Community Health Risk Analysis of Oil and Gas Industry Impacts in Garfield County

Teresa Coons, Ph.D.

Saccomanno Research Institute

Russell Walker, Ph.D.

Mesa State College

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- Garfield County Public Health
- Grand River Hospital District
- Valley View Hospital
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COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

NATURAL GAS INDUSTRY PRODUCERS OPERATING IN GARFIELD COUNTY

TABLE OF CONTENTS

	PAGE
EXECUTIVE SUMMARY	xiv
INTRODUCTION TO THE STUDY	1
PART I: RISK ASSESSMENT	9
Description of steps and components of natural gas operations	
Description of pollutants associated with specific natural gas operations	
Overview of risk assessment and risk management process	
Qualitative description of transport processes	
Data on pollutant concentrations at known or possible exposure points	
Results of pollutant concentration modeling	
Description of toxicity of most important pollutants	
Results of risk assessment for selected pollutants	
Results interpretation	
PART II: HEALTH STUDY	49
Premises of the study	49
Methodology	50
Description of study area and comparison counties	
Perceptions and Concerns (Qualitative data collection)	
Quantitative data collection	
Household survey	
Results	63
Perceptions and Concerns (Qualitative data from focus groups, interviews, public meetings and complaint reports)	63
Quantitative Health Data	66
Birth statistics (1996, 2002-2006)	
Death statistics: rates and leading causes of death (1990-2006)	
Birth defects: types and rates (2000-2005)	
Child and adolescent health measures (2001-2005)	
Injury hospitalization and death: causes and rates (2001-2003)	
Behavioral Risk Factor Study Survey (BRFSS) data (2004-2005)	
West Nile virus (2002-2007)	
Cancer statistics (1992-2005)	
Reportable conditions (1998-2006)	
Sexually transmitted diseases (2000-2007)	
Hospital and Outpatient data	
DRG-based hospital discharge data (2000 through 1st quarter 2007)	
Emergency room data (Grand River Hospital District; Rocky Mountain Health Plans member data; Valley View Hospital)	

PAGE

Rocky Mountain Health Plans (RMHP) inpatient and outpatient hospital visits and ambulatory member data: 4-county comparison
St. Mary's Hospital *CareFlight* data
Household Survey Results 178
Description of survey population demographics
Survey outcomes

PART III: RECOMMENDATIONS AND STUDY LIMITATIONS 226

APPENDICES

A. Equations used in exposure assessment
B. Gaussian Plume model
C. Determination of wind speed for use in Gaussian Plume model
D. Most frequent wind directions
E. Duration of time sun is in each insolation category
F. Fraction of month reported as clear, partly cloudy, or cloudy
G. Occurrence of each air stability class in typical year
H. Calculation of pollutant concentrations in air
IA. Benzene, toluene, and *m,p*-xylene concentrations during flow back
IB. Benzene, toluene, and *m,p*-xylene concentrations from glycol dehydration emissions
IC. Benzene, toluene, and *m,p*-xylene concentrations from condensate tank emissions
J. Risk assessment of total petroleum hydrocarbon residue in soil at 1,000 mg/kg
K. Causes of death by County – 2003-2006
L. Cause of death by race/ethnicity for Garfield County residents – 2006
M. Cancer incidence and mortality rates by County for 1992 through 2005
N. Sexually Transmitted Diseases Rates by County for 2000-20007
O. Colorado Hospital Association utilization data – 2000 through 1st quarter 2007
P. Rocky Mountain Health Plans (RMHP) member data for health plan usage – 2000 through 1st quarter 2007
Q. Grand River Health District emergency room(ER) admissions – 2004-2006, including ER data groupings
R. Valley View Hospital emergency room admissions – 2004-2006
S. *CareFlight* data
T. Household survey instrument and other documents
U. Household survey data analysis and outcomes

LIST OF TABLES AND FIGURES

TABLES

PAGE

INTRODUCTION TO THE STUDY

1. Annual permits to drill 4
2. Colorado coal mine statistics, 2006 (Colorado Division of Reclamation, Mining and Safety) 8

PART I: RISK ASSESSMENT

3. Summary of PM_{10} monitoring results 21
4. Summary of statistics for detected VOCs 23

5A. Benzene concentration in air resulting from selected natural gas development operations 30

5B. Toluene concentrations in air resulting from selected natural gas development operations 31

5C. *m,p*-Xylenes concentrations in air resulting from selected natural gas development operations 32

6. Reference concentrations 34

7A. Benezene cancer risk resulting from flowback with no gas recovery 36

7B. Benezene cancer risk resulting from flowback with 93% recovery of natural gas 37

7C. Benzene cancer risk resulting from operation of wellhead glycol dehydration units 38

7D. Benzene cancer risk resulting from condensate tanks emitting 20 tons per year of volatile organic hydrocarbons 39

7E. Benzene cancer risk resulting from condensate tanks with 98% removal of emissions of 20 tons per year of volatile organic hydrocarbons 40

PART II: HEALTH STUDY

Description of study area and comparison counties

8. Comparison county profiles: 2000 and 2006 data 51

Perceptions and concerns

9. Qualitative data: Interviewee demographics 63

Quantitative health data

10. Vital statistics by county: Delta County 1996, 2002-2006 67
11. Vital statistics by county: Garfield County 1996, 2002-2006 69
12. Vital statistics by county: Mesa County 1996, 2002-2006 71
13. Vital statistics by county: Montrose County 1996, 2002-2006 73
14. Selected birth characteristics by County, 2006 80

PAGE

15. Age-specific death rates by County, 2006 82
16. Number of resident live births in Garfield County: 2000-2005 85
17. Rates of birth defects, 2000-2005 86
18. Major congenital anomaly rates in Garfield County: 2000-2005 88
19. Child and adolescent health by County 92
20A. Injury hospitalizations by County, 2001-2003. Total – intention categories 100
20B. Injury hospitalizations by County, 2001-2003. Total – injury type 101
21A. Injury deaths by County, 2001-2003. Total – intention categories 102
21B. Injury deaths by County, 2001-2003. Total – injury type 103
22. Behavioral Risk Factor Study Survey (BRFSS) data, 2004-2005 104
23. Comparison of county cancer incidence rates with state rates, 1992-2005 107
24. Comparison of county cancer mortality rates with state rates, 1992-2005. 108
25A-K. Reportable conditions rates by County, (2000-2006) and STD rates, 2000-2007 133
26. Hospital utilization, Garfield County residents, 2005-2006 142
27. Top 10 Diagnosis-Related Group (DRG) categories by year in Garfield County 144
28. Emergency room admissions data 163
(Rocky Mountain Health Plans member data, 2000-2007; Grand River Hospital District data, 2004-2006; Valley View Hospital data, 2004-2006)
29. Inpatient hospital admissions data 169
(Rocky Mountain Health Plans member data, 2000-2007)
30. Outpatient hospital visits or lab work data 171
(Rocky Mountain Health Plans member data, 2000-2007)
31. Ambulatory office visits data 174
(Rocky Mountain Health Plans member data, 2000-2007)

Household survey

32. Household survey demographics 178
33. Household survey response rate 179

FIGURES

PAGE

INTRODUCTION TO THE STUDY

1. Relationship between exposure potential and health assessment 1
2. Drilling rigs running in Colorado by County each week in 2007 5
3. Active oil and gas wells – all Colorado Counties, as of 03-06-08 5
4. Location of coal mines, power plants, railroads and coal-bearing regions in Colorado, 2006 6
5. Location of Rifle uranium processing sites and disposal site 7

PART I: RISK ASSESSMENT

6. Piceance Basin, Williams Fork Formation 9
7. A conceptual model for containment transport from Garfield County natural gas Operations 14

PART II: HEALTH STUDY

Description of study area and comparison counties

8. World Health Organization definition of "human health" 49
9. Colorado Counties map 50
10. Population estimates by County, 2000-2006 53
11. Average annual percent change in population, 2000-2006 53
12. Population age as a percentage of total population, Year 2000 census data 54
13. Race and ethnicity as a percentage of total population, Year 2000 census data 54
14. Median household income by County, Year 2000 census data 55
15. Median household income by census tract, Year 2000 census data 55
16. Percent of persons below poverty by County, Year 2000 census data 56
17. Percent of persons below poverty by census tract, Year 2000 census data 57
18. Percent of children below poverty by census tract, Year 2000 census data 57

Perceptions and concerns

19. Community interviews/focus group comments 65

Quantitative health data

20. First trimester pre-natal care by County, 2005 75
21. Low birth weight by County, 2003-2005 76
22. Very low birth weight by County, 2003-2005 77
23. Neonatal mortality by County, 2001-2005 78
24. Infant mortality by County, 2001-2005 79
25. Crude total death rates: Delta, Garfield, Mesa and Montrose Counties, 1996-2006 81
26. Average annual age-adjusted death rates by cause, 2002-2006 81
27. Death rates for Garfield County males by age groups, 1990-2006 83
28. Death rates for Garfield County females by age groups, 1990-2006 83
29. Leading causes of death by County, 2006 84

PAGE

30. Teen fertility rates by County, 2003-2005 94
31. Teen hospitalization rates by County, 2002-2005 95
32. Teen motor vehicle death rates by County, 2004-2005 96
33. Teen suicide rates by County, 2001-2005 97
34. Child abuse rates by County, 2005 98
35. Child death rates by County, 2001-2005 99
36. Injury hospitalizations with intention categories by County, 2001-2003 100
37. Injury hospitalizations by injury type and County, 2001-2003 101
38. Injury deaths with intention categories by County, 2001-2003 102
39. Injury deaths by injury type and County, 2001-2003 103
40A-D. All cancers: incidence and mortality rate trends for males & females by County, 1992-2005 109
41A-B. Prostate cancer: incidence and mortality rate trends by County, 1992-2005 111
42A-B. Breast cancer: incidence and mortality rate trends by County, 1992-2005 112
43A-D. Colorectal cancer: incidence and mortality rate trends for males & females by County, 1992-2005 113
44A-D. Lung cancer: incidence and mortality rate trends for males & females by County, 1992-2005 115
45A-B. Bladder cancer: incidence rate trends for males & females by County, 1992-2005 117
46A-B. Melanoma: incidence rate trends for males & females by County, 1992-2005 118
47A-B. Leukemia: incidence and mortality rate trends for males & females by County, 2003-2005 119
48. Thyroid cancer: incidence rate trends for males & females by County, 2003-2005 120
49. Cervical cancer: incidence rate trends by County, 2003-2005 120
50. West Nile Virus infections by County – 2003 122
51. West Nile Virus infections by County – 2004 123
52. West Nile Virus infections by County – 2005 123
53. West Nile Virus infections by County – 2006 124
54. West Nile Virus infections by County – 2007 124
55. Colorado West Nile Virus human cases – 2002 125
56. Colorado West Nile Virus human cases – 2003 125
57. Colorado West Nile Virus human cases – 2004 126
58. Colorado West Nile Virus human cases – 2005 126
59. Colorado West Nile Virus human cases – 2006 127
60. Colorado West Nile Virus human cases – 2007 127
61. Colorado West Nile Virus surveillance map – 2002 128
62. Colorado West Nile Virus surveillance map – 2003 128
63. Colorado West Nile Virus surveillance map – 2004 129
64. Colorado West Nile Virus surveillance map – 2005 129
65. Colorado West Nile Virus surveillance map – 2006 130
66. Colorado West Nile Virus surveillance map – 2007 130

PAGE

67. All hospitalizations by County of residence -- Combined Diagnostic-Related Group (DRG) Categories, 2000-1st quarter 2007 (Colorado Hospital Association data) 147
68. All trauma hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 147
69. Alcohol and drug disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 147
70. Birthing and pregnancy disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 148
71. Neonatal disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 149
72. Normal births hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 149
73. Female reproductive disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 150
74. Male reproductive disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 150
75. Bone and joint disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 151
76. Circulation disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 151
77. Digestive disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 152
78. Ear, nose, and throat disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 153
79. Infectious and parasitic diseases hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 153
80. Mental disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 154
81. Nervous system disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 155
82. Nutritional, metabolic and thyroid disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 155
83. Pancreas and liver disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 156
84. Red cell and clotting disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 156
85. All Respiratory disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 157
86. Respiratory disorders hospitalizations by County of residence – Bronchitis, asthma, COPD and respiratory infections & inflammation, 2000-1st quarter 2007 (Colorado Hospital Association data) 158
87. Skin disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 158

PAGE

88. Skin grafts, trauma and poisoning hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 159
89. Urinary tract disorders hospitalizations by County of residence, 2000-1st quarter 2007 (Colorado Hospital Association data) 159
90. Hospital discharges: asthma as principal diagnosis by County 160
91. "CareFlights" emergency services by County: all emergencies, 2004-2007 177
92. "CareFlights" emergency calls to drill rigs: Garfield and Rio Blanco Counties, 2004-2007 177

Household survey

93. Quality of household survey interviews 180
94. Length of residence in Garfield County 181
95. Length of residence in Garfield County: Length of time in current residence 181
96. Location of residence in Garfield County 182
97. Household size (residents per household) 182
98. Household ethnicity 183
99. Mean age of household residents 183
100. Gender of household residents 183
101. Percentage of children in respondent households 184
102. Education level of survey respondent 184
103. Percentage of households with health insurance 184
104. Current health of household residents 185
105. Health of household residents one year ago 185
106. Percentage of individuals reporting selected diseases and symptoms – County overall 186
107. Percentage of individuals suffering from frequent headaches or migraines by zip code 187
108. Main water supply and number of individuals reporting frequent headaches 188
109. Primary source of drinking water at home 188
110. Percentage of individuals concerned about health problems related to water supply 189
111. Days per month of alcohol consumption by age – County overall 189
112. Number of drinks per day for individuals who consumed alcohol during the past 30 days – County overall by age 190
113. Percentage of household members who reported using recreational drugs during the previous 30 days by zip code 190
114. Percentage of individuals who have smoked more than 100 cigarettes by zip code 191
115. Percentage of individuals who have smoked more than 100 cigarettes by age group – County overall 191
116. Frequency of smoking for individuals who have smoked more than 100 cigarettes In their lives by zip code 192
117. Smoking frequency of individuals who have respiratory conditions: zip code 81601 193
118. Smoking frequency of individuals who have respiratory conditions: zip code 81623 193
119. Smoking frequency of individuals who have respiratory conditions: zip code 81635 193
120. Smoking frequency of individuals who have respiratory conditions: zip code 81647 194
121. Smoking frequency of individuals who have respiratory conditions: zip code 81650 194

PAGE

122. Smoking frequency of individuals who have respiratory conditions: zip code 81652 194
123. Percentage of household members with asthma by zip code 195
124. Percentage of household members with COPD by zip code 196
125. Percentage of household members with emphysema by zip code 196
126. Percentage of household members with other lung problems by zip code 197
127. Percentage of individuals with diabetes by zip code 197
128. Diabetes complications – Percentage of individuals with diabetes and pain in hands or feet 198
129. Diabetes complications – Percentage of individuals with diabetes and loss of feeling in hands or feet (comparison with "loss of feeling" in non-diabetic survey population) 198
130. Diabetes complications – Percentage of individuals with diabetes and kidney problems/protein in urine (comparison with "kidney problems" in non-diabetic survey population 199
131. Diabetes complications – Percentage of individuals with diabetes and eye problems 199
132. Percentage of individuals with coronary disease by zip code 200
133. Percentage of individuals with coronary disease in each age group – County overall 200
134. Of women who became pregnant, number of pregnancies per woman by zip code 201
135. Percentage of pregnancies that resulted in miscarriages by zip code 201
136. Percentage of children born with birth defects (self defined) by zip code 202
137. Percentage of children developing health or developmental problems within 5 years of birth by zip code 202
138. Percentage of individuals reporting cancers by zip code 203
139. Percentage of reported cancers by age – County overall 204
140. Reported cancer types – County overall 204
141. Current occupation – County overall 205
142. Current occupation by zip code 206
143. Current occupation by zip code – Primarily Spanish-speaking households 206
144. Current industry employment by zip code 207
145. Current industry employment by zip code – Primarily Spanish-speaking households 207
146. Longest occupation by zip code 208
147. Longest occupation by zip code – Primarily Spanish-speaking households 208
148. Longest industry employment by zip code 209
149. Longest industry employment by zip code – Primarily Spanish-speaking households 209
150. Percentage of individuals who "didn't know" or refused to answer occupation or industry employment questions by zip code 210
151. Percentage of individuals employed in the agricultural industry reporting selected diseases and symptoms – County overall 211
152. Percentage of individuals employed in the mining industry reporting selected diseases and symptoms – County overall 211
153. Percentage of individuals employed in the manufacturing industry reporting selected diseases and symptoms – County overall 212
154. Percentage of individuals employed in the wholesale trade industry reporting selected diseases and symptoms – County overall 212

PAGE

155. Percentage of individuals employed in the finance, insurance or real estate industries reporting selected diseases and symptoms – County overall 213
156. Percentage of individuals employed in the personal services industry reporting selected diseases and symptoms – County overall 213
157. Percentage of individuals employed in the professional and related services industries reporting selected diseases and symptoms – County overall 214
158. Percentage of individuals employed in the forestry or fisheries industries reporting selected diseases and symptoms – County overall 214
159. Percentage of individuals employed in the construction industry reporting selected diseases and symptoms – County overall 215
160. Percentage of individuals employed in the transportation, communications or public utilities industries reporting selected diseases and symptoms – County overall 215
161. Percentage of individuals employed in the retail trade industry reporting selected diseases and symptoms – County overall 216
162. Percentage of individuals employed in the business and repair service industries reporting selected diseases and symptoms – County overall 216
163. Percentage of individuals employed in the recreation and entertainment industries reporting selected diseases and symptoms – County overall 217
164. Percentage of adults whose industry employment could not be classified reporting selected diseases and symptoms – County overall 217
165. Percentage of currently unemployed adults reporting selected diseases and symptoms – County overall 218
166. Percentage of currently disabled adults reporting selected diseases and symptoms – County overall 218
167. Percentage of currently retired adults reporting selected diseases and symptoms – County overall 219
168. Percentage of adults who “didn’t know” or refused to provide an industry affiliation reporting selected diseases and symptoms – County overall 219
169. Percentage of individuals concerned about health problems related to home drinking water supply by zip code 220
170. Percentage of households concerned that health problems may be related to chemicals in or near the home by zip code 221
171. Concern that chemicals in or near the home may be related to health problems – correlation with education 221
172. Percentage of households concerned that health problems may be related to environmental or chemical hazards in their neighborhoods by zip code 222
173. Concern that environmental or chemical hazards in the neighborhood may be related to Health problems – correlation with education 223
174. Concern that environmental or chemical hazards may be related to health problems – correlation with household income 224
175. Percentage of households concerned that the natural gas industry may be related to health problems by zip code 225

PAGE

176. Concern that the natural gas industry may be related to health problems – correlation with education 225

EXECUTIVE SUMMARY

INTRODUCTION

This report, both in its format and its content, is intended to meet the needs of several audiences: professional scientists and risk assessors; policy makers at the state, County and local levels; and community members or other interested individuals who may or may not be familiar with this geographic region and/or the natural gas industry. Thus, some of the information included in this report is not typically found in an environmental or health risk assessment study report. We hope, however, that the additional information will add to the understanding of the diverse audience that the study was designed to serve. Similarly, in *Part II, Health Study*, we have presented statistical health outcomes data from several different sources as a means of providing validation and/or contrast with the results of the self-reported household survey data and among the various hospital, insurance provider and state-based data sources that were available to us.

