Potential Exposure-Related Human Health Effects of Oil and Gas Development:

A White Paper

Prepared by:
Roxana Witter[1], MD, MSPH
Kaylan Stinson[1], MSPH
Holly Sackett[1], MSPH
Stefanie Putter[2], BA
Gregory Kinney[1], MPH
Daniel Teitelbaum[1], MD
Lee Newman[1], MD, MA

September 15, 2008

Contact: Roxana Witter, MD, MSPH
Colorado School of Public Health
University of Colorado Denver
4200 East Ninth Ave., B-164
Denver, CO 80262
Roxana.Witter@uchsc.edu

1-University of Colorado Denver, Colorado School of Public Health, Denver, Colorado
2-Colorado State University, Department of Psychology, Fort Collins, Colorado

Executive Summary

Based on the body of scientific evidence, human health risks and social impacts are associated with oil and gas development. This white paper supports the need for an Health Impact Assessment to be included as part of any Environmental Impact Statement or other planning and assessment process when considering oil and gas development, especially in populated areas.

As an illustration of the health issues that should be considered, this white paper focuses on Garfield County, Colorado which has experienced a 39% increase in oil and gas drilling between 2000-2007. A detailed review of the human health literature plus preliminary studies of health status and air and water quality in Garfield County indicate that local residents maybe at risk for adverse health effects and psychological and social impacts.

Data necessary to completely assess the health and social impacts of the oil and gas industry are missing in all areas, including: population demographics, health status, psychological status, social measures, worker health, and environmental exposure. Further monitoring of both the community and the environment of Garfield County is essential. Action to decrease current chemical exposures of concern and improve monitoring should not be delayed. A Health Impact Assessment is an appropriate framework for relating exposure assessment to community health data and for making recommendations to mitigate adverse human health effects.

While this white paper focuses on Garfield County, Colorado as an illustration of the potential exposure-related health impact of oil and gas development, the principles of exposure and the related health issues should be considered generally applicable wherever oil and gas development is occurring.

Introduction

The purpose of the white paper is to:

1. Describe the population of the Western Slope of Colorado potentially exposed to hazards that have been associated with oil and gas exploration and extraction.
2. Describe the baseline health and social parameters of the population that may be at risk.
3. Discuss the possible health, medical, and social issues that face this population in light of the increasing oil and gas drilling and production in close proximity to where they live, work and go to school, using Garfield County, Colorado as an illustration.
4. Provide guidance for future environmental and medical monitoring of the Western Slope population and other similarly affected communities.
5. Weigh the need for conducting a Health Impact Assessment as part of the Environmental Impact Statement (EIS) process and other planning processes for oil and gas development.

Background

United States and global energy needs have driven up prices for fossil fuels. In addition, political instability in major energy producing countries around the world has driven a US energy policy to increase domestic production of all types of energy, in particular fossil fuels. The combination of increasing demand, interest in domestic supplies and new technology has made fuels previously unattainable or too costly now worthy of recovery.

As pressures for increased fossil fuel production increase, areas that had previously been considered too sensitive for drilling are now being drilled. These sites have included an increasing number of oil and gas exploration and extraction facilities, some of which are in close proximity to native and local populations. Human proximity to oil and gas production sites may increase the likelihood that people will be exposed to the hazardous chemicals, emissions and pollutants associated with this activity. (Saadat and Bahaoddini 2004; San Sebastian and Hurtig 2004)

Garfield, Mesa, Rio Blanco and Moffat counties, all on the Western Slope of Colorado, have seen and likely will continue to see dramatic increases in oil and gas drilling. As such, this white paper will focus on Garfield County as a ‘case study’ for considering the potential health consequences of exposure. Others have reported on the assessment of exposure. (Teresa Coons and Walker 2008) The emphasis of this white paper will be on exposure-related health risks.

Oil and gas development starts with obtaining permits to begin exploration. Development next involves drilling into the land in search for fossil fuels. The drilling process very often involves fracturing subsurface land formations in order to release the fuels in question. If the desired product is found, then extraction processes remove the

fuels. The extraction of the fuels in these active wells may take several decades. Occasionally, in an effort to increase production, wells are fractured again. Once the well has ceased production, the wells are capped

As described below, drilling and fracturing activities may use and produce hazardous materials which could threaten human health. In addition, active wells can continue to pose health hazards due to fugitive air emissions from the wells and from emissions from stationary and vehicular traffic. (Oil and Gas Accountability Project) Abandoned wells may continue to be a source of toxic contaminants if proper capping and maintenance procedures are not used. (URS Corporation 2006)

Hazardous chemicals are used and produced by oil and gas extraction processes. Subsurface land formations are "fractured" (known as "fracking or frac'ing) by injection of fluids and/or solids into the ground under high pressure. Some of the chemicals used in this process are brought to the surface, potentially contaminating soil, air and water, while some of the chemicals are left underground, potentially contaminating subsurface aquifers. Other chemicals may also be used in drilling fluids and other products used by industry. Drilling fluids may be fresh or salt water-based muds, oil-based muds, or synthetic materials that contain esters, olefins, paraffins, ethers and alkulbenzenes, among others. Drilling fluids may also contain additives such as metals, acrylic polymers, organic polymers, surfactants, and biocides. Chemicals used in drilling muds and fracking fluids are often considered proprietary and specific composition of these compounds are generally not available to the public. (Oil and Gas Accountability Project)

Drilling sludge brought to the surface can contain fracking fluid, drilling mud, radioactive material from the subsurface land formation, hydrocarbons, metals, and volatile organic compounds. Sludge is often left to dry on the surface in waste pits, potentially contaminating air, water and soil. Sludge may also be removed to waste disposal sites (but not always to hazardous waste sites) or sludge may be tilled into the soil in "land farms." These practices can potentially contaminate soil, air and surface water. So-called "produced water" is brought to the surface during the extraction process. This water may be contaminated with salts, hydrocarbons, radioactive material, metals, drilling fluids and muds. The produced water is often left on the surface to evaporate, or it may be reinjected into the ground or released into surface waters. All of these disposal methods may threaten air, water and soil quality. (Oil and Gas Accountability Project)

Spills of oil and gas wastes and/or chemicals used in production can pollute ground and surface water and soil. The Colorado Oil and Gas Conservation Commission (COGCC) maintains records of reported spills resulting from oil and gas activities. In the four year period January 2003 – March 2008 there were 1549 spills. These spills involved produced water (767), crude oil or gas condensate (449), other materials (134) and unclassified (201). Twenty percent of the spills involved water contamination. Furthermore, the number of spills has increased as the number of wells has increased. For example, in Garfield County, 5 spills were reported in the year 2003, compared to

55 spills reported in 2007. (Colorado Oil and Gas Conservation Commission, Oil and Gas Accountability Project)

Air surrounding oil and gas production areas is particularly susceptible to toxic emissions. Fugitive natural gas emissions may contain many contaminants, such as methane and other hydrocarbons (ethane, propane, butane), hydrogen sulfide (H2S), and water vapor. These emissions can come from production sites, disposal pits or pipelines. In Garfield County, for example, many of these sites tend to be near population centers and adjacent to streams and other bodies of water (see Garfield County map on page 12 below). Some natural gas wells produce a condensate that can contain complex hydrocarbons and aromatic hydrocarbons such as benzene, toluene, ethyl benzene and xylene (BTEX). Natural gas flaring can produce many hazardous chemicals including polycyclic aromatic hydrocarbons (PAHs, including naphthalene), benzene, toluene, xylenes, ethyl benzene, formaldehyde, acrolein, propylene, acetaldehyde and hexane. Glycol dehydrators, used to remove water from natural gas, can produce BTEX leaks into the air. (Oil and Gas Accountability Project)

Oil and gas exploration and production activities have been exempted from standards created to protect health under a number of Federal statutes, including provisions of the Clean Air Act (CAA), the Clean Water Act (CWA), the Safe Drinking Water Act (SDWA), the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or the Superfund Act), and the Emergency Planning and Community Right to Know Act (the Toxics Release Inventory or TRI). These laws are designed to protect the health of the American population by ensuring clean air and water. (Mall 2007)

Because the oil and gas drilling industry is not obliged to comply with certain federal health and environmental regulations (Mall, 2007), there has been virtually no publicly available monitoring of air or water contamination due to the activities of oil and gas drilling and extraction. As drilling for oil and gas moves closer to human populations, hazards associated with these industries are more likely to have a direct effect on the health of those living, working and going to school in proximity to the drilling and production sites. Anecdotal evidence of health effects due to increased drilling has begun to surface. (Oil and Gas Accountability Project) However, in the absence of environmental monitoring data regarding exposure levels and medical evaluation of complaints, it has been scientifically difficult to establish causal relationships between oil and gas activity and health effects. Gaps in the medical literature are profound, as reflected in the literature review that is attached to this white paper. There is a paucity of published literature that directly addresses the health effects of oil and gas exploration and production. However there is a sizeable scientific literature linking many of the exposures to adverse health outcomes in humans.

The National Environmental Policy Act (NEPA) established the Environmental Impact Statement (EIS) as a means for environmental analysis in the United States. When industrial development involving federal resources is proposed, the federal government is tasked to consider effects on the "human environment." In practice, EIS

have traditionally focused on environmental effects, with little consideration of public health effects. When public health is considered, simple compliance with regulatory statutes such as the CAA and CWA are commonly used as a proxy for more substantive analysis. Since industrial projects often have impact on the environment in ways that directly or indirectly affect the health and psychosocial structure of local populations, there is a growing recognition that EIS should include a Health Impact Assessment (HIA) in many cases. (Wernham 2007) This white paper is intended to examine the rationale for an HIA as part of the permitting process for oil and gas drilling on the Western Slope of Colorado and other areas with intensive industrial development. As precedent, an integrated HIA/EIS published in 2007 described the impact of oil development on Alaska's North Slope on the local Inupiat populations. (Wernham 2007) The HIA findings predicted impact on health and social structure. The report provided recommendations for mitigation of these effects, thereby improving the probability that oil development could proceed with less adverse impact on the people who live in the region.

Western Slope of Colorado

The American West has seen a dramatic increase in drilling for oil, gas, and coal bed methane. In Garfield County, on the Western Slope of Colorado, there are presently approximately 4521 active wells. Oil and gas drilling increased by 39% between 2000 and 2007. (Colorado Oil and Gas Conservation Commission) While the total number of drilling permits for 2008 is not yet known, it is estimated that by the end of 2008, approximately 3200 permits are expected to be issued in the county. Looking toward the future, it is estimated that Garfield County will continue on a pace of approximately 1000 new wells per year. It is expected by 2023 there will be between 15,000 and 23,000 wells in Garfield County. (BBC Research & Consulting, 2008) As such, this white paper will focus on Garfield County as an illustrative example of the assessment of potential health hazards due to oil and gas drilling near human populations. It is beyond the scope of this white paper to conduct similar examinations of the other Colorado counties experiencing similar growth in oil and gas activity. Lessons learned in Garfield County are likely to be relevant elsewhere in the region.

As a result of the increased health concerns of residents in Garfield County, County commissioners have commissioned several studies attempting to characterize potential exposures in contaminated air and water. (URS Corporation 2006; Garfield County Public Health Department 2007) This white paper will summarize these and other exposure data available in Garfield County in order to help frame the discussion of potential health consequences. This white paper will include available data characterizing the general population of Garfield County, including those populations that may be more susceptible to the effects of toxic exposures. This white paper will also describe the publicly available health statistics for Garfield County. Such health data can provide public health professionals with an early indication of adverse health trends, some of which might be associated with oil and gas activity. In addition, the white paper examines the available baseline psychosocial characteristics of Garfield County residents. The paper concludes with a discussion of the gaps in knowledge and

the potential role that a Health Impact Assessment (HIA) may have in filling these gaps and ensuring community health.

