APPENDIX D: HUMAN HEALTH RISK ASSESSMENT

Screening Level Human Health Risk Assessment for Battlement Mesa Health Impact Assessment

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Disclaimer

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ACRONYMS

AI:	air intake
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
NAAQS:	National Ambient Air Quality Standard
NIOSH:	National Institute of Occupational Safety and Health
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

Summary of Modifications:

The following modifications to the September 2010 version of the risk assessment were made based on stakeholder comments and data that became available after September 2010.

1. Near a well pad has been defined as living within ½ mile of a well pad. This definition is based on odor complaints in July 2010 from residents living ½ mile from the Watson Ranch pad.
2. An elderly adult is defined as aged 65 years or greater has been added as a receptor.
3. A subchronic exposure scenario of 20 months for exposure to air emissions during well completion operations has been added. This is based on comments received in the citizen's stakeholder meeting that some residents live within ½ mile of more than one of the proposed well pads. Many individuals live within ½ mile of two of the proposed pads and some live within ½ mile of three of the proposed pads. The subchronic exposure scenario was evaluated for all receptors (children, adults, and elderly adults). Previously an intermediate exposure of 10 months was used, based on well-completion activities for 20 wells on one well pad.
4. An acute exposure scenario of 7 days has been added for adults, including elderly adults.
5. A baseline risk was estimated for Battlement Mesa residents based on ambient air samples collected at the Battlement Fire Station from September to November 2010.
6. The exposure point concentrations used in the chronic risk assessment for all Battlement Mesa residents and for residents living near (within ½ mile) a well pad were updated to include data collected through November 2010.
7. The exposure point concentrations for the subchronic exposure (previously defined as an intermediate exposure) used in the time-weighted average to estimate chronic exposure point concentrations for those living near a well pad were revised as follows. The maximum concentration and the 95%UCL from the 2008 Air Toxics Study and Antero's August 2010 sampling was used to provide a range for subchronic exposure point concentration. If a contaminant was not measured in these studies, the maximum concentration from the Bell-Melton Ranch Monitoring station was used as the subchronic exposure point concentration. All subchronic exposure point concentrations were determined from data obtained from 24-hour integrated samples.
8. Subchronic toxicity factors have been found for most contaminants of potential concern (COPCs) and were used to estimate the subchronic risk. If a subchronic toxicity factor was not available, the chronic toxicity factor was used, per EPA guidance (EPA 1989). A more thorough discussion of the bias this introduces has been added to the uncertainty section.
9. The exposure point concentrations for the acute exposure to contaminants in air were revised as follows. The maximum concentration and 95% UCL from the 2005 to 2007 grab samples collected when odors were noticed and the grab

samples Antero collected in their August 2010 sampling were used to provide a range for the exposure point concentration. All acute exposure point concentrations were determined from data collected via grab sampling.

10. If acute toxicity factors were not available, intermediate toxicity factors were used, per EPA guidance (EPA 1989). A more thorough discussion of the bias this introduces has been added to the uncertainty section.
11. The averaging time for the acute exposure of a child to surface water has been revised from 365 days to 7 days.

1 Introduction

This screening level human health risk assessment (HHRA) was conducted in support of the Battlement Mesa health impact assessment (HIA). As in all risk assessments, there are uncertainties that may lead to both over and underestimation of risk estimated in this HHRA. Without further data it is impossible to know how these estimated risks relate to the true risks. The usefulness of the risk estimates are not in predicting the true risk but in providing guidance for future exposure reduction and monitoring efforts. 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 unit 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. Child, adult, and elderly (65 years and greater in age) residents living within the Battlement Mesa PUD were the receptors considered in this HHRA Five exposure scenarios were evaluated:

(1) A long-term chronic exposure scenario for child, adult, and elderly residents
(2) A long-term chronic exposure scenario for child, adult, and elderly residents living near well pads.
(3) A subchronic exposure scenario for Battlement Mesa child, adult, and elderly residents, living near a well pad.
(4) An acute exposure scenario for child residents living near well pads.
(5) An acute exposure scenario for adults and elderly residents living near a well pad.

Residents living within ½ mile of a well pad were considered as living near a well pad based on odor complaints filed with COGCC in July and August 2010.

The HHRA 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).

While risk assessment methods vary and none are perfect, the USEPA methods we used are recommended by the USEPA to protect human health when data are limited, as was the case for this screening level HHRA. These established methods also were used by the CDPHE in their 2007 and 2010 ambient air risk assessments for Garfield County.

A probabilistic USEPA risk assessment approach was not employed because this approach requires site-specific information such as wind patterns and length of residency. This type of data is not currently available for Battlement Mesa and a probabilistic risk

assessment approach is not appropriate at this time, according to USEPA guidance for probabilistic risk assessments (USEPA Risk Assessment Guidance for Superfund Volume III, Part A 2001). The USEPA guidance also emphasizes the importance of involving all stakeholders in determining which site-specific or other information to use in a probabilistic risk assessment.

In this HHRA we used standard USEPA guidance on exposure assumptions, which are sometimes called "default options." The USEPA recommends using default options when community-specific or other community suitable information is not available.

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 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, the 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 nine well pads (approximately 20 wells per pad) in three phases spanning up to 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. As in all risk assessments, there were uncertainties that may lead to both over and underestimation of the risk estimates. 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 exceeded 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, exceeded 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.

ATSDR performed a Health Consultation using the 2005-2007 data. This health consultation concluded that "the ambient air quality in Garfield County constitutes an indeterminate public health hazard, for all current exposures, based on the estimated theoretical cancer risks as well as non-cancer hazards and the uncertainties associated with the available data. It should be noted, however, that the estimated theoretical cancer risks and non-cancer hazards for benzene at Brock, in the oil and gas development area, appear to be significantly higher than those in the urban and rural areas, causing some potential concern. These elevated levels are an indicator of the increased potential for health effects related to benzene exposure at Brock and in the oil and gas development area. Furthermore, the future exposures are considered to represent an indeterminate public health hazard, as changes in the oil and gas industry do not allow for use of the current data to predict future exposure scenarios. However, as Garfield County is expected to experience rapid population and industrial growth in the coming years, the air quality will likely be impacted." (ATSDR 2008).

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 CDPHE 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 acetaldehyde 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. These total risk estimates are based on all carcinogenic chemicals including crotonaldehyde, for which there is high uncertainty in the inhalation unit risk factor. However, the total cancer risks at all monitoring sites remain above the mid-point of EPA's acceptable cancer risk range of 1E-06 to 1E-04 even when crotonaldehyde is excluded. The major contributors to this risk are formaldehyde and benzene. The estimated risks with and without crotonaldehyde indicate a low to moderate increased risk of developing cancer during a lifetime. Overall, it is important to note that the cancer risks are likely to be underestimated in this assessment because cancer toxicity values are only available for a small number of air toxics.
- Each of the 20 individual air toxics, including benzene, 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.

ATSDR performed a Health Consultation using the 2008 data. This health consultation concluded that it could not be determined if breathing ambient air in the monitored areas of Garfield County could harm peoples health because the cancer risks and non-cancer hazards for 65 out of 86 contaminants could not be quantitatively estimated due to limited toxicological information and/or the unavailability of accepted inhalation toxicity values. could harm people's health. ATSDR went on to conclude that the evaluation based on the available toxicity information indicated that (1) the quantitative evaluation of cancer risk, based on the available toxicity values for six carcinogenic contaminants, indicates that inhalation of ambient air in the monitored areas of Garfield County is associated with a low increased risk of developing cancer; (2) The quantitative evaluation of long-term (chronic) non-cancer hazards, based on the available toxicity values for 21contaminants, indicated that inhalation of ambient air in the monitored areas of Garfield County is associated with a low increased risk of developing long-term (chronic) non-cancer health effects; (3) the quantitative evaluation of short-term (acute) non-cancer hazards, based on the available toxicity value for benzene, indicated that inhalation of ambient air in the monitored areas of Garfield County is associated with a low increased risk of developing

acute non-cancer health effects; (4) the qualitative evaluation of 65 contaminants with no toxicity values indicated that exposure to these 65 contaminants individually is not likely to result in significant cancer and noncancer effects because the levels measured are much lower than those known to cause health effects; and (5) it cannot be assumed that the cumulative health effects from these contaminants is minimal because the contaminants are of similar classes and might interact synergistically to cause health effects (ATSDR 2010a).

2 Data Evaluation and Selection of COPCs

Quality assurance project plans (QAPPs) and documented quality assurance/quality control procedures were in place for the collection of the ambient air data used in this HHRA. These QAPPs are available from GCPHD. This is the same data CDPHE used in their 2007 and 2010 risk assessments for Garfield County. In addition, all samples were collected and analyzed using EPA methods by EPA certified laboratories. Field duplicates were collected and are documented in the 2007, 2008, and 2009 CDPHE reports available on Garfield County's web site. The data used in the HHRA is reliable and suitable for identifying COPCs for use in screening level risk assessments. However, as in all risk assessments, uncertainties in the data may lead to both over and underestimation of the risk estimates presented in this HHRA. The usefulness of the risk estimates are not in predicting the true risk but in providing guidance for future exposure reduction and monitoring efforts.

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 noticed odors they attributed to natural gas operations. 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 163 samples collected from the Bell-Melton Ranch monitoring station from January 2008 through November 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.

In September 2010, GCPHD began collecting ambient air samples over 24-hour intervals by the methods described above from a monitoring station located on the roof of the fire station in Battlement Mesa. Data from 13 samples (collected September 2010 through November 2010) were employed in this HHRA for the assessment of baseline conditions in Battlement Mesa.

2.1.4 2010 Antero Sampling

Antero contracted Olsson Associates, Inc. to collect 10 ambient air samples (including 2 field duplicates) at its Watson Ranch well pad during well completion and flow back activities on August 19-20, 2010. The samples were collected in Summa Canisters over 24-hour intervals and shipped to Atmospheric Analysis and Consulting Inc. in Ventura California for analysis of 56 SNMOCs by EPA method TO-12. Antero also collected background air samples and air samples during drilling activities at the Watson Ranch pad. The sample results from the drilling were neither sensitive nor specific enough for the HHRA. The background results were not available at the time the HHRA was prepared.

In addition, two grab samples for carbonyl analysis were collected onto pre-treated 2,4-dinitrophenylhydrazine (DNPH) cartridges on August 20, 2010 and shipped to Atmospheric Analysis and Consulting Inc. in Ventura California for analysis of 13 carbonyls by EPA method TO-11a. These samples were collected at 350 feet and 500 feet to the South of the well pad, along the access road.

Although a QAPP was not prepared for the collection this data, data was collected using EPA methods and accredited laboratories. The data is of suitable quality use in screening level risk assessment.

2.1.5 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 is 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 29 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. The data for the remaining contaminants is adequate for determining potential health impacts.

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

Table 2-4 contains summary statistics for the data from samples collected at the Battlement Mesa monitoring station from September 2010 through November 2010 for evaluation of baseline risk for all Battlement Mesa residents.

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 November 2010 for evaluation of the long-term chronic exposure scenario for all Battlement Mesa residents. Table 2-5 contains summary statistics (number of samples, detection frequency, maximum detected concentrations, and mean) for the Bell-Melton Ranch monitoring station.

Table 2-6 contains summary statistics for the data from samples collected from the well completion sites, during the 2008 Air Toxics Study and Antero's 2010 sampling event. This data was used with the Bell-Melton Ranch data described in the preceding paragraph to calculate a time-weighted average for residents living near well pad and to evaluate subchronic exposures for residents living near a well pad.

Table 2-7 contains summary statistics for data from the grab samples collected during odor events in the 2005 to 2007 air monitoring study and Antero's 2010 sampling event. This data was used to evaluate potential acute exposures for residents living near 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 2-8 summarizes summary statistics for the background data set.

Table 2-8 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 perspective for the calculated risk for COPCs with toxicity values. Per EPA guidance, no background corrections were made and no chemicals were eliminated based on background (EPA 1989).

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 Chemicals of Potential Concern Battlement Mesa Baseline Risk

Table 2-4 summarizes the selection of COPCs from samples collected at the Battlement Mesa monitoring station for the Battlement Mesa baseline risk described in Section 3. 65 out of 90 chemicals measured were selected as COPCs. The following five chemicals were retained as COPCs because the maximum detected concentration exceeded 1/10 the EPA RSL:

- Benzene
- Ethylbenzene
- 1,3-Butadiene
- Acetaldehyde
- Formaldehyde

There was no EPA RSL for the remaining 60 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 Battlement Mesa monitoring station are summarized in Table 2-9.

2.5.2 Bell-Melton Ranch Monitoring Station

Table 2-5 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. 73 out of 126 chemicals were selected as COPCs. The following 11 chemicals were retained as COPCs because the maximum detected concentration exceeded 1/10 the EPA RSL:

- Acetaldehyde
- Formaldehyde
- 1,2,3-Trimethylbenzene
- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene
- 1,4-Dichlorobenzene
- Methylene chloride
- Benzene
- Ethylbenzene
- 1,3-Butadiene
- 2-Hexanone

There was no EPA RSL for the remaining 62 COPCs. They were retained because they were detected in 5 percent or more of the samples.

The EPCs were determined as described in Section 2.5.1. The EPC values for COPCs from the Bell-Melton Ranch monitoring station are summarized in Table 2-10. Also included in Table 2-10 are 95% UCLs and EPCs for chemicals from the Bell-Melton Ranch Monitoring stations that were identified as COPCs in the well completion data.

2.5.3 Contaminants of Potential Concern Well Completion

Table 2-6 summarizes the selection of 69 out of 78 chemicals identified as COPCs from samples collected in the 2008 air toxics study during well completion activities and

Antero's 2010 sampling. In addition, five COPCs identified from the Bell-Melton Ranch data set that were not measured in the 2008 air toxics study were identified as COPCs. 74 contaminants were selected as COPCs. The following 15 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.

- 1,2,3-Trimethylbenzene
- 1,2,4-Trimethylbenzene
- 1,3,5-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 59 COPCs, which were retained because their detection frequency was 5 percent or greater.

Two possible EPCs were evaluated. The first EPCs were determined as described in Section 2.5.1 and are summarized in Table 2-11. The maximum observed concentration was assigned as the second EPC because concentrations of COPCs in ambient air have been measured during completion activities involving up to 3 wells and more wells may be completed at one time during Antero's proposed project. The maximum detected concentrations were observed in the sample collected downwind of and approximately 200 feet from the center of an Antero well pad during flow back operations. In addition, samples were collected over a 24-hour interval which may have diluted out peak emissions during flow back operations. The two EPCs (the maximum detected concentration and the 95%UCL) provides a range for evaluation of risk.

2.5.4 Chemicals of Potential Concern Grab Samples

Table 2-7 summarizes the selection of COPCs from grab samples collected when residents noticed odors they attributed to natural gas operations during the 2005 -2007 ambient air monitoring study and from grab samples collected by Antero in August 2010. The following 11 chemicals were selected as COPCs because the maximum detected concentration exceeded 1/10 the EPA RSL or they had a detection frequency of greater than 5 percent and no EPA RSL was available

- Benzene
- Ethylbenzene
- m&p-Xylene
- o-Xylene
- Toluene
- Chloroform
- Acetaldehyde
- Formaldehyde
- Hexaldehyde
- Crotonaldehyde
- Benzaldehyde

Two possible EPCs were evaluated. The first EPCs were determined as described in Section 2.5.1 and are summarized in Table 2-7. The maximum observed concentration was assigned as the second EPC because the maximum possible exposure was desirable in the evaluation of acute exposure for the maximum exposed individual (MEI). The two EPCs (the maximum detected concentration and the 95%UCL) provides a range for evaluation of risk.

2.6 Statistical Observations for Select COPCs

2.6.1 Comparison Between Ambient Air Samples and Well Completion Samples

Concentrations of COPCs in the ambient air samples collected at the Bell-Melton Ranch Monitoring Station from 2005 to 2010 and ambient air samples collected during well completion activities in 2008 and 2010 were compared using the Mann-Whitney U test in EPA's ProUCL version 4.00.05 software (EPA 2010). The Mann-Whitney U test was used because the data is not normally distributed. Table 2-12 summarizes the results.

Concentrations from the well completion samples were significantly higher than the concentrations from the Bell-Melton Ranch monitoring station at an alpha level of 0.05 for all COPCs tested, with the exception of n-pentane. The concentrations of n-pentane from the well completion samples were higher than the concentrations from the Bell-Melton Ranch monitoring station ($p=0.06$), although not at an alpha level of 0.05. The mean benzene concentration from the well completion samples is approximately six times greater than the mean benzene concentration from Bell-Melton Ranch. The mean concentration of 1,2,4-trimethylbenzene from the well completion samples is 24 times greater than the mean 1,2,4-trimethylbenzene concentration from Bell-Melton Ranch. Similar results were observed when the concentrations of COPCs from the ambient air samples collected at the Battlement Mesa Monitoring station were compared to the concentrations of COPCs from the ambient air samples collected during well completion activities.

These results indicate that short-term (acute) and sub-chronic exposures to COPCs during well completion activities have the potential to be significantly greater than overall ambient air exposures, especially for residents living near the well pads.

2.6.2 Observed Temporal Trends

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 acetaldehyde 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 acetaldehyde. 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. As in all risk assessments there are uncertainties in the exposures assumptions that may lead to both over and underestimation of the risk estimates presented in this HHRA. These uncertainties are discussed further in Section 6.

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. Four 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 near well pad. The second population is residents living within the PUD at a residence near well pad. The third population is elderly adults aged 65 years or more living at a residence near a well pad. The fourth population is child residents aged 3 to 6 living at a residence near a well pad. The fourth population represents the MEI.

Residents living within ½ mile of a well pad were considered as living near a well pad based on odor complaints filed with COGCC in July and August 2010 (COGCC 2010). The odor complaints were filed by Battlement Mesa residents living approximately ½ mile to the North of Antero's Watson Ranch Pad. Several residents noticed odors and experienced self-reported health effects during well completion activities at this pad. Self-reported health effects included eye irritation, breathing problems, coughing, and pneumonia.

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

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. Monument 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 for longer than one week, 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.

Residents could come into direct contact with subsurface soil (i.e. greater than 2 feet bgs). However, this is unlikely because it would involve significant digging or excavation activities unlikely under the residential scenario. This pathway was not considered further in the HHRA.

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 September 2010 through November 2010 at the Battlement Mesa Monitoring Station (Garfield County 2010) for use in estimating the baseline risk in Battlement Mesa. It is

important to note that the ambient air results from the samples collected at the Battlement Mesa monitoring station may be influenced by natural gas development and production operations at the perimeter of the PUD. For example, Antero's Watson Ranch well pad is within ½ mile of the monitoring station and other companies are operating well pads on the periphery of the PUD.

Chronic EPCs for ambient air were estimated from ambient air samples collected from 2005 through November 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 (Battlement Mesa ambient air samples for baseline risk).
- Air quality, as reflected by the Bell-Melton Ranch ambient air results (Battlement Mesa 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 from the Battlement Mesa baseline samples. Table 3-2 summarizes intake rates for ambient air from the Bell-Melton Ranch samples. The intake equation for the chronic exposure scenario follows.

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

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 All Residents Living Near Well Pads Chronic Exposure Assumptions and Intake Equations

Only the ambient air exposure pathway was quantitatively evaluated for the residents living near 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 near 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, Table 2-11). Therefore, subchronic 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 and Antero's 2010 sampling. In the 2008 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 four separate well completion sites (Paul Reaser, personal communication 7/6/2010). In Antero's sampling, eight ambient air samples (two from each cardinal direction) were collected at 350 and 500 feet from the well pad center at the Watson Ranch Pad on the Southwest boundary of the Battlement Mesa PUD. The maximum detected concentration and 95% UCL from these samples were used to provide a range of subchronic EPCs. If a chemical was not measured in the Air Toxics Study or Antero's sampling, but was measured at the Bell-Melton Ranch monitoring station, the maximum concentration measured at the Bell-Melton Ranch monitoring station was used as the subchronic EPC. All subchronic EPCs were from 24-hour integrated samples.

The EPC for chronic exposure for residents living near a well pad was estimated by calculating a time weighted average (TWA) from the subchronic 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 near 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 within ½ mile of a 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.
- Some residents live within ½ mile of more than one well pad and are exposed to emissions from well completion activities for at least 20 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 2008 Air Toxics Study and Antero's 2010 sampling 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 20-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 3-2 summarizes intake rates for ambient air, which were calculated by the intake equations presented in Section 3.5.1. TWA EPCs for residents living near well pads were calculated as follows:

$EPC_{S+c} = (EPC_c \times ED_c/ED) + (EPCs \times ED_s /ED)$

EPC_c = Chronic exposure point concentration ($\mu g/m^3$)
ED_c = Chronic exposure duration = 340 months
EPC_s = Subchronic exposure point concentration ($\mu g/m^3$)
ED_s = Subchronic exposure duration = 20 months
ED = Total exposure duration = 360 months

3.5.3 All Residents Living Near Well Pads Subchronic Exposure Assumptions and Intake Equations

Only the ambient air pathway was quantitatively evaluated for the all resident subchronic exposure scenario because data 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 near well pads.

The subchronic EPCs described in Section 3.5.3 were used for the subchronic exposure scenario.

The following assumptions for subchronic exposure all residents, including children and elderly adults, living near 2 or more well pads to contaminants in ambient air are used in this HHRA based on EPA methodology.

- 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.

- Some residents live within ½ mile of more than one well pad and are exposed to emissions from well completion activities for at least 20 months.
- A resident, including elderly adult, lives, works, and otherwise stays at the home for 24 hours per day for 20 months.
- The air the resident adult 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 20-month period.

Table 3-2 summarizes intake rates for ambient air. The intake equation for the intermediate exposure scenario follows.

$AI = (EPC_s \times EF_s \times ED_s \times ET \times 1\ day/24\ hours)/AT$

AI = Air Intake ($\mu g/m^3$)
EPC_s = Subchronic exposure point concentration ($\mu g/m^3$)
EF_s = Subchronic exposure frequency = 350 days/year
ED_s = Subchronic exposure duration = 20 months (1.66 years)
ET = Exposure time = 24 hours/day
Non-cancer AT = averaging time = 583 days

3.5.4 Child Resident Living Near Well Pad 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 surface soil EPCs is not available. The acute exposure area for contaminants in ambient air is homes and yards located near 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 EPCs for ambient air were the 95% UCL and the maximum detected concentration observed in grab samples collected during odor events in CPDHE's 2005-2007 ambient air study and grab samples collected by Antero during well completion activities in August 2010. 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), as presented in Table 3-3.

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
- 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 3-3 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, µg/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 = 7 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

3.5.5 Adult Residents Living Near Well Pad Acute Exposure Assumptions and Intake Equations

Only the ambient air pathway was quantitatively evaluated for the adult acute exposure scenario because data on which to estimate surface soil EPCs is not available. The acute exposure area for contaminants in ambient air is homes and yards located near a well pad.

The acute EPCs for ambient air for the acute exposure scenarios are described in the preceding section.

The following assumptions for acute exposure of an adult resident, including elderly adults, to contaminants ambient air are used in this HHRA based on EPA methodology.

- An adult lives and otherwise stays at the home for 24 hours per day for 7 days.
- The air the adult breathes, both while indoors and outdoors, contains the same concentration of contaminants measured during odor events in the 2005-2007 ambient air study and by Antero during their August 2010 well completion activities.
- The concentration of contaminants in ambient air will stay constant over the 7-day period.

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, subchronic, chronic or lifetime), age, sex, diet, family traits, lifestyle, and state of health. As in all risk assessments there are uncertainties in the toxicity assessment that may lead to both over and underestimation of the risk estimates presented in this HHRA. Section 6 discusses this uncertainty.

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), subchronic RfDs and RfCs are developed to evaluate exposures of 1 to 7 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 near well pad scenarios. Subchronic RfCs were used for the subchronic adult resident near a well pad scenario. If a subchronic RfC was not available, the chronic toxicity value was used per EPA guidance (EPA 1989) Acute RfDs and RfCs were used for the acute child resident and adult resident near a well pad scenario. If an acute value was not available, the intermediate toxicity value was used per EPA guidance (EPA 1989).

4.2 Summary of Health Effects of COPCs

This section and Table 4-4 summarizes the non-cancer health effects for the COPCs with toxicity values.

4.2.1 Acetaldehyde

Sources of acetaldehyde in ambient air include fuel combustion, forest fires, industrial releases, and secondary formation from the oxidation of other organic compounds in the atmosphere. Motor vehicle emissions are one of the largest sources of acetaldehyde in the environment (Canadian Environmental Protection Act 2000). A potential source of acetaldehyde associated with natural gas development and production is emissions from trucks and diesel generators, as well as secondary formation from other organic compounds that are emitted as a result of natural gas development and production.

EPA has classified acetaldehyde 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, 1991 revision).

Non-cancer effects of inhalation exposure to acetaldehyde include eye and upper respiratory tract irritation and upper respiratory tract tissue damage. Short term inhalation exposure of rats to high concentrations of acetaldehyde was observed to result in degradation of the olfactory epithelium (EPA IRIS 2010, 1991 revision).

4.2.2 Benzene

Sources of benzene in ambient air include petroleum hydrocarbons, fuel combustion, forest fires, industrial releases, and cigarette smoke (ATSDR 2007). Potential sources of benzene associated with natural gas development and production are the natural gas resource itself, emissions from trucks and diesel generators, and fracking fluids containing diesel and other petroleum products (Antero has stated that it does not use diesel in fracking fluids).

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).

Non-cancer health effects from exposure to benzene's can occur 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)".

Maternal exposure to ambient levels of benzene recently has been associated with an increase in birth prevalence of neural tube defects (Lupo 2010).

