

**Roadway Construction Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Light Duty Pickup Trucks: | 50 | Trips/Location | | | |
| Light Duty Haul Trucks | 0 | Trips/Location | Total Trips: | 50 | Trips |
| Heavy Duty Haul Trucks | 2 | Trips/Location | | | |
| Water Trucks | 40 | Trips/Location | Total Trips: | 42 | Trips |

* Miles and number of trips based on research and industry knowledge; please see report for additional information.

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (g/mile)} * \text{\# Trips} * \text{Trip Distance (miles)}}{2000 \text{ (lb/tons)}}$$

| **Construction Vehicles** | **Heavy Haul Trucks** | | **Light Duty Pickups** | | **Total** |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 6.25E-02 | 7.39E-03 | 7.39E-03 | 6.99E-02 |
| **CO** | 1.98E-02 | 1.66E-02 | 7.26E-02 | 7.26E-02 | 8.92E-02 |
| **VOC** | 3.16E-03 | 2.65E-03 | 3.54E-03 | 3.54E-03 | 6.19E-03 |
| **SO2** | 4.57E-05 | 3.84E-05 | 2.83E-05 | 2.83E-05 | 6.67E-05 |
| **PM10** | 4.22E-03 | 3.54E-03 | 1.94E-04 | 1.94E-04 | 3.74E-03 |
| **PM2.5** | 4.09E-03 | 3.44E-03 | 1.79E-04 | 1.79E-04 | 3.61E-03 |
| **CO2** | 1.88E+00 | 1.58E+00 | 1.13E+00 | 1.13E+00 | 2.70E+00 |
| **CH4** | 7.61E-05 | 6.39E-05 | 4.56E-05 | 4.56E-05 | 1.10E-04 |
| **N2O** | 1.52E-05 | 1.28E-05 | 9.13E-06 | 9.13E-06 | 2.19E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

c Assumes maximum development scenario

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** San Juan Basin<br>**Well Type:** Natural Gas |
|---|---|

**Production Phase**

**Pneumatic Device Emissions**

**Wellsite Pneumatic Inventory:**

| | | **Classification** | **Quantity** | **Emission Factor (Scf/hr/unit)** |
|---|---|---|---|---|
| **Devices:** | Dump Valve | Intermittent Bleed | 1 | 13.50 |
| | Pneumatic Controller | Low Bleed | 1 | 1.39 |
| | | | 0 | 0.00 |
| **Pumps:** | | | | |
| | | | | 0.00 |

Annual Equipment Run Time: 8760 Hours/Year — 379.49 Scf/lb-mol

Pneumatic Device Control:[b] 0 Percent

* Low bleed and intermittent bleed emission factors (scf/hr) based on Subpart W, Table W-1A
* Quantity of devices based on typical industry values

| Component | Mole % | Mole Weight lb/lb-mol | Dump Valve Tons/Year | Pneumatic Controller Tons/Year | (None) Tons/Year | Pneumatic Pumps Tons/Year | Total Tons/Year |
|---|---|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 2.224 | 0.229 | 0.000 | 0.000 | 2.453 |
| Ethane | 5.7920 | 30.1 | 0.271 | 0.028 | 0.000 | 0.000 | 0.299 |
| Propane | 1.3650 | 44.1 | 0.094 | 0.010 | 0.000 | 0.000 | 0.103 |
| i-Butane | 0.3700 | 58.1 | 0.034 | 0.003 | 0.000 | 0.000 | 0.037 |
| n-Butane | 0.2610 | 58.1 | 0.024 | 0.002 | 0.000 | 0.000 | 0.026 |
| i-Pentane | 0.1550 | 72.2 | 0.017 | 0.002 | 0.000 | 0.000 | 0.019 |
| n-Pentane | 0.1020 | 72.2 | 0.011 | 0.001 | 0.000 | 0.000 | 0.013 |
| Other Pentanes | 0.0000 | 70.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Hexanes | 0.1460 | 86.2 | 0.020 | 0.002 | 0.000 | 0.000 | 0.022 |
| Heptanes | 0.0930 | 100.2 | 0.015 | 0.001 | 0.000 | 0.000 | 0.016 |
| Octanes | 0.0440 | 114.2 | 0.008 | 0.001 | 0.000 | 0.000 | 0.009 |
| Nonanes | 0.0160 | 128.3 | 0.003 | 0.000 | 0.000 | 0.000 | 0.004 |
| Decanes + | 0.0050 | 142.3 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 |
| Benzene | 0.0270 | 78.1 | 0.003 | 0.000 | 0.000 | 0.000 | 0.004 |
| Toluene | 0.0190 | 92.1 | 0.003 | 0.000 | 0.000 | 0.000 | 0.003 |
| Ethylbenzene | 0.0000 | 106.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Xylenes | 0.0110 | 106.2 | 0.002 | 0.000 | 0.000 | 0.000 | 0.002 |
| n-Hexane | 0.1460 | 86.2 | 0.020 | 0.002 | 0.000 | 0.000 | 0.022 |
| Nitrogen | 0.0940 | 28.0 | 0.004 | 0.000 | 0.000 | 0.000 | 0.005 |
| Carbon Dioxide | 2.5280 | 44.0 | 0.173 | 0.018 | 0.000 | 0.000 | 0.191 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **VOC Subtotal** | 2.8 | 1492.8 | 0.25 | 0.03 | 0.00 | 0.00 | 0.28 |
| **HAPS Subtotal** | 0.2 | 546.9 | 0.03 | 0.00 | 0.00 | 0.00 | 0.03 |
| **Total** | 100.1 | 1645.0 | 2.93 | 0.30 | 0.00 | 0.00 | 3.23 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

[b] 98% control input is a result of the Wyoming Department of Environment Quality requirement, and only pertains to the Upper Green River Basin.

## APPENDIX E

## EMISSION INVENTORY FOR THE WILLISTON BASIN OIL WELL

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Williston Basin
**Well Type:** Oil Well

**Location Selection:**

| Geography: | Well Type: |
|---|---|
| Williston Basin | Oil Well |

- Choose geography/basin, and well type will automatically fill
  < Choose Uinta/Piceance Basin for deep gas wells with little condensate
  < Choose Upper Green River Basin for deep gas wells with dehydrators and higher condensate
  < Choose San Juan Basin for shallow gas wells with little to no condensate
  < Choose Williston Basin for deep oil wells with high gas
  < Choose Denver Basin for shallow oil wells with low gas

If the user wants to change any specifications, do so within the "Constants and References" tab, as all other tabs connect to it.

| | Total Emissions (Tons per Year) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Pollutant:** | **$NO_X$** | **CO** | **VOC** | **$SO_2$** | **$PM_{10}$** | **$PM_{2.5}$** | **$CO_2$** | **$CH_4$** | **$N_2O$** |
| **Construction Phase:** | 0.47 | 0.29 | 0.04 | 0.0001 | 1.99 | 0.06 | 33.84 | 0.001 | 0.0003 |
| **Development Phase:** | 13.24 | 2.86 | 0.68 | 0.0002 | 4.84 | 0.44 | 1900.27 | 1.11 | 0.0498 |
| **Operation Phase:** | 1.87 | 4.85 | 16.83 | 0.0008 | 0.10 | 0.29 | 1222.32 | 15.44 | 0.5251 |
| **Total:** | 15.58 | 8.00 | 17.56 | 0.0011 | 6.93 | 0.79 | 3156.43 | 16.55 | 0.5751 |

| | Total Emissions (Tons per Year) | | | | | |
|---|---|---|---|---|---|---|
| **Pollutant:** | **Benzene** | **Toluene** | **Ethylbenzene** | **Xylene** | **n-Hexane** | **HAPs** |
| **Construction Phase:** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Development Phase:** | 1.36 | 0.95 | 0.0000 | 0.55 | 7.31 | 10.18 |
| **Operation Phase:** | 0.16 | 0.02 | 0.00077 | 0.014 | 0.59 | 0.85 |
| **Total:** | 1.52 | 0.98 | 0.00077 | 0.57 | 7.89 | 11.02 |

| $CO_2$ equivalent (Global Warming Potential) | |
|---|---|
| **Total TPY:** | **3682.34** |
| $CO_2$ equivalent conversions: | |
| $CO_2$ | 1.00 |
| $CH_4$ | 21.00 |
| $N_2O$ | 310.00 |

| $H_2S$ Emissions | |
|---|---|
| **Total TPY:** | **0.00** |

* If $H_2S$ in gas, input value in "Gas Stream Molar Ratios" tab, and potential emissions will calculate here. Current assumption is no $H_2S$ in gas stream.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Williston Basin<br>**Well Type:** Oil Well |
|---|---|

**Construction Phase**

**Road Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 4 | Days/Location | (Typical Value) |
| | 48.0 | Dozer Hours/Location | (Typical Value) |
| | 48.0 | Backhoe Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |

$PM_{10}$ Multiplier: 0.75 * $PM_{15}$ (AP-42 Table 11.9-1, 7/98)

$PM_{2.5}$ Multiplier: 0.105 * TSP (AP-42 Table 11.9-1, 7/98)

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98 & 7/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content }\%)^{1.2} * (\text{soil moisture content }\%)^{-1.3} * \text{Control Efficiency}$

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content }\%)^{1.5} * (\text{soil moisture content }\%)^{-1.4} * \text{Control Efficiency}$

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions [a]** | | **Backhoe Emissions [a]** | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0473 | 1.97 | 0.0473 | 0.0946 |
| **$PM_{15}$** | 0.50 | 0.0120 | 0.50 | 0.0120 | 0.0241 |
| **$PM_{10}$** | 0.38 | 0.0090 | 0.38 | 0.0090 | 0.0181 |
| **$PM_{2.5}$** | 0.21 | 0.0050 | 0.05 | 0.0013 | 0.0062 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Williston Basin<br>**Well Type:** Oil Well |
|---|---|

**Construction Phase**

**Road Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Grading Length: | 6.00 | miles | (Typical Value) |
| Construction Schedule: | 3 | Days/Location | (Typical Value) |
| | 12 | Hours/Day | (Typical Value) |
| | 36 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | |
| Average Grader Speed: | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 16.12 lbs TSP/Location**

**Emissions = 7.71 lbs $PM_{15}$/Location**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 16.12 | 0.45 | 8.06E-03 |
| **$PM_{15}$** | 7.71 | 0.21 | 3.86E-03 |
| **$PM_{10}$** | 4.63 | 0.13 | 2.31E-03 |
| **$PM_{2.5}$** | 0.50 | 0.01 | 2.50E-04 |

| **Kleinfelder, Inc.** | **Base Location:** Williston Basin |
|---|---|
| **Wellsite Emissions** | **Well Type:** Oil Well |

**Construction Phase**

**Well Pad Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | | |
|---|---|---|---|---|
| Construction Schedule: | 7 | Days/Location | | (Typical Value) |
| | 10 | Hours/Day | | (Typical Value) |
| | 70 | Hours/Location | (Dozer) | (Typical Value) |
| | 70 | Hours/Location | (Back Hoe) | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | | AP-42 Table 11.9-3, 7/98 |

$PM_{10}$ Multiplier: 0.75 * $PM_{15}$ (AP-42 Table 11.9-1, 7/98)

$PM_{2.5}$ Multiplier: 0.105 * TSP (AP-42 Table 11.9-1, 7/98)

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs/hr) = 5.7 * (soil silt content %)$^{1.2}$ * (soil moisture content %)$^{-1.3}$* Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = 1.0 * (soil silt content %)$^{1.5}$ * (soil moisture content %)$^{-1.4}$ * Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions** [a] | | **Backhoe Emissions** [a] | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0690 | 1.97 | 0.0690 | 0.14 |
| **$PM_{15}$** | 0.50 | 0.0176 | 0.50 | 0.0176 | 0.04 |
| **$PM_{10}$** | 0.38 | 0.0132 | 0.38 | 0.0132 | 0.03 |
| **$PM_{2.5}$** | 0.21 | 0.0072 | 0.21 | 0.0072 | 0.01 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Williston Basin<br>**Well Type:** Oil Well |
|---|---|

**Construction Phase**

**Well Pad Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 4.0 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 40 | Hours/Location | (Typical Value) |
| Watering Control Efficiency | 50 | Percent (%) | (Typical Value) |
| Average Grader Speed | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| Distance Graded | 2.84 | Miles/Location | (Typical Value) |
| $PM_{10}$ Multiplier | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 7.63 lbs TSP/well pad**

**Emissions = 3.65 lbs $PM_{15}$/well pad**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 7.63 | 0.19 | 0.0038 |
| **$PM_{15}$** | 3.65 | 0.09 | 0.0018 |
| **$PM_{10}$** | 2.19 | 0.05 | 0.0011 |
| **$PM_{2.5}$** | 0.24 | 0.01 | 0.0001 |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Williston Basin<br>**Well Type:** Oil Well |
|---|---|

**Construction Phase**

**Pipeline Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 7.0 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.75 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.105 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 7/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content } \%)^{1.2} * (\text{soil moisture content } \%)^{-1.3} * \text{Control Efficiency}$

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content } \%)^{1.5} * (\text{soil moisture content } \%)^{-1.4} * \text{Control Efficiency}$

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions [a]** | | **Backhoe Emissions [a]** | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0690 | 1.97 | 0.0690 | 0.14 |
| **$PM_{15}$** | 0.50 | 0.0176 | 0.50 | 0.0176 | 0.04 |
| **$PM_{10}$** | 0.38 | 0.0132 | 0.38 | 0.0132 | 0.03 |
| **$PM_{2.5}$** | 0.21 | 0.0072 | 0.21 | 0.0072 | 0.01 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.** | **Base Location:** Williston Basin |
|---|---|
| **Wellsite Emissions** | **Well Type:** Oil Well |

**Construction Phase**

**Pipeline Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Distance Graded: | 12.50 | Miles/Location | (Typical Value) |
| Construction Schedule: | 7 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Mean Vehicle Speed: | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 7/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 33.58 lbs TSP/well**

**Emissions = 16.07 lbs $PM_{15}$/well**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 33.58 | 0.48 | 0.0168 |
| **$PM_{15}$** | 16.07 | 0.23 | 0.0080 |
| **$PM_{10}$** | 9.64 | 0.14 | 0.0048 |
| **$PM_{2.5}$** | 1.04 | 0.01 | 0.0005 |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Williston Basin<br>**Well Type:** Oil Well |
|---|---|

**Construction Phase**

**Roadway Construction Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Heavy Diesel Truck Trips: | | | | | |
| Road Construction: | 7 | Trips | | | |
| Well Pad Construction: | 8 | Trips | Total Trips: | 21 | Trips |
| Pipeline Construction: | 6 | Trips | | | |
| Light Duty Pickup Truck Trips: | | | | | |
| Road Construction: | 16 | Trips | | | |
| Well Pad Construction: | 28 | Trips | Total Trips: | 100 | Trips |
| Pipeline Construction: | 56 | Trips | | | |

* All assumptions above are based on typical industry values

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (lb/mile)} * \text{\# Trips} * \text{Trip Distance (miles)}}{2000 \text{ (lb/tons)}}$$

| Construction Vehicles | Heavy Haul Trucks | | Light Duty Pickups | | Total |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 3.12E-02 | 7.39E-03 | 1.48E-02 | 4.60E-02 |
| **CO** | 1.98E-02 | 8.32E-03 | 7.26E-02 | 1.45E-01 | 1.54E-01 |
| **VOC** | 3.16E-03 | 1.33E-03 | 3.54E-03 | 7.08E-03 | 8.41E-03 |
| **SO2** | 4.57E-05 | 1.92E-05 | 2.83E-05 | 5.66E-05 | 7.58E-05 |
| **PM10** | 4.22E-03 | 1.77E-03 | 1.94E-04 | 3.88E-04 | 2.16E-03 |
| **PM2.5** | 4.09E-03 | 1.72E-03 | 1.79E-04 | 3.58E-04 | 2.08E-03 |
| **CO2** | 1.88 | 0.79 | 1.13 | 2.25 | 3.04 |
| **CH4** | 7.61E-05 | 3.19E-05 | 4.56E-05 | 9.13E-05 | 1.23E-04 |
| **N2O** | 1.52E-05 | 6.39E-06 | 9.13E-06 | 1.83E-05 | 2.46E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Williston Basin<br>**Well Type:** Oil Well |
|---|---|

**Construction Phase**

**Construction Heavy Equipment Tailpipe Emissions**

**Assumptions:**

Fuel and Engine:

| | | | |
|---|---|---|---|
| Brake Specific Fuel Consumption, Avg. (BSFC) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel Higher Heating Value (HHV) | 0.138 | mmBtu/Gallon | (Typical Value) |

Trackhoe:

| | | | |
|---|---|---|---|
| Working Hours | 188 | Total Hours | (Typical Value) |
| Rated Horsepower | 100 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Tractors/Loaders/Backhoes) | |

Dozer:

| | | | |
|---|---|---|---|
| Working Hours | 188 | Total Hours | (Typical Value) |
| Rated Horsepower | 140 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Crawler Tractor/Dozers) | |

Grader:

| | | | |
|---|---|---|---|
| Working Hours | 130 | Total Hours | (Typical Value) |
| Rated Horsepower | 250 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Graders) | |

| | | | |
|---|---|---|---|
| Total Horsepower Hours: | 45795.8 | Hp-hrs | (Sum of all horsepower above) |
| Total Fuel Usage: | 2737.79 | Gallons Diesel Fuel | |

**Equations:**

Total Fuel Usage: ((btu-hp-hr * hp-hrs) / Mmbtu-gal) / 1,000,000

$$\text{Emissions (tons/year/pad)} = \frac{\text{Emission Factor (g/mile) * Trip Distance (miles) * Load Factor}}{\text{453.6 (g/lb) * 2000 (lb/tons)}}$$

| **Heavy Const. Vehicles** | **Backhoe** | | | **Dozer** | | | **Grader** | | |
|---|---|---|---|---|---|---|---|---|---|
| | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) |
| **NOx** | 8.38 | 1.09E+00 | 1.02E-01 | 8.38 | 1.53E+00 | 1.43E-01 | 8.38 | 2.72E+00 | 1.77E-01 |
| **CO** | 2.7 | 3.51E-01 | 3.30E-02 | 2.7 | 4.92E-01 | 4.62E-02 | 2.7 | 8.78E-01 | 5.71E-02 |
| **VOC** [b] | 0.68 | 8.84E-02 | 8.31E-03 | 0.68 | 1.24E-01 | 1.16E-02 | 0.68 | 2.21E-01 | 1.44E-02 |
| **$PM_{10}$** | 0.39 | 5.07E-02 | 4.77E-03 | 0.39 | 7.10E-02 | 6.68E-03 | 0.39 | 1.27E-01 | 8.24E-03 |
| **$PM_{2.5}$** | 0.39 | 5.07E-02 | 4.77E-03 | 0.39 | 7.10E-02 | 6.68E-03 | 0.39 | 1.27E-01 | 8.24E-03 |

| **Heavy Const. Vehicles** | **Total** Emissions [c] (tons/yr) |
|---|---|
| **NOx** | 0.42 |
| **CO** | 0.14 |
| **VOC** | 0.03 |
| **$PM_{10}$** | 0.02 |
| **$PM_{2.5}$** | 0.02 |

**Greenhouse Gas Emissions:**

| | Diesel EF kg/mmbtu | Emissions lbs | Emissions Tons |
|---|---|---|---|
| $CO_2$ | 73.96 | 61604.19 | 30.80 |
| $CH_4$ | 0.003 | 2.50 | 0.0012 |
| $N_2O$ | 0.0006 | 0.50 | 0.0002 |

a From Table A-4 of Exhaust and Crankcase Emission Factors for NONROAD Engine Modeling - Compression Ignition, EPA-420-R-10-018, July 2010.

b Emission Factor represents total Hydrocarbon Emissions

c Converted from emission factor for Distillate Fuel Oil #2 (diesel) as listed in Table C-1 to Subpart C of Part 98 - Default Emission Factors and High Heat Values for Various Types of Fuel.