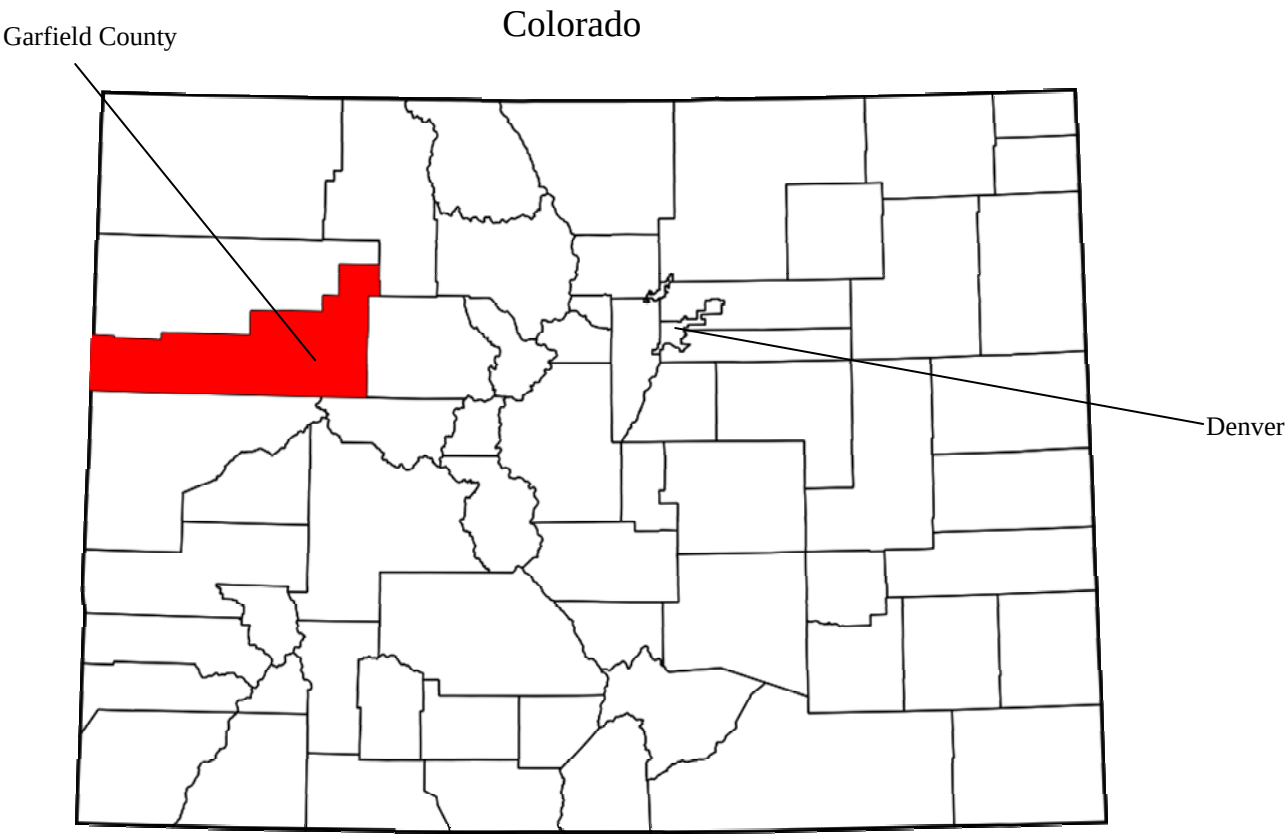
As discussed in the medical and public health literature review (attached), few studies have been published on the health effects of oil and gas exploration and extraction on communities living and working in the vicinity of these activities. A lack of specific evidence, however, does not negate the fact that oil and gas operations use and produce toxic contaminants that adversely affect human health; nor does it negate the potential health effects of the large-scale socio-demographic and economic changes often associated with such projects. Available studies show that exposure to air pollutants, toxic chemicals, metals, radiation, noise and light pollution cause a range of diseases, illnesses, and health problems, including psychological and social disruption. Neighborhoods, schools, and workers in close proximity to oil and gas activities may be at increased risk for cancer, cardiovascular disease, asthma, and other disorders due to uncontrolled or high exposures. Further research is needed to assess the health impact of oil and gas operations on surrounding communities.

Garfield County Community Profile

Understanding the community characteristics can help explain the prevalence of health risk behavior and outcomes. The following sections provide an introduction to Garfield County based on data obtained from a number of publicly available sources. For a complete list of references used for this profile, see Appendix 1. This summary highlights some of the important demographic, geographic, economic, environmental, and social factors that influence many aspects of health.

Geography and Well Locations

Garfield County (2,958 square miles) is located in the northwest region of Colorado, and is bordered to the north by Rio Blanco County, on the east by Eagle County, and on the south by Mesa and Pitkin Counties. Garfield County is made up of six municipalities (listed in decreasing population size): Glenwood Springs, Rifle, Carbondale, New Castle, Silt, and Parachute. Garfield County is primarily a rural county, with most residents (42%), living outside the six major townships. (Garfield County Quick Facts: http://www.garfield-county.com/Index.aspx?page=698)



The Colorado Oil and Gas Conservation Commission provides publicly available data on oil and gas wells in Colorado, such as number of active wells, drilling permits, and location. (Colorado Oil and Gas Conservation Commission: http://oil-gas.state.co.us/)

In 2002, Colorado had just over 22,500 active wells; as of April 7, 2008, the state had 34,734 active wells. Sixty percent of all active wells are located within seven counties throughout Colorado, three of which are located on the Western Slope of Colorado (Garfield, Rio Blanco, and Mesa). (Table 1)

Table 1. Total Active Wells by County (Top 7 drilling counties)

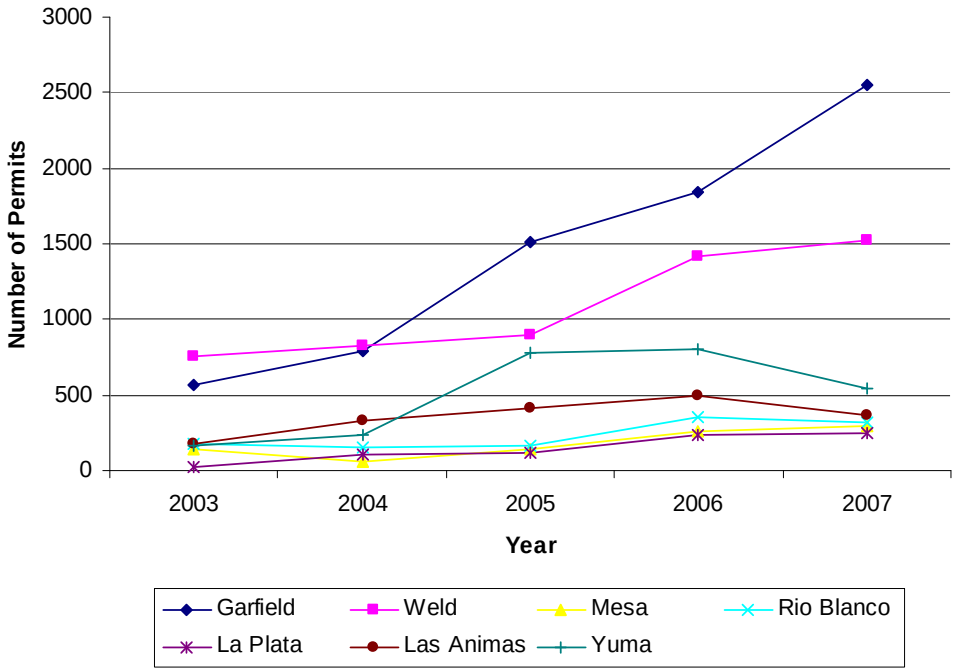
County	**Total Active Wells** (April 7, 2008)
Weld	12,858
Garfield	4,521
Yuma	3,125
Rio Blanco	2,636
La Plata	2,917
Las Animas	2,721
Mesa	660
State Total	34,366

Data Source: Colorado Oil and Gas Conservation Commission

Although close to forty percent of currently active wells are located within Weld County (which is not on the Western Slope), permits for drilling in Garfield County have exceeded permits for all counties since 2005. (Figure 1, Table 2) This dramatic increase in permits demonstrates that Garfield County is rapidly becoming the center of oil and gas extraction activity on Colorado's Western slope. Furthermore, as shown below, many existing wells and permits in Garfield County are located close to population centers, thereby increasing potential human exposure to hazardous chemicals. This white paper focuses on Garfield County as an illustration of the principles and issues that need to be considered when weighing the potential exposure-related health impact of oil and gas development. Similar analyses could be conducted in other counties.

Although we do not yet know the total number of drilling permits issued for the current year, as of May 1, 2008, 1,029 permits, or 35% of all permits issued in the state, have been issued in Garfield County. Currently, most permits issued within the county surround the communities of Rifle, Parachute, and Silt. (Figure 2) It is predicted that by the end of 2008 approximately 3,200 drilling permits will be issued in the county. Looking toward the future, it is estimated that Garfield County will continue at a pace of approximately 1,000 new wells per year. It is expected that by 2023 there will be approximately 15,000 to 23,000, or 3 to 5 times the amount of wells in Garfield County. (BBC Research & Consulting, 2008)

Figure 1. Drilling Permits by County 2003-2007



Data Source: Colorado Oil and Gas Conservation Commission

Consistent with the expansion of oil and gas wells in Garfield County, the number of drilling rigs running per week has also exceeded all counties within the state. On average, during 2007, 58 drilling rigs were running per week. In comparison, Weld County, on average, had 19 drilling rigs running per week during the 2007 year. In the early months of 2008 (January 3-March 25), on average 66 rigs were running in Garfield County per week, compared to Weld County, with an average of 18 drill rigs running per week.

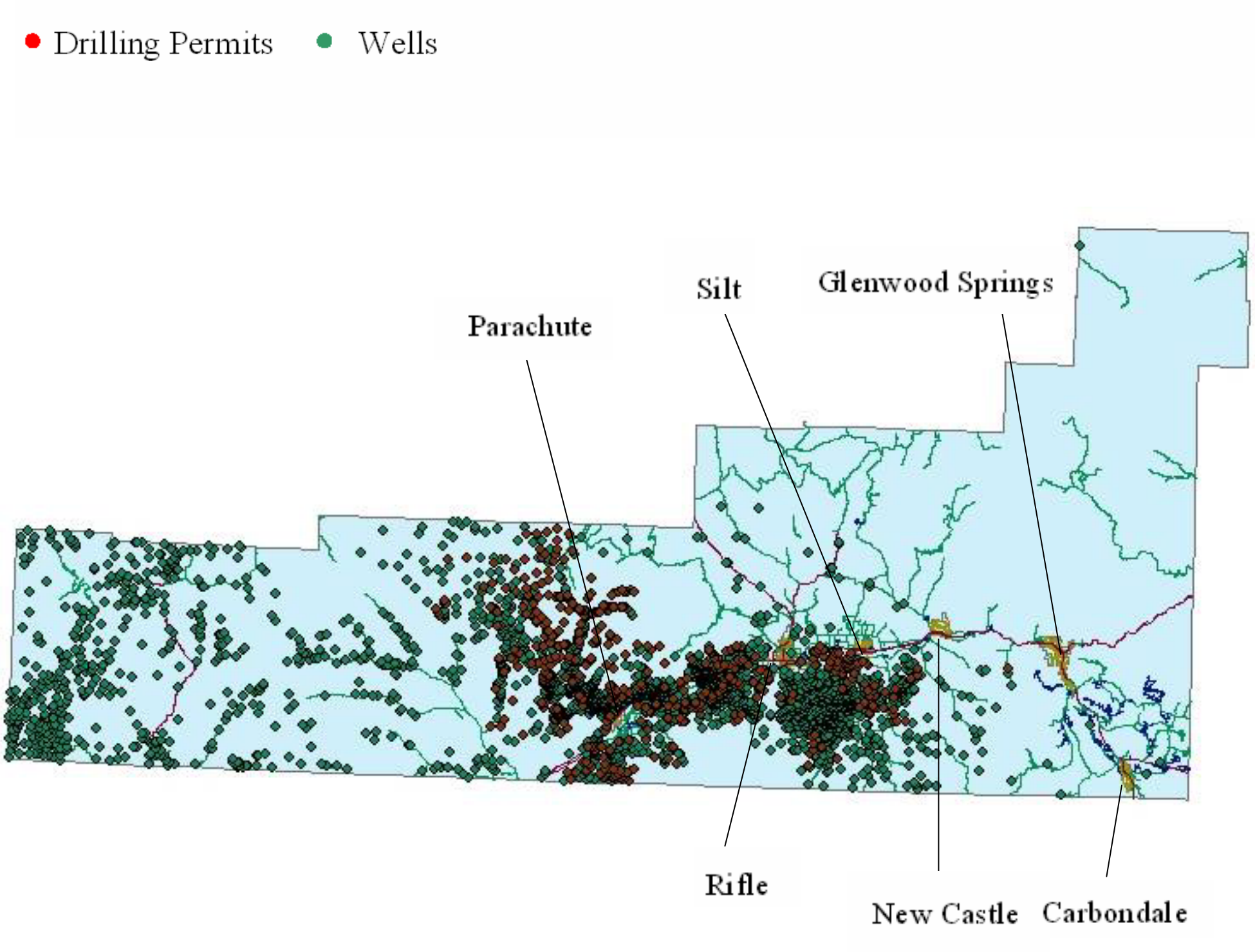
It is important to note that these statistics on drilling do not necessarily reflect the scope, intensity, and location of oil and gas production activity in the state. Some drilling sites can be expected to be active extraction sites, while others may not.