Oil and gas activity within Garfield County has generated public concern with regard to impacts on both the environment and public health. As a result, the Garfield County Commissioners approved using funding from a fine levied against EnCana Corporation by the Colorado Oil and Gas Conservation Commission to conduct a comprehensive study of health and environmental risks to residents of Garfield County. The study, conducted over a period of approximately three years, had two major components: a risk analysis based on environmental exposure data and modeling and a comprehensive health study that creates a baseline assessment of the health of Garfield County residents.

The primary focus of this health and risk assessment study is Garfield County. Mesa, Montrose, and Delta Counties were selected as comparison counties for the health assessment portion of the study. All four counties are located on the Western Slope of Colorado and share similar social and political cultures and population demographics. All four counties have experienced energy and mining activities and the accompanying cycles of economic growth and recession ("boom and bust"), as well as environmental and social impacts. Currently, however, Mesa, Montrose and Delta Counties are experiencing relatively fewer impacts from natural gas industry drilling and processing activities. In addition, the four counties have overlapping healthcare networks and service areas, which made it easier to acquire comparative health data.

PART I – RISK ASSESSMENT

Risk was evaluated for human exposure to pollutants associated with natural gas operations in air, water, and soil in Garfield County. A general lack of data on pollutant concentrations in the environment limited the assessment. With respect to air, pollutant concentrations were generated through a mathematical model to supplement the concentrations collected by sampling and analysis during the *Garfield County Ambient Air Quality Monitoring Report, June 2005-May 2006*. With respect to water and soil, a more qualitative evaluation was performed in lieu of data on pollutant concentrations.

A Gaussian plume model was used to make a plausible prediction of air pollutant concentrations that may occur during natural gas operations. The model was based, to the degree possible, on the meteorological conditions specific to Garfield County, and was applied to five specific natural gas operations: flow back during well completion with no recovery of natural gas, flow back with 93% recovery of natural gas, wellhead glycol dehydration, uncontrolled emissions from condensate tanks, and condensate tank emissions controlled by a combustion device. The pollutant concentrations generated by the model were then used in risk calculations based on the U.S. Environmental Protection Agency's *Risk Assessment Guidance for Superfund, Volume 1. Human Health Evaluation Manual (Part A)*.

The Environmental Protection Agency (EPA) advocates as a *goal* that cancer risk for a specific exposure be no more than 1 chance in 1 million. The EPA further specifies that a cancer risk of up to 1 chance in ten thousand is considered acceptable. The results of the risk assessment indicate that the EPA's acceptable value for cancer risk can be exceeded for benzene in air for the following situations:

- For flow back with no gas recovery, the 70-year exposure exceeds the acceptable range for distances up to 500 meters (550 yards) downwind of the well.

- For flow back with 93% recovery of gas, the 70-year exposure exceeds the acceptable range for distances up to 75 meters (82 yards) downwind of the well.

- For emissions from wellhead glycol dehydration units, the 70-year exposure exceeds the acceptable range for distances up to 50 meters (55 yards) downwind of the well.

- For VOC emissions of twenty tons per year from condensate tanks, the 70-year exposure exceeds the acceptable range for distances up to 100 meters (110 yards) downwind of the tank.

Benzene emissions during uncontrolled flow back present the greatest cancer threat. However, the risk of cancer exceeds the EPA acceptable range only for a seventy-year exposure. An exposure of that duration to uncontrolled flow back appears unlikely. A 70-year exposure to dehydration unit and condensate tank emissions may be more plausible, depending on the actual production life of natural gas resources in Garfield County.

The results of the risk assessment for air also indicate that reference concentrations for non-cancer effects may be exceeded for some situations. Reference concentrations are pollutant concentrations in air representing thresholds below which health effects are very unlikely to occur. Reference concentrations have been developed for acute exposures (one to fourteen days), intermediate exposures (fifteen to 364 days), and chronic exposures (seven years to a lifetime). Modeling results indicate that reference concentrations can be exceeded in the following situations:

- For flow back with no gas recovery, the benzene acute reference concentration of 30 micrograms per cubic meter is exceeded for distances up to 250 meters (275 yards) downwind.
- For flow back with no gas recovery, the benzene intermediate reference concentration of 20 micrograms per cubic meter is exceeded for distances up to 300 meters (330 yards) downwind.
- For flow back with no gas recovery, the benzene chronic reference concentration for benzene of 30 micrograms per cubic meter is exceeded for distances up to 250 meters (275 yards) downwind.
- For flow back with no gas recovery, the *m,p*-xylenes chronic reference concentration of 100 micrograms per cubic meter is exceeded for distances up to 100 meters (110 yards) downwind
- For emissions of VOCs at twenty tons per year from condensate tanks, the *m,p*-xylenes chronic reference concentration of 100 micrograms per cubic meter is exceeded for distances up to 50 meters (55 yards) downwind.

These results suggest that emission of benzene during uncontrolled flow back is the situation that presents the greatest threat of non-cancer effects. These effects may occur in people who spend one day or more within a distance 250 meters downwind of the natural gas well when this operation is taking place. The non-cancer effects of benzene include neurotoxicity and depression of bone marrow function, resulting in blood disorders (decreased counts of specific blood cells, such as erythorocytes, leukocytes, and thrombocytes) and impairment of the immune system.

There are a number of uncertainties in the non-cancer threat and cancer risks determined using pollutant concentrations based on the Gaussian plume model. Some of these uncertainties have the effect of understating threat and risk; others have the effect of overstating threat and risk. The report includes a discussion of these uncertainties.

Garfield County residents have expressed concern about possible effects on ground water and surface water used for drinking and other purposes. Natural gas operations do have the potential to create water contamination, and have done so in certain well-publicized instances. However, because of a lack of water data representative of broad areas of the county, a quantitative risk assessment for ingestion of contaminated ground water or surface water was not performed. Contaminant pathways and drinking water standards are discussed in a qualitative manner instead. Similarly, given the limited data on soil pollutant concentrations, only a qualitative evaluation was performed for possible human health effects from exposure to contaminated soil.

Several recommendations are offered based on the risk assessment. The recommendations, detailed in the report and summarized at the end of the *Executive Summary*, focus on filling in data gaps in order to make a better evaluation of risk, and on the use of best management practices such as "green completions".

PART II – HEALTH ASSESSMENT

Two questions guided data collection for this part of the study:

1. Is the health of residents of Garfield County different than the health of residents of Delta, Mesa or Montrose counties?

2. Is the health of residents of areas of Garfield County that are heavily impacted by the natural gas industry different from the health of residents of less impacted areas of Garfield County?

To answer these questions, data were collected in four ways:

- Public perceptions, concerns and experiences were identified through focus groups, public meetings, interviews with key informants, and by reviewing logs of complaints that had been received by the Garfield County Health Department.

- Quantitative health indicators and outcomes were obtained through two complementary methods:
    - collecting and analyzing health data that are reported annually to the Colorado Department of Public Health and Environment and are available by county, and

    - collecting and analyzing hospital and medical insurance data for the four-county region.

    - Self-reported health outcomes and risk factor information was collected for a representative, random sample of residents from throughout Garfield County (by zip code), using a telephone or mail-based household survey.

The health assessment was intentionally broad and comprehensive, in nature, and one might ask why the study looked at disease and disease symptoms that presumably would not be related to exposures from natural gas industry operations. However, many health conditions have symptoms that are similar and/or have multiple causes, and it is a well-established fact that a person's general health can influence susceptibility to toxins or disease agents. Thus, this study was designed to also look at factors that could contribute to, confound, or exacerbate health conditions or symptoms (i.e., life-style, health insurance, residence, occupational history, concurrent disease, etc.). This comprehensive approach also provides a means of looking at cross-county differences that may or may not be related to natural gas industry activities that occur more intensively in some parts of Garfield County than in other parts.

This study provides a "snapshot in time" of the health of Garfield County residents. It is a population-based, descriptive study, providing correlations and comparisons. The nature of the study and the

available data make it impossible to provide definitive causal relationships between observed health and exposures, particularly at the individual level. It does, however, provide a comprehensive dataset that may be used as a starting place for monitoring health trends or more quickly identifying new trends. It also provides source data for more specific analyses, should other researchers or public health officials wish to delve more deeply into any aspect of the health outcomes described in this report.

Perceptions and Concerns. Health-related perceptions and concerns that were expressed by individuals who participated in public meetings, focus groups, individual interviews or registered complaints with Garfield County Environmental Health could be generally grouped and summarized as follows:

Physical Health Issues/Concerns (Note: The following concerns may or may not have been associated with environmental exposures.)

- Increase in or exacerbations of allergies and asthma and related concerns such as coughing, wheezing, and other respiratory complaints
- Generalized chemical sensitivities
- Fibromyalgia/chronic pain and related concerns such as chronic fatigue and lethargy
- Chronic colds and concern about compromised immune systems
- Headaches, dizziness, burning/itching eyes, nausea/vomiting, sinus problems – most often attributed to odors
- Burning/itching skin
- Mental health issues such as stress, depression, anger, inability to sleep
- Cancer (adrenal cancer, brain tumors, unknown/presumed cancers or "fear of developing cancer")
- Loss of voice or speech problems
- Trauma/work-related injuries
- Age-related illnesses
- Diabetes
- Obesity
- Perceptions that pre-existing health conditions have been exacerbated; people "feeling worse" than in the past.

Social/Community Issues and Concerns

- Increase in child and spousal abuse; child neglect; stressed family relationships
- Alcohol abuse (especially among high school students)
- Drug abuse (especially methamphetamine use)
- High suicide rate
- Increase in sexually transmitted diseases related to increase in temporary workers
- Lack of health insurance and related concerns such as lack of dental care for children and preventive care
- Lack of access to healthcare and mental health services
- Number of low income families

- Growth issues such as the availability of housing and community services, increase in low-income families, cultural clash (long-time residents, industry workers), traffic, public safety

Environmental Concerns

- Noise
- Odors
- Dust
- "Toxic" chemicals in air and water
- Impacts on domestic animals and wildlife such as reported changes in herd animal reproductive patterns/illnesses and decreases in bird, insect, and deer populations.

Quantitative Health Data. Health outcomes data were collected from a number of sources for Garfield County and comparison counties. The search for health outcomes data was driven by two objectives: 1) to complete a "snapshot in time" picture of the health of Garfield County residents in comparison to the health of residents in the comparison counties, and 2) to obtain statistical data that could be used to respond to the concerns voiced by Garfield County residents during the qualitative data collection process. Thus, to the extent that the data were available, we collected statistical information on the prevalence of conditions such as cancer and asthma and the predominant causes of mortality and morbidity in Garfield County.

The following data were obtained from the Colorado Department of Public Health and Environment (CDPHE; datasets represent the most current data available at the time this report was written):

- Death statistics: rates and leading causes of death (1990-2006)
- Birth defects: types and rates (2000-2006)
- Adolescent health measures (2000-2005)
- Reportable conditions (1998-2006)
- West Nile virus (2002-2007)
- Cancer statistics (1992-2005)
- Behavioral Risk Factor Study Survey (BRFSS) data (2000-2005)
- General health status (physical & mental)
- Diabetes, asthma
- Smoking, weight
- Health insurance
- Injury hospitalization and death: causes and rates (2001-2003)

Hospital and outpatient data were obtained from the following sources:

- Colorado Hospital Association (CHA), Diagnosis Related Group (DRG)-based hospital discharge data (2000 through 1st quarter 2006)
- Emergency room data
- Grand River Medical Center (located in Rifle, CO and serving western Garfield County)
- Valley View Hospital (located in Glenwood Springs and serving eastern Garfield County)
- Rocky Mountain Health Plans (RMHP) – member data for 4 counties
- St. Mary's Hospital "CareFlight" data

- RMHP hospital inpatient, outpatient and ambulatory member data – 4 county comparison by DRG category

Outcomes Highlights.

Please see the full report for additional measures and comparisons and actual rates. In the following section, references are made to Garfield County disease or condition rates being lower, higher or similar to those of Delta, Mesa and Montrose Counties. For the following reasons, we specifically did not attempt to designate whether or not the rates themselves should be considered "high or low". First, whether or not a rate is high or low varies with the disease or condition, and has to do with what the expected frequency of that condition would be for a particular population (and hence whether or not the actual frequency is higher or lower than expected). Secondly, whether a rate is high or low is often a matter of individual perception and may depend on why an individual is looking at the rate in question. Thus, for the purposes of this report, the most objective way to report rates is to provide the actual numerical rate (in the full report) and to provide relative comparisons with other communities. Those who use this information may have other measures against which to judge whether or not the rate of a particular disease or condition is acceptably low or too high.

- Cardiovascular disease is the biggest cause of death in all four counties, followed by other heart-related disease and cancer. The rates among the four counties are similar.
    - The age-adjusted, total death rate for Garfield County was comparable to the age-adjusted, total death rate for Delta County, and lower than those for Mesa or Montrose Counties over the period of 1990 – 2006.
    - Garfield County's crude death rate has been the lowest among the four counties for the past 2 ½ decades.
    - Garfield County's rate of neonatal and infant deaths was similar to that of Mesa County, and higher than that of Delta and Montrose Counties.
    - Injury death rates (CDPHE data) for 2001-2003 were significantly higher in Garfield County than for the state overall and for Mesa County.

- Birth defect rates in Garfield County were not different from those seen in the comparison counties for the years 2002-2006.

- For selected measures of child and adolescent health, Garfield County had lower rates of teen pregnancy, teen suicide and child abuse than were documented for the other three counties over the time periods surveyed. Child deaths were higher in Garfield County than in the other counties.

- According to the Behavioral Risk Factor Study Survey (BRFSS) data for 2000 – 2005, the percentage of Garfield County residents that have been diagnosed with diabetes or asthma, are smokers or are overweight/obese, and have health insurance is either lower or similar to the percentages in Delta, Mesa and Montrose Counties. (Please see table below.) However, in every case, the confidence limits for Garfield County are very broad, indicating that there are wide variations within the county on these measures. (The 95% confidence limit is the range within which we can be 95% certain that the actual rate for the entire population of the county

– not just the rate for the individuals sampled in the survey – will fall.) This observation is supported by the household survey data. For example, tobacco use is higher among surveyed residents of zip codes 81635, 81650 and 81652 than among residents of zip codes 81601, 81623 and 81635. The percentage of individuals with health insurance is lower among surveyed residents of zip code areas 81623, 81647, 81650 and 81652 and primarily Spanish-speaking households than it is among residents of zip code areas 81601 and 81635.

Topic	Delta County %	Delta County 95% CI*	Garfield County %	Garfield County 95% CI*	Mesa County %	Mesa County 95% CI*	Montrose County %	Montrose County 95% CI*	Colorado %	Colorado 95% CI*
Diagnosed with diabetes	2.8	0.0-5.8	2.6	0.0-5.1	5.4	3.0-7.8	6.4	1.6-11.2	4.6	3.4-5.0
Current smoker	23.9	14.1-33.7	18.7	9.6-27.7	20.7	15.2-26.3	21.8	12.5-31.1	19.9	18.9-20.9
Currently have health insurance	67.6	56.8-78.4	79.2	20.8-87.6	80.1	74.3-85.9	71.3	60.3-82.3	84.4	83.4-85.3
Ever had asthma	17.2	7.9-26.5	16	8.1-23.9	10.6	7.0-14.2	15	5.2-24.7	17.2	7.9-26.5
Overweight BMI** 25.0-29.9	60.7	49.2-72.2	41.8	31.1-52.5	57.3	50.8-63.8	56.3	44.8-67.8	60.7	49.2-72.2
Obese BMI** >30	14.1	5.4-22.7	12.6	4.9-20.2	20.9	15.5-26.3	21.3	12.2-30.3	14.1	5.4-22.7

*Confidence Interval
**Body Mass index (BMI) is defined as weight in kilograms divided by height in meters squared
Percents are weighted to the total population.

- During the six-year period, 2000-2005, with the exception of 2003, circulation disorders and bone and joint disorders were either the first or second most common reasons for hospitalization (in 2003, birthing and pregnancy disorders was number one, and circulation disorders was third). Respiratory disorders were either the fourth or fifth most common reason for hospitalization in all years; nervous system disorders were ranked either seventh or eighth each year. Digestive disorders ranked third in four out of the six years. Neonatal disorders were sixth in frequency during the entire six-year period.

Injury hospitalization rates obtained from CDPHE for 2001-2003 showed that Garfield County's rates were similar to those for Colorado overall, and lower than those documented for Delta and Montrose Counties. These data correlated with trauma hospitalization data obtained from the Colorado Hospital Association and Rocky Mountain Health Plans. According to CHA and RMHP data, Garfield County's injury hospitalization rates increased for adults (>18 years) after 2005, but still remained lower than the rates for Mesa and Delta Counties. Accident, injury and trauma hospitalization

rates for children (<18 years) residing in Garfield County are the lowest among the four counties.

- The following tables provide a summary of data for hospitalization, outpatient and emergency room visits by diagnosis-related categories for Garfield County, in comparison with Delta, Mesa and Montrose Counties. The data were obtained from the Colorado Hospital Association, Rocky Mountain Health Plans (member data), Grand River Hospital District (located in Rifle; data for residents of Rifle, Parachute/Battlement Mesa and Silt only), and Valley View Hospital (located in Glenwood Springs).

DRG Category	CHA data (2000-1st Q 2007)	RMHP (2000-2007) Inpatient Hospital	RMHP (2000-2007) Outpatient/Ambulatory	RMHP (2000-2007) Emergency Room	GRHD ER (2004-2006)	Valley View ER* (2004-2006)
Accident, Injury, Trauma	Garfield County's injury hospitalization rates increased for adults (>18 years) after 2005, but still remained lower than the rates for Mesa and Delta Counties. Accident, injury and trauma hospitalization rates for children (<18 years) residing in Garfield County are the lowest among the four counties.	Garfield County's rates were the lowest among the four counties until 2005 for both adults and children, and remained the lowest for children through 2007.	Same as for inpatient visit rates.	Adult emergency room visits related to accident, injury or trauma increased from 2003 through 2005, then slightly decreased through 2007.	Emergency room visit data for Grand River Hospital District show increasing rates for Silt, Parachute/Battlement Mesa, and Rifle residents for the period 2004-2006.	Adult ER visit rates were stable throughout the period. Rates for children/young adults decreased between 2004 and 2005, then remained stable for the rest of the period.
Annual Physicals/Well Child Check-ups	Not applicable.	Not applicable.	Garfield County's rates are the lowest among the four counties. **Note: These are RMHP data for insured individuals!**	Not applicable.	Not applicable.	Not applicable.
Birthing, Pregnancy, Reproductive, and Neonatal	Rates are consistently higher for Garfield County than for Delta, Mesa and Montrose Counties for birthing and pregnancy disorders, but lower for male and female reproductive and neonatal disorders .	Garfield County residents had lower utilization rates than did residents of Delta, Mesa and Montrose Counties. *This is likely a reflection of the difference in utilization patterns of insured and uninsured populations.*	Same as for inpatient visits.	Same as for inpatient visits.	Data show an increase in birthing and pregnancy-related patient visits for 2005 through 2006 for Silt, Parachute/Battlement Mesa and Rifle residents.	Adult ER visit rates were stable over the period; ER visit rates for this category decreased among young adults. ER visits for conditions in the perinatal period increased through the time period.

Abbreviations: DRG = Diagnosis-Related Group; CHA = Colorado Hospital Association; RMHP = Rocky Mountain Health Plans; GRHD = Grand River Hospital District. *Data presented for Glenwood Springs zip code areas only.

