Human Health Risk Assessment for Battlement Mesa Health Impact Assessment

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Disclaimer

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ACRONYMS

AI air intake
AIQ Air Quality Standard
Antero Antero Resources Corporation
APCD Air Pollution Control Division
AT averaging time
ATSDR Agency for Toxic Substances and Disease Registry
bgs below ground surface
BMC Battlement Mesa Company
BTEX benzene, toluene, ethylbenzene, and xylene
BTV background threshold value
BW body weight
CDPHE Colorado Department of Public Health and Environment
cm^2 square centimeters
COGCC Colorado Oil and Gas Conservation Commission
COPC contaminant of potential concern
CSM conceptual site model
DNPH 2,4-dinitrophenylhydrazine
ED exposure duration
EF exposure frequency
ET exposure time
EPA United States Environmental Protection Agency
EPC exposure point concentration
ERG Eastern Research Group
GCPHD Garfield County Public Health Department
HHRA Human Health Risk Assessment
HI hazard index
HIA Health Impact Assessement
HQ hazard quotient
IRIS Integrated Risk Information System
kg kilogram
IUR inhalation unit risk
L liter
MEI maximum exposed individual
MRL method reporting limit
NIOSH
PAH polycyclic aromatic hydrocarbon
PAR population attributable risk
PM particulate matter
$PM_{2.5}$ particulate matter of 2.5 microns or less
PM_{10} particulate matter of ten microns or less
ppb parts per billion
ppm parts per million
PPRTVs Provisional Peer-Reviewed Toxicity Values
PRG preliminary remediation goal

PUD Planned urban development
RAGs EPA Risk Assessment Guidance for Superfund
RfC reference concentration
RfD reference dose
RSL regional screening level
SNMOC speciated non-methane organic compound
TWA time weighted average
UCL upper confidence limit
VOC volatile organic compound
$\mu g/m^3$ micrograms per cubic meter

1 Introduction

This human health risk assessment (HHRA) was conducted in support of the Battlement Mesa health impact assessment (HIA). The HIA seeks to evaluate the potential health impacts of Antero Resources Corporation's (Antero) proposed natural gas production operations within the Battlement Mesa planned urban development (PUD). This HHRA specifically addresses potential impacts to the health of Battlement Mesa residents that may be exposed to chemicals released from natural gas production operations to ambient air, surface water, groundwater, and soil. The resident receptor refers to both an adults and children. The child resident receptor refers to children. Three exposure scenarios were evaluated:

(1) A long-term chronic exposure scenario for all Battlement Mesa residents
(2) A long-term chronic exposure scenario for Battlement Mesa residents living adjacent to a well pad.
(3) An acute exposure scenario for Battlement Mesa child residents living adjacent to a well pad

The risk assessment was conducted according to standard United States Environmental Protection Agency (EPA) methodology, including:

(1) EPA Risk Assessment Guidance for Superfund (RAGS) Part Volume 1 Human Health Evaluation Manual (Part A) Interim Final (EPA 1989)
(2) Residual Risk Report to Congress and the EPA Risk Assessment Reference Library (EPA 2004)
(3) ProUCL Version 4.00.05 Technical Guide (Draft). EPA/600/R-07/041 (EPA 2010).

This HHRA is organized as follows:

- Introduction
- Chemical Data Evaluation and Selection of contaminants of potential concern (COPCs)
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization
- Uncertainty Analysis
- Summary and Conclusion
- Data Gaps
- References

1.1 Site Description

The Battlement Mesa Planned Urban Development (PUD) is a 3,200-acre unincorporated jurisdiction divided into several neighborhoods, the names of which are:

- The Reserve
- Battlement Creek Village
- Willow Creek Village
- Willow Ridge Apartments
- Willow Park Apartments
- Eagles Point
- Valley View Village
- Fairway Villas
- Stone Ridge Village
- Monument Creek Village
- Canyon View Village
- Mesa Ridge
- Mesa Vista
- Tamarisk Village
- Tamarisk Meadows
- Saddleback Village

The community sits on a 500 foot mesa approximately to the south of Colorado River and mesas continue to rise above the community for another 500-1000 feet.

1.1.1 Geology

Appendix B of the HIA provides a description of the sites geology.

1.1.2 Population

The most reliable estimates of Battlement Mesa PUD residents' demographic characteristics come from the 2000 US Census. It is important to keep in mind that the demographics of the PUD have likely changed since 2000, though without the most-recent census data it is difficult to tell how or by how much the community makeup has changed.

The 2000 United States census was used to obtain the most accurate population counts as well as information on age, gender, and racial composition for the Battlement Mesa/Parachute zip code 81635 (Zip code 81636 is used for post office boxes and there fore is not included in the demographic data). According to the 2000 United States census estimates, there total population of the Battlement Mesa/Parachute zip code was 5,041; 49.3 percent of the Battlement Mesa/Parachute population was female and 50.7 percent male. The median age was 37.5 years. 26.0 percent of the population were under 18 years of age, 7.2 percent under 5 years, and 19.8 percent were 65 years and older. For people reporting race in Battlement Mesa/Parachute, 93.4 percent identified as White, 0.5

percent as Black or African American; 9.7 percent of the population identified as Hispanic or Latino (of any race).

The Battlement Mesa PUD is often described as a "retirement community" (Miller et al. 2005). While it is difficult to precisely define what is and what is not a "retirement community," several objective measures reflect characteristics of Battlement Mesa's population. In Colorado in 2000, 9.7 percent of the population was 65 years and over compared to 19.8 percent of the population in the Battlement Mesa/Parachute zip code. Furthermore, whereas 63.9% of the United States population (16 and over) was participating in the labor force, only 48.9% of Battlement Mesa residents were either working or looking for work in 2000. There is a 40-unit nursing home in the Battlement Mesa PUD serving seniors of low to moderate income (Miller et al. 2005).

While the lower labor force participation rate of Battlement Mesa residents and the higher proportion of people 65 and over are likely indicators of a high retiree population in the PUD, almost half of the PUD residents 16 and over were either working or looking for work. More than a quarter of the family households in Battlement Mesa had children under the age of 18 (27.2%). While the Battlement Mesa PUD is home to higher proportions of people 65 and over than the US as a whole, the community is not homogeneously "retired."

1.1.3 Economy

Currently, the Battlement Mesa community is entirely residential. The only businesses in the PUD support the local residents. While there has been extensive natural gas drilling in the area surrounding the PUD, there is currently no industrial activity within the PUD itself. Several natural gas operators operate wells in the area surrounding Battlement Mesa. The businesses with in the PUD include:

- A grocery store
- Gas stations
- Several medical facilities
- A public golf course
- Banks
- A café
- A recreation center (paid for by homeowner association dues)
- A local newspaper

In addition to the local businesses, the PUD is home to two churches and two schools – Underwood Elementary (grades K-5) and St. John Middle School (grades 6-8). Battlement Mesa students attend Grand Valley High School in Parachute for grades 9-12.

1.1.4 Antero's Proposed Plan

In the Fall of 2009, Antero announced plans to purchase surface rights and mineral rights from the BMC. Along with this, Antero indicated their intent to drill for natural gas

within the Battlement Mesa PUD. Antero plans to drill approximately 200 natural gas wells on ten well pads (approximately 20 wells per pad) in three phases spanning a total of 5 years. Each well is currently estimated to produce natural gas for 20 to 30 years, after which the well would be abandoned. The possibility exists for some wells to be re-developed.

1.2 Previous Risk Assessments

Four risk assessments have been conducted in Garfield County over the past 8 years to determine if air borne emissions from natural gas production operations have an impact on public health. As described in the following sections, each of these risk assessments evaluated one specific set of data. This HHRA incorporated several of the data sets used in previous risk assessments to provide a more comprehensive evaluation of the potential risks to human health from natural gas production operations.

1.2.1 2002 Community-based Short-term Ambient Air Screening Study in Garfield County for Oil and Gas Related Activities (CDPHE 2002)

The Colorado Department of Public Health and Environment (CDPHE) first conducted a limited screening level risk assessment using ambient air data from 20 samples collected in 2002 by the EPA in response to a request of the Grand Valley Citizen's Alliance. Samples were collected over 24- and 8-hour intervals at wells and residences located in the Parachute valley. The samples were analyzed for 42 volatile organic compounds (VOCs) by EPA method TO-14. Maximum concentrations of acetone, methyl ethyl ketone, benzene, toluene, and xylenes (the only contaminants detected in the samples) were compared to EPA region 9 preliminary remediation goals (PRGs) for residential ambient air. PRGs are protective risk-based levels below which chronic health effects are not expected to occur. Benzene, a known human carcinogen, was the only contaminant, at a concentration of 6.5 $\mu g/m^3$, that exceeded its PRG of 0.23 $\mu g/m^3$. None of the non-carcinogenic VOCs were detected at concentrations that would pose a significant health risk to area residents. While the cancer risk from benzene was within EPA's generally acceptable range of 1E-06 to 1E-04, it was greater than the 1E-06 (l cancer in a million). The report concluded benzene may warrant further review pertaining to exposure scenario assumptions and typical exposure concentrations.

1.2.2 2005-2007 Garfield County Air Toxics Inhalation: Screening Level Human Health Risk Assessment (CDPHE 2007)

CDPHE conducted a second more rigorous screening level HHRA in accordance with Tier-1 of EPA's Air Toxic Risk Assessment Library (EPA, 2004) in 2007. The data for risk assessment was collected from 14 fixed air monitoring sites for 24-hour intervals on a once per month or once per quarter basis. The 14 sites were divided into three categories: Oil and Gas Development (eight sites); Urban (four sites); and Rural

Background (two sites). In addition, grab samples were also collected at 27 locations based on odor complaints. All samples were analyzed for VOCs by EPA method TO-14a/15.

This HHRA concluded that, the non-cancer hazards on either a chronic or short-term basis do not exceed the acceptable health based standard and the cancer risk estimates are at, or slightly above, the upper-end of EPA's acceptable risk range (1 to 100 excess cancers per 1 million individuals). However, the HHRA identified the need for continued air monitoring and source apportionment and strongly supported the need to manage the risk posed by potential exposure of residents of the Garfield County to air toxics as a result of the dramatic increase in oil and gas development for the following reasons:

(1) The estimated cancer risks and the non-cancer hazards across the rural background areas were significantly lower than those across the oil and gas development and urban areas.
(2) Although total cancer risks were slightly higher in the urban areas than those in the oil and gas areas, the major contributors of cancer risk were different between the two areas. Benzene, a known human carcinogen, was the major contributor of risk across the oil and gas development areas, while trichloroethene and 1,4-dichlorobenzene were the major contributors in the urban areas.
(3) The cancer risk estimates for benzene across the oil and gas development areas were significantly higher than those across the urban and rural background areas.
(4) The high-end, short-term, non-cancer hazard estimates across the oil and gas development area exceed an acceptable value of one for benzene (e.g., Hazard Quotient [HQs] of 2 or 3) showing the potential for adverse health effects in areas of oil and gas development.
(5) The high-end acute non-cancer hazard estimates for benzene across the oil and gas development area, as represented by several grab sampling sites collected during observed odor events, exceed an acceptable value of one (e.g., HQs of 2 to 6) showing the potential for adverse health effects associated with odor events.
(6) Exposures may be underestimated because increases in air concentrations of VOCs over time were not evaluated and several important air toxics, such as polycyclic aromatic hydrocarbons (PAHs) were not evaluated.

1.2.3 2008 Community Health Risk Analysis of Oil and Gas Industry Impacts in Garfield County, Colorado (Coons and Walker, 2008)

The Saccomanno Research Institute sought to evaluate the risk associated air, water, and soil contaminants associated with natural gas operations. A lack of data on pollutant concentrations in water and soil limited the quantitative evaluation to contaminants in air. Air concentrations were estimated with a Gaussian plume model, based on meteorological conditions specific to Garfield County (measured at the Rifle Airport) and "typical" emission rates of benzene, toluene, and m&p-xylene from natural gas and condensate to predict air contaminant concentrations that may occur during natural gas operations. It should be noted that these concentrations were not based on actual data

collected in Garfield County. Contaminant concentrations for five specific natural gas operations were modeled: flow back with no recovery of natural gas, flow back with 93% recovery of natural gas, wellhead glycol dehydration, uncontrolled emissions from condensate tanks, and condensate emissions controlled by a combustion device. Risks to human health were calculated from the modeled air concentrations according to EPA's RAGS Volume 1 (EPA 1989).

The results of the risk assessment indicate that the cancer risk from benzene for 70 years of exposure in air exceeds EPA's generally accepted range of 1E-06 to 1E-04 for flow back with no gas recovery for distances up to 500 meters (1640 feet) downwind of the well; flow back with 93% gas recovery for distances up to 75 meters (246 feet) downwind of the well; wellhead glycol dehydration for distances up to 50 meters (164 feet) downwind of the well; and uncontrolled condensate emissions for distances up to 100 meters (328 feet) downwind of the tank.

The results of the risk assessment also indicated that acute (1-<14 day exposure) reference concentrations (RfCs) for non-cancer hazards from benzene and m&p-xylene may be exceeded for flow back with no gas recovery for distances up to 250 meters (820 feet) downwind of the well and uncontrolled condensate emissions for distances, up to 55 meters (180 feet) downwind of the tank.

The risk assessment concluded that benzene emissions during uncontrolled flow back present the greatest threat of cancer risk and non-cancer hazard and that these effects may occur in people who spend one or more days within 250 meters (820 feet) downwind of the natural gas well during flow back operations with no gas recovery. This observation has been sited as a rationale for moving Antero's proposed set back from 500 feet to 1000 feet. Whether or not this finding would apply to Antero's proposed wells, depends on the extent to which Antero intends to control flow back emissions. In addition, the exposure concentrations in this risk assessment were modeled using "typical" emission rates rather than site specific emission rates and meteorological data from the Rifle airport. Actual emission rates and meteorological conditions in the PUD could be different than those used in the model. Therefore, the modeled exposure concentrations may not be applicable to Antero's natural gas production operations within the PUD.

1.2.4 2010 Garfield County Air Toxics Inhalation: Screening Level Human Health Risk Assessment Inhalation of Volatile Organic Compounds Measured in 2008 Air Quality Monitoring Study (CDPHE 2010).

CDPHE conducted a rigorous screening level HHRA in accordance with Tier-1 of EPA's Air Toxic Risk Assessment Library (EPA, 2004) using data for speciated non-methane organic compounds (SNMOCs) and carbonyls collected by the Garfield County Public Health Department (GCPHD) during the 2008 air quality monitoring study. GCPHD collected 24-hour air samples from four fixed monitoring sites on a weekly (SNMOCs) or bi-weekly (carbonyls) basis over the course of 12 months. The four monitoring sites,

Bell-Melton Ranch, Brock, Parachute, and Rifle, were located in close proximity (<1.5 mile) to oil and gas production operations in the rural and urban oil and gas development areas.

The HHRA concluded that there is a potential for public health impacts across the oil and gas development areas in Garfield County for the following reasons.

- The estimated cumulative lifetime cancer risks for the crotonaldehyde, benzene, formaldehyde, ethylbenzene, 1,3-butadiene, and acetylaldehyde are at or slightly above the high-end of EPA's acceptable cancer risk range of 1 to 100 excess cancers in a million (1E-06 to 1E-04) across all monitoring sites.
- Each of the 20 individual air toxics assessed at any monitoring site have a chronic non-cancer hazard estimate well below an acceptable value of one. However, when accounting for the cumulative chronic non-cancer hazards for all of these 20 air toxics the chronic non-cancer hazard estimate is just below the acceptable level of one and the non-cancer hazards are most likely underestimated because non-cancer toxicity values were not available for 65 contaminants. The major contributing chemicals to the cumulative hazard estimate are acetaldehyde, formaldehyde, trimethylbenzenes, and benzene.
- The cumulative health impacts of 86 detected ambient air toxics cannot be determined due to the absence of EPA-reviewed toxicity values for 65 air toxics.

2 Data Evaluation and Selection of COPCs

2.1 Sources of data

Several sources of data collected in Garfield County between 2005 and 2010 were used for this HHRA.

2.1.1 2005 to 2007 Garfield County Ambient Air Quality Study

Garfield County contracted Colorado Mountain College (CMC) to collect ambient air samples from June 2005 through May 2007 for analyses of VOCs and particulate matter of ten microns or less (PM_{10}). The samples for VOC analyses were collected over 24-hours interval into Summa-polished stainless steel canisters (Summa canisters) either monthly or quarterly from 14 monitoring stations. In addition, 28 15-second grab samples were collected into Summa canisters by residents when they observed odors. Columbia Analytical Services analyzed the samples for 43 VOCs by EPA Method TO-14/15a. CDPHE provided some support for equipment and installations as well as data processing and analysis support. CDPHE performed a screening level risk assessment for ambient air with this data (CDPHE 2007).

The VOC data from 29 samples collected from the rural oil and gas impacted Bell-Melton Ranch monitoring station, and 18 samples collected from the rural Silt-Daley and Silt-Cox monitoring stations were employed in this HHRA. The PM_{10} data is discussed in the Uncertainty Section.

2.1.2 2008 Garfield County Air Toxics Study

The GCPHD, in conjunction with the CPDHE's Air Pollution Control Division (APCD), and the aid of a Regional Geographic Initiatives Grant administered by the EPA conducted a study of air toxics associated with natural gas production operations in the summer of 2008. Ambient air samples were collected over 24-hour intervals into Summa canisters and sent to Eastern Research Group (ERG) for analyses of 78 SNMOCs by EPA method TO-12. The samples were collected at each cardinal direction from the perimeter of eight well pads during drilling and well completion activities (four locations for each activity). In addition, one background sample was collected for each location. The well completion and background data was employed in this HHRA.

Data also was collected for particulate matter of 2.5 microns or less ($PM_{2.5}$), real time VOCs, and meteorology during the 2008 air toxics study. This data is discussed in Uncertainty Section.

2.1.3 2008 to 2010 Garfield County Ambient Air Study

The GCPHD collected ambient air samples from five monitoring stations over 24-hour intervals and shipped the samples to ERG for analyses of 78 SNMOCs by EPA method TO-12 and 11 carbonyls by EPA method TO-11a. Samples for SNMOC analysis were collected into Summa canisters every 6 days. Samples for carbonyl analysis were collected onto pre-treated 2,4-dinitrophenylhydrazine (DNPH) cartridges every 12 days. CDPHE performed an annual screening level risk assessment for ambient air with the data collected in 2008 (CDPHE 2010)

The data from 188 samples collected from the Bell-Melton Ranch monitoring station from January 2008 through March 2010 were employed in this HHRA. Ozone, PM_{10}, and $PM_{2.5}$ data collected at the Rifle and Parachute monitoring stations will be discussed in the Uncertainty Section.

2.1.4 2010 annual groundwater quality results – Battlement Mesa Water treatment plant

The Battlement Water Treatment Plant collected one groundwater sample from one of the back-up groundwater wells in July 2010 and submitted the sample to Accutest Laboratories in Wheat Ridge Colorado for analysis of VOCs by EPA method 524.2, endothall by EPA method 548.1, 1,2-dibromo-3-chloropropane and 1,2-dibromoethane by EPA method 504.1, herbicides by EPA method 515.4, carbamates by EPA method 531.1, and pesticides by EPA method 508. This data was used to evaluate baseline groundwater conditions.

2.2 Sample Quantitation Limit Evaluation

Method reporting limits (MRLs) were adjusted for sample characteristics, sample preparation, and analytical adjustments. Therefore, the MRL are equivalent to the sample quantitation limit. Chemicals reported as not detected are considered to have a concentration less than the MRL for the purposes of the HHRA.

The MRLs were compared to EPA regional screening levels (RSLs) (EPA 2010) to determine if they were adequate for the purposes of the HHRA. RSLs are protective health-based levels below which chronic health effects are not expected to occur. If the RSL is greater than the MRL, the MRL is adequate for determining the chemical is not present at a concentration that may impact health. If the RSL is less than the MRL, the MRL is not adequate to determine whether the chemical is present at a concentration which may impact health.

2.2.1 2005 to 2007 VOC data

Table 2-1 summarizes the MRLs for chemicals with a detection frequency less than five percent for the VOC data collected between 2005 and 2007. For the following 15 VOCs with a detection frequency of less than five percent, the EPA RSL was less than the minimum MRL:

- 1,2-Dibromoethane
- 1,1,2,2-tetrachloroethane
- Bromodichloromethane
- 1,2-Dichloroethane
- Chloroform
- 1,1,2-Trichloroethane
- Vinyl Chloride
- 1,4-Dichlorobenzene
- 1,2-Dichloropropane
- Carbon Tetrachloride
- Tetrachloroethene
- cis-1,3-Dichloropropene
- Trans-1,3-Dichloropropene
- Trichloroethene
- Dibromochloromethane

The data for these chemicals is not adequate to determine if the chemical is present at a concentration that may impact health, which contributes to the uncertainty of the HHRA, as discussed in Section 6.1.1.

2.2.2 2008 to 2010 data

Table 2-2 summarizes MRLs for chemicals with a detection frequency less than five percent for the SNOMC and carbonyl data collected between 2008 and 2010. EPA RSLs are not available for the six chemicals with detection frequencies less than five percent and the MRLs were not further evaluated.

2.2.3 Groundwater data

No contaminants were detected in the groundwater sampled by the Battlement Mesa Water Treatment Plant. Table 2-3 compares the MRLs to EPA RSLs for tap water. Out of 98 contaminants, 29 MRLs were greater than the EPA RSL. The data for these contaminants is not adequate to determine if the contaminant is present at a concentration that may impact health, which contributes to the uncertainty of the HHRA, as discussed in Section 6.1.1.

2.3 Data Reduction, Summary Statistics

The data was modified (reduced) as described in this section, for use in the HHRA. The section also discusses the summary statistics that were generated from the reduced data.

2.3.1 Duplicate Analyses

Duplicate analyses were reduced as follows:

1. For duplicate pairs, for which each sample had detectable quantities of a contaminant in question, the higher of the two concentrations was used in the HHRA, per RAGS (EPA 1989).
2. For duplicate pairs, for which neither sample had detectable quantities of a contaminant, the lower of the two MRLs was used in the HHRA.
3. For duplicate pairs, for which one sample contained a detectable quantity of contaminant in question and the other sample does not, the detectable quantity was used in the HHRA.

2.3.2 Summary Statistics of Sample Data

Data from samples collected at the Bell-Melton Ranch monitoring station from 2005 to 2007 was combined with data from samples collected at the Bell-Melton Ranch monitoring station from 2008 through March 2010 for evaluation of the long-term chronic exposure scenario for all Battlement Mesa residents. Table 2-4 contains summary statistics (number of samples, detection frequency, maximum detected concentrations, and mean) for the Bell-Melton Ranch monitoring station.

Table 2-5 contains summary statistics for the data from samples collected from the well completion sites, during the 2008 Air Toxics Study. This data was used with the Bell-Melton Ranch data described in the preceding paragraph to calculate a time-weighted average for residents living adjacent to a well pad and to evaluate acute exposures for the child resident living adjacent to a well pad.

Table 2-6 contains summary statistics for data from the grab samples collected during odor events in the 2005 to 2007 air monitoring study. This data was used to evaluate potential acute exposures for the child resident living adjacent to a well pad.

No contaminants were detected in the groundwater and summary statistics were not performed.

2.4 Background

The VOC data from the samples collected at the rural Silt-Daley and Silt-Cox monitoring sites during the 2005 to 2007 air monitoring study was combined with the SNMOC data from the samples collected during the 2008 air toxics study to compile a background

dataset. Samples have not been collected for carbonyls from background locations. Table 2-7 summarizes summary statistics for the background data set.

Table 2-7 also presents background threshold values (BTVs) computed per EPA guidance (EPA 2010). BTVs are background contaminant concentrations computed based upon the sampled data collected from the site- specific background locations. Site observations can be compared to BTVs. A site observation exceeding a BTV can be viewed as coming from a contaminated area of the site under study. For most of the SNMOCs, only seven samples were available for the background dataset. EPA recommends that the background data set contain greater than 8-10 observations for statistical computation of the BTV (EPA 2010). Therefore, the maximum detected concentration was selected as the BTV for chemicals with seven samples in the background dataset. EPA also recommends that the background data set contain at least 4-6 detected concentrations for statistical computation of the BTV (EPA 2010). Therefore, for chemicals with 18 or 25 samples but less than 4 detected concentrations in the background data set, the maximum detected concentration was assigned as the BTV. The maximum MRL was assigned as the BTV for chemicals that were not detected in the background dataset. For the remaining chemicals, BTVs were calculated using EPA's proUCL version 4.00.05 statistical software (EPA 2010).

These BTVs were not used in the selection of COPCs for the HHRA. Rather, they were used in the qualitative assessments and uncertainty assessment to evaluate COPCs without toxicity values and to add prospective for the calculated risk for COPCs with toxicity values.

2.5 Selection of Contaminants of Potential Concern and Exposure Point Concentrations

The EPA RSL is the level at which health effects are not expected to occur for a given contaminant and exposure route. To account for possible additive effects of multiple contaminants and exposure routes, the maximum detected concentration of each contaminant detected in each of the data sets described in Section 2.3.2 was compared to 1/10 EPA's RSL. If the maximum detected concentration exceeded 1/10 EPA's RSL, the contaminant was retained as a COPC in the HHRA. If the maximum concentration of the contaminant did not exceed 1/10 EPA RSL, the contaminant was not considered further in the HHRA. If EPA did not have an RSL for a contaminant, the contaminant was retained as COPC if its detection frequency was five percent or greater. Contaminants without an EPA RSL and with a detection frequency of less than five percent were not considered further in the HHRA.

2.5.1 Bell-Melton Ranch Monitoring Station

Table 2-4 summarizes the selection of COPCs from samples collected at the Bell-Melton Ranch monitoring station for the all Battlement Mesa residential chronic exposure scenario described in Section 3. 74 out of 126 chemicals were selected as COPCs. The

following nine chemicals were retained as COPCs because the maximum detected concentration exceeded 1/10 the EPA RSL:

- Acetaldehyde
- Formaldehyde
- 1,2,4-Trimethylbenzene
- 1,4-Dichlorobenzene
- Methylene chloride
- Benzene
- Ethylbenzene
- 1,3-Butadiene
- 2-Hexanone

There was no EPA RSL for the remaining 65 COPCs. They were retained because they were detected in 5 percent or more of the samples.

The EPA recommends that the 95 percent upper confidence limit (UCL) of the arithmetic mean concentration be used as the Exposure Point Concentration (EPC) in calculating exposure and risk for contaminants with 10 or more detections. The 95 percent UCL was calculated for COPCs with 10 or more detections using the EPA ProUCL version 4.00.05 software (EPA 2010). Per current EPA guidance, all non-detect sample results were assigned a value at the MRL (EPA 2010). If the 95 percent UCL was greater than the maximum detected concentration, the maximum detected concentration was assigned as the EPC. For COPCs with less than 10 detections, the maximum detected concentration was assigned as the EPC. The EPC values for COPCs from the Bell-Melton monitoring station are summarized in Table 2-8. Also included in Table 2-8 are 95% UCLs and EPCs from the Bell-Melton Ranch Monitoring stations that were identified as COPCs in the well completion data.

2.5.2 Contaminants of Potential Concern Well Completion

Table 2-5 summarizes the selection of COPCs from samples collected in the 2008 air toxics study during well completion activities. In addition, COPCs identified from the Bell-Melton Ranch data set that were not measured in the 2008 air toxics study were identified as COPCs. 73 contaminants were selected as COPCs. The following 13 contaminants were retained as COPCs because the maximum detected concentration exceeded 1/10 the EPA RSL or they were identified as COPCs in the Bell-Melton Ranch data set.

- 1,2,4-Trimethylbenzene
- 1,3-Butadiene
- Benzene
- Ethylbenzene
- m&p-Xylene

- n-Hexane
- n-Nonane
- n-Pentane
- Acetaldehyde
- Formaldehyde
- 1,4-Dichlorobenzene
- Methylene chloride
- 2-Hexanone

There was no EPA RSL for the remaining 61 COPCs, which were retained because their detection frequency was 5 percent or greater.

The maximum detected concentrations were observed in the sample collected downwind of an Antero well during flow back operations. Because flow back is one of the operations with the greatest potential for emissions of contaminants, this maximum concentration assigned as the EPC. In addition, samples were collected over a 24-hour interval which may have diluted out peak emissions during flow back operations.

2.5.3 Chemicals of Potential Concern Odor events

Table 2-6 summarizes the selection of COPCs from grab samples collected when odors were observed in the 2005 -2007 ambient air monitoring study. In addition, COPCs identified from the Bell-Melton Ranch data set or 2008 air toxics study that were not measured in the 2005-2007 study were identified as COPCs. The following 14 contaminants were selected as COPCs because the maximum detected concentration exceeded 1/10 the EPA RSL or they were identified as COPCs in the Bell-Melton Ranch or well completion data set.

- Benzene
- Ethylbenzene
- m&p-Xylene
- o-Xylene
- Toluene
- Chloroform
- 1,2,4-Trimethylbenzene
- 1,3-Butadiene
- n-Hexane
- 2-Hexanone
- n-Nonane
- n-Pentane
- Acetaldehyde
- Formaldehyde

The maximum concentration assigned as the EPC because the maximum possible exposure was desirable in the evaluation of acute exposure for the maximum exposed individual (MEI).

2.6 Observed Trends for Select COPCs

Temporal trends were evaluated for select COPCs from the five year of data that have been collected in Garfield County.

Figure 2-1 illustrates temporal trends for BTEX at the Bell-Melton Ranch monitoring station from 2005 to 2010. There is a consistent seasonal pattern for BTEX with higher concentrations in the winter than the summer, with the exception of one high concentration measured in August 2008. Overall, it does not appear that BTEX concentrations are increasing at the Bell-Melton Ranch monitoring site.

Figure 2-2 illustrates temporal trends for formaldehyde, crotonaldehyde, and acetylaldehyde at the Bell Melton Ranch monitoring station from 2008 to 2010. A consistent seasonal pattern for crotonaldehyde is apparent, with the highest concentrations observed in the summer months. The seasonal pattern is not as apparent for formaldehyde or acetylaldehyde. Overall, it does not appear that carbonyl concentrations are increasing at the Bell-Melton Ranch monitoring site.

Figure 2-2 also show a formaldehyde outlier in the sample collected in January 2009. The 95% UCL for formaldehyde was calculated with and without the outlier. The outlier was retained and not treated separately because the difference between the two 95% UCLs was less than 10 percent.

3 Exposure Assessment

This section presents and discusses potentially exposed populations; the conceptual site model (CSM); exposure assumptions; and estimated intakes of COPCs potentially resulting from natural gas production operations in the Battlement Mesa PUD.

3.1 Potentially Exposed Populations

Current land use within the PUD at Battlement Mesa is primarily residential. It is likely that Battlement Mesa will remain residential in the future. Three populations of residents were evaluated as potential receptors for COPCs resulting from natural gas production operations within the Battlement Mesa PUD. The first population is residents living within the PUD at residence not adjacent to a well pad. The second population is residents living within the PUD at a residence adjacent to a well pad. The third population is child residents aged 3 to 6 living at a residence adjacent to a well pad. The third population represents the MEI.

3.2 Conceptual Site Model

The CSM for human exposure to COPCs resulting from natural gas production operations is shown in Figure 3-1. A CSM is a schematic representation of the chemical sources and release mechanisms, environmental transport media, potential exposure routes, and potential receptors. The purpose of the CSM is to represent chemical sources and exposure pathways that may result in human health risks.

Only potentially complete exposure pathways were evaluated in the risk assessment. A complete exposure pathway includes all of the following elements:

- A source and mechanism of contaminant release
- A transport or contact medium (e.g., air or water)
- An exposure point where receptors can contact the contaminated medium
- An exposure (intake) route such as inhalation or ingestion

The absence of any of these elements results in an incomplete exposure pathway. Where there is no potential exposure, there is no potential risk. The CSM shows (1) incomplete pathways – no evaluation necessary (represented by an “I”); (2) pathways that may be or complete, but for which risk is likely low and only qualitative evaluation is needed (“P”); (3) pathways that are complete and may be significant – quantitative evaluation was performed if there was environmental data available. (“C”). The sources and exposure pathways for each scenario are described in the following sections. Surface soil is defined as 0 to 2 feet below ground surface (bgs) and subsurface soil is defined as greater than 2 feet bgs.