Table 2. Drilling Permit Totals for the Top Seven Counties by Year

County	**2003**	**2004**	**2005**	**2006**	**2007**	**2008** (June 2, 2008)
Garfield	566	796	1,508	1,844	2,550	1,029
Weld	757	832	901	1418	1,527	708
Mesa	138	54	136	265	293	225
Rio Blanco	180	154	161	360	321	200
La Plata	27	102	117	235	251	175
Las Animas	179	332	413	500	362	159
Yuma	162	237	782	798	541	148

Data Source: Colorado Oil and Gas Conservation Commission

Figure 2. Garfield County Wells and Drilling Permits as of April 2008



Demographics

Garfield County has experienced consistent growth since 1970, with the most rapid growth in recent years as local energy development draws in new workers and households to Garfield County. The 2006 population of Garfield County was estimated to be 53,020 people, an increase of 21 percent from the population reported in 2000. An annual growth rate of 3.2 percent (as compared to the state's 1.9%) made Garfield County the fastest-growing county on Colorado's Western Slope. Within Garfield County, the fastest growing community was the town of New Castle, which had an annual growth rate of 9.4 percent, during 2005 to 2006. (Table 3) As energy development increases in Garfield County, the population is projected to increase significantly. By 2035, Garfield County is projected to have a population of 136,697. (BBC Researching & Consulting, 2008)

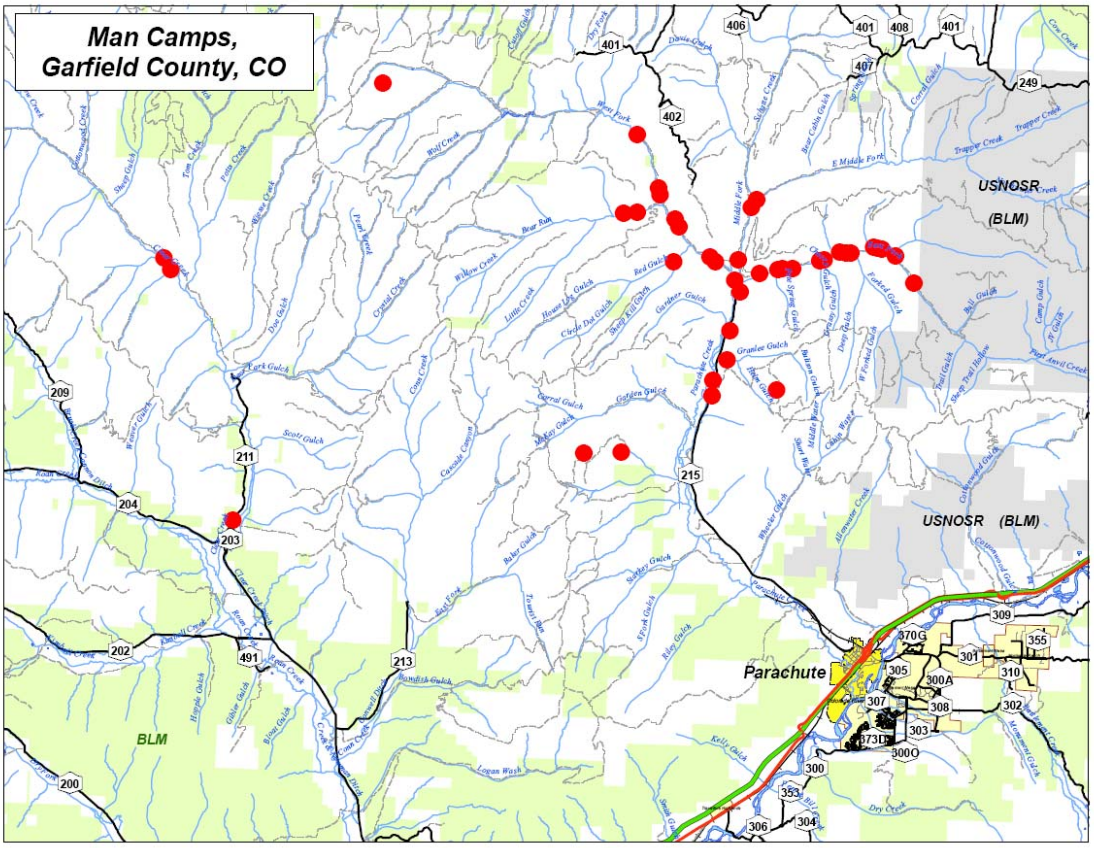
Table 3. Garfield County, Colorado Municipality Populations: 2000-2006

County	2000	2001	2002	2003	2004	2005	2006	Annual Growth Rate 2005-2006
Carbondale	5,196	5,509	5,565	5,689	5,767	5,881	6,088	3.5%
Glenwood Springs	7,736	8,135	8,301	8,406	8,517	8,603	8,743	1.6%
New Castle	1,984	2,268	2,604	2,825	2,949	3,148	3,443	9.4%
Parachute	1,006	1,269	1,297	1,320	1,338	1,360	1,486	9.3%
Rifle	6,784	7,079	7,349	7,541	7,760	8,118	8,706	7.2%
Silt	1,740	1,901	2,039	2,089	2,184	2,319	2,416	4.2%
Unincorporated area	19,345	20,012	20,286	29,526	20,810	21,244	22,138	4.2%
Total Population[1]	43,791	46,173	47,275	57,126	49,325	50,673	53,020	4.4%

Data Source: Colorado Department of Local Affairs. [1]Total population derived by adding each column

Oil and gas development has increased population densities, some of which is the result of an increase in the number of temporary and transient workers. The western slope has a large number of temporary workers living in motel rooms, RV campgrounds, and temporary camps, often called "man camps," in the region. (Figure 3) While there are no data on the exact number of temporary workers, it is estimated that 20 percent of the natural gas workforce is comprised of workers who do not have a permanent residence within the region or the surrounding counties. (BBC Research & Consulting, 2008) In 2006, approximately 6,300 jobs were oil and gas-related (not including supporting jobs) in a four county region (Garfield, Mesa, Moffat, and Rio Blanco). It has been predicted that by 2035 there will be almost 10,000 oil and gas workers in the four county region. (BBC Research & Consulting, 2008) The lack of precise information on this population affects the ability to accurately assess the current and future health of the community.

Figure.3 "Man Camps" Garfield County, Colorado



Source: Garfield County Website: Download Central

According to 2000 U.S. census estimates, 49 percent of the Garfield County population was female and 51 percent male. The median age was 34.2 years. Twenty-seven percent of the population were under 18 years of age, 8 percent under 5 years, and 9 percent were 65 years and older. Fifteen percent of the general population in Garfield County did not have health insurance in 2000. Twelve percent of children under the age of 18 in Garfield County did not have health insurance in 2000. For people reporting race in Garfield County, 92 percent identified as white alone; 0.5 percent identified as Black or African American; 0.7 percent identified as American Indian and Alaska Native; and 0.4 percent identified as Asian. Two percent identified as two or more races. Seventeen percent of the people reporting for Garfield County identified as Hispanic or Latino. Again, there are no demographic data on the temporary oil and gas workers, most of which moved into Garfield County since 2000. These data suggest that approximately one-third of the population, in the year 2000, may be considered to be more susceptible to certain exposures, based on age (27% children and 9% elderly).

Currently, 9533 students pre-kindergarten through 12th grade are enrolled in Garfield County schools across three school districts: Roaring Fork RE-1 (Glenwood Springs, Carbondale), Garfield 16 (Parachute), and Garfield RE-2 (Rifle, Silt, and New Castle). The Roaring Fork RE-1 district is the largest, housing 14 schools and a total of

4864 students. Garfield RE-2 has a total of 7 schools, and a total of 3695 students. The last district, Garfield 16, is made up of 4 schools and a total of 974 students. Colorado Department of Education trend data (2003-2007) show a 12 percent increase in enrollment for the county. Enrollment for the Roaring Fork RE-1 district serving the towns of Glenwood Springs and Carbondale has increased by approximately 6 percent. Enrollment in the RE-2 school district serving the towns of Rifle, Silt, and New Castle, has increased by approximately 15 percent. Enrollment in the Garfield 16 district, serving the town of Parachute, has increased by over 31 percent. These data suggest an increasing population of young people, who are potentially at increased risk for adverse health effects from certain exposures. (http://www.cde.state.co.us/index_stats.htm, http://www.cde.state.co.us/cdereval/rv2007pmlinks.htm)

The energy development boom has increased jobs in Garfield and surrounding Western Slope counties, which in turn has increased the demand for housing, driving home and land values up in the recent years. Housing costs in Garfield County were roughly 35 percent below comparable Denver metropolitan area costs just six years ago. Now the costs often match or exceed Denver area prices. (BBC Research & Consulting, 2008) Housing is also difficult to find in Garfield County. Vacancy rates are at 5%, compared to rates exceeding 25% in 1985. Since 2003, building permits have climbed each year in Garfield County. In particular, the town of Rifle had a 50 percent increase in building permits. This contributes to an understanding of the potential impact of oil and gas industry expansion on infrastructure and social systems.

Traffic congestion in Garfield County increased by 39 percent during the time period of 2000 to 2007, compared to an increase of 11 percent for the state (Northwest Colorado Socioeconomic Analysis and Forecasts, 2008). Surrounding Western Slope Counties experienced a similar increase in traffic congestion: Rio Blanco, 35%, Mesa, 25 %, and Moffat, 23%. Contributing to traffic congestion are a number of important factors, including the increase in vehicular traffic volume due to oil and gas industry activity as well as increased population. As discussed above, the lack of housing within the county for oil and gas employees contributes to commuter traffic and congestion in the county. As discussed in the literature review and elsewhere in this white paper, vehicular traffic contributes to injury rates as well as to air pollution associated health risks.

Conclusions and Recommendations

1. There is a lack of precise demographic data on the Garfield County population. This affects the ability to accurately assess the current and future health of the community.
2. There are no demographic data on the number of temporary oil and gas workers. Most moved into Garfield County since 2000.
3. The available data suggest that approximately one-third of the population may be more susceptible to certain oil and gas industry-related exposures, if exposed.

4. There is a rising population of children, who are potentially at increased risk for adverse health effects from these exposures, if exposed.

Exposure: Known Garfield and Four County contaminants

The purpose of this section is to summarize available exposure data. It is not intended to be a comprehensive analysis of exposure, but rather to provide sufficient information and background for the discussion of potential health effects of interest. In order to be able to determine the impact of oil and gas exploration and extraction activity on the health of a neighboring community, it is necessary to have sufficient exposure data. To be useful, these data must be collected in a systematic, accurate, and current manner. Such data must also be publicly available and provided in a form that can facilitate their use in assessing the relationship between exposure and human health outcomes.

The Western Slope of Colorado has seen a dramatic increase in oil and gas extraction activity. Despite this activity there are very few data regarding the air and water quality impact. Because of citizen concerns, a few, very limited studies have been undertaken. These studies are reviewed below. It should be noted that even with limited sampling and a very limited list of chemicals tested the results of the air sampling demonstrated potentially hazardous levels of benzene. Other volatile organic compounds have also been detected in Garfield County air, as discussed below. Methane has been detected in well water in areas near drilling sites. This study is also reviewed below. Water samples measured at sites removed from active drilling sites had no detectable contaminants. There has been no testing or monitoring of soil quality in Garfield County. These results demonstrate that more comprehensive and ongoing air, water and soil monitoring should be conducted.

Please note: there may be additional sources of exposure information that we were unaware of or were not able to obtain prior to preparing this white paper. If, for example, private corporations or public agencies have conducted sampling that is not in the public domain, we have not had the opportunity to review and include such data sets.