DRG Category	CHA data (2000-1st Q 2007)	RMHP (2000-2007)			GRHD ER (2004-2006)	Valley View ER* (2004-2006)
		Inpatient Hospital	Outpatient/Ambulatory	Emergency Room		
Circulation/Cardiac	Garfield County's rates are the lowest among the four counties.	Garfield County's rates are the lowest among the four counties for both adults and children. Rates show an increasing trend from 2003-2006.	Same as for inpatient visits.	Same as for inpatient visits.	Rates for Silt, Parachute/Battlement Mesa and Rifle residents show an increasing trend for the time period.	Adult ER visits for this category were stable over the period; child/young adult visits decreased.
Endocrine/Metabolic	Overall, Garfield County hospitalization rates for these disorders are not different than the rates for the other three counties. However, diabetes-related hospitalization rates for both adults and children in Garfield County are the lowest among the four counties.	Rates are consistent with the CHA data for both adults and children.	Same as for ER visits.	ER visit rates for these disorders are generally lower for both adult and child residents of Garfield County than for the other three counties; rates show a slight increasing trend over the time period.	Rates for Silt, Parachute/Battlement Mesa and Rifle residents show an increasing trend for the time period.	Adult ER visits decreased between 2004 and 2005, then remained stable for the remainder of the period. Child/young adult rates increased between 2004 and 2005, then decreased from 2005 through 2006.

Abbreviations: DRG = Diagnosis-Related Group; CHA = Colorado Hospital Association; RMHP = Rocky Mountain Health Plans; GRHD = Grand River Hospital District. *Data presented for Glenwood Springs zip code areas only.

DRG Category	CHA data (2000-1st Q 2007)	RMHP (2000-2007)			GRHD ER (2004-2006)	Valley View ER* (2004-2006)
		Inpatient Hospital	Outpatient/Ambulatory	Emergency Room		
Ear, Nose, Throat, Respiratory	Garfield County has the highest rate among the four counties for otitis media, upper respiratory infections, bronchitis, and asthma in children. *Asthma hospitalizations have been higher than in either Mesa or Delta Counties since 1993, but were lower than in Montrose County for the period, 1993-2001.* Garfield adult hospitalization rates for these conditions were lowest among the counties, as were the rates for COPD and other respiratory infections and inflammations for both adults and children. Exceptions are simple pneumonia and pleurisy in children, which, until 2005, were highest among the four counties.	Hospitalization rates for adult ENT and respiratory conditions were the lowest among the four counties for adults and similar to the other counties for children.	Garfield County outpatient/ambulatory visits for adults were the lowest among the four counties, but highest among the four counties for children. Garfield County rates decreased for both adults and children from 2005 through 2007.	Garfield County ER visit rates for adults were the lowest among the four counties and were stable over the 8-year period. Rates for children in Garfield County increase steadily from 2000-2003, but are similar to those for the other three counties.	ER visit rates for Silt, Parachute/Battlement Mesa, and Rifle residents are variable, but generally increasing over the time period.	Adult visits for otitis media increased between 2004 and 2005, then decreased from 2005 through 2006. Rates for respiratory conditions, in general, and asthma, specifically, were stable throughout the time period. Child/young adult ER visits for otitis media decreased steadily through the time period. Rates for respiratory conditions, overall, were stable, however asthma rates increased.

DRG Category	CHA data (2000-1st Q 2007)	RMHP (2000-2007) Inpatient Hospital	Outpatient/Ambulatory	Emergency Room	GRHD ER (2004-2006)	Valley View ER* (2004-2006)
Eye	No data for this category.	Garfield County's rates are the lowest among the four counties for both adults and children.	Same as for hospitalization rates.	Same as for hospitalization rates.	Rates for Silt increased sharply between 2004 and 2005; rate increases for Parachute and Rifle were more gradual over the same period. Rifle's rates continued to increase through 2006, while Parachute and Silt's rates decreased.	Adult ER visits were low and stable throughout the period. Child/young adult rates showed a steady decrease over the time period.
Gastrointestinal/Urinary	Garfield County's rates are either the lowest among the four counties, or are similar to those of the other counties for this group of disorders.	Rates are consistent with the CHA data for both adults and children.	Rates are consistent with the CHA data for both adults and children.	ER visit rates for these disorders are lower for Garfield County adults than for the other three counties, and also generally lower for children, but increase over the time period.	Rates for Silt, Parachute/Battlement Mesa and Rifle residents show an increasing trend for the time period.	Adult ER visits for this category were stable throughout the period. Child/young adult visits increased between 2004 and 2005, then decreased between 2005 and 2006.
Infection	No data for this category.	Garfield County rates are similar to those for the other counties.	Garfield County outpatient/ambulatory visits for adults were the lowest among the four counties, but highest among the four counties for children during the time period 2000 through 2002.	ER rates for Garfield County adults were inconsistent, without a sustained trend in either direction, but similar to other counties. Child ER visits for infections were generally higher than other counties.	Rates for infection-related ER visits were variable over the time period, without consistent trends for the communities of Parachute/Battlement Mesa, Silt and Rifle.	Adult ER visits for infections decreased throughout the period, as did child/young adult visits.

DRG Category	CHA data (2000-1st Q 2007)	RMHP (2000-2007)			GRHD ER (2004-2006)	Valley View ER* (2004-2006)
		Inpatient Hospital	Outpatient/Ambulatory	Emergency Room		
Mental	Garfield County's rates re the lowest among the four counties.	Garfield County rates are lower than for the other counties and steadily decreasing over the time period.	Same as for hospitalization rates.	Same as for hospitalization rates.	Rates for Rifle and Silt show a gradual increase; rates for Parachute/Battlement Mesa increased steeply between 2005 and 2006.	Overall adult ER visit rates decreased between 2004 and 2005, then increased to 2004 levels between 2005 and 2006. Drug/alcohol-related visits showed a steady increase over the period. The same pattern was seen for children and young adults.
Musculoskeletal	Garfield County's rates are the lowest among the four counties.	Rates are consistent with the CHA data for both adults and children.	Same as for inpatient visits.	Same as for inpatient visits.	No data for this category.	Adult ER visits were stable over the time period, as were child/young adult visits.
Nervous System	Overall, Garfield hospitalization rates for these disorders are lower than for the other counties. For the subcategory of seizure and headache, rates for children in Garfield County have increased since 2004, while decreasing in adults.	Rates are consistent with the CHA data for both adults and children.	Rates are consistent with the CHA data for both adults and children.	Garfield County ER visit rates, overall, were the lowest among the four counties.	Rates for Silt, Parachute/Battlement Mesa and Rifle residents show an increasing trend for the time period.	Adult ER visits, including those related to headaches or migraines, were stable over the period. Child/young adult visits overall increased between 2004 and 2005, then decreased through 2006. Visits related to headaches or migraines increased.

Abbreviations: DRG = Diagnosis-Related Group; CHA = Colorado Hospital Association; RMHP = Rocky Mountain Health Plans; GRHD = Grand River Hospital District. *Data presented for Glenwood Springs zip code areas only.

DRG Category	CHA data (2000-1st Q 2007)	RMHP (2000-2007) Inpatient Hospital	Outpatient/Ambulatory	Emergency Room	GRHD ER (2004-2006)	Valley View ER* (2004-2006)
Pancreas/Liver	Rates for these conditions for Delta County were consistently the highest among the four counties. Garfield County's rates were not different from those of Mesa and Montrose Counties.	No data for this category.	No data for this category.	No data for this category.	No data for this category.	Included with "Gastrointestinal/urinary" category.
Red Cell/Clotting	Garfield County's rates steadily decreased from 2001through 2006.	No data for this category.	No data for this category.	No data for this category.	No data for this category.	Adult ER rates increased between 2004 and 2005. Child/young adult rates were stable through 2005, then decreased through 2006.
Skin/Allergy	Rates for these conditions for Delta County were consistently the highest among the four counties. Garfield County's rates were not different from those of Mesa and Montrose Counties.	Garfield County's rates are the lowest among the counties, showing periods of moderate rate decrease (2001-2003) and increase (2003-2005).	Garfield County's rates are the lowest among the four counties, increasing slightly from 2003 to 2004, then decreasing from 2005 through 2007.	Garfield rates are lowest among the counties, and were generally stable throughout the 8-year period, except for an increase between 2003 and 2004, decreasing to previous rates in 2006. (Rates for children in Garfield County decreased steadily from 2005 through 2007.)	Rates for Silt, Parachute/Battlement Mesa and Rifle residents show an increasing trend for the time period.	Adult ER rates were stable. Child/young adult rates decreased through the period.

Cancer

- One of the difficulties of observing relatively recent trends in cancer incidence statistics and trying to draw conclusions about possible changes in risk factors is that, with respect to carcinogenic exposures, these trends reflect events that happened 10- 20 years ago or are cumulative over a lifetime. Generally speaking, the appearance of clinical cancer has a "lag" time of up to two decades following initiation of carcinogenesis. (Childhood cancers and some rare cancers are exceptions.) Thus, with the exception of changes in cancer screening practices that often artifactually inflate cancer rates, short-term trends may not reflect changes in the potential for exposure to carcinogenic materials.

- County-specific cancer rates for Delta, Garfield, Mesa and Montrose counties for the time period of 1992 through 2005 show that incidence rates for all cancers have changed little over this period, although cancer rates in males dropped slightly for Delta, Garfield, and Montrose counties for the most recent time period for which data are available (2003-2005). There is relatively little difference among the counties for either male or female cancer incidence rates across the designated time periods.

- When compared to the state cancer rates, the following observations could be made for Garfield County:
  - The incidence rate of all cancers combined was significantly higher than the state rate for males from 1992 through 2000 and for females from 1992 through 1998.

  - The incidence rate of all cancers combined was significantly lower than the state rate for females from 1999 through 2000.

  - The incidence rate of prostate cancer was significantly higher than the state rate from 1992 through 2000.

  - Incidence rates for colorectal cancer, lung cancer, melanoma, bladder cancer, leukemias, and thyroid cancer in both males and females, and for breast and cervical cancer in females, did not differ significantly from the state rates for the period 1992 through 2005.

- For comparison, the following observations were made for Mesa County:
  - The incidence rate of all cancers combined was significantly higher than the state rate for males from 1992 through 2005.

  - The incidence rate of prostate cancer was significantly higher than the state rate from 1999 through 2005, but was significantly lower than the state rate from 1992 through 1998.

  - The incidence rate of lung cancer was significantly higher than the state rate from 1992 through 2000 and from 2003 through 2005 for both males and females.

- The incidence rate of melanoma in males was significantly higher than the state rate from 1999 through 2000.

- The incidence rate of bladder cancer in females was significantly higher than the state rate from 2001 through 2002.

- The incidence of thyroid cancer in females was significantly lower than the state rate from 2003 through 2005.

- Incidence rates for colorectal cancer, and leukemias in both males and females, and for melanoma, thyroid cancer, breast cancer and cervical cancer in females, did not differ significantly from the state rates for the period 1992 through 2005.

Sexually Transmitted Diseases (STDs)

Of the conditions that are reportable to the state health department, other than cancer, a recent trend in the frequency of STD diagnoses is worth noting:

- For the time period, 2003 through 2007, the rate of reported cases of Chlamydia in both Garfield and Mesa Counties has steadily increased. It is not clear, at this time, whether this rate increase is due to an actual increase in disease or is an artifact of changes in screening patterns in the two counties. Overall, Garfield County's rates are lower than those for Mesa County and the state, but higher than those for Delta and Montrose Counties. Both Delta and Montrose Counties show an increase in reported cases for 2004-2005, but then the rates are flat (Delta) or decrease (Montrose) from 2005 through 2007.

- Similarly, the rate of reported cases of Gonorrhea in Garfield and Mesa Counties steadily increased from 2003 through 2007. Garfield County's rates are again lower than those for both Mesa County and the state, but higher than those for Delta and Montrose Counties. Delta County's Gonorrhea cases showed the same pattern as for Chlamydia; Montrose County's Gonorrhea cases increased slightly over the period 2004 through 2007.

- Garfield County had the highest rate of reported HIV cases among the four counties for the years 2000, 2001, 2003, and 2005. These rates were higher than the state rate for the years 2001 and 2003. (There were no cases reported in 2002, 2006, or 2007.)

- Garfield County had the highest rate of reported AIDS cases among the four counties for the years 2000, 2003, 2004, and 2005. (There were no cases reported in 2001, 2002, or 2006.)

Self-Reported Health Status: Household Survey. A targeted health survey was administered to Garfield County residents by trained interviewers. The in-home surveys captured information about the general health and health risk factors of residents, as well as information about specific health conditions that were identified as priority concerns during focus group discussions. This information was intended to provide a more objective measure of the health status of community residents, and a means of conducting *within* County comparisons.

We collected data on 1,048 individuals, representing ~2% of the households in Garfield County that have listed telephone numbers. This number included 49 interviews, conducted in Spanish, of primarily Spanish-speaking households (representing 195 individuals). Respondents were asked to provide information for every individual living in the household. Thus, we were able to achieve a population sample that is representative of the gender, age, and ethnicity demographics of Garfield County, and approximated the occupational, education, and household income diversity that exists in the county. Respondent households represented each of the zip code areas within Garfield County, with a low of 1.25% and a high of 2.52% of households with listed phone numbers in zip codes 81601 and 81652, respectively, completing the survey. (Zip code areas 81601 and 81623 are the least affected by natural gas drilling and production activities; zip code areas 81635, 81647, 81650, and 81652 are most affected by these industry activities.) The majority of those responding to the survey had lived in Garfield County for greater than 5 years.

Household Survey Outcomes Highlights (Please see the full report for additional measures and comparisons):

- Greater than 80% of individuals from every zip code area in Garfield County rated their current health as either excellent or good, and less than 10% of individuals in every zip code area felt that their current health is somewhat worse or much worse than it was one year ago.

- Approximately 12% of individuals, county-wide, reported that they had suffered an illness or injury during the past year that had affected their health for greater than 5 days.

- Approximately 8% of individuals, county-wide, reported suffering from depression.

- 20% of individuals reported suffering from a variety of allergies, including hay fever.

- 8% of individuals suffer from frequent headaches or migraines; a zip code comparison shows that the lowest frequency of headache sufferers live in zip code 81623 (4%), while the highest frequency was reported from zip codes 81635 and 81647 (8.3% each).

- 3.8% of individuals report living with diabetes and its side effects such as kidney problems, loss of feeling or pain in hands and feet, and eye problems. There was no difference among the zip code areas for frequency of diabetes.

- 24% of individuals have coronary disease, a category that includes heart attack or heart surgery, high blood pressure, stroke and angina. There was no difference among the zip code areas for frequency of coronary disease.

- 10% or less of children born in any zip code area of Garfield County were reported to have developed health or developmental problems within 5 years of their birth.

- 5% of individuals, county-wide, reported having some kind of cancer during their lifetime.
    - ~2X as many individuals residing in zip code area 81635 reported having cancer than was reported for the county overall. *It is important to note, however, that the average age of the respondents from this zip code area was considerably older than for the other zip code areas.*

    - 53.3% of the reported cancers were diagnosed in individuals who were 55 years or older; There were NO cancers reported in individuals under age 25.

    - The most frequently reported cancers were female breast cancer (20.7%), non-melanoma skin cancers (26.4%), prostate cancer (15.1%), cervical cancer (9.4%), and colon cancer (7.5%). Malignant melanoma and lymphoma each accounted for 3.8% of the reported cancers. Uterine, thyroid, liver, kidney, and bladder cancers, along with leukemia, glandular carcinoma, made up the remainder of the cancers reported (1.9% each).

- Because respiratory complaints were expressed so frequently in interviews and focus groups, we asked a number of specific questions about respiratory conditions and contributing factors such as smoking.
    - 6.5% of individuals, county-wide, reported having a diagnosis of asthma; the highest frequency of individuals with asthma was in zip code area 81647 (8.3%), while the lowest frequency of individuals with asthma was in zip code area 81652 (4.7%). Both zip code areas have significant natural gas industry activity.

    - Similar to what was observed with other respiratory conditions such as Chronic Obstructive Pulmonary Disease (COPD), emphysema and other lung or breathing problems, the zip code area having the highest frequency of these conditions was among those most highly impacted by natural gas industry activity, but the lowest or next to lowest frequency was also found among these impacted zip code areas.

    - Age and smoking are factors that clearly influence the incidence of these conditions. 27% of county residents, overall, reported having smoked at least 100 cigarettes during their lifetime; 60% of these have quit smoking. 85% of respondents reported that smoking is NOT allowed within the home.

Occupation and Disease

- Responses to questions about occupational history (current and longest job titles and industry affiliations) allowed correlations with diseases and symptoms reported by survey respondents.

- It is important to note that this study was not designed as an occupational health study, and thus, no conclusions may be drawn regarding occupational exposures and disease outcomes. The numbers of individuals within any occupational category that report having a particular disease or condition are too low for statistical significance. However, the following observations may be made:
    - Individuals who reported that their current and/or longest occupation was in the professional and related services industries (e.g., healthcare providers, attorneys, etc.), personal services occupations (e.g., housekeepers, hair stylists, etc.), construction industries or transportation (including truck drivers), communications and public utilities industries were most likely to have reported having respiratory conditions; neurological symptoms such as dizziness, numbness, weakness; skin problems; and frequent headaches/migraines.

    - Those individuals who refused to answer questions about their occupation and/or industry affiliation were most likely to have reported having frequent headaches/migraines; neurological symptoms such as dizziness, numbness, weakness; anemia; seizures; skin problems; and cancer (but no bladder, kidney, liver, lymphoma or thyroid cancers or leukemia).

Relationships Between Health and Environmental Exposures: Household Member Concern

A series of questions regarding perceptions of risk related to home and outside environmental exposures and their relationship to health outcomes were asked at the end of the survey. These questions were intended to serve as measures of concern and perceptions among a randomly selected population within Garfield County (as opposed to the more self-selected population that provided comments during focus groups, interviews, and public meetings), and to provide some measure of the potential bias with which survey respondents might have responded to questions about their health.

- When asked whether or not they are concerned that their home drinking water source was related to any of their health problems, between 5.5 and 17% of individuals who live in areas with high natural gas industry activity (zip code areas 81635, 81647, 81650, and 81652) responded that they are concerned, while only 3-5% of individuals who live in the areas least impacted by natural gas industry activity (zip code areas 81601 and 81623) responded in the same manner.

- When asked whether or not they are concerned that their health problems may be related to chemicals in or near their homes, between 6 and 16% of individuals who live in areas with high natural gas industry activity (zip code areas 81635, 81647, 81650, and 81652) responded that they are concerned; between 1.4 and 7% of individuals who live

in the areas least impacted by natural gas industry activity (zip code areas 81601 and 81623) responded in the same manner.

- When asked if they are concerned that either environmental or chemical hazards in their neighborhoods may be related to health problems,
  - Between 24 and 38% of individuals residing in zip code areas 81635, 81647, 81650, and 81652 responded that they are not worried at all. Between 76 and 62% of individuals in these zip code areas responded that they are "a little worried", "very much worried", or "don't know/not sure".

  - Between 56 and 43% of individuals residing in zip code areas 81601 and 81623 responded that they are not worried at all. Between 44 and 57% of individuals in these zip code areas responded that they are "a little worried", "very much worried", or "don't know/not sure".

  - County-wide, individuals who have a high school education or less are slightly less worried about the relationship between their health and environmental or chemical hazards in their neighborhoods.

- When asked specifically whether they are concerned that natural gas industry activities may be related to health problems,
  - Between 69 and 92% of individuals residing in zip code areas 81601 and 81623 responded that they are not concern. Between 8 and 31% of individuals in these zip code areas responded either that they are concerned or that they "don't know or are not sure".

  - 90% of individuals residing in zip code areas 81601 and 81623 responded that they are not worried at all. 10% of individuals in these zip code areas responded that they either that they are concerned or that they "don't know or are not sure".

  - There was essentially no difference related to education between individuals who responded that they are concerned about health-related impacts of the natural gas industry and those who are not concerned or are not sure.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions.