3.3 Sources of potential contamination

The extraction of the natural gas resource from tight sands includes several processes, including transporting materials to and from well pads (trucking), well pad preparation, well drilling, well completion (plug pull out, fracturing, and flow back), collection of salable gas from producing well, maintenance of wells, installation and maintenance of well pads, and abandonment of wells. There is the potential for the release of contaminants during all these processes. Sources of contaminants include the natural gas resource itself, chemicals used in well production activities, wastes from well production activities, and exhaust from machinery used in well production and maintenance.

Well completion activities, trucking, well installation errors, and uncontrolled well development (kick backs, blow outs, and well fires) can result in emissions of contaminants to ambient air, groundwater, subsurface soil, surface soil and surface water. Spills of fracturing fluids, drilling muds, condensate, and diesel can result in contamination of surface soil and ambient air. Run-off and infiltration then can result in subsequent contamination of surface waters and of groundwater and subsurface soil, respectively. Wind erosion, run-off, and infiltration from drilling cuttings and produced water stored on well pads or off-site locations can result in contamination of ambient air, surface soil, surface water, groundwater, and subsurface soil. Exhaust from diesel engines can contaminate ambient air and surface soils (through deposition). Fugitive emission of natural gas through pneumatic pumps and devices, pipe lines, and values and venting of condensers and glycol dehydrators can result in emissions of contaminants to ambient air.

VOC contaminants released to the subsurface (groundwater and soil) have the potential to contaminate air inside buildings (indoor air) through infiltration.

3.4 Exposure Pathways

This section discusses exposure pathways that are quantified, evaluated qualitatively, and those than are not evaluated in the HHRA.

3.4.1. Complete Pathways

Complete pathways for residents to contaminants from natural gas production operations include:

- Inhalation of ambient air
- Incidental ingestion of surface soil
- Dermal contact with surface soil
- Inhalation of particulates from surface soil.
- Dermal contact with surface water

Of these, the inhalation of ambient air pathway and surface water pathways were quantitatively evaluated. Surface soil pathways were not evaluated because no surface soil data is available.

3.4.2 Potentially Complete Pathways

Potentially complete pathways for residents to contaminants from natural gas production operations include:

- Ingestion of surface water
- Ingestion of groundwater
- Dermal contact with groundwater
- Inhalation of VOCs from groundwater
- Inhalation of indoor air

The primary source of drinking and domestic water in Battlement Mesa is the Colorado River. The Battlement Mesa Water Treatment Plant draws water from two intakes located in the middle of the river for treatment, as shown in Figure 3-2. Moument Creek, one of the major drainages off of Battlement Mesa discharges to the river downstream of these intakes. It still is possible that surface run-off could introduce contaminants from upstream well pads into the river. However, the Colorado River has a high volume of water and it is most likely that any contamination would be diluted to non-harmful concentrations. The annual surface water quality results have not indicated any detectable levels of contamination from natural gas production operations at the intakes. In addition, natural gas operators must inform the Battlement Mesa Water Treatment Plant of upstream spills or incidents affecting the river per COGCC rules. In the event of such a spill or incident the intakes to the treatment plant can be shut down. The treatment plant routinely stores a week's supply of water allowing time for remediation of spills. Therefore, while the ingestion of surface water is a potentially complete pathway, its contribution to human health risk is considered to be minimal. This pathway was not considered further in the HHRA.

In the event that the Battlement Mesa Water Treatment Plant was shut down, drinking and domestic water for Battlement Mesa residents would be supplied from four groundwater wells along the south bank of the Colorado River (Figure 3-2). These wells are not supplied with water from the Colorado River and it is believed that the source of water in these wells is from an up-gradient aquifer. There could be a hydrologic connection between these wells and the aquifer on Battlement Mesa, allowing for a conduit of natural gas extraction activity contaminants to the secondary drinking water source. However, the hydrologic connection has not been studied and is currently theoretical. The annual water quality results from these wells have not indicated any detectable levels of contamination. For these reasons, the ingestion of, dermal contact with, and inhalation pathway for contaminants in groundwater is considered to be minimal under current conditions. These pathways were not considered further in the HHRA.

Air inside of an occupied building (indoor air) could become contaminated with VOCs through infiltration if shallow subsurface soil or shallow groundwater in close proximity

to the building were contaminated with VOCs. EPA recommends considering this pathway if groundwater or soil within 100 feet (laterally or vertically) of an occupied building is contaminated with VOCs (EPA 2002). This pathway is considered to be minimal because the wells in Battlement Mesa will be set back at least 500 feet from any buildings (Antero Plan), and fracturing occurs at depths much greater than 100 feet bgs. This pathway was not considered further in the HHRA.

3.4.3 Incomplete Pathways

Incomplete pathways for residents include:

- Incidental ingestion of subsurface soil
- Dermal contact with subsurface soil
- Inhalation of subsurface soil particulates

These pathways are incomplete because direct contact with subsurface soil (i.e. greater than 2 feet bgs) involves significant digging or excavation activities unlikely under the residential scenario.

3.5 Exposure Assumptions and Intake Equations

This section presents assumptions for chronic exposures of all residents and residents living adjacent to well pads to contaminants from natural gas production operations within the Battlement Mesa PUD. Assumptions for child residents living adjacent to well pads also are presented.

3.5.1 All Resident Chronic Exposure Assumptions and Intake Equations

Only ambient air was quantitatively evaluated for the residential chronic exposure scenario because data on which to estimate for surface soil EPCs is not available and exposure to surface water run-off from pads is expected to be of short duration. The chronic exposure area for contaminants in ambient air is the entire Battlement Mesa PUD.

Chronic EPCs for ambient air were estimated from ambient air samples collected from 2005 through March 2010 at the Bell-Melton Ranch Monitoring Station (CDPHE 2007, Garfield County 2008, Garfield County 2009, Garfield County, 2010). Of the three ambient air monitoring stations within Garfield County where data has been regularly collected in this time period, Bell-Melton Ranch was considered to most closely represent the impacts of the nature gas production operations that may occur within the Battlement Mesa PUD. The other two monitoring locations, Rifle and Parachute, have greater traffic density, are in closer proximity to a major Interstate (I-70), and have more influence from other industries than Battlement Mesa. The Bell-Melton Ranch monitoring is located

south of Silt Colorado within the midst of natural gas production operations and rural home sites and ranches, as shown in Figure 3-3.

The following assumptions are used in this HHRA based on the EPA methodology regarding chronic exposure and Antero's proposed plan:

- The duration of Antero's project, from preparation of the first well pads to abandonment of the last well will be 30 years.
- A resident lives, works, and otherwise stays within the Battlement Mesa PUD for 24 hours per day, 350 days per year, for a 30-year time period.
- The air a resident breathes, both while indoors and outdoors, contains the same concentration of contaminants measured in the Bell-Melton Ranch ambient air samples.
- Air quality, as reflected by the Bell-Melton Ranch ambient air results, will remain relatively constant over the entire 30-year duration of Antero's proposed project.
- The lifetime of a resident is 70 years.

Table 3-1 summarizes intake rates for ambient air. The intake equation for the chronic exposure scenario follows.

$AI = (EPC_c \times EF_c \times ED_c \times ET \times 1 \text{ day}/24 \text{ hours})/AT$

AI = Air Intake ($\mu g/m^3$)
EPC_c = Chronic exposure point concentration ($\mu g/m^3$)
EF_c = Chronic exposure frequency = 350 days/year
ED_c = Chronic exposure duration = 30 years
ET = Exposure time = 24 hours/day
Non-cancer AT = averaging time = 10950 days
Cancer AT = 25550

3.5.2 Residents Living Adjacent to Well Pads Exposure Assumptions and Intake Equations

Only the ambient air exposure pathway was quantitatively evaluated for the residents living adjacent to well pads because data on which to estimate surface soil EPCs is not available and exposure to surface water run-off from pads is of short duration. The exposure area for contaminants in ambient air is homes and yards adjacent to well pads.

Based on Garfield County's 2008 Air Toxic's Study, the highest concentrations of SNMOCs in ambient air were observed during well completion activities (Garfield County 2008). Therefore, intermediate EPCs for ambient air were estimated from ambient air samples collected at four separate well completion sites in Garfield County's 2008 air toxics study. Four ambient air samples (one from each cardinal direction) were collected at distances ranging from 130 to 430 feet from the well pad center at each site (Paul Reaser, personal communication 7/6/2010).

The EPC for chronic exposure was estimated by calculating a time weighted average (TWA) from the intermediate EPCs described in the preceding paragraph and chronic EPCs described in Section 3.5.1.

The following assumptions regarding the chronic scenario for residents living adjacent to a well pad are used in this HHRA based on the EPA methodology and Antero's proposed plan:

- The duration of Antero's project, from preparation of the first well pads to abandonment of the last well will be 30 years.
- A resident lives, works, and otherwise stays within the Battlement Mesa PUD for 24 hours per day, 350 days per year, for a 30-year time period.
- The resident's home is adjacent to well pad.
- Well completion activities, including plug pull outs, hydraulic fracturing, and flow back occur over two weeks for each well on the well pad. This assumes some overlap between activities and wells.
- For a 20 well pad, well completion activities (flow back and hydraulic fracturing) will occur over 10 months.
- The resident lives, works, or otherwise stays at the home during the duration of well completion activities.
- The air that the resident breathes, both while indoors and outdoors, contains the same concentrations of contaminants measured in the Air Toxics Study during the duration of the well completion activities.
- The air a resident breathes, both while indoors and outdoors, after the well completion activities contains the same concentration of contaminants measured in the Bell-Melton Ranch ambient air samples.
- Air contaminant concentrations will remain constant over the 10-month period of well completion.
- Air quality, as reflected by the Bell-Melton Ranch ambient air results, will remain relatively constant over the entire 30-year duration of Antero's proposed project.
- The lifetime of a resident is 70 years.

Table 3-1 summarizes intake rates for ambient air, which were calculated by the intake equations presented in Section 3.5.1. TWA EPCs for residents living adjacent to well pads were calculated as follows:

$EPC_{I+c} = (EPC_c \times ED_c/ED) + (EPC_I \times ED_I/ED)$

EPC_c = Chronic exposure point concentration ($\mu g/m^3$)
ED_c = Chronic exposure duration = 350 months
EPC_I = Intermediate exposure point concentration ($\mu g/m^3$)
ED_I = Intermediate exposure duration = 10 months
ED = Total exposure duration = 360 months

3.5.3 Child Resident Acute Exposure Assumptions and Intake Equations

Only ambient air and surface water pathways were quantitatively evaluated for the child acute exposure scenario because data on which to estimate for surface soil EPCs is not available. The acute exposure area for contaminants in ambient air is homes and yards located adjacent to a well pad. The acute exposure areas for contaminants in surface water are puddles in the yards of homes adjacent to well pads resulting from well pad run-off during precipitation events. A child resident was evaluated as the receptor for this exposure scenario because a child is more likely to play in a puddle and is a more sensitive receptor than an adult. The acute risk calculated for the ambient air pathway is applicable to both the child and adult resident living adjacent to a well pad.

The EPC for ambient air was estimated from concentrations of contaminants observed during odor events in CPDHE's 2005-2007 ambient air study. If a contaminant was not measured in the 2005-2007 and was identified as the COPC in the 2008 Air Toxics study, the maximum concentration observed in the 2008 Air Toxics study was used as the EPC. If a contaminant was not measured in either of these studies and was identified as a COPC from 2008-2010 ambient air study data, the maximum concentration observed in the 2008-2010 ambient air study was used as the EPC. The EPC for a puddle of surface water run-off was estimated from contaminants observed in snow-melt run-off collected from a well pad within the three-mile radius of the former Project Rulison near Rulison, Colorado (URS 2008).

The following assumptions for acute exposure of a child resident to contaminants in surface water puddles are used in this HHRA based on EPA methodology.

- A child lives, plays, and otherwise stays at the home for 24 hours per day for 7 days.
- The child is 3-6 years old.
- The air the child breathes, both while indoors and outdoors, contains the same concentration of contaminants measured during odor events in the 2005-2007 ambient air study.
- The concentration of contaminants in ambient air will stay constant over the 7-day period.
- The surface water puddle will exist for 7 days before it evaporates or is absorbed into the ground
- The child will have a 70 year lifetime (EPA 1989).
- A child will play for 2 hours per day in the puddle (EPA 2009 and professional judgment).
- The child has a body mass of 18.6 kg (EPA 2009)
- The child will have an exposed skin surface area (arms, hands, legs, and feet) of 5190 cm^2 (EPA 2009).
- The child does not ingest the water.

Table 3-2 summarizes intake rates for surface water. The following equations were used to calculate the intake rates for surface water.

SWI = [(EPC x ET x EF x ED x CF)/(BW x AT)] x [(PC x SA)]

SWI = Surface Water Intake (mg/kg-day)
EPC = Exposure Point Concentration (mg/L for surface water, $\mu g/m^3$ for air)
ET = Exposure Time = 2 hours/day
EF = Exposure Frequency = 7 days per year
ED = Exposure Duration = 1 year
BW = Body Weight = 18.6 kg
AT = Averaging time = 365 days
PC = chemical-specific dermal permeability constant (cm/hour)
SA = exposed skin surface area = 5190 cm^2
CF = conversion factor = 1 L/1000 cm^3

4 Toxicity Assessment

This section presents the toxicity assessment. The purpose of the toxicity assessment is to evaluate available evidence regarding the potential for a particular contaminant to cause adverse health effects in exposed individuals and how the appearance and severity of these adverse effects depends on the dose of the contaminant. In addition, the toxic effects of a chemical frequently depend on the route of exposure (oral, inhalation, dermal), the duration of exposure (acute, intermediate, chronic or lifetime), age, sex, diet, family traits, lifestyle, and state of health.

4.1 Selection of Toxicity Values

The following hierarchy was used to compile a list of inhalation toxicity values for the HHRA. For COPCs identified in ambient air, inhalation values established specifically by the State of Colorado were given priority over all other sources of toxicity values, followed by EPA's Air Toxics Website (http://www.epa.gov/ttn/atw/toxsource/summary.html). The State of Colorado has not established toxicity values for the COPCs identified in this HHRA. If values were not available the Air Toxics Website, toxicity values were filled (in order of preference) EPA's Integrated Risk Information System (IRIS), EPA's Provisional Peer-Reviewed Toxicity Values (PPRTVs), and other applicable secondary sources (e.g., California EPA; ATSDR). Inhalation toxicity values were available for 19 out of 82 COPCs as presented in Table 4-1. Inhalation toxicity values were not available for the remaining 63 COPCs presented in Table 4-2. These COPCs were omitted altogether from the quantitative inhalation risk estimation.

A list of oral toxicity values was complied for the HHRA (in order of preference) from EPA's IRIS and the Agency for Toxic Substances and Disease Registry (ATSDR). Oral toxicity values were available for all the surface water COPC presented in Table 4-3. Dermal toxicity values can be extrapolated from oral toxicity values by adjusting the oral RfD by its oral absorption factor, per EPA guidance (EPA 1989). The oral absorption factor for all the COPCs identified in surface water was 100 percent. Therefore, the dermal RfD is equivalent to the oral RfD.

4.1.1 Cancer Toxicity Values

Potential carcinogens are grouped according to the likelihood that the chemical is human carcinogen, depending on the quality and quantity of carcinogenic potency data for a given chemical.

Group A – Human Carcinogen (sufficient evidence of carcinogenicity in humans)

Group B – Probable Human Carcinogen (B1 – limited evidence of carcinogenicity in humans; B2- sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans).

Group C – Possible Human Carcinogen (limited evidence of carcinogenicity in animals and inadequate or lack of evidence in humans)

Group D – Not Classifiable as to human carcinogenicity (inadequate or no evidence)

Group E – Evidence of non-carcinogenicity (no evidence of carcinogenicity in adequate studies).

Weight of evidence classifications for COPCs are provided in Section 4-2.

Cancer risks are expressed as a probability of suffering an adverse effect (cancer) during a lifetime. They estimate risks to individuals in a population and not to a particular individual.

For carcinogens, inhalation toxicity measurements are generally expressed as a risk per unit concentration (e.g., an inhalation unit risk (IUR) in units of risk per $\mu g/m^3$). The IUR is based on an upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of $1\mu g/m^3$ in air.

4.1.2 Non-Cancer Toxicity Values

Non-cancer hazards are expressed, semi-quantitatively, in terms of the HQ, defined as the ratio between an individual's estimated exposure and the toxicity value. HQs are not an estimate of the likelihood that an effect will occur, but rather an indication of whether there is potential cause for concern for adverse health effects. Like cancer risks, HQs estimate risks to individuals in a population and not to a particular individual (i.e., personal risk).

For non-carcinogens, inhalation toxicity measurements are generally expressed as a concentration in air (e.g., an RfC in units of $\mu g/m^3$ air). The RfC is an exposure that is believed to be without significant risk of adverse non-cancer health effects in a chronically exposed population, including sensitive individuals.

For non-carcinogens, oral toxicity measurements are generally expressed as a reference dose (RfD). The RfD is an estimate of a daily chemical intake per unit body weight for the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime.

Chronic RfDs and RfCs are developed to evaluate long-term exposures of 7 years to a lifetime (70 years), intermediate RfDs and RfCs are developed to evaluate exposures of >14 to 364 days, and acute RfDs and RfCs are developed to evaluate exposures of 1 to 14 days. Chronic RfCs were used for the chronic all resident and resident adjacent to a well pad scenarios. Acute RfDs and RfCs were used for the acute child resident adjacent to a well pad scenario. If an acute value was not available, the intermediate toxicity value

was used. If an intermediate value was not available, the chronic toxicity value was used, per EPA guidance (EPA 1989).

4.2 Summary of Health Effects of COPCs

This section summarizes the adverse of effects for the COPCs with toxicity values (Tables 4-1 and 4-3).

4.2.1 Acetylaldehyde

EPA has classified acetylaldehyde as probable human carcinogen (Class B2). There is inadequate evidence of carcinogenicity in humans, but adequate evidence of carcinogenicity in animals. An increased incidence of nasal and laryngeal tumors has been observed in animals after inhalation exposure (EPA IRIS 2010).

Short term inhalation exposure of rats to high concentrations of actylaldehyde was observed to result in degradation of the olfactory epithelium (EPA IRIS 2010, 1991 revision).

4.2.2 Benzene

Benzene is classified as a "known" human carcinogen (Category A) for all routes of exposure based upon convincing human evidence as well as supporting evidence from animal studies. Exposure to benzene can cause acute nonlymphocytic leukemia, acute myeloid leukemia, and also may cause chronic nonlymphocytic and chronic lymphocytic leukemia. (ATSDR, 2007, IRIS 2010).

Benzene's non-cancer toxicity is observed by all routes of administration. The following is ATSDR's summary of non-cancer health effects. "Brief exposure (5–10 minutes) to very high levels of benzene in air (10,000–20,000 ppm) can result in death. Lower levels (700–3,000 ppm) can cause drowsiness, dizziness, rapid heart rate, headaches, tremors, confusion, and unconsciousness. In most cases, people will stop feeling these effects when they are no longer exposed and begin to breathe fresh air. Eating foods or drinking liquids containing high levels of benzene can cause vomiting, irritation of the stomach, dizziness, sleepiness, convulsions, rapid heart rate, coma, and death. If you spill benzene on your skin, it may cause redness and sores. Benzene in your eyes may cause general irritation and damage to your cornea. Benzene causes problems in the blood. People who breathe benzene for long periods may experience harmful effects in the tissues that form blood cells, especially the bone marrow. These effects can disrupt normal blood production and cause a decrease in important blood components. A decrease in red blood cells can lead to anemia. Reduction in other components in the blood can cause excessive bleeding. Blood production may return to normal after exposure to benzene stops. Excessive exposure to benzene can be

harmful to the immune system, increasing the chance for infection and perhaps lowering the body's defense against cancer (ATSDR 2007a)".

4.2.3 1,3-Butadiene

EPA has classified 1,3-butadiene as a known human carcinogen (Class A). Occupational studies suggest exposure to 1,3 butadiene in ambient air results in an increased risk for cancers of the stomach, blood, respiratory system, and lymphatic system (ATSDR 2009).

Very high exposures to 1,3-butadiene vapors in humans (>10,000 ppm) may result in narcosis and death from respiratory paralysis. Short term exposure to lower levels in ambient air may cause nausea, dry mouth and nose, headache, and decreased blood pressure and heart rate (ATSDR 2009).

4.2.4 Chloroform

EPA has determined that chloroform is a probable carcinogen (Class B2) based on sufficient animal evidence. Cancer of the liver and kidneys was observed in rats and mice that ingested chloroform (ATSDR 1997). "Chloroform is *likely to be carcinogenic to humans by all routes of exposure* under high-exposure conditions that lead to cytotoxicity and regenerative hyperplasia in susceptible tissues. Chloroform is *not likely to be carcinogenic to humans by any route of exposure* under exposure conditions that do not cause cytotoxicity and cell regeneration" (IRIS 2001).

Short term exposure to high concentrations of chloroform in ambient air causes fatigue, dizziness and headache. Long term exposure in ambient air, food, or water may cause liver and kidney damage (ATSDR 1997).

4.2.5 Crotonaldehyde

Crotonaldehyde is classified as a possible human carcinogen (Category C) based on limited animal evidence. An increased incidence of hepatic neoplastic nodules and hepatocellular carcinomas were observed in animal carcinogenicity study that was limited by only one sex of one species (IARC 1995).

Crotonaldehyde is a potent eye, respiratory and skin irritant and brief exposures to moderate concentrations in ambient air can irritate the nose and upper respiratory tract, with lachrymation (IARC 1995). However, no RfC is available for crotonaldehyde.

4.2.6 1,4-Dichlorobenzene

EPA has determined 1,4-dichlorobenzene is likely to be a human carcinogen based on limited animal studies (Class C). Increased risk in kidney and liver tumors have been observed in rats after ingestion of 1,4-dichlorobenzene. An increased incidence of lung adenomas in males and of liver adenomas in females was observed in an inhalation study on mice (IRAC 2000).

Short term exposure to high concentrations of 1,4-dichlorobenzene in ambient may cause eye, nose, and eye irritation and burning, coughing, breathing difficulties, and upset stomach. Long term exposures to high concentrations may case decreased lung function, dizziness, headache, liver problems, skin blotches, and anemia.

4.2.7 Ethylbenzene

EPA has determined ethylbenzene is not classifiable as human carcinogen (Class D). The International Agency for Research on Cancer (IARC) has classified ethylbenzene as possibly carcinogenic to humans, based on sufficient evidence in animal studies (IARC 2000). An increased incidence of lung adenomas in males and of liver adenomas in females was observed in an inhalation study on mice (IRAC 2000).

Short term exposure to high levels of ethylbenzene in ambient air can cause eye and throat irritation, vertigo, and dizziness. Evidence of long-term exposure effects in humans is lacking. Animal studies indicate long-term exposure to low levels of ethylbenzene in ambient air may result in irreversible damage to the inner ear and hearing, as well as kidney damage. Rats ingesting large amounts of ethylbenzene had severe damage to the inner ear. Dermal exposure has caused eye damage and skin irritation in rabbits (ATSDR 2007b).

4.2.8 Formaldehyde

EPA has determined formaldehyde is probable human carcinogen with limited evidence of carcinogenicity in humans and sufficient evidence in animals (Class B1). Exposure to formaldehyde in ambient air may result in an increased risk for nasal and throat cancers (ATSDR 1999a).

NIOSH states that exposure to formaldehyde in ambient air is immediately dangerous to life and health at 20,000 ppb. Lower short-term exposures to lower concentrations can irritate the eyes, nose, and throat (ATSDR 1999a).

4.2.9 n-Hexane

EPA has determined n-hexane is not classifiable as human carcinogen (Class D) (ATSDR 1999b).

Workers exposed to greater than 500,000 ppb of n-hexane in ambient air for over 6 months have experienced numbness in their feet and hands followed by muscle weakness in their feet and lower legs. With continuing exposure, peripheral neuropathy can result in paralysis of the arms and legs developed (ATSDR 1999b).

4.2.10 2-Hexanone

EPA has determined 2-hexanone is not classifiable as human carcinogen (Class D) (EPA IRIS 2010/2009).

Workers exposed to 2-hexanone for almost a year experienced harmful effects to the nervous system. Symptoms included weakness, numbness, and tingling in the skin of the hands and feet (ATSDR 1992).

4.2.11 Methylcyclohexane

EPA has not determined a cancer classification for methylcyclohexane.

Evidence on human exposure to methylcyclohexane is lacking. Decreased body weight has been observed in animal studies on hamsters and male rats, as well as progressive renal nephropathy in male rats, after inhalation of methylcyclohexane (Kinkead et al. 1985)

4.2.12 Methylene Chloride

EPA has classified methylene chloride as a probable human carcinogen (Class B2) based on sufficient evidence in animal studies. Increased incidence of hepatocellular neoplasms, alveolar/bronchiolar neoplasms, mammary tumors, salivary gland sarcomas, and leukemia have been observed in studies on rats (EPA IRIS 1995/2010).

Inhalation of very high concentrations of methylene chloride can cause death. Inhalation of lower concentrations can cause dizziness, nausea, tingling or numbness of fingers and toes, and drunkenness. Symptoms usually disappear shortly after the exposure ends. Methylene chloride vapors also may cause eye irritation. (ATSDR 2000).

4.2.13 n-Nonane

EPA has not determined a cancer classification for n-nonane.

Evidence on human exposure to n-nonane is lacking. Central nervous system or peripheral nervous system abnormalities (tremors, convulsions, coordination loss, and limb paralysis) and irritation, as well as liver and lung lesions have been observed in rats exposed to n-nonane vapor (Carpenter et al. 1978; Nilsen et al. 1988).

4.2.14 n-Pentane

EPA has not determined a cancer classification for n-pentane.

Breathing very high concentrations of n-pentane can cause drowsiness and anesthetic effects. At even higher concentrations, n-pentane can act as an asphyxiant (Galvin and Marashi 1999).

4.2.15 Toluene

Toluene can not be classified as a carcinogen because of inadequate evidence (Class D) (EPA Toxicological Review of Toluene, September 2005, EPA/635/R-05/004).

Human occupational studies have reported experienced altered color vision, dizziness, fatigue, headache, and decreased performance in neurobehavioral tests in humans exposed to toluene via inhalation. Children of mothers who inhaled very high levels of toluene during pregnancy exhibited a number of physical (small mid face, deep-set eyes, micrognathia, and blunting of the fingertips) and clinical (microcephaly, CNS dysfunction, attention deficits, and developmental delay/mental deficiency) changes which were attributed to toluene. Histopathologic lesions, damage to the tubular epithelia of the kidney, decreased antibody body response, and increases in brain neurotransmitter levels have been observed in animals following oral exposure to toluene. (EPA Toxicological Review of Toluene, September 2005, EPA/635/R-05/004).

4.2.16 Trimethylbenzenes

EPA has not classified the trimethylbenzenes for carcinogenicity.

Breathing high levels of 1,2,4-trimethylbenzene for short periods of time adversely affects the human nervous system. Effects range from headaches to fatigue and drowsiness. TMB vapor irritates the nose and the throat. Prolonged contact with liquid TMB irritates the skin (EPA 1994). Health effects and toxicity of 1,3,5-trimethylbenzene and 1,2,3-trimethylbenzene may be similar to those of 1,2,4-trimethylbenzene. Therefore, the RfC for 1,2,4-trimethylbenzene was used as a surrogate for 1,3,5-trimethylbenzene and 1,2,3-trimethylbenzene.

4.2.17 Xylenes

Xylenes have not been classified as carcinogens because of inadequate evidence (Class D) (ATSDR 2007c).

The three forms of xylene (m-xylene, p-xylene, and o-xylene) have very similar effects on human health. Exposure to very high levels of xylene can cause death. Short-term exposure of people to high levels of xylene can cause irritation of the skin, eyes, nose, and throat; difficulty in breathing; impaired function of the lungs; delayed response to a visual stimulus; impaired memory; stomach discomfort; and possible changes in the liver and kidneys. Both short- and long-term exposure to high concentrations of xylene can also cause a number of effects on the nervous system, such as headaches, lack of muscle coordination, dizziness, confusion, and changes in one's sense of balance (ATSDR 2007c).

5 Risk Characterization

Risk characterization integrates the information from the data, exposure and toxicity assessments to provide an estimate of the magnitude of potential risk. Both cancer and non-cancer health effects are evaluated in this HHRA. This section presents an estimation of the baseline risk within the Battlement Mesa PUD and an estimation of excess risk that may be introduced within the Battlement Mesa PUD as a result of Antero's drilling plan.

5.1 Risk Estimations

The methods for estimating cancer, non-cancer, and multiple contaminant risk follow.

5.1.1 Cancer Risk Estimation

The lifetime cancer risk for each COPC for which there is a toxicity value is derived by multiplying the intake values in presented in Table 3-1 for the chronic exposure scenarios and Table 3-2 for the acute exposure scenario by the respective IUR value, as shown in the following equation.

$$Risk_x = Intake_x * IUR_x$$

Where:
$Risk_x$ = the risk of the Xth COPC at a monitor;
$Intake_x$ = the intake concentration of the substance or the maximum detected value;

Estimates of cancer risk are expressed as a probability, represented in scientific notation as a negative exponent of 10. For example, an additional lifetime risk of contracting cancer of 1 chance in 1,000,000 (or one additional person in 1,000,000) is written as 1E-06.

The level of cancer risk that is of concern is a matter of individual, community, and regulatory judgment. However, the EPA typically considers risks below 1E-06 to be so small as to be negligible (USEPA 1991). Therefore, the EPA uses a cancer risk of one in a million (1E-06) as a regulatory goal, which means that regulatory programs are generally designed to try to reduce risk to this level. When it is not feasible to meet this regulatory goal, the EPA may consider cancer risks lower than 1 in 10,000 (1E-04) to be acceptable.

5.1.2 Non-Cancer Hazard Estimation

In contrast to cancer risks, non-cancer hazards are not expressed as a probability of an individual suffering an adverse effect. Instead, the non-cancer hazard to individuals is expressed in terms of the HQ. For a given contaminant, exposures below the reference

concentration (HQ less than one) are not likely to be associated with an appreciable risk of adverse health effects. With exposures increasingly greater than the reference concentration, the potential for adverse effects increases. HQs are calculated as follows:

$$HQ_x = Intake_x/RfC_x$$
$$HQ_x = Intake_x/RfD_x$$

Where:

HQ_x = the hazard quotient of the Xth COPC at a monitor;
$Intake_x$ = the intake concentration of the substance (i.e., most stringent of the 95% UCL or maximum air concentration); and
RfC_x = the reference concentration of the substance.
RfD_x = the reference dose of the substance

When used in the assessment of non-cancer risks, the HQ is commonly reported to one significant figure (USEPA, 1989). For example, a HQ of 0.13 is rounded to 0.1, and a HQ of 1.6 is rounded to 2.

5.1.3 Cumulative Risks for Multiple Chemicals

As noted in the 2008 risk assessment, emissions from natural gas development activities represent a complex mixture of hundreds of contaminants that can include aliphatic, aromatic, and polycyclic aromatic hydrocarbons, and carbonyls. Exposures to these contaminants may occur acutely or chronically, and commonly occur concurrently with exposure to other contaminants and stressors. The toxicity of contaminants in complex mixtures may differ greatly from that of a single compound. Therefore, estimating cancer risks or non-cancer hazard potential by considering one contaminant at a time might significantly underestimate the risks associated with simultaneous exposures to several contaminants. The consequences of the multiple exposures can be quantified, within some limitations, based on EPA's default assumption of additivity.