Listed Factor:

73.96 kg $CO_2$/mmBtu

393 hp-hr = mmBtu

188.2 g $CO_2$/hp-hr

| Kleinfelder, Inc.<br>Wellsite Emissions | Base Location: Williston Basin<br>Well Type: Oil Well |
|---|---|

**Construction Phase**

**Wind Erosion Fugitive Dust**

**Assumptions:**

Threshold Friction Velocity ($U_t$) 1.02 m/s (2.28 mph) for well pads (AP-42 Table 13.2.5-2 Overburden - Western Surface Coal Mine)
1.33 m/s (2.97 mph) for roads (AP-42 Table 13.2.5-2 Roadbed material)

Initial Disturbance Area

| | | | |
|---|---|---|---|
| Total Access Road/ROW Area Per Location: | 976,800 | Square Meters | (Typical Value) |
| Total Well Pad Area Disturbed Per Location: | 50,000 | Square Meters | (Typical Value) |
| Total Area Disturbed Per Location: | 1,026,800 | Square Meters | (Typical Value) |
| Exposed Surface Type | Flat | | |
| Meteorological Data | 2002 Grand Junction (obtained from NCDC website) | | |
| Fastest Mile Wind Speed: | 45 | miles/hour | (Typical Value) |
| Fastest Mile Wind Speed ($U_{10}^{+}$) | 20.12 | meters/sec (45 mph) reported as fastest 2-minute wind speed for Grand Junction (2002) | |
| Number soil of disturbances | 1.00 | for well pads (Assumption, disturbance at construction and reclamation) constant for dirt roads | |

**Equations (AP-42 13.2.5.2 Industrial Wind Erosion)**

Friction Velocity $U^* = 0.053\ U_{10}^{+}$

Erosion Potential P (g/m$^2$/period) = $58*(U^*-U_t^*)^2 + 25*(U^*-U_t^*)$ for $U^*>U_t^*$, $P = 0$ for $U^*< U_t^*$

Emissions (tons/year) = Erosion Potential(g/m$^2$/period)*Disturbed Area(m$^2$)*Disturbances/year*(k)/(453.6 g/lb)/2000 lbs/ton/Develop Period

| Particle Size Multiplier (k) | | |
|---|---|---|
| 30 µm | <10 µm | <2.5 µm |
| 1.0 | 0.5 | 0.075 |

| Maxium $U_{10}^{+}$ Wind Speed (m/s) | Maximum U* Friction Velocity m/s | Well $U_t$* Threshold Velocity[a] m/s | Well Pad Erosion Potential g/m$^2$ | Road $U_t$* Threshold Velocity[a] m/s | Road Erosion Potential g/m$^2$ |
|---|---|---|---|---|---|
| 20.12 | 1.07 | 1.02 | 1.28 | 1.33 | 0.00 |

**Wind Erosion Emissions**

| Particulate Species | Well Pad (tons/year) | Roads/Pipelines (tons/year) |
|---|---|---|
| TSP | 7.05E-02 | 0.00E+00 |
| $PM_{10}$ | 3.52E-02 | 0.00E+00 |
| $PM_{2.5}$ | 5.28E-03 | 0.00E+00 |

| **Kleinfelder, Inc.** | **Base Location:** Williston Basin |
|---|---|
| **Wellsite Emissions** | **Well Type:** Oil Well |

**Construction, Development, and Production Phase**

**Construction, Development, and Operations Traffic Fugitive Dust Emissions**

**Assumptions:**

| | |
|---|---|
| Round Trip Miles | 40 |
| Round Trip (Paved) Miles | 16 |
| Round Trip (Un-Paved) Miles | 24 |
| Precipitation Days (P) | 45 |

Unpaved Calculation AP-42, Chapter 13.2.2
November 2006

$E\,(PM_{10})\,/\,VMT = 1.5 * (S/12)^{0.9} * (W/3)^{0.45} * (365\text{-}p)/365)$

$E\,(PM_{2.5})\,/\,VMT = 0.15 * (S/12)^{0.9} + (W/3)^{0.45} * (365\text{-}p)/365)$

Silt Content (S) 8.5 AP 42 13.2.2-1 Mean Silt Content Construction Sites

Paved Calculation AP-42, Chapter 13.2.1
January 2011

$E\,(PM_{10})\,/\,VMT = 0.0022 * (sL)^{0.91} * (W)^{1.02} * (1\text{-}(P/(365*4))$

$E\,(PM_{2.5})\,/\,VMT = 0.00054 * (sL)^{0.91} * (W)^{1.02} * (1\text{-}(P/(365*4))$

Silt Loading (sL) 0.6 AP-42 Table 13.2.1-2 baseline low volume roads

**Construction Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | $PM_{10}$ (lb/VMT) | $PM_{10}$ (lbs) | $PM_{10}$ (Tons) | $PM_{2.5}$ (lb/VMT) | $PM_{2.5}$ (lbs) | $PM_{2.5}$ (Tons) |
|---|---|---|---|---|---|---|---|---|
| Heavy Duty Haul Trucks | 80,000 | 21 | 3.09 | 1558.9 | 0.8 | 0.3 | 155.9 | 0.1 |
| Light Duty Pickup Trucks | 5,000 | 100 | 0.89 | 2131.8 | 1.1 | 0.1 | 213.2 | 0.1 |
| **Total:** | | | | **3690.67** | **1.85** | | **369.07** | **0.18** |

**Paved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| Heavy Duty Haul Trucks | 80,000 | 21 | 0.0576 | 19.4 | 0.0097 | 0.014 | 4.8 | 0.0024 |
| Light Duty Pickup Trucks | 5,000 | 100 | 0.0034 | 5.5 | 0.0027 | 0.001 | 1.3 | 0.0007 |
| **Total:** | | | | **24.8** | **0.0** | | **6.1** | **0.0** |

**Development Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | $PM_{10}$ (lb/VMT) | $PM_{10}$ (lbs) | $PM_{10}$ (Tons) | $PM_{2.5}$ (lb/VMT) | $PM_{2.5}$ (lbs) | $PM_{2.5}$ (Tons) |
|---|---|---|---|---|---|---|---|---|
| Light Duty Pickup Trucks: | 5,000 | 84 | 0.89 | 1790.7 | 0.9 | 0.1 | 179.1 | 0.1 |
| Light Duty Haul Trucks | 7,500 | 11 | 1.07 | 281.4 | 0.1 | 0.1 | 28.1 | 0.0 |
| Heavy Duty Haul Trucks | 80,000 | 67 | 3.09 | 4973.6 | 2.5 | 0.3 | 497.4 | 0.2 |
| Water Trucks | 70,000 | 24 | 2.91 | 1677.7 | 0.8 | 0.3 | 167.8 | 0.1 |
| **Total:** | | | | **8723.41** | **4.36** | | **872.34** | **0.44** |

**Paved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Light Duty Pickup Trucks:** | 5000 | 84 | 0.00 | 4.6 | 0.0 | 0.0 | 1.1 | 0.0006 |
| **Light Duty Haul Trucks** | 7500 | 11 | 0.01 | 0.9 | 0.0 | 0.0 | 0.2 | 0.0001 |
| **Heavy Duty Haul Trucks** | 80000 | 67 | 0.06 | 61.8 | 0.0 | 0.0 | 15.2 | 0.0076 |
| **Water Trucks** | 70,000 | 24 | 0.05 | 19.3 | 0.0 | 0.0 | 4.7 | 0.0024 |
| **Total:** | | | | **86.6** | **0.0** | | **21.2** | **0.0** |

**Production Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| Light Duty Pickup Trucks: | 5,000 | 50 | 0.89 | 1065.89 | 0.53 | 0.0888 | 106.59 | 0.0533 |
| Light Duty Haul Trucks | 7,500 | 0 | 1.07 | 0.00 | 0.00 | 0.1066 | 0.00 | 0.0000 |
| Heavy Duty Haul Trucks | 80,000 | 2 | 3.09 | 148.47 | 0.07 | 0.3093 | 14.85 | 0.0074 |
| Water Trucks | 70,000 | 40 | 2.91 | 2796.14 | 1.40 | 0.2913 | 279.61 | 0.1398 |
| **Total:** | | | | **4010.50** | **2.01** | | **401.05** | **0.20** |

**Paved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| **Light Duty Pickup Trucks:** | 5,000 | 50 | 0.00 | 2.73 | 0.0014 | 0.0008 | 0.67 | 0.0003 |
| **Light Duty Haul Trucks** | 7,500 | 0 | 0.01 | 0.00 | 0.0000 | 0.0013 | 0.00 | 0.0000 |
| **Heavy Duty Haul Trucks** | 80,000 | 2 | 0.06 | 1.84 | 0.0009 | 0.0141 | 0.45 | 0.0002 |
| **Water Trucks** | 70,000 | 40 | 0.05 | 32.18 | 0.0161 | 0.0123 | 7.90 | 0.0039 |
| **Total:** | | | | **36.75** | **0.02** | | **9.02** | **0.00** |

**Annual Total**

| | Unpaved Roads $PM_{10}$ (tons) | Unpaved Roads $PM_{2.5}$ (tons) |
|---|---|---|
| | **8.21** | **0.8** |
| | **Paved Roads $PM_{10}$** | **Paved Roads $PM_{2.5}$** |
| | **0.1** | **0.0** |
| **Total:** | **8.3** | **0.8** |

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Williston Basin
**Well Type:** Oil Well

**Development Phase**
**Drill Rig Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 18 | (Typical Value) |
| Hours of Operation | 432 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

| Engine | HP [a] | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Vertical Drill Rig Engine | 850 | 0.42 | 144 | 51408 |
| Horizontal Drill Rig Engine 1 | 2,100 | 0.59 | 288 | 356832 |
| Horizontal Drill Rig Engine 2 | 2,100 | 0.59 | 432 | 535248 |
| Drill Rig Generator | 350 | 0.42 | 432 | 63504 |
| Trailers Generator | 150 | 0.42 | 432 | 27216 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor | 550 | 0.42 | 144 | 33264 |
| Air Compressor Booster | 650 | 0.42 | 144 | 39312 |
| Forklift | 120 | 0.42 | 144 | 7257.6 |
| Aerial Lift | 50 | 0.42 | 16 | 336 |
| Frontend loader | 150 | 0.42 | 16 | 1008 |
| Dozer | 175 | 0.60 | 9 | 945 |
| Total HP | 8,895 | | | |

Total: 1,216,123 Hp-hrs

Fuel Usage: 72,703 Gallons of Diesel Total Fuel Usage: (btu/hp-hr * hp-hrs) * gal/btu

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| $CO_2$ | 73.96 | 1635919.59 | 817.96 |
| $CH_4$ | 0.003 | 66.36 | 0.03 |
| $N_2O$ | 0.0006 | 13.27 | 0.01 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu) | Xylenes (lb/mmBtu) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Drill Rig Engine | 51408 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Horizontal Drill Rig Engine 1 | 356832 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Horizontal Drill Rig Engine 2 | 535248 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Drill Rig Generator | 63504 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Trailers Generator | 27216 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 33264 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor Booster | 39312 | 1.3272 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Forklift | 7257.6 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Aerial Lift | 336 | 5.0000 | 6.9000 | 0.8000 | 0.7760 | 1.27E-05 | 1.8000 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frontend loader | 1008 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Dozer | 945 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Drill Rig Engine | | 0.04331 | 0.23234 | 0.00746 | 0.00723 | 7.20E-07 | 0.00927 | 0.00016 | 0.00006 | 0.00004 |
| Horizontal Drill Rig Engine 1 | | 0.30059 | 1.61269 | 0.05176 | 0.05021 | 4.99E-06 | 0.06435 | 0.00114 | 0.00041 | 0.00028 |
| Horizontal Drill Rig Engine 2 | | 0.45089 | 2.41904 | 0.07765 | 0.07532 | 7.49E-06 | 0.09653 | 0.00171 | 0.00062 | 0.00043 |
| Drill Rig Generator | | 0.18900 | 0.58661 | 0.02814 | 0.02730 | 8.89E-07 | 0.04760 | 0.00020 | 0.00007 | 0.00005 |
| Trailers Generator | | 0.08100 | 0.25140 | 0.01206 | 0.01170 | 3.81E-07 | 0.02040 | 0.00009 | 0.00003 | 0.00002 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor | | 0.03089 | 0.15896 | 0.00483 | 0.00468 | 4.66E-07 | 0.00600 | 0.00011 | 0.00004 | 0.00003 |
| Air Compressor Booster | | 0.05751 | 0.17767 | 0.00570 | 0.00553 | 5.50E-07 | 0.00709 | 0.00013 | 0.00005 | 0.00003 |
| Forklift | | 0.02160 | 0.06704 | 0.00322 | 0.00312 | 1.02E-07 | 0.00544 | 0.00002 | 0.00001 | 0.00001 |
| Aerial Lift | | 0.00185 | 0.00256 | 0.00030 | 0.00029 | 4.70E-09 | 0.00067 | 0.00000 | 0.00000 | 0.00000 |
| Frontend loader | | 0.00300 | 0.00931 | 0.00045 | 0.00043 | 1.41E-08 | 0.00076 | 0.00000 | 0.00000 | 0.00000 |
| Dozer | | 0.00281 | 0.00873 | 0.00042 | 0.00041 | 1.32E-08 | 0.00071 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **1.27513** | **6.00321** | **0.20645** | **0.20026** | **0.00002** | **0.27680** | **0.00389** | **0.00141** | **0.00097** |

**Emission Factors**

- Drill rig emission factors based on Tier II engines
- All other engine emission factors based on Tier 0 engines (typical values)
- HAP emission factors from AP-42 Volume I, Large Stationary Diesel Engines Table 3.4-3

**Calculations:**

ton/year: (Total hp-hr * g/hp-hr) * lb-gram / lb-ton

*** Drill rig horsepower developed based on:**

1 Williston Basin: 2,100 from Jonah, Wyoming RMP
2 San Juan Basin: 2,100 from River Valley RMP
3 Upper Green River Basin: 2,100 from Jonah, Wyoming RMP
4 Denver Basin: 2,950 from River Valley RMP
5 Uintah Basin: 2,952 from River Valley RMP

Note, runtime for each drilling event is based on research and industry experience dependent upon each basi

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Williston Basin
**Well Type:** Oil Well

**Development Phase**
**Conductor Pipe Set Emissions**

**Assumptions:**

| Parameter | Value |
|---|---|
| Days of Operation | 2 |
| Hours of Operation | 24 |
| Diesel Fuel Sulfur Content | 0.000015 |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

Workovers:

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Rig Engine | 350 | 0.42 | 24 | 3528 |
| Rig Generator | 50 | 0.42 | 24 | 504 |

Total Horsepower: 400

Total: 4,032 Hp-hrs

Fuel Usage: 241 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

**Greenhouse Gases:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 5423.82 | 2.71 |
| CH4 | 0.003 | 0.22 | 0.00 |
| N2O | 0.0006 | 0.04 | 0.00 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu | Xylenes (lb/mmBtu |
|---|---|---|---|---|---|---|---|---|---|---|
| Rig Engine | 3528 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 0.0008 | 0.0003 | 0.0002 |
| Rig Generator | 504 | 5.0000 | 6.9000 | 0.8000 | 0.7760 | 1.27E-05 | 1.8000 | 0.0008 | 0.0003 | 0.0002 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Rig Engine | | 0.00328 | 0.01686 | 0.00051 | 0.00050 | 0.00000 | 0.00064 | 0.00001 | 0.00000 | 0.00000 |
| Rig Generator | | 0.00278 | 0.00383 | 0.00044 | 0.00043 | 0.00000 | 0.00100 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.00605** | **0.02069** | **0.00096** | **0.00093** | **0.00000** | **0.00164** | **0.00001** | **0.00000** | **0.00000** |

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

* Rig engine emission rates are based on a Tier II engine and rig generator emission rates are based on a Tier 0 engine.
* All days, hours, and HP values above are based on typical industry values

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Williston Basin
**Well Type:** Oil Well

**Development Phase**
**Well Fracturing Engine Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 7 | (Typical Value) |
| Hours of Operation | 168 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Frac Pump | 1,500 | 0.59 | 168 | 148680 |
| Blenders | 500 | 0.42 | 4 | 840 |
| Auxilary Pump | 200 | 0.42 | 4 | 336 |
| Auxilary Pump | 200 | 0.42 | 8 | 672 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Generator | 150 | 0.42 | 168 | 10584 |

Total: 1,500,576 Hp-hrs

Fuel Usage: 89,708 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 2018564.31 | 1009.28 |
| CH4 | 0.003 | 81.88 | 0.04 |
| N2O | 0.0006 | 16.38 | 0.01 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu) | Xylenes (lb/mmBtu) |
|---|---|---|---|---|---|---|---|---|---|---|
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 148680 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Blenders | 840 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Auxilary Pump | 336 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Auxilary Pump | 672 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Generator | 10584 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Frac Pump | | 0.12525 | 0.67195 | 0.02157 | 0.02092 | 2.08E-06 | 0.02681 | 0.00048 | 0.00017 | 0.00012 |
| Blenders | | 0.00078 | 0.00401 | 0.00012 | 0.00012 | 1.18E-08 | 0.00015 | 0.00000 | 0.00000 | 0.00000 |
| Auxilary Pump | | 0.00100 | 0.00310 | 0.00015 | 0.00014 | 4.70E-09 | 0.00025 | 0.00000 | 0.00000 | 0.00000 |
| Auxilary Pump | | 0.00200 | 0.00621 | 0.00030 | 0.00029 | 9.41E-09 | 0.00050 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Generator | | 0.04072 | 0.09683 | 0.00842 | 0.00817 | 1.48E-07 | 0.01155 | 0.00003 | 0.00001 | 0.00001 |
| | **Total:** | **1.30213** | **6.84201** | **0.22574** | **0.21897** | **0.00002** | **0.28205** | **0.00480** | **0.00174** | **0.00119** |

**Emission Factors**

- Frac pump emission factors based on Tier II engines (typical values)
- All other engine emission factors based on Tier 0 engines (typical values)

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Williston Basin
**Well Type:** Oil Well

**Development Phase**
**Hydraulic Fracturing Flowback Emissions**

**Assumptions:**

| | | | |
|---|---|---|---|
| **Estimated Frac flowback Rate:** | 10,000 | Scf/hr | |
| **Combustion Efficiency:** | 95.00 | Percent (%) | |
| **Event Duration:** | 100.00 | Hours | |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* Venting duration based on research and industry knowledge; please see report for additional information.
* Venting control based on Subpart OOOO requirements of 95% minimum control.
Control efficiency can be deleted if applicable.