- At the present time – based on our data sources – there is not a health crisis in Garfield County, but there are some health trends that should be monitored. We cannot say conclusively that any of these health trends are directly related to the presence of natural gas industry activities or to other factors.

- Accident, injury and trauma hospitalization and emergency room visits have been increasing, particularly for adults.

- Child (1-14 years) deaths in Garfield County for 2001-2005 are considerably higher than the state's 2010 goal (35.5/100,000 versus 19/100,000, respectively) and higher than the rates for Mesa and Montrose Counties.

- Although circulation disorders and cardiac disease rates are lower in Garfield County than in the other three counties studied, these conditions have been among the most common reasons for hospitalization, and rates for inpatient, outpatient and emergency room visits appear to be increasing.

- Hospitalization rates for birthing, pregnancy and gynecological disorders are consistently higher for Garfield County than for the other counties studied, and emergency room visits for these disorders appear to be increasing, at least among Silt, Parachute/Battlement Mesa and Rifle residents.

- Upper respiratory infections, bronchitis, asthma and otitis media rates in children, in particular, have generally been higher for Garfield County than in the other counties studied. Emergency room visits for these conditions have been increasing.

- Mental health-related emergency room visits for residents of Silt, Parachute/Battlement Mesa and Rifle increased between 2005 and 2006.

- Hospitalization rates for seizure and headache in children in Garfield County showed an increasing trend between 2004 and 2007. Emergency room visits for the general category of nervous system disorders showed an increasing trend for residents of Parachute/Battlement Mesa and Silt for the 2004-2006 time period. However, it is important to note, that overall, rates for nervous system disorders in Garfield County are as low as or lower than those same rates in Delta, Mesa and Montrose Counties.

- Although the actual number of cases is relatively low, the frequency of diagnosed and reported sexually transmitted diseases has increased steadily in Garfield County since 2003.

- At this time, there are no cancer trends in Garfield County that are of notable concern. However, because of the lag period between exposure and cancer development, cancer rates should be reviewed on a periodic basis.

- Risk modeling indicated that there are industry factors that could present a public health risk – use of best practices can reduce that risk.

Recommendations

- Establish a medical monitoring system – especially through primary care networks – to identify any changes in baseline data or trends and/or anomalies in medical practices.

- Conduct a thorough study of air emissions during drilling, including enough sites to cover the range of drilling approaches.
    - Collect 24-hour samples daily around the perimeter of the drill pad to achieve continuous monitoring during several cycles of well installation.

    - Monitor meteorological conditions.

- Identify the components of hydraulic fracturing fluids.
    - Would allow open evaluation of degree of threat.

    - Would improve public acceptance of natural gas operations.

- Inspect surface soils at completion of drilling operations.
    - Minimize possible exposure of landowners to residual soil contamination.

    - Sample and analyze areas suspected to be contaminated.

    - Clean up areas exceeding action levels.

- Use “green completions” and applicable best management practices, including locating drilling and production facility operations far enough from public buildings and residences to reduce the risk of exposure to air toxics, such as benzene, toluene, and xylenes.

- Establish a monitoring program for private wells
    - Provides the most direct way to assess contamination of drinking water resources

    - Analyze for methane, benzene and other volatile organic compounds, and selected components of hydraulic fracturing fluids having the greatest potential to affect human health

INTRODUCTION TO THE STUDY

The "Community Health Risk Analysis of Oil and Gas Industry Impacts in Garfield County" was a response to a request for proposals for projects that would address public environmental needs in Garfield County. These projects were to be funded by a fine levied on EnCana Oil and Gas (USA), Inc. as a result of a violation of Colorado Oil and Gas Conservation Commission (COGCC) rules. All proposals were due by August 30, 2004. The Garfield County Energy Advisory Board (EAB) discussed the proposals at a meeting on September 2, 2004, at which they made a decision to forward a recommendation to the Garfield County Board of Commissioners to fund three of the proposals. On September 6, 2004, the Garfield County Board of County Commissioners selected three proposals for funding, one of which was the "Community Health Risk Analysis of Oil and Gas Industry Impacts in Garfield County." The initial work on the project was begun by Dr. Teresa Coons (St. Mary's Saccomanno Research Institute) and Dr. Russell Walker (Environmental Sciences and Technology Department, Mesa State College) shortly thereafter, although the final Scope of Work and contract were not signed by the Board of Commissioners until December 31, 2006.

Oil and gas activity within Garfield County has generated public concern with regard to impacts on both the environment and public health. Often, public perception of potential health risks becomes an overriding concern. The public may feel as though their health is at risk and they may wish to obtain an understanding of possible threats to their health, as well as acknowledgement by the oil and gas industries of their concerns. Opening this dialogue through discussion of the real and perceived impacts of extractive industries and could serve as a focal point for collaborative resolutions to community and industry concerns over the balance between the risks and benefits of natural resource extraction.

FOCUS OF THE STUDY

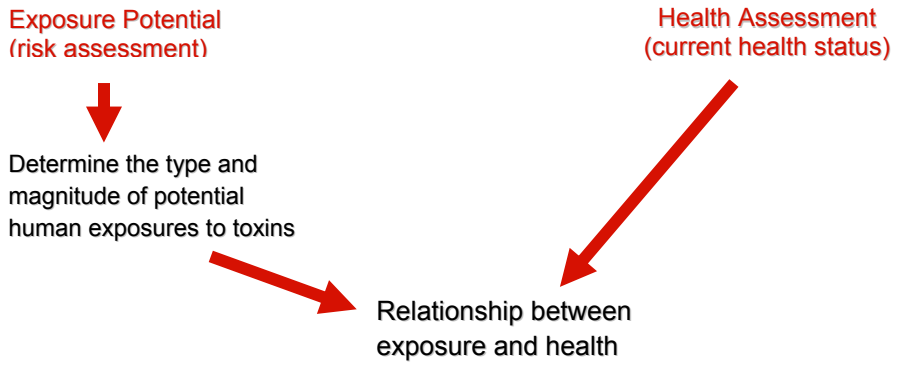


Figure 1. Relationship between Exposure Potential and Health Assessment

Risk Assessment

- Characterize the "sources"
- Natural Gas Operations
- Model showing potential pathways for movement of contaminants from source to human exposure
- Other sources of potentially toxic materials (e.g. mines, mill tailings, landfills, agricultural spraying)?
- Characterize the "contaminants"
- Collect and interpret data on contaminants and their concentrations
- Summarize toxicological information on contaminants

Risk Characterization

- Develop "probability statements" about risk to individuals within the community (current or future risk)
- Exposure potential (proximity to source, dose, etc.)
- Probability of suffering harm from exposure (incorporates factors related to age, health status, etc.)

Health Assessment

- Perception of Health
- How do community members feel about their health and the health of others in the community?
- What do community members feel are the determinants of health in their community?

Matching Perception with Reality

- Statistical health data and self-reported health information

Merging Risk and Health Data

- Point-in-time" picture of the health status of residents of Garfield County
- Information about determinants of health picture
- Relationships between exposure and health status
- Recommendations
- Data gaps that should be filled
- Possible future monitoring needs
- Options for managing risk

STUDY LIMITATIONS

- Funding: study may uncover issues or areas that need more in-depth research than can be performed with existing funding
- Lack of baseline health data with which to determine trends or changes
- Relatively new presence of the industry in the region: health outcomes may not yet be apparent
- Both risk and causation involve probability statements: may never be able to say with certainty that a particular health condition is caused by an exposure to a potentially toxic material.

STUDY AREA

The primary focus of this health and risk assessment study is Garfield County. Mesa, Montrose, and Delta Counties were selected as comparison counties for the health assessment portion of the study. These three counties share a Western Slope of Colorado location with Garfield County (and hence, some common population demographics and culture). However, they all, currently, have fewer impacts from natural gas industry drilling and processing activities.

EXTRACTIVE INDUSTRIES IN COLORADO AND GARFIELD COUNTY

This study was initiated, in large part, because of local concerns about health-related impacts of the natural gas industry. However, it is important to put those impacts into a context that includes natural gas activity in other parts of Colorado (including the comparison counties), as well as impacts from other extractive industries that are now or have in the past, operated in Garfield County.

Natural Gas. The natural gas industry in Garfield County has grown rapidly, over a relatively short period of time, both in scope and intensity. In 1988, a total of 19 permits were issued by the COGCC for drilling in Garfield County (www.oil-gas.state.co.us/staffreports). By 2002, which according to some observers marks the observable beginning of the current "boom", 362 permits had been issued. In 2007, 2550 drilling permits were issued. The following tables and graphs were obtained from the Colorado Oil and Gas Conservation Commission (COGCC) website: www.oil-gas.state.co.us/.

Table 1. Annual permits to drill issued by the Colorado Oil and Gas Conservation Commission (www.oil-gas.state.co.us/staffreports). The number of drilling permits issued does not fully reflect the impacts) of the natural gas industry in a region. A more accurate reflection of industry activity is the number of wells actually being drilled (as reflected by the number of operating drill rigs) and the number of actively producing wells.

	Garfield County	Mesa County	Montrose County	Delta County	Weld County	La Plata County	Cheyenne County
1988	19	1	0	1	424	302	203
2001	353	27	3	0	702	156	3
2002	362	30	2	7	760	104	3
2003	657	27	4	4	757	162	3
2004	796	54	2	5	832	102	3
2005	1509	136	0	10	901	115	10
2006	1845	265	1	9	1418	235	21
2007	1550	293	3	2	1527	251	15

Figure 2.

DRILLING RIGS RUNNING IN COLORADO BY COUNTY EACH WEEK IN 2007

(Based on Data in Anderson Reports Weekly Rig Status Report)

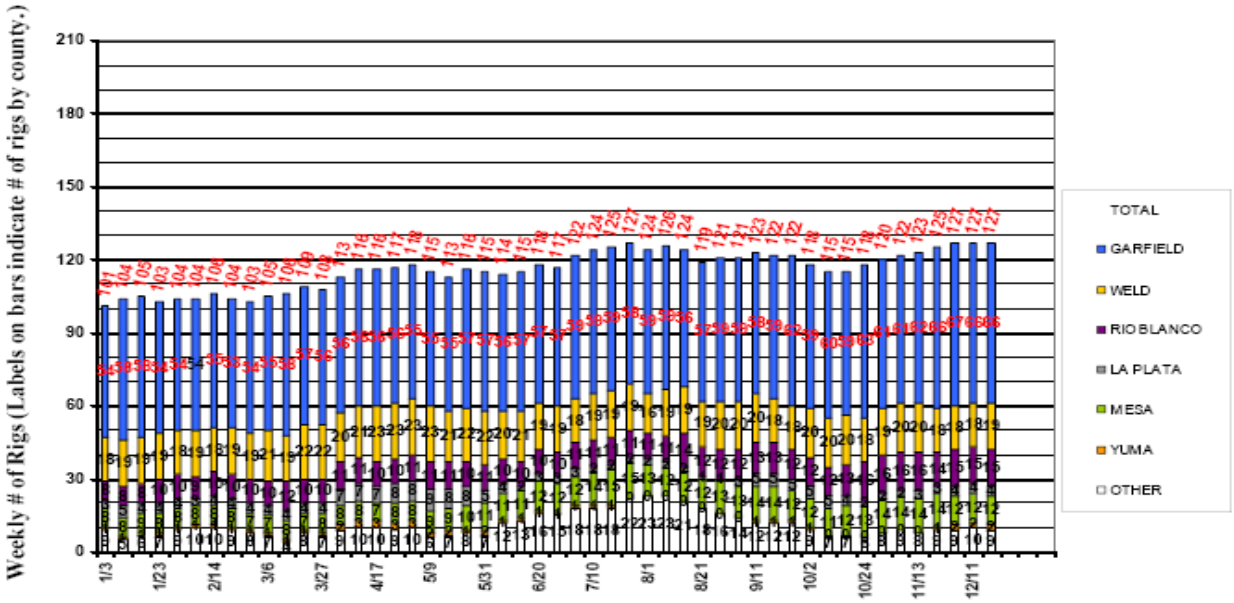
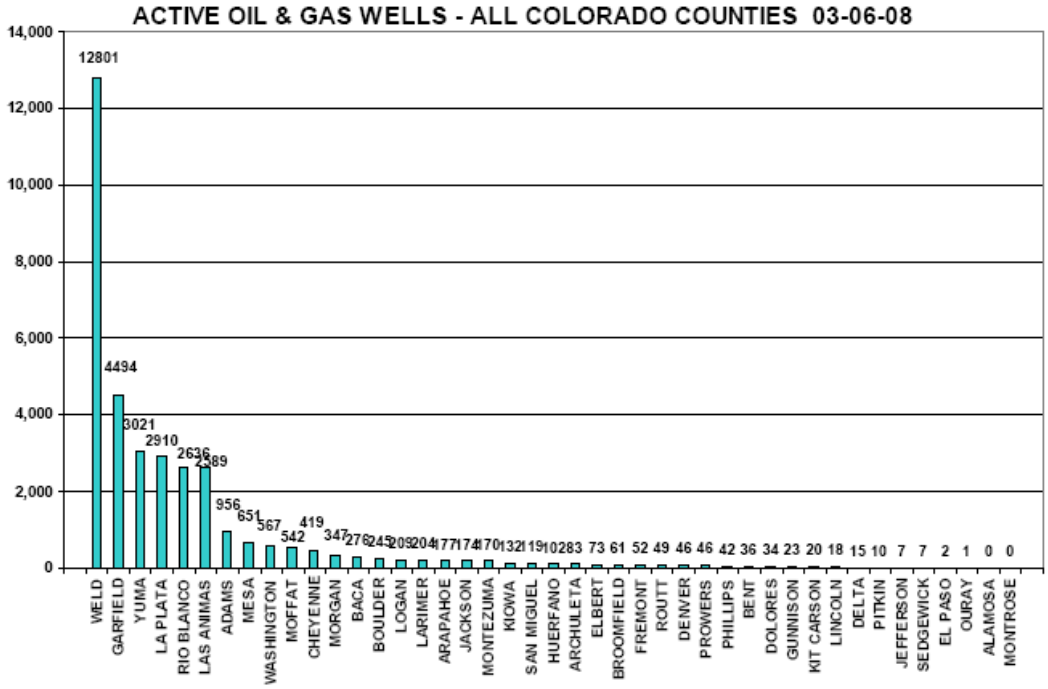


Figure 3.



Coal Mining. Other current and historic mining activities in Garfield County include coal, uranium, and gravel mining. The McClane Canyon underground coal mine is located in the far western part of Garfield County. Coal mining also takes place in Delta and Montrose Counties, and has taken place in Mesa County in the recent past.

Figure 4. Location of Coal Mines, Power Plants, Railroads and Coal-bearing Regions in Colorado, 2006.
Colorado Geological Survey, Information Series 75, Colorado Mineral and Energy Industry Activities

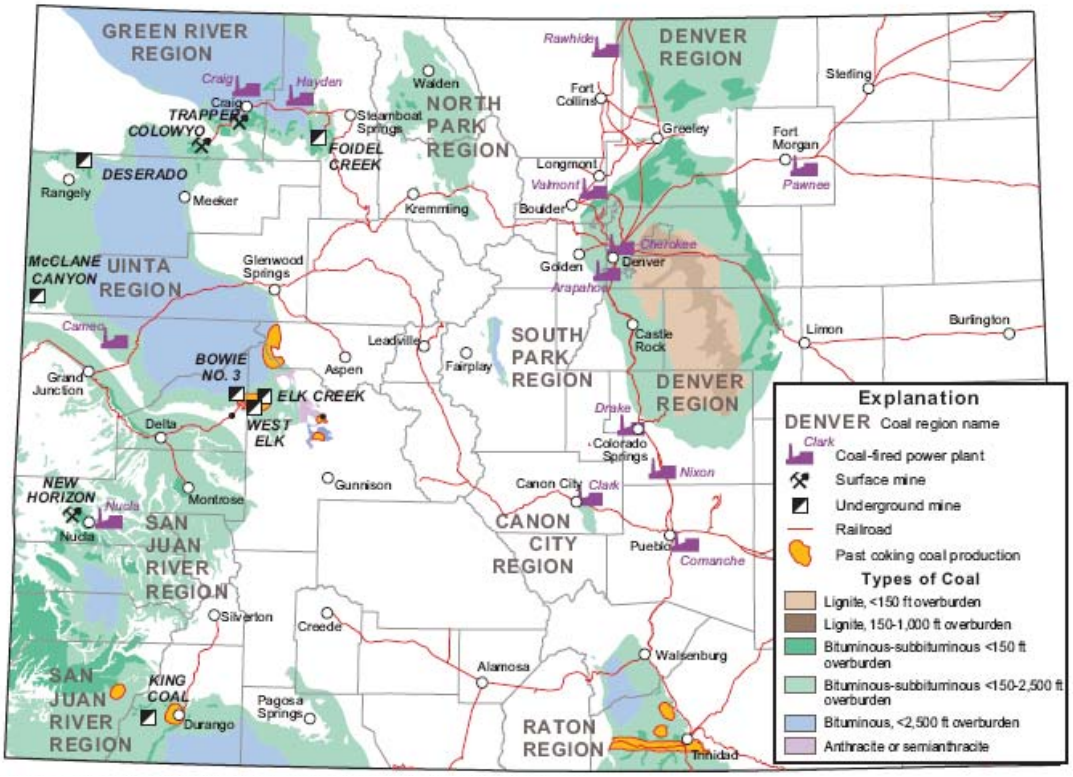


Table 2. Colorado Coal Mine Statistics, 2006.
Colorado Division of Reclamation, Mining and Safety.