4.2.3 1,3-Butadiene

Environmental sources of 1,3-butadiene include, fuel combustion, forest fires, industrial releases, and cigarette smoke (ATSDR 2009). A potential source of 1,3-butadiene associated with natural gas development and production is emissions from trucks and diesel generators.

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).

Non-cancer health effects from inhalation exposure to 1,3-butadiene include respiratory tract irritation, eye irritation, and narcotic effects. 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

Sources of chloroform in ambient air include release from chlorinated waters and industry (ATSDR 1997). A potential source associated with natural gas development and production is not clear. Fracking fluids and other chemicals with unknown composition used in the industry cannot be ruled out as a source because of the unknown composition of the components used in these fluids.

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).

Non-cancer health effects from 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

Sources of crotonaldehyde in ambient air include fuel combustion, forest fires, cigarette smoke, and industrial releases (http://toxnet.nlm.nih.gov). A potential source of crotonaldehyde associated with natural gas development and production is emissions from trucks and diesel generators.

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 irritant and non-cancer health effects from exposure to include eye, respiratory and skin irritation. 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

Sources of 1,4-dichlorobenzene in ambient air include space deodorants, toilet deodorizers, and moth repellents (ATSDR 2006). A potential source of 1,4-dichlorobenzene associated with natural gas development and production is portable toilets on the well pads.

EPA has determined 1,4-dichlorobenzene is a possible 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).

Non-cancer effects of exposure to 1,4-dichlorobenzene include eye and respiratory tract irritation, neurological problems, and liver problems. 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 (ATSDR 2006).

4.2.7 Ethylbenzene

Sources of ethylbenzene in ambient air include petroleum hydrocarbons, fuel combustion, forest fires, solvents, pesticides, printing ink, varnishes, coatings, paints, and cigarette smoke (ATSDR 2010). Potential sources of ethylbenzene associated with natural gas development and production are the natural gas resource itself, emissions from trucks and diesel generators, and fracking fluids containing diesel and other petroleum products (Antero has stated that it does not use diesel in fracking fluids).

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).

Non-cancer health effects from exposure to ethylbenzene in air include eye and respiratory irritation, hearing loss, kidney damage and neurological effects. Short term exposure to high levels of ethylbenzene in ambient air can cause eye and throat irritation, vertigo, and dizziness. 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 2010b).

4.2.8 Formaldehyde

Sources of formaldehyde in ambient air include fuel combustion, forest fires, many household products, and secondary formation from the oxidation of other organic compounds in the atmosphere (ATSDR 1999). A potential source of formaldehyde associated with natural gas development and production is emissions from trucks and diesel generators, as well as secondary formation from other organic compounds that are emitted as a result of natural gas development and production.

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).

Non-cancer health effects from exposure to formaldehyde in air include eye and respiratory tract irritation, changes in pulmonary function, and neurological effects. (ATSDR 2010c).

4.2.9 n-Hexane

Sources of n-hexane in ambient air include petroleum hydrocarbons, industry and household solvents, and paints (EPA 2010). Potential sources of n-hexane associated with natural gas development and production are the natural gas resource itself and fracking fluids containing diesel and other petroleum products (Antero has stated that it does not use diesel in fracking fluids).

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

Non-cancer health effects from exposure to n-hexane in ambient air include muscle weakness and peripheral neuropathy. 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

Sources of 2-Hexanone in ambient air include paint, printing ink thinner, solvents for oils, waxes, and resins, and cleaning agents (EPA (2009). A potential source associated with natural gas development and production is not clear. Fracking fluids and other chemicals cannot be ruled out as a source because of the unknown composition of the components used in these fluids.

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

Non-cancer health effects from exposure to 2-hexanone in air include damage to the nervous system (EPA 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

Sources of methylcyclohexanae in ambient air include petroleum hydrocarbons and solvents (http://toxnet.nlm.nih.gov). Potential sources of methylcyclohexane associated with natural gas development and production are the natural gas resource itself and fracking fluids containing diesel and other petroleum products (Antero has stated that it does not use diesel in fracking fluids).

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

Sources of methylene chloride in ambient air include spray paints, household solvents and cleaners, and industrial solvents (ATSDR 2000a). A potential source associated with natural gas development and production is not clear. Fracking fluids and other chemicals cannot be ruled out as a source because of the unknown composition of the components used in these fluids.

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).

Non-cancer health effects from exposure to methylene chloride in air include eye irritation and neurological effects. 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

Sources of n-nonane in ambient air include petroleum hydrocarbons and solvents (http://toxnet.nlm.nih.gov). Potential sources of n-nonane associated with natural gas development and production are the natural gas resource itself and fracking fluids containing diesel and other petroleum products (Antero has stated that it does not use diesel in fracking fluids).

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

Sources of n-nonane in ambient air include petroleum hydrocarbons and solvents (http://toxnet.nlm.nih.gov). Potential sources of n-nonane associated with natural gas development and production are the natural gas resource itself and fracking fluids containing diesel and other petroleum products (Antero has stated that it does not use diesel in fracking fluids).

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

Sources of toluene in ambient air include petroleum hydrocarbons, fuel combustion, household and industrial solvents, and paint (ATSDR 2000b). Potential sources of toluene associated with natural gas development and production are the natural gas resource itself, emissions from trucks and diesel generators, and fracking fluids containing diesel and other petroleum products (Antero has stated that it does not use diesel in fracking fluids).

Toluene can not be classified as a carcinogen because of inadequate evidence (Class D) (EPA 2005b).

Non-cancer health effects from exposure to toluene in air include neurological effects, developmental effects, and kidney damage. 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 2005b.

4.2.16 Trimethylbenzenes

Sources of trimethylbenzenes in ambient air include petroleum hydrocarbons, fuel combustion, and household and industrial solvents (http://toxnet.nlm.nih.gov).. Potential sources of toluene associated with natural gas development and production are the natural gas resource itself, emissions from trucks and diesel generators, and fracking fluids containing diesel and other petroleum products (Antero has stated that it does not use diesel in fracking fluids).

EPA has not classified the trimethylbenzenes for carcinogenicity.

Non-cancer health effects from exposure to trimethylbenzenes in air include respiratory tract irritation and neurological effects. 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. Trimethylbenzene vapor irritates the nose and the throat. Prolonged contact with liquid trimethylbenzene 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

Sources of xylenes in ambient air include petroleum hydrocarbons, fuel combustion, household and industrial solvents, and paint (ATSDR 2007c). Potential sources of xylenes associated with natural gas development and production are the natural gas resource itself, emissions from trucks and diesel generators, and fracking fluids containing diesel and other petroleum products (Antero has stated that it does not use diesel in fracking fluids).

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

Non-cancer health effects of exposure to xylenes in air include eye and respiratory tract irritation, breathing problems, and neurological effects. 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. As in all risk assessments, there are uncertainties that may lead to both over and underestimation of the risk estimates presented in the HHRA. Without further data, it is impossible to know how the estimated risk estimates relates to the true risks. The usefulness of the risk estimates are not in predicting the true risk but in providing guidance for future exposure reduction and monitoring efforts. Section 6 provides a discussion of this uncertainty.

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 or EPCs presented in Tables 3-1 and 3-2 for the chronic, Tables 2-6 for the subchronic exposure scenarios and Tables 2-7 and 3-3 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 X^{th} 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, such as the Superfund program, 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. Battlement Mesa is not an EPA site and EPA targets and goals are provided here and in the following sections for guidance in interpretation of cancer risks.

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 X^{th} 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 CDPHE's risk assessments, emissions from natural gas development activities represent a complex mixture of many 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 may 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 in Battlement Mesa Before Implementation of Antero's Project

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

5.2.1 Ambient Air Baseline Risk

Cancer Risk Estimates

The sum of the baseline cancer risk is estimated at 5.5E-05 (55 cancers per 1,000,000 individuals), as shown in Table 5-1. This cancer risk exceeds EPA's target of 1 in a million and 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 (3.4E-05), followed by formaldehyde, a probable human carcinogen, (1.26E-05), benzene, a known human carcinogen, (5.2E-06), and acetaldehyde, a probable human carcinogen (1.45E-06). 1,3-butadiene, a known human carcinogen and ethylbenzene, a possible human carcinogen, also contribute to the cancer risk at levels less than 1E-06.

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 0.5, which is less than EPA's level of one below which health effects are not expected to occur.

Qualitative Risk Evaluation

Of the 65 COPCs identified from the September to November 2010 data set used to evaluate the baseline risk for all Battlement Mesa residents, 58 did not have toxicity values. However, background information is available for 52 of these COPCs. As shown in Table 5-2, the EPC for 34 of these COPCs did not exceed the BTV, indicating they would not contribute more to risk than already contributed by background. The remaining 22 COPCs are alkenes and alkanes that may contribute to the risk over background.

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 measured in Battlement Mesa and 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 the COPCs identified in Table 5-2 individually is not likely to result in cancer or non-cancer effects. Any of the six carbonyls without toxicity values could potentially have a contribution to the cancer and/or non-cancer effects. In addition, the cumulative health effects of all the 65 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 Risk After Implementation of Antero's Natural Gas Production Operations in Battlement Mesa

The risk for each of the four 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 near well pad) during natural gas development and production is estimated at 6.1E-05 (61 cancers per 1,000,000 individuals), as shown in Table 5-3. This cancer risk is above EPA's target of one in a million, but within EPA's generally acceptable range of one to 100 in a million. Crotonaldehyde, a possible human carcinogen, is the major contributor to the cancer risk (3.6E-05), followed by 1,4-dichlorobenzene, a possible human carcinogen, (1.0E-05), formaldehyde, a probable human carcinogen, (6.6E-06), benzene, a known human carcinogen (4.9E-06). Acetaldehyde, a probable human carcinogen, 1,3-butadiene, a known 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.

The lifetime excess cancer risk of 6.1E-05 estimated from the Bell-Melton Ranch data is higher than the baseline line cancer risk of 5.5E-05 estimated for Battlement Mesa. However, it is important to note that 1,4-dichlorobenzene and methylene chloride, two of the cancer risk drivers at Bell-Melton Ranch, were not measured at Battlement Mesa. The cancer risk estimated for Bell-Melton Ranch, without considering the 1,4-dichlorobenzene and methylene chloride, of 5.0E-05 is lower than the baseline cancer risk calculated for Battlement Mesa.

The cancer risk of 6.1 E-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 6.1 E-05 cancer risk for the resident not living near 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 5-3. The HI for non-cancer hazard is 0.5, which is less than EPA's level of one below which health effects are not expected to occur. It also is the same as the HI calculated for the Battlement Mesa baseline hazard.

The HI of 0.5 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 74 COPCs identified from the 2005 to 2010 data set used to evaluate the risk for residents not living near a well pad, 62 did not have toxicity values. However, background information is available for 56 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 12 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 the COPCs identified in Table 5-2 individually is not likely to result in cancer and non-cancer effects. Any of the six carbonyls without toxicity values could potentially contribute to the cancer and/or non-cancer effects. In addition, the cumulative health effects of these 74 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 Near a Well Pad

Cancer Risk Estimates

The sum of the cancer risk to Battlement Mesa residents living near a well pad is estimated to range between 7.4 E-05 to 9.3 E-05 (74 to 93 cancers per 1,000,000 individuals), as shown in Table 5-4. This range of cancer risks is above EPA's target of one in a million and within EPA's acceptable range of one to 100 in a million. Crotonaldehyde, a possible human carcinogen, is the major contributor to the cancer risk (4.1E-05), followed by benzene, a known human carcinogen (8.7E-6 to 1.7E-5), ethylbenzene, a possible carcinogen, (3.4E-06 to 1.4E-05), 1,4-dichlorobenzene, a possible human carcinogen, (1.0E-05), and formaldehyde, a probable human carcinogen, (9.3-06). 1,3-butadiene, a known human carcinogen, acetaldehyde, a probable human carcinogen, and methylene chloride, a probable human carcinogen, also contribute to the cancer risk at levels less than 1E-06.

The estimated cancer risk range of 7.4 E-05 to 9.3 E-05 for the resident living near a well pad is higher than the 6.1E-05 estimated cancer risk for the resident not living near well pad. The increase is primarily due the increase in cancer risk from benzene and ethylbenzene. It is important to note that intakes for methylene chloride, and 1,4-dichlorobenzene were the same as the chronic intakes for the residents not living near a well pad and the intakes for acetaldehyde, formaldehyde, and crotonaldehyde were calculated from maximum observed at the Bell-Melton Ranch monitoring station. This is because data for these chemicals was not available from the 2008 air toxics study. If concentrations of these compounds in ambient air are higher or lower during well completion activities, the actual cancer risks for residents living near well pad may be higher or lower. Section 6 provides further discussion.

Non-Cancer Risk Estimates

While no individual contaminant had an HQ greater than one, the HI for the non-cancer hazard ranged from 1 to 3, as shown in Table 5-4. This HI range is greater than EPA's level of one above which health effects may occur. It also is greater than the baseline non-cancer hazard. As shown in Table 4-4, all the COPCs contributing to HI have neurological effects, with the exception of acetaldehyde, and most have respiratory effects. Therefore, HIs for COPC segregated by target organ/system were not calculated.

The HI range of 1 to 3 for residents living near a well pad is higher than the 0.5 HI estimated for the resident not living near a well pad. The increase is primarily due to increased concentrations of trimethylbenzenes, benzene, and xylenes observed during well completion activities.

Qualitative Risk Evaluation

Of the COPCs identified from the 2008 and Antero's 2010 well completion data sets used to evaluate the risk for residents living near a well pad, 63 did not have toxicity values. However, background information is available for 55 of these COPCs. As shown in Table 5-2, the EPC (from Table 2-10) for ten of these COPCs did not exceed the BTV, indicating they would not contribute more to risk than already contributed by the baseline. The remaining 46 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 EPCs for 6 alkanes listed in Table 5-2 exceed 100$\mu g/m^3$. Propane 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).

Four 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 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 contribute 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 Subchronic Hazard - Resident Living Near Well Pad

The subchronic HI ranges from 2 to 8 for residents living near a well pad(s). This HI range is greater than EPA's level of one above which health effects may occur. As shown in Table 4-4, all the COPCs contributing to HI have neurological effects, with the exception of acetaldehyde, and most have respiratory effects. Therefore, HIs for COPC

segregated by target organ/system were not calculated. The xylenes, benzene, and the trimethylbenzenes are the primary contributors to the HI.

Qualitative Risk Evaluation

The qualitative risk evaluation performed for chronic exposure of the resident living near a well pad also applies to the subchronic risk for a 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 contribute 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 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.

5.3.4 Acute Hazard - Child Living Near Well Pad

Ambient Air

The HI for acute hazard to a child from the ambient air pathway ranges from 2 to 7, which exceeds EPA's level of one above which health effects may occur. As shown in Table 5-4, benzene is the primary contributor to the acute hazard from air.

It is important to note that the trimethylbenzenes, 1,3-butadiene, methycyclohexane, n-hexane, n-pentane, and n-nonane, which were all COPCs identified for subchronic exposure during well completion activities were not measured in the grab samples collected when odors were noticed in the 2005 to 2007 air study. If these COPCs were present when odors were noticed, the actual acute non-cancer hazards for the child resident living near well pad may be greater.

This acute non-cancer hazard in ambient air is similar to the acute non-cancer hazard estimated (HI 2-6) in CDPHE's 2007 HHRA.

Surface Water

The HI for the acute hazard to a child from the surface water pathway is 15 which exceeds EPA's level of one above which health effects may occur. As shown in Table 5-4, benzene, ethylbenzene, and toluene are the primary contributors to the acute hazard from surface water.

Combined Ambient Air and Surface Water

The overall HI of 20 for the acute exposure of a resident child living near well pad is greater than EPA's acceptable level of one at which health effects may occur. Benzene in

ambient air and surface water and ethylbenzene and toluene in surface water are the primary contributors to the overall HI.

Qualitative 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 contribute 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 contribution to the acute non-cancer effects. It should be noted that the current state of the science is unable to assess exposures to complex mixtures of air toxics, especially interactions between chemicals that may increase or decrease their effects at low levels.

5.3.5 Acute Risk – Adults and Elderly Adults Living Near Well Pad

The HI for acute hazard to an adult or an elderly adult from the ambient air pathway ranges from 2 to 7, which exceeds 1, the EPA's level above which health effects may occur. As shown in Table 5-5, benzene is the primary contributor to the acute hazard from air.

It is important to note that the trimethylbenzenes, 1,3-butadiene, methycyclohexane, n-hexane, n-pentane, and n-nonane, which were all COPCs identified for subchronic exposure during well completion activities were not measured in the grab samples collected when odors were noticed in the 2005 to 2007 air study. If these COPCs were present when odors were noticed, the actual acute non-cancer hazards for an adult or elderly adult living near well pad may be greater.

This acute non-cancer hazard in ambient air is similar to the acute non-cancer hazard estimated (HI 2-6) in CDPHE's 2007 HHRA.

The qualitative risk evaluation performed for the resident living near a well pad also applies to the acute risk for an adult or elderly adult 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 contribute to acute non-cancer effects for adult and elderly adult residents living adjacent to well pads. Any of the six carbonyls without toxicity values also could potentially have a 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 available data 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 practice (per EPA guidance) to use health protective assumptions when uncertainty in quantifying risks exist, so as not to underestimate potential risk. Therefore the screening risk assessment approach used here is more likely to overestimate than underestimate the potential risk of individual chemicals.

Nonetheless, there are reasons to believe that the uncertainties in this HHRA may also result in an underestimation of the risk. The principal uncertainties that may have led to an underestimation of the risk are lack of data on 1) some exposure pathways (e.g., surface soil and water), 2) toxicity data for many COPCs, 3) the lack of scientific information on the potential impacts of multiple chemicals and 4) chemicals that may be associated with natural gas operations, such as PAHs, that have not been measured. In addition, the exclusion of ozone and PM from the quantitative risk assessment process means that the cancer and non-cancer impacts of these agents are not included in the estimates. The following sections discuss these uncertainties and their potential impact on the risks and hazards presented in the HHRA.

6.1 Uncertainties in Chemical Data

The scope of this screening level HHRA was to use available data to estimate a baseline risk for Battlement Mesa and Section 2 discusses the evaluation and usability of the chemical data used in the HHRA in detail.

6.1.1 Battlement Mesa Monitoring Station Data

Thirteen ambient air samples for SNMOCs and five samples for carbonyls were collected from the Battlement Mesa monitoring station over a three month period. This data was used to estimate the baseline risk in Battlement Mesa. There is 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 from year to year. Uncertainty also arises because data from the Battlement Mesa monitoring station was only collected during the fall season (September to November) and does not capture possible seasonal trends. Monitoring of baseline conditions over several years would be necessary to reduce this uncertainty.

It is important to note that the baseline risk estimated for Battlement Mesa is likely influenced by natural gas development and production operation along the perimeter of the Battlement Mesa PUD. For example, at the time the ambient air samples were collected at the Battlement Mesa monitoring station, the Watson Ranch pad was under development, as well as wells operated by companies other than Antero. The Battlement

Mesa monitoring station is within ½ mile and at times downwind from the Watson Ranch pad. This would lead to an overestimation of the "true" baseline risk, that is the baseline risk without influence from natural gas development and production operations.

6.1.2 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 163 samples for SNMOCs and 74 samples for carbonyls over the next 35 months. There is an 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. These chemicals are mostly chlorinated solvents which may not be associated with natural gas production operations. However, there association with fracking fluids and other industry formulations cannot be ruled out because not all components of fracking fluid and other industry formulations are known. 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.

6.1.3 Well Completion Data

Sixteen ambient air samples for SNMOCs were collected from the perimeter of four different well pads undergoing well completion activities in the Summer of 2008 and eight ambient air samples for a shorter list of SNOMCs were collected from the perimeter of the Watson Ranch pad in August 2010. At each well pad, one sample was collected from each of the four cardinal directions at distances ranging from 130 to 500 feet from the center of the well pads. There is uncertainty that this dataset reflects the 20-month subchronic 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 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 in ambient air and whether the dataset reflects concentrations that would be observed at homes located further than 500 feet from the well pads. This uncertainty may have resulted in an over or an under estimation of the risk. To reduce this uncertainty would require daily monitoring over all stages of well completion at a range of setback distances (e.g. from 50 to 3000 feet) from the pads for several pads.

6.1.4 Data Collected with Noticed Odors at Residences

Sample Collection

Grab samples rather than 24-hour integrated samples were collected when residents noticed odors. There is 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 noticed odors believed to be attributed to natural gas operations. There is 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 in ambient air and whether the dataset reflects concentrations that would be observed at homes located further than 500 feet from the well pads. This uncertainty may have resulted in an over or an under estimation of the risk. To reduce this uncertainty would require daily monitoring over all stages of well completion at a range of setback distances (e.g. from 50 to 3000 feet) from the pads for several pads.

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. These chemicals are mostly chlorinated solvents which may not be associated with natural gas production operations. However, their association with fracking fluids and other industry chemicals cannot be ruled out because not all components of fracking fluid and other industry chemicals are known. 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.

6.1.5 Antero Sampling

Sample Collection

Ten ambient air samples (including two field duplicates) were collected and analyzed for SNMOCs at Antero's Watson Ranch well pad during well completion and flow back activities on August 19-20, 2010 at distances 350 and 500 feet from the pad center. Eight wells were on production, one well had been drilled but not completed, three wells were on flow back and/or undergoing hydraulic fracking at the time these samples were collected. Working and breathing losses, as well as flash vapors from the condensate and produced water from the eight producing wells were collected and routed to a combustor. It is uncertain if this scenario is representative of completion operations that will occur in the Battlement Mesa PUD. If more wells will be flowing back and/or undergoing hydraulic fracking the concentrations of COPCs in the ambient air may be higher, leading to an underestimation of the risk presented in this HHRA. If fewer wells will be flowing back and/or undergoing hydraulic fracking the concentrations of COPCs in the ambient air may be lower, leading to an overestimation of the risk presented in this HHRA. In addition, Antero has indicated that they are developing a lower emission fracking tank. If this fracking tank better controlled emissions during hydraulic fracking and/or flow back, concentrations of COPCs would be expected to be lower and the risk presented here would be an overestimate. It is noted that it would be necessary to test this new technology and compare it to the current technology, through the collection of ambient air samples, to show that it results in lower concentrations of COPCs at various set back distances and under various meteorological conditions. There is uncertainty that this dataset reflects the 20-month subchronic 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 day to day.

In addition, two grab samples for for carbonyl analysis were collected for analysis of 13 carbonyls by EPA method TO-11a. These samples were collected at 350 feet and 500 feet to the South of the well pad, along the access road. There is uncertainty in how well 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. There also is uncertainty how well 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 in ambient air and whether the dataset reflects concentrations that would be observed at homes located further than 500 feet from the well pads. This uncertainty may have resulted in an over or an under estimation of the risk. To reduce this uncertainty would require daily monitoring over all stages of well completion at a range of setback distances (e.g. from 50 to 3000 feet) from the pads for several pads.

6.1.6 Surface Water Run-off Data

One sample of snow melt from one well pad was collected and analyzed for BTEX at the project Rulison site. It is uncertain how well 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. It is noted that if well pads and production tanks have berms compliant with current COGCC rules, the possibility of run off is greatly diminished and the risk from surface water would likely be overestimated.

6.1.7 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 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 at the same frequency as other ambient air sampling.

6.1.8 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 and Antero's 2010 sampling to estimate exposure during well completion, using default reasonable maximum exposure factor values, and estimating exposure point concentrations based on 95% UCLs and maximum 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 may have led to an underestimation of the risk.

Several potentially complete pathways, such as exposure to surface soil were not evaluated in this HHRA because data was not available or potential for exposure is low. Excluding these pathways may lead to underestimation of the risk. It is important to note

that the risk estimates presented in this HHRA do not consider a scenario of groundwater contamination as a result of natural gas production operations, which is then used as a source of drinking water.

6.2.2 Use of Bell-Melton Ranch Monitoring Station

There is uncertainty that the Bell-Melton Ranch monitoring station is representative of a residential exposure in the breathing zone 24 hours a day over 30 years. Concentrations of the COPCs in indoor air within the home and at the workplace may differ from the concentrations measured in the ambient air samples and may be higher or lower. It is not known if concentrations of COPCs could be concentrated in indoor environments (e.g. drawing in ambient air at air intakes) or whether a building or home would provide a shielding effect with windows closed and air intakes shut off. Therefore it is not known if this uncertainty contributed to an over or under estimation of the chronic risk presented in this HHRA. However, this uncertainty also would apply to the baseline risk, subchronic, and acute risk estimates and would not effect the overall conclusion that the chronic risk for all residents is estimated to be similar to the baseline risk, that potential health risks for residents living near well pads are higher than the baseline risk and the chronic risk for all residents, and that there is a higher potential for short term to subchronic health risks during well completion activities. Measurement of COPCs in indoor air as well as measurement of personal exposures would be necessary to reduce this uncertainty.

There also is 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 because the natural gas resource in Battlement Mesa has a higher fraction of hydrocarbons with 6 or more carbons than the resource in Mamm Creek.

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 from sources other than the natural gas industry, leading to an underestimation of the risk calculated in the

HHRA. The additional risk from a greater population density would likely be from other sources than natural gas operations.

- 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 the chronic risk to Battlement Mesa residents from Antero's proposed project contributes uncertainty to the risk estimates. Actual risks may be lower or higher, but are not likely to change the overall conclusion of the HHRA.

6.2.3 Use of Well Completion Samples

As with the samples collected at the Bell-Melton Ranch monitoring station, there is 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 20 months. Actual concentrations may be higher or lower. Additionally, most samples were collected at distances nearer the well head than the 500 foot set back proposed by Antero. However, it is noted that in Antero's sampling higher concentrations of COPCs were observed in samples collected at 500 feet than 350 feet. This highlights the fact the transport and fate of COPCs is not well understood. It is not known if the risk is over or under estimated.