**Equations:**

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf/lb-mol)) * hrs/yr
** Multiply above equation by 0.02 if including 98% control efficiency

**Un-combusted Componet Emissions:**

| Component | Mole % [a] | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 444.86 | 18.81 | 0.94 |
| Ethane | 5.7920 | 30.1 | 28.96 | 2.29 | 0.11 |
| Propane | 1.3650 | 44.1 | 6.83 | 0.79 | 0.04 |
| i-Butane | 0.3700 | 58.1 | 1.85 | 0.28 | 0.01 |
| n-Butane | 0.2610 | 58.1 | 1.31 | 0.20 | 0.01 |
| i-Pentane | 0.1550 | 72.2 | 0.78 | 0.15 | 0.01 |
| n-Pentane | 0.1020 | 72.2 | 0.51 | 0.10 | 0.00 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 0.73 | 0.17 | 0.01 |
| Heptanes | 0.0930 | 100.2 | 0.47 | 0.12 | 0.01 |
| Octanes | 0.0440 | 114.2 | 0.22 | 0.07 | 0.00 |
| Nonanes | 0.0160 | 128.3 | 0.08 | 0.03 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 0.03 | 0.01 | 0.00 |
| Benzene | 0.0270 | 78.1 | 0.14 | 0.03 | 0.00 |
| Toluene | 0.0190 | 92.1 | 0.10 | 0.02 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 0.06 | 0.02 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 0.73 | 0.17 | 0.01 |
| Nitrogen | 0.0940 | 28.0 | 9.40 | 0.69 | 0.03 |
| Carbon Dioxide | 2.5280 | 44.0 | 252.80 | 29.32 | 1.47 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| **VOC Subtotal** | 2.7600 | 1492.8 | 13.80 | 2.14 | 0.11 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 1.02 | 0.23 | 0.01 |
| **Total** | 100.1460 | 1645.0 | 749.82 | 53.26 | 2.66 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 8452.34 | 980.23 | 49.01 |
| C2 | 5.79 | 550.24 | 63.81 | 3.19 |
| C3 | 1.37 | 129.68 | 15.04 | 0.75 |
| C4 | 0.63 | 59.95 | 6.95 | 0.35 |
| C5+ | 0.76 | 72.58 | 8.42 | 0.42 |

**$CO_2$ Total Emissions:** **53.72** **Tons/Event**
**$N_2O$ Emissions:** **1.13E-04** **Tons/Event**

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.37 | 3.80 | 0.19 | AP-42 CH13.5-1 |
| NOx | 0.068 | 0.70 | 0.03 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.00 | *Based on $H2_S$ 34 mol weight and $SO_2$ 64 mol weight |

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Williston Basin
**Well Type:** Oil Well

**Development Phase**
**Workover Cementing Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 2 | (Typical Value) |
| Hours of Operation | 24 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8500 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

Workovers/Cementing:

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Coil Tubing Unit | 550 | 0.42 | 24 | 5544 |
| Circulation Pump | 450 | 0.42 | 24 | 4536 |
| Cement Pump Trucks | 500 | 0.42 | 8 | 1680 |

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 16298.85 | 8.15 |
| CH4 | 0.003 | 0.66 | 0.00 |
| N2O | 0.0006 | 0.13 | 0.00 |

Total Horsepower: 1,500 (Typical Value)

Total: 11,760 Hp-hrs

Fuel Usage: 724 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Formaldehyde (lb/mmBtu) | Toulene (lb/mmBtu | Xylenes (lb/mmBtu |
|---|---|---|---|---|---|---|---|---|---|---|
| Coil Tubing Unit | 5544 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 0.1636 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |
| Circulation Pump | 4536 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 0.1636 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |
| Cement Pump Trucks | 1680 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 0.6800 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Formaldehyde (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Coil Tubing Unit | | 0.00515 | 0.02649 | 0.00080 | 0.00078 | 0.00100 | 0.00002 | 0.00000 | 0.00001 | 0.00000 |
| Circulation Pump | | 0.00421 | 0.02168 | 0.00066 | 0.00064 | 0.00082 | 0.00001 | 0.00000 | 0.00001 | 0.00000 |
| Cement Pump Trucks | | 0.00500 | 0.01552 | 0.00074 | 0.00072 | 0.00126 | 0.00001 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.01436** | **0.06369** | **0.00221** | **0.00214** | **0.00308** | **0.00004** | **0.00000** | **0.00001** | **0.00001** |

**Emission Factors**

- Engine emission factors based on Tier II engines (typical values)

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

| Kleinfelder, Inc.<br>Wellsite Emissions | Base Location: Williston Basin<br>Well Type: Oil Well |
|---|---|

**Development Phase**

**Well Venting During Workover Events**

**Assumptions:**

Significant gas venting only occurs on natural gas wells.

| | | | |
|---|---|---|---|
| **Estimated Venting Rate:** | 5,000 | Scf/Event | (Typical Value) |
| **Combustion Efficiency:** | 0.00 | Percent (%) | |
| **Event Quantity:** | 1.00 | Event | - Assumed one event |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* Vented quantity based on research and industry knowledge; please see report for additional information.

**Equations:**

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf-lb-mol))

** Multiply above equation by 0.02 if including 98% control efficiency

| Component | Mole % | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Event |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 4448.60 | 188.07 | 0.0940 |
| Ethane | 5.7920 | 30.1 | 289.60 | 22.95 | 0.0115 |
| Propane | 1.3650 | 44.1 | 68.25 | 7.93 | 0.0040 |
| i-Butane | 0.3700 | 58.1 | 18.50 | 2.83 | 0.0014 |
| n-Butane | 0.2610 | 58.1 | 13.05 | 2.00 | 0.0010 |
| i-Pentane | 0.1550 | 72.2 | 7.75 | 1.47 | 0.0007 |
| n-Pentane | 0.1020 | 72.2 | 5.10 | 0.97 | 0.0005 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.0000 |
| Hexanes | 0.1460 | 86.2 | 7.30 | 1.66 | 0.0008 |
| Heptanes | 0.0930 | 100.2 | 4.65 | 1.23 | 0.0006 |
| Octanes | 0.0440 | 114.2 | 2.20 | 0.66 | 0.0003 |
| Nonanes | 0.0160 | 128.3 | 0.80 | 0.27 | 0.0001 |
| Decanes + | 0.0050 | 142.3 | 0.25 | 0.09 | 0.0000 |
| Benzene | 0.0270 | 78.1 | 1.35 | 0.28 | 0.0001 |
| Toluene | 0.0190 | 92.1 | 0.95 | 0.23 | 0.0001 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.0000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.0000 |
| Xylenes | 0.0110 | 106.2 | 0.55 | 0.15 | 0.0001 |
| n-Hexane | 0.1460 | 86.2 | 7.30 | 1.66 | 0.0008 |
| Nitrogen | 0.0940 | 28.0 | 4.70 | 0.35 | 0.0002 |
| Carbon Dioxide | 2.5280 | 44.0 | 126.40 | 14.66 | 0.0073 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.0000 |

| | | | | | |
|---|---|---|---|---|---|
| **VOC Subtotal** | 2.7600 | 1492.8 | 138.00 | 21.44 | 0.0107 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 10.15 | 2.32 | 0.0012 |
| **Total** | 100.1460 | 1645.0 | 5007.30 | 247.46 | 0.1237 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed thatthe representative average gas analyses used by the River Valley RMP. was a good representative analyses of general gas wells.

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 0.00 | 0.00 | 0.00 |
| C2 | 5.79 | 0.00 | 0.00 | 0.00 |
| C3 | 1.37 | 0.00 | 0.00 | 0.00 |
| C4 | 0.63 | 0.00 | 0.00 | 0.00 |
| C5+ | 0.76 | 0.00 | 0.00 | 0.00 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **0.00** | **Tons/Event** |
| **$N_2O$ Emissions:** | **5.67E-07** | **Tons/Event** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.00 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| NOx | 0.000 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.000 | *Based on $H2_S$ 34 mol weight and $SO_2$ 64 mol weight |

| Kleinfelder, Inc. Wellsite Emissions | | Base Location: Williston Basin<br>Well Type: Oil Well |
|---|---|---|

**Development Phase**

**Wellsite Development Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Light Duty Pickup Trucks: | 84 | Trips/Location | | | |
| Light Duty Haul Trucks | 11 | Trips/Location | Total Trips: | 95 | Trips |
| Heavy Duty Haul Trucks | 67 | Trips/Location | | | |
| Water Trucks | 24 | Trips/Location | Total Trips: | 91 | Trips |

* Miles and number of trips based on research and industry knowledge; please see report for additional information.

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (lb/mile)} * \text{\# Trips} * \text{Trip Distance (miles)}}{2000 \text{ (lb/tons)}}$$

| Construction Vehicles | Heavy Haul Trucks | | Light Duty Pickups | | Total |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 1.35E-01 | 1.98E-02 | 1.41E-01 | 2.77E-01 |
| **CO** | 1.98E-02 | 3.60E-02 | 3.16E-03 | 3.76E-02 | 7.37E-02 |
| **VOC** | 3.16E-03 | 5.75E-03 | 4.57E-05 | 6.00E-03 | 1.18E-02 |
| **SO2** | 4.57E-05 | 8.32E-05 | 4.22E-03 | 8.68E-05 | 1.70E-04 |
| **PM10** | 4.22E-03 | 7.68E-03 | 4.09E-03 | 8.02E-03 | 1.57E-02 |
| **PM2.5** | 4.09E-03 | 7.44E-03 | 1.88E+00 | 7.77E-03 | 1.52E-02 |
| **CO2** | 1.88E+00 | 3.41E+00 | 7.61E-05 | 3.56E+00 | 6.98E+00 |
| **CH4** | 7.61E-05 | 1.38E-04 | 1.52E-05 | 1.45E-04 | 2.83E-04 |
| **N2O** | 1.52E-05 | 2.77E-05 | 0.00E+00 | 2.89E-05 | 5.66E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite for calendar year 2012.

c Assumes maximum development scenario

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Williston Basin<br>**Well Type:** Oil Well |
|---|---|

**Development Phase**

**Wellhead Gas Combustion**

**Wellhead gas combustion only for Williston Basin wells, due to the regularity of of pit flares combusting all gas coming from the wellhead. If gas being captured, change scf/hr value or hours of event value.

**Assumptions:**

| | | | |
|---|---|---|---|
| **Estimated Gas Flow Rate:** | 6,875 | Scf/hr | |
| **Combustion Efficiency:** | 95.00 | Percent (%) | |
| **Event Duration:** | 2190.00 | Hours | - Estimated 3 months before sales line |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* Gas flow rate based on estimated gas to oil ratio and estimated liquid production
 - GOR of 1100 scf/bbl and 150 bbl/day production: 1100 scf/bbl *150 bbl-d / 24 = 6,875 scf/hr)
* Combustion control percent based on industry knowledge of standard Williston Basin pit flares

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf/lb-mol)) * hrs/yr
** Multiply above equation by 0.05 if including 95% control efficiency

**Combusted Componet Emissions:**

| Component | Mole % [a] | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 305.84 | 12.93 | 14.16 |
| Ethane | 5.7920 | 30.1 | 19.91 | 1.58 | 1.73 |
| Propane | 1.3650 | 44.1 | 4.69 | 0.55 | 0.60 |
| i-Butane | 0.3700 | 58.1 | 1.27 | 0.19 | 0.21 |
| n-Butane | 0.2610 | 58.1 | 0.90 | 0.14 | 0.15 |
| i-Pentane | 0.1550 | 72.2 | 0.53 | 0.10 | 0.11 |
| n-Pentane | 0.1020 | 72.2 | 0.35 | 0.07 | 0.07 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 0.50 | 0.11 | 0.12 |
| Heptanes | 0.0930 | 100.2 | 0.32 | 0.08 | 0.09 |
| Octanes | 0.0440 | 114.2 | 0.15 | 0.05 | 0.05 |
| Nonanes | 0.0160 | 128.3 | 0.06 | 0.02 | 0.02 |
| Decanes + | 0.0050 | 142.3 | 0.02 | 0.01 | 0.01 |
| Benzene | 0.0270 | 78.1 | 0.09 | 0.02 | 0.02 |
| Toluene | 0.0190 | 92.1 | 0.07 | 0.02 | 0.02 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 0.04 | 0.01 | 0.01 |
| n-Hexane | 0.1460 | 86.2 | 0.50 | 0.11 | 0.12 |
| Nitrogen | 0.0940 | 28.0 | 6.46 | 0.48 | 0.52 |
| Carbon Dioxide | 2.5280 | 44.0 | 173.80 | 20.16 | 22.07 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |
| **VOC Subtotal** | 2.7600 | 1492.8 | 9.49 | 1.47 | 1.61 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 0.70 | 0.16 | 0.17 |
| **Total** | 100.1460 | 1645.0 | 515.50 | 36.61 | 40.09 |

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 5810.98 | 673.91 | 737.93 |
| C2 | 5.79 | 378.29 | 43.87 | 48.04 |
| C3 | 1.37 | 89.15 | 10.34 | 11.32 |
| C4 | 0.63 | 41.21 | 4.78 | 5.23 |
| C5+ | 0.76 | 49.90 | 5.79 | 6.34 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **808.86** | **Tons/Year** |
| **$N_2O$ Emissions:** | **1.71E-03** | **Tons/Year** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.37 | 2.61 | 2.86 | AP-42 CH13.5-1 |
| NOx | 0.068 | 0.48 | 0.53 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.00 | *Based on $H_2S$ 34 mol weight and $SO_2$ 64 mol weight |

| **Kleinfelder, Inc.** | **Base Location:** Williston Basin |
|---|---|
| **Wellsite Emissions** | **Well Type:** Oil Well |

**Production Phase**

**Production Equipment Fugitive Component Emissions**

**Assumptions:**

Components Counts:

| | **Fugitive Components** | | | | |
|---|---|---|---|---|---|
| **Component *** | Valves | Flanges | Connectors | OE Lines | Other |
| **Count** | 24 | 44 | 38 | 0 | 0 |
| **Emissions Factor (scf/hr)** [b] | 0.050 | 0.003 | 0.007 | 0.050 | 0.300 |

* Fugitive component counts for natural gas wells from Subpart W, Table W-1B
* Fugitive component counts for oil wells from Subpart W, Table W-1C

Annual Equipment Run Time: 8760 Hours/Year 379.49 Scf/lb-mol

| **Component** | **Mole %** [a] | **Mole Weight lb/lb-mol** | **Emissions Scf/Year** [b] | **Emissions lbs/Year** | **Emissions Tons/Year** |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 12,454.7 | 526.5 | 0.26 |
| Ethane | 5.7920 | 30.1 | 810.8 | 64.2 | 0.03 |
| Propane | 1.3650 | 44.1 | 191.1 | 22.2 | 0.01 |
| i-Butane | 0.3700 | 58.1 | 51.8 | 7.9 | 0.00 |
| n-Butane | 0.2610 | 58.1 | 36.5 | 5.6 | 0.00 |
| i-Pentane | 0.1550 | 72.2 | 21.7 | 4.1 | 0.00 |
| n-Pentane | 0.1020 | 72.2 | 14.3 | 2.7 | 0.00 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 20.4 | 4.6 | 0.00 |
| Heptanes | 0.0930 | 100.2 | 13.0 | 3.4 | 0.00 |
| Octanes | 0.0440 | 114.2 | 6.2 | 1.9 | 0.00 |
| Nonanes | 0.0160 | 128.3 | 2.2 | 0.8 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 0.7 | 0.3 | 0.00 |
| Benzene | 0.0270 | 78.1 | 3.8 | 0.8 | 0.00 |
| Toluene | 0.0190 | 92.1 | 2.7 | 0.6 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 1.5 | 0.4 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 20.4 | 4.6 | 0.00 |
| Nitrogen | 0.0940 | 28.0 | 13.2 | 1.0 | 0.00 |
| Carbon Dioxide | 2.5280 | 44.0 | 353.9 | 41.0 | 0.02 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |
| VOC Subtotal | 2.7600 | | | 60.02 | 0.03 |
| HAPS Subtotal | 0.2030 | | | 6.50 | 0.00 |
| Total | 100.1460 | | | 692.80 | 0.35 |

**Calculation**

lb/hr = (Mol % * SumSCF/yr) / scf/lb-mol

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

[b] Fugitive emission factors from Subpart W, Table W-1A

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Williston Basin
**Well Type:** Oil Well

**Production Phase**
**Process Heater Emissions**

**Wellsite Heater Inventory:**

| | Heating Value (Mbtu/hr) | Fuel Consumption (MMScf/yr) | |
|---|---|---|---|
| **Heater Treater** | **750** | **6.44** | * Heater treater size based on industry standard |

**Annual Run Time:** **8760** **Hours/Year**
**Fuel Gas Heat Value:** **1,020** **Btu/scf (Standard heating value from AP-42)**