County	Parent Company	Operator	Mine Names	Coal Region	Coal Field	Twp., Rng.	Geologic Formation	Producing Bed Names	Seam Thickness	BTU Avg. Shipped	Mine Type	Mining Method	2006 Prod. (tons)	Dec 2006 Miners	Shipment Method
Delta	Colorado Energy Investments, LLC; Sentient Coal Resources, LLC	Bowie Resources Ltd.	Bowie #3	Uinta	Somerset	13S, 91W	Mesaverde	B	12–20 ft	11,650	U	Longwall, continuous	4,420,073	265	Rail
Gunnison	Oxbow Carbon and Minerals Holdings, Inc.	Oxbow Mining, LLC	Elk Creek	Uinta	Somerset	13S, 90W	Mesaverde	D2	D=6–19 ft. D2 seam minable is 14 ft.	12,375	U	Longwall, continuous	5,128,390	291	Rail
Gunnison	Arch Coal Inc.	Mountain Coal Company, Inc.	West Elk	Uinta	Somerset	13S, 90W	Mesaverde	E	12 ft	11,650	U	Longwall, continuous	6,039,936	371	Rail
La Plata	Alpha Natural Resources	National King Coal, LLC	King Coal	San Juan River	Durango	35N, 11W	Upper Menefee	Upper Bed	52–72 in.	12,800	U	Continuous	487,807	74	Truck
Garfield	Rhino Energy, Llc	McClane Canyon Mining, LLC	McClane Canyon	Uinta	Book Cliffs	7S, 102W	Mesaverde	Upper Cameo, Lower Cameo	Upper Cameo= 5–9 ft; Lower Cameo= 8–10 ft	10,475	U	Continuous	266,561	22	Truck
Moffat	Rio Tinto	Colowyo Coal Company, L.P.	Colowyo	Uinta	Danforth Hills	4N, 93W	Williams Fork-Fairfield Coal Group	A–F,X,Y	52.2 ft total; Y=4 ft, X=10.7 ft, A=2 ft, B=6.8 ft, C=6.4 ft, D=10.1 ft, E=6.8 ft, F=5.4 ft	10,453	S	Dragline, Shovels, Dozers	6,342,058	262	Rail
Moffat	PacifiCorp/Tri-State G&T/Salt River	Trapper Mining, Inc.	Trapper	Green River	Yampa	6N, 90W	Williams Fork–Upper Coal Group	H, I, K, L, M, Q	H=6 ft, I=5 ft, K=4 ft, L=4 ft, M=6 ft, Q=10 ft	9,850	S	Dragline, Shovels, Hyd. Excav.	2,080,372	145	Truck
Montrose	Tri-State G&T Assoc.	Western Fuels Colorado, LLC	New Horizon	San Juan River	Nucla-Naturita	46N, 15W	Dakota	1, 2	Kd Upper= 0.80–1.5 ft; Kd Lower= 5.0–7.5 ft	11,680	S	Shovels, dozers	405,611	24	Truck
Rio Blanco	Deseret Generation & Transmission	Blue Mountain Energy, Inc.	Deserado	Uinta	Lower White River	3N, 101W	Williams Fork	B Seam	B= 7–16 ft., D= 6–8 ft.	10,000	U	Longwall, continuous	1,712,553	129	Rail
Routt	Peabody Energy	Twentymile Coal Co.	Twentymile (Foidel Creek)	Green River	Yampa	5N, 86W	Williams Fork-Middle Coal Group	Wadge	8.5–9.5 ft	11,250	U	Longwall, continuous	8,549,845	482	Rail, Truck
Routt	Peabody Energy	Seneca Coal Co.	Seneca II–W/Yoast (closed 2006)	Green River	Yampa	5N,87W	Williams Fork–Middle Coal Group	Wadge, Wolf Cr., Sage Cr.	Wadge= 8.9–12.2 ft (avg. 11.7 ft); Wolf Creek= avg. 20.4 ft; Sage Creek= 3.4–5.4 ft (avg. 4.6 ft)	11,908–12,581	S	Dragline, loaders	57,131	0	Truck
Shaded items indicate new annual production record.							Mine Type abbreviations: U—underground mine, S—surface mine					Totals	35,490,337	2,065	

Uranium mining. Beginning in the early part of the twentieth century, the Rifle area in Garfield County was host to underground vanadium and uranium mining and two processing mills. In 1991, the Bureau of Land Management transferred 205 acres of land in Estes Gulch (approximately six miles north of the city of Rifle) to the Department of Energy to use as a disposal site for the tailings that had been produced and stored at the Old and New Rifle Uranium Mills. "The alluvial aquifer is contaminated by seepage from the former mill tailings piles at both former mill sites. Because of the large dilution by the river (at least a factor of 30,000), contaminants in alluvial groundwater discharging to the river are quickly diluted to background concentrations and no mill-related contamination has been detected in samples of Colorado River water collected at or downstream from the sites. " (Rifle, Colorado, Processing Sites and Disposal Site. U.S. Department of Energy Office of Legacy Management.)

Locations of the Rifle Processing Sites and Disposal Site

Project Rulison. Named after the rural community of Rulison, Colorado, Project Rulison was a 43-kiloton underground nuclear detonation that took place on September 10, 1969, about 8 miles SE of the town of Grand Valley, Colorado (now Parachute, Colorado) in Garfield County. It was part of the Operation Mandrel weapons test series as well as the Operation Plowshare project which explored peaceful uses of nuclear explosions. The peaceful aim of Project Rulison was to determine if natural gas could be easily liberated from underground regions. The test, was performed by the Atomic Energy Commission and two corporate partners, CER Geonuclear and the Austral Oil Company, at the bottom of an 8,426 foot deep shaft. The blast was marginally successful in causing the gas to collect in the cavity and fissures produced by the bomb; however, the gas was too radioactive to be sold commercially. Another nuclear-device gas stimulation test, called Rio Blanco, was performed nearby in 1973.

The surface of the site began to be cleaned up by the Department of Energy in the 1970s, and was completed in 1998. A buffer zone put in place by the state of Colorado still exists around the area. A January 2005 report by the DOE stated that radioactivity levels were normal at the surface and in groundwater.

OTHER ENVIRONMENTAL ISSUES

Although a complete discussion is beyond the scope of this report, it is important to note that there are other local and regional activities that can and do impact air quality or may contribute to human exposures to toxic materials. Among these are agricultural activities; seasonal open burning to clear ditches and prepare fields for planting, and spraying for weeds and insect pests takes place in many areas of Garfield County. Gravel mining along rivers to support local construction and traffic along the I-70 corridor and local roads contributes significantly to

airborne pollutants. Seasonal forest fires and weather inversion patterns also contribute to air quality issues that may impact the health of Garfield County residents.

PART 1. RISK ASSESSMENT

AN OVERVIEW OF NATURAL GAS OPERATIONS IN GARFIELD COUNTY

Most of the natural gas extracted in the Piceance Basin comes from the Williams Fork Formation of the Mesa Verde Group (Figure 6). The gas occurs in sandstone deposits (often referred to by geologists as "sand bodies") which are isolated from each other by non-gas bearing, impermeable shale. The sand bodies are relatively small, averaging about nine feet thick from top to bottom and about 500 feet across. Because of their low permeability, it has not been economically feasible to recover gas from the sand bodies using conventional methods. However, recent advances in well drilling and stimulation technology coupled with a strong national market for natural gas has made the Williams Fork Formation the focus of intense development.

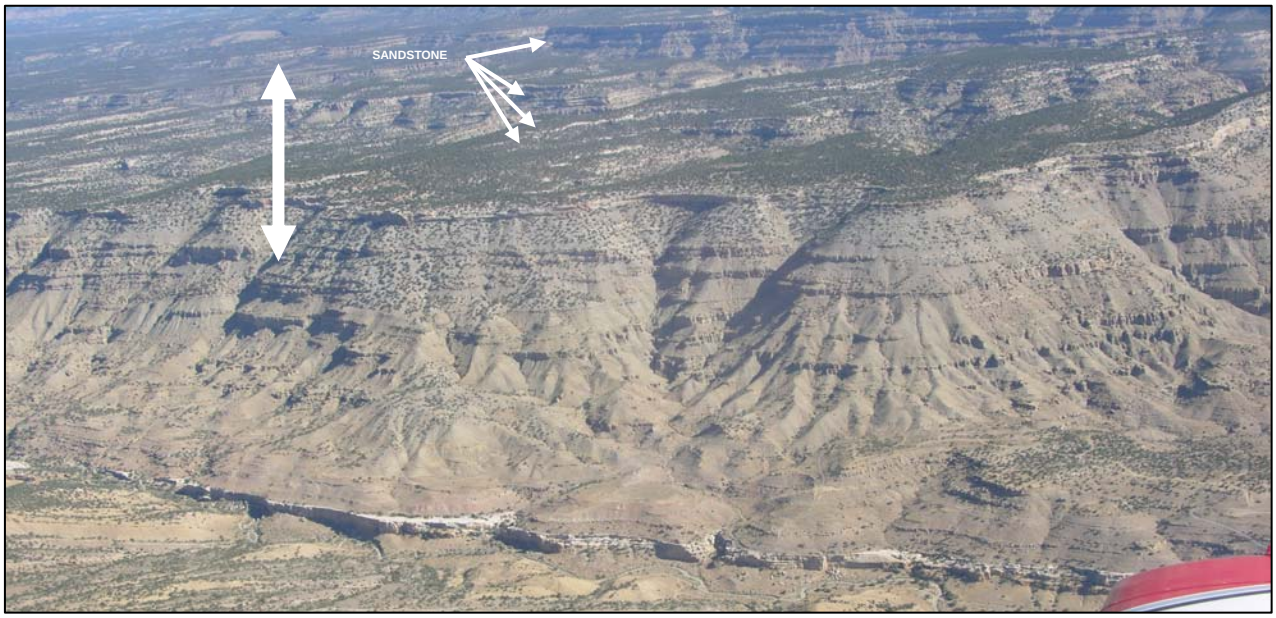


Figure 6. Piceance Basin Williams Fork Formation

Wells are commonly drilled to depths between 4,000 and 9,000 feet below the land surface. Over the last few years, directional drilling has emerged as the dominant approach. This technology allows the drillers to manipulate the direction of the borehole and target sand bodies up to 2,500 feet horizontally away from the drill rig. Each sand body must be penetrated vertically, and each well is designed to access several vertically stacked bodies. Twelve or more wells are commonly installed from the same well pad, reducing the disturbance associated with multiple pads.

A special mud is circulated through the borehole during drilling. The mud is pumped down through the center of the drill stem pipe into the borehole, where it flows back to the land

surface. The mud lubricates the drill bit, conveys cuttings up to the surface, and by virtue of its weight prevents "blowouts" of gas escaping uncontrollably upward through the borehole. After returning to the surface, the mud is passed through a shaker to separate out rock fragments and is then stored in reserve pits, which may or may not be lined. In recent years there has been increasing use of closed-loop systems that do not require a reserve pit.

The well itself is constructed according to specific requirements. A 16- to 20-inch diameter pipe or "conductor casing" is installed to a depth of 20 to 50 feet. This casing stabilizes the uppermost portion of the borehole and facilitates flow of the drilling mud. A "surface casing" about 10 inches in diameter is installed through the conductor casing. This casing isolates the natural gas, drilling mud, and other materials from shallow ground water so as not to contaminate a source of drinking water. The surface casing is required to extend from the land surface through at least 10% of the depth of the well, typically ending at a depth of 600 to 1,000 feet. The space between the casing and the borehole wall is filled with cement to prevent the migration of natural gas or drilling fluids up through this space, thus preventing the contamination of ground water that is used (or may be used in the future) as drinking water. The "production casing" is a pipe about 5 inches in diameter that is installed through the surface casing all the way down to the sand bodies. This casing is also cemented in place to prevent upward migration of gas and fluids.

Hydraulic fracturing ("fracing") is a key step in the development of a viable well. The production casing is perforated at locations that will allow access to the sand bodies penetrated by the well. Water with proprietary additives is pumped through the perforations into the sand bodies at a pressure of about 10,000 pounds per square inch. The pressure induces fractures, which are propped open with sand or other solids that are part of the fracing fluid. These fractures provide a pathway for natural gas to flow out of the sand body into the well more easily than it could if the sand body was left intact. The fractures can extend up to 1,500 feet away from the well. It is important to note that prior to recent years, diesel fuel was routinely used as the base for the fracing fluid rather than water.

After fracing, wells undergo a completion phase. The well head assembly is installed and the well is plumbed to a pipeline. A notable part of completion is a "flow back" period of up to 30 days, in which gas is allowed to vent to the atmosphere in order to remove mud, sand, and other impurities from the well. Sometimes this gas is burned in a flare. In recent years, operators are increasing their use of "green completions", in which the natural gas is captured rather than vented.

During the routine production phase, natural gas recovered from the well is piped to a gas processing plant for purification and distribution. Liquid hydrocarbons also flow out of the well. This "condensate" is separated from the gas stream and collected in a tank at the well head. The tank is periodically emptied into trucks and the condensate is transported to refineries. Dehydrators are also installed at the well head for removing water from the gas stream. Williams Fork wells have an expected lifetime of about 30 years.

THE RISK ASSESSMENT PROCESS

Conceptual model for pollutant migration and human exposure. A conceptual model is a useful starting point for studying human exposure to pollutants released into the environment. The conceptual model serves as a "roadmap" showing the routes by which a pollutant may come into contact with people. This roadmap becomes the basis for evaluating possible health threats and identifying ways to mitigate those threats.

The conceptual model breaks down the exposure process into a pollutant source, release mechanism, exposure medium, exposure route, and receptor.

- The *source* can be viewed as either a device (such as an internal combustion engine), a facility (such as an unlined pond for hydrocarbon-contaminated water), or a process (such as refueling) from which pollutants are released into the environment.

- A *release mechanism* is the specific manner in which the pollutant escapes. Exhaust gases are vented out of the engine; hydrocarbons evaporate from the pond, and hydrocarbon-contaminated water infiltrates into the soil below the unlined pond and possibly percolates all the way to ground water; fuel evaporates into the air during refueling and infiltrates into the ground if spills occur.

- The *exposure medium* is the environmental medium—air, surface water, ground water, or soil—that becomes polluted by the release and brings the pollutant into contact with people. The engine exhaust contaminates air; the hydrocarbons from the pond water contaminate air and possibly ground water; the hydrocarbons from refueling contaminate air and, if spilled, the surface soil.

- The *exposure route* describes how a person may take the pollutant into his or her body. Pollutants in air are inhaled; pollutants in drinking water are ingested; pollutants in soil are ingested in small amounts incidental to yard work or spending time outside on dusty days; certain pollutants in water or soil may be absorbed through the skin when the soil or water contacts the skin.

- A *receptor* is a person who makes contact with a pollutant through one or more of the exposure routes. Receptors can be residents, workers, or visitors either at the site where a release occurs or at nearby sites to which the pollutants migrate.

- *Secondary sources* may occur as a result of a primary source and release. For example, soil contaminated by a fuel spill becomes a secondary source of pollutant as the fuel hydrocarbons undergo a second release by evaporating from the soil into the air.

One can see that linking a source, release mechanism, exposure medium, exposure route, and receptor creates a roadmap by which a pollutant can travel from a particular source to a particular receptor. *Exposure* is actual contact of a pollutant with a receptor. If the journey between source and receptor is complete and exposure has occurred, we have an *actual*

exposure pathway. In many situations, the journey is not complete and there is only a *potential* exposure pathway. These potential pathways must be evaluated carefully to see if they have a significant likelihood of becoming complete and creating an exposure. One consideration is the properties of the pollutant of interest. Not all release mechanisms, exposure media, and exposure routes are relevant to each pollutant. For example, a pollutant with little or no tendency to evaporate will not occur as a gas in air, nor will a pollutant with little or no solubility in water occur at high concentrations in water.

A general conceptual model is shown in Figure 7 for natural gas operations in Garfield County. There is no single, correct way to construct such a model. The general model shown is intended to be a representative rather than exhaustive roadmap of actual and potential exposures to pollutants from natural gas operations.

Drilling and completion operations can be viewed as one source. Releases from drilling and completion include venting of natural gas from the well and exhaust gases from engines associated with the drill rig and support activities. The gases contaminate the on-site air and can migrate off-site. Both on-site and off-site receptors can be exposed.

Wellhead glycol dehydrators, condensate tanks, and condensate transfer operations may be viewed as another source. Hydrocarbons in dehydrators and condensate can evaporate and be vented to the atmosphere, where they can be inhaled by on-site or off-site receptors. Any hydrocarbon liquids that are leaked or spilled may evaporate as well. However, a portion of these liquids would likely infiltrate into the soil, then possibly percolate to the water table and contaminate ground water, which can migrate to neighboring properties where it may be captured by a well. If this contaminated ground water is used for drinking, the pollutants will be ingested. If the water is used for showering, the hydrocarbons may evaporate into the shower air and be inhaled. Absorption of pollutants through the skin may also take place during a shower, if any of the chemicals present have a significant ability to be absorbed that way.

Another source of interest may be open, unlined ponds for produced water. Hydrocarbons will evaporate from these ponds into the air, where they may be inhaled by on-site or off-site receptors. Hydrocarbons dissolved in water that infiltrates into the soil below the pond may undergo the same sequence of events as described above for hydrocarbon liquids that infiltrate into soil as a result of spills or leaks.

There is considerable interest in any threat posed by hydraulic fracturing fluids. These fluids have the potential to escape from the well into a surrounding aquifer if the well casings are breached. They also have potential to escape from the target formation through induced fractures, naturally-occurring fractures, or any other preferential flow paths that may occur in the subsurface. The resulting contaminated ground water has the potential to be used in the same manner as described above.

Some of these pathways are highly likely to be complete, if only on a transient basis. Inhalation of natural gas and of air pollutants from combustion engines is the best example. There is little question that pollutants have been emitted into the air; the question is how much pollutant is present at the location where a receptor breathes the air. Other pathways are less likely to be complete. The best example is the pathway for hydraulic fracturing fluids, which can require migration upward through the subsurface for thousands of feet, arriving in a shallow aquifer at a location in close proximity to a well used for drinking water. The details of pollutant transport through the pathways in the conceptual model are discussed in greater detail in later sections of this report.

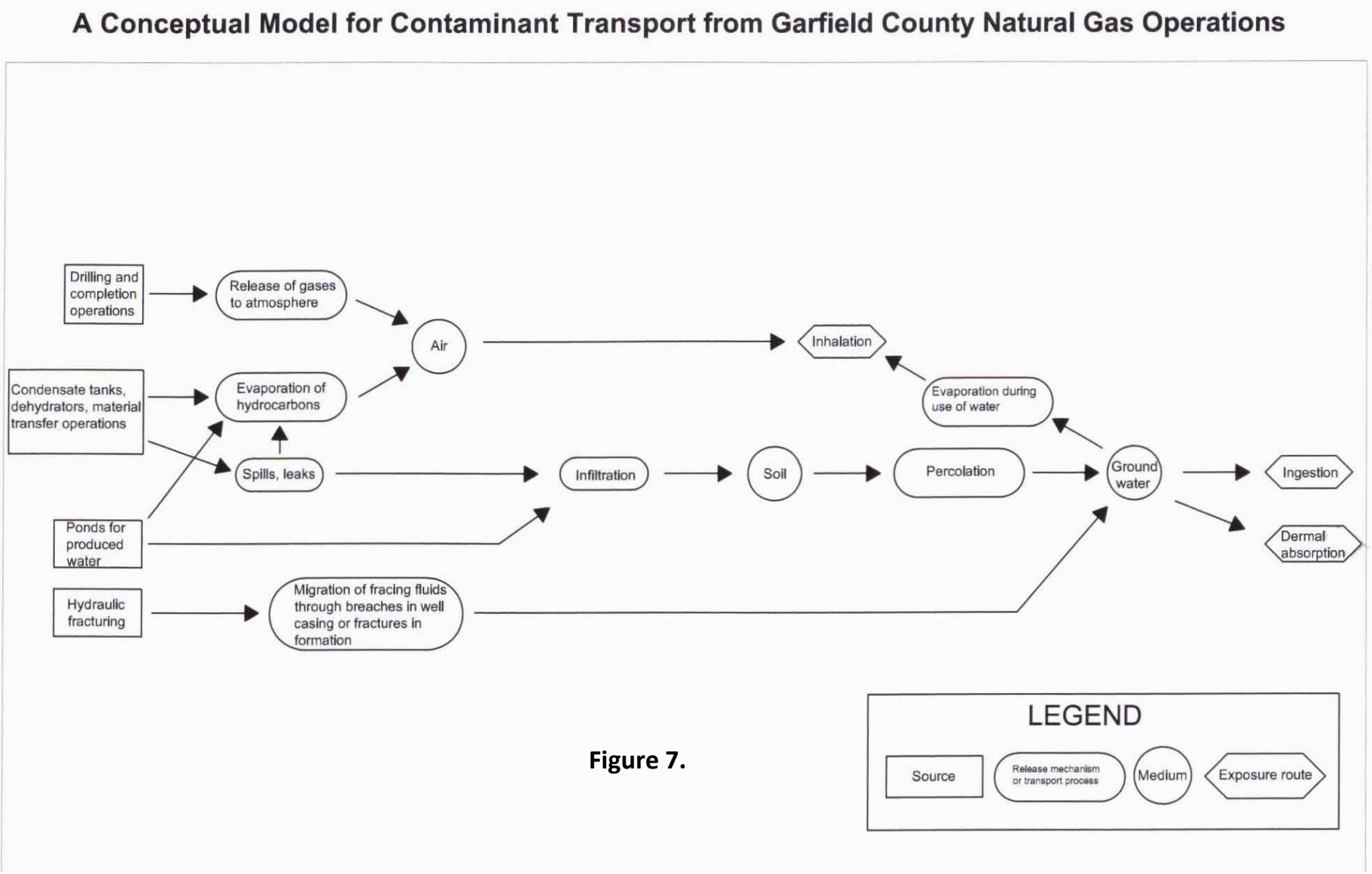

A Conceptual Model for Contaminant Transport from Garfield County Natural Gas Operations
Drilling and completion operations
Release of gases to atmosphere
Air
Inhalation
Condensate tanks, dehydrators, material transfer operations
Evaporation of hydrocarbons
Evaporation during use of water
Spills, leaks
Infiltration
Soil
Percolation
Ground water
Ingestion
Ponds for produced water
Dermal absorption
Hydraulic fracturing
Migration of fracing fluids through breaches in well casing or fractures in formation
LEGEND
Source
Release mechanism or transport process
Medium
Exposure route

Figure 7.