Much uncertainty in the short term (7-day acute risk) scenario stems from inability to monitor intermittent peak exposures. The nature of oil and gas operations is such that emissions vary strongly with time, as evidenced in the 2008 Air Toxics Study (CDPHE 2009a), and the short term risks presented in this HHRA may be either over or underestimated. 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 RME values are recommended. In general, there is a higher uncertainty and protectiveness of health involved in using default values instead of site-specific values. Using the RME values of living for 30 years in a home for 350 days per year and 24 hours per day may have contributed to an overestimation mostly to the chronic (long-term) risk. However, site-specific data on how long residents live in the area and how many days and hours they spend in their homes is not currently available. Because more retirees live in Battlement Mesa than in more typical suburban/rural areas, data from other areas and studies may not apply to Battlement Mesa. It is important to note that the same RME's were applied to the baseline risk estimate for Battlement Mesa. Therefore, the overall conclusion that the chronic risk for all residents is estimated to be similar to the baseline risk and that potential health risks for residents living near well pads are higher than the baseline risk and the chronic risk for all residents is not affected by this potential overestimation.

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. If these COPCs are not included in the calculation of chronic risk for all Battlement Mesa residents, the cancer risk is reduced from 6.1E-0.5 to 5E-05 and the HI is reduced from 0.5 to 0.4. The cancer risk for Battlement Mesa residents living near a well pad is reduced from a range of 7.4E-05 to 9.3E-05 to a range of 6.4E-5 to 8.2E-05, and the HI remains the same. Excluding these COPCs from the subchronic risk scenario results in no change to the calculated HIs. Therefore, excluding these COPCs would not change the conclusions of the HHRA because the cancer risks remain above EPA's target of 1E-06, the HI for residents living near a well pad and the HI for the subchronic exposure scenario remain above EPA's level of one, and the risk for residents living near a well pad remain higher than those for residents not living near a well pad.

The maximum detected concentration from the carbonyl data collected by Antero in August was used as the EPC to estimate acute exposures of child, adult, and elderly residents living near a well pad. Using the maximum concentration may contribute to an overestimation of the short term (acute) risk calculated in this HHRA. However, the intention of the acute exposure scenario was to evaluate the MEI. It is noted that the concentrations of carbonyls measured in these grab samples were approximately 10 times the concentration measured in ambient air samples at Bell-Melton Ranch and Battlement Mesa and that no other measurements of carbonyls from samples collected during well completion activities are available. The carbonyls that were identified as COPCs may be associated with diesel emissions and Antero's samples were collected in the vicinity of truck traffic servicing the well pad.

Results from only one sample were available to estimate the EPC in surface water for an acute exposure to a child resident. This may have lead to either an overestimation or underestimation of the acute risk calculated in this HHRA for a child resident.

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.

It is noted here that the potential for exposure of children to COPCs via surface water is greatly reduced if the spill and pad run off prevention measures and spill remediation procedures specified in the Colorado Oil and Gas Conservation Commission rules, along with Antero's proposed Best Management Practices are rigorously applied and enforced.

6.2.7 Exposures for Elderly Adults

The Battlement Mesa community is different from other Colorado communities in that 19.8 percent of the community is over 65 years old. Elderly adults may have some exposures that differ from younger adults because of differences in physiology and behavior. Elderly adults may have pre-existing morbidity, such as cardiovascular disease that could be aggravated by exposures to COPCs in ambient air that are tolerated by healthier, younger adults. Several studies have found that elderly adults are more susceptible to the health effects of air pollution. Those aged at least 85 years had a 2-7% increase in mortality on high pollution days compared to those under 64 years in urban Chilean centers (Cakmak 2011). A study in South Korean found that exposure to toluene and xylene exerts a harmful effect on pulmonary function by exacerbating oxidative stress in adults at least 60 years of age (Yoon 2010). Adults aged greater than 60 years were found to be at higher risk for mortality from coronary heart disease than younger adults on days with elevated black carbon concentrations in a large cohort study in Vancouver (Gan 2010).

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 may lead to an overestimation of 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 $\mu g/m^3$. 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.

In addition, an IUR is not reported in EPA's IRIS for ethylbenzene. The toxicity of ethylbenzene was evaluated using an IUR from CALEPA based on inhalation studies. The 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)

It is noted that the uncertainty in the IURs used for benzene, crotonaldehyde, and ethylbenzene would not effect the overall conclusion that the chronic risk for all residents is estimated to be similar to the baseline risk, that potential health risks for residents living near well pads are higher than the baseline risk and the chronic risk for all residents, and that there is a higher potential for short term to subchronic health risks during well completion activities.

The IUR for 1,4-dichlorobenzene also is 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. Excluding 1,4-dichlorobenzene from the chronic risk calculations lowers the cancer risk estimate for all Battlement Mesa residents from 6.1E-05 to 5E-05 and the cancer risk estimate to Battlement Mesa residents living near a well from a range of 7.4 to 9.3E-05 to a range of 6.4 to 8.2E-05.

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 chronic RfCs for acetaldehyde, formaldehyde, 2-hexanone, and 1,3-butadiene were used for the subchronic exposure scenario. This may have contributed to an overestimation of the subchronic risk from ambient air. Without these COPCs included

in the calculation of the subchronic risk, the HI is reduced from a range of 2 to 8 to a range of 2 to 7.

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. Excluding ethylbenzene from the calculation for acute risk from surface lowers the HI from 15 to 14.

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 or underestimated of the risk from surface water. Therefore the HI from the acute surface water exposure may be overestimated or underestimated.

6.3.2 COPCs without toxicity values

A source 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 for all exposure scenarios, but the level of underestimation is uncertain.

6.3.3 Potential COPCs Not Measured

Another source 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, drilling mud, and other chemicals used by the industry, 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). 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, drilling mud, and other industry chemicals. The list includes carcinogenic PAHs, metals, irritants, and odorous compounds, such as glutaraldehyde. It is important to note that MSDSs do no capture all chemicals that may be present at a site or used in a process, as some chemical components are proprietary. Cancer risks and non-cancer hazards may be underestimated without data for these chemicals but the level of uncertainty is unknown.

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 and flares. 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 MSDSs for hydraulic fracturing fluids, as well as being one of the components of the natural gas resource. Cancer risks may be 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 for several reasons. Human epidemiological studies have found an association between adverse health outcomes and elevated ambient levels of these compounds. It is unclear how local intermittent elevations of these compounds impact health. These contaminants are regulated by National Ambient Air Quality Standards (NAAQS). The purpose of the NAAQSs is to protect human health. However, there has been much debate over whether the 75 ppb (averaged over 8 hours) NAAQS for ozone is protective and EPA is proposing a lower NAAQS of 60 to 70ppb. 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.

Ozone

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 in healthy adults. These adverse health impacts may be more long-lasting and pronounced in sensitive populations, such as people with asthma, children, and adults over 65 years of age. Children have been found to have irreversible decreased lung capacity. 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 5^{th} out of 64 Colorado counties in levels of these ozone precursors in 2009, while Garfield ranked only 14^{th} in population (CDPHE 2009c). These reports conclude that in the presence of the high VOCs observed in Garfield County, it is likely that ozone formation is limited by nitrogen oxides. Natural gas industry practices of flaring may increase nitrogen oxide emissions, while reducing VOC emissions which may contribute to more ozone formation In 2009, the 8-hr average

ozone concentrations measured at the Rifle monitoring station did not exceed the 75 ppb NAAQS. However, 8-hour average ozone concentrations did exceed the minimum range of the proposed 60 -70 ppb NAAQS on five days in March and April 2009, with a maximum concentration of 64 ppb (Garfield County 2010). For days on which the minimum range of the proposed 8-hour ozone NAAQS 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, elderly 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. In addition, flaring and diesel engines used for generators also may contribute to $PM_{2.5.}$ The NAAQSs for $PM_{2.5}$ are 35 $\mu g/m^3$ (24-hour, 98^{th} percentile averaged over 3 years) and 15 $\mu g/m^3$ (annual, mean averaged over 3 years). The NAAQS for PM_{10} is 150 $\mu g/m^3$ (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 NAAQSs. However, several 24-hour $PM_{2.5}$ concentrations exceeded 35$\mu g/m^3$ in 2009. The highest observed concentration was 41$\mu g/m^3$ (Garfield County 2010). $PM_{2.5}$ concentrations measured during the 2008 Air Toxics Study were all less than the 24-hour NAAQS ranging from 4.9 to 20.5 $\mu g/m^3$ (Garfield County 2009). For days on which the 24-hour $PM_{2.5}$ NAAQS 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 many 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 and flare combustors 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 theoretical potential that some chemical mixtures may result in negating the harmful effects of the individual chemicals resulting in the over- estimation of risk. However, data showing chemical mixtures are protective is lacking.

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 and a study performed by Antero in 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 21 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
- Methylene chloride
- 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 primarily 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

Five exposure scenarios were evaluated:

(1) A long-term chronic exposure scenario for child, adult, and elderly residents
(2) A long-term chronic exposure scenario for child, adult, and elderly residents living near well pads.
(3) A subchronic exposure scenario for Battlement Mesa child, adult, and elderly residents, living near a well pad.
(4) An acute exposure scenario for child residents living near well pads.
(5) An acute exposure scenario for adults and elderly residents living near a well pad.

Residents living within ½ mile of a well pad were considered as living near a well pad based on odor complaints filed with COGCC in July and August 2010.

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

As with all risk assessments and as discussed in Section 6, there is uncertainty associated with the risk estimates presented in this HHRA. Sources of uncertainty that may have lead to an overestimation of risk include using default RMEs assumptions, using chemicals that were only detected once in calculating EPCs, using chronic RfCs values when subchronic values were not available, uncertainty in the inhalation unit risk factors for crotonaldehyde, ethylbenzene, and 1,4-dichlorobenzene, and inclusion of COPCs that may not be associated with the natural gas industry. Sources of uncertainty that may led to an underestimation of the risk include, lack of information on chemicals that may be associated with natural gas development and production that were not measured, lack of toxicity information on most chemicals that were detected in the air samples, lack of information on synergistic effects in mixtures, not accounting for ozone and $PM_{2.5}$, lack of data for soil and surface water exposure pathways, and SQLs for several non-detected chemicals that were greater the risk screening levels. Sources of uncertainty with an unknown direction of bias include using six years of data from the Bell-Melton ranch monitoring station to for a 30-year duration in Battlement Mesa, limited background data, lack of data on concentrations of COPCs in ambient air during a variety of well completion activities and at various setbacks for the wellheads, and lack of data for concentrations of COPCs during peak short term exposures in the breathing zone of residents.

7.2 Conclusions

The data evaluated in this HHRA suggest that there is a potential for natural gas development and production operations within the Battlement Mesa PUD to negatively impact public health. As shown in Figure 7-1, there is greater potential for non-cancer health effects to child, adult, and elderly Battlement Mesa residents living near the well

pads than those not living near well pads and from the baseline estimate, from short term (acute) exposure to COPCs and subchronic exposure to COPCs in ambient air during well development and completion activities. In addition, there also is the potential for non-cancer health effects to child residents living near well pads from short term exposure to COPCs in surface water. Non-cancer health effects may include respiratory effects such as upper airway irritation and decreased lung function, neurological effects such as headaches and dizziness, immunological effects such as anemia, and developmental effects such as birth defects.

There also may be a negative impact to public health through chronic ambient air exposures resulting in an increase in the excess lifetime risk of cancer for Battlement Mesa residents living near well pads compared to residents not living near well pads and the baseline risk, as shown in Figure 7-2.

The following bullets summarize the conclusions for each of the five exposure scenarios.

- The estimated HI of 20 for acute non-cancer hazard to a child resident living near well pad is greater than EPA's level of one above which health effects may occur. Benzene, the trimethylbenzenes, and n-nonane in ambient air and toluene in surface water are the primary contributors to this HI. Potential COPCs, such as PAHs and chemicals in hydraulic fracturing and other natural gas industry chemicals, that were not measured, ozone, $PM_{2.5,}$ PM_{10}, and COPCs without toxicity values also could contribute 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 near the well pads. It is noted that the potential for exposure of children to COPCs in surface water is greatly reduced if the spill and pad run off prevention measures and spill remediation procedures specified in the Colorado Oil and Gas Conservation Commission rules, along with Antero's proposed Best Management Practices are rigorously applied and enforced.
- The estimated HI of 2 to 7 for acute non-cancer hazard to an adult and elderly resident is greater than EPA's level of one at which health effects may occur. Benzene, the trimethylbenzenes and n-nonane in ambient air are the primary contributors to this HI. 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 also could contribute to the acute non-cancer hazard. These potential unmeasured contributions could increase the acute non-cancer hazard via inhalation for Battlement Mesa adult and elderly residents living near the well pads.
- The estimate HI of 2 to 8 for the subchronic non-cancer hazard to child, adult, and elderly residents living near a well pad is greater than EPA's level of one at which health effects may occur. The xylenes, trimethylbenzenes, toluene, and benzene are the primary contributors to this HI. 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 also could contribute to the subchronic non-cancer hazard. These potential unmeasured contributions could increase the

subchronic non-cancer hazard via inhalation for Battlement Mesa child, adult, and elderly residents living near the well pads.

- The estimated lifetime excess cancer risk of 74 to 93 cancers per one million people for Battlement Mesa residents living near a well pad, while within EPA's generally 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 generally acceptable range. It also exceeds the baseline cancer risk of 55 per million. Thus in this screening level assessment the increase in estimated cancer risk over baseline for each person living near a well pad is between 19 and 38 in a million. This increased risk for individuals is greater than the baseline risk and is attributable to Antero's natural gas development and production activities. Considered in the context of the population in Battlement Mesa, this translates to a population attributable risk (PAR) of less than 1 cancer in a population of 5,041 residents. Another way to interpret this cancer risk is that each person living in Battlement Mesa may incur a 19 to 38 in a million chance over baseline of becoming an excess cancer case due to Antero's gas production activities.
- The estimated HI of 1 to 3 for non-cancer hazards to Battlement Mesa residents living near a well pad 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 underestimated. 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 near the well pads.
- The estimated cancer risk of 61 cancers per one million people 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 the baseline risk of 55 in a million. Not all COPCs identified in the all Battlement Mesa chronic exposure scenario were measured for the baseline risk. Excluding the chemicals not measured for the baseline risk from the cancer risk estimate result in a cancer risk lower than the baseline risk. This cancer risk translates to a PAR of less than 1 cancer in a population of 5,041 residents. Another way to interpret this cancer risk is that each person living in Battlement Mesa may incur a 6 in a million chance over baseline of becoming an excess cancer case due to Antero's gas production activities. However, it is important to note that 1,4-dichlorobenzene and methylene chloride, two of the cancer risk drivers at Bell-Melton Ranch, were not measured at Battlement Mesa monitoring station. The cancer risk estimated for Bell-Melton Ranch, without considering the 1,4-dichlorobenzene and methylene chloride, of 5.0E-05 is lower than the baseline cancer risk calculated for Battlement Mesa.
- The estimated HI of 0.5 for non-cancer hazards is less than one, below which health effects are not expected to occur and is the same as the HI calculated for the baseline. 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 and other natural gas industry chemicals 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.

The estimates for cancer risks and non-cancer hazards from chronic and acute ambient air exposures resulting from natural gas development and production activities presented in this HHRA are similar to the conclusions of previous risk assessments performed by CDPHE and by the Saccomono Institute. This HHRA also presents estimates for non-cancer hazards from subchronic exposures to ambient air during well completion activities and non-cancer hazards from acute exposures of children to surface water that have not been presented in previous risk assessments.

While the cancer risks presented here are within EPA's generally acceptable range, guidance from USEPA Region 8 states that "the level of total cancer risk that is of concern is a matter of personal, community, and regulatory judgment." In general, the USEPA considers excess cancer risks that are below about 1 chance in 1,000,000 (1×10-6 or 1E-06) to be so small as to be negligible, and risks above 1E-04 to be sufficiently large that some sort of remediation is desirable. Excess cancer risks that range between 1 and a million and 1 in 10,000 are generally considered to be acceptable, although this is evaluated on a case-by-case basis and EPA may determine that risks lower than 1 in 10,000 are not sufficiently protective and warrant remedial action" (http://www.epa.gov/region8/r8risk/hh_risk.html). Therefore, it is a decision for the risk managers (Garfield County BOCC) in consultation with stakeholders to determine if the estimated cancer risks, with all their uncertainties, warrant risk reducing actions.

Much of the limitations and uncertainties in the risks presented in this HHRA stem from the fact that only existing data was used. No data was collected specifically for this HHRA and there are several data gaps, which Section 8 describes in greater detail. That being said, it is important to state that most of the limitations and uncertainties apply equally to the baseline risk, the chronic risks for all Battlement Mesa residents, and the chronic, subchronic, and acute risks for Battlement Mesa residents living near well pads. There is more certainty in the comparison of the risks for these scenarios. The data that does exist shows that concentrations of several COPCs, including benzene, in ambient air are significantly higher near the well pads during well development and completion activities than in ambient air the at Bell-Melton Ranch and Battlement Mesa monitoring stations. Comparing the risks shows that there is a higher potential for chronic, short term, and subchronic non-cancer health effects and a greater lifetime excess cancer risk for residents living near the well pads compared to baseline and compared to residents not living near the well pads (See Figures 7-1 and 7-2).

8 Key Data Gaps

Concentrations of several chemicals in ambient air that may be directly or indirectly associated with natural gas development and production activities are not known. Data that is necessary to model the fate and transport of COPCs in ambient air and to determine exposures in the personal breathing zone is lacking. Also lacking is the data necessary to understand ambient air concentrations associated with differing natural gas

development and production activities, as well as data on the time residents actually spend in Battlement Mesa. Specifically, the following data is needed to address these uncertainties and to provide a more accurate estimate of the risks to human health from Antero's proposed project in Battlement Mesa.

- Baseline air data for PAHs, ozone, $PM_{2.5}$, and other chemicals potentially associated with natural gas development and production collected within the Battlement Mesa PUD.
- 24-hour air monitoring data for SNMOCs, carbonyls, PAHs, ozone, $PM_{2.5}$, and other chemicals associated with well development and completion collected at 50 to 3000 foot set backs from well heads at all stages of well development and completion.
- Short-term acute and 24-hour air monitoring data for SNMOCs, carbonyls, PAHs, $PM_{2.5}$, and other chemicals associated with well installation collected at the point of exposure (e.g., direct measurements in the breathing zone and at residences) during all stages of well completion and when odors are noticed.
- Continued 24-hour air monitoring data for SNMOCs, carbonyls, PAHs, ozone, $PM_{2.5}$, and chemicals associated with well installation collected at the Battlement Mesa monitoring station.
- Detailed meteorological data for the Battlement Mesa PUD.
- Geological and hydrogeological data specific to the Battlement Mesa PUD.
- Baseline surface soil and surface water data for VOCs, PAHs, and metals.
- Surface soil and surface water data for VOCs, PAHs, and metals from active well pads
- Data on length of residency and the number of days and hours per day Battlement Mesa residents spend in their homes and other areas within Battlement Mesa.
- Toxicity values for 62 air toxics.
- Baseline and continued monitoring of chlorinated VOCs with MRLs at or below EPA RSLs.
- Lastly, a comprehensive modeling approach to estimate exposures to the various chemical stressors over the life of Antero's natural gas project in Battlement Mesa.

The development of these data sources and comprehensive modeling strategies will be needed to predict health impacts over the life of the Antero Project.

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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 ($\mu g/m^3$)	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 November 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

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

$\mu g/m^3$ = 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 November 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 November 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 RSLs[1]

September - November 2010 Ambient Air Data Battlement Mesa

Human Health Risk Assessment

Battlement Mesa Health Impact Assessment

Chemical	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?
1,2,3-Trimethylbenzene	13	13	100	yes	1.07E-01	7.3 E+00[2]	7.30E-01	no	7.73E-02	no
1,2,4-Trimethylbenzene	13	13	100	yes	4.31E-01	7.30E+00	7.30E-01	no	3.17E-01	no
1,3,5-Trimethylbenzene	13	13	100	yes	3.29E-01	7.3 E+00[2]	7.30E-01	no	2.34E-01	no
1,3-Butadiene	**13**	**7**	**54**	**yes**	**7.96E-02**	**8.10E-02**	**8.10E-03**	**yes**	**4.93E-02**	**yes**
1-Decene	13	0	0	no	-	-	-	-	-	no
1-Dodecene	**13**	**10**	**77**	**yes**	**2.10E-01**	**NA**	**NA**	**-**	**8.65E-02**	**yes**
1-Heptene	**13**	**13**	**100**	**yes**	**9.58E-01**	**NA**	**NA**	**-**	**5.59E-01**	**yes**
1-Hexene	**13**	**13**	**100**	**yes**	**2.90E-01**	**NA**	**NA**	**-**	**1.54E-01**	**yes**
1-Nonene	**13**	**11**	**85**	**yes**	**1.17E-01**	**NA**	**NA**	**-**	**8.53E-02**	**yes**
1-Octene	**13**	**10**	**77**	**yes**	**2.63E-01**	**NA**	**NA**	**-**	**1.39E-01**	**yes**
1-Pentene	**13**	**13**	**100**	**yes**	**1.37E+00**	**NA**	**NA**	**-**	**2.91E-01**	**yes**
1-Tridecene	13	0	0	no	-	-	-	-	-	no
1-Undecene	**13**	**1**	**8**	**yes**	**1.59E-01**	**NA**	**NA**	**-**	**-**	**yes**
2,2,3-Trimethylpentane	**13**	**13**	**100**	**yes**	**2.23E-01**	**NA**	**NA**	**-**	**1.46E-01**	**yes**
2,2,4-Trimethylpentane	**13**	**11**	**85**	**yes**	**4.75E-01**	**NA**	**NA**	**-**	**1.78E-01**	**yes**
2,2-Dimethylbutane	**13**	**13**	**100**	**yes**	**1.42E+00**	**NA**	**NA**	**-**	**5.71E-01**	**yes**
2,3,4-Trimethylpentane	**13**	**12**	**92**	**yes**	**2.34E-01**	**NA**	**NA**	**-**	**9.59E-02**	**yes**
2,3-Dimethylbutane	**13**	**13**	**100**	**yes**	**2.84E+00**	**NA**	**NA**	**-**	**1.09E+00**	**yes**
2,3-Dimethylpentane	**13**	**13**	**100**	**yes**	**1.18E+00**	**NA**	**NA**	**-**	**6.11E-01**	**yes**
2,4-Dimethylpentane	**13**	**13**	**100**	**yes**	**8.31E-01**	**NA**	**NA**	**-**	**3.66E-01**	**yes**
2,5-Dimethylbenzaldehyde	5	0	0	no	-	-	-	-	-	no
2-Ethyl-1-butene	13	0	0	no	-	-	-	-	-	no
2-Methyl-1-butene	**13**	**11**	**85**	**yes**	**5.68E+00**	**NA**	**NA**	**-**	**7.55E-01**	**yes**
2-Methyl-1-pentene	**13**	**1**	**8**	**yes**	**2.31E-01**	**NA**	**NA**	**-**	**-**	**yes**
2-Methyl-2-butene	**13**	**12**	**92**	**yes**	**2.74E+00**	**NA**	**NA**	**-**	**4.64E-01**	**yes**
2-Methylheptane	**13**	**13**	**100**	**yes**	**7.42E-01**	**NA**	**NA**	**-**	**4.90E-01**	**yes**
2-Methylhexane	**13**	**13**	**100**	**yes**	**2.17E+00**	**NA**	**NA**	**-**	**1.16E+00**	**yes**
2-Methylpentane	**13**	**12**	**92**	**yes**	**1.08E+01**	**NA**	**NA**	**-**	**3.86E+00**	**yes**
3-Methyl-1-butene	13	0	0	no	-	-	-	-	-	no

Table 2-4

Summary Statistics and Selection of COPCs by Comparison to EPA RSLs[1]