**Equations:**

$$\text{Fuel Consumption (MMscf/yr)} = \frac{\text{Heater Size (MBtu/hr)} * 1{,}000\text{ (Btu/MBtu)} * \text{Hours of Operation (hrs/yr)}}{\text{Fuel Heat Value (Btu/scf)} * 1{,}000{,}000\text{ (scf/MMscf)}}$$

$$\text{NOx/CO/TOC Emissions (tons/yr)} = \frac{\text{AP-42 E.Factor (lbs/MMscf)} * \text{Fuel Consumption (MMscf/yr)} * \text{Fuel heating Value (Btu/scf)}}{2{,}000\text{ (lbs/ton)} * 1{,}020\text{ (Btu/scf - Standard Fuel Heating Value)}}$$

| | Emission Factor (lb/MMscf) | Heater Treater Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) [e] |
|---|---|---|---|---|---|---|
| *Criteria Pollutants & VOC* | | | | | | |
| NOx [a] | 100 | 0.3221 | 0.0000 | 0.0000 | 0.0000 | 0.3221 |
| CO [a] | 84.0 | 0.2705 | 0.0000 | 0.0000 | 0.0000 | 0.2705 |
| VOC | 5.5 | 0.0177 | 0.0000 | 0.0000 | 0.0000 | 0.0177 |
| $SO_2$ [b] | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| TSP [c] | 7.60 | 0.0245 | 0.0000 | 0.0000 | 0.0000 | 0.0245 |
| $PM_{10}$ [c] | 7.60 | 0.0245 | 0.0000 | 0.0000 | 0.0000 | 0.0245 |
| $PM_{2.5}$ [c] | 7.60 | 0.0245 | 0.0000 | 0.0000 | 0.0000 | 0.0245 |
| *Hazardous Air Pollutants* | | | | | | |
| Benzene [d] | 2.10E-03 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Toluene [d] | 3.40E-03 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Hexane [d] | 1.80 | 0.0058 | 0.0000 | 0.0000 | 0.0000 | 0.0058 |
| Formaldehyde [d] | 7.50E-02 | 0.0002 | 0.0000 | 0.0000 | 0.0000 | 0.0002 |
| *Greenhouse Gases* | | | | | | |
| $CO_2$ [f] | 120,162 | 386.9918 | 0.0000 | 0.0000 | 0.0000 | 386.9918 |
| $CH_4$ [f] | 2.27 | 0.0073 | 0.0000 | 0.0000 | 0.0000 | 0.0073 |
| $N_2O$ [f] | 0.23 | 0.0007 | 0.0000 | 0.0000 | 0.0000 | 0.0007 |

a AP-42 Table 1.4-1, Emission Factors for Natural Gas Combustion, 7/98
b Assumes produced gas contains no sulfur
c AP-42 Table 1.4-2, Emission Factors for Natural Gas Combustion, 7/98 (All Particulates are $PM_{1.0}$)
d AP-42 Table 1.4-3, Emission Factors for Organic Compounds from Natural Gas Combustion, 7/98
e Assumes maximum development scenario
f Subpart W - Part 98.233(z)(1) indicates the use of Table C-1 and Table C-2 for fuel combustion of stationary and portable equipment. Table C-1 provides an EF for natural gas combustion of 53.02 kg $CO_2$/mmBtu. Table C-2 provides an EF for natural gas combustion for $CH_4$ as 1.0E-03 kg/MMBtu and for $N_2O$ as 1.0E-04 kg/MMBtu.

| Kleinfelder, Inc.<br>Wellsite Emissions | **Base Location:** Williston Basin<br>**Well Type:** Oil Well |
|---|---|

**Production Phase**

**Atmospheric Oil Tank Flashing Emissions**

**Assumptions:**

| | | | |
|---|---|---|---|
| Production Estimate: | 150 | barrels/day | |
| Production Days: | 365 | Days/Year | |
| Flasing Gas-to-Oil Ratio: | 98 | Scf/bbl | 379.49 Scf/lb-mol |
| Control Efficiency: | 95 | Percent (%) | |

**Flashing Gas Composition:**

| Component | Mole % | Mole Weight (lb/lb-mol) | Emissions (Uncontrolled) Scf/Year | Emissions (Uncontrolled) lbs/Year | Emissions (Uncontrolled) Tons/Year | Emissions (Controlled) Tons/Year |
|---|---|---|---|---|---|---|
| Methane | 17.8400 | 16.043 | 957205.2 | 40466.0018 | 20.2330 | 1.0117 |
| Ethane | 32.2588 | 30.07 | 1730845.914 | 137148.6380 | 68.5743 | 3.4287 |
| Propane | 30.9557 | 44.097 | 1660928.084 | 193000.9900 | 96.5005 | 4.8250 |
| i-Butane | 3.2347 | 58.123 | 173557.8285 | 26582.2595 | 13.2911 | 0.6646 |
| n-Butane | 10.4515 | 58.123 | 560775.2325 | 85888.7951 | 42.9444 | 2.1472 |
| i-Pentane | 1.3981 | 72.150 | 75015.0555 | 14262.1314 | 7.1311 | 0.3566 |
| n-Pentane | 1.7904 | 72.150 | 96063.912 | 18264.0155 | 9.1320 | 0.4566 |
| Other Pentanes | 0.0000 | 70.100 | 0 | 0.0000 | 0.0000 | 0.0000 |
| Hexanes | 0.2392 | 86.177 | 12834.276 | 2914.4889 | 1.4572 | 0.0729 |
| Heptanes | 0.3268 | 100.204 | 17534.454 | 4629.9571 | 2.3150 | 0.1157 |
| Octanes | 0.0810 | 114.231 | 4346.055 | 1308.2142 | 0.6541 | 0.0327 |
| Nonanes | 0.0103 | 128.258 | 552.6465 | 186.7805 | 0.0934 | 0.0047 |
| Decanes + | 0.0000 | 142.285 | 0 | 0.0000 | 0.0000 | 0.0000 |
| Benzene | 0.0204 | 78.120 | 1094.562 | 225.3213 | 0.1127 | 0.0056 |
| Toluene | 0.0163 | 92.130 | 874.5765 | 212.3237 | 0.1062 | 0.0053 |
| Ethylbenzene | 0.0017 | 106.160 | 91.2135 | 25.5164 | 0.0128 | 0.0006 |
| 2,2,4 Trimethylpentane | 0.0030 | 78.120 | 160.965 | 33.1355 | 0.0166 | 0.0008 |
| Xylenes | 0.0062 | 106.160 | 332.661 | 93.0599 | 0.0465 | 0.0023 |
| n-Hexane | 0.1870 | 86.177 | 10033.485 | 2278.4675 | 1.1392 | 0.0570 |
| Nitrogen | 0.8693 | 28.013 | 46642.2915 | 3443.0170 | 1.7215 | 0.0861 |
| Carbon Dioxide | 0.3095 | 44.010 | 16606.2225 | 1925.8475 | 0.9629 | 0.0481 |
| Hydrogen Sulfide | 0.0000 | 34.080 | 0 | 0.0000 | 0.0000 | 0.0000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| VOC Subtotal | 48.72 | | | | 174.95 | 8.75 |
| HAPS Subtotal | 0.23 | | | | 1.43 | 0.07 |
| **Total** | **99.9999** | | | | **266.4445** | **13.3222** |

**Calculation:**

Scf/yr = (Mol% * scf/bbl * bbl/day * days/yr) / 100

lb/yr = (scf/yr * mol wt.) / scf/lb-mol

*** Production and gas to oil ratio based on basin specific differences. Please see "Gas Stream Molar Ratios" tab and report for additional information.**

| | |
|---|---|
| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Williston Basin<br>**Well Type:** Oil Well |

**Production Phase**

**Wellsite Produced Water Tanks Venting**

**Assumptions:**

| | | |
|---|---|---|
| Average Estimated Water Production: | 36000 | Barrels Per Year |
| Number of Water Tanks: | 1 | Tanks |
| VOC Emissions Factor: | 0.2620 | lbs/bbl |
| n-Hexane Emission Factor: | 0.0220 | lbs/bbl |
| Benzene Emission Factor: | 0.0070 | lbs/bbl |

**Calculations:**

| | | |
|---|---|---|
| VOC Emissions: | 4.716 | Tons/Year |
| Hexane Emissions: | 0.396 | Tons/Year |
| Benzene Emissions: | 0.126 | Tons/Year |

* Production conservatively based on estimated industry single well average

* Emission factors based on only known lb/bbl factor, which was developed by the Colorado Department of Health and Environment (PS Memo 09-02).

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Williston Basin<br>**Well Type:** Oil Well |
|---|---|

**Production Phase**

**Truck Loading Emissions**

**AP - 42, Chapter 5.2** $\mathbf{L_L = 12.46 \times S \times P \times M / T}$

$L_L$ = Loading Loss Emission Factor (lbs VOC/1000 gal loaded)

S = Saturation Factor

P = True Vapor Pressure of the Loaded Liquid (psia)

M = Vapor Molecular Weight of the Loaded Liquid (lbs/lbmol)

T = Temperature of Loaded Liquid (ºR)

**VOC Emissions (tpy) =**

$$\frac{L_L \text{ (lbs VOC/1000 gal)} * 42 \text{ gal/bbl} * 365 \text{ days/year} * \text{production (bbl/day)}}{1000 \text{ gal} * 2000 \text{ lbs/ton}}$$

| S[1] | P (psia)[2] | M (lb/lbmol)[3] | T (ºF)[4] | T (ºR) | $L_L$ (lb/1000 gal) | Production (bbl/day) | VOC (tpy) |
|---|---|---|---|---|---|---|---|
| 0.6 | 1.80 | 50.00 | 40.00 | 499.67 | 1.35 | 150.0 | **1.55** |

Notes:

1. Saturation factor from AP-42, Table 5.2-1 (Submerged loading: dedicated normal service)
2. True vapor pressure is estimated from AP-42, Table 7.1-2 assuming an average daily temperature of either 40 or 50 deg F and an RVP of 10.0.
3. Molecular weight liquid vapor is estimated from AP-42, Table 7.1-2 assuming an RVP of 10.0.
4. Temperature based on the annual average temperature for basin location (either 40 or 50 degrees F based on options provided in AP-42 Table 7.1-2

| **Kleinfelder, Inc.** **Wellsite Emissions** | **Base Location:** Williston Basin **Well Type:** Oil Well |
|---|---|

**Production Phase**

**Pumpjack Unit Emissions**

**Assumptions:**

***Pumpjack engines only included at oil wells***

| | | |
|---|---|---|
| Pumpjack Horsepower Rating: | 65.0 | Horsepower |
| Load Factor: | 0.54 | |
| Brake Specific Fuel Consumption: | 7,750 | Btu/hp-hr |
| Annual Operation: | 8,760 | Hours/Year |

**Equations:**

$$\text{Emissions (lbs/hr)} = \frac{\text{Emission Factor (g/hp-hr)} * \text{Power (hp)}}{453.6 \text{ g/lb}}$$

| Pollutant | Emission Factor [a] (lb/MMBtu) | Emission Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) |
|---|---|---|---|---|
| *Criteria Pollutants & VOC* | | | | |
| **NOx** | | 2.80 | 0.22 | 0.9490 |
| **CO** | | 4.80 | 0.37 | 1.6269 |
| **VOC** | 0.12 | - | 0.0326 | 0.1430 |
| **$PM_{10}$** [b] | 4.83E-02 | - | 1.31E-02 | 5.76E-02 |
| **$PM_{2.5}$** [b] | 4.83E-02 | - | 1.31E-02 | 5.76E-02 |
| **$SO_2$** | 5.88E-04 | - | 0.0002 | 0.0007 |
| *Hazardous Air Pollutants* | | | | |
| **Benzene** | 1.94E-03 | - | 5.28E-04 | 2.31E-03 |
| **Toluene** | 9.63E-04 | - | 2.62E-04 | 1.15E-03 |
| **Ethylbenzene** | 1.08E-04 | - | 2.94E-05 | 1.29E-04 |
| **Xylenes** | 2.68E-04 | - | 7.29E-05 | 3.19E-04 |
| **Formaldehyde** | 5.52E-02 | - | 0.0150 | 0.0658 |
| **n-Hexane** | 4.45E-04 | - | 1.21E-04 | 5.30E-04 |
| *Greenhouse Gases* | | | | |
| **$CO_2$** [c] | 117 | - | 31.80 | 139 |
| **$CH_4$** | 0.002 | - | 0.0006 | 0.0026 |
| **$N_2O$** | 0.0002 | - | 0.0001 | 0.0003 |

a AP-42 Table 3.2-3 Uncontrolled Emission Factors for 4-Stroke Rich-Burn Engines, 7/00; and Subpart JJJJ for NOX and CO emission rates.

b PM = sum of PM filterable and PM condensable

c Subpart W - Part 98.233(z)(1) indicates the use of Table C-1 and Table C-2 for fuel combustion of stationary and portable equipment. Table C-1 provides an EF for natural gas combustion of 53.02 kg $CO_2$/mmBtu. Table C-2 provides an EF for natural gas combustion for $CH_4$ as 1.0E-03 kg/MMBtu and for $N_2O$ as 1.0E-04 kg/MMBtu.

- Network website for the 1999 National-Scale Air Toxics Assessment at http://www.epa.gov/ttn/atw/nata1999/nsata99.html

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Williston Basin<br>**Well Type:** Oil Well |
|---|---|

Production Phase

Wellsite Dehydrator Emissions

**Assumptions:**

Number of Dehy Units: 0 Units

**Calculations:**

Calculations and specifications derived from Pinedale Anticline Final SEIS

GRI-GLYCalc 4.0 operated with: 4 MMSCFD, 0.32 gpm glycol flow, average representative gas analysis, and 95% control efficiency

**Emissions:**

| **Species** | **Total Project Emissions (tons/year)** |
|---|---|
| **Total VOC** | 0.000 |
| *Hazardous Air Pollutants* | |
| **Benzene** | 0.000 |
| **Toluene** | 0.000 |
| **Ethylbenzene** | 0.000 |
| **Xylenes** | 0.000 |
| **n-Hexane** | 0.000 |
| *Greenhouse Gases* | |
| **$CO_2$** | 0.000 |
| **$CH_4$ [a]** | 0.000 |
| **$N_2O$** | 0.000 |

Note, no greenhouse gas emissions included for dehydrator in Pinedale EIS

| Kleinfelder, Inc. | | Base Location: Williston Basin |
|---|---|---|
| **Wellsite Emissions** | | **Well Type:** Oil Well |

**Construction Phase**

**Roadway Construction Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Light Duty Pickup Trucks: | 50 | Trips/Location | | | |
| Light Duty Haul Trucks | 0 | Trips/Location | Total Trips: | 50 | Trips |
| Heavy Duty Haul Trucks | 2 | Trips/Location | | | |
| Water Trucks | 40 | Trips/Location | Total Trips: | 42 | Trips |

* Miles and number of trips based on research and industry knowledge; please see report for additional information.

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (g/mile)} * \text{\# Trips} * \text{Trip Distance (miles)}}{\text{2000 (lb/tons)}}$$

| Construction Vehicles | Heavy Haul Trucks | | Light Duty Pickups | | Total |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 6.25E-02 | 7.39E-03 | 7.39E-03 | 6.99E-02 |
| **CO** | 1.98E-02 | 1.66E-02 | 7.26E-02 | 7.26E-02 | 8.92E-02 |
| **VOC** | 3.16E-03 | 2.65E-03 | 3.54E-03 | 3.54E-03 | 6.19E-03 |
| **SO2** | 4.57E-05 | 3.84E-05 | 2.83E-05 | 2.83E-05 | 6.67E-05 |
| **PM10** | 4.22E-03 | 3.54E-03 | 1.94E-04 | 1.94E-04 | 3.74E-03 |
| **PM2.5** | 4.09E-03 | 3.44E-03 | 1.79E-04 | 1.79E-04 | 3.61E-03 |
| **CO2** | 1.88E+00 | 1.58E+00 | 1.13E+00 | 1.13E+00 | 2.70E+00 |
| **CH4** | 7.61E-05 | 6.39E-05 | 4.56E-05 | 4.56E-05 | 1.10E-04 |
| **N2O** | 1.52E-05 | 1.28E-05 | 9.13E-06 | 9.13E-06 | 2.19E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

c Assumes maximum development scenario

| Kleinfelder, Inc.<br>Wellsite Emissions | Base Location: Williston Basin<br>Well Type: Oil Well |
|---|---|

**Production Phase**

**Pneumatic Device Emissions**

**Wellsite Pneumatic Inventory:**

| | Classification | Quantity | Emission Factor (Scf/hr/unit) |
|---|---|---|---|
| **Devices:** | | 0 | 0.00 |
| | | 0 | 0.00 |
| | | 0 | 0.00 |
| **Pumps:** | | | |
| | | | 0.00 |

Annual Equipment Run Time: 8760 Hours/Year — 379.49 Scf/lb-mol

Pneumatic Device Control:[b] 0 Percent

* Low bleed and intermittent bleed emission factors (scf/hr) based on Subpart W, Table W-1A
* Quantity of devices based on typical industry values

| Component | Mole % | Mole Weight lb/lb-mol | (None) Tons/Year | (None) Tons/Year | (None) Tons/Year | Pneumatic Pumps Tons/Year | Total Tons/Year |
|---|---|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Ethane | 5.7920 | 30.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Propane | 1.3650 | 44.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| i-Butane | 0.3700 | 58.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| n-Butane | 0.2610 | 58.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| i-Pentane | 0.1550 | 72.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| n-Pentane | 0.1020 | 72.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Other Pentanes | 0.0000 | 70.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Hexanes | 0.1460 | 86.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Heptanes | 0.0930 | 100.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octanes | 0.0440 | 114.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Nonanes | 0.0160 | 128.3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Decanes + | 0.0050 | 142.3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Benzene | 0.0270 | 78.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Toluene | 0.0190 | 92.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Ethylbenzene | 0.0000 | 106.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Xylenes | 0.0110 | 106.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| n-Hexane | 0.1460 | 86.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Nitrogen | 0.0940 | 28.0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Carbon Dioxide | 2.5280 | 44.0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **VOC Subtotal** | 2.8 | 1492.8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **HAPS Subtotal** | 0.2 | 546.9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | 100.1 | 1645.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

[b] 98% control input is a result of the Wyoming Department of Environment Quality requirement, and only pertains to the Upper Green River Basin.