Risk assessment. The U.S. Environmental Protection Agency (EPA) developed a standard process for assessing risk to human health from pollutants in the environment. The process is described in Risk Assessment Guidance for Superfund, Volume 1. Human Health Evaluation Manual (Part A) published by the EPA in 1989. While tailored to sites being investigated and cleaned up under the Comprehensive Environmental Response, Compensation, and Liability Act (also known as "Superfund"), the basic principles and procedures of the guidance are applicable to any situation in which people are exposed to pollutants. The overall risk assessment process is divided into four steps—hazard identification, exposure assessment, toxicity assessment, and risk characterization.

Hazard Identification

The purpose of this step is to identify those pollutants that have the ability to cause harm to people, and single out for further consideration those pollutants that are likely to result in the most significant exposures. Toxicity is an obvious key property, but the mobility and persistence of a pollutant are factors as well. Pollutants whose physical and chemical properties make them more likely to migrate away from their source are considered to be more of a threat to off-site receptors. For example, a high water solubility or a strong tendency to evaporate make a pollutant more mobile. Less mobile pollutants can be more of a threat to on-site receptors because the pollutants can remain near their source in high concentrations. Persistence refers to how long a pollutant remains unchanged in the environment. Many pollutants have the ability to be biodegraded (broken down into simpler, usually less toxic substances by naturally-occurring bacteria), hydrolyzed (broken down by reaction with water), or photodegraded (broken down by exposure to light). These pollutants will be less of a threat because they are less persistent. Pollutant distribution is considered as well. If more than one pollutant is present, those that occur in the most samples and at the highest concentrations are given a higher priority. Those pollutants having the greatest toxicity, mobility, persistence, and distribution are carried forward for further study.

Exposure Assessment

Exposure assessment is the second step in risk assessment. The goal of this step is to quantify the exposure experienced by a receptor to each of the pollutants of concern. The outcome of exposure assessment is a number for pollutant intake expressed as milligrams of pollutant absorbed per kilogram of body weight per day. The equations used in exposure assessment are shown in Appendix A. Much of the essence of the equations is easy to understand.

- Intuition suggests that the more contaminated the exposure medium, the greater the health threat will be. The degree of contamination is expressed as concentration—the mass of a specific pollutant in a given amount of the medium. For example, pollutant concentration in air is typically expressed as micrograms of pollutant per cubic meter of air. In water, concentration is typically milligrams of pollutant per liter of water, and in soil, milligrams of pollutant per kilogram of soil.

- Intuition also suggests that the greater the contact rate with the polluted medium, the greater the threat will be. In other words, the greater the volume of contaminated air

inhaled, or the greater the volume of contaminated water consumed, the greater the threat will be.

- The entire amount of pollutant to which a person is exposed may not be absorbed into the body. For example, when we inhale, not all of the pollutant gas molecules drawn into our lungs will pass through lung cell membranes into the bloodstream. Some will, but others will exit the lungs during the next exhalation. The degree of actual absorption is difficult to know for any particular pollutant and any particular individual. It is customary to make the protective assumption that *all* of the pollutant contacting the receptor is absorbed. If such an assumption turns out to be wrong, then we will have erred on the side of being more protective rather than less.

- Intuition suggests that the longer the duration of exposure, the greater the health threat will be. Duration can be viewed as the number of days of exposure per year combined with the number of years that a person spends at the site where exposure takes place. In general, the protective assumption is made that the exposure occurs for 24 hours each day.

The body mass of the receptor plays a role. For example, imagine that a mouse is exposed to one milligram of a pollutant, and that this amount has a definite adverse effect. Exposing an elephant to only one milligram of the pollutant may well have no effect at all. The larger the body mass of the receptor, the less the pollutant intake is on a per kilogram of body mass basis.

Averaging time is the final factor. The averaging time depends on what type of health effect the pollutant of interest causes. For a non-cancer effect, the averaging time is taken to be the duration of the exposure. For cancer, the pollutant intake is averaged over a lifetime, which is generally taken to be 70 years. The basis for this approach is the assumption that a high intake received for a short time period has the same cancer effect as a low intake received for a long time period.

Toxicity assessment

This step in the risk assessment process brings into consideration the known or estimated toxicity of the pollutants. Toxicity is primarily determined by observing what effects occur when test animals (such as mice and rats) are exposed to a pollutant in a controlled laboratory setting. The use of animals rather than people is a fundamental limitation in toxicity testing because of possible differences between the response in humans compared with the response in a test species. However, when similar effects are observed across numerous test species and for exposure by both oral ingestion and inhalation, the relevance of these studies to humans becomes more convincing.

Toxicity tests are conducted by dividing the test animals into groups, with each group receiving a different exposure to the pollutant. At the end of a specific period of time (anywhere from four days to a lifetime), each animal is examined for adverse effects. Not every animal in a group will show an effect because individual response varies with a variety of factors, such as

age, sex, health status, genetics, prior exposures to that pollutant, and co-exposures to other toxic substances. We generally find that the percentage of animals in each group that experience an adverse effect is greater for greater exposures. A notable exception to this generalization occurs for pollutants that exhibit endocrine disrupting effects. These effects sometimes appear to occur at lower exposures but not at higher exposures.

Panels of toxicology experts are convened by the EPA to evaluate the results and reliability of laboratory toxicity studies. When available, information from epidemiological and clinical studies of humans is also considered. For non-cancer effects, the panels determine a "reference concentration" or "reference dose" for the pollutant. These reference values are a minimum daily exposure level that is highly unlikely to produce an adverse effect, not only in the general population but for sensitive sub-populations as well. Separate reference values are developed for acute (one to 14-day), intermediate (15- to 365-day), subchronic (2 weeks to 7 years), and chronic (7- to 70-year) exposures, and for exposures by oral ingestion and by inhalation. This approach reflects the experimental observation that non-cancer effects show a threshold exposure level—below that threshold, no adverse effects are observed, while above that threshold effects occur with increasing frequency as the exposure increases beyond the threshold. The smaller the reference concentration or reference dose, the more toxic the pollutant is.

Similar testing and evaluation is conducted for cancer as the adverse effect. However, a pollutant's cancer potency is expressed as a "slope factor" rather than a reference concentration or dose. The greater the slope factor, the greater the probability that a receptor will develop cancer for a given exposure. Inherent in the slope factor is a protective assumption by the EPA that exposure to *any* amount of a carcinogen will increase an individual's chance of developing cancer. In other words, unlike non-cancer effects, cancer is not considered to have a threshold exposure level below which no cancer will occur.

The EPA classifies chemicals according to their carcinogenicity using an approach based on "weight of evidence". If it is the opinion of expert toxicologists that epidemiologic studies of humans establish a cause and effect relationship between exposure to the chemical and the occurrence of cancer, the chemical is classified as a Category A human carcinogen. If the evidence from human studies is judged to be limited or inadequate, but there is sufficient evidence of carcinogenicity in animals, the chemical is classified as a Category B probable human carcinogen. Category C, possible human carcinogens, is for chemicals with even less evidence of carcinogenicity than Category B chemicals. Category D chemicals are unclassifiable due to inadequate study. Class E chemicals are those for which evidence suggests they are not carcinogenic.

The primary source of toxicity information for risk assessment is the EPA Integrated Risk Information System (IRIS). This extensive data base provides reference doses, reference concentrations, and slope factors for over 500 substances along with an explanation of how these quantities were determined. A discussion is also provided regarding the level of

confidence in the toxicity values and supporting studies. The complete IRIS data base can be accessed at www.epa.gov/iris.

Risk characterization

This is the final step in the risk assessment process, where toxicity assessment and exposure assessment are integrated into an expression of the degree of health threat.

To evaluate the threat from non-cancer effects, the intake determined in the exposure assessment is compared with the reference dose or reference concentration for the pollutant. The duration of the exposure is taken into account. For example, the intake from a chronic exposure is compared with a reference value derived from chronic exposure studies. The reference value is considered to be safe by a wide margin, so that if the intake is less than the reference value, it is highly unlikely that even a sensitive subpopulation will experience adverse health effects. Intakes that exceed the reference values are considered to be unacceptable and usually trigger actions that will reduce the exposure. An alternate way of making the comparison is to divide the intake by the reference value to obtain a "hazard quotient". A hazard quotient greater than one corresponds to an unacceptable exposure, based on the possible occurrence of non-cancer health effects.

To evaluate the threat of cancer, we perform a calculation to determine cancer risk for an individual experiencing the exposure of concern. The equation for this calculation is shown in Appendix A. Cancer risk is often expressed as a probability, such as "a 1 in 10,000 chance of developing cancer from this exposure". This probability statement can be interpreted in two ways—as the chance that an individual experiencing the exposure will develop cancer from this exposure, or that one person out of every 10,000 people experiencing this exposure will develop cancer from this specific exposure. The risk obtained from this procedure is considered to be an "upper bound estimate"; in other words, the true risk is likely to be less than the calculated value. The EPA uses a cancer risk of 1 in 1,000,000 (one in one million) as a regulatory goal, meaning that regulatory programs are generally designed to try to reduce risk to this level. When it is not feasible to meet this regulatory goal, the EPA considers cancer risks lower than 1 in 10,000 to be acceptable.

It is important to note that cancer occurs at a poorly characterized "background level" due to natural causes beyond our control. Ionizing radiation is one such cause; we are constantly exposed to a low level of radiation from the earth's crust and outer space. Naturally occurring chemical carcinogens (such as certain polynuclear aromatic hydrocarbons, which can occur in soot from natural fires) are another cause. Random mutations in DNA are also a factor. The cancer risk calculated in a risk assessment is an additional risk on top of the background risk.

It is often the case that a receptor is exposed to more than one pollutant at the same time. As a first approximation of the threat from a combined exposure, the hazard quotients calculated for non-cancer effects are added together to obtain a "hazard index", which is interpreted in the same manner as a hazard quotient—an index greater than one is considered unacceptable. Similarly, the total cancer risk from multiple carcinogenic pollutants is obtained by adding the

risks calculated for the individual pollutants, with total risk values greater than 1 in 10,000 considered to be unacceptable. A more refined approach to multiple pollutants is to segregate the pollutants according to their major effect, summing only those pollutants with similar effects. This approach requires advanced knowledge of toxicology and must be done with care so as to avoid underestimating health threat.

A report on the results of a risk assessment must always include a discussion of the uncertainties inherent in the results, of which there can be many. Among these uncertainties are the degree to which actual exposure parameters (pollutant concentration, contact with polluted media, duration of exposure, body mass of receptor) match those used in the risk calculations and uncertainties caused by the limitations of toxicity testing.

The *Garfield County Air Toxics Inhalation Screening Level Human Health Risk Assessment* (available at http://www.garfield-county.com/index.aspx?page=1098) demonstrates the applicability of this risk assessment process to natural gas operations in Garfield County. This study, conducted by the Disease Control and Environmental Epidemiology Division of the Colorado Department of Public Health and Environment, focuses on data collected in the *Garfield County Ambient Air Quality Monitoring Report* (available at the same site).

The present study complements the *Garfield County Air Toxics* study. Rather than relying solely on monitoring data that presents only a partial picture of air quality, this study uses pollutant transport modeling as a way of augmenting our understanding of possible human exposures to hydrocarbons in air from natural gas operations. Risk calculations are then based on the results of modeling rather than on actual air monitoring data. The present study also includes a qualitative examination of possible threats from pollutants in water and soil.

HEALTH EFFECTS OF SELECTED HYDROCARBONS

Benzene, toluene, and *m,p*-xylenes are hydrocarbons that are prominent environmental pollutants associated with natural gas operations. Their health effects are summarized below based on information shown in IRIS.

Benzene. Benzene is considered to be a known human carcinogen (Category A in the weight-of-evidence system) both by oral ingestion and inhalation based on reliable human evidence as well as supporting animal studies. There is clear causation between exposure to benzene and the occurrence of leukemia. Hematologic neoplasms, aplastic anemia, and Hodgkin's lymphoma are other cancer-related effects associated with benzene. An increased risk of oral and nasal cancer as well as liver, stomach, lung, ovary, and mammary gland cancer is associated with benzene through animal studies. The non-cancer effects of benzene include neurotoxicity and depression of bone marrow function, resulting in blood disorders (decreased counts of specific blood cells, such as erythrocytes, leukocytes, and thrombocytes) and impairment of the immune system.

Toluene. The available study results for toluene are inadequate to determine the ability of toluene to cause cancer (Category D in the weight-of-evidence system). Non-cancer effects observed in human studies include many of a neurological nature, such as impaired color vision, impaired hearing, changes in nerve conduction, headache, dizziness and possible respiratory irritation.

m,p-Xylenes. There are no adequate human data on the carcinogenicity of *m,p*-xylenes and animal studies are inconclusive (Category D in the weight-of-evidence system). Non-cancer effects include mild neurological impairment (such as reduced motor coordination) based on human and animal studies, and possible developmental effects in animals (such as cleft palate, observed in mouse studies.)

AIR POLLUTION EFFECTS

Air pollutant transport. Of the three exposure pathways—air, water, and soil—air is likely to be the most significant pathway related to natural gas operations in Garfield County. In general, people experience relatively little contact with soil outside of their own property, hence their exposure to soil is limited. Many people do not consume a great deal of water from their home tap, and thus have a limited exposure to ground water. However, everyone breathes the air and has considerable opportunity to be exposed to air pollutants.

Whether a specific pollutant contributes to the air pathway when released into the environment depends on the pollutant's tendency to evaporate. Substances that are gases at normal temperatures and pressures (i.e., ambient conditions) will be found in the air when released to the environment. The lighter hydrocarbons, such as methane, ethane, and propane behave in this manner. Substances that are liquids at ambient conditions may also occur in the air. If the liquid has a low boiling temperature and high vapor pressure, at least a portion of that liquid readily evaporates into the atmosphere. Hydrocarbons that are somewhat heavier, such as benzene, toluene, and *m,p*-xylenes are good examples of liquids that readily evaporate. The chemicals known as "volatile organic compounds (VOCs)" have a strong tendency to evaporate and we expect them to occur as air pollutants. This holds true regardless of whether the VOCs are released into the environment as hydrocarbon liquids or dissolved in water.

Once a pollutant enters the atmosphere, it does not remain at the release location for long. If there is any wind, the pollutant is carried with the wind in a process called advection. As the pollutant moves downwind, the turbulent motion of the wind disperses the pollutant from side to side (perpendicular to the wind direction) and up and down. The region of contaminated air (the "plume") takes on the approximate shape of a cone, with the point of the cone at the location of the release. At any given distance from the release location, the highest concentration of pollutant is on the centerline of the cone. The concentration along the centerline decreases with increasing distance from the release location. Higher wind speeds

spread the pollutant over a larger volume of air, resulting in smaller pollutant concentrations than would be observed for lower wind speeds.

This description of air pollutant transport is an idealized picture. Real conditions result in a more complex shape for the contaminated region of air, and a more complex pattern of pollutant concentrations within that shape. Variability in wind direction results in dispersal of the pollutant over a greater volume of air. The presence of hills, valleys, trees, and buildings influences both the horizontal and vertical movement of air and air pollutants. Atmospheric conditions are an important factor as well. When temperature inversions occur, pollutants are trapped in a distinct layer of air whose thickness is typically anywhere from a few tens of feet to hundreds of feet. The development of the cone-shaped region of contaminated air is limited when the upper edge of the cone reaches the top of the inversion layer of air.

Air pollutant concentrations determined by sampling and analysis. As described in the preceding section on risk assessment, the magnitude of the health threat posed by a pollutant depends on the concentration of the pollutant that a person is exposed to. The best way to obtain pollutant concentrations for risk assessment is to collect and analyze samples that are representative of the range of concentrations and conditions that occur while an exposure is taking place. In the absence of such samples, mathematical models of pollutant transport can be used to predict pollutant concentrations that occur for specific conditions. Modeling is the primary approach used in the present study.

The Garfield County Ambient Air Quality Monitoring Study, June 2005–May 2007 focused on particulate matter less than 10 microns in diameter (PM_{10}) and VOCs. Measurements of PM_{10} occurred every three days for two years at seven sites in Garfield County, including urban areas, rural areas, and both urban and rural areas close to natural gas operations. A summary of the results is shown below (Table 3). Average PM_{10} concentrations found at each location ranged from 9.2 to 27.0 micrograms per cubic meter. The maximum concentrations found at each location ranged from 28 to 92 micrograms per cubic meter.

Table 3. Summary of PM_{10} Monitoring Results

Site	Overall Arithmetic Average ($\mu g/m^3$)	Overall 24-Hour Maximum ($\mu g/m^3$)	Possible Number of Sample Days	Number of Samples Recovered	Percent Data Recovery (%)
Glenwood-Courthouse	14.4	36	243	235	97%
New Castle-Library	22.8	92	243	238	98%
Silt-Bell	10.7	34	243	237	98%
Silt-Daley	9.2	28	243	231	95%
Silt-Cox	13.6	62	243	223	92%
Rifle-Henry Bldg.	27.9	72	243	240	99%
Parachute	27.9	76	243	234	96%

From Garfield County Ambient Air Quality Monitoring Study, June 2005 – May 2007.

Samples of air for analysis of VOCs were collected over a 24-hour period on 232 occasions over the course of the Ambient Air Quality Monitoring Study from the same sampling locations used for PM_{10}. An additional twenty-seven "grab samples" were collected over a 15-second period from seven additional rural sites close to natural gas operations on occasions when odors were reported by the public. Two additional grab samples were collected in the immediate vicinity of a condensate tank as condensate was being transferred from the well pad tank to a tank truck. Of the forty-three VOCs covered by the EPA-approved methods used for analysis, fifteen were detected in at least one sample. Only six of these VOCs were detected in more than 20% of the total number of samples: acetone, vinyl acetate, 2-butanone (MEK), benzene, toluene, and *m*,*p*-xylenes. A summary of the results is shown in Table 4.

Of the VOCs shown in Table 4, benzene, toluene, and *m,p*-xylenes are expected to have the strongest association with natural gas. They are known to occur in unpurified natural gas, albeit in concentrations well under 1%. Their association with natural gas is supported by the high frequency of occurrence (93%) observed for the complaint-driven grab samples for each of these three VOCs, as well as the high concentrations found in samples of condensate vapors.

It is difficult to obtain air samples that are representative of benzene, toluene, and *m,p*-xylenes at locations of interest, such as a property line or residence near a natural gas well. The difficulty lies in the inherent variability of pollutant concentrations at the location of interest because of variations over time in emissions from the well along with variations in meteorological factors that affect pollutant transport through the air.

During the life of a well, emissions of natural gas components into the air are highly variable. Few, if any, emissions occur from the borehole until it is extended into natural gas-producing zones. Then, during a period of well conditioning called "flow back", natural gas may be vented from the well into the air. Once the well goes into its routine production phase, the natural gas is piped to a local facility for processing and injection into regional and transcontinental pipelines. However, a fraction of the heavier, non-methane gases emerging from the well are captured at the well head as "condensate" and diverted to an on-site storage tank. About 10% of condensate is benzene, toluene, and *m,p*-xylenes, and thus condensate tank emissions are a source of these compounds in air.