AIR QUALITY

ATSDR 2005-2007

The Colorado Department of Public Health and Environment (CDPHE), in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR), undertook an air sampling project from 2005-2007 to assess possible air quality impacts posed by increasing oil and gas activities in Garfield County, Colorado. Intermittent twenty-four hour sampling occurred at 14 fixed sites, coinciding with an EPA air sampling schedule, over a 24 month period. A total of 232 samples were taken (averaging 24 hours of sampling at each site every 45 days). In addition, twenty-seven 10-15 second grab samples (averaging 10 – 15 seconds of sampling every 27 days) were taken during "odor events," when odors felt to be caused by oil and gas activities were noted by local citizens.

The study used EPA risk assessment tools to examine carcinogenic and noncarcinogenic effects. For carcinogenic concerns, EPA Region 3 Risk Based Concentrations (RBC) were used in the risk analysis. Chemicals were listed as Contaminants of Potential Concern (COPC) if levels measured could produce greater than 1 excess cancer in one million. For noncancer health effects, if levels were found to be greater than Massachusetts Allowable Ambient Limits (ALLs) or above ATSDR Chronic, Intermediate, Acute Minimal Risk Levels (MRLs) in at least 5% of samples the chemical was listed as a COPC. It should be noted that recent literature suggests adverse health effects due to benzene may occur at lower levels than previously thought.

Results of the limited sampling indicate that local populations may be exposed to chemicals at levels hazardous to health. Benzene was identified at COPC levels at 12 of 14 sites and at 7 of the 8 oil and gas sites. Excess cancer risks ranged from 5-58 cancers/million. Four urban sites had cancer risks ranging from 15-22 cancers/ million and 1 rural site at 8 cancers/million. The Brock oil and gas site had benzene levels associated with excess cancer risk of 58 per million. The Brock site recorded a 24-hour sample of 49 ug/m3. This site also recorded the highest grab sample for benzene at 180 ug/m3 (3 ug/m3=1 ppb). Measurements here and at other locations also exceeded all minimum levels for noncancer health effects as well as for cancer health effects. While the Brock site is highlighted because it had the highest levels of benzene, it should be remembered that 12 of the 14 sites had potentially hazardous levels of benzene, indicating that potential for benzene exposure is the rule and not the exception. Although 86% of the sites tested demonstrated hazardous benzene levels, the CDPHE and ATSDR determined that benzene posed only an intermediate health risk because of lack of data and the hypothesis that other unnamed sources could be contributing to the measured benzene levels. No action is recommended by ATSDR other than a call for more monitoring.

In addition to benzene, other chemicals were found at elevated, potentially hazardous, levels. Methylene chloride (1 site), tetrachoroethene (2 sites), trichloroethene (1 site), 1,4-dichlorobenzene (8 sites), m,p-xylenes (6 sites) and 2-hexanone (3 sites) were noted at levels that could produced carcinogenic or non carcinogenic health effects. Toluene and acetone were also detected, frequently but at levels that did not reach cut-offs set for COPC. Based on these data, in its report ATSDR concluded that these chemicals were unlikely to be a significant hazard.

This conclusion may be problematic for several reasons. First, relatively few samples were obtained relative to the geographic area and the time period of concern. When chemicals are detected using an infrequent sampling scheme, there is no way of knowing if the results are truly representative of exposure. A conservative, precautionary approach would dictate that these results be considered as warnings that these chemicals exist, at levels as yet undetermined. Second, the quantitative measure of concentration for these chemicals may not be accurately represented. There is no way of knowing with certainty if the levels recorded were minimum, maximum or

somewhere in between. The grab samples are especially problematic, since they represent only a 10-15 second snapshot, without any information as to how high the levels may actually have reached, nor for how long levels may have been elevated. Similarly, the 24-hour samples may have been taken at a peak, nadir or somewhere in between. In conclusion, the actual level and extent of chemical contamination remains unknown.

The ATSDR did not look at levels of other air toxics that would be expected to be found. Potentially hazardous airborne chemicals associated with oil and gas extraction include particulate matter, nitrogen oxides, sulfur oxides, hydrogen sulfide, ground level ozone, metals (lead, arsenic, mercury, selenium, barium, cadmium, chromium, zinc). Although drilling permits may be granted based upon projected discharges and modeling, in the absence of actual, publicly available data, true exposures remain unknown.

Garfield County and CDPHE have responded to the ATSDR study with plans to continue air monitoring. The CDPHE has released its plan for this monitoring effort. Particulate monitoring will be reduced to only one sampling site, either in Rifle or Parachute, Colorado. They will, however, begin monitoring for particulate matter <2.5 micron diameter (PM2.5), based on accepted literature that has found that PM2.5 is more highly associated with human health risk than is particulate matter <10 micron diameter (PM10) (See Literature Review). Monitoring for hazardous ultrafine airborne particles is not planned, although there is compelling scientific evidence that ultrafine particles (<0.1 micron diameter) pose a particularly high human health risk. Nonmethane organic compounds (NOMC total and 54 species of chemicals) will be monitored for 24 hours every 6 days (264 samples in next year) and low molecular weight carbonyl compounds (LOMCC, e.g. formaldehyde, acetaldehyde, acetone, acrolein, and others) will be sampled for 24 hours every 12 days (180 samples in the next year) at Rifle, Parachute, Bell Ranch and a fourth fixed or mobile location (Rada, 2008).

While this plan represents an improvement in the amount and scope of sampling to be taken at a given site (60 samples per site for NOMC and 30 samples per site for LMWCC), the number of sites has been decreased 70%. Furthermore, the site that registered the highest levels of benzene in the ASTDR study is not included in future monitoring plans. The planned air monitoring also does nothing to address the already documented hazardous levels of benzene.

United States Forest Service Ozone Monitoring 2006-Current

Little is known about ozone levels in the rural, Western Slope of Colorado. Because ozone is highly toxic to plants, the U.S. Forest Service monitors ozone in some forests, including locations in this region. The U.S. Forest Service uses both passive and solar-powered battery-operated continuous monitors to measure ozone. Although new National Ambient Air Quality Standards (NAAQS) for ozone is 75 ppb, the EPA

acknowledges that for O3 (and PM2.5) levels substantially below NAAQS are still associated with increased mortality, cardiovascular events, and respiratory problems.

The preliminary results indicate that ozone in the Colorado high country is detected at concentrations that, at times, exceed National Ambient Air Quality Standards. Ozone concentrations on Ajax Mountain in Aspen ranged from 40 parts per billion (ppb) to almost 80 ppb during the months April-August, 2007. Additionally, ozone monitors on the Bell Ranch near Rifle found ozone levels averaging in the 40-50 ppb range, with spikes in ozone levels surpassing 75 ppb throughout the summer months of 2007. These results demonstrate that air quality in these areas may actually be hazardous to humans and that further monitoring by agencies tasked to protect human health is warranted.

Secondary findings are also important. The U.S. Forest Service found that ozone concentrations increase with altitude. CDPHE is installing ozone and PM monitors in Rifle (elevation 5130 f), Cortez (elevation 6201 f), and Palisade (elevation 4728 f). These locations may not be indicative of the ozone levels of communities at higher elevations (Musselman and Korfmacher 2008).*EPA Ozone Monitoring, La Plata County, 2007*

The EPA has two stationary ozone monitors in La Plata County; the first one is located a mile from Ignacio on County Road 517 and the second is on Highway 5505. The first location recorded spikes in ozone levels above 75 ppb and 8 hour average levels in the 58-71ppb range. The second location recorded ozone exceeding NAAQS (82 ppb) on one occasion and the next three highest levels (73, 73, 71 ppb) approached the limits of the standard (75 ppb). The monitoring in La Plata County demonstrates that air quality in some of Colorado's rural areas approaches and may at times exceed established Federal health standards (United States Environmental Protection Agency 2007).

CDPHE Air Quality monitoring

CDPHE has conducted limited air quality monitoring on the Western Slope. In 2006 there were 11 sites monitoring PM10 (Delta, Parachute, Rifle, New Castle, three ranches near Silt, Glenwood Springs, Durango, Grand Junction, and Telluride). In addition, Grand Junction had monitors for PM2.5, carbon monoxide (CO) and meteorological measurements. In 2006, none of the monitors recorded particulate levels exceeding NAAQS, with the exception of those associated with natural occurrence events (high winds or forest fires). It should be noted, however, that particulate levels in Parachute, Rifle and New Castle (towns in areas of the largest growth of oil and gas drilling in Garfield County) have recorded the highest monthly averages for particulate matter and have been trending upward over the last few years. For 2008, CDPHE has added PM2.5, ozone and meteorological monitors in Rifle and ozone and meteorological monitors in Palisade and Cortez. (Colorado Department of Public Health and Environment 2006; Garfield County Public Health Department 2007; Colorado Department of Public Health and Environment 2008)

WATER QUALITY

Garfield County Hydrogeologic Study 2006

In 2006 a report commissioned by the Garfield County Board of County Commissioners was released. This report contained a compilation of existing hydrogeologic data for a 110 square mile area which included the Mamm Creek gas field, south of Rifle and Silt and south of the Colorado River. (URS Corporation 2006)

The results of this report demonstrate many domestic wells, water wells, irrigation wells, monitoring wells, air sparging wells, springs, seeps, ponds, and rivers had detectable levels of methane. Out of 184 locations, 135 locations had detectable levels of methane (73% of locations); 872 samples were taken and 656 samples had detectable levels of methane (75% of samples). In the eastern portion of the study, the West Divide creek area recorded several wells with elevated levels of methane (>2 mg/l) and some with much higher levels (10-26 mg/l). Data from COGCC indicate that at least some of the groundwater and surface water contaminated with methane has been a result of gas development activities, while other sources of methane in domestic water wells remains unknown or is likely due to biogenic sources. In the southeast portion of the study area, domestic water contamination is likely due to older, abandoned wells that have been leaking for almost 30 years.

This study also reports on benzene and other organic compounds in surface waters. Benzene and methane levels in excess of MCL (5 ug/L and 1000ug/L, respectively) have been recorded in seeps in the study area. The two highest benzene recordings were in the West Divide Creek seep area (360 ug/L and 150 ug/L) and these two locations also recorded the highest ethylbenzene (10 and 16 ug/L) and some of the highest toluene (28-130 ub/L), xylene (17-110ug/L) and methane (1.2-12mg/L) measurements.

While this study is preliminary, it demonstrates that hazardous substances are present in the area's surface and subsurface water. The authors of this hydrogeologic report also point out that water sources with high levels of benzene, toluene, ethylene, and xylene (BTEX) chemicals also contain high levels of methane from gas well sources. They propose BTEX measurements as a method for determining gas well contamination of water sources. The authors also note that parts of the study area have undergone extensive oil and gas development, but there are few current data available regarding the groundwater quality in the same area. Some of the recommended follow up (Phase 2) studies include: further evaluation of wells with elevated methane levels, develop a long-term groundwater and surface water sample collection program, sample all domestic water wells on a two-year frequency for methane, major ions, selenium, fluoride and bromide, as well as other recommendations. (URS Corporation 2006)

Garfield County Phase IV Baseline Water Quality Study 2007

The Colorado Oil and Gas Conservation Commission (COGCC) contracted for a water quality field study in July and August of 2006. Seventy domestic water supply wells in Garfield County, between New Castle and Rifle north of the Colorado River were tested for inorganic, organic chemicals and 29 wells were tested for gas composition. Methane, BTEX and Methyl Tertiary Butyl Ether **(**MTBE) were not detected in any samples tested at STL Laboratories, but methane was detected in some water samples using gas chromatography methods used by the Isotech laboratory.

While this study provided some evidence that wells in the study area did not have the chemicals tested for at the time, it should be noted that the study area of this report differs significantly from that of the 2006 Hydrogeologic Report study area. The 2007 COGCC report study area is *north* of the Colorado River, whereas the report commissioned by Garfield County in 2006 studied an area *south* of the Colorado River. It should be noted that the greater extent of gas drilling in this area is taking place south of the Colorado River. This report illustrates the need not only for further water quality studies in Garfield County, but also for studies that are relevant to the areas where the most drilling activity is occurring. (Garfield County IT Department 2007; S.S. Papadpipulos & Associates 2007)

NOISE

La Plata County Impact Report 2002

Elevated noise levels are associated with all stages of oil and gas development: construction, vehicle noise, pumps and condensers all contribute to well pad noise. COGCC uses the State of Colorado noise guidelines for oil and gas monitoring. According to COGCC Rule 802, sound from oil and gas activities should not exceed the noise levels for predominant land use in the zone where a well exists and noise should be measured 25 feet beyond the property line or at a residential home.