September - November 2010 Ambient Air Data Battlement Mesa

Human Health Risk Assessment

Battlement Mesa Health Impact Assessment

Chemical	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?
3-Methylheptane	**13**	**13**	**100**	**yes**	**6.89E-01**	**NA**	**NA**	**-**	**4.23E-01**	**yes**
3-Methylhexane	**13**	**13**	**100**	**yes**	**2.40E+00**	**NA**	**NA**	**-**	**1.38E+00**	**yes**
3-Methylpentane	**13**	**13**	**100**	**yes**	**5.99E+00**	**NA**	**NA**	**-**	**2.27E+00**	**yes**
4-Methyl-1-pentene	**13**	**4**	**31**	**yes**	**1.30E-01**	**NA**	**NA**	**-**	**8.23E-02**	**yes**
Acetaldehyde	**5**	**5**	**100**	**yes**	**1.60E+00**	**1.10E+00**	**1.10E-01**	**yes**	**1.07E+00**	**yes**
Acetone	5	5	100	yes	8.72E+00	3.20E+04	3.20E+03	no	6.73E+00	no
Acetylene	**13**	**13**	**100**	**yes**	**8.57E-01**	**NA**	**NA**	**-**	**5.89E-01**	**yes**
a-Pinene	**13**	**7**	**54**	**yes**	**1.63E-01**	**NA**	**NA**	**-**	**7.94E-02**	**yes**
Benzaldehyde	**5**	**5**	**100**	**yes**	**1.06E+00**	**NA**	**NA**	**-**	**4.39E-01**	**yes**
Benzene	**13**	**13**	**100**	**yes**	**2.91E+00**	**3.10E-01**	**3.10E-02**	**yes**	**1.31E+00**	**yes**
b-Pinene	**13**	**1**	**8**	**yes**	**2.32E-01**	**NA**	**NA**	**-**	**-**	**yes**
Butyraldehyde	**5**	**5**	**100**	**yes**	**2.06E-01**	**NA**	**NA**	**-**	**1.13E-01**	**yes**
cis-2-Butene	**13**	**13**	**100**	**yes**	**3.48E+00**	**NA**	**NA**	**-**	**6.70E-01**	**yes**
cis-2-Hexene	13	0	0	no	-	-	-	-	-	no
cis-2-Pentene	**13**	**13**	**100**	**yes**	**1.40E+00**	**NA**	**NA**	**-**	**2.71E-01**	**yes**
Crotonaldehyde	**5**	**5**	**100**	**yes**	**1.55E-01**	**NA**	**NA**	**-**	**8.83E-02**	**yes**
Cyclohexane	13	13	100	yes	3.22E+00	6.30E+03	6.30E+02	no	2.00E+00	no
Cyclopentane	**13**	**13**	**100**	**yes**	**1.78E+00**	**NA**	**NA**	**-**	**6.44E-01**	**yes**
Cyclopentene	**13**	**1**	**8**	**yes**	**6.63E-02**	**NA**	**NA**	**-**	**-**	**yes**
Ethane	**13**	**13**	**100**	**yes**	**8.18E+01**	**NA**	**NA**	**-**	**4.33E+01**	**yes**
Ethylbenzene	**13**	**13**	**100**	**yes**	**3.98E-01**	**9.70E-01**	**9.70E-02**	**yes**	**2.79E-01**	**yes**
Ethylene	**13**	**13**	**100**	**yes**	**1.56E+00**	**NA**	**NA**	**-**	**9.56E-01**	**yes**
Formaldehyde	**5**	**5**	**100**	**yes**	**2.36E+00**	**1.90E-01**	**1.90E-02**	**yes**	**1.62E+00**	**yes**
Hexaldehyde	**5**	**5**	**100**	**yes**	**4.01E-01**	**NA**	**NA**	**-**	**1.38E-01**	**yes**
Isobutane	**13**	**13**	**100**	**yes**	**3.68E+01**	**NA**	**NA**	**-**	**1.28E+01**	**yes**
Isobutene/1-Butene	**13**	**13**	**100**	**yes**	**2.44E+00**	**NA**	**NA**	**-**	**7.36E-01**	**yes**
Isopentane	**13**	**13**	**100**	**yes**	**6.67E+01**	**NA**	**NA**	**-**	**1.58E+01**	**yes**
Isoprene	**13**	**13**	**100**	**yes**	**3.06E-01**	**NA**	**NA**	**-**	**1.65E-01**	**yes**
Isopropylbenzene	13	10	77	yes	8.80E-02	4.20E+02	4.20E+01	-	6.63E-02	no
Isovaleraldehyde	5	0	0	no	-	-	-	-	-	no

Table 2-4

Summary Statistics and Selection of COPCs by Comparison to EPA RSLs[1]

September - November 2010 Ambient Air Data Battlement Mesa

Human Health Risk Assessment

Battlement Mesa Health Impact Assessment

Chemical	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-Diethylbenzene	**13**	**6**	**46**	**yes**	**8.20E-02**	**NA**	**NA**	**-**	**6.13E-02**	**yes**
Methylcyclohexane	**13**	**13**	**100**	**yes**	**6.88E+00**	**NA**	**NA**	**-**	**4.05E+00**	**yes**
Methylcyclopentane	**13**	**13**	**100**	**yes**	**4.11E+00**	**NA**	**NA**	**-**	**2.11E+00**	**yes**
m-Ethyltoluene	**13**	**13**	**100**	**yes**	**3.22E-01**	**NA**	**NA**	**-**	**2.05E-01**	**yes**
m-Xylene/p-Xylene	13	13	100	yes	1.75E+00	7.30E+02	7.30E+01	no	1.36E+00	no
n-Butane	**13**	**12**	**92**	**yes**	**5.14E+01**	**NA**	**NA**	**-**	**1.90E+01**	**yes**
n-Decane	**13**	**13**	**100**	**yes**	**5.66E-01**	**NA**	**NA**	**-**	**4.30E-01**	**yes**
n-Dodecane	**13**	**13**	**100**	**yes**	**6.68E-01**	**NA**	**NA**	**-**	**2.68E-01**	**yes**
n-Heptane	**13**	**13**	**100**	**yes**	**2.72E+00**	**NA**	**NA**	**-**	**1.68E+00**	**yes**
n-Hexane	13	13	100	yes	7.17E+00	7.30E+02	7.30E+01	no	3.43E+00	no
n-Nonane	13	13	100	yes	7.40E-01	2.10E+02	2.10E+01	no	5.62E-01	no
n-Octane	**13**	**13**	**100**	**yes**	**1.64E+00**	**NA**	**NA**	**-**	**1.09E+00**	**yes**
n-Pentane	13	13	100	yes	3.11E+01	1.00E+03	1.00E+02	no	1.03E+01	no
n-Propylbenzene	13	13	100	yes	1.43E-01	1.00E+03	1.00E+02	no	1.06E-01	no
n-Tridecane	13	0	0	no	-	-	-	-	-	no
n-Undecane	**13**	**13**	**100**	**yes**	**9.94E-01**	**NA**	**NA**	**-**	**3.70E-01**	**yes**
o-Ethyltoluene	**13**	**12**	**92**	**yes**	**2.39E-01**	**NA**	**NA**	**-**	**1.53E-01**	**yes**
o-Xylene	13	13	100	yes	4.81E-01	7.30E+02	7.30E+01	no	3.52E-01	no
p-Diethylbenzene	**13**	**6**	**46**	**yes**	**2.18E-01**	**NA**	**NA**	**-**	**6.63E-02**	**yes**
p-Ethyltoluene	**13**	**13**	**100**	**yes**	**1.99E-01**	**NA**	**NA**	**-**	**1.48E-01**	**yes**
Propane	**13**	**13**	**100**	**yes**	**4.67E+01**	**NA**	**NA**	**-**	**2.48E+01**	**yes**
Propionaldehyde	5	5	100	yes	2.23E-01	8.30E+00	8.30E-01	no	1.11E-01	no
Propylene	13	13	100	yes	7.63E-01	3.10E+03	3.10E+02	no	4.97E-01	no
Propyne	13	0	0	no	-	NA	NA	-	-	no
Styrene	13	4	31	yes	6.50E-02	1.00E+03	1.00E+02	no	5.91E-02	no
Tolualdehydes	**5**	**5**	**100**	**yes**	**5.16E-01**	**NA**	**NA**	**-**	**2.42E-01**	**yes**
Toluene	13	13	100	yes	4.13E+00	5.20E+03	5.20E+02	no	2.71E+00	no
trans-2-Butene	**13**	**13**	**100**	**yes**	**3.84E+00**	**NA**	**NA**	**-**	**7.44E-01**	**yes**
trans-2-Hexene	**13**	**3**	**23**	**yes**	**2.56E-01**	**NA**	**NA**	**-**	**8.76E-02**	**yes**
trans-2-Pentene	**13**	**13**	**100**	**yes**	**2.68E+00**	**NA**	**NA**	**-**	**4.79E-01**	**yes**

Table 2-4

Summary Statistics and Selection of COPCs by Comparison to EPA RSLs[1]

September - November 2010 Ambient Air Data Battlement Mesa

Human Health Risk Assessment

Battlement Mesa Health Impact Assessment

Chemical	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?
Valeraldehyde	**5**	**5**	**100**	**yes**	**1.48E-01**	**NA**	**NA**	**-**	**6.27E-02**	**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, November 2010

[2]RSL = EPA regional screening levels for 1,2,4-trimethylbenzene

Table 2-5

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**	**163**	**64**	**39**	**yes**	**8.47E-01**	**7.3 E+00[2]**	**7.30E-01**	**yes**	**7.93E-02**	**yes**
1,2,4-Trimethylbenzene	**95-63-6**	**163**	**156**	**96**	**yes**	**3.09E+00**	**7.30E+00**	**7.30E-01**	**yes**	**2.61E-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**	**163**	**135**	**83**	**yes**	**1.20E+00**	**7.3 E+00[2]**	**7.30E-01**	**yes**	**1.52E-01**	**yes**
1,3-Butadiene	**106-99-0**	**163**	**12**	**7**	**yes**	**1.53E-01**	**8.10E-02**	**8.10E-03**	**yes**	**5.44E-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**	-	**yes**
1-Decene	872-05-9	163	0	0	no	-	-	-	-	-	no
1-Dodecene	**112-41-4**	**163**	**59**	**36**	**yes**	**1.02E+00**	**NA**	**NA**	-	**1.59E-01**	**yes**
1-Heptene	**592-76-7**	**163**	**153**	**94**	**yes**	**2.98E+00**	**NA**	**NA**	-	**5.85E-01**	**yes**
1-Hexene	**592-41-6**	**163**	**103**	**63**	**yes**	**3.24E-01**	**NA**	**NA**	-	**1.05E-01**	**yes**
1-Nonene	**124-11-8**	**163**	**84**	**52**	**yes**	**9.01E-01**	**NA**	**NA**	-	**1.07E-01**	**yes**
1-Octene	**111-66-0**	**163**	**47**	**29**	**yes**	**1.37E+00**	**NA**	**NA**	-	**1.10E-01**	**yes**
1-Pentene	**109-67-1**	**163**	**159**	**98**	**yes**	**3.80E-01**	**NA**	**NA**	-	**1.07E-01**	**yes**
1-Tridecene	**2437-56-1**	**163**	**12**	**7**	**yes**	**2.04E-01**	**NA**	**NA**	-	**1.01E-01**	**yes**
1-Undecene	**821-95-4**	**163**	**46**	**28**	**yes**	**2.64E+00**	**NA**	**NA**	-	**1.59E-01**	**yes**
2,2,3-Trimethylpentane	**564-02-3**	**163**	**83**	**51**	**yes**	**1.64E+00**	**NA**	**NA**	-	**1.48E-01**	**yes**
2,2,4-Trimethylpentane	**540-84-1**	**163**	**80**	**49**	**yes**	**2.48E+00**	**NA**	**NA**	-	**1.52E-01**	**yes**
2,2-Dimethylbutane	**75-83-2**	**163**	**163**	**100**	**yes**	**2.34E+00**	**NA**	**NA**	-	**5.72E-01**	**yes**
2,3,4-Trimethylpentane	**565-75-3**	**163**	**98**	**60**	**yes**	**1.79E+00**	**NA**	**NA**	-	**9.00E-02**	**yes**
2,3-Dimethylbutane	**79-29-8**	**163**	**161**	**99**	**yes**	**5.05E+00**	**NA**	**NA**	-	**1.11E+00**	**yes**

Table 2-5

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?
2,3-Dimethylpentane	**565-59-3**	**163**	**163**	**100**	**yes**	**2.18E+00**	**NA**	**NA**	**-**	**5.42E-01**	**yes**
2,4-Dimethylpentane	**108-08-7**	**163**	**162**	**99**	**yes**	**1.48E+00**	**NA**	**NA**	**-**	**3.47E-01**	**yes**
2,5-Dimethylbenzaldehyde	5779-94-2	74	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	163	1	1	no	2.75E+00	NA	NA	-	-	no
2-Hexanone	**591-78-6**	**29**	**1**	**3**	**no**	**4.40E+00**	**3.10E+01**	**3.10E+00**	**yes**	-	**yes**
2-Methyl-1-butene	**563-46-2**	**163**	**47**	**29**	**yes**	**3.94E+01**	**NA**	**NA**	**-**	**5.00E-01**	**yes**
2-Methyl-1-pentene	763-29-1	163	2	1	no	1.52E-01	NA	NA	-	9.93E-02	no
2-Methyl-2-butene	**513-35-9**	**163**	**58**	**36**	**yes**	**4.17E-01**	**NA**	**NA**	-	**8.53E-02**	**yes**
2-Methylheptane	**592-27-8**	**163**	**163**	**100**	**yes**	**2.93E+00**	**NA**	**NA**	-	**5.85E-01**	**yes**
2-Methylhexane	**591-76-4**	**163**	**161**	**99**	**yes**	**5.71E+00**	**NA**	**NA**	-	**1.31E+00**	**yes**
2-Methylpentane	**107-83-5**	**163**	**163**	**100**	**yes**	**2.20E+01**	**NA**	**NA**	-	**4.95E+00**	**yes**
3-Methyl-1-butene	**563-45-1**	**163**	**9**	**6**	**yes**	**2.00E-01**	**NA**	**NA**	-	**6.32E-02**	**yes**
3-Methylheptane	**589-81-1**	**163**	**163**	**100**	**yes**	**3.53E+00**	**NA**	**NA**	-	**3.93E-01**	**yes**
3-Methylhexane	**589-34-4**	**163**	**149**	**91**	**yes**	**4.84E+00**	**NA**	**NA**	-	**1.10E+00**	**yes**
3-Methylpentane	**96-14-0**	**163**	**163**	**100**	**yes**	**1.16E+01**	**NA**	**NA**	-	**2.54E+00**	**yes**
4-Methyl-1-pentene	**691-37-2**	**163**	**26**	**16**	**yes**	**4.68E+00**	**NA**	**NA**	-	**1.42E-01**	**yes**
4-Methyl-2-pentanone	108-10-1	29	0	0	no	-	-	-	-	-	no
Acetaldehyde	**75-07-0**	**74**	**74**	**100**	**yes**	**1.96E+00**	**1.10E+00**	**1.10E-01**	yes	**8.17E-01**	**yes**
Acetone	67-64-1	103	99	96	yes	5.70E+01	3.20E+04	3.20E+03	no	7.18E+00	no
Acetylene	**74-86-2**	**163**	**163**	**100**	**yes**	**2.92E+00**	**NA**	**NA**	**-**	**6.03E-01**	**yes**
a-Pinene	**80-56-8**	**163**	**102**	**63**	**yes**	**3.37E+00**	**NA**	**NA**	**-**	**1.79E-01**	**yes**
Benzaldehyde	**100-52-7**	**74**	**71**	**96**	**yes**	**2.52E-01**	**NA**	**NA**	**-**	**7.81E-02**	**yes**
Benzene	**71-43-2**	**192**	**176**	**92**	**yes**	**1.36E+01**	**3.10E-01**	**3.10E-02**	**yes**	**1.37E+00**	**yes**
b-Pinene	**127-91-3**	**163**	**17**	**10**	**yes**	**1.43E+00**	**NA**	**NA**	**-**	**7.95E-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**	**74**	**72**	**97**	**yes**	**2.71E-01**	**NA**	**NA**	**-**	**7.48E-02**	**yes**
Carbon Disulfide	75-15-0	29	0	0	no	-	-	-	-	-	no

Table 2-5

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?
Carbon Tetrachloride	56-23-5	29	0	0	no	-	-	-	-	-	no
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**	**163**	**94**	**58**	**yes**	**9.52E-01**	**NA**	**NA**	**-**	**7.90E-02**	**yes**
cis-2-Hexene	**7688-21-3**	**163**	**21**	**13**	**yes**	**7.00E-01**	**NA**	**NA**	**-**	**1.00E-01**	**yes**
cis-2-Pentene	**627-20-3**	**163**	**62**	**38**	**yes**	**1.45E-01**	**NA**	**NA**	**-**	**5.81E-02**	**yes**
Crotonaldehyde	**123-73-9**	**74**	**71**	**96**	**yes**	**5.53E-01**	**NA**	**NA**	**-**	**1.35E-01**	**yes**
Cyclohexane	110-82-7	163	163	100	yes	1.05E+02	6.30E+03	6.30E+02	no	3.41E+00	no
Cyclopentane	**287-92-3**	**163**	**163**	**100**	**yes**	**2.94E+00**	**NA**	**NA**	**-**	**6.65E-01**	**yes**
Cyclopentene	**142-29-0**	**163**	**72**	**44**	**yes**	**9.58E-01**	**NA**	**NA**	**-**	**1.23E-01**	**yes**
Dibromochloromethane	124-48-1	29	0	0	no	-	-	-	-	-	no
Ethane	**74-84-0**	**163**	**163**	**100**	**yes**	**4.11E+02**	**NA**	**NA**	**-**	**7.23E+01**	**yes**
Ethylbenzene	**100-41-4**	**192**	**156**	**81**	**yes**	**8.14E+00**	**9.70E-01**	**9.70E-02**	**yes**	**3.96E-01**	**yes**
Ethylene	**74-85-1**	**163**	**163**	**100**	**yes**	**2.94E+00**	**NA**	**NA**	**-**	**1.04E+00**	**yes**
Formaldehyde	**50-00-0**	**74**	**74**	**100**	**yes**	**1.02E+01**	**1.90E-01**	**1.90E-02**	**yes**	**1.18E+00**	**yes**
Hexaldehyde	**66-25-1**	**74**	**59**	**80**	**yes**	**1.31E-01**	**NA**	**NA**	**-**	**4.81E-02**	**yes**
Isobutane	**75-28-5**	**163**	**163**	**100**	**yes**	**1.18E+02**	**NA**	**NA**	**-**	**2.15E+01**	**yes**
Isobutene/1-Butene	**-11-7 / 106-9**	**163**	**119**	**73**	**yes**	**1.36E+01**	**NA**	**NA**	**-**	**1.12E+00**	**yes**
Isopentane	**78-78-4**	**163**	**158**	**97**	**yes**	**1.23E+02**	**NA**	**NA**	**-**	**1.74E+01**	**yes**
Isoprene	**78-79-5**	**163**	**116**	**71**	**yes**	**3.33E+00**	**NA**	**NA**	**-**	**3.36E-01**	**yes**
Isopropylbenzene (cumene)	98-82-8	163	62	38	yes	3.27E-01	4.20E+02	4.20E+01	no	7.67E-02	no
Isovaleraldehyde	590-86-3	74	3	4	no	1.13E-01	NA	NA	-	3.11E-03	no
m-Diethylbenzene	**141-93-5**	**163**	**59**	**36**	**yes**	**8.84E-01**	**NA**	**NA**	**-**	**8.82E-02**	**yes**
Methyl tert-Butyl Ether	1634-04-4	29	0	0	no	-	-	-	-	-	no
Methylcyclohexane	**108-87-2**	**163**	**163**	**100**	**yes**	**2.39E+01**	**NA**	**NA**	**-**	**5.00E+00**	**yes**
Methylcyclopentane	**96-37-7**	**163**	**163**	**100**	**yes**	**1.04E+01**	**NA**	**NA**	**-**	**2.38E+00**	**yes**

Table 2-5

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?
Methylene chloride	**75-09-2**	**29**	**1**	**3**	**no**	**2.90E+00**	**5.20E+00**	**5.20E-01**	**yes**	**-**	**yes**
m-Ethyltoluene	**620-14-4**	**163**	**155**	**95**	**yes**	**1.63E+00**	**NA**	**NA**	**-**	**1.81E-01**	**yes**
m-Xylene/p-Xylene	-38-3 / 106-4	192	183	95	yes	1.40E+01	7.30E+02	7.30E+01	no	1.56E+00	no
n-Butane	**106-97-8**	**163**	**160**	**98**	**yes**	**1.57E+02**	**NA**	**NA**	**-**	**2.51E+01**	**yes**
n-Decane	**124-18-5**	**163**	**160**	**98**	**yes**	**6.98E+01**	**NA**	**NA**	**-**	**9.47E-01**	**yes**
n-Dodecane	**112-40-3**	**163**	**142**	**87**	**yes**	**7.14E+01**	**NA**	**NA**	**-**	**1.02E+00**	**yes**
n-Heptane	**142-82-5**	**163**	**163**	**100**	**yes**	**1.14E+01**	**NA**	**NA**	**-**	**2.34E+00**	**yes**
n-Hexane	110-54-3	163	163	100	yes	2.50E+01	7.30E+02	7.30E+01	no	5.31E+00	no
n-Nonane	111-84-2	163	162	99	yes	3.08E+00	2.10E+02	2.10E+01	no	5.91E-01	no
n-Octane	**111-65-9**	**163**	**163**	**100**	**yes**	**6.72E+00**	**NA**	**NA**	**-**	**1.32E+00**	**yes**
n-Pentane	109-66-0	163	163	100	yes	6.20E+01	1.00E+03	1.00E+02	no	1.22E+01	no
n-Propylbenzene	103-65-1	163	108	66	yes	7.10E-01	1.00E+03	1.00E+02	no	8.46E-02	no
n-Tridecane	**629-50-5**	**163**	**45**	**28**	**yes**	**5.68E+00**	**NA**	**NA**	**-**	**1.79E-01**	**yes**
n-Undecane	**1120-21-4**	**163**	**159**	**98**	**yes**	**2.55E+02**	**NA**	**NA**	**-**	**2.28E+00**	**yes**
o-Ethyltoluene	**611-14-3**	**163**	**117**	**72**	**yes**	**1.44E+00**	**NA**	**NA**	**-**	**1.27E-01**	**yes**
o-Xylene	95-47-6	192	161	84	yes	3.61E+00	7.30E+02	7.30E+01	no	3.97E-01	no
p-Diethylbenzene	**105-05-5**	**163**	**40**	**25**	**yes**	**4.20E-01**	**NA**	**NA**	**-**	**5.42E-02**	**yes**
p-Ethyltoluene	**622-96-8**	**163**	**127**	**78**	**yes**	**1.26E+00**	**NA**	**NA**	**-**	**1.31E-01**	**yes**
Propane	**74-98-6**	**163**	**163**	**100**	**yes**	**3.16E+02**	**NA**	**NA**	**-**	**5.53E+01**	**yes**
Propionaldehyde	123-38-6	74	71	96	yes	2.47E-01	8.30E+00	8.30E-01	no	8.51E-02	no
Propylene	115-07-1	163	163	100	yes	2.46E+00	3.10E+03	3.10E+02	no	3.78E-01	no
Propyne	74-99-7	163	1	1	no	3.50E-01	NA	NA	-	5.45E-02	no
Styrene	100-42-5	192	24	13	yes	3.44E+00	1.00E+03	1.00E+02	no	2.17E-01	no
Tetrachloroethene	127-18-4	29	0	0	no	-	-	-	-	-	no
Tolualdehydes	**NA**	**74**	**65**	**88**	**yes**	**2.51E-01**	**NA**	**NA**	**-**	**7.77E-02**	**yes**
Toluene	108-88-3	192	191	99	yes	7.91E+01	5.20E+03	5.20E+02	no	3.60E+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**	**163**	**131**	**80**	**yes**	**3.34E+00**	**NA**	**NA**	**-**	**1.22E-01**	**yes**
trans-2-Hexene	4050-45-7	163	1	1	no	3.04E-02	NA	NA	-	9.94E-02	no

Table 2-5

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?
trans-2-Pentene	**4050-45-7**	**163**	**89**	**55**	**yes**	**5.00E-01**	**NA**	**NA**	**-**	**7.54E-02**	**yes**
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**	**74**	**43**	**58**	**yes**	**8.50E-02**	**NA**	**NA**	**-**	**2.32E-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, November 2010

[2]RSL = EPA regional screening levels for 1,2,4-trimethylbenzene

Table 2-6

Summary Statistics and Selection of COPCs by Comparision to EPA RSLs[1] Well Completion Operations 2008, 2010

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	24	18	75	yes	1.17E+01	1.07E+00	7.3 E+00[2]	7.30E-01	yes	yes
1,2,4-Trimethylbenzene	95-63-6	24	24	100	yes	8.30E+01	6.28E+00	7.30E+00	7.30E-01	yes	yes
1,3,5-Trimethylbenzene	108-67-8	24	24	100	yes	7.75E+01	5.53E+00	7.3 E+00[2]	7.30E-01	yes	yes
1,3-Butadiene	106-99-0	16	6	38	yes	1.66E-01	6.93E-02	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	9.24E-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	24	16	67	yes	1.63E-01	2.25E-01	NA	-	-	yes
1-Nonene	124-11-8	16	15	94	yes	1.68E+01	1.55E+00	NA	-	-	yes
1-Octene	111-66-0	16	10	63	yes	3.16E+00	3.61E-01	NA	-	-	yes
1-Pentene	109-67-1	24	16	67	yes	3.89E-01	2.58E-01	NA	-	-	yes
1-Tridecene	2437-56-1	16	6	38	yes	3.63E-01	1.30E-01	NA	-	-	yes
1-Undecene	821-95-4	16	11	69	yes	4.72E+00	5.10E-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	24	2	8	yes	1.73E+00	2.71E-01	NA	-	-	yes
2,2-Dimethylbutane	75-83-2	24	24	100	yes	4.12E+01	3.47E+00	NA	-	-	yes
2,3,4-Trimethylpentane	565-75-3	24	16	67	yes	1.21E+00	3.18E-01	NA	-	-	yes
2,3-Dimethylbutane	79-29-8	24	24	100	yes	6.58E+01	6.26E+00	NA	-	-	yes
2,3-Dimethylpentane	565-59-3	24	24	100	yes	3.56E+01	3.44E+00	NA	-	-	yes
2,4-Dimethylpentane	108-08-7	24	24	100	yes	2.36E+01	2.25E+00	NA	-	-	yes
2-Ethyl-1-butene	760-21-4	16	0	0	no	-	-	-	-	-	no
2-Methyl-1-butene	563-46-2	16	7	44	yes	1.26E+00	2.95E-01	NA	-	-	yes
2-Methyl-1-pentene	763-29-1	16	1	6	yes	8.43E-02	1.21E-01	NA	-	-	yes
2-Methyl-2-butene	513-35-9	16	9	56	yes	3.87E-01	1.03E-01	NA	-	-	yes
2-Methylheptane	592-27-8	24	24	100	yes	1.46E+02	1.14E+01	NA	-	-	yes
2-Methylhexane	591-76-4	24	24	100	yes	1.21E+02	1.12E+01	NA	-	-	yes
2-Methylpentane	107-83-5	24	24	100	yes	2.21E+02	2.38E+01	NA	-	-	yes
3-Methyl-1-butene	563-45-1	16	1	6	yes	2.49E-01	6.93E-02	NA	-	-	yes
3-Methylheptane	589-81-1	24	24	100	yes	9.74E+01	7.58E+00	NA	-	-	yes
3-Methylhexane	589-34-4	24	24	100	yes	1.14E+02	1.12E+01	NA	-	-	yes