## APPENDIX F

## EMISSION INVENTORY FOR THE DENVER BASIN OIL WELL

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Denver Basin
**Well Type:** Oil Well

**Location Selection:**

| **Geography:** | **Well Type:** |
|---|---|
| Denver Basin | Oil Well |

- Choose geography/basin, and well type will automatically fill
  < Choose Uinta/Piceance Basin for deep gas wells with little condensate
  < Choose Upper Green River Basin for deep gas wells with dehydrators and higher condensate
  < Choose San Juan Basin for shallow gas wells with little to no condensate
  < Choose Williston Basin for deep oil wells with high gas
  < Choose Denver Basin for shallow oil wells with low gas

If the user wants to change any specifications, do so within the "Constants and References" tab, as all other tabs connect to it.

| | Total Emissions (Tons per Year) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Pollutant:** | **$NO_X$** | **CO** | **VOC** | **$SO_2$** | **$PM_{10}$** | **$PM_{2.5}$** | **$CO_2$** | **$CH_4$** | **$N_2O$** |
| **Construction Phase:** | 0.47 | 0.29 | 0.04 | 0.0001 | 1.96 | 0.06 | 33.84 | 0.001 | 0.0003 |
| **Development Phase:** | 4.45 | 1.16 | 0.31 | 0.0002 | 4.48 | 0.16 | 623.66 | 1.06 | 0.0394 |
| **Operation Phase:** | 1.34 | 1.99 | 6.39 | 0.0008 | 0.10 | 0.28 | 391.46 | 0.72 | 0.0010 |
| **Total:** | 6.26 | 3.43 | 6.74 | 0.0010 | 6.55 | 0.50 | 1048.97 | 1.78 | 0.0407 |

| | Total Emissions (Tons per Year) | | | | | |
|---|---|---|---|---|---|---|
| **Pollutant:** | **Benzene** | **Toluene** | **Ethylbenzene** | **Xylene** | **n-Hexane** | **HAPs** |
| **Construction Phase:** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Development Phase:** | 1.35 | 0.95 | 0.0000 | 0.55 | 7.31 | 10.17 |
| **Operation Phase:** | 0.06 | 0.01 | 0.00062 | 0.004 | 0.24 | 0.38 |
| **Total:** | 1.41 | 0.96 | 0.00062 | 0.56 | 7.54 | 10.54 |

| **$CO_2$ equivalent (Global Warming Potential)** | |
|---|---|
| **Total TPY:** | **1098.95** |
| $CO_2$ equivalent conversions: | |
| $CO_2$ | 1.00 |
| $CH_4$ | 21.00 |
| $N_2O$ | 310.00 |

| **$H_2S$ Emissions** | |
|---|---|
| **Total TPY:** | **0.00** |

* If $H_2S$ in gas, input value in "Gas Stream Molar Ratios" tab, and potential emissions will calculate here. Current assumption is no $H_2S$ in gas stream.

**Kleinfelder, Inc.**
**Wellsite Emissions**

**Base Location:** Denver Basin
**Well Type:** Oil Well

**Construction Phase**
**Road Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 4 | Days/Location | (Typical Value) |
| | 48.0 | Dozer Hours/Location | (Typical Value) |
| | 48.0 | Backhoe Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |

$PM_{10}$ Multiplier: 0.75 * $PM_{15}$ (AP-42 Table 11.9-1, 7/98)

$PM_{2.5}$ Multiplier: 0.105 * TSP (AP-42 Table 11.9-1, 7/98)

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98 & 7/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content }\%)^{1.2} * (\text{soil moisture content }\%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content }\%)^{1.5} * (\text{soil moisture content }\%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions [a]** | | **Backhoe Emissions [a]** | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0473 | 1.97 | 0.0473 | 0.0946 |
| **$PM_{15}$** | 0.50 | 0.0120 | 0.50 | 0.0120 | 0.0241 |
| **$PM_{10}$** | 0.38 | 0.0090 | 0.38 | 0.0090 | 0.0181 |
| **$PM_{2.5}$** | 0.21 | 0.0050 | 0.05 | 0.0013 | 0.0062 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Construction Phase**

**Road Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Grading Length: | 6.00 | miles | (Typical Value) |
| Construction Schedule: | 3 | Days/Location | (Typical Value) |
| | 12 | Hours/Day | (Typical Value) |
| | 36 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | |
| Average Grader Speed: | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 16.12 lbs TSP/Location**

**Emissions = 7.71 lbs $PM_{15}$/Location**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 16.12 | 0.45 | 8.06E-03 |
| **$PM_{15}$** | 7.71 | 0.21 | 3.86E-03 |
| **$PM_{10}$** | 4.63 | 0.13 | 2.31E-03 |
| **$PM_{2.5}$** | 0.50 | 0.01 | 2.50E-04 |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Construction Phase**

**Well Pad Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | | |
|---|---|---|---|---|
| Construction Schedule: | 7 | Days/Location | | (Typical Value) |
| | 10 | Hours/Day | | (Typical Value) |
| | 70 | Hours/Location | (Dozer) | (Typical Value) |
| | 70 | Hours/Location | (Back Hoe) | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | | AP-42 Table 11.9-3, 7/98 |

$PM_{10}$ Multiplier: $0.75 * PM_{15}$ (AP-42 Table 11.9-1, 7/98)

$PM_{2.5}$ Multiplier: $0.105 * TSP$ (AP-42 Table 11.9-1, 7/98)

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content }\%)^{1.2} * (\text{soil moisture content }\%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content }\%)^{1.5} * (\text{soil moisture content }\%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | **Dozer Emissions [a]** | | **Backhoe Emissions [a]** | | **Total** |
|---|---|---|---|---|---|
| | **lbs/hr** | **Tons/Location** | **lbs/hr** | **Tons/Location** | **Tons/Location** |
| **TSP** | 1.97 | 0.0690 | 1.97 | 0.0690 | 0.14 |
| **$PM_{15}$** | 0.50 | 0.0176 | 0.50 | 0.0176 | 0.04 |
| **$PM_{10}$** | 0.38 | 0.0132 | 0.38 | 0.0132 | 0.03 |
| **$PM_{2.5}$** | 0.21 | 0.0072 | 0.21 | 0.0072 | 0.01 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Construction Phase**

**Well Pad Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 4.0 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 40 | Hours/Location | (Typical Value) |
| Watering Control Efficiency | 50 | Percent (%) | (Typical Value) |
| Average Grader Speed | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| Distance Graded | 2.84 | Miles/Location | (Typical Value) |
| $PM_{10}$ Multiplier | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 10/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 7.63 lbs TSP/well pad**

**Emissions = 3.65 lbs $PM_{15}$/well pad**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 7.63 | 0.19 | 0.0038 |
| **$PM_{15}$** | 3.65 | 0.09 | 0.0018 |
| **$PM_{10}$** | 2.19 | 0.05 | 0.0011 |
| **$PM_{2.5}$** | 0.24 | 0.01 | 0.0001 |

# Kleinfelder, Inc.

## Wellsite Emissions

**Base Location:** Denver Basin
**Well Type:** Oil Well

**Construction Phase**

**Pipeline Dozer and Backhoe Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Construction Schedule: | 7.0 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Soil Moisture Content: | 7.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| Soil Silt Content: | 6.9 | Percent (%) | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.75 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.105 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 7/98

Emissions (TSP lbs/hr) = $5.7 * (\text{soil silt content }\%)^{1.2} * (\text{soil moisture content }\%)^{-1.3} *$ Control Efficiency

Emissions ($PM_{15}$ lbs/hr) = $1.0 * (\text{soil silt content }\%)^{1.5} * (\text{soil moisture content }\%)^{-1.4} *$ Control Efficiency

**Emissions = 1.97 lbs TSP/hour/piece of equipment**

**Emissions = 0.50 lbs $PM_{15}$/hour/piece of equipment**

| | Dozer Emissions [a] | | Backhoe Emissions [a] | | Total |
|---|---|---|---|---|---|
| | lbs/hr | Tons/Location | lbs/hr | Tons/Location | Tons/Location |
| **TSP** | 1.97 | 0.0690 | 1.97 | 0.0690 | 0.14 |
| **$PM_{15}$** | 0.50 | 0.0176 | 0.50 | 0.0176 | 0.04 |
| **$PM_{10}$** | 0.38 | 0.0132 | 0.38 | 0.0132 | 0.03 |
| **$PM_{2.5}$** | 0.21 | 0.0072 | 0.21 | 0.0072 | 0.01 |

a Assumes one dozer and one backhoe. Backhoe emissions factors are conservatively estimated as equivalent to Dozer emissions.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Construction Phase**

**Pipeline Grader Particulate Matter**

**Assumptions:**

| | | | |
|---|---|---|---|
| Distance Graded: | 12.50 | Miles/Location | (Typical Value) |
| Construction Schedule: | 7 | Days/Location | (Typical Value) |
| | 10 | Hours/Day | (Typical Value) |
| | 70 | Hours/Location | (Typical Value) |
| Watering Control Efficiency: | 50 | Percent (%) | (Typical Value) |
| Mean Vehicle Speed: | 7.1 | Miles/Hour | AP-42 Table 11.9-3, 7/98 |
| $PM_{10}$ Multiplier: | 0.6 * $PM_{15}$ | (AP-42 Table 11.9-1, 7/98) | |
| $PM_{2.5}$ Multiplier: | 0.031 * TSP | (AP-42 Table 11.9-1, 7/98) | |

**Equations:** From AP-42 tables 11.9-1 and 11.9-3 for
Bulldozing Overburden Emissions, Western Surface Coal Mining, 7/98

Emissions (TSP lbs) = 0.040 * (Mean Vehicle Speed)$^{2.5}$ * Distance Graded * Control Efficiency

Emissions ($PM_{15}$ lbs) = 0.051 * (Mean Vehicle Speed)$^{2.0}$ * Distance Graded * Control Efficiency

**Emissions = 33.58 lbs TSP/well**

**Emissions = 16.07 lbs $PM_{15}$/well**

| | **Grader Construction Emissions** | | |
|---|---|---|---|
| | **lbs/Location** | **lbs/hr/Location** | **Tons/Location** |
| **TSP** | 33.58 | 0.48 | 0.0168 |
| **$PM_{15}$** | 16.07 | 0.23 | 0.0080 |
| **$PM_{10}$** | 9.64 | 0.14 | 0.0048 |
| **$PM_{2.5}$** | 1.04 | 0.01 | 0.0005 |

| Kleinfelder, Inc. Wellsite Emissions | Base Location: Denver Basin Well Type: Oil Well |
|---|---|

**Construction Phase**

**Roadway Construction Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Heavy Diesel Truck Trips: | | | | | |
| Road Construction: | 7 | Trips | | | |
| Well Pad Construction: | 8 | Trips | Total Trips: | 21 | Trips |
| Pipeline Construction: | 6 | Trips | | | |
| Light Duty Pickup Truck Trips: | | | | | |
| Road Construction: | 16 | Trips | | | |
| Well Pad Construction: | 28 | Trips | Total Trips: | 100 | Trips |
| Pipeline Construction: | 56 | Trips | | | |

* All assumptions above are based on typical industry values

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (lb/mile)} * \text{\# Trips} * \text{Trip Distance (miles)}}{\text{2000 (lb/tons)}}$$

| Construction Vehicles | Heavy Haul Trucks | | Light Duty Pickups | | Total |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 3.12E-02 | 7.39E-03 | 1.48E-02 | 4.60E-02 |
| **CO** | 1.98E-02 | 8.32E-03 | 7.26E-02 | 1.45E-01 | 1.54E-01 |
| **VOC** | 3.16E-03 | 1.33E-03 | 3.54E-03 | 7.08E-03 | 8.41E-03 |
| **SO2** | 4.57E-05 | 1.92E-05 | 2.83E-05 | 5.66E-05 | 7.58E-05 |
| **PM10** | 4.22E-03 | 1.77E-03 | 1.94E-04 | 3.88E-04 | 2.16E-03 |
| **PM2.5** | 4.09E-03 | 1.72E-03 | 1.79E-04 | 3.58E-04 | 2.08E-03 |
| **CO2** | 1.88 | 0.79 | 1.13 | 2.25 | 3.04 |
| **CH4** | 7.61E-05 | 3.19E-05 | 4.56E-05 | 9.13E-05 | 1.23E-04 |
| **N2O** | 1.52E-05 | 6.39E-06 | 9.13E-06 | 1.83E-05 | 2.46E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

| Kleinfelder, Inc.<br>Wellsite Emissions | Base Location: Denver Basin<br>Well Type: Oil Well |
|---|---|

**Construction Phase**

**Construction Heavy Equipment Tailpipe Emissions**

**Assumptions:**

Fuel and Engine:

| | | | |
|---|---|---|---|
| Brake Specific Fuel Consumption, Avg. (BSFC) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel Higher Heating Value (HHV) | 0.138 | mmBtu/Gallon | (Typical Value) |

Trackhoe:

| | | | |
|---|---|---|---|
| Working Hours | 188 | Total Hours | (Typical Value) |
| Rated Horsepower | 100 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Tractors/Loaders/Backhoes) | |

Dozer:

| | | | |
|---|---|---|---|
| Working Hours | 188 | Total Hours | (Typical Value) |
| Rated Horsepower | 140 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Crawler Tractor/Dozers) | |

Grader:

| | | | |
|---|---|---|---|
| Working Hours | 130 | Total Hours | (Typical Value) |
| Rated Horsepower | 250 | (Estimate) | |
| Load Factor | 0.59 | (Default LF from NONROAD model for Graders) | |

| | | | |
|---|---|---|---|
| Total Horsepower Hours: | 45795.8 | Hp-hrs | (Sum of all horsepower above) |
| Total Fuel Usage: | 2737.79 | Gallons Diesel Fuel | |

**Equations:**

Total Fuel Usage: ((btu-hp-hr * hp-hrs) / Mmbtu-gal) / 1,000,000

$$\text{Emissions (tons/year/pad)} = \frac{\text{Emission Factor (g/mile)} * \text{Trip Distance (miles)} * \text{Load Factor}}{453.6\ \text{(g/lb)} * 2000\ \text{(lb/tons)}}$$

| Heavy Const. Vehicles | Backhoe | | | Dozer | | | Grader | | |
|---|---|---|---|---|---|---|---|---|---|
| | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) | E. Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) |
| **NOx** | 8.38 | 1.09E+00 | 1.02E-01 | 8.38 | 1.53E+00 | 1.43E-01 | 8.38 | 2.72E+00 | 1.77E-01 |
| **CO** | 2.7 | 3.51E-01 | 3.30E-02 | 2.7 | 4.92E-01 | 4.62E-02 | 2.7 | 8.78E-01 | 5.71E-02 |
| **VOC [b]** | 0.68 | 8.84E-02 | 8.31E-03 | 0.68 | 1.24E-01 | 1.16E-02 | 0.68 | 2.21E-01 | 1.44E-02 |
| **$PM_{10}$** | 0.39 | 5.07E-02 | 4.77E-03 | 0.39 | 7.10E-02 | 6.68E-03 | 0.39 | 1.27E-01 | 8.24E-03 |
| **$PM_{2.5}$** | 0.39 | 5.07E-02 | 4.77E-03 | 0.39 | 7.10E-02 | 6.68E-03 | 0.39 | 1.27E-01 | 8.24E-03 |

| Heavy Const. Vehicles | Total Emissions [c] (tons/yr) |
|---|---|
| **NOx** | 0.42 |
| **CO** | 0.14 |
| **VOC** | 0.03 |
| **$PM_{10}$** | 0.02 |
| **$PM_{2.5}$** | 0.02 |

**Greenhouse Gas Emissions:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | kg/mmbtu | lbs | Tons |
| $CO_2$ | 73.96 | 61604.19 | 30.80 |
| $CH_4$ | 0.003 | 2.50 | 0.0012 |
| $N_2O$ | 0.0006 | 0.50 | 0.0002 |

a From Table A-4 of Exhaust and Crankcase Emission Factors for NONROAD Engine Modeling - Compression Ignition, EPA-420-R-10-018, July 2010.
b Emission Factor represents total Hydrocarbon Emissions
c Converted from emission factor for Distillate Fuel Oil #2 (diesel) as listed in Table C-1 to Subpart C of Part 98 - Default Emission Factors and High Heat Values for Various Types of Fuel.
Listed Factor:

73.96 kg $CO_2$/mmBtu
393 hp-hr = mmBtu
188.2 g $CO_2$/hp-hr

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Construction Phase**

**Wind Erosion Fugitive Dust**

**Assumptions:**

Threshold Friction Velocity ($U_t$) 1.02 m/s (2.28 mph) for well pads (AP-42 Table 13.2.5-2 Overburden - Western Surface Coal Mine)
1.33 m/s (2.97 mph) for roads (AP-42 Table 13.2.5-2 Roadbed material)

Initial Disturbance Area

| | | | |
|---|---|---|---|
| Total Access Road/ROW Area Per Location: | 976,800 | Square Meters | (Typical Value) |
| Total Well Pad Area Disturbed Per Location: | 50,000 | Square Meters | (Typical Value) |
| Total Area Disturbed Per Location: | 1,026,800 | Square Meters | (Typical Value) |
| Exposed Surface Type | Flat | | |
| Meteorological Data | 2002 Grand Junction (obtained from NCDC website) | | |
| Fastest Mile Wind Speed: | 45 | miles/hour | (Typical Value) |
| Fastest Mile Wind Speed ($U_{10}^{+}$) | 20.12 | meters/sec (45 mph) reported as fastest 2-minute wind speed for Grand Junction (2002) | |
| Number soil of disturbances | 1.00 | for well pads (Assumption, disturbance at construction and reclamation) constant for dirt roads | |

**Equations (AP-42 13.2.5.2 Industrial Wind Erosion)**

Friction Velocity $U^* = 0.053\ U_{10}^{+}$

Erosion Potential P ($g/m^2$/period) = $58*(U^*-U_t^*)^2 + 25*(U^*-U_t^*)$ for $U^*>U_t^*$, $P = 0$ for $U^*< U_t^*$

Emissions (tons/year) = Erosion Potential($g/m^2$/period)*Disturbed Area($m^2$)*Disturbances/year*(k)/(453.6 g/lb)/2000 lbs/ton/Develop Period

| **Particle Size Multiplier (k)** | | |
|---|---|---|
| **30 µm** | **<10 µm** | **<2.5 µm** |
| 1.0 | 0.5 | 0.075 |

| **Maxium $U_{10}^{+}$ Wind Speed (m/s)** | **Maximum U* Friction Velocity m/s** | **Well $U_t$* Threshold Velocity[a] m/s** | **Well Pad Erosion Potential $g/m^2$** | **Road $U_t$* Threshold Velocity[a] m/s** | **Road Erosion Potential $g/m^2$** |
|---|---|---|---|---|---|
| 20.12 | 1.07 | 1.02 | 1.28 | 1.33 | 0.00 |

**Wind Erosion Emissions**

| **Particulate Species** | **Well Pad (tons/year)** | **Roads/Pipelines (tons/year)** |
|---|---|---|
| TSP | 7.05E-02 | 0.00E+00 |
| $PM_{10}$ | 3.52E-02 | 0.00E+00 |
| $PM_{2.5}$ | 5.28E-03 | 0.00E+00 |

| **Kleinfelder, Inc.** | **Base Location:** Denver Basin |
|---|---|
| **Wellsite Emissions** | **Well Type:** Oil Well |

**Construction, Development, and Production Phase**

**Construction, Development, and Operations Traffic Fugitive Dust Emissions**

**Assumptions:**

| | |
|---|---|
| Round Trip Miles | 40 |
| Round Trip (Paved) Miles | 16 |
| Round Trip (Un-Paved) Miles | 24 |
| Precipitation Days (P) | 50 |