La Plata County did an extensive County Impact Report (CIR) in 2002, assessing the impacts of proposed gas drilling. Contained in this report were measurements of ambient noise in rural residential, subdivision residential, and transportation land use areas in La Plata County. The average residential noise levels ranged from 42-46 decibels (dBA) and were substantially less than those allowed by State of Colorado Noise Guidelines (50 dBA at night and 55 dBA in the day). The La Plata report also used published noise levels for drilling activities to model well pads layouts to meet COCGG requirements. The final staff report made recommendations to change the noise level requirements to reflect the ambient noise of the county. (La Plata County 2002)

We were unable to find any publicly available data that directly measured noise levels associated with oil and gas development activities on the Western Slope. If such information exists, it is not readily available. Noise can contribute to a variety of adverse health effects, as discussed in the accompanying literature review. Of particular note, when noise exposure occurs in combination with exposure to volatile organic compounds, hearing loss can develop at lower levels than with just noise alone. As oil and gas development continues to increase in close proximity to populated areas, noise monitoring and mitigation should be implemented.

Conclusions and Recommendations

1. There are major gaps in the past assessment of air and water quality related to oil and gas development on the Western Slope.
2. Air and water quality studies conducted to date indicate that potential exposures to hazardous emissions exist.
3. Many air toxics are essentially unmeasured in Garfield County, despite the increase in oil and gas development known to produce these chemicals. Air quality measurements should not be considered complete until monitoring of all known potential hazardous substances is performed.
4. Current plans for further air sampling may not be comprehensive enough to enable public health officials to determine the community health impact of oil and gas development.
5. There are no plans for comprehensive and systematic monitoring of surface and subsurface waters. Water monitoring must occur and results made public, in order to protect human health.
6. Although some levels of harmful chemicals in both air and water measured in Garfield County may not fall within a specific regulatory standard, adverse health impacts are known to occur at levels below standards. As discussed in the attached literature review, this must be taken into account when mitigation measures aimed at reducing health impacts are undertaken. (Glass, Gray et al. 2003; Glass, Gray et al 2005)
7. Environmental monitoring must be relevant to the areas where oil and gas development activity is occurring.
8. Environmental monitoring results must be readily available to the public. Unbiased interpretation of the results must occur in a timely manner and be made available to the public.
9. There are no available studies examining the impact of oils and gas development on the noise levels in Garfield County. These studies should be conducted to assess and mitigate adverse effects of increased noise levels.
10. There are no available studies examining the impact of oil and gas development on soil quality in Garfield County. These studies should be conducted to assess and mitigate adverse affects of soil contaminants on human health.

Garfield County Health Status

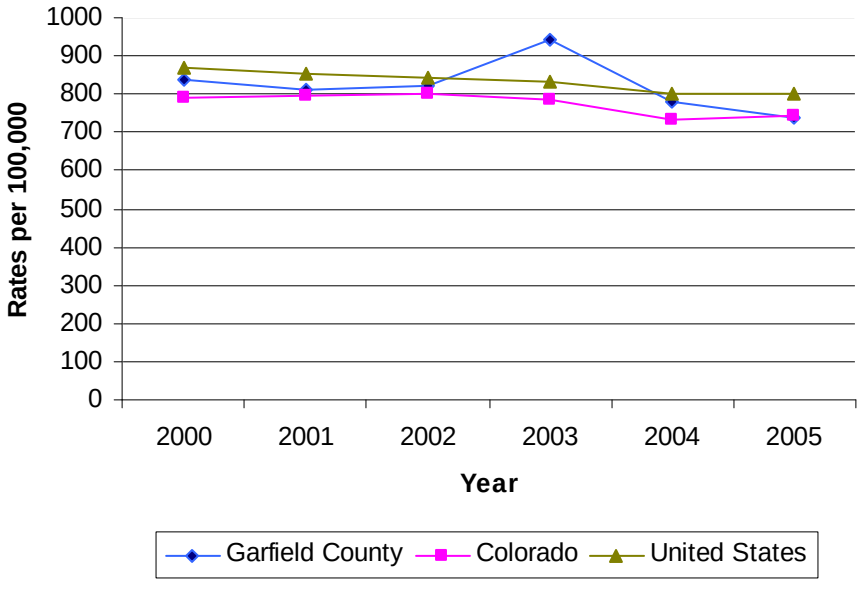
We examined heath status data publicly available for Garfield County residents; outlined below are some of the health status and determinants. A complete list of references can be found in Appendix 1. It is important to note that this is publicly available data. The data have significant limitations, the most notable being that oil and gas development in Garfield County did not start to rapidly expand until 2003. Most publicly available data for the county are still not available for the most recent years. Also, most of the data are population based, therefore lacking the ability to identify rare and individual health events. Listed below are the publicly available data we recovered for Garfield County, Colorado.

- Mortality Data (General, Infant): 1990-2005
- Cause of Death: 1990-2005
- Cancer Statistics: 1992-2002
- Cardiovascular Disease: 2000-2006
- Low Birth Weight: 2006-2006
- Asthma: 1993-2001
- Chronic Obstructive Pulmonary Disease (COPD): 1990-2006

Mortality

Mortality rates in Garfield County declined during the five-year period (2000-2005) with the exception of 2003, when the oil and gas industry started to rapidly expand in Garfield County, and the rates were higher than both U.S. and Colorado rates. (Figure 4.) Infant mortality rates are consistently lower in Garfield County (5/1,000) when compared to statewide rates (6.2/1,000), providing a good baseline health status when examining more recent years.

Figure 4. General Mortality Rates 2000-2005



Data Source: Garfield County Births and Deaths 2006

According to the Colorado Health Information Dataset: Death Statistics Section, the leading causes of death in 2006 for Garfield County closely mimicked those for the leading causes of death across the state and surrounding Western Slope Counties, with Garfield County having slightly higher mortality rates for heart disease, unintentional injuries, cerebrovascular diseases, Alzheimer's disease, suicide, and diabetes mellitus, compared to state rates. Although, cardiovascular disease was the number one cause of death in Garfield County in 2006, age-adjusted rates for the county have declined since 2000. In 2000 age-adjusted mortality rates for cardiovascular disease were 269.2/100,000. All four counties on the Western Slope had higher age-adjusted mortality rates for: diabetes mellitus, Alzheimer's disease, unintentional injuries and suicide when compared to state mortality rates. (Table 4)

Table 4. Leading Causes of Death for Garfield County Colorado (2006)

Cause of Death	**Age-Adjusted Rate** (Colorado)	**Age-Adjusted Rate** (Garfield)
Heart Disease	157.8	163.4
Malignant neoplasm's	158.8	138.4
Unintentional Injuries	42.0	63.1
Cerebrovascular diseases	40.5	46.2
Chronic lower respiratory diseases	50.4	43.7
Alzheimer's disease	29.7	42.3
Suicide	14.9	15.8
Diabetes mellitus	17.0	20.6

Data Source: Colorado Health Information Dataset: Death Statistics

In the remainder of this section, the white paper addresses five major health conditions: cancer, cardiovascular disease, low birth weight, asthma, and chronic obstructive pulmonary disease (COPD). We have emphasized these five because of their potential importance. Based on the literature review, these are among the likely health conditions that may potentially be caused by or aggravated by the contaminant exposures encountered in oil and gas exploration and extraction. As such, it is important to have accurate baseline and prospective data on these and other such health outcomes of concern. It is important to note that since latency periods exist for some diseases (especially for many cancers) and their significant exposures, even current health statistics may not reflect the current population health status.

Cancer

As indicated in the literature review, certain exposures seen in oil and gas exploration and extraction are considered significant cancer risks. Since 1992, both cancer incidence and mortality rates have declined in Garfield County. Garfield County overall cancer incidence rates were significantly higher in males compared to state incidence rates, for all years that public data were available. Overall cancer mortality rates for males were higher in Garfield County when compared to the state for the time periods of 1992-1998 and1999-2000, but were slightly lower in the 2000-2001 time

period than state rates. Overall females in Garfield County have lower rates of cancer incidence and mortality than state rates. Specific cancer incidence and mortality rates showed males with higher lung cancer mortality rates compared to state rates and higher prostate cancer incidence rates, and both males and females having higher bladder cancer incidence rates compared to state rates. (Figures 5,6.)

Figure 5.

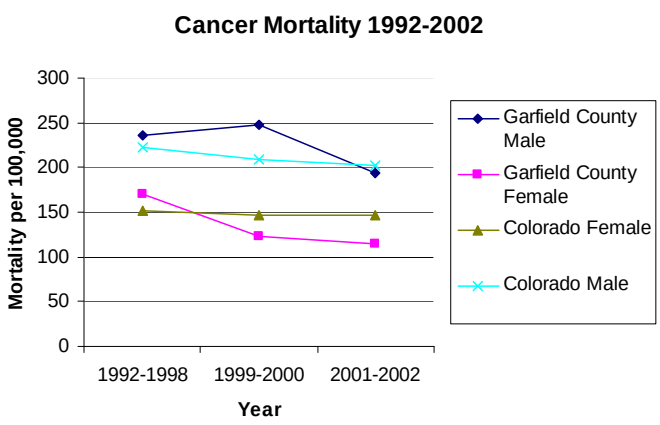
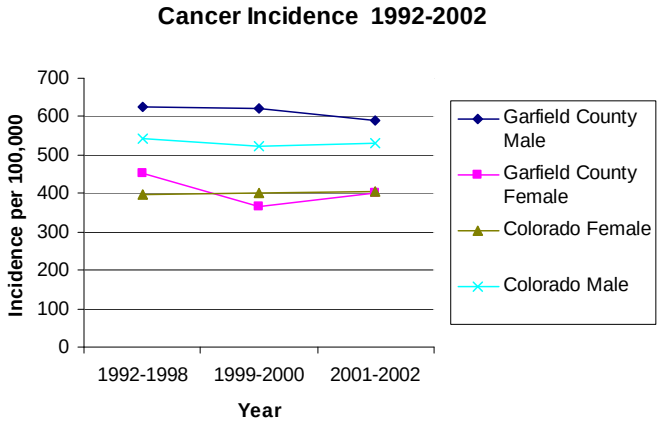


Figure 6.



Data Source: Cancer in Colorado: 1992-2002

Low Birth Weight

As indicated in the literature review, certain exposures seen in oil and gas exploration and extraction are considered significant risk factors for fetal outcome, including low birth weight. As such, this is an outcome of potential importance for tracking purposes. Colorado has a relatively higher percentage of low weight births than the United States overall. Garfield County has consistently has a lower percentages of low weight births then Colorado state percentages. The percentage of low birth rates in Garfield County, in 2005 was 6.8 percent, falling below the state percentage of 9.3 percent. In 2005, the percentage in Garfield County rose to 8.8 percent, still lower then state percentages, but increasing from the prior year. Continued monitoring of low birth weight infants in Garfield County is needed, as low weight infants are at a much higher risk for long-term morbidity, susceptibility to respiratory problems, and early death.

Asthma

Literature examining health effects of air pollutants produced by both stationary (e.g. industrial sources) as well as mobile sources (e.g. fossil fuel combustion emissions from vehicles and traffic density) have shown clear relationships with respiratory disease, most notably asthma and chronic obstructive pulmonary disease. A recent health study completed by the Saccomano Institute reported that children in Garfield County had an increased asthma rate, as discussed below in more detail. Asthma incidence in Colorado is mostly estimated by use of hospital discharge records. The age adjusted rate for asthma, obtained from hospital discharge records (principal diagnosis),

in Garfield County for the nine-year period of 1993 to 2001 was 7.9/10,000. The age-adjusted rates for surrounding counties were similar with Moffat having a slightly higher incidence, 12.8/10,000 and Mesa and Rio Blanco having a slightly lower incidence of 7.5/10,000 and 6.7/10,000, respectively. Publicly available data are only available through the year 2001. Because oil and gas development activities did not rapidly expand in the region until the year 2003, asthma data for more recent years such as increased rates reported in the Saccomano Institute study are of more value. It is also important to note that not all asthma related incidents are accounted for with hospital discharge data, as not all asthma related incidents will require admittance to hospitals. Emergency room visit data and outpatient clinic data for asthma incidence and prevalence in Garfield County would also be of more use.