Table 4. Summary Statistics for Detected VOCs

Detected compounds		**Overall 24-Hr Samples (232 samples, 14 sites)**				**Overall Grab Samples (27 samples)**			
CAS #	Compound	**Avg µg/m³**	**Max µg/m³**	**Min µg/m³**	**% Detects**	**Avg µg/m³**	**Max µg/m³**	**Min µg/m³**	**% Detects**
74-87-3	Chloromethane				0.0%	1.5	15.0	0.7	3.7%
67-64-1	Acetone	18.5	80.0	3.6	81.9%	26.0	81.0	3.7	77.8%
75-69-4	Trichlorofluoromethane	1.0	26.0	0.7	0.4%	1.5	15.0	0.7	7.4%
75-09-2	Methylene chloride	1.0	8.4	0.7	1.7%				0.0%
108-05-4	Vinyl Acetate	2.1	15.0	0.7	23.3%	2.5	15.0	0.7	14.8%
78-93-3	2-Butanone (MEK)	2.2	12.0	0.7	55.2%	3.0	15.0	0.8	70.4%
67-66-3	Chloroform				0.0%	1.5	15.0	0.7	3.7%
71-43-2	Benzene	2.2	49.0	0.8	39.2%	28.2	180.0	0.8	92.6%
79-01-6	Trichloroethene	0.9	2.7	0.7	0.4%				0.0%
108-88-3	Toluene	7.4	130.0	0.8	89.7%	91.4	540.0	0.8	92.6%
591-78-6	2-Hexanone	1.0	4.4	0.7	3.0%	1.7	15.0	0.7	14.8%
127-18-4	Tetrachloroethene	0.9	2.3	0.7	0.9%				0.0%
100-41-4	Ethylbenzene	1.0	3.4	0.7	3.4%	8.3	96.0	0.8	63.0%
136777-61-2	*m,p*-Xylenes	3.9	24.0	0.8	64.2%	106.6	1500.0	0.8	92.6%
100-42-5	Styrene	0.9	6.0	0.7	0.9%				0.0%
95-47-6	o-Xylene	1.1	4.3	0.7	10.3%	18.1	260.0	0.8	81.5%
106-46-7	1,4-Dichlorobenzene	1.1	12.0	0.7	3.4%				0.0%

Detected compounds		**Condensate Load-out Grabs (2 samples)**		
CAS #	Compound	**Vent Outlet µg/m³**	**50' distance µg/m³**	**% Detects**
71-43-2	Benzene	590000	360	100.0%
108-88-3	Toluene	770000	480	100.0%
100-41-4	Ethylbenzene	37000	29	100.0%
136777-61-2	*m,p*-Xylenes	250000	200	100.0%
95-47-6	o-Xylene	49000	43	100.0%

NOTE: 1/2 of the Minimum Reporting Level was substituted for non-detect values for statistical calculations.
From Garfield County Ambient Air Quality Monitoring Study, June 2005 – May 2007, November 2007.

Meteorological conditions also change with time. Wind speed undergoes considerable variation, with greater speeds dispersing pollutants more effectively than lesser speeds, leading to lower concentrations at the location of interest. Wind direction at most sites varies through all the compass directions, so that pollutants are transported toward the location of interest only part of the time. Nighttime temperature inversions and multi-day winter inversions trap pollutants in a relatively thin layer of stable air from the land surface upward, with the top of the inversion layer just a few tens of feet above the surface early in the evening (leading to high pollutant concentrations) but rising to several hundred feet before sunrise (leading to lower pollutant concentrations, providing the inversion does not persist for an extended period of time). In contrast, on a clear, sunny afternoon in mid-summer, pollutants may be dispersed by convection currents throughout a larger volume of air, from the ground to elevations of several thousand feet (creating lower pollutant concentrations). Given the complexity and variability of real conditions, air at a location of interest would need to be characterized at least hourly for a year or more to develop an accurate knowledge of the range and distribution of pollutant concentrations.

Samples collected over a 24-hour period provide a "snapshot" of the average concentration for that time period; samples collected over just a 15-second period provide more of a "snapshot" of transient conditions. Unless samples are collected continuously (e.g., a 24-hour sample every day), neither sampling approach provides a reliable indication of concentrations over longer periods. As discussed in Section 1, we are interested in concentrations representative of longer periods in order to evaluate the degree of health threat from exposure to a pollutant.

The variability in emissions, wind speed, and air stability along with the relatively small number of samples collected at natural gas-affected locations during the Garfield County Ambient Air Quality Monitoring Study suggests that we cannot draw conclusions about natural-gas related pollutant concentrations with the desired degree of confidence. Do the results of the study reflect high-end pollutant concentrations? Or averages? Or conditions somewhere else on the spectrum between maximum and minimum concentrations? Without knowing, we are handicapped in our ability to make a reliable assessment of the degree of health threat experienced by Garfield County residents. However, we can use mathematical modeling to estimate or predict pollutant concentrations and, in effect, generate "missing" data, giving us a better idea of the range and distribution of concentrations. That said, one must bear in mind that mathematical models have limitations. Modeling inevitably requires that a number of simplifying assumptions be made in order to make the calculations feasible. These assumptions do limit the ability of the model to accurately reflect real conditions, but as long as the limitations of modeling are understood and taken into account when interpreting the results, modeling can provide a useful "ball park" level of accuracy that helps to illuminate the degree of threat and provides guidance to decision-makers.

Air pollutant concentrations determined by modeling. The Gaussian plume model is the simplest approach to predicting pollutant transport from a single, well-defined "point source" of air pollutant emissions (such as a well or condensate tank). A Gaussian plume is the qualitative picture described earlier—the cone-shaped region of contaminated air extending

downwind from the pollutant release point. The result of Gaussian plume modeling is an estimate of pollutant concentration at any specific location of interest downwind of the pollutant source. The model is based on user-specified values for pollutant emission rate, position of the location of interest relative to the source, wind speed, and atmospheric stability (*Air Pollution Modeling*, Paolo Zannetti, Van Nostrand Reinhold, 1990). The mathematical equations used in this model are shown in Appendix B.

The Gaussian plume model was used to estimate concentrations of benzene, toluene, and *m,p*-xylenes in air for meteorological conditions characteristic of Garfield County.

Wind speeds were based on data collected during the Garfield County Ambient Air Quality Monitoring Study for five sites: Silt-Bell, Silt-Cox, Silt-Daley, Parachute, and Newcastle Library. Data from all five sites were combined to generate an average proportion of time over the course of a typical year that each wind speed range occurred, with separate averages for day and night (Appendix C).

The wind direction data from the Ambient Air Quality Monitoring Study were examined to determine the maximum proportion of time in which the wind blew in any given direction (Appendix D).

- One of the factors that determines air stability is insolation – the intensity of sunlight. Assuming a clear sky, strong insolation occurs when the angle between the horizon and the sun is greater than sixty degrees; moderate insolation occurs for angles between thirty-five and sixty degrees; and weak insolation occurs for angles between fifteen and thirty-five degrees. Sun angle tables were consulted to determine the proportion of the year in which the sun was in each of these three angle ranges (Appendix E).

  Air stability is also determined by the degree of cloudiness. No cloud cover information was available for Garfield County. The best available information was a month-by-month breakdown of the average number of days classified as clear, partly cloudy, and cloudy developed by the National Weather Service for Grand Junction. These data were converted to the proportion of a year in each cloud cover category (Appendix F).

- The Gaussian plume model requires that meteorological conditions be characterized as falling into one of six air stability classes. The information on wind speed, insolation, and cloudiness described above was combined so as to determine the proportion of time during a typical year that could be classified as falling into each of these six stability classes (Appendix G).

  Generic pollutant concentrations were calculated for each stability class for distances ranging from 25 meters to 4,800 meters directly downwind of the source for a convenient, arbitrary emission rate of 1 gram per second. The concentration results for each stability class were combined into a single set of results by weighting each class according to the proportion of a typical year in which that stability class occurs

(Appendix H). The result was a set of concentrations for various distances downwind from the pollutant source. These generic concentrations, which are characteristic of meteorological conditions over a typical year, were used as the basis for calculating specific concentrations for each of the pollutants and emission scenarios described below.

Five specific emission scenarios were examined using the Gaussian plume model:

- "Flow back" is a stage in the conditioning of a new natural gas well prior to production. In the traditional flow back process, gas is allowed to vent from the well to the atmosphere for as long as thirty days. Typical gas emission rates and composition were used to calculate representative emission rates specifically for benzene (0.07 grams per second), toluene (0.07 grams per second), and *m,p*-xylenes (0.07 grams per second) (Appendix Ia).

- In recent years, more companies are turning to "green completions," in which the natural gas vented during flow back is captured and processed for sale. A typical capture rate and gas composition were used to calculate representative emission rates under this scenario for benzene (0.0049 grams per second), toluene (0.0049 grams per second), and *m,p*-xylenes (0.0049 grams per second) (Appendix Ia).

- Glycol dehydration units are used at the wellhead during routine production to remove water from the gas stream before injecting it into a pipeline for transport to a local processing facility. A typical emission rate and composition for dehydration emissions was used to calculate representative emission rates for benzene (0.0036 grams per second), toluene (0.01 grams per second), and *m,p*-xylenes (0.01 grams per second) (Appendix Ib).

- During routine production, heavier hydrocarbons are captured at the wellhead and separated from the gas stream as "condensate." The condensates are stored at the wellhead in condensate tanks, from which they are periodically collected and transported to refineries. Emissions from condensate tanks vary with the rate at which condensate is produced by the well, which varies from one well to another as well as during the lifetime of the well. In Weld County, Colorado, condensate tank emissions are limited to 20 tons per year of total volatile organic hydrocarbons (VOCs) as part of the effort to reduce the formation of ozone in Front Range air. As a point of reference, this emission rate was used along with typical condensate emission composition to calculate representative emission rates for benzene (0.0081 grams per second), toluene (0.0415 grams per second), and *m,p*-xylenes (0.0415 grams per second) (Appendix Ic).

- Condensate tanks can be outfitted with combustors to destroy VOC emissions. These combustors can typically operate with a destruction efficiency of 98%, leading to lower emission rates for benzene (0.00016 grams per second), toluene (0.00083 grams per second), and *m,p*-xylenes (0.00083 grams per second) (Appendix Ic)

The Gaussian plume model was used to calculate air concentrations for benzene, toluene, and *m,p*-xylenes at multiple distances ranging from 25 meters (82 feet) to 4,800 meters (approximately 3 miles) for each of the five emission scenarios. The results of the model calculations are shown in Tables 5A – 5C.

Of the five scenarios, flow back with no gas recovery produces the highest concentrations of each of these pollutants. In this emission scenario, benzene concentrations ranged from 358 micrograms per cubic meter at a location 25 meters downwind of the source to 0.1 micrograms per cubic meter at a distance 4,800 meters downwind. Benzene concentrations reported for actual air samples in the Garfield County Ambient Air Quality Monitoring Study had a maximum of 49 micrograms per cubic meter for 24-hour samples and 180 micrograms per cubic meter for 15-second grab samples. These concentrations predicted by the model are similar to the range of concentrations found through sampling and analysis.

In this same emission scenario, toluene and *m,p*-xylenes were calculated to range from 215 micrograms per cubic meter at a location 25 meters downwind to 0.1 micrograms per cubic meter at a location 4,800 meters downwind. Toluene concentrations reported in actual air samples collected for the Ambient Air Quality Monitoring Study were as high as 130 micrograms per cubic meter in the 24-hour samples and 540 micrograms per cubic meter in the 15-second samples, although the concentrations averaged only 7.4 and 91 micrograms per cubic meter, respectively. It is noteworthy that the 15-second maximum value exceeds the maximum calculated using the model. *m,p*-Xylenes concentrations were as high as 24 micrograms per cubic meter in the 24-hour samples and 1,500 micrograms per cubic meter in the 15-second samples, with averages of 3.9 and 107 micrograms per cubic meter, respectively. Again, the maximum 15-second value exceeds the range calculated using the model.

For any specific location, time, and conditions, actual concentrations may vary from those predicted by the model for several reasons. The model is based on wind speeds, wind directions, cloudiness, sun angles, and atmospheric stability averaged over the course of a specific year. However, conditions at any specific time can be considerably different than the average. For example, pollutant concentrations in air can be especially high in early evening as a nighttime inversion begins to develop. Emissions are trapped in a layer of air that, for a limited period of time, may be no thicker than a few tens of meters above the land surface, confining the pollutants to a smaller volume of air leading to high concentrations. Topography in the form of hills and valleys can sometimes channel air flow and alter pollutant dispersion.

Table 5A. Benzene Concentrations in Air Resulting from Selected Natural Gas Development Operations

(Concentrations in micrograms per cubic meter)

Downwind distance (meters)	Flow back, no recovery	Flow back, 93% recovery	Wellhead glycol dehydration	Condensate emissions at 20 tons per year total VOCs	Condensate emissions with 98% removal of 20 tons per year total VOCs
25	214.5	15.0	11.0	24.8	0.5
50	96.5	6.8	5.0	11.2	0.2
75	58.5	4.1	3.0	6.8	0.1
100	39.4	2.8	2.0	4.6	0.1
125	28.3	2.0	1.5	3.3	0.1
150	21.5	1.5	1.1	2.5	0.0
175	16.9	1.2	0.9	2.0	0.0
200	13.7	1.0	0.7	1.6	0.0
250	9.6	0.7	0.5	1.1	0.0
300	7.2	0.5	0.4	0.8	0.0
350	5.6	0.4	0.3	0.6	0.0
400	4.4	0.3	0.2	0.5	0.0
500	3.1	0.2	0.2	0.4	0.0
600	2.3	0.2	0.1	0.3	0.0
700	1.7	0.1	0.1	0.2	0.0
800	1.4	0.1	0.1	0.2	0.0
900	1.1	0.1	0.1	0.1	0.0
1000	1.0	0.1	0.0	0.1	0.0
1100	0.8	0.1	0.0	0.1	0.0
1200	0.7	0.0	0.0	0.1	0.0
1300	0.6	0.0	0.0	0.1	0.0
1400	0.6	0.0	0.0	0.1	0.0
1500	0.5	0.0	0.0	0.1	0.0
1600	0.4	0.0	0.0	0.1	0.0
3200	0.2	0.0	0.0	0.0	0.0
4800	0.1	0.0	0.0	0.0	0.0

Table 5B. Toluene Concentrations in Air Resulting from Selected Natural Gas Development Operations

(Concentrations in micrograms per cubic meter)

Downwind distance (meters)	Flow back, no recovery	Flow back, 93% recovery	Wellhead glycol dehydration	Condensate emissions at 20 tons per year total VOCs	Condensate emissions with 98% removal of 20 tons per year total VOCs
25	214.5	15.0	30.6	127.2	2.5
50	96.5	6.8	13.8	57.2	1.1
75	58.5	4.1	8.4	34.7	0.7
100	39.4	2.8	5.6	23.3	0.5
125	28.3	2.0	4.0	16.8	0.3
150	21.5	1.5	3.1	12.7	0.3
175	16.9	1.2	2.4	10.0	0.2
200	13.7	1.0	2.0	8.1	0.2
250	9.6	0.7	1.4	5.7	0.1
300	7.2	0.5	1.0	4.2	0.1
350	5.6	0.4	0.8	3.3	0.1
400	4.4	0.3	0.6	2.6	0.1
500	3.1	0.2	0.4	1.8	0.0
600	2.3	0.2	0.3	1.3	0.0
700	1.7	0.1	0.2	1.0	0.0
800	1.4	0.1	0.2	0.8	0.0
900	1.1	0.1	0.2	0.7	0.0
1000	1.0	0.1	0.1	0.6	0.0
1100	0.8	0.1	0.1	0.5	0.0
1200	0.7	0.0	0.1	0.4	0.0
1300	0.6	0.0	0.1	0.4	0.0
1400	0.6	0.0	0.1	0.3	0.0
1500	0.5	0.0	0.1	0.3	0.0
1600	0.4	0.0	0.1	0.3	0.0
3200	0.2	0.0	0.0	0.1	0.0
4800	0.1	0.0	0.0	0.1	0.0

Table 5C. *m,p*- Xylenes Concentrations in Air Resulting from Selected Natural Gas Development Operations

(Concentrations in micrograms per cubic meter)

Downwind distance (meters)	Flow back, no recovery	Flow back, 93% recovery	Wellhead glycol dehydration	Condensate emissions at 20 tons per year total VOCs	Condensate emissions with 98% removal of 20 tons per year total VOCs
25	214.5	15.0	30.6	127.2	2.5
50	96.5	6.8	13.8	57.2	1.1
75	58.5	4.1	8.4	34.7	0.7
100	39.4	2.8	5.6	23.3	0.5
125	28.3	2.0	4.0	16.8	0.3
150	21.5	1.5	3.1	12.7	0.3
175	16.9	1.2	2.4	10.0	0.2
200	13.7	1.0	2.0	8.1	0.2
250	9.6	0.7	1.4	5.7	0.1
300	7.2	0.5	1.0	4.2	0.1
350	5.6	0.4	0.8	3.3	0.1
400	4.4	0.3	0.6	2.6	0.1
500	3.1	0.2	0.4	1.8	0.0
600	2.3	0.2	0.3	1.3	0.0
700	1.7	0.1	0.2	1.0	0.0
800	1.4	0.1	0.2	0.8	0.0
900	1.1	0.1	0.2	0.7	0.0
1000	1.0	0.1	0.1	0.6	0.0
1100	0.8	0.1	0.1	0.5	0.0
1200	0.7	0.0	0.1	0.4	0.0
1300	0.6	0.0	0.1	0.4	0.0
1400	0.6	0.0	0.1	0.3	0.0
1500	0.5	0.0	0.1	0.3	0.0
1600	0.4	0.0	0.1	0.3	0.0
3200	0.2	0.0	0.0	0.1	0.0
4800	0.1	0.0	0.0	0.1	0.0

Exposure scenarios. Three standard exposure scenarios for non-cancer effects were considered: acute exposures lasting from one to fourteen days; intermediate exposures lasting from fifteen to 364 days; and chronic exposures lasting from seven years to a lifetime. Three exposure scenarios tailored to natural gas operations in Garfield County were used in the evaluation of cancer risk:

Lifetime exposure (seventy years) to on-going natural gas development—A person lives for seventy years in one or more locations where he or she is always downwind of natural gas operations. Because on-going development of new wells appears to be unlikely for such an extended time in Garfield County, this is unlikely to occur for exposures due to flow back. However, this scenario may be more realistic for exposure to condensate tank emissions and glycol dehydration unit emissions, which may continue as long as the well is in production. The lifetime exposure scenario will result in the greatest cancer risk and is included primarily as a possible worst case.

Two-year exposure to natural gas development—A person lives for two years in a location downwind of natural gas operations. This scenario includes situations in which multiple well pads are developed in proximity to this person, with the total duration of development being two years.

One-year exposure to natural gas development—A person lives for one year in a location downwind of a well pad that is developed over the course of that year.

The *Draft Garfield County Air Toxics Inhalation Screening Level Human Health Risk Assessment* identified two sites, Cox and Daley, as representative of rural "background" locations representative of areas unaffected by natural gas operations. The exposure point concentrations for benzene identified in Table A7 of that study are 1.9 micrograms per cubic meter for the Cox site and 0 for the Daley site. An average of 1.0 micrograms per cubic meter was thus used as a background concentration applicable to all three of the above exposure scenarios for cancer risk. In addition to the seventy-year, two-year, and one-year exposure to benzene from natural gas operations, a seventy-year exposure to the background concentration of benzene was included.