For cancer risk, the individual contaminant risks are added to estimate the total risk for the site. This summation is based upon the principle that the addition of each risk produces a combined total cancer risk estimate.

For non-carcinogenic contaminants, the HQs for each exposure pathway can be summed to develop a HI for that exposure pathway. For screening purposes, it is acceptable to sum all HQ values in order to derive an HI value. If the resulting HI is less than one, no further evaluation is necessary and it can be concluded that no unacceptable risks are present. If the HI is greater than one as a consequence of summing several HQs of similar value, it would be appropriate to segregate the contaminants by effect and by mechanism of action and to derive separate HIs for each group.

5.2 Baseline Risk

Baseline risks were estimated for ambient air, groundwater, and surface water. There is no data available for the estimation of a baseline risk for surface or subsurface soil.

5.2.1 Ambient Air Baseline Risk

The baseline risks determined for the Silt-Daley and Silt-Cox monitoring sites in the risk assessment performed with the 2005-2007 ambient air study data were employed as an estimate of the baseline risk within the Battlement Mesa PUD (CDPHE 2007). The Silt-Daley and Silt-Cox monitoring sites are described as rural sites without natural gas production operations.

COPCs for cancer risk across the two rural background monitoring sites are limited to benzene at Silt-Daley and 1,4-dichlorobenzene at Silt-Cox. The cancer risk estimates ranged from 1.5E-05 for benzene (15 excess cancers per 1 million individuals) to 5.1E-05 for 1,4-dichlorobenzene (51 excess cancers per 1 million individuals). These risks were based on a 70-year exposure duration and a 365 day/year exposure frequency. Adjusting these risks for a 30-year exposure duration and a 350 day/year, results in baseline cancer risks ranging from 6.2 E-06 to 2.1E-05 (6.2 to 21 excess cancers per 1 million individuals).

None of the individual chemicals that were assessed at any monitoring location were found to have an HQ exceeding a value of one for chronic as well as short-term (average) exposure durations. None of the HIs exceeded a value of one for either exposure duration.

It is important to note that the following 11 out of 19 COPCs with toxicity values identified in this HHRA were not determined in the 2005-2007 study.

1,3-Butadiene
Acetylaldehyde
Crotonaldehye
Formaldehyde
Methylcyclohexane
n-Hexane
n-Nonane
n-Pentane
1,2,3-Trimethylbenzene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene

Seven background results for the trimethylbenzenes, 1,3-butadiene, methylcyclohexane, n-hexane, n-nonane, and n-pentane are available from the 2008 air toxics study. As shown in table 2-10, 1,3-butadiene was not detected in any of the background samples. The trimethylbenzenes, n-hexane, n-nonane, and n-pentane were detected in 100 percent of these background samples, but their maximum detected values did not exceed the EPA

RSL for residential ambient air. Methylcyclohexane also was detected in 100 percent these background samples. However, the maximum detected concentration for methylcyclohexane was much less than the RfC listed in Table 4-1. For these reasons, it is unlikely that the trimethylbenzenes, 1,3-butadiene, methylcyclohexane, n-hexane, n-nonane, and n-pentane contribute significantly to the baseline risk in the Battlement Mesa PUD.

There are no background results available for acetylaldehyde, formaldehyde, and crotonaldehyde. Therefore, it is not possible to estimate the contribution of these chemicals to the baseline risk.

5.3 Risk After Implementation of Natural Gas Production operations

The risk for each of the three populations discussed in Section 3 was quantitatively evaluated for COPCs with toxicity values. Risk for COPCs without toxicity values was addressed qualitatively.

5.3.1 All Battlement Mesa Residents Chronic Risk

Cancer Risk Estimates

The sum of the cancer risk to all Battlement Mesa residents (i.e., not living adjacent to a well pad is estimated at 7.1E-05 (71 cancers per 1,000,000 individuals), as shown in Table 5-1. This cancer risk is within EPA's acceptable range of 1E-06 to 1E-04. Crotonaldehyde, a possible human carcinogen, is the major contributor to the cancer risk (4.5E-05), followed by 1,4-dichlorobenzene, a possible human carcinogen, (1.0E-05), formaldehyde, a probable human carcinogen, (6.7E-06), benzene, a known human carcinogen, (5.4E-06), and 1,3-butadiene, a known human carcinogen (1.9E-06). Acetylaldehyde, a probable human carcinogen, methylene chloride, a probable human carcinogen, and ethylbenzene, a possible human carcinogen, also contribute to the cancer risk at levels less than 1E-06.

As noted in Section 5-2, data for crotonaldehyde, acetylaldehyde, and formaldehyde were not available for the baseline risk assessment. Therefore, it is not appropriate to directly compare the 7.1E-05 cancer risk to the baseline risk. It is possible to compare contribution of benzene, 1,4-dichlorobenzene, 1,3-butadiene, methylene chloride, and ethylbenzene to cancer risk to the baseline risk. These contaminants contribute 1.9E-05 of the cancer risk, which is within the baseline cancer risk range of 6.2E-06 to 2.1E-05.

The cancer risk of 7.1E-05 is less than the 1.2E-4 cancer risk reported in the 2008 risk assessment for the Bell-Melton Ranch monitoring station (CDPHE 2010). Adjusting the 1.2E-04 cancer risk reported in the 2008 risk assessment for Bell-Melton Ranch for a 30-year exposure duration and a 350 day/year exposure frequency results in a cancer risk of 4.9 E-05, which is less than the 7.1E-05 cancer risk for the resident not living adjacent to a well pad. The main reasons for this difference is because of the inclusion of 1,4-

dichlorobenzene results from the 2005-2007 air study that were not considered in the 2008 risk assessment and differences in EPCs. EPCs were different because this HHRA included results from 2009 and 2010.

Non-Cancer Risk Estimates

No COPC had an HQ greater than one, as shown in Table 5-1. The HI for non-cancer hazard is 0.6, which is less than EPA's level of one below which health effects are not expected to occur.

The HI of 0.6 is higher than the 0.4 HI (0.2 adjusted for a 30-year exposure duration) reported in the 2008 risk assessment for the Bell-Melton monitoring station (CDPHE 2010). Differences between the two estimates are mainly because this HHRA included chemicals not measured in the 2005-2007 study.

Qualitative Risk Evaluation

Of the COPCs identified from the 2005 to 2010 data set used to evaluate the risk for residents not living near a well pad, 61 did not have toxicity values. However, background information is available for 55 of these COPCs. As shown in Table 5-2, the EPC for 42 of these COPCs did not exceed the BTV, indicating they would not contribute more to risk than already contributed by the baseline. The remaining 13 COPCs are alkenes and alkanes that may contribute to the risk over baseline.

At low concentrations, the toxicity of alkanes and alkenes is generally considered to be minimal (Sandmeyer, 1981). For example, the RfCs for the three alkanes with toxicity values, n-hexane, n-pentane, and n-nonane, range from 200 to 1000 $\mu g/m^3$. None of the EPCs for the alkenes and alkanes listed in table 5-2 exceed $100 \mu g/m^3$.

Six of the COPCs for which there are no toxicity values or background/baseline data are aldehydes, which generally act as irritants of the eyes, skin, and respiratory tract. Some aldehydes have also been shown to be mutagenic and/or carcinogenic. The variation in toxicity among the individual aldehydes is large. Investigations are needed to further characterize the health effects of the common aldehydes.

Overall, based on the qualitative evaluation of health risks, it appears that exposure to 55 COPCs identified in Table 5-2 individually is not likely to result in significant cancer and non-cancer effects. Any of the six carbonyls without toxicity values could potentially have a significant contribution to the cancer and/or non-cancer effects. In addition, the cumulative health effects of these 61 COPCs cannot be estimated. It should be noted that the current state of the science is unable to assess exposures to complex mixtures of air toxics, especially, synergistic and antagonistic interactions at low levels.

5.3.2 Residents Living Adjacent to a Well Pad

Cancer Risk Estimates

The sum of the cancer risk to Battlement Mesa residents living adjacent to a well pad is estimated at 8.3 E-05 (83 cancers per 1,000,000 individuals), as shown in Table 5-3. This cancer risk is within EPA's acceptable range of 1E-06 to 1E-04. Crotonaldehyde, a possible human carcinogen, is the major contributor to the cancer risk (4.5E-05), followed by benzene, a known human carcinogen (1.13E-5), 1,4-dichlorobenzene, a possible human carcinogen, (1.0E-05), ethylbenzene, a possible human carcinogen (6.9E-06), formaldehyde, a probable human carcinogen, (6.7E-06), and 1,3-butadiene, a known human carcinogen (1.9 E-06). Acetylaldehyde, a probable human carcinogen, and methylene chloride, a probable human carcinogen, also contribute to the cancer risk at levels less than 1E-06.

As noted in Section 5-2, data for crotonaldehyde, acetylaldehyde, and formaldehyde were not available for the baseline risk assessment. Therefore, it is not appropriate to directly compare the 9.4E-05 cancer risk to the baseline risk. It is possible to compare contribution of benzene, 1,4-dichlorobenzene, 1,3-butadiene, methylene chloride, and ethylbenzene to cancer risk to the baseline risk. These contaminants contribute 3.1E-05 of the cancer risk, which is greater than the baseline cancer risk range of 6.2E-06 to 2.1E-05.

The cancer risk of 8.3E-05 for the resident living adjacent to a well pad is higher than the 7.1E-05 estimated cancer risk for the resident not living adjacent to a well pad. The increase is due the increase in cancer risk from benzene and ethylbenzene. It is important to note that intakes for crotonaldehyde, acetylaldehyde, formaldehyde, methylene chloride, and 1,4-dichlorobenzene were the same as the chronic intakes for the residents not living near a well pad because data for these chemical was not available from the 2008 air toxics study. If concentrations of these compounds in ambient air are higher during well completion activities, the actual cancer risks for residents living adjacent to a well pad may be higher.

Non-Cancer Risk Estimates

While no individual contaminant had an HQ greater than one, the HI for the non-cancer hazard is 2, as shown in Table 5-3. The HI is greater than EPA's level of one above which health effects may occur. It also is greater than the baseline non-cancer hazard. It is important to note that if concentrations of acetylaldehyde, formaldehyde, methylene chloride, and 1,4-dichlorobenzene in ambient air are higher during well completion activities, the actual non-cancer hazards for residents living adjacent to a well pad may be even greater.

Qualitative Risk Evaluation

Of the COPCs identified from the 2008 well completion data sets used to evaluate the risk for residents living near a well pad, 64 did not have toxicity values. However, background information is available for 57 of these COPCs. As shown in Table 5-2, the

maximum detected concentration for six of these COPCs did not exceed the BTV, indicating they would not contribute more to risk than already contributed by the baseline. The remaining 51 COPCs are alkenes, alkanes, and aromatic hydrocarbons that may contribute to the risk over baseline.

At low concentrations, the toxicity of alkanes and alkenes is generally considered to be minimal (Sandmeyer, 1981). For example, the RfCs for the three alkanes with toxicity values, n-hexane, n-pentane, and n-nonane, range from 200 to 1000 $\mu g/m^3$. The maximum concentrations for 15 alkanes listed in Table 5-2 exceed $100\mu g/m^3$. Ethane, propane, n-butane, and iso-butane concentrations exceed $1000\mu g/m^3$. At high concentrations, health effects that are associated with alkanes include acting as anesthetics and subsequently asphyxiants, showing narcotic or other central nervous system depression effects, and dermal and pulmonary irritation. Some alkanes (propane, butane and isobutane) may be weak cardiac sensitizers in humans following inhalation exposures to high concentrations (greater than 5 percent for isobutane and greater than 10 percent for propane).

Five of the COPCs which exceed BTVs and for which there are no toxicity values are aromatic hydrocarbons. The toxicity of aromatic hydrocarbons has is varied and some, such as benzene and ethylbenzene have been shown to carcinogenic. Investigations are needed to further characterize the health effects of these aromatic hydrocarbons.

Six of the COPCs for which there are no toxicity values or background/baseline data are aldehydes, which generally act as irritants of the eyes, skin, and respiratory tract. Some aldehydes have also been shown to be mutagenic and/or carcinogenic. The variation in toxicity among the individual aldehydes is large. Investigations are needed to further characterize the health effects of the common aldehydes.

Overall, based on the qualitative evaluation of health risks, it appears that exposure to several of the alkanes, and aromatic hydrocarbons identified in Table 5-2 that exceed BTVs could potentially make a significant contribution to cancer and/or non-cancer effects for residents living adjacent to well pads. Any of the six carbonyls without toxicity values also could potentially have a significant contribution to the cancer and/or non-cancer effects. In addition, the cumulative health effects of these 63 COPCs cannot be estimated. It should be noted that the current state of the science is unable to assess exposures to complex mixtures of air toxics, especially, synergistic and antagonistic interactions at low levels.

5.3.3 Acute Risk - Child Living Adjacent to a Well Pad

Non-Cancer Risk Estimates Ambient Air

Ambient air HQs for 1,2,3-trimethylbenzene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene, and n-nonane all exceed EPA's level of one above which

health effects may occur, as shown in Table 5-4. The HI for the ambient air pathway is 30.

It is important to note that acetylaldehyde, formaldehyde, the trimethylbenzenes, 1,3-butadiene, methycyclohexane, n-hexane, n-pentane, and n-nonane were not measured for odor complaints in the 2005 to 2007 air study. If concentrations of these chemicals are higher for odor complaints, the actual acute non-cancer hazards for the child resident living adjacent to a well pad may be even greater.

This acute non-cancer hazard in ambient air is greater than the acute non-cancer hazard estimated (HI 2-6) in CDPHE's 2007 HHRA. The difference is due the inclusion of the trimethylbenzenes in this estimate. The data for the trimethylbenzenes had not been collected at the time of the 2007 HHRA.

Non-Cancer Risk Estimates Surface Water

For the surface water pathway, no individual COPC has an HQ greater than one, as shown in Table 5-4. The HI for non-cancer risks is 0.6, which is less than EPA's level of one below which health effects are not expected to occur.

Non-Cancer Risk Estimates Combined Ambient Air and Surface Water

The overall HI of 40 for the acute exposure of a resident child living adjacent to a well pad is 40, which is much greater than EPA's acceptable level of one at which health effects may occur. The trimethylbenzenes, benzene, and n-nonane in ambient air are the primary contributors to the overall HI.

Qualitative Risk Evaluation

The qualitative risk evaluation performed for the resident living near a well pad also applies to the acute risk for a child resident living near a well pad. Overall, based on the qualitative evaluation of health risks, it appears that exposure to several of the alkanes, and aromatic hydrocarbons identified in Table 5-2 that exceed BTVs could make a significant contribution to acute non-cancer effects for child residents living adjacent to well pads. Any of the six carbonyls without toxicity values also could potentially have a significant contribution to the acute non-cancer effects. In addition, the cumulative health effects cannot be estimated. It should be noted that the current state of the science is unable to assess exposures to complex mixtures of air toxics, especially, synergistic and antagonistic interactions at low levels.

6 Uncertainty in Risk Assessment

Uncertainties and limitations are inherent in the risk assessment process. The level of uncertainty associated with the conclusions of a risk assessment is conditional upon data quality and models used to estimate exposure concentrations, assumptions in estimating exposure, and methods used to develop toxicity factors. Uncertainties in the risk assessment process could result in an underestimation or overestimation of risk. However, it is standard in risk assessment (per EPA guidance) to use health protective assumptions when uncertainty in quantifying risks exist, so as not to underestimate potential risk. While, the risk assessment process is generally skewed towards overestimating rather than underestimating risk, the risk estimated is this HHRA is most likely underestimated because of lack of data for the surface soil and water pathways, lack of toxicity data for most of the COPCs, lack of data for many potential COPCs, ozone and PM are not included in the quantitative risk assessment, and the chemicals reactions between the hundreds of chemicals in ambient air are not evaluated.

6.1 Uncertainties in Chemical Data

Section 2 discusses the evaluation and usability of the chemical data used in the HHRA in detail.

6.1.1 Bell-Melton Ranch Monitoring Station Data

Sample Frequency

Twenty-nine ambient air samples for VOCs were collected from the Bell-Melton monitoring station once per month for 29 months, followed by the collection of 128 samples for SNMOCs and 60 samples for carbonyls over the next 27 months. There is a low to moderate uncertainty that this dataset reflects the 30-year exposure assumed in this HHRA as changes in meteorology and chemical emissions could lead to lower or higher concentrations in air from year to year. However, the temporal trends illustrated in Figures 2-1 and 2-2 indicate no overall increase or decrease in ambient air concentrations over the past five years. To reduce this uncertainty would require monitoring over several years or modeling based on observed changes in meteorology and chemical emissions.

The 29 ambient air samples collected for VOCs were analyzed for 43 chemicals. Thirty-six of these chemicals were not included in the SNMOC or carbonyl analysis. Therefore, for 36 chemicals evaluated in this HHRA, there are only 29 results for a 29 month period. There is more uncertainty that this sub-dataset reflects the 30-year exposure assumed in the HHRA, than the overall dataset.

Method Reporting Limits

For the 15 VOCs listed in Section 2.2.1 with a detection frequency of less than five percent, the RSL was less than the MRL. It is uncertain if these chemicals are present at a concentration that may impact human health. The presence of any of these chemicals in ambient at concentrations that could impact human health would contribute to an underestimation of the risks calculated in this HHRA. The contribution to the uncertainty would be expected be low because these chemicals are mostly chlorinated solvents which have not been associated with natural gas production operations. To reduce this uncertainty would require collection of ambient air samples for VOCs for analysis by a method with MRLs below EPA RSLs for ambient air.

6.1.2 Well Completion Data

Sixteen ambient air samples for SNMOCs were collected from the perimeter of four different well pads undergoing well completion activities. At each well pad, one sample was collected from each of the four cardinal directions (four total samples). There is high level of uncertainty that this dataset reflects the 10-month exposure assumed for well completion in this HHRA as changes in meteorology and chemical emissions could lead to lower or higher concentrations in air from month to month. In addition, it is uncertain whether this dataset reflects all stages of well completion as different stages of well completion can lead to lower or higher concentrations in ambient air. To reduce this uncertainty would require daily monitoring over all stages of well completion or modeling based on observed changes in meteorology and chemical emissions.

6.1.3 Data Collected with Observed Odors at Residences

Sample Collection

Grab samples rather than 24-hour integrated samples were collected during odor events. There is a high level of uncertainty that a grab sample reflects the 24 hour per day exposure time assumed in this HHRA as changes in meteorology and chemical emissions could lead to lower or higher concentrations in air from minute to minute.

Sample Frequency

Twenty-eight samples for VOCs were collected during the 2005-2007 Garfield County Air Quality Study by residents when they observed odors. There is a high level of uncertainty that this dataset reflects the 7 day acute exposure scenario in this HHRA as changes in meteorology and chemical emissions could lead to lower or higher concentrations in air from day to day. In addition, it is uncertain whether this dataset reflects all stages of well completion as different stages of well completion can lead to lower or higher concentrations of chemicals in ambient air. To reduce this uncertainty would require sample collection over many odor events associated with different stages of well completion or modeling based on observed changes in meteorology and chemical emissions.

Method Reporting Limits

For the 15 VOCs listed in Section 2.2.1 with a detection frequency of less than five percent, the RSL was less than the MRL. It is uncertain if these chemicals are present at a concentration that may impact human health. The presence of any of these chemicals in ambient at concentrations that could impact human health would contribute to an underestimation of the risks calculated in this HHRA. The contribution to the uncertainty would be expected be low because these chemicals are mostly chlorinated solvents which have not been associated with natural gas production operations. To reduce this uncertainty would require collection of ambient air samples for VOCs for analysis by a method with MRLs below EPA RSLs for ambient air.

6.1.4 Surface Water Run-off Data

One sample of snow melt from one well pad was collected and analyzed for BTEX. There is a high level of uncertainty that this sample represents concentrations in surface water run-off from other well pads and during various stages of well drilling and completion. Potential surface water run off from the well pads proposed for Battlement Mesa could have lower or higher concentrations of chemicals. To reduce this uncertainty would require sample collection of surface water run off from many well pads over the stages of well completion.

6.1.5 Background Data for Ambient Air

BTVs determined for 72 out of the 115 chemicals listed in Table 2-7 were determined from seven background samples collected during the 2008 Air Toxics study. For the remaining 43 chemicals, only 5 had 8 or more detected observations. EPA recommends that BTVs be determined from data sets containing at least 8 to 10 samples with detectable observations (EPA 2010). It is moderately uncertain that the datasets with only 7 samples or less than 8 detected observations truly reflect background conditions. Actual background concentrations may be higher or lower. To reduce this uncertainty would require collection of additional background samples.

6.1.6 Groundwater Data

Out of 98 contaminants measured in groundwater, 29 had MRLs greater than the EPA RSL for tapwater. Because the groundwater exposure pathway is currently incomplete, this has minimal impact on this HHRA.

6.2 Uncertainty in Exposure Assessment

There are uncertainties in the exposure assessment related to potentially complete pathways that were not evaluated, use of ambient air stations to represent residential exposure, use of Bell-Melton Ranch monitoring station to represent Battlement Mesa, using well completion data from the 2008 perimeter study to estimate exposure during well completion, using default exposure factor values, and estimating exposure point concentrations.

6.2.1 Potentially Complete Exposure Pathways Not Evaluated

As discussed in Section 3, complete pathways involving surface soil were not evaluated in this HHRA because data was not available. Excluding the surface soil pathway could moderately affect the results of the HHRA and lead to an underestimation of the risk.

Several potentially complete pathways were not evaluated in this HHRA because data was not available or potential for exposure is low. Excluding these pathways would not be expected to significantly affect the results of this HHRA and may lead to a low underestimation of the risk. It is important to note that if the groundwater became contaminated as a result of natural gas production operations and was used as a source of drinking water, the risk calculated in this HHRA could be significantly underestimated.

6.2.2 Use of Bell-Melton Ranch Monitoring Station

There is a moderate level of uncertainty that the Bell-Melton Ranch monitoring station is representative of air concentrations to which a resident is exposed in the breathing zone 24 hours a day over 30 years. Actual concentrations may be higher or lower. Additionally, actual risk to residents living near sources of high concentrations of contaminant emissions may be underestimated.

There also is moderate level of uncertainty that the concentrations of contaminants measured at the Bell-Melton Ranch monitoring station are representative of what may be expected within the Battlement Mesa PUD. The Bell-Melton Ranch Monitoring Station is located in the Mamm Creek natural gas field. The natural gas produced from this field contains 83.1 to 84.3 molar percent methane and 13.5 to 16.2 molar percent heavier hydrocarbons (S.S. Papadopulos, 2008). Measurements of natural gas produced from Antero's Watson Ranch well pad (which is on the border of the PUD and within the same natural gas field as the PUD) indicate the produced gas is 91.1 molar percent methane and 6.4 molar percent heavier hydrocarbons (Antero personnel communication). However, the natural gas from the Watson Ranch pad contains 0.45 molar percent of hydrocarbons with 6 or more carbon atoms, which is a larger fraction than the 0.155 to 0.369 molar percent of hydrocarbons with 6 or more carbon atoms measured at Mamm Creek. Of the hydrocarbons identified as COPCs in this HHRA, all but one (n-pentane) have 6 or more carbon atoms. Therefore the uncertainty associated with the difference in the natural gas resources my result in an underestimation of the estimated risk for the Battlement Mesa PUD.

Other differences between the Bell-Melton Ranch monitoring station and Battlement Mesa include:

- Population density - Battlement Mesa is more densely populated which could result in greater emissions of contaminants in ambient air, leading to an underestimation of the risk calculated in the HHRA.
- Well Emission Controls – Not all of the wells in the vicinity of Bell-Melton Ranch flare vented gas, whereas Antero has indicated flares will be installed on all wells within the Battlement Mesa PUD. This could result in an overestimation of the risk calculated in the HHRA

Overall, using data from the Bell Melton Ranch monitoring station to estimate risk to Battlement Mesa residents introduces a low to moderate level of uncertainty to the risk estimates. Actual risks may be lower or higher.

6.2.3 Use of Well Completion Samples

As with the samples collected at the Bell-Melton Ranch monitoring station, there is a moderate level of uncertainty that the samples collected at the perimeter of the well pads represent air concentrations to which a resident is exposed in the breathing zone for 24 hours a day over 10 months. Actual concentrations may be higher or lower. Additionally, samples were collected at distances nearer the well head than the 500 foot set back proposed by Antero. This may result in a low overestimation in the calculated risk.

A large uncertainty stems from inability to monitor intermittent peak exposure. The nature of oil and gas operations is such that emissions vary strongly with time. To reduce this uncertainty, short-term air monitoring is needed.

6.2.4 Use of EPA Default Exposure Factor Values

EPA recommends the use of site-specific exposure factor values for HHRAs when available. When site-specific information is not available, such as was the case for exposure frequencies and the surface water exposure factor values, EPA standard default values are recommended. In general, there is a higher uncertainty and protectiveness of health involved in using default values instead of site-specific values. Therefore default values used for exposure frequency and the surface water exposure factor values may have contributed to a low to moderate overestimation of risk.

6.2.5 Exposure Point Concentrations

The EPCs for 1,4-dichlorobenzene, 2-hexanone, and methylene chloride are based on one detected result out of 29 samples. Actual concentrations of 1,4-dichlorbenzene, 2-

hexanone, and methylene chloride may be lower and risks from these contaminants may be overestimated.

The maximum detected concentration was used from the well completion data was used to calculate the TWA for the EPC used to estimate the exposure of a resident living adjacent to a well pad. The maximum concentration was observed in the sample collected at 200 feet from the well head at an Antero well pad. The proposed set back for the wells in the Battlement Mesa PUD is 500 feet. Using the maximum concentration collected from a sample collected at a distance closer to a well head than the proposed set back may contribute moderately to an overestimation of the risk calculated in this HHRA. To reduce this uncertainty would require collection of samples at the proposed set back distance.

The maximum detected concentration for the data collected during odor events was used as the EPC to estimate an acute exposure of a child resident living adjacent to a well pad. Using the maximum concentration may contribute moderately to an overestimation of the risk calculated in this HHRA. However, the intention of the acute exposure scenario was to evaluate the MEI.

6.2.6 Exposures for children

The uncertainty noted for children in the 2007 risk assessment also applies to this HHRA (CDPHE 2007). Children generally are expected to have some exposures that differ (higher or lower) from those of adults because of differences in size, physiology, and behavior. For example, children exposed to the same concentration of a chemical in air as adults may receive a higher dose because of greater lung surface area-to-body weight ratios and higher ventilation rate per kilogram of body weight. EPA has recently concluded that cancer risks of mutagenic carcinogens generally are higher from early-life exposures than from similar exposure durations later in life. It is, however, important to note that when exposures are fairly uniform over a lifetime exposure of 70 years, the effect of child adjustments on the estimated lifetime cancer risk is relatively small. These adjustments are more important when estimating the cancer risks from less than 70 years of exposure duration, such as the 30-year exposure duration used in this HHRA. In addition, children are more at risk because of the availability of a longer latency period for the development of cancer.

6.3 Uncertainty in the Toxicity Assessment

There are uncertainties in the toxicity assessment related to the toxicity values, COPCs without toxicity data, the lack of data on potential COPCs for which there is no data, interactions resulting from exposures to multiple chemicals, and the effect of other pollutants such as ozone and particulate matter on toxicity.

6.3.1 Toxicity Values

The RfC and RfD values used to evaluate non-cancer risk and the IUR values used to quantify cancer are often derived from limited toxicity databases. This can result in substantial qualitative and quantitative uncertainty. To account for this uncertainty, EPA derives RfCs, RfDs, and IURs in a way that is intentionally conservative (protective of human health). Risk estimates based on the RfCs, RfDs, and IURs are likely to overestimate risk.

The 2008 risk assessment notes that the EPA has calculated a range of IURs for benzene between 2.2×10^{-6} and 7.8×10^{-6} per µg/m³. The upper-bound value was used in this HHRA, as was done in the 2008 risk assessment, in accordance with the EPA Air Toxic guidance, which may slightly overestimate risk (up to 3-fold). The set of risk estimates falling within this interval reflects both the inherent uncertainties in the risk assessment of benzene and the limitations of the epidemiologic studies in determining dose-response and exposure data (CDPHE 2010).

Also noted in the 2008 risk assessment, the IUR for crotonaldehyde is particularly uncertain (CDPHE 2010). An IUR is not reported in EPA's IRIS for crotonaldehyde. The toxicity of crotonaldehyde was evaluated using a cancer toxicity value derived in the EPA Health Effects Assessment Summary Tables (HEAST) from oral exposure studies. Although conversion of oral dose-response information to inhalation exposure is not optimal risk assessment practice, the alternative would be to omit this substance altogether from any quantitative evaluation. Crotonaldehyde is classified as a possible human carcinogen (Category C). The classification was assigned based on one animal study in which an increase in the incidence of hepatic neoplastic nodules and hepatocellular carcinomas was observed in only one sex of one species. There is insufficient evidence that inhalation is a route that results in crotonaldehyde- induced liver lesions or neoplastia.

The IUR for 1,4-dichlorobenzene also is particularly uncertain. An IUR is not reported in EPA's IRIS for 1,4-dichlorobenzene. The toxicity of 1,4-dichlorobenzene was evaluated using a cancer toxicity derived by CALEPA from oral exposure studies. 1,4-dichlorobenzene is classified as a possible human carcinogen (Category C). The classification was assigned based on two animal studies in which an increase in the incidence of hepatocellular adenomas and carcinomas was observed in male rats and both sexes of mice.

The RfC for 1,2,4-trichlorobenzene was used as a surrogate toxicity value for 1,2,3-trichlorobenzene and 1,3,5-trichlorobenzene. This may have resulted in an underestimation or overestimation of the contribution of these two contaminants to the risk.

The RfD for chronic benzene exposure was used for the acute benzene exposure in surface water. This may have contributed to an overestimation of the risk from surface

water. However, the HI from the acute surface water exposure was less than one and the overall effect on the risk estimate is minimal.

The RfC for intermediate ethylbenzene exposure was used for the acute ethylbenzene exposure in surface water. This may have contributed to an overestimation of the risk from surface water. However, the HI from the acute surface water exposure was less than one and the overall effect on the risk estimate is minimal.

RfDs for dermal exposure were extrapolated from oral RfDs for the evaluation of acute exposure from surface water. This may have contributed to an overestimation of the risk from surface water. However, the HI from the acute surface water exposure was less than one and the overall effect on the risk estimate is minimal.

6.3.2 COPCs without toxicity values

One of the largest sources of uncertainty in the toxicity assessment is unavailability of toxicity values for 63 out of 82 COPCs in ambient air. Therefore, cancer risks and non-cancer hazards are likely to be underestimated for ambient air.

6.3.3 Potential COPCs Not Measured

Another one of the largest sources of uncertainty in the HHRA is lack of data for many chemicals in ambient air and surface water run-off that could be associated with natural gas production operations. These include chemicals in hydraulic fracturing fluid and drilling mud, polycyclic aromatic hydrocarbons (PAHs), and metals. Of the contaminants detected in samples collected at observed odor events between 2005 and 2007, only m&p-xylene exceeded Texas Commission on Environmental Quality's acute odor based effects screening level (ESL) (Table 2-6). The ESL is the level at which 50 percent of people can smell a contaminant and is not necessarily associated with health effects (TCEQ 2006). Health effects are possible for some contaminants, such as benzene, at levels below the odor threshold. The fact that only m&p-xylene exceeded the odor threshold indicates that there may be other ambient air contaminants associated in with natural gas production operations that have not been measured.

Table 6-1 lists 234 chemicals complied from Antero's material safety data sheets (MSDS) for natural gas production operations that have not been measured in ambient air or surface water samples. These include chemicals in hydraulic fracturing fluids and drilling mud. The list includes carcinogenic PAHs, metals, irritants, and odorous compounds, such as glutaraldehyde. Cancer risks and non-cancer hazards may be significantly underestimated without data for these chemicals.