Chronic Obstructive Pulmonary Disease (COPD)

As mentioned above, clear relationships have been established through literature between COPD and air pollutants given off by stationary and industrial sources. Currently there are no true COPD prevalence data for the state of Colorado. Recent data on COPD mortality specific to Garfield County are not publicly available. However, we do know that during the years 1990 to 2004 Garfield County had age adjusted rates of 90-70 deaths due to COPD per 100,000 residents. We also know COPD mortality rates in Colorado are one of the highest in the nation, despite being one of the states with the lowest smoking prevalence, and that rural and frontier counties in Colorado, like Garfield County, have higher mortality rates compared to urban regions in Colorado. In the recent study conducted by the Saccomano Institute, they reported residents of Silt had an increased rate of COPD compared to the rest of Garfield County.

Summary of recent "Community Health Risk Assessment"

The Saccomanno Institute in Grand Junction, Colorado recently completed a two-year study of the health trends in Garfield County. Although this study is as yet unpublished, the major findings have been the subject of public presentations. Because of its relevance to Garfield County and as an illustration of the type of research that is needed, this white paper summarizes the major conclusions and considers the available information from this project. ("Community Health Risk Assessment: An assessment of risk related to the natural gas industry in Garfield County Part II: Health Study.")

This study was completed in two parts: one focusing on exposure, the other on health. In the health study, four-county (Mesa, Garfield, Montrose, Delta) comparisons were made using seven sets of available statistics from the Colorado Department of Public Health and Environment (birth statistics, death statistics, birth defects, adolescent health measures, reportable conditions, West Nile virus, and Cancer statistics), as well as data from a behavioral risk factor study survey and injury hospitalization and death rates/causes, hospital and medical insurance data sets. In addition, the researchers conducted a telephone and mailed household survey to obtain self-reported health status information (participation rate of 18%).

The authors of this study observed some trends of illness in Garfield County, as compared to other Western Colorado counties. According to the authors, a number of the trends may be important indicators to track prospectively, including alcohol and drug disorders, birth and pregnancy outcomes, children in Garfield county having an increased seizure and headache hospital admittance, bronchitis and asthma rates, and respiratory infections and inflammation. The authors of this study have recommended a prospective medical monitoring system to identify any changes in baseline data or trends. (Teresa Coons and Walker 2008)

A critical assessment of the study design, methodology, results and conclusions will have to await a more complete release of the data.

Conclusions and Recommendations

1. Publicly available information about health status of Garfield County residents is incomplete.
2. Recent data, which is most important, are lacking and often delayed in public distribution.
3. Trends from the Saccomonno Institute study support the need for better prospective monitoring. According to those authors, these trends include alcohol and drug disorders, birth and pregnancy outcomes, increased seizure and headache diagnoses for hospital admittance of children, bronchitis and asthma rates, and respiratory infections and inflammation.
4. In light of the rapid pace of oil and gas activities in Garfield County, and the lack of recent available data, one is not able to make any definitive conclusions about the health status of Garfield County residents.
5. At this point in time, there are many uncertainties regarding the health effects of oil and gas industry activity on general markers of health within the surrounding communities.
6. This lack of information, combined with the lack of comprehensive, systematic health and exposure monitoring and recording, make it difficult to draw any definitive conclusions about the causality and severity of these effects.
7. Ongoing surveillance of both asthma and COPD in Garfield County is needed. A way to measure and subsequently monitor both incidence and prevalence for the county should be implemented. These are diseases that occur in great enough frequency to act as meaningful sentinel events for monitoring purposes.
8. Continued monitoring and interpretation of data concerning low birth weight is warranted.
9. By improving our measurement and monitoring of health outcomes in Garfield County, it should be possible to better intervene and mitigate any adverse impact resulting from oil and gas development.

Worker Health

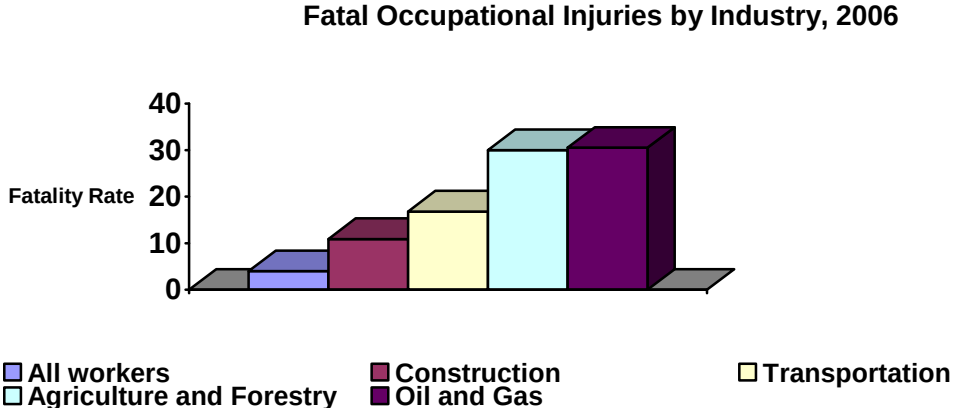
Although the majority of this white paper addresses exposures to neighboring communities, it is important to note that the health impact on the community includes those who work in the oil and gas industry or who work in industries that support this development.

Occupational Fatalities

An increase in oil and gas production has led to a rise in employment in this industry. Nationwide, the average number of workers employed in the oil and gas industry has increased almost 32% from 2003 to 2006, as discussed in the accompanying literature review. An increase in oil and gas extraction activities has been significantly correlated with an increase in the rate of fatal occupational injuries among oil and gas extraction workers employed in the U.S. The average annual rate of fatal occupational injuries in the U.S. in the oil and gas industry from 2003 to 2006 was 30.5 per 100,000 workers. This rate is high compared to the overall national rate of 4.0 fatalities per 100,000 workers for all workers for these same years. Fatalities that occurred in the oil and gas industry for this time period were attributable to transportation incidences and being struck by machinery or equipment. (MMWR April 25, 2008 / 57(16); 429-431)

The oil and gas industry is considered a high risk industry for fatality as demonstrated by the rates above. Oil and gas workers in the U.S. experience a disproportional rate of occupational fatalities compared to other industries except agriculture and forestry. In 2006, compared to other high-risk industries, the fatality rate per 100,000 workers was 31.9 for the oil and gas industry, 30.0 for agriculture and forestry, 16.8 for transportation, and 10.9 for construction. Notably, fatalities among oil and gas workers accounted for nearly two-thirds of the fatalities in the mining industry as a whole. (MMWR April 25, 2008 / 57(16); 429-431; http://www.bls.gov/iif/oshwc/cfoi/cfch0005.pdf)

Figure 7.



Further detail describing fatalities among oil and gas workers can be obtained by accessing the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI). Occupational fatalities are classified by industry, event or exposure, including transportation incidents, assaults and violent acts, contact with objects and equipment, falls, exposure to harmful substances and fires/explosions. CFOI does not report fatalities caused by occupational illnesses due to latency issues.
(http://www.bls.gov/iif/oshcfoi1.htm)

The Colorado Department of Public Health and Environment provides detailed data describing occupational fatalities in Colorado by selected industry. Fatalities in the mining industry (all mining) from 2003 to 2006 have represented approximately 5% of all work-related fatalities in Colorado for those years. Fatality rates for the oil and gas industry specifically are not available in Colorado. Fatalities in the mining industry in Colorado have been lower than other high risk industries.
(http://www.bls.gov/iif/oshstate.htm#CO)

Occupational Injuries and Illnesses

Survey of Occupational Injuries and Illnesses (SOII)

The BLS Survey of Occupational Injuries and Illnesses (SOII) reports incidence rates of non-fatal occupational injuries and illnesses by industry. In the U.S. the overall rate of non-fatal injuries and illnesses among private industry employees in 2006 was 4.4 per 100 full-time workers. Comparing goods-producing industries, the injury and illness rate was 3.5 for mining, 5.9 for construction, and 6.0 for both agriculture and manufacturing.
(BLS, USDL 07-1562 http://www.bls.gov/iif/oshwc/osh/os/osnr0028.pdf)

Injury characteristics reported in the SOII include days away from work, the 'physical' nature of the injury such as a sprain or burn, part of the body affected, source of injury such as chemical, machinery, tools or equipment, and the 'physical' event or exposure such as fall or transportation incident. In the U.S. in 2006, industry sectors experiencing the most injuries were manufacturing (20%), health care and social assistance (16%), and retail (15%). Within the goods-producing industry, 20% of non-fatal injuries occurred in manufacturing, 10% in construction, 1.3% in agriculture and forestry, and 0.6% in mining. Illnesses categories in the SOII include skin diseases or disorders, respiratory conditions, poisonings, and 'all other illnesses.' In the U.S. in 2006, mining accounted for 0.4% of all non-fatal occupational illnesses. (BLS, USDL 07-1562
http://www.bls.gov/iif/oshwc/osh/os/osnr0028.pdf)

Nationwide non-fatal injury and illness data are reported for sectors within the mining industry, as reported below. These data, however, are not comparable to other

industry sectors due to differences in data collection and reporting standards. Therefore, comparisons are not made.

The average incidence rates reported by mining subsector (per 10,000 full time workers) of nonfatal occupational injuries from 2003 to 2006 nationwide was 2.0 for oil and gas extraction workers, 5.3 for workers involved in drilling oil and gas wells, and 3.1 for workers performing support activities for oil and gas operations. (SOII Table SNR05 for years 2003 – 2006 http://www.bls.gov/iif/oshsum.htm)

The average incidence rates by mining subsector (per 10,000 full time workers) of nonfatal occupational illnesses from 2003 to 2006 nationwide was 13.5 for oil and gas extraction workers, 13.6 (excluding 2004) for workers involved in drilling oil and gas wells, and 8.8 for workers performing support activities for oil and gas operations. (SOII Table SNR08 for years 2003-2006 http://www.bls.gov/iif/oshsum.htm) Since Colorado is one of seven states that do not participate in the Survey of Occupational Illnesses and Injury, comparison of state data with national data cannot be accomplished.

Colorado Workers' Compensation Data

The Colorado Division of Workers' Compensation collects data on employer/employee submitted work-related injury and illness claims, providing another source of data with which to estimate health impact in workers. Occupational injuries and illnesses can be described by industry, county, part of the body, nature of injury and illness and cause of injury or illness.

Data are currently available and reported for the calendar years 2001 to 2003. In Colorado, the mining industry represented 0.6% of total average annual employment. Approximately 1% of all lost-time claims filed with the state were from the mining industry, including fatalities. The fatality rate for the mining industry per 10,000 employed decreased from 7.79 in 2001 to 2.29 in 2003.

When separated into mining subsectors, workers in the support activities had the highest number of lost-time claims (1%) compared to mining (except oil and gas) (0.5%) and oil and gas extraction (0.1%). Fatality rates were not available by sub-sector.
http://www.coworkforce.com/dwc/PUBS/Work_Related_Injuries_03.pdf
http://www.coworkforce.com/dwc/PUBS/Work_Related_Injuries_02.pdf
http://www.coworkforce.com/dwc/PUBS/Work_Related_Injuries_01.pdf

Colorado Hospital Association Data

The Colorado Hospital Association collects data on hospitalizations occurring in Colorado. Estimates of work-related hospitalizations need to be determined by identifying hospitalizations for which workers' compensation is the payer. Although we

have requested this information, the data were unavailable at the time of completion of this white paper.

Conclusions and Recommendations

1. In any assessment of health impact on a region, occupational fatalities, injuries and illnesses should be taken into account along with the health impact on the local community.
2. National data indicate significant rates of occupational illness, injury and fatality associated with the oil and gas industry.
3. We were unable to obtain specific fatality rates for the oil and gas development-associated subsectors in Colorado. Further analysis is needed to determine the fatality rates in oil and gas extraction, drilling oil and gas wells, and support industries, such as construction trades.
4. We were unable to obtain data on the rates of nonfatal occupational injuries and illnesses for Colorado. These data need to be determined in Colorado. At this time, Colorado is one of only seven states that do not participate in the SOII.
5. Workers' compensation and hospital discharge data may be important additional sources that can be used to estimate the health impact of the oil and gas industry for workers.

Social and Psychological Health Effects

While limited research has examined the physical health consequences associated with oil and gas development, even less research has focused on the social and psychological health effects of these activities (Mall, 2007). A review of the available literature about the social and psychological implications of oil and gas exploration reveals some interesting trends found in industrial communities throughout the world.