Unpaved Calculation AP-42, Chapter 13.2.2
November 2006

$E (PM_{10}) / VMT = 1.5 * (S/12)^{0.9} * (W/3)^{0.45} * (365-p)/365)$

$E (PM_{2.5}) / VMT = 0.15 * (S/12)^{0.9} + (W/3)^{0.45} * (365-p)/365)$

Silt Content (S) 8.5 AP 42 13.2.2-1 Mean Silt Content Construction Sites

Paved Calculation AP-42, Chapter 13.2.1
January 2011

$E (PM_{10}) / VMT = 0.0022 * (sL)^{0.91} * (W)^{1.02} * (1-(P/(365*4))$

$E (PM_{2.5}) / VMT = 0.00054 * (sL)^{0.91} * (W)^{1.02} * (1-(P/(365*4))$

Silt Loading (sL) 0.6 AP-42 Table 13.2.1-2 baseline low volume roads

**Construction Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | $PM_{10}$ (lb/VMT) | $PM_{10}$ (lbs) | $PM_{10}$ (Tons) | $PM_{2.5}$ (lb/VMT) | $PM_{2.5}$ (lbs) | $PM_{2.5}$ (Tons) |
|---|---|---|---|---|---|---|---|---|
| Heavy Duty Haul Trucks | 80,000 | 21 | 3.04 | 1534.5 | 0.8 | 0.3 | 153.5 | 0.1 |
| Light Duty Pickup Trucks | 5,000 | 100 | 0.87 | 2098.5 | 1.0 | 0.1 | 209.8 | 0.1 |
| **Total:** | | | | **3633.00** | **1.82** | | **363.30** | **0.18** |

**Paved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| Heavy Duty Haul Trucks | 80,000 | 21 | 0.0574 | 19.3 | 0.0096 | 0.014 | 4.7 | 0.0024 |
| Light Duty Pickup Trucks | 5,000 | 100 | 0.0034 | 5.4 | 0.0027 | 0.001 | 1.3 | 0.0007 |
| **Total:** | | | | **24.7** | **0.0** | | **6.1** | **0.0** |

**Development Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | $PM_{10}$ (lb/VMT) | $PM_{10}$ (lbs) | $PM_{10}$ (Tons) | $PM_{2.5}$ (lb/VMT) | $PM_{2.5}$ (lbs) | $PM_{2.5}$ (Tons) |
|---|---|---|---|---|---|---|---|---|
| Light Duty Pickup Trucks: | 5,000 | 84 | 0.87 | 1762.7 | 0.9 | 0.1 | 176.3 | 0.1 |
| Light Duty Haul Trucks | 7,500 | 11 | 1.05 | 277.0 | 0.1 | 0.1 | 27.7 | 0.0 |
| Heavy Duty Haul Trucks | 80,000 | 67 | 3.04 | 4895.9 | 2.4 | 0.3 | 489.6 | 0.2 |
| Water Trucks | 70,000 | 24 | 2.87 | 1651.5 | 0.8 | 0.3 | 165.1 | 0.1 |
| **Total:** | | | | **8587.11** | **4.29** | | **858.71** | **0.43** |

**Paved Calculations:**

| **Vehicle Type** | **Average Weight (lbs)** | **Vehicle Round Trips** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Light Duty Pickup Trucks:** | 5000 | 84 | 0.00 | 4.6 | 0.0 | 0.0 | 1.1 | 0.0006 |
| **Light Duty Haul Trucks** | 7500 | 11 | 0.01 | 0.9 | 0.0 | 0.0 | 0.2 | 0.0001 |
| **Heavy Duty Haul Trucks** | 80000 | 67 | 0.06 | 61.5 | 0.0 | 0.0 | 15.1 | 0.0076 |
| **Water Trucks** | 70,000 | 24 | 0.05 | 19.2 | 0.0 | 0.0 | 4.7 | 0.0024 |
| **Total:** | | | | **86.3** | **0.0** | | **21.2** | **0.0** |

**Production Phase**

**Unpaved Calculations:**

| Vehicle Type | Average Weight (lbs) | Vehicle Round Trips | PM10 (lb/VMT) | PM10 (lbs) | PM10 (Tons) | PM2.5 (lb/VMT) | PM2.5 (lbs) | PM2.5 (Tons) |
|---|---|---|---|---|---|---|---|---|
| Light Duty Pickup Trucks: | 5,000 | 50 | 0.87 | 1049.23 | 0.52 | 0.0874 | 104.92 | 0.0525 |
| Light Duty Haul Trucks | 7,500 | 0 | 1.05 | 0.00 | 0.00 | 0.1049 | 0.00 | 0.0000 |
| Heavy Duty Haul Trucks | 80,000 | 2 | 3.04 | 146.15 | 0.07 | 0.3045 | 14.61 | 0.0073 |
| Water Trucks | 70,000 | 40 | 2.87 | 2752.45 | 1.38 | 0.2867 | 275.25 | 0.1376 |
| **Total:** | | | | **3947.83** | **1.97** | | **394.78** | **0.20** |

**Paved Calculations:**

| **Vehicle Type** | **Average Weight (lbs)** | **Vehicle Round Trips** | **PM10 (lb/VMT)** | **PM10 (lbs)** | **PM10 (Tons)** | **PM2.5 (lb/VMT)** | **PM2.5 (lbs)** | **PM2.5 (Tons)** |
|---|---|---|---|---|---|---|---|---|
| **Light Duty Pickup Trucks:** | 5,000 | 50 | 0.00 | 2.72 | 0.0014 | 0.0008 | 0.67 | 0.0003 |
| **Light Duty Haul Trucks** | 7,500 | 0 | 0.01 | 0.00 | 0.0000 | 0.0013 | 0.00 | 0.0000 |
| **Heavy Duty Haul Trucks** | 80,000 | 2 | 0.06 | 1.84 | 0.0009 | 0.0141 | 0.45 | 0.0002 |
| **Water Trucks** | 70,000 | 40 | 0.05 | 32.07 | 0.0160 | 0.0123 | 7.87 | 0.0039 |
| **Total:** | | | | **36.62** | **0.02** | | **8.99** | **0.00** |

**Annual Total**

| | Unpaved Roads $PM_{10}$ (tons) | Unpaved Roads $PM_{2.5}$ (tons) |
|---|---|---|
| | **8.08** | **0.8** |
| | **Paved Roads $PM_{10}$** | **Paved Roads $PM_{2.5}$** |
| | **0.1** | **0.0** |
| **Total:** | **8.2** | **0.8** |

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Development Phase**

**Drill Rig Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 12 | (Typical Value) |
| Hours of Operation | 288 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

| Engine | HP [a] | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Vertical Drill Rig Engine | 550 | 0.42 | 96 | 22176 |
| Horizontal Drill Rig Engine | 2,950 | 0.59 | 192 | 334176 |
| Drill Rig Generator | 350 | 0.42 | 288 | 42336 |
| Trailers Generator | 150 | 0.42 | 288 | 18144 |
| Air Compressor | 550 | 0.42 | 96 | 22176 |
| Air Compressor | 550 | 0.42 | 96 | 22176 |
| Air Compressor Booster | 650 | 0.42 | 96 | 26208 |
| Forklift | 120 | 0.42 | 96 | 4838.4 |
| Aerial Lift | 50 | 0.42 | 12 | 252 |
| Frontend loader | 150 | 0.42 | 12 | 756 |
| Dozer | 175 | 0.42 | 6 | 441 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| Total HP | 6,245 | | | |

Total: 493,679 Hp-hrs

Fuel Usage: 29,513 Gallons of Diesel Total Fuel Usage: (btu/hp-hr * hp-hrs) * gal/btu

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| $CO_2$ | 73.96 | 664094.07 | 332.05 |
| $CH_4$ | 0.003 | 26.94 | 0.01 |
| $N_2O$ | 0.0006 | 5.39 | 0.00 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu) | Xylenes (lb/mmBtu) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Drill Rig Engine | 22176 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Horizontal Drill Rig Engine | 334176 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Drill Rig Generator | 42336 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Trailers Generator | 18144 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 22176 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor | 22176 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Air Compressor Booster | 26208 | 1.3272 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Forklift | 4838.4 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Aerial Lift | 252 | 3.4900 | 8.3800 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frontend loader | 756 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Dozer | 441 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Drill Rig Engine | | 0.02059 | 0.10597 | 0.00322 | 0.00312 | 3.10E-07 | 0.00400 | 0.00007 | 0.00003 | 0.00002 |
| Horizontal Drill Rig Engine | | 0.28150 | 1.51030 | 0.04848 | 0.04702 | 4.68E-06 | 0.06026 | 0.00107 | 0.00039 | 0.00027 |
| Drill Rig Generator | | 0.12600 | 0.39107 | 0.01876 | 0.01820 | 5.93E-07 | 0.03173 | 0.00014 | 0.00005 | 0.00003 |
| Trailers Generator | | 0.05400 | 0.16760 | 0.00804 | 0.00780 | 2.54E-07 | 0.01360 | 0.00006 | 0.00002 | 0.00001 |
| Air Compressor | | 0.02059 | 0.10597 | 0.00322 | 0.00312 | 3.10E-07 | 0.00400 | 0.00007 | 0.00003 | 0.00002 |
| Air Compressor | | 0.02059 | 0.10597 | 0.00322 | 0.00312 | 3.10E-07 | 0.00400 | 0.00007 | 0.00003 | 0.00002 |
| Air Compressor Booster | | 0.03834 | 0.11845 | 0.00380 | 0.00369 | 3.67E-07 | 0.00473 | 0.00008 | 0.00003 | 0.00002 |
| Forklift | | 0.01440 | 0.04469 | 0.00214 | 0.00208 | 6.77E-08 | 0.00363 | 0.00002 | 0.00001 | 0.00000 |
| Aerial Lift | | 0.00097 | 0.00233 | 0.00020 | 0.00019 | 3.53E-09 | 0.00028 | 0.00000 | 0.00000 | 0.00000 |
| Frontend loader | | 0.00225 | 0.00698 | 0.00034 | 0.00032 | 1.06E-08 | 0.00057 | 0.00000 | 0.00000 | 0.00000 |
| Dozer | | 0.00131 | 0.00407 | 0.00020 | 0.00019 | 6.17E-09 | 0.00033 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.58057** | **2.56341** | **0.09160** | **0.08886** | **0.00001** | **0.12712** | **0.00158** | **0.00057** | **0.00039** |

**Emission Factors**

- Drill rig emission factors based on Tier II engines
- All other engine emission factors based on Tier 0 engines (typical values)
- HAP emission factors from AP-42 Volume I, Large Stationary Diesel Engines Table 3.4-3

**Calculations:**

ton/year: (Total hp-hr * g/hp-hr) * lb-gram / lb-ton

*** Drill rig horsepower developed based on:**

1 Williston Basin: 2,100 from Jonah, Wyoming RMP
2 San Juan Basin: 2,100 from River Valley RMI
3 Upper Green River Basin: 2,100 from Jonah, Wyoming RMP
4 Denver Basin: 2,950 from River Valley RMI
5 Uintah Basin: 2,952 from River Valley RMI

Note, runtime for each drilling event is based on research and industry experience dependent upon each basi

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Denver Basin
**Well Type:** Oil Well

**Development Phase**
**Conductor Pipe Set Emissions**

**Assumptions:**

| Parameter | Value |
|---|---|
| Days of Operation | 2 |
| Hours of Operation | 24 |
| Diesel Fuel Sulfur Content | 0.000015 |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

Workovers:

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Rig Engine | 350 | 0.42 | 24 | 3528 |
| Rig Generator | 50 | 0.42 | 24 | 504 |

Total Horsepower: 400

Total: 4,032 Hp-hrs

Fuel Usage: 241 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

**Greenhouse Gases:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 5423.82 | 2.71 |
| CH4 | 0.003 | 0.22 | 0.00 |
| N2O | 0.0006 | 0.04 | 0.00 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu | Xylenes (lb/mmBtu |
|---|---|---|---|---|---|---|---|---|---|---|
| Rig Engine | 3528 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 0.0008 | 0.0003 | 0.0002 |
| Rig Generator | 504 | 5.0000 | 6.9000 | 0.8000 | 0.7760 | 1.27E-05 | 1.8000 | 0.0008 | 0.0003 | 0.0002 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Rig Engine | | 0.00328 | 0.01686 | 0.00051 | 0.00050 | 0.00000 | 0.00064 | 0.00001 | 0.00000 | 0.00000 |
| Rig Generator | | 0.00278 | 0.00383 | 0.00044 | 0.00043 | 0.00000 | 0.00100 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.00605** | **0.02069** | **0.00096** | **0.00093** | **0.00000** | **0.00164** | **0.00001** | **0.00000** | **0.00000** |

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

* Rig engine emission rates are based on a Tier II engine and rig generator emission rates are based on a Tier 0 engine.
* All days, hours, and HP values above are based on typical industry values

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Development Phase**

**Well Fracturing Engine Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 3 | (Typical Value) |
| Hours of Operation | 72 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8250 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Frac Pump | 1,500 | 0.59 | 72 | 63720 |
| Frac Pump | 1,500 | 0.59 | 72 | 63720 |
| Frac Pump | 1,500 | 0.59 | 72 | 63720 |
| Frac Pump | 1,500 | 0.59 | 72 | 63720 |
| Frac Pump | 1,500 | 0.59 | 72 | 63720 |
| Blenders | 500 | 0.42 | 4 | 840 |
| Auxilary Pump | 200 | 0.42 | 4 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Sand King | 100 | 0.42 | 8 | 336 |
| Generator | 150 | 0.42 | 72 | 4536 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |
| - | 0 | 0.00 | 0 | 0 |

**Greenhouse Gasses:**

| | Diesel EF | Emissions | Emissions |
|---|---|---|---|
| | Kg/mmBtu | lbs/Location | Tons/Location |
| CO2 | 73.96 | 437166.20 | 218.58 |
| CH4 | 0.003 | 17.73 | 0.01 |
| N2O | 0.0006 | 3.55 | 0.00 |

Greenhouse gas emission factors from Subpart C, Table C-1 and C-2

Total: 324,984 Hp-hrs

Fuel Usage: 19,428 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | $SO_2$ (lb/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Toulene (lb/mmBtu) | Xylenes (lb/mmBtu) |
|---|---|---|---|---|---|---|---|---|---|---|
| Frac Pump | 63720 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 63720 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 63720 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 63720 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Frac Pump | 63720 | 0.7642 | 4.1000 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Blenders | 840 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 1.27E-05 | 0.1636 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Auxilary Pump | 336 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 1.27E-05 | 0.6800 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Sand King | 336 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| Generator | 4536 | 3.4900 | 8.3000 | 0.7220 | 0.7003 | 1.27E-05 | 0.9900 | 7.76E-04 | 2.81E-04 | 1.93E-04 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| - | 0 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.27E-05 | 0.0000 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | $SO_2$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Frac Pump | | 0.05368 | 0.28798 | 0.00924 | 0.00897 | 8.92E-07 | 0.01149 | 0.00020 | 0.00007 | 0.00005 |
| Frac Pump | | 0.05368 | 0.28798 | 0.00924 | 0.00897 | 8.92E-07 | 0.01149 | 0.00020 | 0.00007 | 0.00005 |
| Frac Pump | | 0.05368 | 0.28798 | 0.00924 | 0.00897 | 8.92E-07 | 0.01149 | 0.00020 | 0.00007 | 0.00005 |
| Frac Pump | | 0.05368 | 0.28798 | 0.00924 | 0.00897 | 8.92E-07 | 0.01149 | 0.00020 | 0.00007 | 0.00005 |
| Frac Pump | | 0.05368 | 0.28798 | 0.00924 | 0.00897 | 8.92E-07 | 0.01149 | 0.00020 | 0.00007 | 0.00005 |
| Blenders | | 0.00078 | 0.00401 | 0.00012 | 0.00012 | 1.18E-08 | 0.00015 | 0.00000 | 0.00000 | 0.00000 |
| Auxilary Pump | | 0.00100 | 0.00310 | 0.00015 | 0.00014 | 4.70E-09 | 0.00025 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Sand King | | 0.00129 | 0.00307 | 0.00027 | 0.00026 | 4.70E-09 | 0.00037 | 0.00000 | 0.00000 | 0.00000 |
| Generator | | 0.01745 | 0.04150 | 0.00361 | 0.00350 | 6.35E-08 | 0.00495 | 0.00001 | 0.00001 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| - | | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00E+00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.29020** | **1.49467** | **0.05063** | **0.04911** | **0.00000** | **0.06354** | **0.00104** | **0.00038** | **0.00026** |

**Emission Factors**

- Frac pump emission factors based on Tier II engines (typical values)
- All other engine emission factors based on Tier 0 engines (typical values)

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Denver Basin
**Well Type:** Oil Well

**Development Phase**
**Hydraulic Fracturing Flowback Emissions**

**Assumptions:**

| | | | |
|---|---|---|---|
| **Estimated Frac flowback Rate:** | 10,000 | Scf/hr | |
| **Combustion Efficiency:** | 95.00 | Percent (%) | |
| **Event Duration:** | 100.00 | Hours | |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* Venting duration based on research and industry knowledge; please see report for additional information.
* Venting control based on Subpart OOOO requirements of 95% minimum control.
Control efficiency can be deleted if applicable.