Several of the PAHs are probable human carcinogens, including benzo (a) pyrene, dibenz(a,h)anthracene, benz(a)anthracene, benzo(b)fluoranthene, and indeno(c,d)pyrene (EPA IRIS). Others, such as naphthalene, are possible human carcinogens (EPA IRIS).

PAHs are associated with emissions from diesel engines. Once emitted to the air, the PAHs can contaminate surface soil and water via dry deposition. The trucks and generators used during natural gas production operations are powered by diesel engines. The truck traffic within the Battlement Mesa PUD is expected to be extensive with as many as 280 truck trips per day during peak well pad construction activities (Antero, 2010). Generator use is expected to be extensive during hydraulic fracturing operations. Naphthalene also is one of the chemicals listed on the MSDS sheets for hydraulic fracturing fluids, as well as being one of the components of the natural gas resource. Cancer risks may be significantly underestimated without PAH data for both ambient air and surface soil.

6.4 Uncertainty in Risk Estimation Due to Ozone and Particulate Matter

Ozone, PM_{10} and $PM_{2.5}$ were not evaluated in the HHRA because they are regulated by federal Air Quality Standards (AQS). The purpose of the AQSs is to protect human health. However, there has been much debate over whether the 75 ppb (147 $\mu g/m^3$) (averaged over 8 hours) AQS for ozone is protective and EPA is proposing a lower AQS of 60 ppb (118 $\mu g/m^3$). In addition, applying these standards on an individual basis does not account for potential additive affects in multiple chemical mixtures, as occurs in ambient air. A qualitative evaluation of the effects of these air pollutants on the risk estimates follows.

<u>Ozone</u>

There is not any conclusive evidence that ozone is a human carcinogen (EPA 2006, EPA 2009a).

Short-term exposure to ground level ozone through inhalation can cause reversible decrements to lung function, airway inflammation, coughing, chest pain, wheezing, and airway hyperactivity. These symptoms may be more long-lasting and pronounced in sensitive populations, such as people with asthma, children, and adults over 65 years of age. Acute ozone exposure also is associated with increased cardiovascular morbidity and non-accidental and cardiovascular mortality. There is some evidence long term exposure to ozone may cause decreased pulmonary function, but it is inconclusive (EPA 2006, EPA 2009a).

High concentrations of ozone precursors (VOCs and nitrogen oxides) have been observed in areas with high natural gas production operations in Garfield County (CDPHE 2009b). CDPHE ranked Garfield County as 5th out of 64 Colorado counties in levels of these ozone precursors in 2009, while Garfield ranked only 14th in population (CDPHE 2009c). In 2009, the 8-hr average ozone concentrations measured at the Rifle monitoring station did not exceed the 75 ppb AQS. However, 8-hour average ozone concentrations did exceed the proposed 60 ppb AQS on five days in March and April 2009, with a maximum concentration of 64 ppb (Garfield County 2010). For days on which the proposed 8-hour ozone AQS is exceeded, the acute non-cancer hazard calculated in this HHRA may be underestimated.

Particulate Matter

There is suggestive evidence indicating $PM_{2.5}$ may be associated with increased mortality from lung cancer (EPA 2009b).

Short-term exposure to $PM_{2.5}$ through inhalation is associated with increased emergency room visits and hospitalizations for ischemic heart disease, congestive heart failure chronic obstructive pulmonary disease (COPD), respiratory infections. Increases in all-cause, cardiovascular, and respiratory mortality are associated with short exposure to $PM_{2.5}$. Long-term exposure to $PM_{2.5}$ has been associated with cardiovascular mortality, decrements in lung function, and development of asthma (EPA 2009b). There is suggestive evidence that short-term and long term exposure to PM_{10} may cause health effects similar to those of $PM_{2.5.}$ Sensitive populations, such as children, older adults, and people with cardiopulmonary disease are more susceptible to these health effects.

Increased truck traffic can result in increased levels of $PM_{2.5}$ and PM_{10} through diesel emissions and stirring up road dust, respectively. The AQSs for $PM_{2.5}$ are 35 µg/m^3 (24-hour, 98th percentile averaged over 3 years) and 15 µg/m^3 (annual, mean averaged over 3 years). The AQS for PM_{10} is 150 µg/m^3 (24-hour, not to be exceeded more than once per year on a 3-year average). Neither $PM_{2.5}$ or PM_{10} concentrations measured at the Rifle monitoring station nor PM_{10} concentrations measured at the Parachute monitoring station exceeded any of these AQSs. However, several 24-hour $PM_{2.5}$ concentrations exceeded 35 µg/m^3 in 2009. The highest observed concentration was 41µg/m^3 (Garfield County 2010). $PM_{2.5}$ concentrations measured during the 2008 Air Toxics Study were all less than the 24-hour AQS ranging from 4.9 to 20.5 µg/m^3 (Garfield County 2009). For days on which the 24-hour $PM_{2.5}$ AQS is exceeded, the acute non-cancer hazard calculated in this HHRA may be underestimated.

6.5 Uncertainty in Risk Estimation Due to Chemical Mixtures

Interactions among components within ambient air, such as hydrocarbons, carbonyls, ozone, and ozone, are not well understood. Natural gas production operations and the diesel engines used to support them have the potential to release hundreds of hydrocarbons, including alkanes, alkenes, aromatics, and PAHs, and chemicals used in operations, such as hydraulic fracturing into the air, soil, and water. The diesel engines also release $PM_{2.5}$ and nitrogen oxides. Hydrocarbons, carbonyls, and nitrogen oxides serve as precursors for ground level ozone formation. The number of possible interactions this complex mixture of hydrocarbons, carbonyls, ozone, particulate matter, and other chemicals is very large. The effects of these complex interactions on human health are not well understood, but there is some indication that these complex mixtures can act additively or synergistically to increase effects on human health.

As previously stated, diesel engine exhaust is a complex mixture of hydrocarbons, $PM_{2.5}$ and nitrogen oxides. EPA has classified diesel engine exhaust as *likely to be carcinogenic to humans* based on: (1) strong, but less than sufficient evidence for a causal association

between diesel engine exhaust exposure and increased lung cancer risk among workers in occupational studies; (2) extensive supporting data including the demonstrated mutagenic and/or chromosomal effects of diesel engine exhaust and its organic constituents, and knowledge of the known mutagenic and/or carcinogenic activity of a number of individual organic compounds that adhere to the particles and are present in the diesel engine gases; (3) evidence of carcinogenicity of diesel particulate matter and the associated organic compounds in rats and mice by other routes of exposure (dermal, intratracheal, and subcutaneous and intraperitoneal injection); and (4) suggestive evidence for the bioavailability of organic compounds from diesel engine exhaust in humans and animals. Non-cancer health effects of exposure to diesel engine exhaust include pulmonary inflammation and histopathology (IRIS 2003/2010).

Studies on air pollution indicate that continuous exposure of healthy human adults to sulfur dioxide or nitrogen dioxide increases ozone absorption, suggesting that co-exposure to other gaseous pollutants in the ambient air may enhance ozone absorption. Studies that evaluated response to allergens in asthmatics (allergic and dust-mite sensitive) suggest that ozone enhances response to allergen challenge. Other studies have reported increased response (lung tissue injury, inflammatory and phagocytosis) to the mixture of PM and ozone compared to either PM or ozone alone (EPA 2006).

There also is the potential that some interactions may have an antagonistic effect on human health, resulting in the over- estimation of risk. However, it is more likely that the risk calculated in this HHRA is underestimated by not accounting for interactions of the complex mixture of chemicals in ambient air.

7 Summary and Conclusions

7.1 Summary

COPCs for ambient air were selected from data collected in three major Garfield County air studies between 2005 and 2010 by comparing the maximum detected concentration for each contaminant determined in the study to 1/10 EPA's RSL for that contaminant in residential ambient air. If an EPA RSL was not available for a contaminant it was retained as a COPC if it had a detection frequency greater than 5 percent. The following 20 COPCs for which toxicity values are available were evaluated quantitatively.

- Acetaldehyde
- Crotonaldehyde
- Formaldehyde
- 1,2,3-Trimethylbenzene
- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene
- 1,4-Dichlorobenzene
- 2-Hexanone
- Benzene
- Ethylbenzene
- 1,3-Butadiene
- m&p-Xylene
- methylcyclohexane
- n-Hexane
- n-Octane
- n-Nonane
- n-Pentane
- Chloroform
- o-Xylene
- Toluene

There are no toxicity values for the 62 COPCs listed in Table 4-2. These COPCs are primarly alkanes, alkenes, aromatic hydrocarbons, and carbonyls. They were addressed qualitatively in the HHRA.

The following COPCs were selected for surface water run-off.

- Benzene
- Ethylbenzene
- m&p-Xylene
- o-Xylene
- Toluene

Three exposure scenarios were evaluated:

(1) A long-term (30-year) chronic exposure scenario for all Battlement Mesa residents
(2) A long-term (30-year) chronic exposure scenario for Battlement Mesa residents living adjacent to a well pad.
(3) An acute (7-day) exposure scenario for Battlement Mesa child residents living adjacent to a well pad

Table 7-1 summarizes the cancer risk and non-cancer HI for each of these exposure scenarios.

7.2 Conclusions

The data evaluated in this HHRA suggest that there is a potential for natural gas production operations within the Battlement Mesa PUD to negatively impact public health, particularly through acute ambient air exposures during well completion activities, for the following reasons:

- The estimated HI of 40 for acute non-cancer hazard to a child resident living adjacent to a well pad is much greater than one. Benzene, the trimethylbenzenes, and n-nonane in ambient air are the primary contributors to this HI. The surface water exposure pathway contribution to this HI is less than one. Potential COPCs, such as PAHs and chemicals in hydraulic fracturing, that were not measured, ozone, $PM_{2.5,}$ PM_{10}, and COPCs without toxicity values could have significant contributions to the acute non-cancer hazard. These potential unmeasured contributions could increase the acute non-cancer hazard via inhalation for Battlement Mesa child residents living adjacent to well pads. This acute non-cancer hazard also applies to adult residents living adjacent to well pads.
- The estimated cancer risk of 83 cancers per one million people (8.3E-05) for Battlement Mesa residents living adjacent to a well pad, while within EPA's acceptable range of 1 to 100 cancers per million people, exceeds EPA's goal of less than 1 in a million and is near the high end of the acceptable range. It also exceeds the baseline cancer risk of 1 per million. This cancer risk translates to a population attributable risk (PAR) of less than 1 cancer in a population of 5,041 residents. The estimated HI of 2 for non-cancer hazards exceeds one, above which health effects may occur. The qualitative evaluation of the COPCs without toxicity values concluded the cancer risk and non-cancer hazard may be significant underestimates. In addition potential COPCs, such as PAHs and chemicals in hydraulic fracturing, that were not measured, could have contributions to the cancer risk and non-cancer hazard. These potential unmeasured contributions could increase the cancer risk or non-cancer hazard for Battlement Mesa residents living adjacent to well pads.
- The estimated cancer risk of 71 cancers per one million people (7.1 E-05) for all Battlement Mesa residents, while within EPA's acceptable range of 1 to 100

cancers per million people exceeds EPA's goal of less than 1 in a million and is near the high end of the acceptable range. This cancer risk translates to a PAR of less than 1 cancer in a population of 5,041 residents. The estimated HI of 0.6 for non-cancer hazards is less than one, below which health effects are not expected to occur. The qualitative evaluation of the COPCs without toxicity values concluded the cancer risk and non-cancer hazard are underestimates. In addition potential COPCs, such as PAHs and chemicals in hydraulic fracturing, that were not measured contribute to the cancer risk and non-cancer hazard. These potential unmeasured contributions could increase the cancer risk or non-cancer hazard for Battlement Mesa residents.

8 Key Data Gaps

To address the uncertainties in this HHRA, the following data is needed.

- Baseline air data for SNMOCs, carbonyls, PAHs, ozone, $PM_{2.5}$, and chemicals associated with well installation collected within the Battlement Mesa PUD.
- 24-hour air monitoring data for SNMOCs, carbonyls, PAHs, ozone, $PM_{2.5}$, and chemicals associated with well installation collected at 500 foot set backs from well heads at all stages of well installation and completion
- Short-term acute air monitoring data for SNMOCs, carbonyls, PAHs, $PM_{2.5}$, and chemicals associated with well installation collected at 500 foot set backs from well heads at all stages of well completion and when odors are observed.
- 24-hour air monitoring data for SNMOCs, carbonyls, PAHs, ozone, $PM_{2.5}$, and chemicals associated with well installation collected at a centralized monitoring station within Battlement Mesa.
- Direct measurements of air concentrations for toxics in the breathing zone.
- Toxicity values for 62 air toxics.
- Baseline surface soil data for PAHs.

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Table 2-1
Comparison of MRLs for 2005 - 2007 Data to EPA RSLs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Detection frequency (%)	Minimum MRL (µg/m^3)	Maximum MRL (µg/m3)	EPA RSL[1] (µg/m3)	EPA RSL greater than Maximum MRL?	EPA RSL greater than minimum MRL?
1,1,2,2-Tetrachloroethane	**0**	**1.50E+00**	**2.20E+00**	**4.20E-02**	**no**	**no**
1,1,2-Trichloroethane	**0**	**1.50E+00**	**2.20E+00**	**1.50E-01**	**no**	**no**
1,1-Dichloroethane	**0**	**1.50E+00**	**2.20E+00**	**1.50E+00**	**no**	**no**
1,2-Dibromoethane	0	1.50E+00	2.20E+00	4.10E-03	no	yes
1,2-Dichloroethane	**0**	**1.50E+00**	**2.20E+00**	**9.40E-02**	**no**	**no**
1,2-Dichloropropane	**0**	**1.50E+00**	**2.20E+00**	**2.40E-01**	**no**	**no**
1,4-Dichlorobenzene	**3**	**1.50E+00**	**2.20E+00**	**2.20E-01**	**no**	**no**
Bromodichloromethane	**0**	**1.50E+00**	**2.20E+00**	**6.60E-02**	**no**	**no**
Bromoform	0	1.50E+00	2.20E+00	2.20E+00	yes	yes
Carbon Tetrachloride	**0**	**1.50E+00**	**2.20E+00**	**4.10E-01**	**no**	**no**
Chloroform	**0**	**1.50E+00**	**2.20E+00**	**1.10E-01**	**no**	**no**
cis-1,3-Dichloropropene	**0**	**1.50E+00**	**2.20E+00**	**6.10E-01**	**no**	**no**
Dibromochloromethane	**0**	**1.50E+00**	**2.20E+00**	**9.00E-02**	**no**	**no**
Tetrachloroethene	**0**	**1.50E+00**	**2.20E+00**	**4.10E-01**	**no**	**no**
trans-1,3-Dichloropropene	**0**	**1.50E+00**	**2.20E+00**	**6.10E-01**	**no**	**no**
Trichloroethene	**0**	**1.50E+00**	**2.20E+00**	**1.20E+00**	**no**	**no**
Vinyl Chloride	**0**	**1.50E+00**	**2.20E+00**	**1.60E-01**	**no**	**no**
1,1,1-Trichloroethane	0	1.50E+00	2.20E+00	5.20E+03	yes	yes
1,1-Dichloroethene	0	1.50E+00	2.20E+00	2.10E+02	yes	yes
1,2-Dichlorobenzene	0	1.50E+00	2.20E+00	2.10E+02	yes	yes
1,3-Dichlorobenzene	0	1.50E+00	2.20E+00	NA	yes	yes
2-Hexanone	3	1.50E+00	2.20E+00	3.10E+01	yes	yes
4-Methyl-2-pentanone	0	1.50E+00	2.20E+00	3.10E+03	yes	yes
Bromomethane	0	1.50E+00	2.20E+00	5.20E+00	yes	yes
Carbon Disulfide	0	1.50E+00	2.20E+00	7.30E+02	yes	yes
Chlorobenzene	0	1.50E+00	2.20E+00	5.20E+01	yes	yes
Chloroethane	0	1.50E+00	2.20E+00	1.00E+04	yes	yes
Chloromethane	0	1.50E+00	2.20E+00	9.40E+01	yes	yes
cis-1,2-Dichloroethene	0	1.50E+00	2.20E+00	NA	-	-
Methyl tert-Butyl Ether	0	1.50E+00	2.20E+00	9.40E+00	yes	yes
Methylene chloride	3	1.50E+00	2.20E+00	5.20E+00	yes	yes
Styrene	0	1.50E+00	2.20E+00	1.00E+03	yes	yes
trans-1,2-Dichloroethene	0	1.50E+00	2.20E+00	6.30E+01	yes	yes
Trichlorofluoromethane	0	1.50E+00	2.20E+00	7.30E+02	yes	yes
Trichlorotrifluoroethane	0	1.50E+00	2.20E+00	3.10E+04	yes	yes

Notes:

Bold text indicates the EPA RSL is lower than the MRL. The MRL is not adequate for a HHRA.

[1]EPA Regional Screening values for residential ambient air May 2010. Based on exposure of 24 hours per day for 350 days per year for 30 years: http://www.epa.gov/region9/superfund/prg/index.html

RSL = regional screening values: Health effects are not expected to occur at or below this level.

MRL = method reporting limit: Results less than this level were reported as not detected.

NA = not available

µg/m^3 = micrograms per cubic meter

% = percent

Table 2-2
Comparison of MRLs from 2008 to 2010 Data to EPA RSLs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Detection frequency (%)	Minimum MRL (µg/m^3)	Maximum MRL (µg/m3)	EPA RSL[1] (µg/m3)	EPA RSL greater than Maximum MRL?	EPA RSL greater than minimum MRL?
1-Decene	0	1.15E-01	1.43E-01	NA	-	-
2,5-Dimethylbenzaldehyde	0	2.20E-03	1.10E-02	NA	-	-
2-Ethyl-1-butene	1	1.49E-01	2.47E-01	NA	-	-
Propyne	1	9.83E-02	1.09E-01	NA	-	-
trans-2-Hexene	1	1.49E-01	2.47E-01	NA	-	-
2-Methyl-1-pentene	2	1.49E-01	2.47E-01	NA	-	-

[1]EPA Regional Screening values for residential ambient air May 2010. Based on exposure of 24 hours per day for 350 days per year for 30 years: http://www.epa.gov/region9/superfund/prg/index.html
RSL = regional screening values: Health effects are not expected to occur at or below this level.
MRL = method reporting limit: Results less than this level were reported as not detected.
NA = not available
µg/m^3 = micrograms per cubic meter
% = percent

Table 2-3
Comparison of MRLs for 2010 Groundwater Data to EPA RSLs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Detection frequency (%)	MRL (µg/L)	EPA RSL[1] (µg/L)	EPA RSL greater than MRL?
1,1,1,2-Tetrachloroethane	0	5.00E-01	5.10E-01	yes
1,1,1-Trichloroethane	0	5.00E-01	9.10E+03	yes
1,1,2,2-Tetrachloroethane	**0**	**5.00E-01**	**6.70E-02**	**no**
1,1,2-Trichloroethane	**0**	**5.00E-01**	**2.40E-01**	**no**
1,1-Dichloroethane	0	5.00E-01	2.40E+00	yes
1,1-Dichloroethylene	0	5.00E-01	3.40E+02	yes
1,1-Dichloropropylene	0	5.00E-01	NA	-
1,2,3-Trichlorobenzene	0	5.00E-01	2.90E+01	yes
1,2,3-Trichloropropane	**0**	**5.00E-01**	**7.20E-04**	**no**
1,2,4-Trichlorobenzene	0	5.00E-01	2.30E+00	yes
1,2,4-Trimethylbenzene	0	5.00E-01	1.50E+01	yes
1,2-Dibromo-3-chloropropane	**0**	**2.00E-02**	**3.40E-04**	**no**
1,2-Dibromoethane	**0**	**1.00E-02**	**6.50E-03**	**no**
1,2-Dichlorobenzene	0	5.00E-01	3.70E+02	yes
1,2-Dichloroethane	**0**	**5.00E-01**	**1.50E-01**	**no**
1,2-Dichloropropane	**0**	**5.00E-01**	**3.90E-01**	**no**
1,3,5-Trimethylbenzene	0	5.00E-01	3.70E+02	yes
1,3-Dichlorobenzene	0	5.00E-01	NA	-
1,3-Dichloropropane	0	5.00E-01	7.30E+02	yes
1,3-Dichloropropene	**0**	**5.00E-01**	**4.30E-01**	**no**
1,4-Dichlorobenzene	**0**	**5.00E-01**	**4.30E-01**	**no**
2,2-Dichloropropane	0	5.00E-01	NA	-
2,4,5-TP	0	2.00E-01	2.00E+01	yes
2,4-D	0	1.00E-01	3.70E+02	yes
3-Hydroxycarbofuran	0	5.00E-01	NA	-
Aldrin	**0**	**1.00E-02**	**4.00E-03**	**no**
Alicarb	0	5.00E-01	3.70E+01	yes
Alicarb Sulfone	0	5.00E-01	3.70E+01	yes
Alicarb Sulfoxide	0	5.00E-01	NA	-
alpha-Chlordane	0	1.00E-02	1.90E-01	yes
Arochlor 1016	0	8.00E-02	9.60E-01	yes
Arochlor 1221	**0**	**1.00E-01**	**6.80E-03**	**no**
Arochlor 1232	**0**	**1.00E-01**	**6.80E-03**	**no**
Arochlor 1242	**0**	**1.00E-01**	**3.40E-02**	**no**
Arochlor 1248	**0**	**1.00E-01**	**3.40E-02**	**no**
Arochlor 1254	**0**	**1.00E-01**	**3.40E-02**	**no**
Arochlor 1260	**0**	**1.00E-01**	**3.40E-02**	**no**
Benzene	**0**	**5.00E-01**	**4.10E-01**	**no**
Bromobenzene	0	5.00E-01	8.80E+01	yes
Bromochloromethane	0	5.00E-01	NA	-
Bromodichloromethane	**0**	**5.00E-01**	**1.20E-01**	**no**
Bromoform	0	5.00E-01	8.50E+00	yes
Bromomethane	0	5.00E-01	8.70E+00	yes
Carbaryl	0	5.00E-01	3.70E+03	yes
Carbofuran	0	5.00E-01	1.80E+02	yes

Table 2-3
Comparison of MRLs for 2010 Groundwater Data to EPA RSLs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Detection frequency (%)	MRL (µg/L)	EPA RSL[1] (µg/L)	EPA RSL greater than MRL?
Carbon Tetrachloride	0	5.00E-01	4.40E+01	yes
Chlordane	**0**	**2.00E-01**	**1.90E-01**	**no**
Chlorobenzene	0	5.00E-01	9.10E+01	yes
Chloroethane	0	5.00E-01	2.10E+04	yes
Chloroform	**0**	**5.00E-01**	**1.90E-01**	**no**
Chloromethane	0	5.00E-01	1.90E+02	yes
cis-1,2-dichloroethene	0	5.00E-01	3.70E+02	yes
cis-1,3-dichloropropene	**0**	**5.00E-01**	**4.30E-01**	**no**
Dalapon	0	1.00E+00	1.10E+03	yes
Dibromochloromethane	**0**	**5.00E-01**	**1.50E-01**	**no**
Dibromomethane	0	5.00E-01	8.20E+00	yes
Dicamba	0	3.00E-01	1.10E+03	yes
Dichlorodifluoromethane	0	5.00E-01	3.90E+02	yes
Dieldrin	**0**	**1.00E-02**	**4.20E-03**	**no**
Dinoseb	0	2.00E-01	3.70E+01	yes
Endothall	0	1.80E+00	7.30E+02	yes
Endrin	0	1.00E-02	1.10E+01	yes
Ethylbenzene	0	5.00E-01	1.50E+00	yes
gamma-BHC (Lindane)	0	1.00E-02	6.10E-02	yes
gamma-Chlordane	0	1.00E-02	1.90E-01	yes
Heptachlor	0	1.00E-02	1.50E-02	yes
Heptachlor Epoxide	**0**	**1.00E-02**	**7.43E-03**	**no**
Hexachlorobenzene	0	2.00E-02	4.20E-02	yes
Hexachlorobutadiene	0	5.00E-01	8.60E-01	yes
Hexachlorocyclopentadiene	0	5.00E-02	2.20E+02	yes
Isopropylbenzene	0	5.00E-01	6.80E+02	yes
m,p-Xylene	0	5.00E-01	1.20E+03	yes
Methiocarb	0	5.00E-01	NA	-
Methiomyl	0	5.00E-01	9.10E+02	yes
Methoxychlor	0	5.00E-02	1.80E+02	yes
Methylene chloride	0	5.00E-01	4.80E+00	yes
Naphthalene	**0**	**5.00E-01**	**1.40E-01**	**no**
n-Butylbenzene	0	5.00E-01	NA	-
n-propylbenzene	0	5.00E-01	1.30E+03	yes
o-Chlorotoluene	0	5.00E-01	7.30E+02	yes
Oxamyl	0	5.00E-01	9.10E+01	yes
o-Xylene	0	5.00E-01	1.20E+03	yes
p-Chlorotoluene	0	5.00E-01	2.60E+03	yes
Pentachlorophenol	0	4.00E-02	5.60E-01	yes
Picloram	0	1.00E-01	2.60E+03	yes
p-Isopropyltoluene	0	5.00E-01	NA	-
Propoxur	0	5.00E-01	1.50E+02	yes
sec-Butylbenzene	0	5.00E-01	NA	-
Styrene	0	5.00E-01	1.60E+03	yes
tert-Butylbenzene	0	5.00E-01	NA	-

Table 2-3
Comparison of MRLs for 2010 Groundwater Data to EPA RSLs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Detection frequency (%)	MRL (µg/L)	EPA RSL[1] (µg/L)	EPA RSL greater than MRL?
Tetrachloroethene	**0**	**5.00E-01**	**1.10E-01**	**no**
Toluene	0	5.00E-01	2.30E+03	yes
Toxaphene	**0**	**5.00E-01**	**6.10E-02**	**no**
trans-1,2-dichloroethene	0	5.00E-01	1.10E+02	yes
trans-1,3-dichloropropene	**0**	**5.00E-01**	**4.30E-01**	**no**
Trichloroethene	0	5.00E-01	2.00E+00	yes
Trichlorofluoromethane	0	5.00E-01	1.30E+03	yes
Vinyl chloride	**0**	**5.00E-01**	**1.60E-02**	**no**

Notes:
Bold text indicates the EPA RSL is lower than the MRL. The MRL is not adequate for a HHRA.
[1]EPA Regional Screening values for residential tapwater May 2010.
RSL = regional screening values: Health effects are not expected to occur at or below this level.
MRL = method reporting limit: Results less than this level were reported as not detected.
NA = not available
µg/L = micrograms per liter
% = percent

Table 2-4
Summary Statistics and Selection of COPCs by Comparison to EPA RSL[1]
2005-2010 Ambient Air Data Bell-Melton Ranch Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (µg/m^3)	EPA RSL[1] (µg/m^3)	1/10 EPA RSL (µg/m^3)	Maximum Detected Concentration ≥ 1/10 EPA RSL?	Mean Concentration (µg/m^3)	COPC?
1,1,1-Trichloroethane	71-55-6	29	0	0	no	-	-	-	-	-	no
1,1,2,2-Tetrachloroethane	79-34-5	29	0	0	no	-	-	-	-	-	no
1,1,2-Trichloroethane	79-00-5	29	0	0	no	-	-	-	-	-	no
1,1-Dichloroethane	75-34-3	29	0	0	no	-	-	-	-	-	no
1,1-Dichloroethene	75-35-4	29	0	0	no	-	-	-	-	-	no
1,2,3-Trimethylbenzene	**526-73-8**	**128**	**44**	**34**	**yes**	**8.47E-01**	**NA**	**NA**	**-**	**8.10E-02**	**yes**
1,2,4-Trimethylbenzene	**95-63-6**	**128**	**121**	**95**	**yes**	**3.09E+00**	**7.30E+00**	**7.30E-01**	**yes**	**2.75E-01**	**yes**
1,2-Dibromoethane	106-93-4	29	0	0	no	-	-	-	-	-	no
1,2-Dichlorobenzene	95-50-1	29	0	0	no	-	-	-	-	-	no
1,2-Dichloroethane	107-06-2	29	0	0	no	-	-	-	-	-	no
1,2-Dichloropropane	78-87-5	29	0	0	no	-	-	-	-	-	no
1,3,5-Trimethylbenzene	**108-67-8**	**128**	**101**	**79**	**yes**	**1.20E+00**	**NA**	**NA**	**-**	**1.51E-01**	**yes**
1,3-Butadiene	**106-99-0**	**128**	**9**	**7**	**yes**	**1.53E-01**	**8.10E-02**	**8.10E-03**	**yes**	**5.58E-02**	**yes**
1,3-Dichlorobenzene	541-73-1	29	0	0	no	-	-	-	-	-	no
1,4-Dichlorobenzene	**106-46-7**	**29**	**1**	**3**	**no**	**2.30E+00**	**2.20E-01**	**2.20E-02**	**yes**	**9.36E-01**	**yes**
1-Decene	872-05-9	128	0	0	no	-	-	-	-	-	no
1-Dodecene	**112-41-4**	**128**	**32**	**25**	**yes**	**1.02E+00**	**NA**	**NA**	**-**	**1.44E-01**	**yes**
1-Heptene	**592-76-7**	**128**	**123**	**96**	**yes**	**2.98E+00**	**NA**	**NA**	**-**	**6.30E-01**	**yes**
1-Hexene	**592-41-6**	**128**	**69**	**54**	**yes**	**2.77E-01**	**NA**	**NA**	**-**	**9.55E-02**	**yes**
1-Nonene	**124-11-8**	**128**	**59**	**46**	**yes**	**4.28E-01**	**NA**	**NA**	**-**	**1.07E-01**	**yes**
1-Octene	**111-66-0**	**128**	**24**	**19**	**yes**	**1.37E+00**	**NA**	**NA**	**-**	**1.06E-01**	**yes**
1-Pentene	**109-67-1**	**128**	**124**	**97**	**yes**	**3.80E-01**	**NA**	**NA**	**-**	**1.04E-01**	**yes**
1-Tridecene	**2437-56-1**	**128**	**12**	**9**	**yes**	**2.04E-01**	**NA**	**NA**	**-**	**1.06E-01**	**yes**
1-Undecene	**821-95-4**	**128**	**35**	**27**	**yes**	**1.07E+00**	**NA**	**NA**	**-**	**1.21E-01**	**yes**
2,2,3-Trimethylpentane	**564-02-3**	**128**	**58**	**45**	**yes**	**1.64E+00**	**NA**	**NA**	**-**	**1.49E-01**	**yes**
2,2,4-Trimethylpentane	**540-84-1**	**128**	**58**	**45**	**yes**	**2.48E+00**	**NA**	**NA**	**-**	**1.52E-01**	**yes**
2,2-Dimethylbutane	**75-83-2**	**128**	**128**	**100**	**yes**	**2.34E+00**	**NA**	**NA**	**-**	**6.15E-01**	**yes**
2,3,4-Trimethylpentane	**565-75-3**	**128**	**74**	**58**	**yes**	**1.79E+00**	**NA**	**NA**	**-**	**9.21E-02**	**yes**
2,3-Dimethylbutane	**79-29-8**	**128**	**128**	**100**	**yes**	**5.05E+00**	**NA**	**NA**	**-**	**1.22E+00**	**yes**
2,3-Dimethylpentane	**565-59-3**	**128**	**128**	**100**	**yes**	**2.08E+00**	**NA**	**NA**	**-**	**5.26E-01**	**yes**