Table 2-6

Summary Statistics and Selection of COPCs by Comparision to EPA RSLs[1] Well Completion Operations 2008, 2010

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?
3-Methylpentane	96-14-0	24	24	100	yes	1.29E+02	1.37E+01	NA	-	-	yes
4-Methyl-1-pentene	691-37-2	16	8	50	yes	9.35E-01	2.43E-01	NA	-	-	yes
Acetylene	74-86-2	24	24	100	yes	1.36E+00	4.41E-01	NA	-	-	yes
a-Pinene	80-56-8	16	16	100	yes	3.09E+01	3.04E+00	NA	-	-	yes
Benzene	71-43-2	24	24	100	yes	6.85E+01	7.80E+00	3.10E-01	3.10E-02	yes	yes
b-Pinene	127-91-3	16	7	44	yes	8.96E+00	7.65E-01	NA	-	-	yes
cis-2-Butene	590-18-1	24	15	63	yes	1.97E-01	2.19E-01	NA	-	-	yes
cis-2-Hexene	7688-21-3	16	13	81	yes	2.93E-01	1.78E-01	NA	-	-	yes
cis-2-Pentene	627-20-3	24	9	38	yes	1.48E-01	2.09E-01	NA	-	-	yes
Cyclohexane	110-82-7	24	24	100	yes	2.04E+02	2.03E+01	6.30E+03	6.30E+02	no	no
Cyclopentane	287-92-3	24	24	100	yes	2.23E+01	2.90E+00	NA	-	-	yes
Cyclopentene	142-29-0	16	16	100	yes	6.51E-01	2.21E-01	NA	-	-	yes
Ethane	74-84-0	24	24	100	yes	2.41E+03	3.18E+02	NA	-	-	yes
Ethylbenzene	100-41-4	24	24	100	yes	2.28E+02	1.22E+01	9.70E-01	9.70E-02	yes	yes
Ethylene	74-85-1	24	24	100	yes	4.19E+00	1.13E+00	NA	-	-	yes
Isobutane	75-28-5	24	24	100	yes	1.60E+03	1.17E+02	NA	-	-	yes
Isobutene/1-Butene	NA	16	7	44	yes	6.71E+00	2.03E+00	NA	-	-	yes
Isopentane	78-78-4	24	24	100	yes	8.32E+02	8.14E+01	NA	-	-	yes
Isoprene	78-79-5	24	21	88	yes	1.15E+00	4.36E-01	NA	-	-	yes
Isopropylbenzene (cumene)	98-82-8	24	14	58	yes	4.85E+00	5.34E-01	4.20E+02	4.20E+01	no	no
m&p-Xylene	1330-20-7	24	24	100	yes	8.84E+02	7.12E+01	7.30E+02	7.30E+01	yes	yes
m-Diethylbenzene	141-93-5	24	16	67	yes	7.08E+00	6.76E-01	NA	-	-	yes
Methylcyclohexane	108-87-2	24	24	100	yes	7.23E+02	6.20E+01	NA	-	-	yes
Methylcyclopentane	96-37-7	24	24	100	yes	1.20E+02	1.38E+01	NA	-	-	yes
m-Ethyltoluene	620-14-4	24	23	96	yes	4.45E+01	3.74E+00	NA	-	-	yes
n-Butane	106-97-8	24	24	100	yes	1.29E+03	1.07E+02	NA	-	-	yes
n-Decane	124-18-5	24	24	100	yes	2.08E+02	1.40E+01	NA	-	-	yes
n-Dodecane	112-40-3	24	24	100	yes	5.15E+01	5.42E+00	NA	-	-	yes
n-Heptane	142-82-5	24	24	100	yes	3.04E+02	2.76E+01	NA	-	-	yes
n-Hexane	110-54-3	24	24	100	yes	2.55E+02	2.85E+01	7.30E+02	7.30E+01	yes	yes
n-Nonane	111-84-2	24	24	100	yes	3.03E+02	2.08E+01	2.10E+02	2.10E+01	yes	yes

Table 2-6

Summary Statistics and Selection of COPCs by Comparision to EPA RSLs[1] Well Completion Operations 2008, 2010

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-Octane	**111-65-9**	**24**	**24**	**100**	**yes**	**4.17E+02**	**3.18E+01**	**NA**	**-**	**-**	**yes**
n-Pentane	**109-66-0**	**24**	**24**	**100**	**yes**	**5.53E+02**	**7.40E+01**	**1.00E+03**	**1.00E+02**	**yes**	**yes**
n-Propylbenzene	103-65-1	24	19	79	yes	1.20E+01	1.09E+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**	**24**	**24**	**100**	**yes**	**1.21E+02**	**9.79E+00**	**NA**	**-**	**-**	**yes**
o-Ethyltoluene	**611-14-3**	**24**	**20**	**83**	**yes**	**2.92E+01**	**2.06E+00**	**NA**	**-**	**-**	**yes**
o-Xylene	**95-47-6**	**24**	**24**	**100**	**yes**	**1.90E+02**	**1.30E+01**	**7.30E+02**	**7.30E+01**	**yes**	**yes**
p-Diethylbenzene	**105-05-5**	**24**	**13**	**54**	**yes**	**5.01E+00**	**5.22E-01**	**NA**	**-**	**-**	**yes**
p-Ethyltoluene	**622-96-8**	**24**	**24**	**100**	**yes**	**3.22E+01**	**2.59E+00**	**NA**	**-**	**-**	**yes**
Propane	**74-98-6**	**24**	**24**	**100**	**yes**	**4.67E+03**	**3.12E+02**	**NA**	**-**	**-**	**yes**
Propylene	115-07-1	24	24	100	yes	1.94E+00	4.95E-01	3.10E+03	3.10E+02	no	no
Propyne	74-99-7	16	0	0	no	-	-	-	-	-	no
Styrene	100-42-5	24	5	21	yes	5.90E+00	5.77E-01	1.00E+03	1.00E+02	no	no
Toluene	108-88-3	24	24	100	yes	3.19E+02	3.27E+01	5.20E+03	5.20E+02	no	no
trans-2-Butene	**624-64-6**	**24**	**15**	**63**	**yes**	**1.89E+00**	**3.71E-01**	**NA**	**-**	**-**	**yes**
trans-2-Hexene	**4050-45-7**	**16**	**1**	**6**	**yes**	**4.53E-02**	**1.18E-01**	**NA**	**-**	**-**	**yes**
trans-2-Pentene	**646-04-8**	**24**	**17**	**71**	**yes**	**1.06E+00**	**2.75E-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, November 2010

[2]RSL = EPA regional screening levels for 1,2,4-trimethylbenzene

Table 2-7
Summary Statistics and Selection of COPCs by Comparison to EPA RSLs[1]
2005-2007 Odor Events, 2010 Grab Samples
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?	95% UCL
Vinyl Chloride	75-01-4	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	-
Valeraldehyde	110-62-3	2	0	0	no	-	-	-	-	-	no	-
Trichlorotrifluoroethane	76-13-1	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	-
Trichloroethene	79-01-6	28	0	0	no	-	-	-	-	-	no	-
trans-1,3-Dichloropropene	10061-02-6	28	0	0	no	-	-	-	-	-	no	-
trans-1,2-Dichloroethene	156-60-5	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**	**2.04E+02**
Tetrachloroethene	127-18-4	28	0	0	no	-	-	-	-	-	no	-
Styrene	100-42-5	28	0	0	no	-	-	-	-	-	no	-
Proionaldehyde	123-38-6	2	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**	**5.82E+01**
m-Tolualdehyde	1334-78-7	2	0	0	no	-	-	-	-	-	no	-
Methylene chloride	75-09-2	28	0	0	no	-	-	-	-	-	no	-
Methyl tert-Butyl Ether	1634-04-4	28	0	0	no	-	-	-	-	-	no	-
Methacrolein	78-85-3	2	0	0	no	-	-	-	-	-	no	-
m,p-Xylenes	**179601-23-1**	**28**	**26**	**93**	**yes**	**1.50E+03**	**1.38E+02**	**7.30E+02**	**7.30E+01**	**yes**	**yes**	**3.38E+02**
Hexaldehyde	**66-25-1**	**2**	**2**	**100**	**yes**	**1.72E+00**	**-**	**NA**	**NA**	**-**	**yes**	-
Gluteraldehyde	111-30-8	2	0	0	no	-	-	-	-	-	no	-
Formaldehyde	**50-00-0**	**2**	**2**	**100**	**yes**	**8.28E+00**	-	**1.90E-01**	**1.90E-02**	**yes**	**yes**	-
Ethylbenzene	**100-41-4**	**28**	**19**	**68**	**yes**	**9.60E+01**	**8.87E+00**	**9.70E-01**	**9.70E-02**	**yes**	**yes**	**1.39E+01**
Dibromochloromethane	124-48-1	28	0	0	no	-	-	-	-	-	no	-
Crotonaldehyde	**123-73-9**	2	2	100	yes	1.42E+00	-	NA	NA	-	yes	-
cis-1,3-Dichloropropene	10061-01-5	28	0	0	no	-	-	-	-	-	no	-
cis-1,2-Dichloroethene	156-59-2	28	0	0	no	-	-	-	-	-	no	-
Chloromethane	74-87-3	28	1	4	no	2.20E+00	1.37E+00	9.40E+01	9.40E+00	no	no	-
Chloroform	**67-66-3**	**28**	**1**	**4**	**no**	**1.60E+00**	-	**1.10E-01**	**1.10E-02**	**yes**	**yes**	-

Table 2-7
Summary Statistics and Selection of COPCs by Comparison to EPA RSLs[1]
2005-2007 Odor Events, 2010 Grab Samples
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?	95% UCL
Chloroethane	75-00-3	28	0	0	no	-	-	-	-	-	no	-
Chlorobenzene	108-90-7	28	0	0	no	-	-	-	-	-	no	-
Carbon Tetrachloride	56-23-5	28	0	0	no	-	-	-	-	-	no	-
Carbon Disulfide	75-15-0	28	0	0	no	-	-	-	-	-	no	-
Bromomethane	74-83-9	28	0	0	no	-	-	-	-	-	no	-
Bromoform	75-25-2	28	0	0	no	-	-	-	-	-	no	-
Bromodichloromethane	75-27-4	28	0	0	no	-	-	-	-	-	no	-
Benzene	**71-43-2**	**28**	**26**	**93**	**yes**	**1.80E+02**	**3.16E+01**	**3.10E-01**	**3.10E-02**	**yes**	**yes**	6.24E+01
Benzaldehyde	**100-52-7**	2	0	0	no	-	-	NA	NA	-	yes	-
Acrolein	107-02--8	2	0	0	no	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Acetone	67-64-1	28	22	79	yes	8.10E+01	2.81E+01	3.20E+04	3.20E+03	no	no	-
Acetaldehyde	**75-07-0**	**2**	**2**	**100**	**yes**	**5.49E+00**	**-**	**1.10E+00**	**1.10E-01**	**yes**	**yes**	**-**
4-Methyl-2-pentanone	108-10-1	28	0	0	no	-	-	-	-	-	no	-
2-Hexanone	591-78-6	28	4	14	yes	2.40E+00	1.47E+00	3.10E+01	3.10E+00	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	-
1,4-Dichlorobenzene	106-46-7	28	0	0	no	-	-	-	-	-	no	-
1,3-Dichlorobenzene	541-73-1	28	0	0	no	-	-	-	-	-	no	-
1,2-Dichloropropane	78-87-5	28	0	0	no	-	-	-	-	-	no	-
1,2-Dichloroethane	107-06-2	28	0	0	no	-	-	-	-	-	no	-
1,2-Dichlorobenzene	95-50-1	28	0	0	no	-	-	-	-	-	no	-
1,2-Dibromoethane	106-93-4	28	0	0	no	-	-	-	-	-	no	-
1,1-Dichloroethene	75-35-4	28	0	0	no	-	-	-	-	-	no	-
1,1-Dichloroethane	75-34-3	28	0	0	no	-	-	-	-	-	no	-
1,1,2-Trichloroethane	79-00-5	28	0	0	no	-	-	-	-	-	no	-
1,1,2,2-Tetrachloroethane	79-34-5	28	0	0	no	-	-	-	-	-	no	-
1,1,1-Trichloroethane	71-55-6	28	0	0	no	-	-	-	-	-	no	-

Notes:

Table 2-7

Summary Statistics and Selection of COPCs by Comparison to EPA RSLs[1]

2005-2007 Odor Events, 2010 Grab Samples

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?	95% UCL

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, November 2010

Table 2-8
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 2-8
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 2-8
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 2-8
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 2-9
95% UCLs and Selection of EPCs[1]
September to November 2010 Battlement Mesa Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Maximum Detected Concentration (µg/m^3)	95% UCL[2] (µg/m^3)	Statistical Method to Calculate 95% UCL	EPC (µg/m^3)
1,3-Butadiene	7.96E-02	NC	Maximum	7.96E-02
1-Dodecene	2.10E-01	1.16E-01	KM (t)	1.16E-01
1-Heptene	9.58E-01	6.80E-01	Student t	6.80E-01
1-Hexene	2.90E-01	1.88E-01	Student t	1.88E-01
1-Nonene	1.17E-01	9.92E-02	KM (t)	9.92E-02
1-Octene	2.63E-01	1.77E-01	KM (t)	1.77E-01
1-Pentene	1.37E+00	7.04E-01	Chebyshev	7.04E-01
1-Undecene	1.59E-01	NC	Maximum	1.59E-01
2,2,3-Trimethylpentane	2.23E-01	1.73E-01	Student t	1.73E-01
2,2,4-Trimethylpentane	4.75E-01	3.53E-01	KM (Chebyshev)	3.53E-01
2,2-Dimethylbutane	1.42E+00	7.31E-01	Approximate Gamma	7.31E-01
2,3,4-Trimethylpentane	2.34E-01	1.21E-01	KM (BCA)	1.21E-01
2,3-Dimethylbutane	2.84E+00	1.47E+00	Approximate Gamma	1.47E+00
2,3-Dimethylpentane	1.18E+00	7.40E-01	Student t	7.40E-01
2,4-Dimethylpentane	8.31E-01	4.67E-01	Student t	4.67E-01
2-Methyl-1-butene	5.68E+00	2.67E+00	KM (Chebyshev)	2.67E+00
2-Methyl-1-pentene	2.31E-01	NC	Maximum	2.31E-01
2-Methyl-2-butene	2.74E+00	1.36E+00	KM (Chebyshev)	1.36E+00
2-Methylheptane	7.42E-01	5.80E-01	Student t	5.80E-01
2-Methylhexane	2.17E+00	1.42E+00	Student t	1.42E+00
2-Methylpentane	1.08E+01	5.22E+00	KM (BCA)	5.22E+00
3-Methylheptane	6.89E-01	5.00E-01	Student t	5.00E-01
3-Methylhexane	2.40E+00	1.66E+00	Student t	1.66E+00
3-Methylpentane	5.99E+00	3.04E+00	Approximate Gamma	3.04E+00
4-Methyl-1-pentene	1.30E-01	1.08E-01	KM (t)	1.08E-01
Acetaldehyde	1.60E+00	NC	Maximum	1.60E+00
Acetylene	8.57E-01	6.77E-01	Student t	6.77E-01
a-Pinene	1.63E-01	1.08E-01	KM (t)	1.08E-01
Benzaldehyde	1.06E+00	NC	Maximum	1.06E+00
Benzene	2.91E+00	1.62E+00	Student t	1.62E+00
b-Pinene	2.32E-01	NC	Maximum	2.32E-01
Butyraldehyde	2.06E-01	NC	Maximum	2.06E-01
cis-2-Butene	3.48E+00	1.85E+00	Chebyshev	1.85E+00
cis-2-Pentene	1.40E+00	4.57E-01	H-UCL	4.57E-01
Crotonaldehyde	1.55E-01	NC	Maximum	1.55E-01
Cyclopentane	1.78E+00	8.77E-01	Approximate Gamma	8.77E-01
Cyclopentene	6.63E-02	NC	Maximum	6.63E-02
Ethane	8.18E+01	5.35E+01	Student t	5.35E+01
Ethylbenzene	3.98E-01	3.16E-01	Student t	3.16E-01
Ethylene	1.56E+00	1.09E+00	Student t	1.09E+00
Formaldehyde	2.36E+00	NC	Maximum	2.36E+00
Hexaldehyde	4.01E-01	NC	Maximum	4.01E-01
Isobutane	3.68E+01	1.92E+01	Approximate Gamma	1.92E+01

Table 2-9
95% UCLs and Selection of EPCs[1]
September to November 2010 Battlement Mesa Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Maximum Detected Concentration (µg/m^3)	95% UCL[2] (µg/m^3)	Statistical Method to Calculate 95% UCL	EPC (µg/m^3)
Isobutene/1-Butene	2.44E+00	1.62E+00	Chebyshev	1.62E+00
Isopentane	6.67E+01	3.19E+01	H-UCL	3.19E+01
Isoprene	3.06E-01	2.04E-01	Student t	2.04E-01
m-Diethylbenzene	8.20E-02	NC	Maximum	8.20E-02
Methylcyclohexane	6.88E+00	4.94E+00	Student t	4.94E+00
Methylcyclopentane	4.11E+00	2.65E+00	Student t	2.65E+00
m-Ethyltoluene	3.22E-01	2.34E-01	Student t	2.34E-01
n-Butane	5.14E+01	3.88E+01	KM (Chebyshev)	3.88E+01
n-Decane	5.66E-01	4.87E-01	Student t	4.87E-01
n-Dodecane	6.68E-01	3.42E-01	Student t	3.42E-01
n-Heptane	2.72E+00	2.04E+00	Student t	2.04E+00
n-Octane	1.64E+00	1.28E+00	Student t	1.28E+00
n-Undecane	9.94E-01	4.97E-01	Approximate Gamma	4.97E-01
o-Ethyltoluene	2.39E-01	1.78E-01	KM (t)	1.78E-01
p-Diethylbenzene	2.18E-01	1.04E-01	KM (t)	1.04E-01
p-Ethyltoluene	1.99E-01	1.63E-01	Student t	1.63E-01
Propane	4.67E+01	3.06E+01	Student t	3.06E+01
Tolualdehydes	5.16E-01	NC	Maximum	5.16E-01
trans-2-Butene	3.84E+00	2.09E+00	Chebyshev	2.09E+00
trans-2-Hexene	2.56E-01	NC	Maximum	2.56E-01
trans-2-Pentene	2.68E+00	9.07E-01	H-UCL	9.07E-01
Valeraldehyde	1.48E-01	NC	Maximum	1.48E-01

Notes:

[1]EPC = Exposure Point Concentration: The lower value between the UCL and maximum detected value.
For contaminants with < 10 detections a UCL was not calculated and the maximum value was used for the EPC

[2]UCL = Upper Confidence Limit calculated for 2010 Battlement Mesa monitoring station data using EPA's ProUCL v. 4.005 (EPA
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.
µg/m^3 = micrograms per cubic meter

Table 2-9
95% UCLs and Selection of EPCs[1]
September to November 2010 Battlement Mesa Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Table 2-9
95% UCLs and Selection of EPCs[1]
September to November 2010 Battlement Mesa Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

2010)

Table 2-10
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 Concentration (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	9.82E-02	KM (t)	9.82E-02
1,2,4-Trimethylbenzene	3.09E+00	3.13E-01	KM (BCA)	3.13E-01
1,3,5-Trimethylbenzene	1.20E+00	1.74E-01	KM (t)	1.74E-01
1,3-Butadiene	1.53E-01	4.65E-02	KM (t)	4.65E-02
1,4-Dichlorobenzene	2.30E+00	NC	Maximum	2.30E+00
1-Dodecene	1.02E+00	1.85E-01	KM (t)	1.85E-01
1-Heptene	2.98E+00	6.47E-01	KM (BCA)	6.47E-01
1-Hexene	3.24E-01	1.11E-01	KM (Percentile bootstrap)	1.11E-01
1-Nonene	9.01E-01	1.18E-01	KM (t)	1.18E-01
1-Octene	1.37E+00	1.34E-01	KM (t)	1.34E-01
1-Pentene	3.80E-01	1.14E-01	KM (BCA)	1.14E-01
1-Tridecene	2.04E-01	8.73E-02	KM (t)	8.73E-02
1-Undecene	2.64E+00	2.04E-01	KM (t)	2.04E-01
2,2,3-Trimethylpentane	1.64E+00	1.82E-01	KM (t)	1.82E-01
2,2,4-Trimethylpentane	2.48E+00	2.01E-01	KM (BCA)	2.01E-01
2,2-Dimethylbutane	2.34E+00	7.12E-01	KM (Chebyshev)	7.12E-01
2,3,4-Trimethylpentane	1.79E+00	1.18E-01	KM (BCA)	1.18E-01
2,3-Dimethylbutane	5.05E+00	1.23E+00	KM (BCA)	1.23E+00
2,3-Dimethylpentane	2.18E+00	5.81E-01	H-UCL	5.81E-01
2,4-Dimethylpentane	1.48E+00	3.80E-01	KM (BCA)	3.80E-01
2-Hexanone	4.40E+00	NC	Maximum	4.40E+00
2-Methyl-1-butene	3.94E+01	9.10E-01	KM (BCA)	9.10E-01
2-Methyl-2-butene	4.17E-01	9.86E-02	KM (t)	9.86E-02
2-Methylheptane	2.93E+00	6.43E-01	H-UCL	6.43E-01
2-Methylhexane	5.71E+00	1.43E+00	KM (BCA)	1.43E+00
2-Methylpentane	2.20E+01	6.20E+00	Chebyshev	6.20E+00
3-Methyl-1-butene	2.00E-01	9.39E-02	KM (t)	9.39E-02
3-Methylheptane	3.53E+00	5.20E-01	Chebyshev	5.20E-01
3-Methylhexane	4.84E+00	1.24E+00	KM (BCA)	1.24E+00
3-Methylpentane	1.16E+01	3.21E+00	Chebyshev	3.21E+00
4-Methyl-1-pentene	4.68E+00	1.95E-01	KM (t)	1.95E-01
Acetaldehyde	1.96E+00	8.88E-01	student t	8.88E-01
Acetylene	2.92E+00	6.55E-01	H-UCL	6.55E-01
a-Pinene	3.37E+00	2.29E-01	KM (BCA)	2.29E-01
Benzaldehyde	2.52E-01	8.97E-02	KM (BCA)	8.97E-02
Benzene	1.36E+01	1.54E+00	KM (BCA)	1.54E+00
b-Pinene	1.43E+00	1.06E-01	KM (t)	1.06E-01
Butyraldehyde	2.71E-01	8.51E-02	KM (BCA)	8.51E-02
cis-2-Butene	9.52E-01	9.60E-02	KM (t)	9.60E-02
cis-2-Hexene	7.00E-01	7.62E-02	KM (t)	7.62E-02
cis-2-Pentene	1.45E-01	6.80E-02	KM (t)	6.80E-02
Crotonaldehyde	5.53E-01	1.63E-01	KM (BCA)	1.63E-01
Cyclopentane	2.94E+00	8.28E-01	Chebyshev	8.28E-01

Table 2-10
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 Concentration (µg/m^3)	95% UCL[2] (µg/m^3)	Statistical Method to Calculate 95% UCL	EPC (µg/m^3)
Cyclopentene	9.58E-01	1.51E-01	KM (t)	1.51E-01
Ethane	4.11E+02	8.27E+01	H-UCL	8.27E+01
Ethylbenzene	8.14E+00	3.89E-01	KM (BCA)	3.89E-01
Ethylene	2.94E+00	1.11E+00	appproximate gamma	1.11E+00
Formaldehyde	1.02E+01	1.25E+00	H-UCL	1.25E+00
Hexaldehyde	1.31E-01	5.87E-02	KM (Percentile bootstrap)	5.87E-02
Isobutane	1.18E+02	2.83E+01	Chebyshev	2.83E+01
Isobutene/1-Butene	1.36E+01	1.74E+00	KM (Chebyshev)	1.74E+00
Isopentane	1.23E+02	1.97E+01	KM (BCA)	1.97E+01
Isoprene	3.33E+00	5.07E-01	KM (Chebyshev)	5.07E-01
Isovaleraldehyde	1.13E-01	NC	Maximum	1.13E-01
m-Diethylbenzene	8.84E-01	1.08E-01	KM (t)	1.08E-01
Methylcyclohexane	2.39E+01	6.29E+00	Chebyshev	6.29E+00
Methylcyclopentane	1.04E+01	2.63E+00	H-UCL	2.63E+00
Methylene chloride	2.90E+00	NC	Maximum	2.90E+00
m-Ethyltoluene	1.63E+00	2.09E-01	KM (BCA)	2.09E-01
m-Xylene/p-Xylene	1.40E+01	1.79E+00	KM (BCA)	1.79E+00
n-Butane	1.57E+02	2.83E+01	KM (BCA)	2.83E+01
n-Decane	6.98E+01	1.80E+00	KM (BCA)	1.80E+00
n-Dodecane	7.14E+01	2.99E+00	KM (Chebyshev)	2.99E+00
n-Heptane	1.14E+01	2.58E+00	H-UCL	2.58E+00
n-Hexane	2.50E+01	6.73E+00	Chebyshev	6.73E+00
n-Nonane	3.08E+00	6.55E-01	KM (BCA)	6.55E-01
n-Octane	6.72E+00	1.46E+00	H-UCL	1.46E+00
n-Pentane	6.20E+01	1.38E+01	H-UCL	1.38E+01
n-Tridecane	5.68E+00	2.44E-01	KM (BCA)	2.44E-01
n-Undecane	2.55E+02	9.08E+00	KM (Chebyshev)	9.08E+00
o-Ethyltoluene	1.44E+00	1.55E-01	KM (BCA)	1.55E-01
o-Xylene	3.61E+00	3.68E-01	KM (BCA)	3.68E-01
p-Diethylbenzene	4.20E-01	6.91E-02	KM (t)	6.91E-02
p-Ethyltoluene	1.26E+00	1.54E-01	KM (BCA)	1.54E-01
Propane	3.16E+02	6.25E+01	KM (BCA)	6.25E+01
Tolualdehydes	2.51E-01	9.12E-02	KM (BCA)	9.12E-02
trans-2-Butene	3.34E+00	1.78E-01	KM (BCA)	1.78E-01
trans-2-Pentene	5.00E-01	8.99E-02	KM (BCA)	8.99E-02
Valeraldehyde	8.50E-02	3.38E-02	KM (t)	3.38E-02