**Equations:**

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf/lb-mol)) * hrs/yr
** Multiply above equation by 0.02 if including 98% control efficiency

**Un-combusted Componet Emissions:**

| Component | Mole % [a] | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 444.86 | 18.81 | 0.94 |
| Ethane | 5.7920 | 30.1 | 28.96 | 2.29 | 0.11 |
| Propane | 1.3650 | 44.1 | 6.83 | 0.79 | 0.04 |
| i-Butane | 0.3700 | 58.1 | 1.85 | 0.28 | 0.01 |
| n-Butane | 0.2610 | 58.1 | 1.31 | 0.20 | 0.01 |
| i-Pentane | 0.1550 | 72.2 | 0.78 | 0.15 | 0.01 |
| n-Pentane | 0.1020 | 72.2 | 0.51 | 0.10 | 0.00 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 0.73 | 0.17 | 0.01 |
| Heptanes | 0.0930 | 100.2 | 0.47 | 0.12 | 0.01 |
| Octanes | 0.0440 | 114.2 | 0.22 | 0.07 | 0.00 |
| Nonanes | 0.0160 | 128.3 | 0.08 | 0.03 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 0.03 | 0.01 | 0.00 |
| Benzene | 0.0270 | 78.1 | 0.14 | 0.03 | 0.00 |
| Toluene | 0.0190 | 92.1 | 0.10 | 0.02 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 0.06 | 0.02 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 0.73 | 0.17 | 0.01 |
| Nitrogen | 0.0940 | 28.0 | 9.40 | 0.69 | 0.03 |
| Carbon Dioxide | 2.5280 | 44.0 | 252.80 | 29.32 | 1.47 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| **VOC Subtotal** | 2.7600 | 1492.8 | 13.80 | 2.14 | 0.11 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 1.02 | 0.23 | 0.01 |
| **Total** | 100.1460 | 1645.0 | 749.82 | 53.26 | 2.66 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 8452.34 | 980.23 | 49.01 |
| C2 | 5.79 | 550.24 | 63.81 | 3.19 |
| C3 | 1.37 | 129.68 | 15.04 | 0.75 |
| C4 | 0.63 | 59.95 | 6.95 | 0.35 |
| C5+ | 0.76 | 72.58 | 8.42 | 0.42 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **53.72** | **Tons/Event** |
| **$N_2O$ Emissions:** | **1.13E-04** | **Tons/Event** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.37 | 3.80 | 0.19 | AP-42 CH13.5-1 |
| NOx | 0.068 | 0.70 | 0.03 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.00 | *Based on $H2_S$ 34 mol weight and $SO_2$ 64 mol weight |

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Denver Basin
**Well Type:** Oil Well

**Development Phase**
**Workover Cementing Emissions**

**Assumptions:**

| Parameter | Value | |
|---|---|---|
| Days of Operation | 2 | (Typical Value) |
| Hours of Operation | 24 | (Typical Value) |
| Diesel Fuel Sulfur Content | 0.000015 | (Typical Value) |

| Parameter | Value | Units | |
|---|---|---|---|
| BSFC (Avg.) | 8500 | btu/hp-hr | (Typical Value) |
| Diesel HHV | 0.138 | mmbtu/gal | (Typical Value) |

Workovers/Cementing:

| Engine | HP | Load Factor | Run time (hrs) | Total Hp-hrs |
|---|---|---|---|---|
| Coil Tubing Unit | 550 | 0.42 | 24 | 5544 |
| Circulation Pump | 450 | 0.42 | 24 | 4536 |
| Cement Pump Trucks | 500 | 0.42 | 8 | 1680 |

**Greenhouse Gasses:**

| | Diesel EF Kg/mmBtu | Emissions lbs/Location | Emissions Tons/Location |
|---|---|---|---|
| $CO_2$ | 73.96 | 16298.85 | 8.15 |
| $CH_4$ | 0.003 | 0.66 | 0.00 |
| $N_2O$ | 0.0006 | 0.13 | 0.00 |

Total Horsepower: 1,500 (Typical Value)

Total: 11,760 Hp-hrs

Fuel Usage: 724 Gallons of Diesel Total Fuel Usage: ((btu/hp-hr * hp-hrs) * gal/btu

| Engine | Total Hp-hrs | CO (g/hp-hr) | $NO_x$ (g/hp-hr) | $PM_{10}$ (g/hp-hr) | $PM_{2.5}$ (g/hp-hr) | VOC (g/hp-hr) | Benzene (lb/mmBtu) | Formaldehyde (lb/mmBtu) | Toulene (lb/mmBtu | Xylenes (lb/mmBtu |
|---|---|---|---|---|---|---|---|---|---|---|
| Coil Tubing Unit | 5544 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 0.1636 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |
| Circulation Pump | 4536 | 0.8425 | 4.3351 | 0.1316 | 0.1277 | 0.1636 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |
| Cement Pump Trucks | 1680 | 2.7000 | 8.3800 | 0.4020 | 0.3899 | 0.6800 | 0.0008 | 0.0001 | 0.0003 | 0.0002 |

| Engine | | CO (Tons/yr) | $NO_x$ (Tons/yr) | $PM_{10}$ (Tons/yr) | $PM_{2.5}$ (Tons/yr) | VOC (Tons/yr) | Benzene (Tons/yr) | Formaldehyde (Tons/yr) | Toulene (Tons/yr) | Xylenes (Tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|
| Coil Tubing Unit | | 0.00515 | 0.02649 | 0.00080 | 0.00078 | 0.00100 | 0.00002 | 0.00000 | 0.00001 | 0.00000 |
| Circulation Pump | | 0.00421 | 0.02168 | 0.00066 | 0.00064 | 0.00082 | 0.00001 | 0.00000 | 0.00001 | 0.00000 |
| Cement Pump Trucks | | 0.00500 | 0.01552 | 0.00074 | 0.00072 | 0.00126 | 0.00001 | 0.00000 | 0.00000 | 0.00000 |
| | **Total:** | **0.01436** | **0.06369** | **0.00221** | **0.00214** | **0.00308** | **0.00004** | **0.00000** | **0.00001** | **0.00001** |

**Emission Factors**

- Engine emission factors based on Tier II engines (typical values)

**Calculations:**

ton/year: (Total hp-hr * g-hp-hr) * lb-gram / lb-ton

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Development Phase**

**Well Venting During Workover Events**

**Assumptions:**

Significant gas venting only occurs on natural gas wells.

| | | | |
|---|---|---|---|
| **Estimated Venting Rate:** | 5,000 | Scf/Event | (Typical Value) |
| **Combustion Efficiency:** | 0.00 | Percent (%) | |
| **Event Quantity:** | 1.00 | Event | - Assumed one event |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* Vented quantity based on research and industry knowledge; please see report for additional information.

**Equations:**

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf-lb-mol))

** Multiply above equation by 0.02 if including 98% control efficiency

| Component | Mole % | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Event |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 4448.60 | 188.07 | 0.0940 |
| Ethane | 5.7920 | 30.1 | 289.60 | 22.95 | 0.0115 |
| Propane | 1.3650 | 44.1 | 68.25 | 7.93 | 0.0040 |
| i-Butane | 0.3700 | 58.1 | 18.50 | 2.83 | 0.0014 |
| n-Butane | 0.2610 | 58.1 | 13.05 | 2.00 | 0.0010 |
| i-Pentane | 0.1550 | 72.2 | 7.75 | 1.47 | 0.0007 |
| n-Pentane | 0.1020 | 72.2 | 5.10 | 0.97 | 0.0005 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.0000 |
| Hexanes | 0.1460 | 86.2 | 7.30 | 1.66 | 0.0008 |
| Heptanes | 0.0930 | 100.2 | 4.65 | 1.23 | 0.0006 |
| Octanes | 0.0440 | 114.2 | 2.20 | 0.66 | 0.0003 |
| Nonanes | 0.0160 | 128.3 | 0.80 | 0.27 | 0.0001 |
| Decanes + | 0.0050 | 142.3 | 0.25 | 0.09 | 0.0000 |
| Benzene | 0.0270 | 78.1 | 1.35 | 0.28 | 0.0001 |
| Toluene | 0.0190 | 92.1 | 0.95 | 0.23 | 0.0001 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.0000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.0000 |
| Xylenes | 0.0110 | 106.2 | 0.55 | 0.15 | 0.0001 |
| n-Hexane | 0.1460 | 86.2 | 7.30 | 1.66 | 0.0008 |
| Nitrogen | 0.0940 | 28.0 | 4.70 | 0.35 | 0.0002 |
| Carbon Dioxide | 2.5280 | 44.0 | 126.40 | 14.66 | 0.0073 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.0000 |

| | | | | | |
|---|---|---|---|---|---|
| **VOC Subtotal** | 2.7600 | 1492.8 | 138.00 | 21.44 | 0.0107 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 10.15 | 2.32 | 0.0012 |
| **Total** | 100.1460 | 1645.0 | 5007.30 | 247.46 | 0.1237 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed thatthe representative average gas analyses used by the River Valley RMP. was a good representative analyses of general gas wells.

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 0.00 | 0.00 | 0.00 |
| C2 | 5.79 | 0.00 | 0.00 | 0.00 |
| C3 | 1.37 | 0.00 | 0.00 | 0.00 |
| C4 | 0.63 | 0.00 | 0.00 | 0.00 |
| C5+ | 0.76 | 0.00 | 0.00 | 0.00 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **0.00** | **Tons/Event** |
| **$N_2O$ Emissions:** | **5.67E-07** | **Tons/Event** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.00 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| NOx | 0.000 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.000 | *Based on $H2_S$ 34 mol weight and $SO_2$ 64 mol weight |

| **Kleinfelder, Inc.** | **Base Location:** Denver Basin |
|---|---|
| **Wellsite Emissions** | **Well Type:** Oil Well |

**Development Phase**

**Wellsite Development Traffic Tailpipe Emissions**

**Assumptions:**

Average Round Trip Distance: 40.0 Miles/Trip Average

| | | | | | |
|---|---|---|---|---|---|
| Light Duty Pickup Trucks: | 84 | Trips/Location | | | |
| Light Duty Haul Trucks | 11 | Trips/Location | Total Trips: | 95 | Trips |
| Heavy Duty Haul Trucks | 67 | Trips/Location | | | |
| Water Trucks | 24 | Trips/Location | Total Trips: | 91 | Trips |

* Miles and number of trips based on research and industry knowledge; please see report for additional information.

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (lb/mile)} * \text{\# Trips} * \text{Trip Distance (miles)}}{2000 \text{ (lb/tons)}}$$

| Construction Vehicles | Heavy Haul Trucks | | Light Duty Pickups | | Total |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 1.35E-01 | 1.98E-02 | 1.41E-01 | 2.77E-01 |
| **CO** | 1.98E-02 | 3.60E-02 | 3.16E-03 | 3.76E-02 | 7.37E-02 |
| **VOC** | 3.16E-03 | 5.75E-03 | 4.57E-05 | 6.00E-03 | 1.18E-02 |
| **SO2** | 4.57E-05 | 8.32E-05 | 4.22E-03 | 8.68E-05 | 1.70E-04 |
| **PM10** | 4.22E-03 | 7.68E-03 | 4.09E-03 | 8.02E-03 | 1.57E-02 |
| **PM2.5** | 4.09E-03 | 7.44E-03 | 1.88E+00 | 7.77E-03 | 1.52E-02 |
| **CO2** | 1.88E+00 | 3.41E+00 | 7.61E-05 | 3.56E+00 | 6.98E+00 |
| **CH4** | 7.61E-05 | 1.38E-04 | 1.52E-05 | 1.45E-04 | 2.83E-04 |
| **N2O** | 1.52E-05 | 2.77E-05 | 0.00E+00 | 2.89E-05 | 5.66E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite for calendar year 2012.

c Assumes maximum development scenario

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Development Phase**

**Wellhead Gas Combustion**

**Wellhead gas combustion only for Williston Basin wells, due to the regularity of of pit flares combusting all gas coming from the wellhead. If gas being captured, change scf/hr value or hours of event value.

**Assumptions:**

| | | | |
|---|---|---|---|
| **Estimated Gas Flow Rate:** | 0 | Scf/hr | |
| **Combustion Efficiency:** | 0.00 | Percent (%) | |
| **Event Duration:** | 0.00 | Hours | - Estimated 3 months before sales line |
| | 379.49 | Scf/lb-mol | - Typical/Constant Conversion Value |

* It is assumed that all produced natural gas is sent to a sales line after the well is completed.

Emissions (Tons/Year) = ((Scf/hr * Mole% / 100) * Mole Wt.) / (2000 * scf/lb-mol)) * hrs/yr
** Multiply above equation by 0.05 if including 95% control efficiency

**Combusted Componet Emissions:**

| Component | Mole % [a] | Mole Weight lb/lb-mole | Emissions Scf/hr | Emissions lbs/hour | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 0.00 | 0.00 | 0.00 |
| Ethane | 5.7920 | 30.1 | 0.00 | 0.00 | 0.00 |
| Propane | 1.3650 | 44.1 | 0.00 | 0.00 | 0.00 |
| i-Butane | 0.3700 | 58.1 | 0.00 | 0.00 | 0.00 |
| n-Butane | 0.2610 | 58.1 | 0.00 | 0.00 | 0.00 |
| i-Pentane | 0.1550 | 72.2 | 0.00 | 0.00 | 0.00 |
| n-Pentane | 0.1020 | 72.2 | 0.00 | 0.00 | 0.00 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 0.00 | 0.00 | 0.00 |
| Heptanes | 0.0930 | 100.2 | 0.00 | 0.00 | 0.00 |
| Octanes | 0.0440 | 114.2 | 0.00 | 0.00 | 0.00 |
| Nonanes | 0.0160 | 128.3 | 0.00 | 0.00 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 0.00 | 0.00 | 0.00 |
| Benzene | 0.0270 | 78.1 | 0.00 | 0.00 | 0.00 |
| Toluene | 0.0190 | 92.1 | 0.00 | 0.00 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 0.00 | 0.00 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 0.00 | 0.00 | 0.00 |
| Nitrogen | 0.0940 | 28.0 | 0.00 | 0.00 | 0.00 |
| Carbon Dioxide | 2.5280 | 44.0 | 0.00 | 0.00 | 0.00 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| **VOC Subtotal** | 2.7600 | 1492.8 | 0.00 | 0.00 | 0.00 |
| **HAPS Subtotal** | 0.2030 | 546.9 | 0.00 | 0.00 | 0.00 |
| **Total** | 100.1460 | 1645.0 | 0.00 | 0.00 | 0.00 |

**Flare Combustion GHG emissions:**

| | Component Molar Ratio (%) | Emissions Scf/hr | Emissions lbs/hr | Emissions Tons/Year |
|---|---|---|---|---|
| C1 | 88.97 | 0.00 | 0.00 | 0.00 |
| C2 | 5.79 | 0.00 | 0.00 | 0.00 |
| C3 | 1.37 | 0.00 | 0.00 | 0.00 |
| C4 | 0.63 | 0.00 | 0.00 | 0.00 |
| C5+ | 0.76 | 0.00 | 0.00 | 0.00 |

| | | |
|---|---|---|
| **$CO_2$ Total Emissions:** | **0.00** | **Tons/Year** |
| **$N_2O$ Emissions:** | **0.00E+00** | **Tons/Year** |

**Flare Combustion Emissions:** Fuel Heating Value: 1028.00 btu/scf

| | lbs/mmBTU | lbs/hour | Tons/event | |
|---|---|---|---|---|
| CO | 0.00 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| NOx | 0.000 | 0.00 | 0.00 | AP-42 CH13.5-1 |
| $SO_2$ | - | 0.00 | 0.00 | *Based on $H_2S$ 34 mol weight and $SO_2$ 64 mol weight |

## Kleinfelder, Inc.
### Wellsite Emissions

**Base Location:** Denver Basin
**Well Type:** Oil Well

**Production Phase**

**Production Equipment Fugitive Component Emissions**

**Assumptions:**

Components Counts:

| | Fugitive Components | | | | |
|---|---|---|---|---|---|
| **Component *** | Valves | Flanges | Connectors | OE Lines | Other |
| **Count** | 18 | 32 | 28 | 0 | 0 |
| **Emissions Factor (scf/hr)** [b] | 0.050 | 0.003 | 0.007 | 0.050 | 0.300 |

* Fugitive component counts for natural gas wells from Subpart W, Table W-1B
* Fugitive component counts for oil wells from Subpart W, Table W-1C

Annual Equipment Run Time: 8760 Hours/Year 379.49 Scf/lb-mol

| Component | Mole % [a] | Mole Weight lb/lb-mol | Emissions Scf/Year [b] | Emissions lbs/Year | Emissions Tons/Year |
|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 9,290.4 | 392.8 | 0.20 |
| Ethane | 5.7920 | 30.1 | 604.8 | 47.9 | 0.02 |
| Propane | 1.3650 | 44.1 | 142.5 | 16.6 | 0.01 |
| i-Butane | 0.3700 | 58.1 | 38.6 | 5.9 | 0.00 |
| n-Butane | 0.2610 | 58.1 | 27.3 | 4.2 | 0.00 |
| i-Pentane | 0.1550 | 72.2 | 16.2 | 3.1 | 0.00 |
| n-Pentane | 0.1020 | 72.2 | 10.7 | 2.0 | 0.00 |
| Other Pentanes | 0.0000 | 70.1 | 0.00 | 0.00 | 0.00 |
| Hexanes | 0.1460 | 86.2 | 15.2 | 3.5 | 0.00 |
| Heptanes | 0.0930 | 100.2 | 9.7 | 2.6 | 0.00 |
| Octanes | 0.0440 | 114.2 | 4.6 | 1.4 | 0.00 |
| Nonanes | 0.0160 | 128.3 | 1.7 | 0.6 | 0.00 |
| Decanes + | 0.0050 | 142.3 | 0.5 | 0.2 | 0.00 |
| Benzene | 0.0270 | 78.1 | 2.8 | 0.6 | 0.00 |
| Toluene | 0.0190 | 92.1 | 2.0 | 0.5 | 0.00 |
| Ethylbenzene | 0.0000 | 106.2 | 0.00 | 0.00 | 0.00 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.00 | 0.00 | 0.00 |
| Xylenes | 0.0110 | 106.2 | 1.1 | 0.3 | 0.00 |
| n-Hexane | 0.1460 | 86.2 | 15.2 | 3.5 | 0.00 |
| Nitrogen | 0.0940 | 28.0 | 9.8 | 0.7 | 0.00 |
| Carbon Dioxide | 2.5280 | 44.0 | 264.0 | 30.6 | 0.02 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.00 | 0.00 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| VOC Subtotal | 2.7600 | | | 44.77 | 0.02 |
| HAPS Subtotal | 0.2030 | | | 4.85 | 0.00 |
| Total | 100.1460 | | | 516.78 | 0.26 |

**Calculation**

lb/hr = (Mol % * SumSCF/yr) / scf/lb-mol

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

[b] Fugitive emission factors from Subpart W, Table W-1A

## Kleinfelder, Inc.
**Wellsite Emissions**

**Base Location:** Denver Basin
**Well Type:** Oil Well

**Production Phase**
**Process Heater Emissions**

**Wellsite Heater Inventory:**

| | Heating Value (Mbtu/hr) | Fuel Consumption (MMScf/yr) | |
|---|---|---|---|
| **Heater Treater** | **750** | **6.44** | * Heater treater size based on industry standard |

**Annual Run Time:** **8760** **Hours/Year**
**Fuel Gas Heat Value:** **1,020** **Btu/scf (Standard heating value from AP-42)**