Table 2-4
Summary Statistics and Selection of COPCs by Comparison to EPA RSL[1]
2005-2010 Ambient Air Data Bell-Melton Ranch Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (µg/m^3)	EPA RSL[1] (µg/m^3)	1/10 EPA RSL (µg/m^3)	Maximum Detected Concentration ≥ 1/10 EPA RSL?	Mean Concentration (µg/m^3)	COPC?
2,4-Dimethylpentane	**108-08-7**	**128**	**127**	**99**	**yes**	**1.48E+00**	**NA**	**NA**	**-**	**3.69E-01**	**yes**
2,5-Dimethylbenzaldehyde	5779-94-2	128	0	0	no	-	-	-	-	-	no
2-Butanone (MEK)	78-93-3	29	16	55	yes	9.80E+00	5.20E+03	5.20E+02	no	2.62E+00	no
2-Ethyl-1-butene	760-21-4	128	1	1	no	2.75E+00	NA	NA	-	1.19E-01	no
2-Hexanone	**591-78-6**	**29**	**1**	**3**	**no**	**4.40E+00**	**3.10E+01**	**3.10E+00**	**yes**	**1.00E+00**	**yes**
2-Methyl-1-butene	**563-46-2**	**128**	**44**	**34**	**yes**	**3.94E+01**	**NA**	**NA**	**-**	**5.98E-01**	**yes**
2-Methyl-1-pentene	763-29-1	128	2	2	no	1.52E-01	NA	NA	-	9.82E-02	no
2-Methyl-2-butene	**513-35-9**	**128**	**51**	**40**	**yes**	**4.17E-01**	**NA**	**NA**	**-**	**8.95E-02**	**yes**
2-Methylheptane	**592-27-8**	**128**	**128**	**100**	**yes**	**2.93E+00**	**NA**	**NA**	**-**	**6.28E-01**	**yes**
2-Methylhexane	**591-76-4**	**128**	**126**	**98**	**yes**	**5.71E+00**	**NA**	**NA**	**-**	**1.39E+00**	**yes**
2-Methylpentane	**107-83-5**	**128**	**128**	**100**	**yes**	**2.20E+01**	**NA**	**NA**	**-**	**5.39E+00**	**yes**
3-Methyl-1-butene	**563-45-1**	**128**	**9**	**7**	**yes**	**2.00E-01**	**NA**	**NA**	**-**	**6.16E-02**	**yes**
3-Methylheptane	**589-81-1**	**128**	**128**	**100**	**yes**	**3.53E+00**	**NA**	**NA**	**-**	**4.17E-01**	**yes**
3-Methylhexane	**589-34-4**	**128**	**116**	**91**	**yes**	**4.84E+00**	**NA**	**NA**	**-**	**1.11E+00**	**yes**
3-Methylpentane	**96-14-0**	**128**	**128**	**100**	**yes**	**1.16E+01**	**NA**	**NA**	**-**	**2.80E+00**	**yes**
4-Methyl-1-pentene	**691-37-2**	**128**	**13**	**10**	**yes**	**4.68E+00**	**NA**	**NA**	**-**	**1.41E-01**	**yes**
4-Methyl-2-pentanone	108-10-1	29	0	0	no	-	-	-	-	-	no
Acetaldehyde	**75-07-0**	**128**	**128**	**100**	**yes**	**1.96E+00**	**1.10E+00**	**1.10E-01**	**yes**	**7.98E-01**	**yes**
Acetone	67-64-1	128	124	97	yes	5.70E+01	3.20E+04	3.20E+03	no	6.88E+00	no
Acetylene	**74-86-2**	**128**	**128**	**100**	**yes**	**2.92E+00**	**NA**	**NA**	**-**	**6.30E-01**	**yes**
a-Pinene	**80-56-8**	**128**	**75**	**59**	**yes**	**3.37E+00**	**NA**	**NA**	**-**	**1.74E-01**	**yes**
Benzaldehyde	**100-52-7**	**128**	**125**	**98**	**yes**	**2.04E-01**	**NA**	**NA**	**-**	**7.10E-02**	**yes**
Benzene	**71-43-2**	**128**	**112**	**88**	**yes**	**1.36E+01**	**3.10E-01**	**3.10E-02**	**yes**	**1.47E+00**	**yes**
b-Pinene	**127-91-3**	**128**	**10**	**8**	**yes**	**1.43E+00**	**NA**	**NA**	**-**	**8.08E-02**	**yes**
Bromodichloromethane	75-27-4	29	0	0	no	-	-	-	-	-	no
Bromoform	75-25-2	29	0	0	no	-	-	-	-	-	no
Bromomethane	74-83-9	29	0	0	no	-	-	-	-	-	no
Butyraldehyde	**123-72-8**	**128**	**126**	**98**	**yes**	**2.71E-01**	**NA**	**NA**	**-**	**6.98E-02**	**yes**
Carbon Disulfide	75-15-0	29	0	0	no	-	-	-	-	-	no
Carbon Tetrachloride	56-23-5	29	0	0	no	-	-	-	-	-	no

Table 2-4
Summary Statistics and Selection of COPCs by Comparison to EPA RSL[1]
2005-2010 Ambient Air Data Bell-Melton Ranch Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (µg/m^3)	EPA RSL[1] (µg/m^3)	1/10 EPA RSL (µg/m^3)	Maximum Detected Concentration ≥ 1/10 EPA RSL?	Mean Concentration (µg/m^3)	COPC?
Chlorobenzene	108-90-7	29	0	0	no	-	-	-	-	-	no
Chloroethane	75-00-3	29	0	0	no	-	-	-	-	-	no
Chloroform	67-66-3	29	0	0	no	-	-	-	-	-	no
Chloromethane	74-87-3	29	0	0	no	-	-	-	-	-	no
cis-1,2-Dichloroethene	156-59-2	29	0	0	no	-	-	-	-	-	no
cis-1,3-Dichloropropene	10061-01-5	29	0	0	no	-	-	-	-	-	no
cis-2-Butene	**590-18-1**	**128**	**63**	**49**	**yes**	**3.73E-01**	**NA**	**NA**	**-**	**6.79E-02**	**yes**
cis-2-Hexene	**7688-21-3**	**128**	**21**	**16**	**yes**	**7.00E-01**	**NA**	**NA**	**-**	**9.97E-02**	**yes**
cis-2-Pentene	**627-20-3**	**128**	**34**	**27**	**yes**	**1.45E-01**	**NA**	**NA**	**-**	**5.37E-02**	**yes**
Crotonaldehyde	**123-73-9**	**128**	**128**	**100**	**yes**	**5.53E-01**	**NA**	**NA**	**-**	**1.26E-01**	**yes**
Cyclohexane	110-82-7	128	128	100	yes	1.05E+02	6.30E+03	6.30E+02	no	3.85E+00	no
Cyclopentane	**287-92-3**	**128**	**128**	**100**	**yes**	**2.94E+00**	**NA**	**NA**	**-**	**7.28E-01**	**yes**
Cyclopentene	**142-29-0**	**128**	**67**	**52**	**yes**	**9.58E-01**	**NA**	**NA**	**-**	**1.34E-01**	**yes**
Dibromochloromethane	124-48-1	29	0	0	no	-	-	-	-	-	no
Ethane	**74-84-0**	**128**	**128**	**100**	**yes**	**4.11E+02**	**NA**	**NA**	**-**	**8.00E+01**	**yes**
Ethylbenzene	**100-41-4**	**128**	**92**	**72**	**yes**	**4.34E+00**	**9.70E-01**	**9.70E-02**	**yes**	**3.78E-01**	**yes**
Ethylene	**74-85-1**	**128**	**128**	**100**	**yes**	**2.94E+00**	**NA**	**NA**	**-**	**1.00E+00**	**yes**
Formaldehyde	**50-00-0**	**128**	**128**	**100**	**yes**	**1.02E+01**	**1.90E-01**	**1.90E-02**	**yes**	**1.17E+00**	**yes**
Hexaldehyde	**66-25-1**	**128**	**113**	**88**	**yes**	**1.31E-01**	**NA**	**NA**	**-**	**4.21E-02**	**yes**
Isobutane	**75-28-5**	**128**	**128**	**100**	**yes**	**1.18E+02**	**NA**	**NA**	**-**	**2.34E+01**	**yes**
Isobutene/1-Butene	**-11-7 / 106-9**	**128**	**84**	**66**	**yes**	**1.36E+01**	**NA**	**NA**	**-**	**1.29E+00**	**yes**
Isopentane	**78-78-4**	**128**	**123**	**96**	**yes**	**1.23E+02**	**NA**	**NA**	**-**	**1.97E+01**	**yes**
Isoprene	**78-79-5**	**128**	**82**	**64**	**yes**	**3.33E+00**	**NA**	**NA**	**-**	**3.13E-01**	**yes**
Isopropylbenzene (cumene)	98-82-8	128	34	27	yes	3.27E-01	4.20E+02	4.20E+01	no	7.80E-02	no
Isovaleraldehyde	**590-86-3**	**128**	**71**	**55**	**yes**	**1.13E-01**	**NA**	**NA**	**-**	**5.69E-03**	**yes**
m-Diethylbenzene	**141-93-5**	**128**	**44**	**34**	**yes**	**8.84E-01**	**NA**	**NA**	**-**	**9.25E-02**	**yes**
Methyl tert-Butyl Ether	1634-04-4	29	0	0	no	-	-	-	-	-	no
Methylcyclohexane	**108-87-2**	**128**	**128**	**100**	**yes**	**2.39E+01**	**NA**	**NA**	**-**	**5.38E+00**	**yes**
Methylcyclopentane	**96-37-7**	**128**	**128**	**100**	**yes**	**1.04E+01**	**NA**	**NA**	**-**	**2.60E+00**	**yes**
Methylene chloride	**75-09-2**	**29**	**1**	**3**	**no**	**2.90E+00**	**5.20E+00**	**5.20E-01**	**yes**	**9.59E-01**	**yes**

Table 2-4
Summary Statistics and Selection of COPCs by Comparison to EPA RSL[1]
2005-2010 Ambient Air Data Bell-Melton Ranch Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (µg/m^3)	EPA RSL[1] (µg/m^3)	1/10 EPA RSL (µg/m^3)	Maximum Detected Concentration ≥ 1/10 EPA RSL?	Mean Concentration (µg/m^3)	COPC?
m-Ethyltoluene	**620-14-4**	**128**	**122**	**95**	**yes**	**1.63E+00**	**NA**	**NA**	**-**	**1.87E-01**	**yes**
m-Xylene/p-Xylene	-38-3 / 106-4	128	119	93	yes	1.40E+01	7.30E+02	7.30E+01	no	1.69E+00	no
n-Butane	**106-97-8**	**128**	**128**	**100**	**yes**	**1.57E+02**	**NA**	**NA**	**-**	**2.79E+01**	**yes**
n-Decane	**124-18-5**	**128**	**126**	**98**	**yes**	**6.98E+01**	**NA**	**NA**	**-**	**1.11E+00**	**yes**
n-Dodecane	**112-40-3**	**128**	**107**	**84**	**yes**	**7.14E+01**	**NA**	**NA**	**-**	**1.24E+00**	**yes**
n-Heptane	**142-82-5**	**128**	**128**	**100**	**yes**	**1.14E+01**	**NA**	**NA**	**-**	**2.55E+00**	**yes**
n-Hexane	110-54-3	128	128	100	yes	2.50E+01	7.30E+02	7.30E+01	no	5.89E+00	no
n-Nonane	111-84-2	128	127	99	yes	3.08E+00	2.10E+02	2.10E+01	no	6.36E-01	no
n-Octane	**111-65-9**	**128**	**128**	**100**	**yes**	**6.72E+00**	**NA**	**NA**	**-**	**1.45E+00**	**yes**
n-Pentane	109-66-0	128	128	100	yes	6.20E+01	1.00E+03	1.00E+02	no	1.36E+01	no
n-Propylbenzene	103-65-1	128	76	59	yes	7.10E-01	1.00E+03	1.00E+02	no	8.26E-02	no
n-Tridecane	**629-50-5**	**128**	**45**	**35**	**yes**	**5.68E+00**	**NA**	**NA**	**-**	**2.05E-01**	**yes**
n-Undecane	**1120-21-4**	**128**	**125**	**98**	**yes**	**2.55E+02**	**NA**	**NA**	**-**	**2.81E+00**	**yes**
o-Ethyltoluene	**611-14-3**	**128**	**86**	**67**	**yes**	**1.44E+00**	**NA**	**NA**	**-**	**1.31E-01**	**yes**
o-Xylene	95-47-6	128	97	76	yes	3.61E+00	7.30E+02	7.30E+01	no	4.35E-01	no
p-Diethylbenzene	**105-05-5**	**128**	**31**	**24**	**yes**	**4.20E-01**	**NA**	**NA**	**-**	**5.50E-02**	**yes**
p-Ethyltoluene	**622-96-8**	**128**	**93**	**73**	**yes**	**1.26E+00**	**NA**	**NA**	**-**	**1.33E-01**	**yes**
Propane	**74-98-6**	**128**	**128**	**100**	**yes**	**3.16E+02**	**NA**	**NA**	**-**	**6.15E+01**	**yes**
Propionaldehyde	123-38-6	60	57	95	yes	2.04E-01	8.30E+00	8.30E-01	no	8.14E-02	no
Propylene	115-07-1	128	128	100	yes	2.46E+00	3.10E+03	3.10E+02	no	3.62E-01	no
Propyne	74-99-7	128	1	1	no	3.50E-01	NA	NA	-	5.45E-02	no
Styrene	100-42-5	157	11	7	yes	3.45E+00	1.00E+03	1.00E+02	no	2.49E-01	no
Tetrachloroethene	127-18-4	29	0	0	no	-	-	-	-	-	no
Tolualdehydes	**NA**	**60**	**56**	**93**	**yes**	**2.51E-01**	**NA**	**NA**	**no**	**8.16E-02**	**yes**
Toluene	108-88-3	157	156	99	yes	7.91E+01	5.20E+03	5.20E+02	no	4.02E+00	no
trans-1,2-Dichloroethene	156-60-5	29	0	0	no	-	-	-	-	-	no
trans-1,3-Dichloropropene	10061-02-6	29	0	0	no	-	-	-	-	-	no
trans-2-Butene	**624-64-6**	**128**	**102**	**80**	**yes**	**3.34E+00**	**NA**	**NA**	**-**	**1.13E-01**	**yes**
trans-2-Hexene	4050-45-7	128	1	1	no	3.04E-02	NA	NA	-	9.83E-02	no
trans-2-Pentene	**4050-45-7**	**128**	**58**	**45**	**yes**	**3.18E-01**	**NA**	**NA**	**-**	**6.72E-02**	**yes**

Table 2-4
Summary Statistics and Selection of COPCs by Comparison to EPA RSL[1]
2005-2010 Ambient Air Data Bell-Melton Ranch Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (µg/m^3)	EPA RSL[1] (µg/m^3)	1/10 EPA RSL (µg/m^3)	Maximum Detected Concentration ≥ 1/10 EPA RSL?	Mean Concentration (µg/m^3)	COPC?
Trichloroethene	79-01-6	29	0	0	no	-	-	-	-	-	no
Trichlorofluoromethane	75-69-4	29	0	0	no	-	-	-	-	-	no
Trichlorotrifluoroethane	76-13-1	29	0	0	no	-	-	-	-	-	no
Valeraldehyde	**110-62-3**	**60**	**32**	**53**	**yes**	**8.10E-02**	**NA**	**NA**	**-**	**2.25E-02**	**yes**
Vinyl Acetate	108-05-4	29	5	17	yes	1.30E+01	2.10E+02	2.10E+01	no	1.85E+00	no
Vinyl Chloride	75-01-4	29	0	0	no	-	-	-	-	-	no

Notes:
Bold text indicates contaminant selected as a COPC.
µg/m^3: micrograms per cubic meter
CAS: Chemical Abstract Service
COPC: Contaminant of potential concern
EPA: United States Environmental Protection Agency
NA: Not Available
[1]RSL = EPA regional screening levels for ambient air based on exposure of 24 hours per day for 350 days per year for 30 years :
Health effects are not expected to occur at or below the RSL. To select COPCs, maximum detected concentration was compared to 1/10 the RSL to account for additive health effects from multiple chemicals. : http://www.epa.gov/region9/superfund/prg/index.html, May 2010

Table 2-5
Summary Statistics and Selection of COPCs by Comparision to EPA RSLs[1] Summer 2008 Ambient Air Data Well Completion Operations
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (µg/m^3)	Mean Concentration (µg/m^3)	EPA RSL (µg/m^3)	1/10 EPA RSL (µg/m^3)	Maximum Concentration > 1/10 EPA RSL?	COPC?
1,2,3-Trimethylbenzene	526-73-8	16	16	100	yes	1.17E+01	1.32E+00	NA	-	-	yes
1,2,4-Trimethylbenzene	95-63-6	16	16	100	yes	8.30E+01	7.66E+00	7.30E+00	7.30E-01	yes	yes
1,3,5-Trimethylbenzene	108-67-8	16	16	100	yes	7.75E+01	6.77E+00	NA	-	-	yes
1,3-Butadiene	106-99-0	16	7	44	yes	1.66E-01	1.02E-01	8.10E-02	8.10E-03	yes	yes
1-Decene	872-05-9	16	0	0	no	-	-	-	-	-	no
1-Dodecene	112-41-4	16	12	75	yes	6.08E+00	9.54E-01	NA	-	-	yes
1-Heptene	592-76-7	16	16	100	yes	6.08E+01	7.23E+00	NA	-	-	yes
1-Hexene	592-41-6	16	16	100	yes	1.63E-01	8.23E-02	NA	-	-	yes
1-Nonene	124-11-8	16	15	94	yes	1.68E+01	1.56E+00	NA	-	-	yes
1-Octene	111-66-0	16	11	69	yes	3.16E+00	3.94E-01	NA	-	-	yes
1-Pentene	109-67-1	16	16	100	yes	3.89E-01	1.31E-01	NA	-	-	yes
1-Tridecene	2437-56-1	16	6	38	yes	3.63E-01	2.05E-01	NA	-	-	yes
1-Undecene	821-95-4	16	11	69	yes	4.72E+00	5.25E-01	NA	-	-	yes
2,2,3-Trimethylpentane	564-02-3	16	16	100	yes	2.47E+01	2.62E+00	NA	-	-	yes
2,2,4-Trimethylpentane	540-84-1	16	1	6	yes	1.98E-01	1.33E-01	NA	-	-	yes
2,2-Dimethylbutane	75-83-2	16	16	100	yes	4.12E+01	4.73E+00	NA	-	-	yes
2,3,4-Trimethylpentane	565-75-3	16	16	100	yes	1.21E+00	2.17E-01	NA	-	-	yes
2,3-Dimethylbutane	79-29-8	16	16	100	yes	6.58E+01	8.49E+00	NA	-	-	yes
2,3-Dimethylpentane	565-59-3	16	16	100	yes	3.56E+01	4.46E+00	NA	-	-	yes
2,4-Dimethylpentane	108-08-7	16	16	100	yes	2.36E+01	2.92E+00	NA	-	-	yes
2-Ethyl-1-butene	760-21-4	16	0	0	no	-	-	-	-	-	no
2-Methyl-1-butene	563-46-2	16	9	56	yes	1.26E+00	3.28E-01	NA	-	-	yes
2-Methyl-1-pentene	763-29-1	16	1	6	yes	8.43E-02	2.37E-01	NA	-	-	yes
2-Methyl-2-butene	513-35-9	16	9	56	yes	3.87E-01	1.28E-01	NA	-	-	yes
2-Methylheptane	592-27-8	16	16	100	yes	1.46E+02	1.50E+01	NA	-	-	yes
2-Methylhexane	591-76-4	16	16	100	yes	1.21E+02	1.45E+01	NA	-	-	yes
2-Methylpentane	107-83-5	16	16	100	yes	2.21E+02	3.18E+01	NA	-	-	yes
3-Methyl-1-butene	563-45-1	16	1	6	yes	2.49E-01	1.23E-01	NA	-	-	yes
3-Methylheptane	589-81-1	16	16	100	yes	9.74E+01	9.73E+00	NA	-	-	yes
3-Methylhexane	589-34-4	16	16	100	yes	1.14E+02	1.38E+01	NA	-	-	yes
3-Methylpentane	96-14-0	16	16	100	yes	1.29E+02	1.80E+01	NA	-	-	yes

Table 2-5

Summary Statistics and Selection of COPCs by Comparision to EPA RSLs[1] Summer 2008 Ambient Air Data Well Completion Operations

Human Health Risk Assessment

Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (µg/m^3)	Mean Concentration (µg/m^3)	EPA RSL (µg/m^3)	1/10 EPA RSL (µg/m^3)	Maximum Concentration > 1/10 EPA RSL?	COPC?
4-Methyl-1-pentene	691-37-2	16	8	50	yes	9.35E-01	3.05E-01	NA	-	-	yes
Acetylene	74-86-2	16	16	100	yes	8.40E-01	3.97E-01	NA	-	-	yes
a-Pinene	80-56-8	16	16	100	yes	3.09E+01	3.04E+00	NA	-	-	yes
Benzene	71-43-2	16	16	100	yes	6.85E+01	8.85E+00	3.10E-01	3.10E-02	yes	yes
b-Pinene	127-91-3	16	7	44	yes	8.96E+00	7.96E-01	NA	-	-	yes
cis-2-Butene	590-18-1	16	15	94	yes	1.97E-01	7.65E-02	NA	-	-	yes
cis-2-Hexene	7688-21-3	16	13	81	yes	2.93E-01	2.01E-01	NA	-	-	yes
cis-2-Pentene	627-20-3	16	9	56	yes	1.48E-01	8.14E-02	NA	-	-	yes
Cyclohexane	110-82-7	16	16	100	yes	2.04E+02	2.64E+01	6.30E+03	6.30E+02	no	no
Cyclopentane	287-92-3	16	16	100	yes	2.23E+01	3.84E+00	NA	-	-	yes
Cyclopentene	142-29-0	16	16	100	yes	6.51E-01	2.34E-01	NA	-	-	yes
Ethane	74-84-0	16	16	100	yes	2.41E+03	4.08E+02	NA	-	-	yes
Ethylbenzene	100-41-4	16	16	100	yes	2.28E+02	1.74E+01	9.70E-01	9.70E-02	yes	yes
Ethylene	74-85-1	16	16	100	yes	4.19E+00	1.17E+00	NA	-	-	yes
Isobutane	75-28-5	16	16	100	yes	1.60E+03	1.65E+02	NA	-	-	yes
Isobutene/1-Butene	NA	16	8	50	yes	6.71E+00	2.05E+00	NA	-	-	yes
Isopentane	78-78-4	16	16	100	yes	8.32E+02	1.14E+02	NA	-	-	yes
Isoprene	78-79-5	16	16	100	yes	1.15E+00	4.64E-01	NA	-	-	yes
Isopropylbenzene (cumene)	98-82-8	16	14	88	yes	4.85E+00	5.97E-01	4.20E+02	4.20E+01	no	no
m-Diethylbenzene	141-93-5	16	16	100	yes	7.08E+00	7.98E-01	NA	-	-	yes
Methylcyclohexane	108-87-2	16	16	100	yes	7.23E+02	8.00E+01	NA	-	-	yes
Methylcyclopentane	96-37-7	16	16	100	yes	1.20E+02	1.77E+01	NA	-	-	yes
m-Ethyltoluene	620-14-4	16	16	100	yes	4.45E+01	4.26E+00	NA	-	-	yes
m&p-Xylene	1330-20-7	16	16	100	yes	8.84E+02	9.47E+01	7.30E+02	7.30E+01	yes	yes
n-Butane	106-97-8	16	16	100	yes	1.29E+03	1.48E+02	NA	-	-	yes
n-Decane	124-18-5	16	16	100	yes	2.08E+02	1.89E+01	NA	-	-	yes
n-Dodecane	112-40-3	16	16	100	yes	5.15E+01	7.71E+00	NA	-	-	yes
n-Heptane	142-82-5	16	16	100	yes	3.04E+02	3.55E+01	NA	-	-	yes
n-Hexane	110-54-3	16	16	100	yes	2.55E+02	3.72E+01	7.30E+02	7.30E+01	yes	yes
n-Nonane	111-84-2	16	16	100	yes	3.03E+02	2.71E+01	2.10E+02	2.10E+01	yes	yes
n-Octane	111-65-9	16	16	100	yes	4.17E+02	4.10E+01	NA	-	-	yes

Table 2-5

Summary Statistics and Selection of COPCs by Comparision to EPA RSLs[1] Summer 2008 Ambient Air Data Well Completion Operations

Human Health Risk Assessment

Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (µg/m^3)	Mean Concentration (µg/m^3)	EPA RSL (µg/m^3)	1/10 EPA RSL (µg/m^3)	Maximum Concentration > 1/10 EPA RSL?	COPC?
n-Pentane	**109-66-0**	**16**	**16**	**100**	**yes**	**5.53E+02**	**1.05E+02**	**1.00E+03**	**1.00E+02**	**yes**	**yes**
n-Propylbenzene	103-65-1	16	16	100	yes	1.20E+01	1.28E+00	1.00E+03	1.00E+02	no	no
n-Tridecane	**629-50-5**	**16**	**16**	**100**	**yes**	**9.05E+00**	**1.64E+00**	**NA**	**-**	**-**	**yes**
n-Undecane	**1120-21-4**	**16**	**16**	**100**	**yes**	**1.21E+02**	**1.36E+01**	**NA**	**-**	**-**	**yes**
o-Ethyltoluene	**611-14-3**	**16**	**16**	**100**	**yes**	**2.92E+01**	**2.77E+00**	**NA**	**-**	**-**	**yes**
o-Xylene	**95-47-6**	**16**	**16**	**100**	**yes**	**1.90E+02**	**1.79E+01**	**730**	**7.30E+01**	**-**	**yes**
p-Diethylbenzene	**105-05-5**	**16**	**13**	**81**	**yes**	**5.01E+00**	**5.45E-01**	**NA**	**-**	**-**	**yes**
p-Ethyltoluene	**622-96-8**	**16**	**16**	**100**	**yes**	**3.22E+01**	**3.10E+00**	**NA**	**-**	**-**	**yes**
Propane	**74-98-6**	**16**	**16**	**100**	**yes**	**4.67E+03**	**4.37E+02**	**NA**	**-**	**-**	**yes**
Propylene	115-07-1	16	16	100	yes	1.94E+00	5.05E-01	3.10E+03	3.10E+02	no	no
Propyne	74-99-7	16	0	0	no	-	-	-	-	-	no
Styrene	100-42-5	16	3	19	yes	5.90E+00	5.57E-01	1.00E+03	1.00E+02	no	no
Toluene	108-88-3	16	16	100	yes	3.19E+02	3.63E+01	5.20E+03	5.20E+02	no	no
trans-2-Butene	**624-64-6**	**16**	**15**	**94**	**yes**	**1.89E+00**	**3.04E-01**	**NA**	**-**	**-**	**yes**
trans-2-Hexene	**4050-45-7**	**16**	**1**	**6**	**yes**	**4.53E-02**	**2.34E-01**	**NA**	**-**	**-**	**yes**
trans-2-Pentene	**646-04-8**	**16**	**14**	**88**	**yes**	**3.05E-01**	**1.07E-01**	**NA**	**-**	**-**	**yes**

Notes:

Bold text indicates contaminant selected as a COPC

µg/m^3: micrograms per cubic meter

CAS: Chemical Abstract Service

COPC: Contaminant of potential concern

EPA: United States Environmental Protection Agency

NA: Not Available

[1]RSL = EPA regional screening levels for ambient air based on exposure of 24 hours per day for 350 days per year for 30 years :
Health effects are not expected to occur at or below the RSL. To select COPCs, maximum detected concentration was compared to 1/10 the RSL to account for additive health effects from multiple chemicals. : http://www.epa.gov/region9/superfund/prg/index.html, May 2010

Table 2-6
Summary Statistics and Selection of COPCs by Comparison to EPA RSLs[1] Odor Thresholds[2]
2005-2007 Odor Events
Human Health Risk Assessment
Battlement Mesa HIA

Chemical	CAS Number	Number of Samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥5%?	Maximum Detected Concentration (µg/m^3)	Mean (µg/m3)	EPA RSL (µg/m3)	1/10 EPA RSL (µg/m3)	Maximum Concentration > 1/10 EPA RSL	COPC?	Texas Acute Odor ESL (µg/m^3)
1,1,1-Trichloroethane	71-55-6	28	0	0	no	-	-	-	-	-	no	-
1,1,2,2-Tetrachloroethane	79-34-5	28	0	0	no	-	-	-	-	-	no	-
1,1,2-Trichloroethane	79-00-5	28	0	0	no	-	-	-	-	-	no	-
1,1-Dichloroethane	75-34-3	28	0	0	no	-	-	-	-	-	no	-
1,1-Dichloroethene	75-35-4	28	0	0	no	-	-	-	-	-	no	-
1,2-Dibromoethane	106-93-4	28	0	0	no	-	-	-	-	-	no	-
1,2-Dichlorobenzene	95-50-1	28	0	0	no	-	-	-	-	-	no	-
1,2-Dichloroethane	107-06-2	28	0	0	no	-	-	-	-	-	no	-
1,2-Dichloropropane	78-87-5	28	0	0	no	-	-	-	-	-	no	-
1,3-Dichlorobenzene	541-73-1	28	0	0	no	-	-	-	-	-	no	-
1,4-Dichlorobenzene	106-46-7	28	0	0	no	-	-	-	-	-	no	-
2-Butanone (MEK)	78-93-3	28	20	71	yes	1.00E+01	3.19E+00	5.20E+03	5.20E+02	no	no	3.90E+03
2-Hexanone	591-78-6	28	4	14	yes	2.40E+00	1.47E+00	3.10E+01	3.10E+00	no	no	9.80E+01
4-Methyl-2-pentanone	108-10-1	28	0	0	no	-	-	-	-	-	no	-
Acetone	67-64-1	28	22	79	yes	8.10E+01	2.81E+01	3.20E+04	3.20E+03	no	no	8.50E+03
Benzene	**71-43-2**	**28**	**26**	**93**	**yes**	**1.80E+02**	**3.16E+01**	**3.10E-01**	**3.10E-02**	**yes**	**yes**	**8.60E+03**
Bromodichloromethane	75-27-4	28	0	0	no	-	-	-	-	-	no	-
Bromoform	75-25-2	28	0	0	no	-	-	-	-	-	no	-
Bromomethane	74-83-9	28	0	0	no	-	-	-	-	-	no	-
Carbon Disulfide	75-15-0	28	0	0	no	-	-	-	-	-	no	-
Carbon Tetrachloride	56-23-5	28	0	0	no	-	-	-	-	-	no	-
Chlorobenzene	108-90-7	28	0	0	no	-	-	-	-	-	no	-
Chloroethane	75-00-3	28	0	0	no	-	-	-	-	-	no	-
Chloroform	**67-66-3**	**28**	**1**	**4**	**no**	**1.60E+00**	**1.34E+00**	**1.10E-01**	**1.10E-02**	**yes**	**yes**	**4.20E+05**
Chloromethane	74-87-3	28	1	4	no	2.20E+00	1.37E+00	9.40E+01	9.40E+00	no	no	-
cis-1,2-Dichloroethene	156-59-2	28	0	0	no	-	-	-	-	-	no	-
cis-1,3-Dichloropropene	10061-01-5	28	0	0	no	-	-	-	-	-	no	-
Dibromochloromethane	124-48-1	28	0	0	no	-	-	-	-	-	no	-
Ethylbenzene	**100-41-4**	**28**	**19**	**68**	**yes**	**9.60E+01**	**8.87E+00**	**9.70E-01**	**9.70E-02**	**yes**	**yes**	**2.00E+03**
m,p-Xylenes	**179601-23-1**	**28**	**26**	**93**	**yes**	**1.50E+03**	**1.38E+02**	**7.30E+02**	**7.30E+01**	**yes**	**yes**	**3.50E+02**

Table 2-6
Summary Statistics and Selection of COPCs by Comparison to EPA RSLs[1] Odor Thresholds[2]
2005-2007 Odor Events
Human Health Risk Assessment
Battlement Mesa HIA

Chemical	CAS Number	Number of Samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥5%?	Maximum Detected Concentration (µg/m^3)	Mean (µg/m3)	EPA RSL (µg/m3)	1/10 EPA RSL (µg/m3)	Maximum Concentration > 1/10 EPA RSL	COPC?	Texas Acute Odor ESL (µg/m^3)
Methyl tert-Butyl Ether	1634-04-4	28	0	0	no	-	-	-	-	-	no	-
Methylene chloride	75-09-2	28	0	0	no	-	-	-	-	-	no	-
o-Xylene	**95-47-6**	**28**	**24**	**86**	**yes**	**2.60E+02**	**2.22E+01**	**7.30E+02**	**7.30E+01**	**yes**	**yes**	**1.60E+03**
Styrene	100-42-5	28	0	0	no	-	-	-	-	-	no	-
Tetrachloroethene	127-18-4	28	0	0	no	-	-	-	-	-	no	-
Toluene	**108-88-3**	**28**	**26**	**93**	**yes**	**5.40E+02**	**1.05E+02**	**5.20E+03**	**5.20E+02**	**yes**	**yes**	**6.40E+02**
trans-1,2-Dichloroethene	156-60-5	28	0	0	no	-	-	-	-	-	no	-
trans-1,3-Dichloropropene	10061-02-6	28	0	0	no	-	-	-	-	-	no	-
Trichloroethene	79-01-6	28	0	0	no	-	-	-	-	-	no	-
Trichlorofluoromethane	75-69-4	28	2	7	yes	1.50E+00	1.36E+00	7.30E+02	7.30E+01	no	no	2.80E+04
Trichlorotrifluoroethane	76-13-1	28	0	0	no	-	-	-	-	-	no	-
Vinyl Acetate	108-05-4	28	4	14	yes	1.50E+01	2.60E+00	2.10E+02	2.10E+01	no	no	NA
Vinyl Chloride	75-01-4	28	0	0	no	-	-	-	-	-	no	-

Notes:
Bold text indicates contaminant was selected as a COPC.
µg/m^3: micrograms per cubic meter
CAS: Chemical Abstract Service
COPC: Contaminant of potential concern
EPA: United States Environmental Protection Agency
HIA: Health Impact Assessment
NA: Not Available
[1]RSL = EPA regional screening levels for ambient air based on exposure of 24 hours per day for 350 days per year for 30 years :
Health effects are not expected to occur at or below the RSL. To select COPCs, maximum detected concentration was compared to 1/10 the RSL to account for additive health effects from multiple chemicals. : http://www.epa.gov/region9/superfund/prg/index.html, May 2010
[2]Texas acute odor ESLs are odor based effects screening levels at which 50 percent of human subjects detect an odor (Texas Commission on Environmental Quality 2006).