[1]EPC = Exposure Point Concentration: The lower value between the UCL and maximum detected value.
For contaminants with < 10 detections a UCL was not calculated and the maximum value was used for the EPC

[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

Table 2-10
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 Concentration ($\mu g/m^3$)	95% UCL[2] ($\mu g/m^3$)	Statistical Method to Calculate 95% UCL	EPC ($\mu g/m^3$)

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 2-11
95% UCLs and Selection of EPCs[1]
Well Completion 2008 and 2010
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Maximum Detected Concentration (µg/m^3)	95% UCL[2] (µg/m^3)	Statistical Method to Calculate 95% UCL	EPC (µg/m^3)
1,2,3-Trimethylbenzene	1.17E+01	3.20E+00	KM (Chebyshev)	3.20E+00
1,2,4-Trimethylbenzene	8.30E+01	2.11E+01	KM (Chebyshev)	2.11E+01
1,3,5-Trimethylbenzene	7.75E+01	1.95E+01	KM (Chebyshev)	1.95E+01
1,3-Butadiene	1.66E-01	NC	Maximum	1.66E-01
1-Dodecene	6.08E+00	2.60E+00	KM (Chebyshev)	2.60E+00
1-Heptene	6.08E+01	2.39E+01	KM (Chebyshev)	2.39E+01
1-Hexene	1.63E-01	5.31E-01	KM (Chebyshev)	1.63E-01
1-Nonene	1.68E+01	6.08E+00	KM (Chebyshev)	6.08E+00
1-Octene	3.16E+00	1.22E+00	KM (Chebyshev)	1.22E+00
1-Pentene	3.89E-01	3.85E-01	KM (BCA)	3.85E-01
1-Tridecene	3.63E-01	NC	Maximum	3.63E-01
1-Undecene	4.72E+00	1.78E+00	KM (Chebyshev)	1.78E+00
2,2,3-Trimethylpentane	2.47E+01	9.35E+00	KM (Chebyshev)	9.35E+00
2,2,4-Trimethylpentane	1.73E+00	NC	Maximum	1.73E+00
2,2-Dimethylbutane	4.12E+01	1.11E+01	KM (Chebyshev)	1.11E+01
2,3,4-Trimethylpentane	1.21E+00	6.78E-01	KM (Chebyshev)	6.78E-01
2,3-Dimethylbutane	6.58E+01	1.91E+01	KM (Chebyshev)	1.91E+01
2,3-Dimethylpentane	3.56E+01	1.00E+01	KM (Chebyshev)	1.00E+01
2,4-Dimethylpentane	2.36E+01	6.61E+00	KM (Chebyshev)	6.61E+00
2-Methyl-1-butene	1.26E+00	NC	Maximum	1.26E+00
2-Methyl-1-pentene	8.43E-02	NC	Maximum	8.43E-02
2-Methyl-2-butene	3.87E-01	1.61E-01	KM (BCA)	1.61E-01
2-Methylheptane	1.46E+02	3.82E+01	KM (Chebyshev)	3.82E+01
2-Methylhexane	1.21E+02	3.34E+01	KM (Chebyshev)	3.34E+01
2-Methylpentane	2.21E+02	6.82E+01	KM (Chebyshev)	6.82E+01
3-Methyl-1-butene	2.49E-01	NC	Maximum	2.49E-01
3-Methylheptane	9.74E+01	2.53E+01	KM (Chebyshev)	2.53E+01
3-Methylhexane	1.14E+02	3.21E+01	KM (Chebyshev)	3.21E+01
3-Methylpentane	1.29E+02	3.91E+01	KM (Chebyshev)	3.91E+01
4-Methyl-1-pentene	9.35E-01	NC	Maximum	9.35E-01
Acetylene	1.36E+00	5.48E-01	Approximate Gamma	5.48E-01
a-Pinene	3.09E+01	1.13E+01	KM (Chebyshev)	1.13E+01
Benzene	6.85E+01	2.04E+01	KM (Chebyshev)	2.04E+01
b-Pinene	8.96E+00	NC	Maximum	8.96E+00
cis-2-Butene	1.97E-01	9.45E-02	KM (Chebyshev)	9.45E-02
cis-2-Hexene	2.93E-01	2.35E-01	KM (t)	2.35E-01
cis-2-Pentene	1.48E-01	NC	Maximum	1.48E-01
Cyclopentane	2.23E+01	7.82E+00	KM (Chebyshev)	7.82E+00
Cyclopentene	6.51E-01	3.84E-01	KM (Chebyshev)	3.84E-01
Ethane	2.41E+03	7.81E+02	KM (Chebyshev)	7.81E+02
Ethylbenzene	2.28E+02	5.36E+01	KM (Chebyshev)	5.36E+01
Ethylene	4.19E+00	1.36E+00	Approximate Gamma	1.36E+00
Isobutane	1.60E+03	4.12E+02	KM (Chebyshev)	4.12E+02

Table 2-11
95% UCLs and Selection of EPCs[1]
Well Completion 2008 and 2010
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Maximum Detected Concentration (µg/m^3)	95% UCL[2] (µg/m^3)	Statistical Method to Calculate 95% UCL	EPC (µg/m^3)
Isobutene/1-Butene	6.71E+00	NC	Maximum	6.71E+00
Isopentane	8.32E+02	2.46E+02	KM (Chebyshev)	2.46E+02
Isoprene	1.15E+00	8.04E-01	KM (Chebyshev)	8.04E-01
m-Diethylbenzene	7.08E+00	2.05E+00	KM (Chebyshev)	2.05E+00
Methylcyclohexane	7.23E+02	1.94E+02	KM (Chebyshev)	1.94E+02
Methylcyclopentane	1.20E+02	3.76E+01	KM (Chebyshev)	3.76E+01
m-Ethyltoluene	4.45E+01	1.17E+01	KM (Chebyshev)	1.17E+01
m&p-Xylene	8.84E+02	2.44E+02	KM (Chebyshev)	2.44E+02
n-Butane	1.29E+03	3.57E+02	KM (Chebyshev)	3.57E+02
n-Decane	2.08E+02	5.14E+01	KM (Chebyshev)	5.14E+01
n-Dodecane	5.15E+01	1.56E+01	KM (Chebyshev)	1.56E+01
n-Heptane	3.04E+02	8.39E+01	KM (Chebyshev)	8.39E+01
n-Hexane	2.55E+02	7.96E+01	KM (Chebyshev)	7.96E+01
n-Nonane	3.03E+02	7.55E+01	KM (Chebyshev)	7.55E+01
n-Octane	4.17E+02	1.08E+02	KM (Chebyshev)	1.08E+02
n-Pentane	5.53E+02	2.13E+02	KM (Chebyshev)	2.13E+02
n-Tridecane	9.05E+00	4.07E+00	KM (Chebyshev)	4.07E+00
n-Undecane	1.21E+02	3.17E+01	KM (Chebyshev)	3.17E+01
o-Ethyltoluene	2.92E+01	7.31E+00	KM (Chebyshev)	7.31E+00
o-Xylene	1.90E+02	4.85E+01	KM (Chebyshev)	4.85E+01
p-Diethylbenzene	5.01E+00	9.66E-01	KM (BCA)	9.66E-01
p-Ethyltoluene	3.22E+01	4.40E+00	Approximate Gamma	4.40E+00
Propane	4.67E+03	1.16E+03	KM (Chebyshev)	1.16E+03
trans-2-Butene	1.89E+00	8.51E-01	KM (Chebyshev)	8.51E-01
trans-2-Hexene	4.53E-02	NC	Maximum	4.53E-02
trans-2-Pentene	1.06E+00	6.75E-01	KM (Chebyshev)	6.75E-01

Notes:

[1]EPC = Exposure Point Concentration: The lower value between the UCL and maximum detected value.
For contaminants with < 10 detections a UCL was not calculated and the maximum value was used for the EPC

[2]UCL = Upper Confidence Limit calculated for 2008 and 2010 well completion 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.

µg/m^3 = micrograms per cubic meter
CAS = Chemical Abstract Service

Table 2-12
Comparison of Means between Well Completion Samples and Bell-Melton Ranch Samples
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Statistic	Benzene		1,2,4-Trimethylbenzene		1,3,5-Trimethylbenzene		Ethylbenzene		Methylcyclohexane		m,p-Xylene	
	Well Completion	Bell-Melton Ranch	Well Completion	Bell-Melton Ranch	Well Completion	Bell-Melton Ranch	Well Completion	Bell-Melton Ranch	Well Completion	Bell-Melton Ranch	Well Completion	Bell-Melton Ranch
Minimum (µg/m^3)	0.941	0.0958	0.439	0.0634	0.331	0.024	0.253	0.0564	3.068	0.145	1.997	0.162
Maximum (µg/m3)	68.55	13.63	82.98	3.091	77.52	1.202	228.4	8.141	722.5	23.92	884.5	14
Mean (µg/m3)	7.802	1.444	6.278	0.264	5.531	0.159	12.23	0.528	62.05	4.931	71.23	1.607
Median (µg/m3)	2.601	1.073	1.663	0.184	1.291	0.123	0.771	0.183	14.03	3.694	7.788	1.012
SD (µg/m3)	14.12	1.351	16.66	0.342	15.64	0.132	46.51	0.874	148.7	3.969	193.8	1.814
U-Statistic		5.858		7.556		7.733		5.493		6.534		7.145
Mann-Whitney Test P-value		***<0.001***		***<0.001***		***<0.001***		***<0.001***		***<0.001***		***<0.001***

Statistic	n-Hexane		n-nonane		n-Pentane		o-Xylene		Toluene		Ethane	
	Well Completion	Bell-Melton Ranch	Well Completion	Bell-Melton Ranch	Well Completion	Bell-Melton Ranch	Well Completion	Bell-Melton Ranch	Well Completion	Bell-Melton Ranch	Well Completion	Bell-Melton Ranch
Minimum (µg/m^3)	1.697	0.132	1.199	0.0635	3.943	0.225	0.383	0.064	2.73	0.106	31.81	1.082
Maximum (µg/m3)	254.9	24.96	302.8	3.077	552.9	61.96	190.5	3.609	318.7	79.13	2405	411.3
Mean (µg/m3)	28.54	5.306	20.84	0.591	74.05	12.18	12.99	0.519	32.73	3.604	317.7	72.32
Median (µg/m3)	7.724	4	3.593	0.439	10.53	9.088	1.232	0.233	7.833	2.078	107.9	49.25
SD (µg/m3)	57.41	4.182	61.47	0.492	156.2	9.82	39.92	0.648	66.74	8.217	520.8	69.57
U-Statistic		4.28		7.612		1.555		5.995		6.667		4.801
Mann-Whitney Test P-value		***<0.001***		***<0.001***		0.06		***<0.001***		***<0.001***		***<0.001***

Notes:
Bold-italic font indicates statisitical significance at an alpha of 0.05
µg/m^3 = micrograms per cubic meter
SD = standard deviation

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

Chemical	Chronic EPC[1] (µg/m^3)	Chronic Non-cancer Intake (µg/m^3)	Chronic Cancer Intake (µg/m^3)
1,3-Butadiene	7.96E-02	7.64E-02	3.27E-02
1-Dodecene	1.16E-01	1.11E-01	4.77E-02
1-Heptene	6.80E-01	6.52E-01	2.79E-01
1-Hexene	1.88E-01	1.80E-01	7.73E-02
1-Nonene	9.92E-02	9.51E-02	4.08E-02
1-Octene	1.77E-01	1.70E-01	7.27E-02
1-Pentene	7.04E-01	6.75E-01	2.89E-01
1-Undecene	1.59E-01	1.53E-01	6.55E-02
2,2,3-Trimethylpentane	1.73E-01	1.66E-01	7.11E-02
2,2,4-Trimethylpentane	3.53E-01	3.38E-01	1.45E-01
2,2-Dimethylbutane	7.31E-01	7.01E-01	3.00E-01
2,3,4-Trimethylpentane	1.21E-01	1.16E-01	4.97E-02
2,3-Dimethylbutane	1.47E+00	1.41E+00	6.05E-01
2,3-Dimethylpentane	7.40E-01	7.10E-01	3.04E-01
2,4-Dimethylpentane	4.67E-01	4.48E-01	1.92E-01
2-Methyl-1-butene	2.67E+00	2.56E+00	1.10E+00
2-Methyl-1-pentene	2.31E-01	2.22E-01	9.49E-02
2-Methyl-2-butene	1.36E+00	1.30E+00	5.58E-01
2-Methylheptane	5.80E-01	5.56E-01	2.38E-01
2-Methylhexane	1.42E+00	1.36E+00	5.84E-01
2-Methylpentane	5.22E+00	5.00E+00	2.14E+00
3-Methylheptane	5.00E-01	4.79E-01	2.05E-01
3-Methylhexane	1.66E+00	1.59E+00	6.83E-01
3-Methylpentane	3.04E+00	2.92E+00	1.25E+00
4-Methyl-1-pentene	1.08E-01	1.04E-01	4.44E-02
Acetaldehyde	1.60E+00	1.54E+00	6.58E-01
Acetylene	6.77E-01	6.49E-01	2.78E-01
a-Pinene	1.08E-01	1.04E-01	4.44E-02
Benzaldehyde	1.06E+00	1.02E+00	4.35E-01
Benzene	1.62E+00	1.55E+00	6.66E-01
b-Pinene	2.32E-01	2.22E-01	9.53E-02
Butyraldehyde	2.06E-01	1.98E-01	8.48E-02
cis-2-Butene	1.85E+00	1.77E+00	7.60E-01
cis-2-Pentene	4.57E-01	4.38E-01	1.88E-01
Crotonaldehyde	1.55E-01	1.48E-01	6.36E-02
Cyclopentane	8.77E-01	8.41E-01	3.60E-01
Cyclopentene	6.63E-02	6.36E-02	2.72E-02
Ethane	5.35E+01	5.13E+01	2.20E+01
Ethylbenzene	3.16E-01	3.03E-01	1.30E-01
Ethylene	1.09E+00	1.04E+00	4.47E-01
Formaldehyde	2.36E+00	2.26E+00	9.69E-01
Hexaldehyde	4.01E-01	3.85E-01	1.65E-01
Isobutane	1.92E+01	1.84E+01	7.87E+00
Isobutene/1-Butene	1.62E+00	1.55E+00	6.64E-01
Isopentane	3.19E+01	3.05E+01	1.31E+01
Isoprene	2.04E-01	1.96E-01	8.38E-02
m-Diethylbenzene	8.20E-02	7.86E-02	3.37E-02
Methylcyclohexane	4.94E+00	4.74E+00	2.03E+00

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

Chemical	Chronic EPC[1] (µg/m^3)	Chronic Non-cancer Intake (µg/m^3)	Chronic Cancer Intake (µg/m^3)
Methylcyclopentane	2.65E+00	2.54E+00	1.09E+00
m-Ethyltoluene	2.34E-01	2.24E-01	9.62E-02
n-Butane	3.88E+01	3.72E+01	1.60E+01
n-Decane	4.87E-01	4.67E-01	2.00E-01
n-Dodecane	3.42E-01	3.28E-01	1.41E-01
n-Heptane	2.04E+00	1.96E+00	8.39E-01
n-Octane	1.28E+00	1.23E+00	5.27E-01
n-Undecane	4.97E-01	4.77E-01	2.04E-01
o-Ethyltoluene	1.78E-01	1.71E-01	7.32E-02
p-Diethylbenzene	1.04E-01	9.97E-02	4.27E-02
p-Ethyltoluene	1.63E-01	1.56E-01	6.70E-02
Propane	3.06E+01	2.93E+01	1.26E+01
Tolualdehydes	5.16E-01	4.95E-01	2.12E-01
trans-2-Butene	2.09E+00	2.00E+00	8.57E-01
trans-2-Hexene	2.56E-01	2.45E-01	1.05E-01
trans-2-Pentene	9.07E-01	8.70E-01	3.73E-01
Valeraldehyde	1.48E-01	1.42E-01	6.08E-02

Notes:

µg/m^3: micrograms per cubic meter

EPC: Exposure Concentration

[1]EPC for chronic exposure (30 year duration) of all Battlement Mesa residents from September to November 2011 (See Table 2-9)

Table 3-2
Cancer and Non-Cancer Air Intake Values for Chronic and Subchronic Exposures
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Chronic EPC[1] (µg/m^3)	Subchronic Maximum (µg/m^3)	Subchronic 95%UCL[2] (µg/m^3)	TWA with Subchronic Maximum[3] (µg/m^3)	TWA with Subchronic 95%UCL[3] (µg/m^3)	Chronic Non-cancer Intake (µg/m^3)	TWA Non-cancer Intake with maximum (µg/m^3)	TWA Non-cancer Intake with 95%UCL (µg/m^3)	Chronic Cancer Intake (µg/m^3)	TWA Cancer Intake with Maximum (µg/m^3)	TWA Cancer Intake with 95%UCL (µg/m^3)
1,2,3-Trimethylbenzene	9.82E-02	1.17E+01	3.20E+00	7.42E-01	2.71E-01	9.42E-02	7.11E-01	2.59E-01	4.04E-02	3.05E-01	1.11E-01
1,2,4-Trimethylbenzene	3.13E-01	8.30E+01	2.11E+01	4.91E+00	1.47E+00	3.00E-01	4.70E+00	1.41E+00	1.29E-01	2.02E+00	6.03E-01
1,3,5-Trimethylbenzene	1.74E-01	7.75E+01	1.95E+01	4.47E+00	1.24E+00	1.67E-01	4.29E+00	1.19E+00	7.15E-02	1.84E+00	5.12E-01
1,3-Butadiene	4.65E-02	1.66E-01	1.66E-01	5.31E-02	5.31E-02	4.46E-02	5.09E-02	5.10E-02	1.91E-02	2.18E-02	2.18E-02
1,4-Dichlorobenzene	2.30E+00	2.30E+00	2.30E+00	2.30E+00	2.30E+00	2.21E+00	2.21E+00	2.21E+00	9.45E-01	9.45E-01	9.45E-01
1-Dodecene	1.85E-01	6.08E+00	2.60E+00	5.12E-01	3.19E-01	1.77E-01	4.91E-01	3.06E-01	7.60E-02	2.11E-01	1.31E-01
1-Heptene	6.47E-01	6.08E+01	2.39E+01	3.99E+00	1.94E+00	6.20E-01	3.82E+00	1.86E+00	2.66E-01	1.64E+00	7.96E-01
1-Hexene	1.11E-01	1.63E-01	1.63E-01	1.14E-01	1.14E-01	1.06E-01	1.09E-01	1.09E-01	4.56E-02	4.68E-02	4.68E-02
1-Nonene	1.18E-01	1.68E+01	6.08E+00	1.04E+00	4.49E-01	1.13E-01	1.00E+00	4.31E-01	4.85E-02	4.29E-01	1.85E-01
1-Octene	1.34E-01	3.16E+00	7.37E-01	3.02E-01	1.68E-01	1.28E-01	2.90E-01	1.61E-01	5.51E-02	1.24E-01	6.88E-02
1-Pentene	1.14E-01	3.89E-01	3.85E-01	1.29E-01	1.29E-01	1.09E-01	1.24E-01	1.24E-01	4.68E-02	5.31E-02	5.30E-02
1-Tridecene	8.73E-02	3.63E-01	3.63E-01	1.03E-01	1.03E-01	8.37E-02	9.84E-02	9.84E-02	3.59E-02	4.22E-02	4.22E-02
1-Undecene	2.04E-01	4.72E+00	1.78E+00	4.55E-01	2.92E-01	1.96E-01	4.36E-01	2.80E-01	8.38E-02	1.87E-01	1.20E-01
2,2,3-Trimethylpentane	1.82E-01	2.47E+01	9.35E+00	1.55E+00	6.91E-01	1.75E-01	1.48E+00	6.63E-01	7.48E-02	6.35E-01	2.84E-01
2,2,4-Trimethylpentane	2.01E-01	1.73E+00	1.73E+00	2.86E-01	2.86E-01	1.93E-01	2.74E-01	2.74E-01	8.26E-02	1.17E-01	1.17E-01
2,2-Dimethylbutane	7.12E-01	4.12E+01	1.11E+01	2.96E+00	1.29E+00	6.83E-01	2.84E+00	1.24E+00	2.93E-01	1.22E+00	5.31E-01
2,3,4-Trimethylpentane	1.18E-01	1.21E+00	6.78E-01	1.79E-01	1.49E-01	1.13E-01	1.71E-01	1.43E-01	4.85E-02	7.34E-02	6.13E-02
2,3-Dimethylbutane	1.23E+00	6.58E+01	1.91E+01	4.81E+00	2.22E+00	1.18E+00	4.62E+00	2.13E+00	5.05E-01	1.98E+00	9.12E-01
2,3-Dimethylpentane	5.81E-01	3.56E+01	1.00E+01	2.53E+00	1.11E+00	5.57E-01	2.42E+00	1.06E+00	2.39E-01	1.04E+00	4.54E-01
2,4-Dimethylpentane	3.80E-01	2.36E+01	6.61E+00	1.67E+00	7.26E-01	3.64E-01	1.60E+00	6.96E-01	1.56E-01	6.86E-01	2.98E-01
2-Hexanone	4.40E+00	4.40E+00	4.40E+00	4.40E+00	4.40E+00	4.22E+00	4.22E+00	4.22E+00	1.81E+00	1.81E+00	1.81E+00
2-Methyl-1-butene	9.10E-01	1.26E+00	1.26E+00	9.29E-01	9.29E-01	8.73E-01	8.91E-01	8.91E-01	3.74E-01	3.82E-01	3.82E-01
2-Methyl-2-butene	9.86E-02	8.43E-02	8.43E-02	9.78E-02	9.78E-02	9.45E-02	9.38E-02	9.38E-02	4.05E-02	4.02E-02	4.02E-02
2-Methyl-2-pentene	1.52E-01	3.87E-01	1.61E-01	1.65E-01	1.53E-01	1.46E-01	1.58E-01	1.46E-01	6.25E-02	6.78E-02	6.27E-02
2-Methylheptane	6.43E-01	1.46E+02	3.82E+01	8.74E+00	2.73E+00	6.17E-01	8.38E+00	2.62E+00	2.64E-01	3.59E+00	1.12E+00
2-Methylhexane	1.43E+00	1.21E+02	3.34E+01	8.05E+00	3.21E+00	1.37E+00	7.72E+00	3.08E+00	5.88E-01	3.31E+00	1.32E+00
2-Methylpentane	6.20E+00	2.21E+02	6.82E+01	1.82E+01	9.64E+00	5.94E+00	1.74E+01	9.25E+00	2.55E+00	7.46E+00	3.96E+00
3-Methyl-1-butene	9.39E-02	2.49E-01	2.49E-01	1.03E-01	1.03E-01	9.00E-02	9.83E-02	9.83E-02	3.86E-02	4.21E-02	4.21E-02
3-Methylheptane	5.20E-01	9.74E+01	2.53E+01	5.90E+00	1.90E+00	4.99E-01	5.66E+00	1.82E+00	2.14E-01	2.43E+00	7.80E-01
3-Methylhexane	1.24E+00	1.14E+02	3.21E+01	7.51E+00	2.96E+00	1.19E+00	7.20E+00	2.84E+00	5.11E-01	3.09E+00	1.22E+00
3-Methylpentane	3.21E+00	1.29E+02	3.91E+01	1.02E+01	5.20E+00	3.08E+00	9.79E+00	4.99E+00	1.32E+00	4.20E+00	2.14E+00
4-Methyl-1-pentene	1.95E-01	9.35E-01	9.35E-01	2.36E-01	2.36E-01	1.87E-01	2.26E-01	2.26E-01	8.01E-02	9.70E-02	9.70E-02