**Equations:**

$$\text{Fuel Consumption (MMscf/yr)} = \frac{\text{Heater Size (MBtu/hr)} * 1{,}000 \text{ (Btu/MBtu)} * \text{Hours of Operation (hrs/yr)}}{\text{Fuel Heat Value (Btu/scf)} * 1{,}000{,}000 \text{ (scf/MMscf)}}$$

$$\text{NOx/CO/TOC Emissions (tons/yr)} = \frac{\text{AP-42 E.Factor (lbs/MMscf)} * \text{Fuel Consumption (MMscf/yr)} * \text{Fuel heating Value (Btu/scf)}}{2{,}000 \text{ (lbs/ton)} * 1{,}020 \text{ (Btu/scf - Standard Fuel Heating Value)}}$$

| | Emission Factor (lb/MMscf) | Heater Treater Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) | Total Emissions (Tons/Year) [e] |
|---|---|---|---|---|---|---|
| *Criteria Pollutants & VOC* | | | | | | |
| NOx [a] | 100 | 0.3221 | 0.0000 | 0.0000 | 0.0000 | 0.3221 |
| CO [a] | 84.0 | 0.2705 | 0.0000 | 0.0000 | 0.0000 | 0.2705 |
| VOC | 5.5 | 0.0177 | 0.0000 | 0.0000 | 0.0000 | 0.0177 |
| $SO_2$ [b] | 0.00 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| TSP [c] | 7.60 | 0.0245 | 0.0000 | 0.0000 | 0.0000 | 0.0245 |
| $PM_{10}$ [c] | 7.60 | 0.0245 | 0.0000 | 0.0000 | 0.0000 | 0.0245 |
| $PM_{2.5}$ [c] | 7.60 | 0.0245 | 0.0000 | 0.0000 | 0.0000 | 0.0245 |
| *Hazardous Air Pollutants* | | | | | | |
| Benzene [d] | 2.10E-03 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Toluene [d] | 3.40E-03 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Hexane [d] | 1.80 | 0.0058 | 0.0000 | 0.0000 | 0.0000 | 0.0058 |
| Formaldehyde [d] | 7.50E-02 | 0.0002 | 0.0000 | 0.0000 | 0.0000 | 0.0002 |
| *Greenhouse Gases* | | | | | | |
| $CO_2$ [f] | 120,162 | 386.9918 | 0.0000 | 0.0000 | 0.0000 | 386.9918 |
| $CH_4$ [f] | 2.27 | 0.0073 | 0.0000 | 0.0000 | 0.0000 | 0.0073 |
| $N_2O$ [f] | 0.23 | 0.0007 | 0.0000 | 0.0000 | 0.0000 | 0.0007 |

a AP-42 Table 1.4-1, Emission Factors for Natural Gas Combustion, 7/98
b Assumes produced gas contains no sulfur
c AP-42 Table 1.4-2, Emission Factors for Natural Gas Combustion, 7/98 (All Particulates are $PM_{1.0}$)
d AP-42 Table 1.4-3, Emission Factors for Organic Compounds from Natural Gas Combustion, 7/98
e Assumes maximum development scenario
f Subpart W - Part 98.233(z)(1) indicates the use of Table C-1 and Table C-2 for fuel combustion of stationary and portable equipment. Table C-1 provides an EF for natural gas combustion of 53.02 kg $CO_2$/mmBtu. Table C-2 provides an EF for natural gas combustion for $CH_4$ as 1.0E-03 kg/MMBtu and for $N_2O$ as 1.0E-04 kg/MMBtu.

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Production Phase**

**Atmospheric Oil Tank Flashing Emissions**

**Assumptions:**

| | | | |
|---|---|---|---|
| Production Estimate: | 125 | barrels/day | |
| Production Days: | 365 | Days/Year | |
| Flasing Gas-to-Oil Ratio: | 45 | Scf/bbl | 379.49 Scf/lb-mol |
| Control Efficiency: | 95 | Percent (%) | |

**Flashing Gas Composition:**

| Component | Mole % | Mole Weight (lb/lb-mol) | Emissions (Uncontrolled) Scf/Year | Emissions (Uncontrolled) lbs/Year | Emissions (Uncontrolled) Tons/Year | Emissions (Controlled) Tons/Year |
|---|---|---|---|---|---|---|
| Methane | 23.6778 | 16.043 | 486134.8313 | 20551.4272 | 10.2757 | 0.5138 |
| Ethane | 31.6716 | 30.07 | 650257.5375 | 51525.0577 | 25.7625 | 1.2881 |
| Propane | 27.0752 | 44.097 | 555887.7 | 64594.5345 | 32.2973 | 1.6149 |
| i-Butane | 2.3870 | 58.123 | 49008.09375 | 7506.1199 | 3.7531 | 0.1877 |
| n-Butane | 6.1325 | 58.123 | 125907.8906 | 19284.1559 | 9.6421 | 0.4821 |
| i-Pentane | 0.9352 | 72.150 | 19200.825 | 3650.5297 | 1.8253 | 0.0913 |
| n-Pentane | 1.5003 | 72.150 | 30803.03438 | 5856.3834 | 2.9282 | 0.1464 |
| Other Pentanes | 0.6754 | 70.100 | 13867.52484 | 2561.6314 | 1.2808 | 0.0640 |
| Hexanes | 2.2516 | 86.177 | 46228.1625 | 10497.7848 | 5.2489 | 0.2624 |
| Heptanes | 0.7869 | 100.204 | 16156.04063 | 4265.9883 | 2.1330 | 0.1066 |
| Octanes | 0.1469 | 114.231 | 3016.040625 | 907.8641 | 0.4539 | 0.0227 |
| Nonanes | 0.0463 | 128.258 | 950.596875 | 321.2776 | 0.1606 | 0.0080 |
| Decanes + | 0.0105 | 142.285 | 215.578125 | 80.8283 | 0.0404 | 0.0020 |
| Benzene | 0.1540 | 78.120 | 3161.8125 | 650.8756 | 0.3254 | 0.0163 |
| Toluene | 0.0709 | 92.130 | 1455.665625 | 353.3966 | 0.1767 | 0.0088 |
| Ethylbenzene | 0.0034 | 106.160 | 69.80625 | 19.5279 | 0.0098 | 0.0005 |
| 2,2,4 Trimethylpentane | 0.0253 | 78.120 | 519.440625 | 106.9296 | 0.0535 | 0.0027 |
| Xylenes | 0.0219 | 106.160 | 449.634375 | 125.7825 | 0.0629 | 0.0031 |
| n-Hexane | 0.9119 | 86.177 | 18722.44688 | 4251.6122 | 2.1258 | 0.1063 |
| Nitrogen | 0.0000 | 28.013 | 0 | 0.0000 | 0.0000 | 0.0000 |
| Carbon Dioxide | 2.1907 | 44.010 | 44977.80938 | 5216.1411 | 2.6081 | 0.1304 |
| Hydrogen Sulfide | 0.0000 | 34.080 | 0 | 0.0000 | 0.0000 | 0.0000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| VOC Subtotal | 43.14 | | | | 62.52 | 3.13 |
| HAPS Subtotal | 1.19 | | | | 2.75 | 0.14 |
| **Total** | **100.6753** | | | | **101.1639** | **5.0582** |

**Calculation:**

Scf/yr = (Mol% * scf/bbl * bbl/day * days/yr) / 100

lb/yr = (scf/yr * mol wt.) / scf/lb-mol

*** Production and gas to oil ratio based on basin specific differences. Please see "Gas Stream Molar Ratios" tab and report for additional information.**

| Kleinfelder, Inc.<br>Wellsite Emissions | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Production Phase**

**Wellsite Produced Water Tanks Venting**

**Assumptions:**

| | | |
|---|---|---|
| Average Estimated Water Production: | 11000 | Barrels Per Year |
| Number of Water Tanks: | 1 | Tanks |
| VOC Emissions Factor: | 0.2620 | lbs/bbl |
| n-Hexane Emission Factor: | 0.0220 | lbs/bbl |
| Benzene Emission Factor: | 0.0070 | lbs/bbl |

**Calculations:**

| | | |
|---|---|---|
| VOC Emissions: | 1.441 | Tons/Year |
| Hexane Emissions: | 0.121 | Tons/Year |
| Benzene Emissions: | 0.0385 | Tons/Year |

* Production conservatively based on estimated industry single well average
* Emission factors based on only known lb/bbl factor, which was developed by the Colorado Department of Health and Environment (PS Memo 09-02).

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Production Phase**

**Truck Loading Emissions**

**AP - 42, Chapter 5.2** $L_L = 12.46 \times S \times P \times M / T$

$L_L$ = Loading Loss Emission Factor (lbs VOC/1000 gal loaded)

S = Saturation Factor

P = True Vapor Pressure of the Loaded Liquid (psia)

M = Vapor Molecular Weight of the Loaded Liquid (lbs/lbmol)

T = Temperature of Loaded Liquid (ºR)

**VOC Emissions (tpy) =**

$$\frac{L_L \text{ (lbs VOC/1000 gal) * 42 gal/bbl * 365 days/year * production (bbl/day)}}{\text{1000 gal * 2000 lbs/ton}}$$

| $S^1$ | $P$ (psia)$^2$ | $M$ (lb/lbmol)$^3$ | $T$ (ºF)$^4$ | $T$ (ºR) | $L_L$ (lb/1000 gal) | Production (bbl/day) | VOC (tpy) |
|---|---|---|---|---|---|---|---|
| 0.6 | 2.30 | 50.00 | 50.00 | 509.67 | 1.69 | 125.0 | **1.62** |

Notes:

1. Saturation factor from AP-42, Table 5.2-1 (Submerged loading: dedicated normal service)
2. True vapor pressure is estimated from AP-42, Table 7.1-2 assuming an average daily temperature of either 40 or 50 deg F and an RVP of 10.0.
3. Molecular weight liquid vapor is estimated from AP-42, Table 7.1-2 assuming an RVP of 10.0.
4. Temperature based on the annual average temperature for basin location (either 40 or 50 degrees F based on options provided in AP-42 Table 7.1-2

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Production Phase**

**Pumpjack Unit Emissions**

**Assumptions:**

***Pumpjack engines only included at oil wells***

| | | |
|---|---|---|
| Pumpjack Horsepower Rating: | 65.0 | Horsepower |
| Load Factor: | 0.54 | |
| Brake Specific Fuel Consumption: | 8,000 | Btu/hp-hr |
| Annual Operation: | 8,760 | Hours/Year |

**Equations:**

$$\text{Emissions (lbs/hr)} = \frac{\text{Emission Factor (g/hp-hr)} * \text{Power (hp)}}{453.6 \text{ g/lb}}$$

| Pollutant | Emission Factor [a] (lb/MMBtu) | Emission Factor [a] (g/hp-hr) | Emissions (lb/hr) | Emissions (Tons/Year) |
|---|---|---|---|---|
| *Criteria Pollutants & VOC* | | | | |
| **NOx** | | 2.80 | 0.22 | 0.9490 |
| **CO** | | 4.80 | 0.37 | 1.6269 |
| **VOC** | 0.12 | - | 0.0337 | 0.1476 |
| **$PM_{10}$** [b] | 4.83E-02 | - | 1.36E-02 | 5.94E-02 |
| **$PM_{2.5}$** [b] | 4.83E-02 | - | 1.36E-02 | 5.94E-02 |
| **$SO_2$** | 5.88E-04 | - | 0.0002 | 0.0007 |
| *Hazardous Air Pollutants* | | | | |
| **Benzene** | 1.94E-03 | - | 5.45E-04 | 2.39E-03 |
| **Toluene** | 9.63E-04 | - | 2.70E-04 | 1.18E-03 |
| **Ethylbenzene** | 1.08E-04 | - | 3.03E-05 | 1.33E-04 |
| **Xylenes** | 2.68E-04 | - | 7.53E-05 | 3.30E-04 |
| **Formaldehyde** | 5.52E-02 | - | 0.0155 | 0.0679 |
| **n-Hexane** | 4.45E-04 | - | 1.25E-04 | 5.47E-04 |
| *Greenhouse Gases* | | | | |
| **$CO_2$** [c] | 117 | - | 32.82 | 144 |
| **$CH_4$** | 0.002 | - | 0.0006 | 0.0027 |
| **$N_2O$** | 0.0002 | - | 0.0001 | 0.0003 |

a AP-42 Table 3.2-3 Uncontrolled Emission Factors for 4-Stroke Rich-Burn Engines, 7/00; and Subpart JJJJ for NOX and CO emission rates.

b PM = sum of PM filterable and PM condensable

c Subpart W - Part 98.233(z)(1) indicates the use of Table C-1 and Table C-2 for fuel combustion of stationary and portable equipment. Table C-1 provides an EF for natural gas combustion of 53.02 kg $CO_2$/mmBtu. Table C-2 provides an EF for natural gas combustion for $CH_4$ as 1.0E-03 kg/MMBtu and for $N_2O$ as 1.0E-04 kg/MMBtu.

- Network website for the 1999 National-Scale Air Toxics Assessment at http://www.epa.gov/ttn/atw/nata1999/nsata99.html

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

Production Phase

Wellsite Dehydrator Emissions

**Assumptions:**

Number of Dehy Units: 0 Units

**Calculations:**

Calculations and specifications derived from Pinedale Anticline Final SEIS
GRI-GLYCalc 4.0 operated with: 4 MMSCFD, 0.32 gpm glycol flow, average representative gas analysis, and 95% control efficiency

**Emissions:**

| Species | Total Project Emissions (tons/year) |
|---|---|
| **Total VOC** | 0.000 |
| *Hazardous Air Pollutants* | |
| **Benzene** | 0.000 |
| **Toluene** | 0.000 |
| **Ethylbenzene** | 0.000 |
| **Xylenes** | 0.000 |
| **n-Hexane** | 0.000 |
| *Greenhouse Gases* | |
| **$CO_2$** | 0.000 |
| **$CH_4$ [a]** | 0.000 |
| **$N_2O$** | 0.000 |

Note, no greenhouse gas emissions included for dehydrator in Pinedale EIS

| **Kleinfelder, Inc.**<br>**Wellsite Emissions** | **Base Location:** Denver Basin<br>**Well Type:** Oil Well |
|---|---|

**Construction Phase**

**Roadway Construction Traffic Tailpipe Emissions**

**Assumptions:**

| | | | | | |
|---|---|---|---|---|---|
| Average Round Trip Distance: | 40.0 | Miles/Trip Average | | | |
| Light Duty Pickup Trucks: | 50 | Trips/Location | | | |
| Light Duty Haul Trucks | 0 | Trips/Location | Total Trips: | 50 | Trips |
| Heavy Duty Haul Trucks | 2 | Trips/Location | | | |
| Water Trucks | 40 | Trips/Location | Total Trips: | 42 | Trips |

* Miles and number of trips based on research and industry knowledge; please see report for additional information.

**Equations:**

$$\text{Emissions (tons/year)} = \frac{\text{Emission Factor (g/mile) * \# Trips * Trip Distance (miles)}}{\text{2000 (lb/tons)}}$$

| Construction Vehicles | Heavy Haul Trucks | | Light Duty Pickups | | Total |
|---|---|---|---|---|---|
| | E. Factor [a] (lb/mile) | Emissions (Tons/Location) | E. Factor [b] (lb/mile) | Emissions (Tons/Location) | Emissions (Tons/Location) |
| **NOx** | 7.44E-02 | 6.25E-02 | 7.39E-03 | 7.39E-03 | 6.99E-02 |
| **CO** | 1.98E-02 | 1.66E-02 | 7.26E-02 | 7.26E-02 | 8.92E-02 |
| **VOC** | 3.16E-03 | 2.65E-03 | 3.54E-03 | 3.54E-03 | 6.19E-03 |
| **SO2** | 4.57E-05 | 3.84E-05 | 2.83E-05 | 2.83E-05 | 6.67E-05 |
| **PM10** | 4.22E-03 | 3.54E-03 | 1.94E-04 | 1.94E-04 | 3.74E-03 |
| **PM2.5** | 4.09E-03 | 3.44E-03 | 1.79E-04 | 1.79E-04 | 3.61E-03 |
| **CO2** | 1.88E+00 | 1.58E+00 | 1.13E+00 | 1.13E+00 | 2.70E+00 |
| **CH4** | 7.61E-05 | 6.39E-05 | 4.56E-05 | 4.56E-05 | 1.10E-04 |
| **N2O** | 1.52E-05 | 1.28E-05 | 9.13E-06 | 9.13E-06 | 2.19E-05 |

a Emission factors developed using EPA MOVES model, assuming Heavy-Heavy Duty Diesel Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

b Emission factors developed using EPA MOVES model, assuming Light Heavy Duty Gasoline Trucks, traveling 15 mph onsite in typical oil and gas development area, for calendar year 2012.

c Assumes maximum development scenario

| **Kleinfelder, Inc.** | **Base Location:** Denver Basin |
|---|---|
| **Wellsite Emissions** | **Well Type:** Oil Well |

**Production Phase**

**Pneumatic Device Emissions**

**Wellsite Pneumatic Inventory:**

| | Classification | Quantity | Emission Factor (Scf/hr/unit) |
|---|---|---|---|
| **Devices:** | | 0 | 0.00 |
| | | 0 | 0.00 |
| | | 0 | 0.00 |
| **Pumps:** | | | |
| | | | 0.00 |

| | | | |
|---|---|---|---|
| Annual Equipment Run Time: | 8760 | Hours/Year | 379.49 Scf/lb-mol |
| Pneumatic Device Control:[b] | 0 | Percent | |

* Low bleed and intermittent bleed emission factors (scf/hr) based on Subpart W, Table W-1A

* Quantity of devices based on typical industry values

| Component | Mole % | Mole Weight lb/lb-mol | (None) Tons/Year | (None) Tons/Year | (None) Tons/Year | Pneumatic Pumps Tons/Year | Total Tons/Year |
|---|---|---|---|---|---|---|---|
| Methane | 88.9720 | 16.0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Ethane | 5.7920 | 30.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Propane | 1.3650 | 44.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| i-Butane | 0.3700 | 58.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| n-Butane | 0.2610 | 58.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| i-Pentane | 0.1550 | 72.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| n-Pentane | 0.1020 | 72.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Other Pentanes | 0.0000 | 70.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Hexanes | 0.1460 | 86.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Heptanes | 0.0930 | 100.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Octanes | 0.0440 | 114.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Nonanes | 0.0160 | 128.3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Decanes + | 0.0050 | 142.3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Benzene | 0.0270 | 78.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Toluene | 0.0190 | 92.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Ethylbenzene | 0.0000 | 106.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2,2,4 Trimethylpentane | 0.0000 | 78.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Xylenes | 0.0110 | 106.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| n-Hexane | 0.1460 | 86.2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Nitrogen | 0.0940 | 28.0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Carbon Dioxide | 2.5280 | 44.0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Hydrogen Sulfide | 0.0000 | 34.1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **VOC Subtotal** | 2.8 | 1492.8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **HAPS Subtotal** | 0.2 | 546.9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | 100.1 | 1645.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

[a] Gas analyses for gas wells are based on research done on different RMP's and private industry analyses. Research showed that the representative average gas analyses used by the River Valley RMP was a good representative analyses of general gas wells.

[b] 98% control input is a result of the Wyoming Department of Environment Quality requirement, and only pertains to the Upper Green River Basin.