Table 2-7
Ambient Air Summary Statistics and BTVs[1] for Background Samples
2005 - 2008
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Number of Samples	Number of detects	Detection frequency (%)	Minimum MRL (µg/m^3)	Maximum MRL (µg/m3)	Minimum Detected value (µg/m3)	Maximum detected value (µg/m3)	Mean (µg/m3)	BTV (µg/m3)	Statistical Basis for BTV
1,1,1-Trichloroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,1,2,2-Tetrachloroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,1,2-Trichloroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,1-Dichloroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,1-Dichloroethene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,2,3-Trimethylbenzene	7	7	100	1.20E-01	1.20E-01	4.40E-02	1.48E-01	9.54E-02	1.48E-01	< 8 observations, Maximum detected value
1,2,4-Trimethylbenzene	7	7	100	1.31E-01	1.31E-01	1.94E-01	8.79E-01	4.24E-01	8.79E-01	< 8 observations, Maximum detected value
1,2-Dibromoethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,2-Dichlorobenzene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,2-Dichloroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,2-Dichloropropane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,3,5-Trimethylbenzene	7	7	100	1.09E-01	1.09E-01	9.50E-02	4.63E-01	2.59E-01	4.63E-01	< 8 observations, Maximum detected value
1,3-Butadiene	7	0	0	1.05E-01	1.05E-01	-	-	-	1.05E-01	Not detected, maximum MRL
1,3-Dichlorobenzene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,4-Dichlorobenzene	18	1	6	1.60E+00	2.30E+00	4.60E+00	4.60E+00	1.11E+00	4.60E+00	< 7 detections, maximum detected value
1-Decene	7	0	0	1.15E-01	1.15E-01	-	-	-	1.15E-01	Not detected, maximum MRL
1-Dodecene	7	5	71	2.41E-01	2.41E-01	1.40E-01	8.83E-01	3.05E-01	8.83E-01	< 8 observations, Maximum detected value
1-Heptene	7	7	100	2.24E-01	2.24E-01	4.25E-01	1.28E+00	7.82E-01	1.28E+00	< 8 observations, Maximum detected value
1-Hexene	7	7	100	2.47E-01	2.47E-01	4.93E-02	1.01E-01	7.19E-02	1.01E-01	< 8 observations, Maximum detected value
1-Nonene	7	5	71	1.83E-01	1.83E-01	4.47E-02	1.49E-01	1.05E-01	1.49E-01	< 8 observations, Maximum detected value
1-Octene	7	3	43	1.78E-01	1.78E-01	7.51E-02	1.42E-01	9.53E-02	1.42E-01	< 8 observations, Maximum detected value
1-Pentene	7	7	100	6.88E-02	6.88E-02	7.11E-02	1.50E-01	9.59E-02	1.50E-01	< 8 observations, Maximum detected value
1-Tridecene	7	1	14	2.41E-01	2.41E-01	2.69E-02	2.69E-02	1.07E-01	2.69E-02	< 8 observations, Maximum detected value
1-Undecene	7	0	0	9.75E-02	9.75E-02	-	-	-	9.75E-02	Not detected, maximum MRL
2,2,3-Trimethylpentane	7	7	100	1.81E-01	1.81E-01	9.39E-02	4.29E-01	2.30E-01	4.29E-01	< 8 observations, Maximum detected value
2,2,4-Trimethylpentane	7	1	14	1.28E-01	1.28E-01	2.46E-01	2.46E-01	9.02E-02	2.46E-01	< 8 observations, Maximum detected value
2,2-Dimethylbutane	7	7	100	8.22E-02	8.22E-02	3.88E-01	1.00E+00	5.82E-01	1.00E+00	< 8 observations, Maximum detected value
2,3,4-Trimethylpentane	7	6	86	1.05E-01	1.05E-01	5.48E-02	2.25E-01	1.08E-01	2.25E-01	< 8 observations, Maximum detected value
2,3-Dimethylbutane	7	7	100	1.17E-01	1.17E-01	5.68E-01	1.85E+00	9.75E-01	1.85E+00	< 8 observations, Maximum detected value
2,3-Dimethylpentane	7	7	100	2.28E-01	2.28E-01	3.43E-01	9.48E-01	5.34E-01	9.48E-01	< 8 observations, Maximum detected value
2,4-Dimethylpentane	7	7	100	1.40E-01	1.40E-01	2.14E-01	6.55E-01	3.64E-01	6.55E-01	< 8 observations, Maximum detected value
2-Butanone (MEK)	18	9	50	1.60E+00	2.30E+00	2.10E+00	3.70E+00	1.63E+00	3.26E+00	95% KM UTL
2-Ethyl-1-butene	7	0	0	2.47E-01	2.47E-01	-	-	-	2.47E-01	Not detected, maximum MRL
2-Hexanone	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL

Table 2-7
Ambient Air Summary Statistics and BTVs[1] for Background Samples
2005 - 2008
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Number of Samples	Number of detects	Detection frequency (%)	Minimum MRL (µg/m^3)	Maximum MRL (µg/m3)	Minimum Detected value (µg/m3)	Maximum detected value (µg/m3)	Mean (µg/m3)	BTV (µg/m3)	Statistical Basis for BTV
2-Methyl-1-butene	7	5	71	1.15E-01	1.15E-01	6.76E-02	1.38E+00	3.88E-01	1.38E+00	< 8 observations, Maximum detected value
2-Methyl-1-pentene	7	0	0	2.47E-01	2.47E-01	-	-	-	2.47E-01	Not detected, maximum MRL
2-Methyl-2-butene	7	5	71	1.15E-01	1.15E-01	9.23E-02	3.05E-01	1.35E-01	3.05E-01	< 8 observations, Maximum detected value
2-Methylheptane	7	7	100	1.05E-01	1.05E-01	4.41E-01	1.61E+00	9.18E-01	1.61E+00	< 8 observations, Maximum detected value
2-Methylhexane	7	7	100	1.05E-01	1.05E-01	9.83E-01	2.71E+00	1.64E+00	2.71E+00	< 8 observations, Maximum detected value
2-Methylpentane	7	7	100	4.70E-02	4.70E-02	2.73E+00	8.75E+00	4.58E+00	8.75E+00	< 8 observations, Maximum detected value
3-Methyl-1-butene	7	0	0	1.15E-01	1.15E-01	-	-	-	1.15E-01	Not detected, maximum MRL
3-Methylheptane	7	7	100	1.17E-01	1.17E-01	2.98E-01	1.17E+00	7.18E-01	1.17E+00	< 8 observations, Maximum detected value
3-Methylhexane	7	7	100	1.35E-01	1.35E-01	8.02E-01	2.72E+00	1.53E+00	2.72E+00	< 8 observations, Maximum detected value
3-Methylpentane	7	7	100	1.06E-01	1.06E-01	1.38E+00	5.63E+00	2.60E+00	5.63E+00	< 8 observations, Maximum detected value
4-Methyl-1-pentene	7	2	29	2.47E-01	2.47E-01	2.50E-01	7.00E-01	2.24E-01	7.00E-01	< 8 observations, Maximum detected value
4-Methyl-2-pentanone	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Acetone	18	15	83	8.20E+00	1.10E+01	1.00E+01	3.10E+01	1.47E+01	2.96E+01	95% KM UTL
Acetylene	7	7	100	5.85E-02	5.85E-02	1.95E-01	3.03E-01	2.28E-01	3.03E-01	< 8 observations, Maximum detected value
a-Pinene	7	7	100	1.78E-01	1.78E-01	2.23E-01	5.90E-01	3.75E-01	5.90E-01	< 8 observations, Maximum detected value
Benzene	25	8	32	1.28E-01	2.30E+00	8.71E-01	2.70E+00	1.06E+00	1.83E+00	95% KM UTL
b-Pinene	7	5	71	1.11E-01	1.11E-01	9.63E-02	3.72E-01	1.85E-01	3.72E-01	< 8 observations, Maximum detected value
Bromodichloromethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Bromoform	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Bromomethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Carbon Disulfide	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Carbon Tetrachloride	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Chlorobenzene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Chloroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Chloroform	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Chloromethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
cis-1,2-Dichloroethene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
cis-1,3-Dichloropropene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
cis-2-Butene	7	5	71	1.09E-01	1.09E-01	4.59E-02	8.14E-02	5.91E-02	8.14E-02	< 8 observations, Maximum detected value
cis-2-Hexene	7	6	86	2.47E-01	2.47E-01	5.56E-02	2.95E-01	1.69E-01	2.95E-01	< 8 observations, Maximum detected value
cis-2-Pentene	7	2	29	1.09E-01	1.09E-01	3.84E-02	6.07E-02	5.31E-02	6.07E-02	< 8 observations, Maximum detected value
Cyclohexane	7	7	100	1.26E-01	1.26E-01	1.79E+00	7.57E+00	3.32E+00	7.57E+00	< 8 observations, Maximum detected value
Cyclopentane	7	7	100	4.58E-02	4.58E-02	3.27E-01	9.63E-01	5.33E-01	9.63E-01	< 8 observations, Maximum detected value
Cyclopentene	7	7	100	1.11E-01	1.11E-01	1.64E-01	4.72E-01	2.92E-01	4.72E-01	< 8 observations, Maximum detected value

Table 2-7
Ambient Air Summary Statistics and BTVs[1] for Background Samples
2005 - 2008
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Number of Samples	Number of detects	Detection frequency (%)	Minimum MRL (µg/m^3)	Maximum MRL (µg/m3)	Minimum Detected value (µg/m3)	Maximum detected value (µg/m3)	Mean (µg/m3)	BTV (µg/m3)	Statistical Basis for BTV
Dibromochloromethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Ethane	7	7	100	5.54E-02	5.54E-02	3.28E+01	8.30E+01	5.85E+01	8.30E+01	< 8 observations, Maximum detected value
Ethylbenzene	25	7	28	1.14E-01	2.30E+00	1.80E-01	7.05E-01	7.68E-01	6.37E-01	95% KM UTL
Ethylene	7	7	100	4.01E-02	4.01E-02	3.71E-01	9.39E-01	6.48E-01	9.39E-01	< 8 observations, Maximum detected value
Isobutane	7	7	100	4.75E-02	4.75E-02	6.71E+00	2.28E+01	1.29E+01	2.28E+01	< 8 observations, Maximum detected value
Isobutene/1-Butene	7	6	86	8.03E-02	8.03E-02	4.61E+00	1.07E+01	6.08E+00	1.07E+01	< 8 observations, Maximum detected value
Isopentane	7	7	100	1.00E-01	1.00E-01	9.91E+00	2.38E+01	1.52E+01	2.38E+01	< 8 observations, Maximum detected value
Isoprene	7	7	100	1.11E-01	1.11E-01	1.67E-01	1.10E+00	5.45E-01	1.10E+00	< 8 observations, Maximum detected value
Isopropylbenzene	7	3	43	1.75E-01	1.75E-01	5.19E-02	9.06E-02	7.97E-02	9.06E-02	< 8 observations, Maximum detected value
m,p -Xylenes	25	10	40	1.68E-01	2.30E+00	9.88E-01	4.90E+00	1.44E+00	3.68E+00	95% KM UTL
m-Diethylbenzene	7	6	86	9.87E-02	9.87E-02	7.62E-02	4.10E-01	1.95E-01	4.10E-01	< 8 observations, Maximum detected value
Methyl tert-Butyl Ether	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Methylcyclohexane	7	7	100	8.60E-02	8.60E-02	3.44E+00	1.16E+01	6.62E+00	1.16E+01	< 8 observations, Maximum detected value
Methylcyclopentane	7	7	100	7.46E-02	7.46E-02	1.33E+00	5.85E+00	2.65E+00	5.85E+00	< 8 observations, Maximum detected value
Methylene chloride	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
m-Ethyltoluene	7	7	100	8.19E-02	8.19E-02	1.72E-01	6.28E-01	3.32E-01	6.28E-01	< 8 observations, Maximum detected value
n-Butane	7	7	100	6.53E-02	6.53E-02	7.66E+00	2.61E+01	1.39E+01	2.61E+01	< 8 observations, Maximum detected value
n-Decane	7	7	100	1.16E-01	1.16E-01	4.72E-01	1.81E+00	1.06E+00	1.81E+00	< 8 observations, Maximum detected value
n-Dodecane	7	7	100	2.44E-01	2.44E-01	2.34E-01	1.55E+00	6.80E-01	1.55E+00	< 8 observations, Maximum detected value
n-Heptane	7	7	100	1.17E-01	1.17E-01	1.58E+00	5.48E+00	3.00E+00	5.48E+00	< 8 observations, Maximum detected value
n-Hexane	7	7	100	1.35E-01	1.35E-01	2.88E+00	1.25E+01	5.56E+00	1.25E+01	< 8 observations, Maximum detected value
n-Nonane	7	7	100	9.90E-02	9.90E-02	4.34E-01	2.00E+00	1.16E+00	2.00E+00	< 8 observations, Maximum detected value
n-Octane	7	7	100	1.40E-01	1.40E-01	1.00E+00	3.74E+00	2.43E+00	3.74E+00	< 8 observations, Maximum detected value
n-Pentane	7	7	100	5.89E-02	5.89E-02	4.66E+00	1.48E+01	8.26E+00	1.48E+01	< 8 observations, Maximum detected value
n-Propylbenzene	7	6	86	1.04E-01	1.04E-01	8.52E-02	1.79E-01	1.05E-01	1.79E-01	< 8 observations, Maximum detected value
n-Tridecane	7	7	100	2.44E-01	2.44E-01	3.83E-02	3.12E-01	1.49E-01	3.12E-01	< 8 observations, Maximum detected value
n-Undecane	7	7	100	9.87E-02	9.87E-02	7.67E-01	2.17E+00	1.25E+00	2.17E+00	< 8 observations, Maximum detected value
o-Ethyltoluene	7	7	100	1.58E-01	1.58E-01	9.61E-02	3.08E-01	1.94E-01	3.08E-01	< 8 observations, Maximum detected value
o-Xylene	25	7	28	9.22E-02	2.30E+00	2.36E-01	8.25E-01	7.94E-01	7.22E-01	95% KM UTL
p-Diethylbenzene	7	5	71	6.58E-02	6.58E-02	6.69E-02	1.12E-01	7.29E-02	1.12E-01	< 8 observations, Maximum detected value
p-Ethyltoluene	7	7	100	1.42E-01	1.42E-01	9.50E-02	3.60E-01	1.95E-01	3.60E-01	< 8 observations, Maximum detected value
Propane	7	7	100	1.08E-01	1.08E-01	2.01E+01	5.26E+01	3.33E+01	5.26E+01	< 8 observations, Maximum detected value
Propylene	7	7	100	4.02E-02	4.02E-02	2.22E-01	4.34E-01	2.89E-01	4.34E-01	< 8 observations, Maximum detected value
Propyne	7	0	0	9.83E-02	9.83E-02	-	-	-	9.83E-02	Not detected, maximum MRL

Table 2-7
Ambient Air Summary Statistics and BTVs[1] for Background Samples
2005 - 2008
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Number of Samples	Number of detects	Detection frequency (%)	Minimum MRL (µg/m^3)	Maximum MRL (µg/m3)	Minimum Detected value (µg/m3)	Maximum detected value (µg/m3)	Mean (µg/m3)	BTV (µg/m3)	Statistical Basis for BTV
Styrene	25	1	4	1.33E-01	2.30E+00	7.23E-01	7.23E-01	7.31E-01	7.23E-01	< 7 detections, maximum detected value
Tetrachloroethene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Toluene	25	14	56	1.78E-01	2.30E+00	1.81E+00	1.77E+01	2.65E+00	1.49E+01	95% KM UTL
trans-1,2-Dichloroethene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
trans-1,3-Dichloropropene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
trans-2-Butene	7	6	86	7.45E-02	7.45E-02	8.26E-02	2.06E-01	1.19E-01	2.06E-01	< 8 observations, Maximum detected value
trans-2-Hexene	7	1	14	2.47E-01	2.47E-01	1.03E-01	1.03E-01	1.20E-01	1.03E-01	< 8 observations, Maximum detected value
trans-2-Pentene	7	5	71	1.09E-01	1.09E-01	5.96E-02	1.27E-01	7.56E-02	1.27E-01	< 8 observations, Maximum detected value
Trichloroethene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Trichlorofluoromethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Trichlorotrifluoroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Vinyl Acetate	18	5	28	1.60E+00	2.30E+00	3.20E+00	7.90E+00	1.78E+00	7.90E+00	< 7 detections, maximum detected value
Vinyl Chloride	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL

Notes:

[1]BTV: Background Threshold Value: BTVs are background contaminant concentrations computed based upon the sampled data collected from the site- specific background locations.
95% KM UTL: 95 percentileKaplan Meier Upper Tolerance Limit
MRL: Method Reporting Limit

Table 2-8
95% UCLs and Selection of EPCs[1]
2005 to 2010 Bell-Melton Ranch Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Maximum Detected Value (µg/m^3)	Mean Value (µg/m^3)	95% UCL[2] (µg/m^3)	Statistical Method to Calculate 95% UCL	EPC (µg/m^3)
1,2,3-Trimethylbenzene	8.47E-01	8.10E-02	1.01E-01	KM (t)	1.01E-01
1,2,4-Trimethylbenzene	3.09E+00	2.75E-01	3.39E-01	KM (BCA)	3.39E-01
1,3,5-Trimethylbenzene	1.20E+00	1.51E-01	1.78E-01	KM (BCA)	1.78E-01
1,3-Butadiene	1.53E-01	5.58E-02	NC	NC	1.53E-01
1,4-Dichlorobenzene	2.30E+00	9.36E-01	NC	NC	2.30E+00
1-Dodecene	1.02E+00	1.44E-01	1.74E-01	KM (t)	1.74E-01
1-Heptene	2.98E+00	6.30E-01	7.10E-01	KM (BCA)	7.10E-01
1-Hexene	2.77E-01	9.55E-02	9.72E-02	KM (t)	9.72E-02
1-Nonene	4.28E-01	1.07E-01	1.20E-01	(%bootstrap)	1.20E-01
1-Octene	1.37E+00	1.06E-01	1.13E-01	KM (t)	1.13E-01
1-Pentene	3.80E-01	1.04E-01	1.12E-01	KM (BCA)	1.12E-01
1-Tridecene	2.04E-01	1.06E-01	8.89E-02	KM (%bootstrap)	8.89E-02
1-Undecene	1.07E+00	1.21E-01	1.48E-01	KM (t)	1.48E-01
2,2,3-Trimethylpentane	1.64E+00	1.49E-01	1.91E-01	KM (%bootstrap)	1.91E-01
2,2,4-Trimethylpentane	2.48E+00	1.52E-01	2.14E-01	KM (%bootstrap)	2.14E-01
2,2-Dimethylbutane	2.34E+00	6.15E-01	6.76E-01	H-UCL	6.76E-01
2,3,4-Trimethylpentane	1.79E+00	9.21E-02	1.27E+00	KM (%bootstrap)	1.27E+00
2,3-Dimethylbutane	5.05E+00	1.22E+00	1.36E+00	H-UCL	1.36E+00
2,3-Dimethylpentane	2.08E+00	5.26E-01	5.70E-01	H-UCL	5.70E-01
2,4-Dimethylpentane	1.48E+00	3.69E-01	4.06E-01	KM (BCA)	4.06E-01
2-Hexanone	4.40E+00	1.00E+00	NC	NC	4.40E+00
2-Methyl-1-butene	3.94E+01	5.98E-01	1.23E+00	KM (BCA)	1.23E+00
2-Methyl-1-pentene	1.52E-01	9.82E-02	NC	NC	1.52E-01
2-Methyl-2-butene	4.17E-01	8.95E-02	1.07E-01	KM (t)	1.07E-01
2-Methylheptane	2.93E+00	6.28E-01	7.01E-01	H-UCL	7.01E-01
2-Methylhexane	5.71E+00	1.39E+00	1.54E+00	KM (BCA)	1.54E+00
2-Methylpentane	2.20E+01	5.39E+00	5.98E+00	H-UCL	5.98E+00
3-Methyl-1-butene	2.00E-01	6.16E-02	NC	NC	2.00E-01
3-Methylheptane	3.53E+00	4.17E-01	4.55E-01	H-UCL	4.55E-01
3-Methylhexane	4.84E+00	1.11E+00	1.27E+00	KM (BCA)	1.27E+00
3-Methylpentane	1.16E+01	2.80E+00	3.12E+00	H-UCL	3.12E+00
4-Methyl-1-pentene	4.68E+00	1.41E-01	2.28E-01	KM (BCA)	2.28E-01
Acetaldehyde	1.96E+00	7.98E-01	8.74E-01	Student-t	8.74E-01
Acetylene	2.92E+00	6.30E-01	6.97E-01	H-UCL	6.97E-01
a-Pinene	3.37E+00	1.74E-01	2.31E-01	KM (%bootstrap)	2.31E-01
Benzaldehyde	2.04E-01	7.10E-02	9.74E-02	KM (Chebyshev)	9.74E-02
Benzene	1.36E+01	1.47E+00	1.67E+00	KM (BCA)	1.67E+00
b-Pinene	1.43E+00	8.08E-02	1.23E-01	KM (t)	1.23E-01
Butyraldehyde	2.71E-01	6.98E-02	8.11E-02	KM (BCA)	8.11E-02
cis-2-Butene	3.73E-01	6.79E-02	7.95E-02	KM (t)	7.95E-02
cis-2-Hexene	7.00E-01	9.97E-02	1.00E-01	KM (Chebyshev)	1.00E-01
cis-2-Pentene	1.45E-01	5.37E-02	6.12E-02	KM (t)	6.12E-02
Crotonaldehyde	5.53E-01	1.26E-01	2.02E-01	Chebyshev (mean, s	2.02E-01

Table 2-8
95% UCLs and Selection of EPCs[1]
2005 to 2010 Bell-Melton Ranch Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Maximum Detected Value (µg/m^3)	Mean Value (µg/m^3)	95% UCL[2] (µg/m^3)	Statistical Method to Calculate 95% UCL	EPC (µg/m^3)
Cyclopentane	2.94E+00	7.28E-01	8.00E-01	H-UCL	8.00E-01
Cyclopentene	9.58E-01	1.34E-01	1.66E-01	KM (%bootstrap)	1.66E-01
Ethane	4.11E+02	8.00E+01	9.02E+01	H-UCL	9.02E+01
Ethylbenzene	4.34E+00	3.78E-01	3.33E-01	KM (Chebyshev)	4.11E-01
Ethylene	2.94E+00	1.00E+00	1.09E+00	Gamma	1.09E+00
Formaldehyde	1.02E+01	1.17E+00	1.26E+00	H-UCL	1.26E+00
Formaldehyde w/o outlier	2.24E+00	1.02E+00	1.11E+00	Student-t	1.11E+00
Hexaldehyde	1.31E-01	4.21E-02	2.56E-02	KM (Chebyshev)	2.56E-02
Isobutane	1.18E+02	2.34E+01	2.62E+01	Gamma	2.62E+01
Isobutene/1-Butene	1.36E+01	1.29E+00	1.60E+00	KM (% bootstrap)	1.60E+00
Isopentane	1.23E+02	1.97E+01	2.24E+01	KM (BCA)	2.24E+01
Isoprene	3.33E+00	3.13E-01	5.03E-01	KM (Chebyshev)	5.03E-01
Isovaleraldehyde	1.13E-01	5.69E-03	3.29E-02	KM (t)	3.29E-02
m&p-Xylene	1.40E+01	1.69E+00	1.98E+00	KM (BCA)	1.98E+00
m-Diethylbenzene	8.84E-01	9.25E-02	1.18E-01	KM (%bootstrap)	1.18E-01
Methylcyclohexane	2.39E+01	5.38E+00	5.96E+00	Gamma	5.96E+00
Methylcyclopentane	1.04E+01	2.60E+00	2.89E+00	H-UCL	2.89E+00
Methylene Chloride	2.90E+00	9.59E-01	NC	NC	2.90E+00
m-Ethyltoluene	1.63E+00	1.87E-01	2.21E-01	KM (BCA)	2.21E-01
n-Butane	1.57E+02	2.79E+01	3.14E+01	H-UCL	3.14E+01
n-Decane	6.98E+01	1.11E+00	2.24E+00	KM (BCA)	2.24E+00
n-Dodecane	7.14E+01	1.24E+00	3.74E+00	KM (Chebyshev)	3.74E+00
n-Heptane	1.14E+01	2.55E+00	2.85E+00	H-UCL	2.85E+00
n-Hexane	2.50E+01	5.89E+00	6.53E+00	H-UCL	6.53E+00
n-Nonane	3.08E+00	6.36E-01	7.23E-01	KM (BCA)	7.23E-01
n-Octane	6.72E+00	1.45E+00	1.61E+00	H-UCL	1.61E+00
n-Pentane	6.20E+01	1.36E+01	1.50E+01	Gamma	1.50E+01
n-Tridecane	5.68E+00	2.05E-01	2.92E-01	KM (BCA)	2.92E-01
n-Undecane	2.55E+02	2.81E+00	1.15E+01	KM (Chebyshev)	1.15E+01
o-Ethyltoluene	1.44E+00	1.31E-01	1.65E-01	KM (BCA)	1.65E-01
o-Xylene	3.61E+00	4.35E-01	4.03E-01	KM (Chebyshev)	4.94E-01
p-Diethylbenzene	4.20E-01	5.50E-02	7.00E-02	KM (%bootstrap)	7.00E-02
p-Ethyltoluene	1.26E+00	1.33E-01	1.62E-01	KM (BCA)	1.62E-01
Propane	3.16E+02	6.15E+01	6.94E+01	H-UCL	6.94E+01
Tolualdehydes	2.51E-01	8.16E-02	9.32E-02	KM (BCA)	9.32E-02
trans-2-Butene	3.34E+00	1.13E-01	1.74E-01	KM (BCA)	1.74E-01
trans-2-Hexene	3.04E-02	9.83E-02	NC	NC	3.04E-02
trans-2-Pentene	3.18E-01	6.72E-02	8.08E-02	KM (t)	8.08E-02
Valeraldehyde	8.10E-02	2.25E-02	3.49E-02	KM (%bootstrap)	3.49E-02

[1]EPC = Exposure Point Concentration: The lower value between the UCL and maximum detected value.
For contaminants with < 11 detections a UCL was not calculated and the maximum value was used for the EPC

Table 2-8
95% UCLs and Selection of EPCs[1]
2005 to 2010 Bell-Melton Ranch Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Maximum Detected Value ($\mu g/m^3$)	Mean Value ($\mu g/m^3$)	95% UCL[2] ($\mu g/m^3$)	Statistical Method to Calculate 95% UCL	EPC ($\mu g/m^3$)

[2]UCL = Upper Confidence Limit calculated for 2005 - 2010 Bell-Melton Ranch data using EPA's ProUCL v. 4.005 (EPA 2010)
H-UCL = UCL based upon Land's H-statistic
KM (%bootstrap) = UCL based upon Kaplan-Meier estimates using the percentile bootstrap method
KM (chebyshev) UCL based upon Kaplan-Meier estimates using the Chebyshev inequality
KM (t) UCL based upon Kaplan-Meier estimates using the Student's t-distribution cutoff value
KM (BCA) UCL based upon Kaplan-Meier bias-corrected accelerated bootstrap method
NC = Not calculated because less than 10 detected values
Student t: UCL based upon the Student t-distribution cutoff value
Gamma: UCL based upon the Gamma distribution cutoff value.
$\mu g/m^3$ = micrograms per cubic meter
CAS = Chemical Abstract Service