Table 3-2
Cancer and Non-Cancer Air Intake Values for Chronic and Subchronic Exposures
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Chronic EPC[1] (µg/m^3)	Subchronic Maximum (µg/m^3)	Subchronic 95%UCL[2] (µg/m^3)	TWA with Subchronic Maximum[3] (µg/m^3)	TWA with Subchronic 95%UCL[3] (µg/m^3)	Chronic Non-cancer Intake (µg/m^3)	TWA Non-cancer Intake with maximum (µg/m^3)	TWA Non-cancer Intake with 95%UCL (µg/m^3)	Chronic Cancer Intake (µg/m^3)	TWA Cancer Intake with Maximum (µg/m^3)	TWA Cancer Intake with 95%UCL (µg/m^3)
Acetaldehyde	8.88E-01	1.96E+00	1.96E+00	9.48E-01	9.48E-01	8.52E-01	9.09E-01	9.09E-01	3.65E-01	3.89E-01	3.89E-01
Acetylene	6.55E-01	1.36E+00	5.48E-01	6.94E-01	6.49E-01	6.28E-01	6.66E-01	6.22E-01	2.69E-01	2.85E-01	2.67E-01
a-Pinene	2.29E-01	3.09E+01	1.13E+01	1.93E+00	8.44E-01	2.20E-01	1.85E+00	8.09E-01	9.41E-02	7.94E-01	3.47E-01
Benzaldehyde	8.97E-02	2.52E-01	2.52E-01	9.87E-02	9.87E-02	8.60E-02	9.47E-02	9.47E-02	3.69E-02	4.06E-02	4.06E-02
Benzene	1.54E+00	6.85E+01	2.04E+01	5.26E+00	2.58E+00	1.47E+00	5.04E+00	2.48E+00	6.31E-01	2.16E+00	1.06E+00
b-Pinene	1.06E-01	8.96E+00	8.96E+00	5.98E-01	5.98E-01	1.02E-01	5.73E-01	5.73E-01	4.36E-02	2.46E-01	2.46E-01
Butyraldehyde	8.51E-02	2.71E-01	2.71E-01	9.54E-02	9.54E-02	8.16E-02	9.15E-02	9.15E-02	3.50E-02	3.92E-02	3.92E-02
cis-2-Butene	9.60E-02	1.97E-01	9.45E-02	1.02E-01	9.59E-02	9.21E-02	9.74E-02	9.20E-02	3.95E-02	4.17E-02	3.94E-02
cis-2-Hexene	7.62E-02	2.93E-01	2.35E-01	8.82E-02	8.50E-02	7.31E-02	8.46E-02	8.15E-02	3.13E-02	3.63E-02	3.49E-02
cis-2-Pentene	6.80E-02	1.48E-01	8.68E-02	7.25E-02	6.90E-02	6.52E-02	6.95E-02	6.62E-02	2.79E-02	2.98E-02	2.84E-02
Crotonaldehyde	1.63E-01	5.53E-01	5.53E-01	1.85E-01	1.85E-01	1.56E-01	1.77E-01	1.77E-01	6.70E-02	7.59E-02	7.59E-02
Cyclopentane	8.28E-01	2.23E+01	7.82E+00	2.02E+00	1.22E+00	7.94E-01	1.94E+00	1.17E+00	3.40E-01	8.30E-01	5.00E-01
Cyclopentene	1.51E-01	6.51E-01	3.84E-01	1.79E-01	1.64E-01	1.45E-01	1.71E-01	1.57E-01	6.21E-02	7.35E-02	6.74E-02
Ethane	8.27E+01	2.41E+03	7.81E+02	2.12E+02	1.22E+02	7.93E+01	2.03E+02	1.17E+02	3.40E+01	8.70E+01	4.99E+01
Ethylbenzene	3.89E-01	2.28E+02	5.36E+01	1.31E+01	3.35E+00	3.73E-01	1.25E+01	3.21E+00	1.60E-01	5.37E+00	1.37E+00
Ethylene	1.11E+00	4.19E+00	1.36E+00	1.28E+00	1.12E+00	1.06E+00	1.23E+00	1.08E+00	4.55E-01	5.26E-01	4.61E-01
Formaldehyde	1.25E+00	1.02E+01	1.02E+01	1.74E+00	1.74E+00	1.19E+00	1.67E+00	1.67E+00	5.12E-01	7.16E-01	7.16E-01
Hexaldehyde	5.87E-02	1.31E-01	1.31E-01	6.27E-02	6.27E-02	5.63E-02	6.01E-02	6.01E-02	2.41E-02	2.58E-02	2.58E-02
Isobutane	2.83E+01	1.60E+03	4.12E+02	1.16E+02	4.96E+01	2.71E+01	1.11E+02	4.76E+01	1.16E+01	4.76E+01	2.04E+01
Isobutene/1-Butene	1.74E+00	6.71E+00	6.71E+00	2.02E+00	2.02E+00	1.67E+00	1.94E+00	1.94E+00	7.17E-01	8.30E-01	8.30E-01
Isopentane	1.97E+01	8.32E+02	2.46E+02	6.48E+01	3.23E+01	1.89E+01	6.22E+01	3.10E+01	8.11E+00	2.66E+01	1.33E+01
Isoprene	5.07E-01	1.15E+00	8.04E-01	5.43E-01	5.24E-01	4.86E-01	5.20E-01	5.02E-01	2.08E-01	2.23E-01	2.15E-01
Isovaleraldehyde	1.13E-01	1.13E-01	1.13E-01	1.13E-01	1.13E-01	1.08E-01	1.08E-01	1.08E-01	4.63E-02	4.63E-02	4.63E-02
m-Diethylbenzene	1.08E-01	7.08E+00	2.05E+00	4.95E-01	2.16E-01	1.04E-01	4.75E-01	2.07E-01	4.44E-02	2.03E-01	8.87E-02
Methylcyclohexane	6.29E+00	7.23E+02	1.94E+02	4.61E+01	1.67E+01	6.03E+00	4.42E+01	1.60E+01	2.58E+00	1.89E+01	6.88E+00
Methylcyclopentane	2.63E+00	1.20E+02	3.76E+01	9.14E+00	4.57E+00	2.52E+00	8.77E+00	4.38E+00	1.08E+00	3.76E+00	1.88E+00
Methylene Chloride	2.90E+00	2.90E+00	2.90E+00	2.90E+00	2.90E+00	2.78E+00	2.78E+00	2.78E+00	1.19E+00	1.19E+00	1.19E+00
m-Ethyltoluene	2.09E-01	4.45E+01	1.17E+01	2.67E+00	8.47E-01	2.00E-01	2.56E+00	8.12E-01	8.59E-02	1.10E+00	3.48E-01
m&p-Xylene	1.79E+00	8.84E+02	2.44E+02	5.08E+01	1.52E+01	1.72E+00	4.87E+01	1.46E+01	7.36E-01	2.09E+01	6.26E+00
n-Butane	2.83E+01	1.29E+03	3.57E+02	9.83E+01	4.66E+01	2.71E+01	9.42E+01	4.47E+01	1.16E+01	4.04E+01	1.91E+01
n-Decane	1.80E+00	2.08E+02	5.14E+01	1.33E+01	4.56E+00	1.73E+00	1.27E+01	4.37E+00	7.41E-01	5.45E+00	1.87E+00
n-Dodecane	2.99E+00	5.15E+01	1.56E+01	5.69E+00	3.70E+00	2.87E+00	5.45E+00	3.54E+00	1.23E+00	2.34E+00	1.52E+00

Table 3-2
Cancer and Non-Cancer Air Intake Values for Chronic and Subchronic Exposures
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Chronic EPC[1] (µg/m^3)	Subchronic Maximum (µg/m^3)	Subchronic 95%UCL[2] (µg/m^3)	TWA with Subchronic Maximum[3] (µg/m^3)	TWA with Subchronic 95%UCL[3] (µg/m^3)	Chronic Non-cancer Intake (µg/m^3)	TWA Non-cancer Intake with maximum (µg/m^3)	TWA Non-cancer Intake with 95%UCL (µg/m^3)	Chronic Cancer Intake (µg/m^3)	TWA Cancer Intake with Maximum (µg/m^3)	TWA Cancer Intake with 95%UCL (µg/m^3)
n-Heptane	2.58E+00	3.04E+02	8.39E+01	1.93E+01	7.10E+00	2.48E+00	1.85E+01	6.81E+00	1.06E+00	7.95E+00	2.92E+00
n-Hexane	6.73E+00	2.55E+02	7.96E+01	2.05E+01	1.08E+01	6.46E+00	1.97E+01	1.03E+01	2.77E+00	8.43E+00	4.43E+00
n-Nonane	6.55E-01	3.03E+02	7.55E+01	1.74E+01	4.81E+00	6.28E-01	1.67E+01	4.62E+00	2.69E-01	7.17E+00	1.98E+00
n-Octane	1.46E+00	4.17E+02	1.08E+02	2.46E+01	7.36E+00	1.40E+00	2.35E+01	7.06E+00	5.98E-01	1.01E+01	3.03E+00
n-Pentane	1.38E+01	5.53E+02	2.13E+02	4.38E+01	2.49E+01	1.32E+01	4.20E+01	2.39E+01	5.68E+00	1.80E+01	1.02E+01
n-Tridecane	2.44E-01	9.05E+00	4.07E+00	7.33E-01	4.57E-01	2.34E-01	7.03E-01	4.38E-01	1.00E-01	3.01E-01	1.88E-01
n-Undecane	9.08E+00	1.21E+02	3.17E+01	1.53E+01	1.03E+01	8.71E+00	1.47E+01	9.91E+00	3.73E+00	6.28E+00	4.25E+00
o-Ethyltoluene	1.55E-01	2.92E+01	7.31E+00	1.77E+00	5.53E-01	1.49E-01	1.69E+00	5.30E-01	6.37E-02	7.26E-01	2.27E-01
o-Xylene	3.68E-01	1.90E+02	4.85E+01	1.09E+01	3.04E+00	3.53E-01	1.05E+01	2.92E+00	1.51E-01	4.49E+00	1.25E+00
p-Diethylbenzene	6.91E-02	5.01E+00	9.66E-01	3.44E-01	1.19E-01	6.63E-02	3.29E-01	1.14E-01	2.84E-02	1.41E-01	4.89E-02
p-Ethyltoluene	1.54E-01	3.22E+01	4.40E+00	1.93E+00	3.90E-01	1.48E-01	1.86E+00	3.74E-01	6.33E-02	7.95E-01	1.60E-01
Propane	6.25E+01	4.67E+03	1.16E+03	3.19E+02	1.24E+02	6.00E+01	3.06E+02	1.19E+02	2.57E+01	1.31E+02	5.08E+01
Tolualdehydes	9.12E-02	2.51E-01	2.51E-01	1.00E-01	1.00E-01	8.75E-02	9.59E-02	9.59E-02	3.75E-02	4.11E-02	4.11E-02
trans-2-Butene	1.78E-01	1.89E+00	8.51E-01	2.73E-01	2.15E-01	1.71E-01	2.62E-01	2.07E-01	7.32E-02	1.12E-01	8.85E-02
trans-2-Pentene	8.99E-02	1.06E+00	2.75E-01	6.75E-01	1.00E-01	8.62E-02	6.47E-01	9.60E-02	3.69E-02	2.77E-01	4.12E-02
Valeraldehyde	3.38E-02	8.50E-02	8.50E-02	3.66E-02	3.66E-02	3.24E-02	3.51E-02	3.51E-02	1.39E-02	1.51E-02	1.51E-02

Notes:

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

[1]EPC for chronic exposure (30 year duration) of all Battlement Mesa residents from 2005 to 2010 Bell Melton Ranch Data (Table 10)

[2]95% UCL for subchronic 20 month exposure of Battlement Mesa residents living within 1/2 mile from a well pad from 2008 and 2010 Well completion data (See Table 2-11)

[3]TWA for a chronic 30 year duration for Battlement Mesa residents living within a 1/2 from a well pad calculated from chronic (340 months) and intermediate (20 months) EPCs.

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

Chemical	CAS	EPC[1] (mg/L)	Dermal Intake (mg/kg-day)
Benzene	71-43-2	1.70E-02	1.04E-01
Ethylbenzene	100-41-4	8.30E-03	6.39E-01
m&p-Xylene	1330-20-7	5.60E-02	2.50E-01
o-Xylene	95-47-6	2.00E-02	8.93E-02
Toluene	108-88-3	4.50E-02	2.54E+00

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	RfC - chronic (mg/m^3)	Source	RfC - acute (mg/m^3)	Source	RfC - Intermediate	Source	RfC Subchronic ((mg/m3)	Source	IUR ($1/(\mu g/m^3)$)
1,2,3-Trimethylbenzene	7.00E-03	based on 1,2,4-TMB	NA	-	NA	-	7.00E-02	based on 1,2,4-TMB	NA
1,2,4-Trimethylbenzene	7.00E-03	PPTRV	NA	-	NA	-	7.00E-02	PPTRV for subchronic	NA
1,3,5-Trimethylbenzene	7.00E-03	based on 1,2,4-TMB	NA	-	NA	-	6.00E-02	PPTRV for subchronic	NA
1,3-Butadiene	2.00E-03	ATW-IRIS	2.20E-01	ATSDR -MRL	NA	-	NA	-	3.00E-05
1,4-Dichlorobenzene	8.00E-01	ATW-IRIS	1.20E+01	ATW-MRL	1.20E+00	ATSDR	2.50E+00	HEAST	1.10E-05
2-Hexanone	3.00E-02	ATW-IRIS	NA	NA	NA	-	NA	-	NA
Acetaldehyde	9.00E-03	ATW-IRIS	4.70E-01	CAL	NA	-	NA	-	2.20E-06
Benzene	3.00E-02	ATW-ATSDR	2.88E-02	ATW-MRL	1.92E-02	ATSDR	8.00E-02	PPTRV for subchronic	7.80E-06
Chloroform	9.80E-02	ATW-ATSDR	4.90E-01	ATW-MRL	2.44E-01	ATSDR	NA	-	2.30E-05
Crotonaldehyde	NA	NA	NA	NA	NA	-	NA	-	5.43E-04
Ethylbenzene	1.00E+00	ATW-ATSDR	4.30E+01	ATW-MRL	3.04E-04	ATSDR	1.00E+00	PPTRV for subchronic	2.50E-06
Formaldehyde	9.80E-03	ATW-ATSDR	4.90E-02	ATSDR-MRL	3.68E-02	ATSDR	NA	-	1.30E-05
Methylcyclohexane	3.01E+00	HEAST	3.00E+00	HEAST	NA	-	3.00E+00	HEAST	NA
Methylene Chloride	1.00E+00	ATW-ATSDR	2.10E+00	ATW-MRL	1.04E+00	ATSDR	3.00E+00	HEAST	4.70E-07
m-Xylene/p-Xylene	1.00E-01	ATW-IRIS	8.70E+00	ATW-MRL	2.61E+00	ATSDR	4.00E-01	PPTRV for subchronic	NA
n-Hexane	7.00E-01	ATW-IRIS	NA	-	NA	-	2.00E+00	PPTRV for subchronic	NA
n-Nonane	2.00E-01	PPTRV	NA	-	NA	-	2.00E+00	PPTRV for subchronic	NA
n-Pentane	1.00E+00	PPTRV	NA	-	NA	-	1.00E+01	PPTRV for subchronic	NA
o-Xylene	7.00E-01	CAL	2.20E+01	CAL	NA	-	4.00E-01	PPTRV for subchronic xylene mixture	NA
Toluene	5.00E+00	ATW-IRIS	3.80E+00	ATW-MRL	NA	-	9.23E-01	PPTRV for subchronic	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.

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

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 http://rais.ornl.gov/tools/profile.php

RfC = Reference concentration

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

Source
NA
NA
NA
ATW-IRIS
ATW-CAL
NA
ATW-IRIS
ATW-IRIS
IRIS
HEAST
ATW-CAL
ATW-IRIS
NA
ATW-IRIS
NA
NA
NA
NA
NA
NA

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

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
Benzene	c/nc	1.00E-02	PPTRV	NA	NA
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 4-4
Target Organ/Systems for Non-Cancer COPCs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Target Organ/System	References
1,2,3-Trimethylbenzene	Neurologic, Respiratory	EPA Chemical Summary for 1,2,4-Trimethylbenzene, August 1994, EPA-749-F-94-022a
1,2,4-Trimethylbenzene	Neurologic, Respiratory	EPA Chemical Summary for 1,2,4-Trimethylbenzene, August 1994, EPA-749-F-94-022a
1,3,5-Trimethylbenzene	Neurologic, Respiratory	EPA Chemical Summary for 1,2,4-Trimethylbenzene, August 1994, EPA-749-F-94-022a
1,3-Butadiene	Neurologic, Respiratory	ATSDR Toxicological Profile for 1,3-Butadiene, September 2009
1,4-Dichlorobenzene	Respiratory, neurologic, liver, kidney	ATSDR Toxicological Profile for Dichlorobenzenes, August 2006
2-Hexanone	Neurologic	EPA Toxicological Review of 2-Hexanone, September 2009, EPA/635/R-09/008F
Acetaldehyde	Respiratory	IRIS, October 1991
Benzene	bone marrow, neurologic, developmental, reproductive	EPA Toxicological Review of Benzene Noncancer Effects, October 2002, EPA/635/R-02/001F, Lupo, P., Symanski, E., Waller, D., Chan, W., Langlosi, P., Canfield, M., Mitchell, L. 2010. Maternal Exposure to Ambient Levels of Benzene and Neural Tube Defects among Offspring, Texas 1999-2004. Environmental Health Perspectives, National Instiute of Environmental Health Sciences, October 5, 2010. ephonline.org.
Ethylbenzene	Auditory, neurological, respiratory, kidneys	ATSDR Toxicological Profile for Ethylbenzene, November 2010
Formaldehyde	Respiratory, neurologic	ATSDR Toxicological Profile for Formaldehyde, July 1999 and October 2010 addendum
Methylcyclohexane	Kidney	http://rais.ornl.gov/tools/profile.php
Methylene Chloride	Neurologic, respiratory	ATSDR Toxicological Profile for Methylene Chloride, September 2000
m&p-Xylene	Neurologic, Developmental	EPA Toxilogical Review of Xylenes,September 2003, EPA 635/R-003/001F
n-Hexane	Neurologic	EPA Toxilogical Review of n-Hexane, November 2005, EPA 635/R-03/012F
n-Nonane	Neurologic, Respiratory	http://toxnet.nlm.nih.gov
n-Pentane	Neurologic	http://toxnet.nlm.nih.gov
o-Xylene	Neurologic, Developmental	EPA Toxilogical Review of Xylenes, September 2003, EPA 635/R-003/001F
Toluene	Neurologic, Developmental, Kidney	EPA Toxilogical Review of Toluene, September 2005, EPA 635/R-05/004F

Table 5-1
Baseline Risk Characterization for all Battlement Mesa Residents
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**
1,3-Butadiene	2.00E+00	7.64E-02	3.82E-02	A	3.00E-05	3.27E-02	9.82E-07
Acetaldehyde	9.00E+00	1.54E+00	1.71E-01	B2	2.20E-06	6.58E-01	1.45E-06
Benzene	3.00E+01	1.55E+00	5.18E-02	A	7.80E-06	6.66E-01	5.20E-06
Crotonaldehyde	-	-	-	C	5.43E-04	6.36E-02	3.45E-05
Ethylbenzene	1.00E+03	3.03E-01	3.03E-04	D	2.50E-06	1.30E-01	3.25E-07
Formaldehyde	9.80E+00	2.26E+00	2.31E-01	B1	1.30E-05	9.69E-01	1.26E-05
Methylcyclohexane	3.01E+03	4.74E+00	1.57E-03	-	-	-	-
Hazard Index (HI)			**5.E-01**	**Total Cancer Risk**			**5.5E-05**

Notes:
$\mu g/m^3$: micrograms 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 Battlement Mesa 2010 (µg/m3)	EPC> BTV?	EPC Bell-Melton Ranch 2005-2010 (µg/m^3)	EPC> BTV?	EPC 2008 and 2010 Well Completion (µg/m^3)	EPC> BTV?
1-Dodecene	112-41-4	8.83E-01	1.16E-01	no	1.85E-01	no	2.60E+00	yes
1-Heptene	592-76-7	1.28E+00	6.80E-01	no	6.47E-01	no	2.39E+01	yes
1-Hexene	592-41-6	1.01E-01	1.88E-01	yes	1.11E-01	yes	1.63E-01	yes
1-Nonene	124-11-8	1.49E-01	9.92E-02	no	1.18E-01	no	6.08E+00	yes
1-Octene	111-66-0	1.42E-01	1.77E-01	yes	1.34E-01	no	1.22E+00	yes
1-Pentene	109-67-1	1.50E-01	7.04E-01	yes	1.14E-01	no	3.85E-01	yes
1-Tridecene	2437-56-1	2.69E-02	1.59E-01	yes	8.73E-02	yes	3.63E-01	yes
1-Undecene	821-95-4	9.75E-02	1.59E-01	yes	2.04E-01	yes	1.78E+00	yes
2,2,3-Trimethylpentane	564-02-3	4.29E-01	1.73E-01	no	1.82E-01	no	9.35E+00	yes
2,2,4-Trimethylpentane	540-84-1	2.46E-01	3.53E-01	yes	2.01E-01	no	1.73E+00	yes
2,2-Dimethylbutane	75-83-2	1.00E+00	7.31E-01	no	7.12E-01	no	1.11E+01	yes
2,3,4-Trimethylpentane	565-75-3	2.25E-01	1.21E-01	no	1.18E-01	no	6.78E-01	yes
2,3-Dimethylbutane	79-29-8	1.85E+00	1.47E+00	no	1.23E+00	no	1.91E+01	yes
2,3-Dimethylpentane	565-59-3	9.48E-01	7.40E-01	no	5.81E-01	no	1.00E+01	yes
2,4-Dimethylpentane	108-08-7	6.55E-01	4.67E-01	no	3.80E-01	no	6.61E+00	yes
2-Methyl-1-butene	563-46-2	1.38E+00	2.67E-01	no	9.10E-01	no	1.26E+00	no
2-Methyl-2-butene	513-35-9	3.05E-01	1.36E+00	yes	9.86E-02	no	1.61E-01	no
2-Methylheptane	592-27-8	1.61E+00	5.80E-01	no	6.43E-01	no	3.82E+01	yes
2-Methylhexane	591-76-4	2.71E+00	1.42E+00	no	1.43E+00	no	3.34E+01	yes
2-Methylpentane	107-83-5	8.75E+00	5.22E+00	no	6.20E+00	no	6.82E+01	yes
3-Methyl-1-butene	563-45-1	1.15E-01	-	-	9.39E-02	no	2.49E-01	yes
3-Methylheptane	589-81-1	1.17E+00	5.00E-01	no	5.20E-01	no	2.53E+01	yes
3-Methylhexane	589-34-4	2.72E+00	1.66E+00	no	1.24E+00	no	3.21E+01	yes
3-Methylpentane	96-14-0	5.63E+00	3.04E+00	no	3.21E+00	no	3.91E+01	yes
4-Methyl-1-pentene	691-37-2	7.00E-01	1.08E-01	no	1.95E-01	no	9.35E-01	yes
Acetylene	74-86-2	3.03E-01	6.77E-01	yes	6.55E-01	yes	5.48E-01	yes
a-Pinene	80-56-8	5.90E-01	1.08E-01	no	2.29E-01	no	1.13E+01	yes
b-Pinene	127-91-3	3.72E-01	2.32E-01	no	1.06E-01	no	8.96E+00	yes
cis-2-Butene	590-18-1	8.14E-02	1.85E+00	yes	9.60E-02	yes	9.45E-02	yes
cis-2-Hexene	7688-21-3	2.95E-01	-	-	7.62E-02	no	2.35E-01	no
cis-2-Pentene	627-20-3	6.07E-02	4.57E-01	yes	6.80E-02	yes	1.48E-01	yes
Cyclopentane	287-92-3	9.63E-01	8.77E-01	no	8.28E-01	no	7.82E+00	yes

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

Chemical	CAS	BTV	EPC Battlement Mesa 2010 (µg/m3)	EPC> BTV?	EPC Bell-Melton Ranch 2005-2010 (µg/m^3)	EPC> BTV?	EPC 2008 and 2010 Well Completion (µg/m^3)	EPC> BTV?
Cyclopentene	142-29-0	4.72E-01	6.63E-02	no	1.51E-01	no	3.84E-01	no
Ethane	74-84-0	8.30E+01	5.35E+01	no	8.27E+01	no	7.81E+02	yes
Ethylene	74-85-1	9.39E-01	1.09E+00	yes	1.11E+00	yes	1.36E+00	yes
Isobutane	75-28-5	2.28E+01	1.92E+01	no	2.83E+01	yes	4.12E+02	yes
Isobutene/1-Butene	115-11-7 / 106-98-9	1.07E+01	1.62E+00	no	1.74E+00	no	6.71E+00	no
Isopentane	78-78-4	2.38E+01	3.19E+01	yes	1.97E+01	no	2.46E+02	yes
Isoprene	78-79-5	1.10E+00	2.04E-01	no	5.07E-01	no	8.04E-01	no
m-Diethylbenzene	141-93-5	4.10E-01	8.20E-02	no	1.08E-01	no	2.05E+00	yes
Methylcyclopentane	96-37-7	5.85E+00	2.65E+00	no	2.63E+00	no	3.76E+01	yes
m-Ethyltoluene	620-14-4	6.28E-01	2.34E-01	no	2.09E-01	no	1.17E+01	yes
n-Butane	106-97-8	2.61E+01	3.88E+01	yes	2.83E+01	yes	3.57E+02	yes
n-Decane	124-18-5	1.81E+00	4.87E-01	no	1.80E+00	no	5.14E+01	yes
n-Dodecane	112-40-3	1.55E+00	3.42E-01	no	2.99E+00	yes	1.56E+01	yes
n-Heptane	142-82-5	5.48E+00	2.04E+00	no	2.58E+00	no	8.39E+01	yes
n-Octane	111-65-9	3.74E+00	1.28E+00	no	1.46E+00	no	1.08E+02	yes
n-Tridecane	629-50-5	3.12E-01	-	-	2.44E-01	no	4.07E+00	yes
n-Undecane	1120-21-4	2.17E+00	4.97E-01	no	9.08E+00	yes	3.17E+01	yes
o-Ethyltoluene	611-14-3	3.08E-01	1.78E-01	no	1.55E-01	no	7.31E+00	yes
p-Diethylbenzene	105-05-5	1.12E-01	1.04E-01	no	6.91E-02	no	9.66E-01	yes
p-Ethyltoluene	622-96-8	3.60E-01	1.63E-01	no	1.54E-01	no	4.40E+00	yes
Propane	74-98-6	5.26E+01	3.06E+01	no	6.25E+01	yes	1.16E+03	yes
trans-2-Butene	624-64-6	2.06E-01	2.09E+00	yes	1.78E-01	no	8.51E-01	yes
trans-2-Pentene	4050-45-7	1.27E-01	9.07E-01	yes	8.99E-02	no	6.75E-01	yes