The literature review attached to this paper suggests a number of social and psychological concerns that may be associated with industrial activity moving into populated areas. These concerns include possible increases in domestic violence, rape, assault, child abuse, suicide, homicide and crime. (Bhatia, 2007, Srinivasan, 2003, Wernham, 2007, Forsyth, 2007, Luthra, 2007, Seydlitz, 1993, Kettl, 1998) Given the limited number of studies and the mixed nature of the results, further study in this area is warranted.

Garfield County Crime Rates

Crime rates for Garfield County, for years 2000-2005, were calculated using data describing the number of arrests made in the county (Lowden, 2007) and the population information described above. In Garfield County, between 2000 and 2005, the total number rate of adult violent arrests continually increased. (Table 5) Although there are some fluctuations from year to year, there is an overall increase in the rate of violent crime arrests and drug violations in Garfield County from 2000-2005. While the cause of these increases remains to be determined, this finding is consistent with studies finding that violent crime rates can increase in communities involved in rapid growth of industrial activity. Nonviolent crime rates did not increase across the same time period. (Table 6)

Table 5. Rate per 10,000 residents (Number) of Arrests for Violent Crimes and Drug Violations, Garfield County, 2000-2005

Year	Popula-tion	Murder	Rape	Other Sex Crimes	Rob-bery	Aggravated Assault	Violent crimes total	Drug violations
2000	43,791	0 (0)	.68 (3)	.23 (1)	0 (0)	7.54 (33)	8.45 (37)	19.41 (85)
2001	46,173	0 (0)	.65 (3)	1.52 (7)	.86 (4)	9.31 (43)	12.34 (57)	23.39 (108)
2002	47,275	0 (0)	.85 (4)	2.32 (11)	.21 (1)	10.15 (48)	13.54 (64)	29.83 (141)
2003	57,126	.18 (1)	.35 (2)	1.05 (6)	.18 (1)	6.65 (38)	10.15 (48)	22.06 (126)
2004	49,325	0 (0)	.61 (3)	1.01 (5)	.20 (1)	14.60 (72)	16.42 (81)	20.48 (101)
2005	50,673	0 (0)	1.18 (6)	1.18 (6)	.20 (1)	17.17 (87)	19.73 (100)	39.67 (201)

Table 6. Rate per 10,000 residents (Number) of Arrests for Nonviolent Crimes, Garfield County, 2000-2005

Year	Popula-tion	Burglary	Larceny/Theft	Motor Vehicle Theft	Arson	Nonviolent crimes total
2000	43,791	2.97 (13)	31.74 (139)	1.60 (7)	0 (0)	36.31 (159)
2001	46,173	4.55 (21)	16.46 (76)	1.95 (9)	.87 (4)	23.82 (110)
2002	47,275	5.08 (24)	25.38 (120)	.63 (3)	.21 (1)	31.31 (148)
2003	57,126	2.63 (15)	19.43 (111)	1.58 (9)	0 (0)	23.63 (135)
2004	49,325	3.65 (18)	18.04 (89)	.81 (4)	.41 (2)	22.91 (113)
2005	50,673	5.92 (30)	17.37 (88)	2.76 (14)	.20 (1)	26.25 (133)

Conclusions and Recommendations

1. The literature supports the concept that rapid industrial change can have deleterious effects (in addition to possible positive effects) on the psychosocial welfare of a local population.
2. The data shown above indicate that there has been an increase in violent crimes and drug violations in Garfield County. Further study is needed to determine if industrial development, in the form of oil and gas drilling, is contributing to this increase, especially since literature suggests that this is possible.
3. At this point in time, there are many unknowns about the effects of oil and gas industry activity on psychosocial health outcomes. This lack of information, combined with the lack of a comprehensive, systematic health and exposure monitoring make it impossible to draw any definitive conclusions about the causality and severity of these effects.
4. Improved monitoring of the psychosocial health Garfield County residents is needed in order to intervene and mitigate any adverse impact resulting from oil and gas development.

White Paper Conclusions and Recommendations

Community at Risk

1. There is a lack of precise demographic, exposure and health information on the Garfield County population. This affects the ability to accurately assess the current and future health of the community.
2. There are no demographic data on the temporary oil and gas workers. Most moved into Garfield County since 2000.
3. The available data discussed above suggest that approximately one-third of the Garfield County population (27% children and 9% over 65) may be more susceptible to certain oil and gas industry-related exposures.
4. As discussed above, there is an increasing population of children in Garfield County, who are potentially at increased risk for adverse health effects from these exposures.

Hazardous Exposure Information

1. There are major gaps in the past assessment of air and water quality related to oil and gas development on the Western Slope.
2. Air and water quality studies conducted to date indicate that potential exposures to hazardous emissions exist.
3. Many air toxics are essentially unmeasured in Garfield County, despite the increase in oil and gas development known to produce these chemicals. Air quality measurements should not be considered complete until monitoring of all known potential hazardous substances is performed.
4. Current plans for further air sampling may not be comprehensive enough to enable public health officials to determine the community health impact of oil and gas development.
5. There are no plans for comprehensive and systematic monitoring of surface and subsurface waters. Water monitoring must occur and results made public, in order to protect human health.
6. Although some levels of harmful chemicals in both air and water measured in Garfield County may not fall within a specific regulatory standard, adverse health impacts are known to occur at levels below standards. As discussed in the attached literature review, this must be taken into account when mitigation measures aimed at reducing health impacts are undertaken. (Glass, Gray et al. 2003; Glass, Gray et al 2005)
7. Environmental monitoring must be relevant to the areas where oil and gas development activity is occurring.
8. Environmental monitoring results must be readily available to the public. Unbiased interpretation of the results must occur in a timely manner and be made available to the public.
9. There are no available studies examining the impact of oil and gas development on the noise levels in Garfield County. These studies should

be conducted to assess and if necessary, mitigate adverse effects of increased noise levels.

10. There are no available studies examining the impact of oil and gas development on soil quality in Garfield County. These studies should be conducted to assess and if needed, mitigate adverse affects of soil contaminants on human health.

Health Status of the Community

1. Publicly available information about health status of Garfield County residents is incomplete.
2. Recent data, which is most important, are lacking and often delayed in public distribution.
3. Trends from the Saccomonno Institute study support the need for better prospective monitoring. According to those authors, these trends include alcohol and drug disorders, birth and pregnancy outcomes, increased seizure and headache diagnoses for hospital admittance of children, bronchitis and asthma rates, and respiratory infections and inflammation.
4. Sources of health statistics are available only up to years 2001 (asthma), 2002 (cancer), 2005 (mortality), and 2006 (cardiovascular disease, COPD, low birth weight) Changes in health may not yet be apparent in these statistics. Since drilling has been rapidly increasing since 2003, the health of the residents of Garfield County may be impacted, yet this may not yet be reflected in the available data.
5. At this point in time, there are many uncertainties regarding the health effects of oil and gas industry activity on general markers of health (such as mortality, birth outcomes, cancer, etc) within the surrounding communities.
6. This lack of information, combined with the lack of comprehensive, systematic health and exposure monitoring and recording, make it difficult to draw any definitive conclusions about the causality and severity of these effects. Given the marked anticipated expansion of oil and gas activities, the current lack of information will seriously impede adequate planning for protecting human health.
7. Ongoing surveillance of both asthma and COPD in Garfield County is needed. Implementation of effective monitoring systems, such as reporting to the county health department, should be established. These are diseases that occur in great enough frequency to act as meaningful sentinel events for monitoring purposes.
8. Continued monitoring and interpretation of data concerning low birth weight is warranted.
9. By improving measurement and monitoring of health outcomes in Garfield County, it should be possible to better intervene and mitigate any adverse impact resulting from oil and gas development.

Worker Health

1. In any assessment of health impact on a region, occupational fatalities, injuries and illnesses should be taken into account along with the health impact on the local community.
2. As noted above, national data indicate significant rates of occupational illness, injury and fatality associated with the oil and gas industry.
3. We were unable to obtain specific fatality rates for the oil and gas development-associated subsectors in Colorado. Further analysis is needed to determine the fatality rates in oil and gas extraction, drilling oil and gas wells, and support industries, such as construction trades, since national statistics suggest they could be significant.
4. We were unable to obtain data on the rates of nonfatal occupational injuries and illnesses for Colorado. Without these data rates of occupational illness and injury due to oil and gas activities in Colorado are unknown. At this time, Colorado is one of only seven states that do not participate in the Survey of Occupational Illness and Injury (SOII).
5. Workers' compensation and hospital discharge data may be important additional sources that can be used to estimate the health impact of the oil and gas industry for workers.

Psychological and Social Impact

1. The literature supports the concept that rapid industrial change can have deleterious effects (in addition to possible positive effects) on the psychosocial welfare of a local population.
2. The data shown above indicate that there has been an increase in violent crimes and drug violations in Garfield County. Further study is needed to determine if industrial development, in the form of oil and gas drilling, is contributing to this increase, especially since literature suggests that this is possible.
3. At this point in time, there are many unknowns about the effects of oil and gas industry activity on psychosocial health outcomes. This lack of information, combined with the lack of a comprehensive, systematic health and exposure monitoring make it impossible to draw any definitive conclusions about the causality and severity of these effects.
4. Improved monitoring of the psychosocial health Garfield County residents is needed in order to intervene and mitigate any adverse impact resulting from oil and gas development.

General Conclusions/Recommendations:

1. The literature review conducted in parallel with this white paper yielded important information regarding the impact of exposure on human health and welfare. A more comprehensive literature review that includes foreign language literature, older studies, reviews, formal assessment of quality of

evidence, and conflict of interest considerations would be expected to yield additional useful information.

2. The available data and lines of evidence indicate that there is an acute problem with toxic emissions of uncertain proportions and a possible emergent problem for the health of the citizens of Garfield County.
3. The available data regarding the health and social impact of oil and gas development need further analysis.
4. Data, such as air and water quality data collected by the oil and gas companies, that may have been collected but are not in the public domain should be made available for analysis and publication.
5. In the interest of public health, the credible evidence currently available about the impact on the health and welfare of the population by oil and gas development requires action now as outlined in this white paper. It is important not to ignore what is already known.
6. There is an immediate need for specific information on exposures and the impact from oil and gas development on all aspects of human health. This white paper and literature review indicate a number of fertile areas for further study.
7. An adequate monitoring program should be developed through a rigorous scientific process that addresses all currently recognized data gaps and health risks. This process should be developed in a transparent and explicitly unbiased way.
8. A Health Impact Assessment (HIA) is a practical tool to evaluate future impacts, alternatives and appropriate strategies to promote and protect human health. An integrated HIA/EIS published in 2007 described the impact of oil development on Alaska's North Slope on the local Inupiat populations. (Wernham 2007) The HIA findings predicted impact on health and social structure. The report provided recommendations for mitigation of these effects, thereby improving the probability that oil development could proceed with less adverse impact on the people who live in the region.
9. An HIA could provide a framework for exposure assessment (from air and water quality monitoring), health data collection and monitoring (for example asthma, COPD incidence and prevalence, birth outcomes), and recommendations for mitigation of potential adverse effects.
10. Given that oil and gas extraction activities are known to use and produce chemicals that are hazardous to human health and that these activities are occurring in close proximity to human populations in Garfield County, a Health Impact Assessment of oil and gas development in Colorado should be done. At the present time there is no systematic collection of air or water quality data, assessment of exposure, nor of health or social outcomes. Through an HIA, air and water quality monitoring systems and health and social outcome monitoring systems could be established. Given that even limited air and water quality studies revealed dangerous levels of benzene and other chemicals of potential concern, continued ignorance of the status of the air and water quality and the potential health impacts in Garfield County should not be considered acceptable. An HIA should be a critical

component of planning for future expansion of oil and gas activities, so that these activities do not put local residents at risk. Because an Environmental Impact Statement is intended to consider the effects of the development in question on the "human environment," an HIA should be considered a necessary part of a complete Environmental Impact Statement. An HIA, or a similar assessment, should be a part of any oil and gas permitting process that occurs near human populations. Without an HIA, a comprehensive EIS should be considered incomplete.

11. While this white paper focuses on Garfield County, Colorado as an illustration of the potential exposure-related health impact of oil and gas development, the principles of exposure and the related health issues should be considered generally applicable wherever oil and gas development is occurring.