Table 3-1
Cancer and Non-Cancer Air Intake Values for Chronic Exposures
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Chronic EPC[1] (µg/m^3)	Intermediate EPC[2] (µg/m^3)	TWA[3] (µg/m^3)	Chronic Non-cancer Intake (µg/m^3)	TWA Non-cancer Intake (µg/m^3)	Chronic Cancer Intake (µg/m^3)	TWA Cancer Intake (µg/m^3)
1,2,3-Trimethylbenzene	1.01E-01	1.17E+01	4.23E-01	9.68E-02	4.05E-01	4.15E-02	1.74E-01
1,2,4-Trimethylbenzene	3.39E-01	8.30E+01	2.63E+00	3.25E-01	2.53E+00	1.39E-01	1.08E+00
1,3,5-Trimethylbenzene	1.78E-01	7.75E+01	2.33E+00	1.70E-01	2.23E+00	7.30E-02	9.56E-01
1,3-Butadiene	1.53E-01	1.66E-01	1.53E-01	1.47E-01	1.47E-01	6.29E-02	6.30E-02
1,4-Dichlorobenzene	2.30E+00	NM	NC	2.21E+00	2.21E+00	9.45E-01	9.45E-01
1-Dodecene	1.74E-01	6.08E+00	3.37E-01	1.66E-01	3.24E-01	7.13E-02	1.39E-01
1-Heptene	7.10E-01	6.08E+01	2.38E+00	6.80E-01	2.28E+00	2.92E-01	9.77E-01
1-Hexene	9.72E-02	1.63E-01	9.91E-02	9.32E-02	9.50E-02	4.00E-02	4.07E-02
1-Nonene	1.20E-01	1.68E+01	5.83E-01	1.15E-01	5.59E-01	4.94E-02	2.40E-01
1-Octene	1.13E-01	3.16E+00	1.97E-01	1.08E-01	1.89E-01	4.63E-02	8.11E-02
1-Pentene	1.12E-01	3.89E-01	1.20E-01	1.08E-01	1.15E-01	4.62E-02	4.93E-02
1-Tridecene	8.89E-02	3.63E-01	9.65E-02	8.53E-02	9.26E-02	3.65E-02	3.97E-02
1-Undecene	1.48E-01	4.72E+00	2.75E-01	1.42E-01	2.64E-01	6.09E-02	1.13E-01
2,2,3-Trimethylpentane	1.91E-01	2.47E+01	8.73E-01	1.83E-01	8.37E-01	7.84E-02	3.59E-01
2,2,4-Trimethylpentane	2.14E-01	1.98E-01	2.14E-01	2.05E-01	2.05E-01	8.81E-02	8.79E-02
2,2-Dimethylbutane	6.76E-01	4.12E+01	1.80E+00	6.48E-01	1.73E+00	2.78E-01	7.41E-01
2,3,4-Trimethylpentane	1.27E+00	1.21E+00	1.26E+00	1.21E+00	1.21E+00	5.20E-01	5.19E-01
2,3-Dimethylbutane	1.36E+00	6.58E+01	3.15E+00	1.30E+00	3.02E+00	5.59E-01	1.29E+00
2,3-Dimethylpentane	5.70E-01	3.56E+01	1.54E+00	5.47E-01	1.48E+00	2.34E-01	6.35E-01
2,4-Dimethylpentane	4.06E-01	2.36E+01	1.05E+00	3.89E-01	1.01E+00	1.67E-01	4.31E-01
2-Hexanone	4.40E+00	NM	NC	4.22E+00	4.22E+00	1.81E+00	1.81E+00
2-Methyl-1-butene	1.23E+00	1.26E+00	1.23E+00	1.17E+00	1.18E+00	5.03E-01	5.04E-01
2-Methyl-2-butene	1.07E-01	8.43E-02	1.07E-01	1.03E-01	1.02E-01	4.41E-02	4.38E-02
2-Methyl-1-pentene	1.52E-01	3.87E-01	1.59E-01	1.46E-01	1.52E-01	6.25E-02	6.51E-02
2-Methylheptane	7.01E-01	1.46E+02	4.75E+00	6.72E-01	4.55E+00	2.88E-01	1.95E+00
2-Methylhexane	1.54E+00	1.21E+02	4.85E+00	1.48E+00	4.65E+00	6.33E-01	1.99E+00
2-Methylpentane	5.98E+00	2.21E+02	1.20E+01	5.73E+00	1.15E+01	2.46E+00	4.91E+00
3-Methyl-1-butene	2.00E-01	2.49E-01	2.01E-01	1.92E-01	1.93E-01	8.22E-02	8.28E-02
3-Methylheptane	4.55E-01	9.74E+01	3.15E+00	4.36E-01	3.02E+00	1.87E-01	1.29E+00
3-Methylhexane	1.27E+00	1.14E+02	4.40E+00	1.21E+00	4.22E+00	5.21E-01	1.81E+00
3-Methylpentane	3.12E+00	1.29E+02	6.62E+00	2.99E+00	6.35E+00	1.28E+00	2.72E+00
4-Methyl-1-pentene	2.28E-01	9.35E-01	2.47E-01	2.18E-01	2.37E-01	9.36E-02	1.02E-01
Acetaldehyde	8.74E-01	NM	NC	8.38E-01	8.38E-01	3.59E-01	3.59E-01
Acetylene	6.97E-01	8.40E-01	7.01E-01	6.68E-01	6.72E-01	2.86E-01	2.88E-01
a-Pinene	2.31E-01	3.09E+01	1.08E+00	2.21E-01	1.04E+00	9.48E-02	4.45E-01
Benzaldehyde	9.74E-02	NM	NC	9.34E-02	9.34E-02	4.00E-02	4.00E-02
Benzene	1.67E+00	6.85E+01	3.53E+00	1.60E+00	3.38E+00	6.87E-01	1.45E+00
b-Pinene	1.23E-01	8.96E+00	3.69E-01	1.18E-01	3.54E-01	5.07E-02	1.52E-01
Butyraldehyde	8.11E-02	NM	NC	7.78E-02	7.78E-02	3.33E-02	3.30E-02
cis-2-Butene	7.95E-02	1.97E-01	8.28E-02	7.63E-02	7.94E-02	3.27E-02	3.40E-02
cis-2-Hexene	1.00E-01	2.93E-01	1.05E-01	9.59E-02	1.01E-01	4.11E-02	4.33E-02
cis-2-Pentene	6.12E-02	1.48E-01	6.36E-02	5.87E-02	6.10E-02	2.51E-02	2.61E-02
Crotonaldehyde	2.02E-01	NM	NC	1.94E-01	1.94E-01	8.30E-02	8.30E-02
Cyclopentane	8.00E-01	2.23E+01	1.40E+00	7.67E-01	1.34E+00	3.29E-01	5.74E-01
Cyclopentene	1.66E-01	6.51E-01	1.79E-01	1.59E-01	1.72E-01	6.81E-02	7.37E-02
Ethane	9.02E+01	2.41E+03	1.54E+02	8.65E+01	1.48E+02	3.71E+01	6.35E+01
Ethylbenzene	4.11E-01	2.28E+02	6.75E+00	3.94E-01	6.47E+00	1.69E-01	2.77E+00
Ethylene	1.09E+00	4.19E+00	1.17E+00	1.04E+00	1.12E+00	4.46E-01	4.81E-01

Table 3-1
Cancer and Non-Cancer Air Intake Values for Chronic Exposures
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Chronic EPC[1] (µg/m^3)	Intermediate EPC[2] (µg/m^3)	TWA[3] (µg/m^3)	Chronic Non-cancer Intake (µg/m^3)	TWA Non-cancer Intake (µg/m^3)	Chronic Cancer Intake (µg/m^3)	TWA Cancer Intake (µg/m^3)
Formaldehyde	1.26E+00	NM	NC	1.20E+00	1.20E+00	5.16E-01	5.16E-01
Formaldehyde w/o outlier	1.11E+00	NM	NC	1.06E+00	1.06E+00	4.54E-01	4.54E-01
Hexaldehyde	2.56E-02	NM	NC	2.45E-02	2.45E-02	1.05E-02	1.05E-02
Isobutane	2.62E+01	1.60E+03	7.00E+01	2.51E+01	6.71E+01	1.07E+01	2.87E+01
Isobutene/1-Butene	1.60E+00	6.71E+00	1.74E+00	1.54E+00	1.67E+00	6.58E-01	7.17E-01
Isopentane	2.24E+01	8.32E+02	4.49E+01	2.15E+01	4.31E+01	9.22E+00	1.85E+01
Isoprene	5.03E-01	1.15E+00	5.21E-01	4.82E-01	4.99E-01	2.07E-01	2.14E-01
Isovaleraldehyde	3.29E-02	NM	NC	3.15E-02	3.15E-02	1.35E-02	1.35E-02
m-Diethylbenzene	1.18E-01	7.08E+00	3.11E-01	1.13E-01	2.98E-01	4.84E-02	1.28E-01
Methylcyclohexane	5.96E+00	7.23E+02	2.59E+01	5.72E+00	2.48E+01	2.45E+00	1.06E+01
Methylcyclopentane	2.89E+00	1.20E+02	6.14E+00	2.77E+00	5.89E+00	1.19E+00	2.52E+00
Methylene Chloride	2.90E+00	NM	NC	2.78E+00	4.33E+00	1.19E+00	1.86E+00
m-Ethyltoluene	2.21E-01	4.45E+01	1.45E+00	2.12E-01	1.39E+00	9.07E-02	5.96E-01
m&p-Xylene	1.98E+00	8.84E+02	2.65E+01	1.90E+00	2.54E+01	8.14E-01	1.09E+01
n-Butane	3.14E+01	1.29E+03	6.63E+01	3.01E+01	6.36E+01	1.29E+01	2.72E+01
n-Decane	2.24E+00	2.08E+02	7.96E+00	2.14E+00	7.63E+00	9.19E-01	3.27E+00
n-Dodecane	3.74E+00	5.15E+01	5.07E+00	3.59E+00	4.86E+00	1.54E+00	2.08E+00
n-Heptane	2.85E+00	3.04E+02	1.12E+01	2.73E+00	1.08E+01	1.17E+00	4.61E+00
n-Hexane	6.53E+00	2.55E+02	1.34E+01	6.26E+00	1.29E+01	2.68E+00	5.52E+00
n-Nonane	7.23E-01	3.03E+02	9.11E+00	6.93E-01	8.74E+00	2.97E-01	3.75E+00
n-Octane	1.16E+00	4.17E+02	1.27E+01	1.11E+00	1.22E+01	4.77E-01	5.23E+00
n-Pentane	1.50E+01	5.53E+02	3.00E+01	1.44E+01	2.87E+01	6.18E+00	1.23E+01
n-Tridecane	2.92E-01	9.05E+00	5.36E-01	2.80E-01	5.14E-01	1.20E-01	2.20E-01
n-Undecane	1.15E+01	1.21E+02	1.45E+01	1.10E+01	1.39E+01	4.73E+00	5.97E+00
o-Ethyltoluene	1.65E-01	2.92E+01	9.71E-01	1.59E-01	9.31E-01	6.80E-02	3.99E-01
o-Xylene	4.94E-01	1.90E+02	5.77E+00	4.74E-01	5.53E+00	2.03E-01	2.37E+00
p-Diethylbenzene	7.00E-02	5.01E+00	2.07E-01	6.72E-02	1.99E-01	2.88E-02	8.52E-02
p-Ethyltoluene	1.62E-01	3.22E+01	1.05E+00	1.56E-01	1.01E+00	6.67E-02	4.33E-01
Propane	6.94E+01	4.67E+03	1.97E+02	6.65E+01	1.89E+02	2.85E+01	8.11E+01
Tolualdehydes	9.32E-02	NM	NC	8.94E-02	7.74E-02	3.83E-02	3.32E-02
trans-2-Butene	1.74E-01	1.89E+00	2.22E-01	1.67E-01	2.13E-01	7.16E-02	9.12E-02
trans-2-Hexene	3.04E-02	4.53E-02	3.08E-02	2.92E-02	2.95E-02	1.25E-02	1.27E-02
trans-2-Pentene	8.08E-02	3.05E-01	8.70E-02	7.74E-02	8.34E-02	3.32E-02	3.58E-02
Valeraldehyde	3.49E-02	NM	NC	3.35E-02	3.35E-02	1.44E-02	1.44E-02

Notes:
µg/m^3: micrograms per cubic meter
EPC: Exposure Concentration
NC: Not calculated
NM: Not measured
TWA: Time weighted average

[1]EPC for chronic exposure (30 year duration) of all Battlement Mesa residents from 2005 to 2010 Bell Melton Ranch Data (Table 2-8)

[2]EPC for intermediate 10 month exposure of Battlement Mesa residents living adjacent to a well pad from 2008 Well completion data (Maximum value Table 2-5)

[3]TWA for a chronic 30 year duration for Battlement Mesa residents living adjacent to a well pad calculated from chronic (350 months) and intermediate (10 months) EPCs.

Table 3-2
EPCs, Dermal Permeability Constants and Surface Water Intakes for Acute Exposure of Child Resident
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	EPC[1] (mg/L)	[2]PC (cm/hr)	Dermal Intake (mg/kg-day)
Benzene	1.70E-02	0.11	2.00E-03
Ethylbenzene	8.30E-03	1.38	1.23E-02
m&p-Xylene	5.60E-02	0.08	4.79E-03
o-Xylene	2.00E-02	0.08	1.71E-03
Toluene	4.50E-02	1.01	4.86E-02

Notes:

[1]EPCs from URS (2008). Second Quarter 2008 Report: Operational and Environmental Monitoring within a Three-Mile Radius of Project Rulison, Noble Energy, Williams, and EnCana

[2]PC: permeability constants: EPA EPA/600/8-91/011B 1992, Dermal Exposure Assessment: Principles and Applications
cm/hr: centimeters per hour
mg/kg-day: mg per kilogram per day
mg/L: Milligrams per Liter

Table 4-1
Cancer and Non-Cancer Inhalation Toxicity Values
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Available Toxicity Factors	RfC - chronic (mg/m^3)	Source	RfC - acute (mg/m^3)	Source	IUR ($1/(\mu g/m^3)$)	Source
1,2,3-Trimethylbenzene	nc	7.00E-03	based on 1,2,4-TMB	NA	NA	NA	NA
1,2,4-Trimethylbenzene	nc	7.00E-03	PPTRV	NA	NA	NA	NA
1,3,5-Trimethylbenzene	nc	7.00E-03	based on 1,2,4-TMB	NA	NA	NA	NA
1,3-Butadiene	c/nc	2.00E-03	ATW-IRIS	NA	NA	3.00E-05	ATW-IRIS
1,4-Dichlorobenzene	c/nc	8.00E-01	ATW-IRIS	1.20E+01	ATW-MRL	1.10E-05	ATW-CAL
2-Hexanone	nc	3.00E-02	ATW-IRIS	NA	NA	NA	NA
Acetaldehyde	c/nc	9.00E-03	ATW-IRIS	NA	NA	2.20E-06	ATW-IRIS
Benzene	c/nc	3.00E-02	ATW-ATSDR	2.90E-02	ATW-MRL	7.80E-06	ATW-IRIS
Chloroform	nc	9.80E-02	ATW-ATSDR	4.90E-01	ATW-MRL	2.30E-05	IRIS
Crotonaldehyde	c	NA	NA	NA	NA	5.43E-04	HEAST
Ethylbenzene	c/nc	1.00E+00	ATW-ATSDR	4.30E+01	ATW-MRL	2.50E-06	ATW-CAL
Formaldehyde	c/nc	9.80E-03	ATW-ATSDR	4.90E-02	ATSDR-MRL	1.30E-05	ATW-IRIS
Methylcyclohexane	nc	3.01E+00	HEAST	NA	NA	NA	NA
Methylene Chloride	c/nc	1.00E+00	ATW-ATSDR	2.10E+00	ATW-MRL	4.70E-07	ATW-IRIS
m-Xylene/p-Xylene	nc	1.00E-01	ATW-IRIS	8.70E+00	ATW-MRL	NA	NA
n-Hexane	nc	7.00E-01	ATW-IRIS	NA	NA	NA	NA
n-Nonane	nc	2.00E-01	PPTRV	NA	NA	NA	NA
n-Pentane	nc	1.00E+00	PPTRV	NA	NA	NA	NA
o-Xylene	nc	7.00E-01	CAL	NA	NA	NA	NA
Toluene	nc	5.00E+00	ATW-IRIS	3.80E+00	ATW-MRL	NA	NA

Notes:
µg/m3 = microgram per cubic meter
ATSDR-MRL: Agency for Toxic Substances Disease Registry Minimal Risk Level for Hazardous Substances, 2009
ATW-CAL: Value from EPA's Air Toxic Web-Site searched on 7/28/10. ATW obtained value from CAL.
ATW-IRIS: Value from EPA's Air Toxic Web-Site searched on 7/28/10. ATW obtained value from IRIS.
ATW-MRL: Value from EPA's Air Toxic Web-Site searched on 7/28/10. ATW obtained value from ATSDR MRL.
c = IUR for cancer available, nc = RfC for non-cancer effects available , c/nc = both are available
CAL: California EPA Office of Environmental Health Hazard Assessment Toxicity Criteria Database searched 7/28/10
CAS = Chemical Abstract Service
HEAST: EPA Health Effects Assessment Summary Tables 1997
IRIS: Value from EPA integrated risk information system searched on 7/28/10
IUR = incremental unit risk
mg/m3 = milligram per cubic meter
NA = Not available
PPTRV: EPA's Provisional Peer-Reviewed Toxicity Values from May 2010 risk screening level table
RfC = Reference concentration

Table 4-2
Contaminants of Potential Concern for without Toxicity Values
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Contaminant	CAS Number	Contaminant	CAS Number
1-Dodecene	112-41-4	cis-2-Butene	590-18-1
1-Heptene	592-76-7	cis-2-Hexene	7688-21-3
1-Hexene	592-41-6	cis-2-Pentene	627-20-3
1-Nonene	124-11-8	Cyclopentane	287-92-3
1-Octene	111-66-0	Cyclopentene	142-29-0
1-Pentene	109-67-1	Ethane	74-84-0
1-Tridecene	2437-56-1	Ethylene	74-85-1
1-Undecene	821-95-4	Hexaldehyde	66-25-1
2,2,3-Trimethylpentane	564-02-3	Isobutane	75-28-5
2,2,4-Trimethylpentane	540-84-1	Isobutene/1-Butene	115-11-7 / 106-98-9
2,2-Dimethylbutane	75-83-2	Isopentane	78-78-4
2,3,4-Trimethylpentane	565-75-3	Isoprene	78-79-5
2,3-Dimethylbutane	79-29-8	Isovaleraldehyde	590-86-3
2,3-Dimethylpentane	565-59-3	m-Diethylbenzene	141-93-5
2,4-Dimethylpentane	108-08-7	Methylcyclopentane	96-37-7
2-Methyl-1-butene	563-46-2	m-Ethyltoluene	620-14-4
2-Methyl-2-butene	513-35-9	n-Butane	106-97-8
2-Methyl-2-butene	513-35-9	n-Decane	124-18-5
2-Methylheptane	592-27-8	n-Dodecane	112-40-3
2-Methylhexane	591-76-4	n-Heptane	142-82-5
2-Methylpentane	107-83-5	n-Octane	111-65-9
3-Methyl-1-butene	563-45-1	n-Tridecane	629-50-5
3-Methylheptane	589-81-1	n-Undecane	1120-21-4
3-Methylhexane	589-34-4	o-Ethyltoluene	611-14-3
3-Methylpentane	96-14-0	p-Diethylbenzene	105-05-5
4-Methyl-1-pentene	691-37-2	p-Ethyltoluene	622-96-8
Acetylene	74-86-2	Propane	74-98-6
a-Pinene	80-56-8	Tolualdehydes	NA
Benzaldehyde	100-52-7	trans-2-Butene	624-64-6
b-Pinene	127-91-3	trans-2-Hexene	4050-45-7
Butyraldehyde	123-72-8	trans-2-Pentene	4050-45-7
		Valeraldehyde	110-62-3

Table 4-3
Oral/Dermal Non-cancer Toxicity Factors
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Available Toxicity Values	RfD-acute (mg/kg-day)	Source	RFD-intermediate (mg/kg-day)	Source	RfD-chronic (mg/kg-day)	Source
Benzene	c/nc	NA	NA	NA	NA	4.00E-03	IRIS
Ethylbenzene	c/nc	NA	NA	5.00E-01	ATSDR-MRL	-	-
m&p-Xylene	nc	1.00E+00	ATSDR-MRL	-	-	-	-
o-Xylene	nc	1.00E+00	from m&p-xylene	-	-	-	-
Toluene	nc	8.00E-01	ATSDR-MRL	-	-	-	-

NA = Not available
- = Not applicable
c = carcinogen
c = Slope factor for cancer available, nc = RfD for non-cancer effects available , c/nc = both are available
RfD = Reference Dose
mg/kg-day = millgrams per kilogram per day
CAS = Chemical Abstract Service
IRIS: Value from EPA integrated risk information system searched on 7/28/10
ATSDR-MRL: Agency for Toxic Substances Disease Registry Minimal Risk Level for Hazardous Substances, 2009

Table 5-1
Chronic Risk Characterization for all Battlement Mesa Residents - 30 year Duration
Human Health Risk Assessment
Health Impact Assessment

	Non-Cancer Hazards			*Cancer Risks*			
Chemical	**RfC - chronic ($\mu g/m^3$)**	**Chronic Non-Cancer Intake ($\mu g/m^3$)**	**HQ**	**EPA WOE**	**IUR (1/(µg/m3)**	**Chronic Cancer Intake ($\mu g/m^3$)**	**Cancer Risk**
1,2,3-Trimethylbenzene	7.00E+00	9.68E-02	1.38E-02	-	-	-	-
1,2,4-Trimethylbenzene	7.00E+00	3.25E-01	4.65E-02	D	-	-	-
1,3,5-Trimethylbenzene	7.00E+00	1.70E-01	2.43E-02	-	-	-	-
1,3-Butadiene	2.00E+00	1.47E-01	7.35E-02	A	3.00E-05	6.29E-02	1.89E-06
1,4-Dichlorobenzene	8.00E+02	2.21E+00	2.76E-03	C	1.10E-05	9.45E-01	1.04E-05
2-Hexanone	3.00E+01	4.22E+00	1.41E-01	D	-	-	-
Acetaldehyde	9.00E+00	8.30E-01	9.22E-02	B2	2.20E-06	3.59E-01	7.90E-07
Benzene	3.00E+01	1.60E+00	5.33E-02	A	7.80E-06	6.87E-01	5.36E-06
Crotonaldehyde	-	-	-	C	5.43E-04	8.30E-02	4.51E-05
Ethylbenzene	1.00E+03	3.94E-01	3.94E-04	D	2.50E-06	1.69E-01	4.23E-07
Formaldehyde	9.80E+00	1.20E+00	1.22E-01	B1	1.30E-05	5.16E-01	6.70E-06
Methylcyclohexane	3.01E+03	5.72E+00	1.90E-03	-	-	-	-
Methylene Chloride	1.00E+03	2.78E+00	2.78E-03	B2	4.70E-07	1.19E+00	5.59E-07
Hazard Index (HI)			**6.E-01**	**Total Cancer Risk**			**7.1E-05**

Notes:
$\mu g/m^3$: michrograms per cubic meter
EPA: Environmental Protection Agency
HQ: Hazard Quotient
IUR: Incremental Unit Risk
RfC: Reference Concentration
WOE: Weight of Evidence: A - known human carcinogen; B1&B2 probable human carcinogen;
C-possible human carcinogen; D-Not enough evidence to classify carcinogencity

Table 5-2
Comparison of EPCs to BTVs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS	BTV	EPC Bell-Melton Ranch 2005-2010 (µg/m^3)	EPC> BTV?	Maximum Detected Concentration 2008 Well Completion (µg/m^3)	Maximum Detected Concentration > BTV?
1-Dodecene	112-41-4	8.83E-01	1.74E-01	no	6.08E+00	yes
1-Heptene	592-76-7	1.28E+00	7.10E-01	no	6.08E+01	yes
1-Hexene	592-41-6	1.01E-01	9.72E-02	no	1.63E-01	yes
1-Nonene	124-11-8	1.49E-01	1.20E-01	no	1.68E+01	yes
1-Octene	111-66-0	1.42E-01	1.13E-01	no	3.16E+00	yes
1-Pentene	109-67-1	1.50E-01	1.12E-01	no	3.89E-01	yes
1-Tridecene	2437-56-1	2.69E-02	8.89E-02	yes	3.63E-01	yes
1-Undecene	821-95-4	9.75E-02	1.48E-01	yes	4.72E+00	yes
2,2,3-Trimethylpentane	564-02-3	4.29E-01	1.91E-01	no	2.47E+01	yes
2,2,4-Trimethylpentane	540-84-1	2.46E-01	2.14E-01	no	1.98E-01	no
2,2-Dimethylbutane	75-83-2	1.00E+00	6.76E-01	no	4.12E+01	yes
2,3,4-Trimethylpentane	565-75-3	2.25E-01	1.27E+00	yes	1.21E+00	yes
2,3-Dimethylbutane	79-29-8	1.85E+00	1.36E+00	no	6.58E+01	yes
2,3-Dimethylpentane	565-59-3	9.48E-01	5.70E-01	no	3.56E+01	yes
2,4-Dimethylpentane	108-08-7	6.55E-01	4.06E-01	no	2.36E+01	yes
2-Methyl-1-butene	563-46-2	1.38E+00	1.23E+00	no	1.26E+00	no
2-Methyl-1-pentene	763-29-1	2.47E-01	1.52E-01	no	8.43E-02	no
2-Methyl-2-butene	513-35-9	3.05E-01	1.07E-01	no	3.87E-01	yes
2-Methylheptane	592-27-8	1.61E+00	7.01E-01	no	1.46E+02	yes
2-Methylhexane	591-76-4	2.71E+00	1.54E+00	no	1.21E+02	yes
2-Methylpentane	107-83-5	8.75E+00	5.98E+00	no	2.21E+02	yes
3-Methyl-1-butene	563-45-1	1.15E-01	9.44E-02	no	2.49E-01	yes
3-Methylheptane	589-81-1	1.17E+00	4.55E-01	no	9.74E+01	yes
3-Methylhexane	589-34-4	2.72E+00	1.27E+00	no	1.14E+02	yes
3-Methylpentane	96-14-0	5.63E+00	3.12E+00	no	1.29E+02	yes
4-Methyl-1-pentene	691-37-2	7.00E-01	2.28E-01	no	9.35E-01	yes
Acetylene	74-86-2	3.03E-01	6.97E-01	yes	8.40E-01	yes
a-Pinene	80-56-8	5.90E-01	2.31E-01	no	3.09E+01	yes
b-Pinene	127-91-3	3.72E-01	1.23E-01	no	8.96E+00	yes
cis-2-Butene	590-18-1	8.14E-02	7.95E-02	no	1.97E-01	yes
cis-2-Hexene	7688-21-3	2.95E-01	1.00E-01	no	2.93E-01	no
cis-2-Pentene	627-20-3	6.07E-02	6.12E-02	yes	1.48E-01	yes
Cyclopentane	287-92-3	9.63E-01	8.00E-01	no	2.23E+01	yes
Cyclopentene	142-29-0	4.72E-01	1.66E-01	no	6.51E-01	yes
Ethane	74-84-0	8.30E+01	9.02E+01	yes	2.41E+03	yes
Ethylene	74-85-1	9.39E-01	1.09E+00	yes	4.19E+00	yes
Isobutane	75-28-5	2.28E+01	2.62E+01	yes	1.60E+03	yes
Isobutene/1-Butene	115-11-7 / 106-98-9	1.07E+01	1.60E+00	no	6.71E+00	no
Isopentane	78-78-4	2.38E+01	2.24E+01	no	8.32E+02	yes
Isoprene	78-79-5	1.10E+00	5.03E-01	no	1.15E+00	yes
m-Diethylbenzene	141-93-5	4.10E-01	1.18E-01	no	7.08E+00	yes
Methylcyclopentane	96-37-7	5.85E+00	2.89E+00	no	1.20E+02	yes
m-Ethyltoluene	620-14-4	6.28E-01	2.21E-01	no	4.45E+01	yes

Table 5-2
Comparison of EPCs to BTVs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS	BTV	EPC Bell-Melton Ranch 2005-2010 (µg/m^3)	EPC> BTV?	Maximum Detected Concentration 2008 Well Completion (µg/m^3)	Maximum Detected Concentration > BTV?
n-Butane	106-97-8	2.61E+01	3.14E+01	yes	1.29E+03	yes
n-Decane	124-18-5	1.81E+00	2.24E+00	yes	2.08E+02	yes
n-Dodecane	112-40-3	1.55E+00	3.74E+00	yes	5.15E+01	yes
n-Heptane	142-82-5	5.48E+00	2.85E+00	no	3.04E+02	yes
n-Octane	111-65-9	3.74E+00	1.61E+00	no	4.17E+02	yes
n-Tridecane	629-50-5	3.12E-01	2.92E-01	no	9.05E+00	yes
n-Undecane	1120-21-4	2.17E+00	1.15E+01	yes	1.21E+02	yes
o-Ethyltoluene	611-14-3	3.08E-01	1.65E-01	no	2.92E+01	yes
p-Diethylbenzene	105-05-5	1.12E-01	7.00E-02	no	5.01E+00	yes
p-Ethyltoluene	622-96-8	3.60E-01	1.62E-01	no	3.22E+01	yes
Propane	74-98-6	5.26E+01	6.94E+01	yes	4.67E+03	yes
trans-2-Butene	624-64-6	2.06E-01	1.74E-01	no	1.89E+00	yes
trans-2-Hexene	4050-45-7	1.03E-01	3.04E-02	no	4.53E-02	no
trans-2-Pentene	4050-45-7	1.27E-01	8.08E-02	no	3.05E-01	yes

Notes
BTV: Background Threshold Value
EPC: Exposure Point Concentration
CAS: Chemical Abstract Service
µg/m^3: micrograms per cubic meter

Table 5-3
Chronic Risk Characterization for Residents Living Adjacent to a Well Pad - 30 Year Duration
Human Health Risk Assessment
Health Impact Assessment

	Non-Cancer Hazards			*Cancer Risks*			
Chemical	**RfC - chronic ($\mu g/m^3$)**	**TWA Inon-Cancer Intake ($\mu g/m^3$)**	**HQ**	**EPA WOE**	**IUR (1/(µg/m3)**	**TWA Cancer Intake ($\mu g/m^3$)**	**Cancer Risk**
1,2,3-Trimethylbenzene	7.00E+00	4.05E-01	5.79E-02	-	-	-	-
1,2,4-Trimethylbenzene	7.00E+00	2.53E+00	3.61E-01	D	-	-	-
1,3,5-Trimethylbenzene	7.00E+00	2.23E+00	3.19E-01	-	-	-	-
1,3-Butadiene	2.00E+00	1.47E-01	7.35E-02	A	3.00E-05	6.30E-02	1.89E-06
1,4-Dichlorobenzene	8.00E+02	2.21E+00	2.76E-03	C	1.10E-05	9.45E-01	1.04E-05
2-Hexanone	3.00E+01	4.22E+00	1.41E-01	D	-	-	-
Acetaldehyde	9.00E+00	8.38E-01	9.31E-02	B2	2.20E-06	3.59E-01	7.90E-07
Benzene	3.00E+01	3.38E+00	1.13E-01	A	7.80E-06	1.45E+00	1.13E-05
Crotonaldehyde	-	-	-	C	5.43E-04	8.30E-02	4.51E-05
Ethylbenzene	1.00E+03	6.47E+00	6.47E-03	D	2.50E-06	2.77E+00	6.93E-06
Formaldehyde	9.80E+00	1.20E+00	1.22E-01	B1	1.30E-05	5.16E-01	6.70E-06
Methylcyclohexane	3.01E+03	2.48E+01	8.24E-03	-	-	-	-
Methylene Chloride	1.00E+03	4.33E+00	4.33E-03	B2	4.70E-07	1.86E+00	8.74E-07
m&p-Xylene	1.00E+02	2.54E+01	2.54E-01	D	-	-	-
n-Hexane	7.00E+02	1.29E+01	1.84E-02	D	-	-	-
n-Nonane	2.00E+02	8.74E+00	4.37E-02	-	-	-	-
n-Pentane	1.00E+03	2.87E+01	2.87E-02	-	-	-	-
o-Xylene	7.00E+02	5.53E+00	7.91E-03	D	-	-	-
Hazard Index (HI)			**2.E+00**	**Total Cancer Risk**			**8.3E-05**

Notes:
$\mu g/m^3$: micrograms per cubic meter
EPA: Environmental Protection Agency
HQ: Hazard Quotient
IUR: Incremental Unit Risk
RfC: Reference Concentration
TWA: Time weighted average
WOE: Weight of Evidence: A - known human carcinogen; B1&B2 probable human carcinogen; C-possible human carcinogen; D-Not enough evidence to classify carcinogencity

Table 5-4
Acute Risk Characterization for Child Resident Living Adjacent to Well Pad - 7-day Duration
Human Health Risk Assessement
Health Impact Assessment