Notes
BTV: Background Threshold Value from Table 2-8
EPC: Exposure Point Concentrations from Tables 2-9, 2-10, and 2-11
CAS: Chemical Abstract Service
µg/m^3: micrograms per cubic meter

Table 5-3
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/($\mu g/m3$)**	**Chronic Cancer Intake ($\mu g/m^3$)**	**Cancer Risk**
1,2,3-Trimethylbenzene	7.00E+00	9.42E-02	1.35E-02	-	-	-	-
1,2,4-Trimethylbenzene	7.00E+00	3.00E-01	4.29E-02	D	-	-	-
1,3,5-Trimethylbenzene	7.00E+00	1.67E-01	2.38E-02	-	-	-	-
1,3-Butadiene	2.00E+00	4.46E-02	2.23E-02	A	3.00E-05	1.91E-02	5.73E-07
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	8.52E-01	9.46E-02	B2	2.20E-06	3.65E-01	8.03E-07
Benzene	3.00E+01	1.47E+00	4.91E-02	A	7.80E-06	6.31E-01	4.92E-06
Crotonaldehyde	-		-	C	5.43E-04	6.70E-02	3.64E-05
Ethylbenzene	1.00E+03	3.73E-01	3.73E-04	D	2.50E-06	1.60E-01	4.00E-07
Formaldehyde	9.80E+00	1.19E+00	1.22E-01	B1	1.30E-05	5.12E-01	6.66E-06
Methylcyclohexane	3.01E+03	6.03E+00	2.00E-03	-	-	-	-
Methylene Chloride	1.00E+03	2.78E+00	2.78E-03	B2	4.70E-07	1.19E+00	5.60E-07
Hazard Index (HI)			**5.E-01**	**Total Cancer Risk**			**6.1E-05**

Notes:
$\mu g/m^3$: micrograms 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 5-4
Chronic Risk Characterization for Residents Living Near 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 non-Cancer Intake with Maximum ($\mu g/m^3$)**	**HQ Maximum**	**TWA non-Cancer Intake with 95%UCL ($\mu g/m^3$)**	**HQ 95% UCL**	**EPA WOE**	**IUR (1/(µg/m3)**	**TWA Cancer Intake with maximum ($\mu g/m^3$)**	**Cancer Risk-Maximum**	**TWA Cancer Intake with EPC ($\mu g/m^3$)**
1,2,3-Trimethylbenzene	7.00E+00	7.11E-01	1.02E-01	2.59E-01	3.71E-02	-	-	-	-	-
1,2,4-Trimethylbenzene	7.00E+00	4.70E+00	6.72E-01	1.41E+00	2.01E-01	D	-	-	-	-
1,3,5-Trimethylbenzene	7.00E+00	4.29E+00	6.12E-01	1.19E+00	1.71E-01	-	-	-	-	-
1,3-Butadiene	2.00E+00	5.09E-02	2.55E-02	5.09E-02	2.55E-02	A	3.00E-05	2.18E-02	6.55E-07	2.18E-02
1,4-Dichlorobenzene	8.00E+02	2.21E+00	2.76E-03	2.21E+00	2.76E-03	C	1.10E-05	9.45E-01	1.04E-05	9.45E-01
2-Hexanone	3.00E+01	4.22E+00	1.41E-01	4.22E+00	1.41E-01	D	-	-	-	-
Acetaldehyde	9.00E+00	9.09E-01	1.01E-01	9.09E-01	1.01E-01	B2	2.20E-06	3.89E-01	8.56E-07	3.89E-01
Benzene	3.00E+01	5.04E+00	1.68E-01	2.48E+00	8.25E-02	A	7.80E-06	2.16E+00	1.69E-05	1.06E+00
Crotonaldehyde	-	-	-	-	-	C	5.43E-04	7.59E-02	4.12E-05	7.59E-02
Ethylbenzene	1.00E+03	1.25E+01	1.25E-02	3.21E+00	3.21E-03	D	2.50E-06	5.37E+00	1.34E-05	1.37E+00
Formaldehyde	9.80E+00	1.67E+00	1.71E-01	1.67E+00	1.71E-01	B1	1.30E-05	7.16E-01	9.31E-06	7.16E-01
Methylcyclohexane	3.01E+03	4.42E+01	1.47E-02	1.60E+01	5.33E-03	-	-	-	-	-
Methylene Chloride	1.00E+03	2.78E+00	2.78E-03	2.78E+00	2.78E-03	B2	4.70E-07	1.19E+00	5.60E-07	1.19E+00
m&p-Xylene	1.00E+02	4.87E+01	4.87E-01	1.46E+01	1.46E-01	D	-	-	-	-
n-Hexane	7.00E+02	1.97E+01	2.81E-02	1.03E+01	1.48E-02	D	-	-	-	-
n-Nonane	2.00E+02	1.67E+01	8.36E-02	4.62E+00	2.31E-02	-	-	-	-	-
n-Pentane	1.00E+03	4.20E+01	4.20E-02	2.39E+01	2.39E-02	-	-	-	-	-
o-Xylene	7.00E+02	1.05E+01	1.50E-02	2.92E+00	4.17E-03	D	-	-	-	-
Hazard Index (HI)			**3.E+00**		**1.E+00**	**Total Cancer Risk**			**9.3E-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
Chronic Risk Characterization for Residents Living Near a Well Pad - 30 Year Duration
Human Health Risk Assessment
Health Impact Assessment

Cancer Risk -95%UCL
-
-
-
6.55E-07
1.04E-05
-
8.56E-07
8.27E-06
4.12E-05
3.44E-06
9.31E-06
-
5.60E-07
-
-
-
-
-
7.4E-05

Table 5-5
Subchronic Risk Characterization for All Residents Near a Well Pad - 20-Month Duration
Human Health Risk Assessement
Health Impact Assessment

Chemical	RfC - subchronic ($\mu g/m^3$)	Maximum Subchronic Intake ($\mu g/m^3$)	HQ (Maximum)	95% UCL Subchronic Intake ($\mu g/m^3$)	HQ (Maximum)
1,2,3-Trimethylbenzene	7.00E+01	1.17E+01	1.67E-01	3.20E+00	4.57E-02
1,2,4-Trimethylbenzene	7.00E+01	8.30E+01	1.41E+00	2.11E+00	3.01E-02
1,3,5-Trimethylbenzene	6.00E+01	7.75E+01	1.29E+00	1.95E+01	3.24E-01
1,3-Butadiene	2.00E+00	1.66E-01	8.29E-02	1.66E-01	8.30E-02
1,4-Dichlorobenzene	2.50E+03	2.30E+00	9.20E-04	2.30E+00	9.20E-04
2-Hexanone	3.00E+01	4.40E+00	1.47E-01	4.40E+00	1.47E-01
Acetaldehyde	9.00E+00	1.96E+00	2.18E-01	1.96E+00	2.18E-01
Benzene	8.00E+01	6.85E+01	8.57E-01	2.04E+01	2.55E-01
Ethylbenzene	1.00E+03	2.28E+02	2.28E-01	5.36E+01	5.36E-02
Formaldehyde	9.80E+00	1.02E+01	1.04E+00	1.02E+01	1.04E+00
Methylcyclohexane	3.00E+03	7.23E+02	2.41E-01	1.94E+02	6.48E-02
Methylene chloride	3.00E+03	2.90E+00	9.67E-04	2.90E+00	9.67E-04
m&p-Xylene	4.00E+02	8.84E+02	2.21E+00	2.44E+02	6.09E-01
n-Hexane	2.00E+03	2.55E+02	1.27E-01	7.96E+01	3.98E-02
n-Nonane	2.00E+03	3.03E+02	1.51E-01	7.55E+01	3.78E-02
n-Pentane	1.00E+04	5.53E+02	5.53E-02	2.13E+02	2.13E-02
o-Xylene	4.00E+02	1.90E+02	4.76E-01	4.85E+01	1.21E-01
Toluene	9.23E+02	3.19E+02	3.45E-01	9.21E+01	9.98E-02
Hazard Index (HI)			***9.E+00***		***3.E+00***

Notes:
$\mu g/m^3$: micrograms 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 5-6
Acute Risk Characterization for Child Resident Living Near a Well Pad - 7-day Duration
Human Health Risk Assessement
Health Impact Assessment

Chemical	RfC - acute (µg/m^3)	Acute Intake for Maximum (µg/m^3)	HQ from Maximum	Acute Intake for 95% UCL	HQ from 95% UCL
Ambient Air					
Acetaldehyde	4.70E+02	5.49E+00	1.17E-02	5.49E+00	1.17E-02
Benzene	2.90E+01	1.80E+02	6.21E+00	6.24E+01	2.15E+00
Chloroform	4.90E+02	1.60E+00	3.27E-03	1.60E+00	3.27E-03
Ethylbenzene	4.30E+04	9.60E+01	2.23E-03	1.39E+01	3.24E-04
Formaldehyde	4.90E+01	8.28E+00	1.69E-01	8.28E+00	1.69E-01
m&p-Xylene	8.70E+03	1.50E+03	1.72E-01	3.38E+02	3.89E-02
o-Xylene	2.20E+04	2.60E+02	1.18E-02	5.82E+01	2.65E-03
Toluene	3.80E+03	5.40E+02	1.42E-01	2.04E+02	5.36E-02
Hazard Index (HI)			***7.E+00***		***2.E+00***
	RfD - acute (mg/kg-day)	**Acute Intake (mg/kg-day)**	**HQ**	**Acute Intake (mg/kg-day)**	**HQ**
Surface Water					
Benzene	1.00E-02	1.04E-01	1.04E+01	1.04E-01	1.04E+01
Ethylbenzene	5.00E-01	6.39E-01	1.28E+00	6.39E-01	1.28E+00
m&p-Xylene	1.00E+00	2.50E-01	2.50E-01	2.50E-01	2.50E-01
o-Xylene	1.00E+00	8.93E-02	8.93E-02	8.93E-02	8.93E-02
Toluene	8.00E-01	2.54E+00	3.17E+00	2.54E+00	3.17E+00
Hazard Index (HI)			***1.5E+01***		***1.5E+01***
Ambient Air and Surface Water					
Total Hazard Index (HI)			**2.E+01**		**2.E+01**

Notes:
µg/m^3: micrograms 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 5-7
Acute Risk Characterization for Adult and Elderly Resident Living Near a Well Pad - 7-day Duration
Human Health Risk Assessement
Health Impact Assessment

Chemical	RfC - acute ($\mu g/m^3$)	Acute Intake for Maximum ($\mu g/m^3$)	HQ from Maximum	Acute Intake for 95% UCL	HQ from 95% UCL
Ambient Air					
Acetaldehyde	4.70E+02	5.49E+00	1.17E-02	5.49E+00	1.17E-02
Benzene	2.90E+01	1.80E+02	6.21E+00	6.24E+01	2.15E+00
Chloroform	4.90E+02	1.60E+00	3.27E-03	1.60E+00	3.27E-03
Ethylbenzene	4.30E+04	9.60E+01	2.23E-03	1.39E+01	3.24E-04
Formaldehyde	4.90E+01	8.28E+00	1.69E-01	8.28E+00	1.69E-01
m&p-Xylene	8.70E+03	1.50E+03	1.72E-01	3.38E+02	3.89E-02
o-Xylene	2.20E+04	2.60E+02	1.18E-02	5.82E+01	2.65E-03
Toluene	3.80E+03	5.40E+02	1.42E-01	2.04E+02	5.36E-02
Hazard Index (HI)			***7.E+00***		***2.E+00***

Notes:
$\mu g/m^3$: micrograms 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
Baseline Risk All Battlement Mesa Residents - 30 years	Chronic	0.5	5.50E-05
All Battlement Mesa Residents - 30 years	Chronic	0.5	6.1E-05
Residents living near a well pad - 30 years	Chronic	1 to 3	7.4 E-05 to 9.3E-05
Residents living near a well pad - 20 months	Subchronic	3 to 9	-
Child Resident living near a well pad - 7 days			
-Ambient Air Exposure Pathway	Acute	2 to 7	-
-Surface Water Exposure Pathway	Acute	15	-
'-Ambient Air plus Surface Water Pathways	Acute	20	-
Adult and Elderly Resident living near well pad - 7days	Acute	2 to 7	-

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

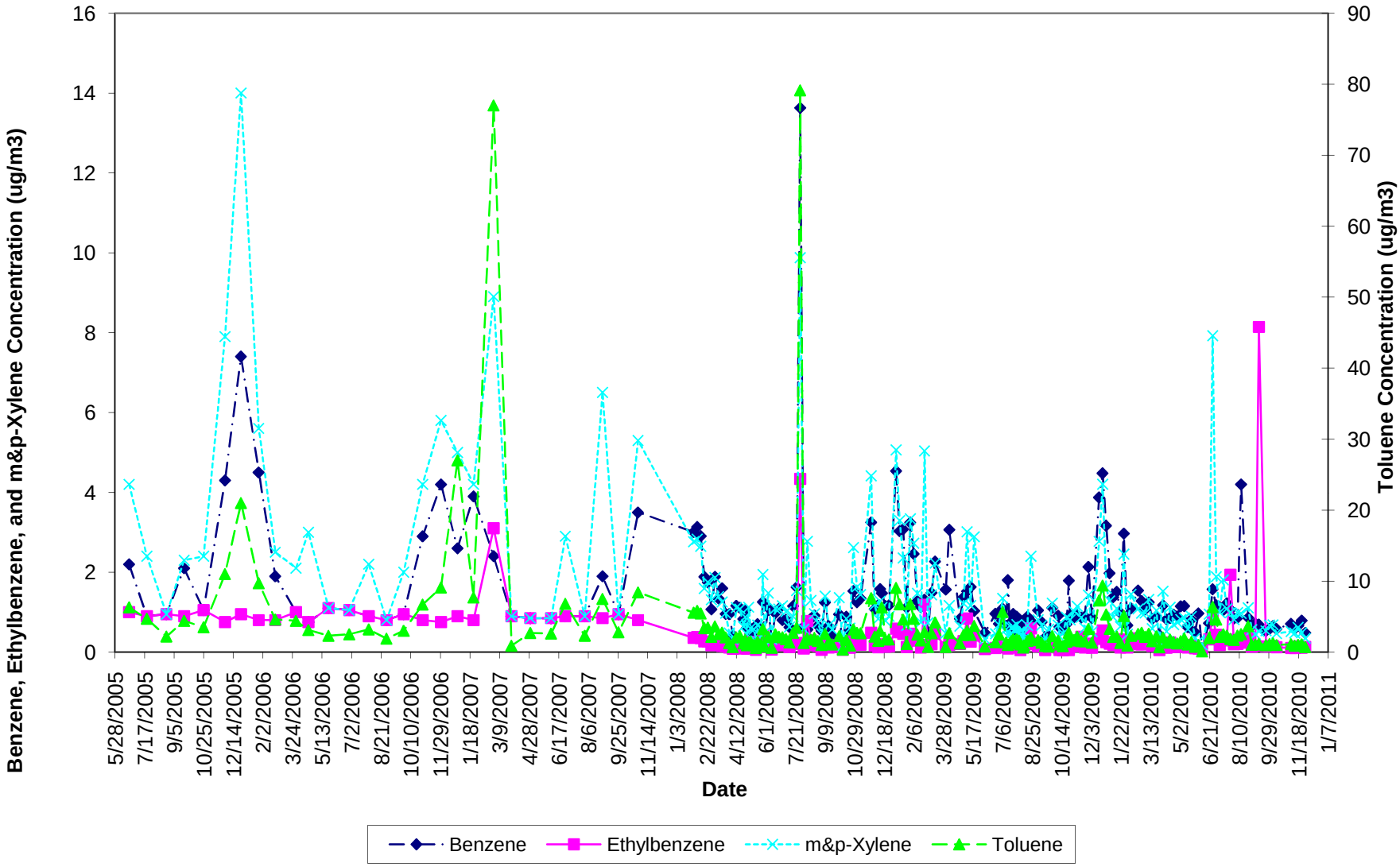
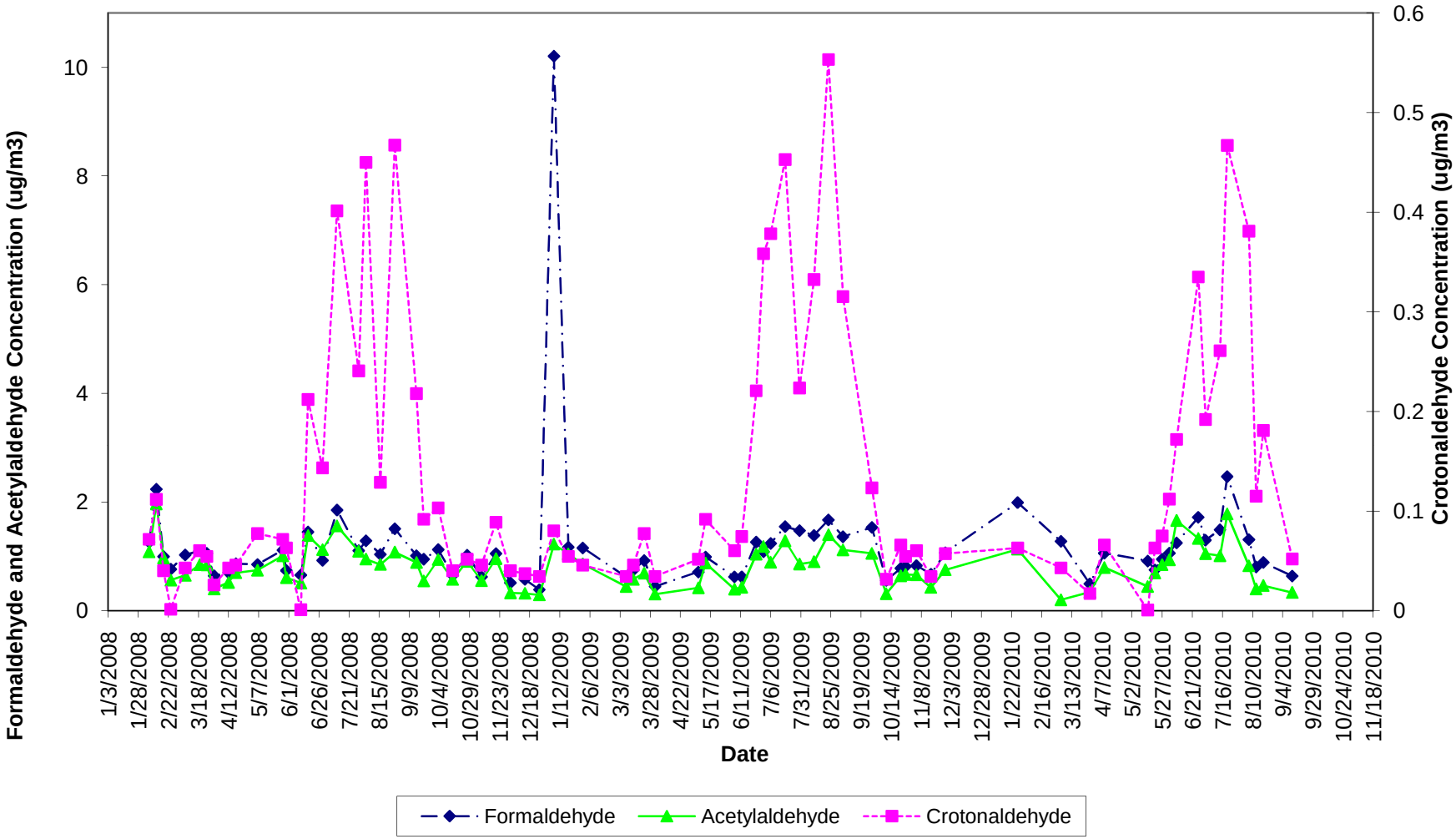


Figure 2-2
Temporal Trends for Carbonyls
Bell Melton Ranch Monitoring Station



Sources	Potential Releases	Exposure Media	Secondary Media	Receptors: Resident Ingestion	Resident Dermal	Resident Inhalation
Natural Gas, Drilling Mud, and Fracking Fluids	Well Installation errors/leaks	Groundwater		P	P	P
			Indoor Air	NA	NA	P
		Subsurface Soil		P	P	P
		Ambient Air		NA	NA	C
	Well Blow-outs/Uncontrolled releases/Fires	Groundwater		P	P	P
			Indoor Air	NA	NA	P
		Subsurface Soil		P	P	P
		Surface Soil		C	C	C
		Surface Water		P	C	I
		Ambient Air		NA	NA	C
	Venting	Ambient Air		NA	NA	C
Drilling Mud, Fracking Fluids, Diesel, and Condensate and Produced Water	Spills	Surface Soil	Surface Water	P	C	I
				C	C	C
			Groundwater	P	P	P
			Indoor Air	NA	NA	P
			Subsurface Soil	P	P	P
		Ambient Air		NA	NA	C
Trucks and Generators	Exhaust	Ambient Air		NA	NA	C
			Surface Soil	C	C	C
Drill Cuttings and Produced Water	Surface Run-off	Surface Soil	Groundwater	P	P	P
			Indoor Air	NA	NA	P
			Subsurface Soil	P	P	P
				C	C	C
		Surface Water		P	C	I
	Infiltration	Subsurface Soil	Groundwater	P	P	P
				P	P	P
			Indoor Air	NA	NA	P
	Evaporation	Ambient Air		NA	NA	C
Condensers/Glycol Dehydrators	Venting	Ambient Air		NA	NA	C
Pneumatic Pumps and Devices, Pipeline and valves	Leaks	Ambient Air		NA	NA	C

Figure 3-1: 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
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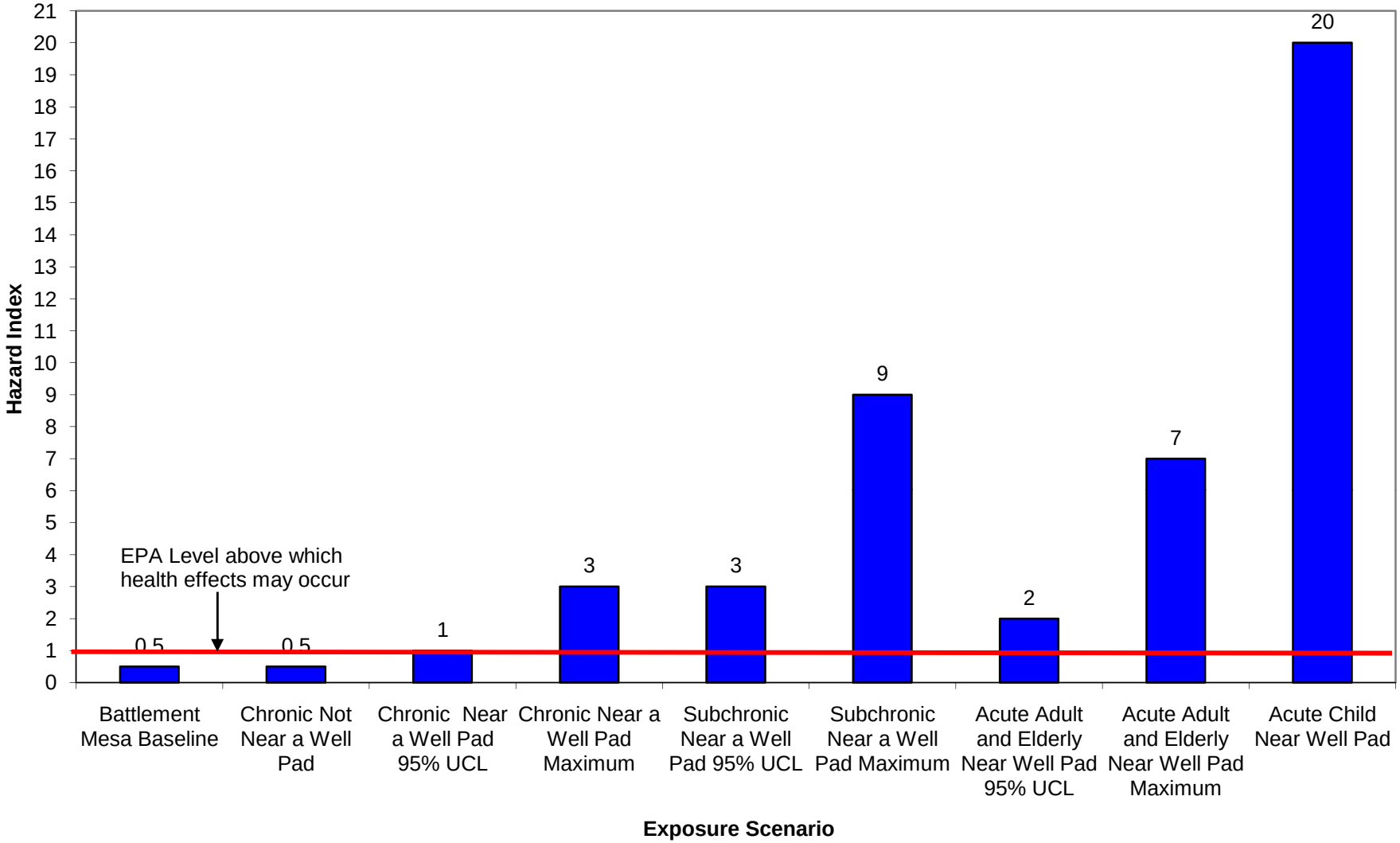
Imagery Dates: Jun 17, 2005 - Sep 11, 2005 39°26'20.80" N 108°02'02.92" W elev 5375 ft Eye alt 21261 ft

Summary of Non-cancer Health Hazards



Summary of Excess Lifetime Cancer Risk