Closing Statement

Oil and gas development has the potential to impact human health when toxic chemicals are released into the air and water near human population centers. Without precise demographic, exposure and health information of the Garfield County population, assessment of the current and future health of the community is compromised. Air and water quality studies conducted in Garfield County demonstrate that potential exposures to hazardous emissions exist. As noted above and in the literature review, although some levels of harmful chemicals in both air and water measured may not fall within a specific regulatory standard, adverse health impacts are known to occur at levels below standards. This must be taken into account when mitigation measures aimed at reducing health impacts are undertaken. Furthermore, publicly available information about the health status of Garfield County residents is incomplete. This lack of information, combined with the lack of comprehensive, systematic health and exposure monitoring and recording make it impossible to draw any definitive conclusions about the causality and severity of health effects. Given the marked anticipated expansion of oil and gas activities, the current lack of information will seriously impede adequate planning for protecting human health. Additionally, in any assessment of health impact on a region, occupational fatalities, injuries and illnesses should be taken into account along with the health impact on the local community, given that national data indicate significant rates of occupational illness, injury and fatality associated with the oil and gas industry. Also, the literature supports the concept that oil and gas boom and bust cycles have deleterious effects on the psychosocial welfare of a local population. Further data collection, analysis and subsequent recommendations could mitigate the psychological and social impacts oil and gas drilling. A Health Impact Assessment of oil and gas development in Colorado should be done as a critical component of planning for future expansion of oil and gas activities and as such would be essential to an adequate Environmental Impact Statement and other planning and assessment processes. A comprehensive EIS must include an HIA in order to be considered complete.

Furthermore, the principles of exposure and the related health issues should be considered generally applicable wherever oil and gas development is occurring.

Acknowledgements

The Natural Resources Defense Council paid the University of Colorado Denver (University Physicians, Inc, Dr. Lee Newman, Principal Investigator, Dr. Roxana Witter, Co-Principal Investigator) for preparation of this literature review and white paper. The UCD/CSU team that performed this work has no financial or other conflict of interest to report. The statements made in this literature review and white paper are the work product of the authors and do not represent the position of any university or organization. The NRDC, which contracted for this work, did not participate in any aspect of its planning, preparation, or conclusions. The authors thank Paul Blomquist, MLS, reference librarian, University of Colorado Denver Health Sciences Library for his assistance in designing and conducting literature searches.

Appendix 1. References

Introduction & Background References

Colorado Department of Public Health and Environment (2006). Colorado Air Quality Data Report. C. D. o. P. H. a. Environment. Denver, CO.

Colorado Department of Public Health and Environment (2008). Colorado Annual Monitoring Network Plan. C. D. o. P. H. a. Environment.

Garfield County IT Department (2007). Gas Wells, Well Permits & Pipleines, Including Public lands, Western Garfield County, Colorado. Glenwood Springs, Colorado**:** Composed Utilizing Colorado Oil and Gas Conservation Commission Well Site, Permit GIS Data Downloaded 11-7-07.

Garfield County Public Health Department (2007). Garfield County Ambient Air Quality Monitoring Study June 2005-May 2007. G. C. P. H. Department. Garfield County, CO.

Garfield County Public Health Department (2007). Garfield County Ambient Air Quality Monitoring Study June 2005-May 2007. G. C. P. H. Department. Garfield County, CO.

Glass, D. C., C. N. Gray, et al. (2003). "Leukemia risk associated with low-level benzene exposure.[see comment]." Epidemiology **14**(5): 569-77.

Glass, D. C., C. N. Gray, et al. (2005). "Health Watch exposure estimates: do they underestimate benzene exposure?" Chemico-Biological Interactions **153-154**: 23-32.

La Plata County (2002). La Plata County Final Oil and Gas Impact Report.

Musselman, R. and J. Korfmacher (2008). Focus: Air Quality in Mountain Ecosystems-Ozone. Air, Water and Aquatics Environments Science Program. Fort Collins, Co, United States Forest Service, Rocky Mountain Research Station.

Oil and Gas Accountability Project. (2006). "Colorado Oil and Gas Industry Spills A review of COGCC data (June 2002 – June 2006)." Retrieved 5-15-08, from http://www.bettermines.org/pubs/Spills.pdf.

S.S. Papadpipulos & Associates, I. (2007). Piceance Basin Phase IV
Baseline Water Quality Study –
Garfield County, Colorado. Boulder, Colorado 80303.

Saadat, M. and A. Bahaoddini (2004). "Hematological changes due to chronic exposure to natural gas leakage in polluted areas of Masjid-i-Sulaiman (Khozestan province, Iran)." Ecotoxicology & Environmental Safety **58**(2): 273-6.

San Sebastian, M. and A. K. Hurtig (2004). "Cancer among indigenous people in the Amazon Basin of Ecuador, 1985-2000." Rev Panam Salud Publica **16**(5): 328-33.

Teresa Coons, P. and R. Walker, PhD (2008). Community Health Risk Assessment An Assessment of Risk Related to the Natural Gas Industry in Garfield County
Part I: Risk Study. Power Point Presentations From the Community Presentation June 17th, 2008. West Garfield Colorado Mountain College 3695 Airport Road, Rifle.

Part II: Health Study. Power Point Presentations From the Community Presentation June 17th, 2008. West Garfield Colorado Mountain College 3695 Airport Road, Rifle.

United States Environmental Protection Agency (2007). Monitor Values Report - Criteria Air Pollutants, La Plata County, CO.

URS Corporation (2006). Phase I Hydrogeologic Characterization of the Mamm Creek Field Area in Garfield County Denver Colorado.

Wernham, A. (2007). "Inupiat Health and Proposed Alaskan Oil Development: Results of the First Integrated Health Impact Assessment/ Environmental Impact Statement for Proposed Oil Development on Alaska's North Slope." EcoHealth **4**: 500-513.

Garfield County Contaminant References**:**

Colorado Department of Public Health and Environment (2006). Colorado Air Quality Data Report. C. D. O. P. H. a. Environment. Denver, CO.

Colorado Department of Public Health and Environment (2008). Colorado Annual Monitoring Network Plan. C. D. O. P. H. a. Environment.

Garfield County IT Department (2007). Gas Wells, Well Permits & Pipleines, Including Public lands, Western Garfield County, Colorado. Glenwood Springs, Colorado**:** Composed Utilizing Colorado Oil and Gas Conservation Commission Well Site, Permit GIS Data Downloaded 11-7-07.
Garfield County Public Health Department (2007). Garfield County Ambient Air Quality Monitoring Study June 2005-May 2007. G. C. P. H. Department. Garfield County, CO.

La Plata County (2002). La Plata County Final Oil and Gas Impact Report.

Musselman, R. and J. Korfmacher (2008). Focus: Air Quality in Mountain Ecosystems-Ozone. Air, Water and Aquatics Environments Science Program. Fort Collins, Co, United States Forest Service, Rocky Mountain Research Station.

S.S. Papadpipulos & Associates, I. (2007). Piceance Basin Phase IV Baseline Water Quality Study –Garfield County, Colorado. Boulder, Colorado 80303.

United States Environmental Protection Agency (2007). Monitor Values Report - Criteria Air Pollutants, La Plata County, CO. http://iaspub.epa.gov/airsdata/adaqs.monvals?geotype=co&geocode=08067&geoinfo=co~08067~La+Plata+Co%2C+Colorado&pol=O3&year=2007&fld=monid&fld=siteid&fld=address&fld=city&fld=county&fld=stabbr&fld=regn&rpp=25

URS Corporation (2006). Phase I Hydrogeologic Characterization of the Mamm Creek Field Area in Garfield County Denver Colorado.

Demographic References:

Colorado Oil and Gas Conservation Commission:
http://oil-gas.state.co.us/

Colorado Department of Local Affairs:
http://www.dola.state.co.us/dlg/demog/pop_cnty_estimates.html

Garfield County Quick Facts:
http://www.garfield-county.com/Index.aspx?page=698

Garfield Public and Private Schools:
http://colorado.schooltree.org/Garfield-County-Schools.html

Colorado Education Statistics:
http://www.cde.state.co.us/index_stats.htm
http://www.cde.state.co.us/cdereval/rv2007pmlinks.htm

Headwaters Economics (2007). A SocioEconomic Profile: Garfield County, Colorado.
http://www.headwaterseconomics.org/profiles/colorado.html

National Center for Health Statistics: National Vital Statistics:
http://www.cdc.gov/nchs/products/pubs/pubd/nvsr/nvsr.htm

Northwest Colorado Socioeconomic Analysis and Forecasts. BBC Researching & Consulting, April 4, 2008. www.bbcresearch.com

Population, Employment, Poverty and Demographic from the 2000 U.S. Census. Sonoran Institute, 2003. http://www.sonoran.org/

Garfield County Health Data:

2007 Colorado Chronic Obstructive Pulmonary Disease Surveillance Report: http://www.lungcolorado.org/pdf/Colorado%20COPD%20Strategic%20Plan%202007.pdf

Finch, J. Cancer in Colorado: 1992-2002 Incidence and Mortality by County, 2005.

Colorado Information Dataset: Death Statistics, Injury Statistics, and Behavioral Risk Factor Statistics: http://www.cdphe.state.co.us/cohid/

Colorado Asthma Surveillance Report 2004. http://www.cdphe.state.co.us/ps/asthma/asthmahom.asp

Colorado Chronic Obstructive Pulmonary Disease Surveillance Report: 2007 http://www.coloradocopdcoalition.org/pdf/2007%20Colorado%20COPD%20Surveillance%20Report.pdf

Colorado Department of Public Health and Environment. Hospitalizations for Asthma: Colorado Asthma Program Quarterly Data Brief. http://www.cdphe.state.co.us/ps/asthma/health_statistics.html

Garfield County Births and Deaths 2006 (Health Statistics Section of CDPHE) http://www.cdphe.state.co.us/hs/county2006/Garfield00.pdf

National Center for Health Statistics (National Vital Statistics) http://www.cdc.gov/nchs/nvss.htm

National Vital Statistics Report, Vol. 50, No. 15, September 16, 2002. http://www.cdc.gov/nchs/data/nvsr/nvsr50/nvsr50_15.pdf

Worker Health References:

Occupational Fatalities:
MMWR April 25, 2008 / 57(16); 429-431
http://www.bls.gov/iif/oshwc/cfoi/cfch0005.pdf
http://www.bls.gov/iif/oshcfoi1.htm
http://www.bls.gov/iif/oshstate.htm#CO

Occupational Injuries and Illnesses:

http://www.bls.gov/iif/oshwc/osh/os/osnr0028.pdf

http://www.bls.gov/iif/oshwc/osh/os/osnr0028.pdf
http://www.bls.gov/iif/oshsum.htm

Colorado Workers Compensation:
http://www.coworkforce.com/dwc/PUBS/Work_Related_Injuries_03.pdf
http://www.coworkforce.com/dwc/PUBS/Work_Related_Injuries_02.pdf
http://www.coworkforce.com/dwc/PUBS/Work_Related_Injuries_01.pdf

Psychology/Social References**:**

Bhatia, R. (2007). "Protecting health using an environmental impact assessment: a case study of san francisco land use decisionmaking." American Journal of Public Health **97**(3): 406-413.

Forsyth, C. J., A. D. Luthra, et al. (2007). "Framing perceptions of oil development and social disruption." Social Science Journal **44**(2): 287-299.

Kettl, P. (1998). "Alaska native suicide: Lessons for elder suicide." International Psychogeriatrics **10**(2): 205-211.

Lowden, K., English, K., Harrison, L., Pasini-Hill, D., Lounders, P. (2007). “Crime and Justice in Colorado, 2006”, http://cdpsweb.state.co.us/cccjj/PDF/complete_Crime_Justice-2006.pdf

Luthra, A. D., W. B. Bankston, et al. (2007). "Economic fluctuation and crime: A time-series analysis of the effects of oil development in the coastal regions of Louisiana." Deviant Behavior **28**(2): 113-130.

Mall, A., Buccino, S., & Nichols, J. (2007). "Protecting western communities from the health and environmental effects of oil and gas production." NRDC: Drilling Down.

Seydlitz, R., Laska, S., Spain, D., Triche, E., & Bishop, K. (1993). "Development and social problems: The impact of the offshore oil industry on suicide and homicide rates." Rural Sociology **58**(1), 93-110.

Srinivasan, S., L. R. O'Fallon, et al. (2003). "Creating Healthy Communities, Healthy Homes, Healthy People: Initiating a Research Agenda on the Built Environment and Public Health." American Journal of Public Health **93**(9): 1446-1450.

Wernham, A. (2007). "Inupiat health and proposed Alaskan oil development: Results of the first integrated health impact assessment/environmental impact statement for proposed oil development on Alaska's north slope." EcoHealth: 500-513.