Chemical	Primary target system	RfC - acute (µg/m^3)	Acute Intake (µg/m^3)	HQ
Ambient Air				
1,2,3-Trimethylbenzene	Neurologic, Respiratory, Immunologic	7.00E+00	1.17E+01	1.67E+00
1,2,4-Trimethylbenzene	Neurologic, Respiratory, Immunologic	7.00E+00	8.30E+01	1.19E+01
1,3,5-Trimethylbenzene	Neurologic, Respiratory, Immunologic	7.00E+00	7.75E+01	1.11E+01
1,3-Butadiene	Reproductive	2.00E+00	1.66E-01	8.29E-02
2-Hexanone	Neurologic	3.00E+01	4.22E+00	1.41E-01
Acetaldehyde	Respiratory	9.00E+00	1.96E+00	2.18E-01
Benzene	Immunologic	2.90E+01	1.80E+02	6.21E+00
Chloroform	Neurologic	4.90E+02	1.60E+00	3.27E-03
Ethylbenzene	Developmental	4.30E+04	9.60E+01	2.23E-03
Formaldehyde	Respiratory	4.90E+01	1.02E+01	2.08E-01
Methylcyclohexane	Renal	3.01E+03	7.23E+02	2.40E-01
m&p-Xylene	Neurologic	8.70E+03	1.50E+03	1.72E-01
n-Hexane	Neurologic	7.00E+02	2.55E+02	3.64E-01
n-Nonane	Neurologic	2.00E+02	3.03E+02	1.51E+00
n-Pentane	Neurologic	1.00E+03	5.53E+02	5.53E-01
o-Xylene	Neurologic	7.00E+02	2.60E+02	3.71E-01
Toluene	Neurological and Respiratory	3.80E+03	5.40E+02	1.42E-01
Hazard Index (HI)				***3.47E+01***
		RfD - acute (mg/kg-day)	**Acute Intake (mg/kg-day)**	**HQ**
Surface Water				
Benzene	Immunologic	4.00E-03	2.00E-03	5.00E-01
Ethylbenzene	Developmental	5.00E-01	1.23E-02	2.45E-02
m&p-Xylene	Neurologic	1.00E+00	4.79E-03	4.79E-03
o-Xylene	Neurologic	1.00E+00	1.71E-03	1.71E-03
Toluene	Neurological and Respiratory	8.00E-01	4.86E-02	6.08E-02
Hazard Index (HI)				***5.92E-01***
Ambient Air and Surface Water				
Total Hazard Index (HI)				**4.E+01**

Notes:
µg/m^3: michrograms per cubic meter
EPA: Environmental Protection Agency
HQ: Hazard Quotient
mg/kg-day: milligrams per kilogram per day
RfC: Reference Concentration
RfD: Reference Dose

Table 6-1
Chemicals Identified from Antero's MSDS
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number
#1 diesel	8008-20-6
#2 Diesel	68476-34-6
(sulfonic acids, petroleum, calcium salts)	61789-86-4
1,2 benzanthracene	56-55-3
1,2-benzphenanthrene	218-01-9
2-Aminoethanol	141-43-5
2-ethoxyethanol	110-80-5
2-methyl-4-isothiazolin-3-one	2682-20-40
2-pentanone, 4 -methyl(hexone)	108101
5-cholro-2-methyl-4-isothiazolin-3-one	26172-55-4
acenaphthene	83-32-9
Additives	proprietary
aliminum oxide	1344-28-1
aliphatic glyicdyl ether	2461-15-6
Aliphatic petroleum distallates	64742-89-8
alkali carbonates	584-08-7
alkoxylated long-chain alkyl amine	proprietary
alkyd resin	Not listed
Alkyl (C12-16) dimethylbenzylammonium chloride	68424-85-1
aluminum	7429-90-5
aluminum stearate	68442-97-7
Amino Methylene Phosphonic Acid Salt	proprietary
amino silane	1760-24-3
ammonium sulfate	7783-20-2
amorphous fumed silica	112945-52-5
anthracene	120-12-7
antioxidant	trade secret
argon	7440-37-1
aromatic petroleum distallates	64742-96-6
asphalt	8052-42-4
attaclay	8031-18-3
barium sulfate	7727-43-7
bentonite	1302-78-9
benzo(a)pyrene	50-32-8
benzo(b)fluoranthene	205-99-2
benzo(g,h,i)perylene	191-24-2
benzo(J)fluoranthene	205-82-3
benzo(K)fluoranthene	207-08-9
benzyldimethlamine	103-83-3
bisphenol A	80-05-7
bisphenol'A'/epichlorohydrin based epoxy	25068-38-6
boric acid	10043-35-3
calcium aluminate	12042783
calcium aluminate /iron oxide	12068358
calcium carbonate	471-34-1
calcium carbonate	1317-65-3
calcium fluoride	7789755
calcium hydroxide	01305-62-0

Table 6-1
Chemicals Identified from Antero's MSDS
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number
calcium hypochlorite	7778-54-3
calcium oxide	1305-78-8
calcium oxide, magnesium oxide, potassium sulfate, sodium sulfate	1003
calcium silicates	various
calcium sulfate	13397245
carbon	7440-44-0
carbon black	1333-86-4
carbon dioxide	124-38-9
carbon monoxide	0630-08-0
cellulose	65996-61-4
chlorinated paraffin	Not listed
chromium	7440-47-3
chromium (VI) as Cr	7440-47-3
Copper	7440-50-8
corrosion inhibitor	mixture
crystalline silica (cristobalite)	14464-46-1
crystalline silica (quartz)	14808-60-7
dibenz(A,H)anthracene	53-70-3
dibenzo(a)pyrene	189-55-9
dibenzo(a,e)pyrene	192-65-4
dibenzo(a,h)pyrene	189-64-0
dibutyl phthalate	84-74-2
diethylene glycol	111-46-6
diethylene glycol monoethyl ether	111-90-0
dipentamethylene thiuram tetrasulfide	120-54-7
dipotassium phosphate	2139900
dipropylene glycol	34590948
di-tocopherol	59-02-9
epoxy resin	25085-99-8
ethanol	64-17-5
ethyl acetate	141-78-6
ethyl ether	60-29-7
ethyl mercaptan	75-08-1
ethyl silicate	78-10-4
ethylene glycol	107-21-1
ethylene glycol monobutyl ether	111-76-2
ethylene glycol monoethyl ether acetate	111-15-9
ethylene glycol monomethyl ether	109-86-4
feldspar	Not listed
ferric oxide hydroxide	51274-00-0
fluoranthene	206-44-0
fluorene	86-73-7
fluorides	7789-75-5
fumed silica	67762-90-7
gasoline	mixture
Glutaraldehyde	111-30-8
glycerine (glycerol)	56-81-5

Table 6-1
Chemicals Identified from Antero's MSDS
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number
glycerol	56-81-5
glycol ether EB acetate	112-07-2
graphite	7782-42-5
gypsum	777-8-18-9
heavy aromatic naphtha	68603-08-7
helium	7440-59-7
highly refined base oils	mixture
highly refined mineral oil C15-C50	mixture
highly solvent-refinded base oils	64741-88-4
	64742-01-4
hydrocarbon propellant	684 76-86-8
Hydrochloric acid	7647-01-0
hydrogen	133-74-0
hydrogen sulfide	7783-06-4
hydrosulferized kerosene C9-16	64742-81-0
hydrotreated distallate, light C9-16	64742-47-8
hydrotreated heavy naphtha (petroleum(	64742489
hydrous alluminum silicate	Not listed
indeno (1,2,3-cd) pyrene	193-39-5
iron	7439-89-6
iron oxides	65996-74-9
isohexane isomers	107-83-5
Isopropanol	67-63-0
isopropyl acetate	108-21-4
lead chromate	1344372
leonardite	1414-93-6
lithium compounds	554-13-2
lithium sterate soap	7620-77-1
lubicant base oil	various
magnesite	1309-48-4
magnesium	7439954
magnesium carbonate	546-93-0
magnesium oxide	1309-58-4
manganese	7439-96-5
mercaptobenzothiazole	149-30-4
metallic coating	mixture
Methanaminium, N N N trimethyl-,chloride	75-57-0
methane	0074-82-8
Methanol	67-56-1
methyl n-amyl ketone	110-43-0
methyl n-propyl ketone	107-87-9
mica	12001-26-2
mineral oil	8042-47-5
Mineral oil, petroleum distallates, hydrotreated (severe) heavy naphthenic; (mineral oil)	64742525
Mineral oil, petroleum distallates, hydrotreated (severe) light naphthenic; (mineral oil petroleum distallates)	64742536
mineral silicates	1332-58-7

Table 6-1
Chemicals Identified from Antero's MSDS
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number
mineral spirits	8052-41-3
mineral spirits (F)	64742-88-7
modified aliphatic amine	Not listed
molybdenum	7439-98-7
mono ammonium phosphate	7733-76-1
N-aminoethypiperazine	140-31-8
Naphthalene	91-20-3
n-butanol	71-36-3
nickel	7440-02-0
nitrogen	7727-37-9
non-phenol ethoyxalates	Not listed
nonyl phenol	25154-52-3
nonylphenol ethoxylates	9016-45-9
nut shells	NA
octyl alcohol	111-87-5
oil mists	mixture
organic cobalt compounds	various
organophillic clay	71011-26-2
partially hydrolized polyacrylamide	Not listed
perchloroethylene	127-18-4
petroleum base oil	64742-65-0
Petroleum Grease Mixture	64742-52-5, 7620-77-1, 68783-36-8, Mixture
petroleum product additive	Not listed
phenanthrene	85-01-8
phosphated polyester	proprietary
phosphorous (yellow)	7723-14-0
poly[oxyethylene(dimethylimino)ethylene(dimethyleimino)ethylenedichloride	31512-74-0
polyamide resin	68410-23-1
polyanionic carboxymethyl cellulose	Not listed
polyethelene co-polymer	Not listed
polyethylene	9002884
polyethylene or polyethylene-butene copolymer or polyethylene-hekene copolymer	9002883
polyethylene-butene	25087347
polyethylene-hexene	25213029
Polytef [USAN]	9002-84-0
polyvinyl chloride	Not listed
Polyvinyl Chloride Resin	non/haz
portland cement	65997-15-1
potassium acid fluoride	7789-29-9
potassium aluminum silicate (potassium feldspar)	68476255
potassium borate	1332-77-0
potassium pentaborate	11128-29-3
potassium silicate	1312761
proprietary additives	proprietary

Table 6-1
Chemicals Identified from Antero's MSDS
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number
proprietary pigment (nuisance dust)	proprietary
propylene carbonate	108-32-7
PVC resin	9002-86-2
pyrene	129-00-0
red dye	4477-79-6
red iron oxide	1309-37-1
refined coal tar pitch (contains PAH's)	65996-93-2
silica (precipitated)	112926-00-8
silica amorphous	7631-86-9
silica, crystalline, quartz	148-06-60-7
silica, crystalline, tridymite	15468-32-3
silicic acid, disodium salt (sodium silicate)	6834920
silicon	7440-21-3
silicon fluid (poly (dimethylsiloxane), dimethyl	63148629
silicone oil	63148-57-2
slag coal	Not listed
sodium carbonate	497-19-8
sodium acid pyrophosphate	7758-16-9
sodium bicarbonate	7447-40-7
sodium carbomethyl starch	9063-38-1
sodium chloride	7647-14-5
sodium fluoride	7681-49-4
sodium hydroxide	1310-73-2
sodium silicate	1344-09-8
soft/hard wood sawdust ex W red cedar	mixture
soluble barium compound	Not listed
subtilisin	1/1/9014
sulfamic acids	5329-14-6
sulfur	7404-34-9
talc (respirable dust)	14807-96-9
talc [JAN]	14807-96-6
tetrahydrofuran	109-99-9
thiocarbamates	Not listed
tin	7440-31-5
titanium	12719-90-5
titanium dioxide	13463-67-7
triclosan	3380-34-5
triethylenetetramine	112-24-3
Triisopropanolamine	122-20-3
vanadium	1314-62-1
violet dye	81-48-1
yellow pigment	5468-75-7
zinc	1314-13-2
zinc compound	proprietary
Zinc dialkyldithiophosphate	68649-42-3
zinc oxide	1314-13-2
zirconium	12004-83-0
Zirconium acetate lactate ammonium complex	68909-34-2

Table 6-1
Chemicals Identified from Antero's MSDS
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number
zirconium dioxide (zirconium silicate)	7440677
zirconium silicate	14940-68-2

Table 7-1
Summary of Risk Characterization
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Exposure Scenario	Exposure	Hazard Index (HI)	Cancer Risk
All Battlement Mesa Residents - 30 years	Chronic	1	7.1E-05
Residents living near a well pad - 30 years	Chronic	2	8.3E-05
Child Resident living near a well pad - 7 days			
-Ambient Air Exposure Pathway[1]	Acute	35	-
-Surface Water Exposure Pathway	Acute	0.6	-
'-Ambient Air plus Surface Water Pathways	Acute	40	-

[1]Also applies to adult residents for 7-day acute exposure

Figure 2-1
Temporal Trends of BTEX at Bell-Melton Monitoring Station - 2005 to 2010

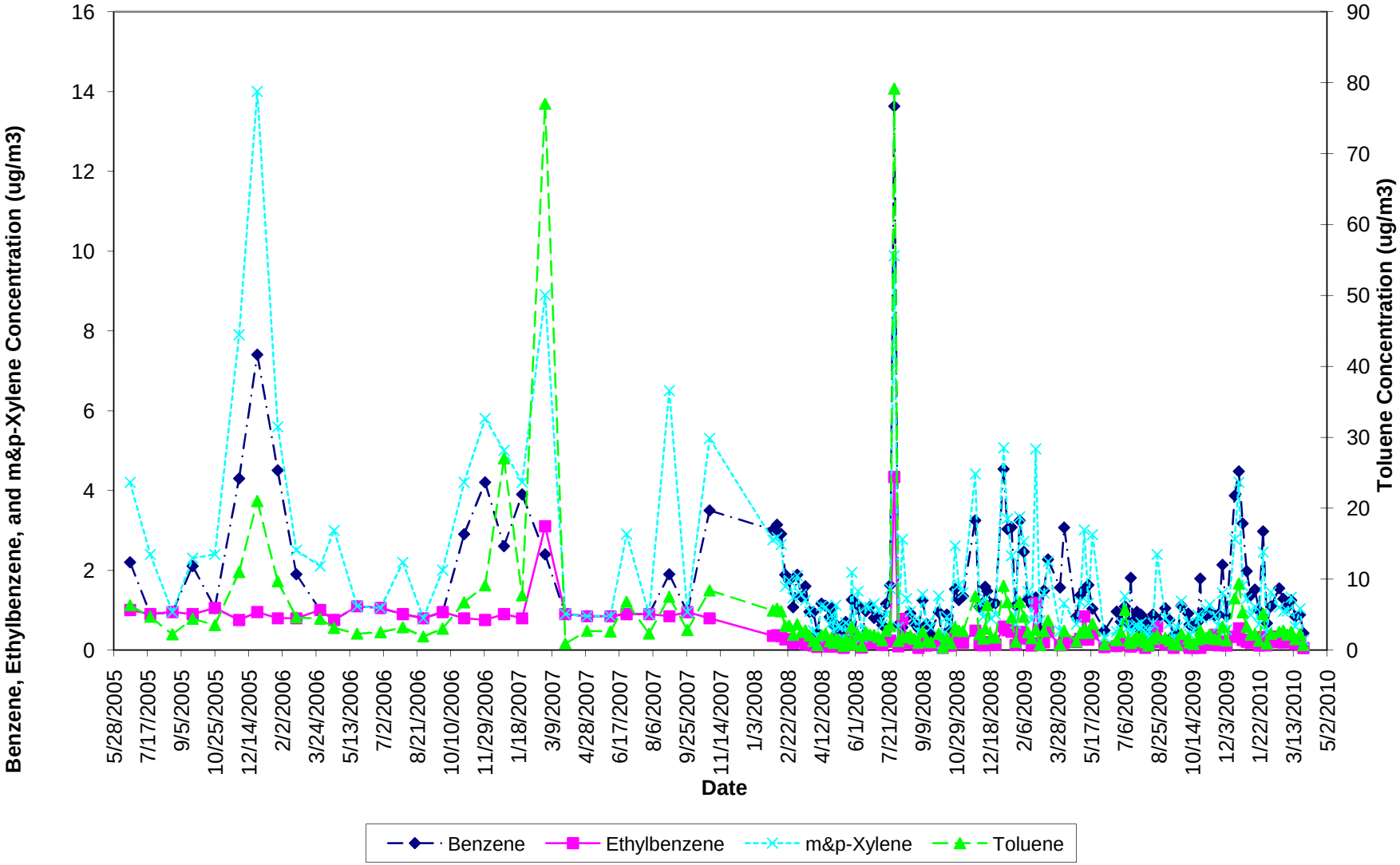
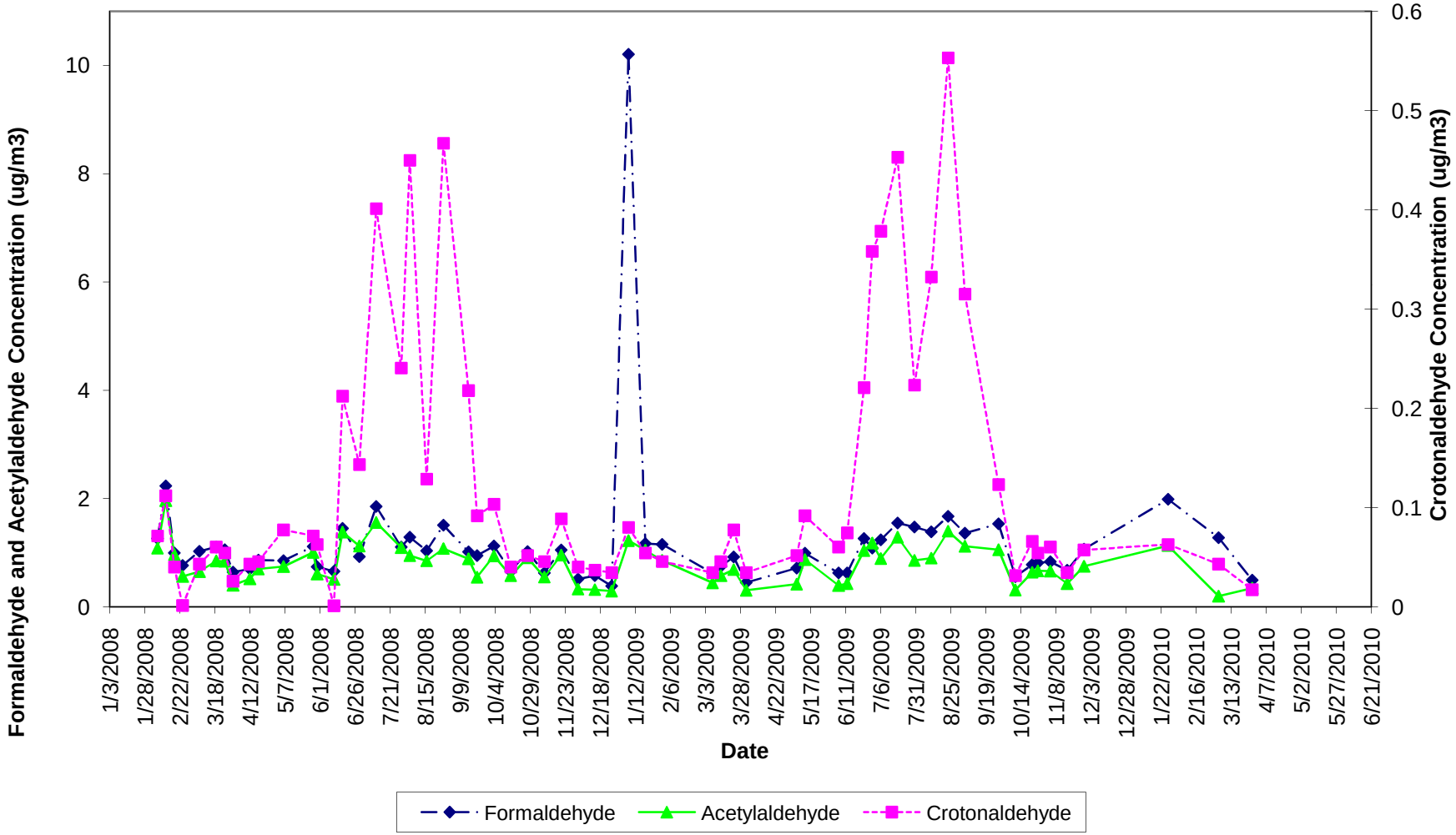


Figure 2-2
Temporal Trends for Carbonyls
Bell Melton Ranch Monitoring Station



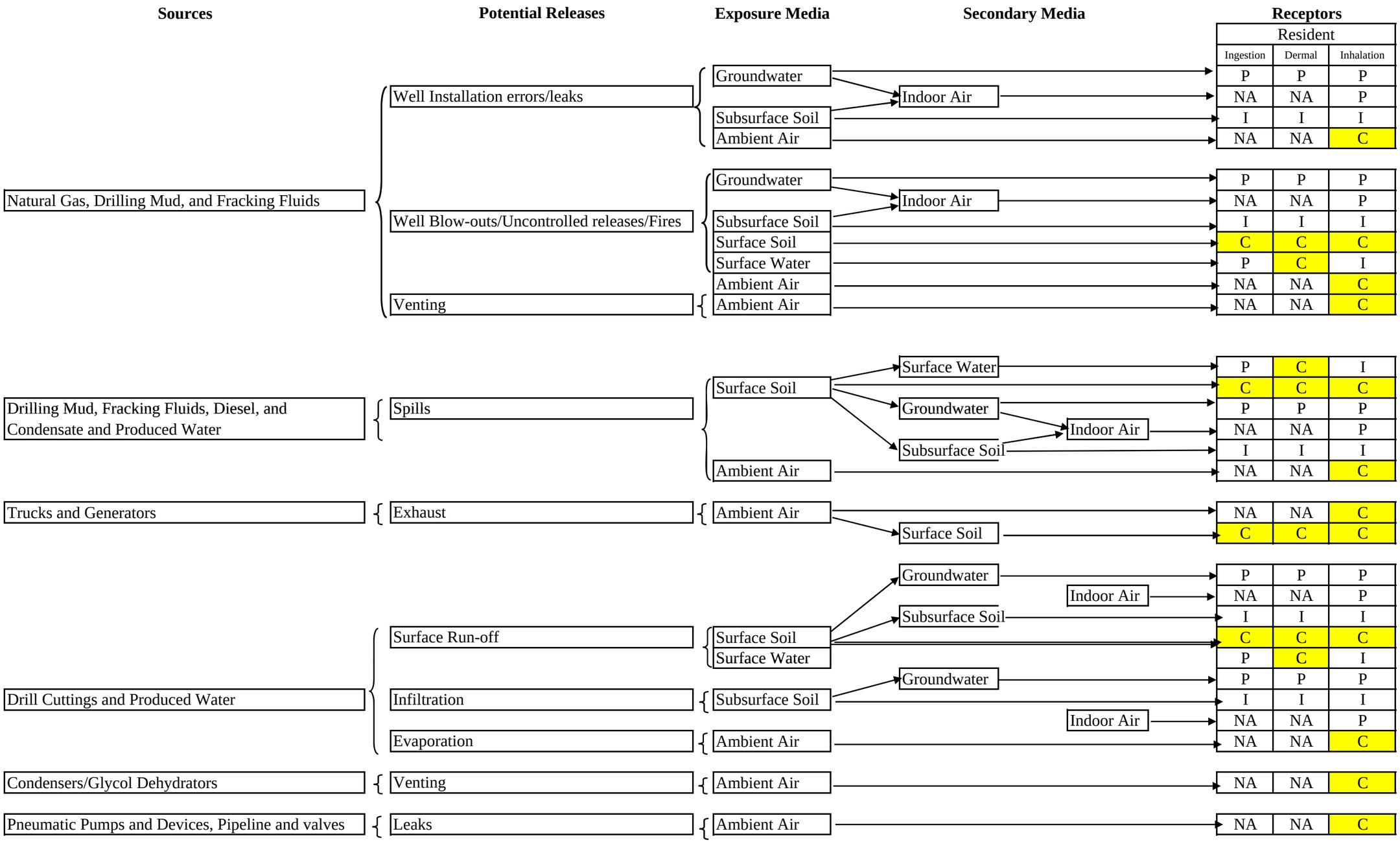


Figure 3-2: Conceptual Site Model for Battlement Mesa Health Impact Assessment
C = Complete Pathway I = Incomplete Pathway P = Potential Pathway NA = Not Applicable

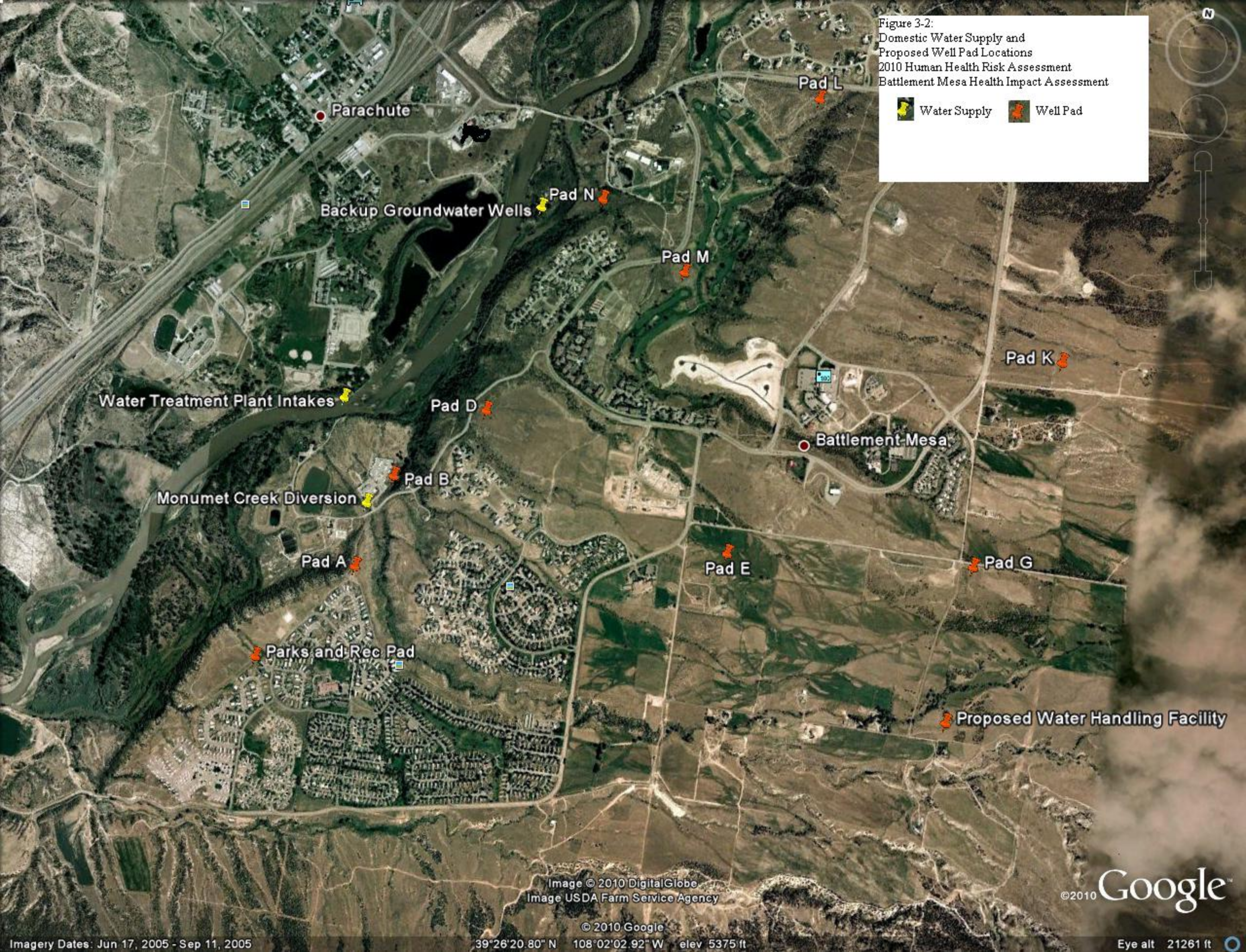


Figure 3-2:
Domestic Water Supply and
Proposed Well Pad Locations
2010 Human Health Risk Assessment
Battlement Mesa Health Impact Assessment
Water Supply
Well Pad
Parachute
Pad L
Pad N
Backup Groundwater Wells
Pad M
Pad K
Water Treatment Plant Intakes
Pad D
Battlement Mesa
Pad B
Monumet Creek Diversion
Pad A
Pad E
Pad G
Parks and Rec Pad
Proposed Water Handling Facility
Image © 2010 DigitalGlobe
Image USDA Farm Service Agency
© 2010 Google
©2010 Google
Imagery Dates: Jun 17, 2005 - Sep 11, 2005
39°26'20.80" N 108°02'02.92" W elev 5375 ft
Eye alt 21261 ft

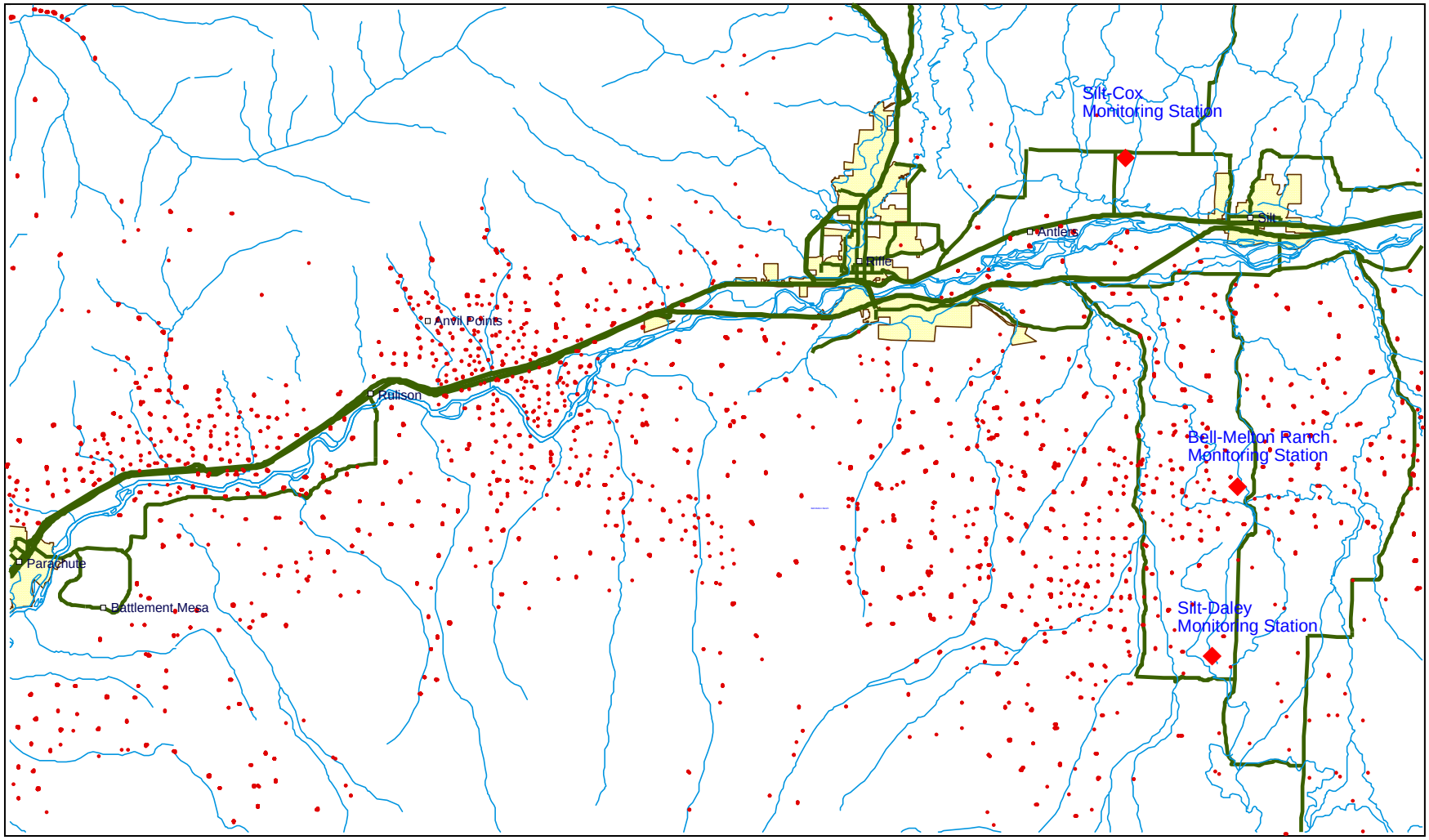


Figure 3-3: Locations of Baseline and Bell-Melton Ranch Monitoring Stations
2010 Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

● = Natural gas or oil well ■ = Monitoring Station ▬ = Road