Each of these three exposure scenarios also includes a lifetime exposure to background concentrations of benzene in air reported for rural areas in the Garfield County Ambient Air Quality Monitoring Study.

Threat of non-cancer effects from air pollutants. The threat of non-cancer effects from PM_{10} is below any level of concern. The EPA has established a National Ambient Air Quality Standard for twenty-four hour average concentrations of PM_{10} that is protective of not only the general population but sensitive subpopulations as well. As discussed in Section 2.2 of the *Garfield County Ambient Air Quality Monitoring Study*, there were no exceedances of this standard.

The threat of non-cancer effects from exposure to benzene, toluene, and *m,p*-xylenes was evaluated using the risk assessment procedure described in Section 1. Pollutant concentrations were generated using the Gaussian plume model, as described above. Exposures to benzene, toluene, and *m,p*-xylenes may produce non-cancer health effects if the exposures are high enough. "Reference concentrations" are pollutant concentrations in air that represent thresholds below which health effects are not expected to occur. Reference concentrations have been developed for acute exposures (one to fourteen days), intermediate exposures (fifteen to 364 days), and chronic exposures (seven years to a lifetime). Table 6 shows reference concentrations used in this study.

Table 6. Reference Concentrations (in micrograms per cubic meter)

	Acute	Intermediate	Chronic
Benzene	30	20	30
Toluene	3,766	none available	5,000
m,p-xylenes	9,000	3,037	100

From Draft Garfield County Air Toxics Inhalation Screening Level Human Health Risk Assessment, December 2007.

Tables 7A–E show the following situations in which one or more reference concentrations are exceeded:

- For flow back with no gas recovery, the acute reference concentration for benzene is exceeded for distances up to 125 meters downwind.
- For flow back with no gas recovery, the intermediate reference concentration for benzene is exceeded for distances up to 150 meters downwind.
- For flow back with no gas recovery, the chronic reference concentration for benzene is exceeded for distances up to 125 meters downwind.
- For flow back with no gas recovery, the chronic reference concentration for *m,p*-xylenes is exceeded for distances up to twenty-five meters downwind
- For emissions of VOCs at twenty tons per year from condensate tanks, the chronic reference concentration for *m,p*-xylenes is exceeded for distances up to twenty-five meters downwind.

Flow back with no gas recovery is the only operation that exceeds reference concentrations at distances beyond twenty-five meters. Of the three pollutants whose emissions were modeled, benzene is the only one that exceeds reference concentrations at distances beyond twenty-five meters. These results suggest that emission of benzene during uncontrolled flow back is the situation that presents the greatest threat of non-cancer effects. These effects may occur in

people who spend one day or more within a distance 125 meters downwind of the natural gas well.

The threat of non-cancer effects was also examined in the *Garfield County Air Toxics Inhalation Screening Level Human Health Risk Assessment*. That study was based on pollutant concentrations generated by sampling and analysis using a reasonable estimate of the concentration likely to be contacted over time (i.e., the 95% upper confidence level on the arithmetic mean). One of the fourteen sites evaluated (Brock) exceeded the acute reference concentration for benzene. That site and one other (Newcastle Library) had an excessive level of intermediate exposure, mostly due to benzene.

Cancer risk from air pollutants. Of the three pollutants that are the focus of this study, benzene is the only carcinogen. According to the U.S. Environmental Protection Agency (EPA) Integrated Risk Information System, benzene has a slope factor that ranges from 0.000077 up to 0.00027 per microgram per kilogram per day. The higher of the two slope factors was used in this study.

Tables 5A–E show the benzene cancer risks for each of the above exposure scenarios applied to each of the five emission scenarios. The EPA advocates as a goal that cancer risk for a specific exposure be no more than 1 chance in 1 million. However, the EPA further specifies that cancer risk for a particular exposure be considered acceptable when it is between 1 chance in 1 million and 1 chance in ten thousand. Of the risks shown in Tables 5A–E, the following exceed the upper end of the EPA acceptable range:

For flow back with no gas recovery, the seventy-year exposure exceeds the acceptable range for distances up to 200 meters downwind of the well.

For flow back with 93% recovery of gas, the seventy-year exposure exceeds the acceptable range for distances up to twenty-five meters downwind of the well.

For VOC emissions of twenty tons per year from condensate tanks, the seventy-year exposure exceeds the acceptable range for distances up to twenty-five meters downwind of the well.

Benzene emissions during uncontrolled flow back present the greatest risk of cancer. However, the risk of cancer exceeds the EPA acceptable range only for a seventy-year exposure. An exposure of that duration appears unlikely.

Cancer risk was also examined in the *Draft Garfield County Air Toxics Inhalation Screening Level Human Health Risk Assessment*. Three sites—Brock, Parachute, and Glenwood Springs—were determined to have cancer risk exceeding the upper end of the EPA acceptable range for a seventy-year exposure. Brock, identified as a site affected by natural gas operations, had a cancer risk slightly over the upper end of the range due entirely to benzene. Parachute was identified as urban, with the usual urban sources of VOCs, as well as being directly affected by natural gas operations. Cancer risk in Parachute was from cumulative exposure to

Table 7A. Benzene Cancer Risk Resulting from Flow Back with No Gas Recovery

(Benzene emission rate of 0.07 grams per second)

Downwind distance (meters)	Concentration (micrograms per cubic meter)	Rural background cancer risk (chances per million)	70-Year exposure, total benzene cancer risk (chances per million)	2-Year exposure, total benzene cancer risk (chances per million)	1-Year exposure, total benzene cancer risk (chances per million)
25	214.5	7.8	1680.6	55.6	31.7
50	96.5	7.8	760.2	29.3	18.5
75	58.5	7.8	463.8	20.8	14.3
100	39.4	7.8	314.7	16.6	12.2
125	28.3	7.8	228.8	14.1	11.0
150	21.5	7.8	175.3	12.6	10.2
175	16.9	7.8	139.7	11.6	9.7
200	13.7	7.8	114.7	10.9	9.3
250	9.6	7.8	82.7	9.9	8.9
300	7.2	7.8	63.6	9.4	8.6
350	5.6	7.8	51.1	9.0	8.4
400	4.4	7.8	42.5	8.8	8.3
500	3.1	7.8	31.7	8.5	8.1
600	2.3	7.8	25.3	8.3	8.0
700	1.7	7.8	21.3	8.2	8.0
800	1.4	7.8	18.6	8.1	8.0
900	1.1	7.8	16.7	8.1	7.9
1000	1.0	7.8	15.3	8.0	7.9
1100	0.8	7.8	14.2	8.0	7.9
1200	0.7	7.8	13.3	8.0	7.9
1300	0.6	7.8	12.7	7.9	7.9
1400	0.6	7.8	12.1	7.9	7.9
1500	0.5	7.8	11.7	7.9	7.9
1600	0.4	7.8	11.3	7.9	7.8
3200	0.2	7.8	9.0	7.8	7.8
4800	0.1	7.8	8.5	7.8	7.8

Table 7B. Benzene Cancer Risk Resulting from Flow Back with 93% Recovery of Natural Gas

(Benzene emission rate of 0.0049 grams per second)

Downwind distance (meters)	Concentration (micrograms per cubic meter)	Rural background cancer risk (chances per million)	70-Year exposure, total benzene cancer risk (chances per million)	2-Year exposure, total benzene cancer risk (chances per million)	1-Year exposure, total benzene cancer risk (chances per million)
25	15.0	7.8	124.9	11.1	9.5
50	6.8	7.8	60.5	9.3	8.5
75	4.1	7.8	39.7	8.7	8.3
100	2.8	7.8	29.3	8.4	8.1
125	2.0	7.8	23.3	8.2	8.0
150	1.5	7.8	19.5	8.1	8.0
175	1.2	7.8	17.0	8.1	7.9
200	1.0	7.8	15.3	8.0	7.9
250	0.7	7.8	13.0	7.9	7.9
300	0.5	7.8	11.7	7.9	7.9
350	0.4	7.8	10.8	7.9	7.8
400	0.3	7.8	10.2	7.9	7.8
500	0.2	7.8	9.5	7.8	7.8
600	0.2	7.8	9.0	7.8	7.8
700	0.1	7.8	8.7	7.8	7.8
800	0.1	7.8	8.6	7.8	7.8
900	0.1	7.8	8.4	7.8	7.8
1000	0.1	7.8	8.3	7.8	7.8
1100	0.1	7.8	8.2	7.8	7.8
1200	0.0	7.8	8.2	7.8	7.8
1300	0.0	7.8	8.1	7.8	7.8
1400	0.0	7.8	8.1	7.8	7.8
1500	0.0	7.8	8.1	7.8	7.8
1600	0.0	7.8	8.0	7.8	7.8
3200	0.0	7.8	7.9	7.8	7.8
4800	0.0	7.8	7.8	7.8	7.8

Table 7C. Benzene Cancer Risk Resulting from Operation of Wellhead Glycol Dehydration Units

(Benzene emission rate of 0.0036 grams per second)

Downwind distance (meters)	Concentration (micrograms per cubic meter)	Rural background cancer risk (chances per million)	70-Year exposure, total benzene cancer risk (chances per million)	2-Year exposure, total benzene cancer risk (chances per million)	1-Year exposure, total benzene cancer risk (chances per million)
25	11.0	7.8	93.8	10.3	9.0
50	5.0	7.8	46.5	8.9	8.3
75	3.0	7.8	31.2	8.5	8.1
100	2.0	7.8	23.6	8.2	8.0
125	1.5	7.8	19.2	8.1	8.0
150	1.1	7.8	16.4	8.0	7.9
175	0.9	7.8	14.6	8.0	7.9
200	0.7	7.8	13.3	8.0	7.9
250	0.5	7.8	11.7	7.9	7.9
300	0.4	7.8	10.7	7.9	7.8
350	0.3	7.8	10.0	7.9	7.8
400	0.2	7.8	9.6	7.8	7.8
500	0.2	7.8	9.0	7.8	7.8
600	0.1	7.8	8.7	7.8	7.8
700	0.1	7.8	8.5	7.8	7.8
800	0.1	7.8	8.4	7.8	7.8
900	0.1	7.8	8.3	7.8	7.8
1000	0.0	7.8	8.2	7.8	7.8
1100	0.0	7.8	8.1	7.8	7.8
1200	0.0	7.8	8.1	7.8	7.8
1300	0.0	7.8	8.0	7.8	7.8
1400	0.0	7.8	8.0	7.8	7.8
1500	0.0	7.8	8.0	7.8	7.8
1600	0.0	7.8	8.0	7.8	7.8
3200	0.0	7.8	7.9	7.8	7.8
4800	0.0	7.8	7.8	7.8	7.8

Table 7D. Benzene Cancer Risk Resulting from Condensate Tanks Emitting 20 Tons Per Year of Volatile Organic Hydrocarbons

(Benzene emission rate of 0.0081 grams per second)

Downwind distance (meters)	Concentration (micrograms per cubic meter)	Rural background cancer risk (chances per million)	70-Year exposure, total benzene cancer risk (chances per million)	2-Year exposure, total benzene cancer risk (chances per million)	1-Year exposure, total benzene cancer risk (chances per million)
25	24.8	7.8	201.4	13.3	10.6
50	11.2	7.8	94.9	10.3	9.0
75	6.8	7.8	60.6	9.3	8.6
100	4.6	7.8	43.3	8.8	8.3
125	3.3	7.8	33.4	8.5	8.2
150	2.5	7.8	27.2	8.4	8.1
175	2.0	7.8	23.1	8.2	8.0
200	1.6	7.8	20.2	8.2	8.0
250	1.1	7.8	16.5	8.0	7.9
300	0.8	7.8	14.2	8.0	7.9
350	0.6	7.8	12.8	7.9	7.9
400	0.5	7.8	11.8	7.9	7.9
500	0.4	7.8	10.6	7.9	7.8
600	0.3	7.8	9.8	7.9	7.8
700	0.2	7.8	9.4	7.8	7.8
800	0.2	7.8	9.0	7.8	7.8
900	0.1	7.8	8.8	7.8	7.8
1000	0.1	7.8	8.7	7.8	7.8
1100	0.1	7.8	8.5	7.8	7.8
1200	0.1	7.8	8.4	7.8	7.8
1300	0.1	7.8	8.4	7.8	7.8
1400	0.1	7.8	8.3	7.8	7.8
1500	0.1	7.8	8.2	7.8	7.8
1600	0.1	7.8	8.2	7.8	7.8
3200	0.0	7.8	7.9	7.8	7.8
4800	0.0	7.8	7.9	7.8	7.8

Table 7E. Benzene Cancer Risk Resulting from Condensate Tanks with 98% Removal of Emissions of 20 Tons per Year of Volatile Organic Hydrocarbons

(Benzene emission rate of 0.0016 grams per second)

Downwind distance (meters)	Concentration (micrograms per cubic meter)	Rural background cancer risk (chances per million)	70-Year exposure, total benzene cancer risk (chances per million)	2-Year exposure, total benzene cancer risk (chances per million)	1-Year exposure, total benzene cancer risk (chances per million)
25	0.5	7.8	11.6	7.9	7.9
50	0.2	7.8	9.5	7.8	7.8
75	0.1	7.8	8.8	7.8	7.8
100	0.1	7.8	8.5	7.8	7.8
125	0.1	7.8	8.3	7.8	7.8
150	0.0	7.8	8.2	7.8	7.8
175	0.0	7.8	8.1	7.8	7.8
200	0.0	7.8	8.0	7.8	7.8
250	0.0	7.8	8.0	7.8	7.8
300	0.0	7.8	7.9	7.8	7.8
350	0.0	7.8	7.9	7.8	7.8
400	0.0	7.8	7.9	7.8	7.8
500	0.0	7.8	7.9	7.8	7.8
600	0.0	7.8	7.8	7.8	7.8
700	0.0	7.8	7.8	7.8	7.8
800	0.0	7.8	7.8	7.8	7.8
900	0.0	7.8	7.8	7.8	7.8
1000	0.0	7.8	7.8	7.8	7.8
1100	0.0	7.8	7.8	7.8	7.8
1200	0.0	7.8	7.8	7.8	7.8
1300	0.0	7.8	7.8	7.8	7.8
1400	0.0	7.8	7.8	7.8	7.8
1500	0.0	7.8	7.8	7.8	7.8
1600	0.0	7.8	7.8	7.8	7.8
3200	0.0	7.8	7.8	7.8	7.8
4800	0.0	7.8	7.8	7.8	7.8

Benzene, 1,4-dichlorobenzene, and trichloroethene. Cancer risk in Glenwood Springs, identified as having only urban characteristics, was from cumulative exposure to benzene, 1,4-dichlorobenzene, and methylene chloride.

Uncertainties in non-cancer threat and cancer risk. There are a number of uncertainties in the non-cancer threat and cancer risks determined using pollutant concentrations based on the Gaussian plume model. Some of these uncertainties have the effect of reducing threat and risk.

- Actual pollutant emission rates may be less than those used in the model calculations. There is some variation in emission rates from one well pad to another. There may be variation from one company to another as well, if different operating practices are used.

- Site-specific meteorological conditions and topography may differ from the average conditions upon which the model is based. If site-specific conditions and topography enhance the dispersion of pollutants, there will be less exposure to residents at that site and less likelihood of health effects.

- Cancer risk would be less if the less potent of the two slope factors provided in the EPA *Integrated Risk Information System* was used.

Other uncertainties have the effect of increasing threat and risk.

- Actual pollutant emission rates may be greater than those used in the model calculations, for the same reasons identified above that rates may be less.

- Similarly, if site-specific meteorological conditions and topography limit pollutant dispersal, the likelihood of health effects would be increased. This situation is most likely to apply to acute exposures, which may occur from transient or short-term conditions, such as a multi-day winter inversion.

- The presence of other natural-gas related sources of these pollutants may increase the likelihood of health effects. Benzene, toluene, and *m,p*-xylenes are components of fuel and exhaust from vehicles or engines that are used on well pads. This emission source was not included in the model.

- If multiple well pads are in development at the same time in the same vicinity, their effects will be additive for any site that receives pollutant emissions from each site.

- The presence of other carcinogens in outdoor air, not included in the model, will increase cancer risk. For example, 1,4-dichlorobenzene was occasionally observed in the Garfield County Ambient Air Quality Monitoring Study. This consideration applies as well to the presence of other air pollutants having non-cancer effects.

- The presence of other pollutants in indoor air may increase the likelihood of non-cancer effects and cancer. Combustion devices (such as gas and wood stoves), tobacco smoke, paints, furnishings, and building materials all emit pollutants.

Discussion. Given the above uncertainties, the use of modeling as a substitute for sampling and analysis is no panacea. However, modeling can provide pollutant concentrations that can be used to illuminate an approximate understanding of the likelihood of health effects.

The results presented above suggest that the single operation creating the greatest threat from exposure to benzene, toluene, and *m,p*-xylenes is flow back with no recovery of natural gas. Until recently it was routine to conduct flow back in this manner. However, at this time companies are making increasing use of "green completions," in which over 90% of the natural gas is recovered during flow back. This practice is an effective way to reduce the single most significant exposure to benzene, toluene, and *m,p*-xylenes. For cases in which the green completion approach is not used, a setback requirement is desirable.

WATER POLLUTION EFFECTS

Pollutant transport in ground water. A useful starting point is to consider the general behavior of pollutants in ground water. Contamination in ground water has several possible origins. Liquids that are spilled, leaked, or dumped onto the land surface may infiltrate into the soil and percolate downward to ground water. These can be organic liquids, such as gasoline or condensate, or water-based liquids containing dissolved pollutants. Liquids may leak into the subsurface soil from pits, ponds, underground tanks, and pipelines. These liquids can also percolate downward to ground water. Solid materials that are spilled, leaked, or dumped onto the land surface may undergo the same process, provided they are water soluble, by dissolving into rain water that infiltrates into the soil.

As any liquid moves through the subsurface, it may leave behind a thin film of itself on the soil and rock surfaces. This effect gradually decreases the amount of liquid that continues to flow downward, and releases of small volumes of liquid are less likely to reach the ground water than releases of larger volumes. Another complicating factor is the tendency of most pollutant molecules to undergo sorption to the rock and soil surfaces through physical and chemical interactions. The sorbed pollutant becomes a residue that is left behind as the rest of the liquid continues to percolate. This residue can act as a secondary source of contamination. When clean rain water percolates through the subsurface, pollutant molecules in the residue can desorb or redissolve ("leach") into this water and be carried downward to the ground water.

When polluted water reaches the water table, it mixes with the ground water and creates a "slug" or "plume" of contaminated ground water. When a hydrocarbon liquid reaches ground water, a large portion of the hydrocarbon liquid will float on the water table. Over time, hydrocarbon molecules from this floating hydrocarbon layer will dissolve into the ground water, creating a slug or plume of contamination.

Ground water typically flows slowly through an aquifer. The contaminant plume is carried along with the moving ground water by advection. The velocity of the ground water depends on the hydraulic gradient of the ground water the hydraulic conductivity of the aquifer. (Hydraulic gradient can be pictured as the slope of the water table, with ground water flowing from an area of high water table to an area of low water table. Hydraulic conductivity refers to how readily the water can move through the aquifer. High values of gradient and conductivity lead to a higher velocity of ground water flow.) The contaminant plume itself usually moves at a slower velocity than the ground water due to the sorption process described above. Any particular dissolved pollutant molecule will sorb at some random time. While the pollutant molecule is sorbed, it is stationary. When it desorbs at some later random time, the pollutant becomes mobile and resumes advection. Overall, any given pollutant molecule will spend part of its time stationary rather than all of its time mobile, and thus will move at a slower velocity than the ground water itself, which is mobile all of the time.

Initially, the plume is small and the pollutant concentrations within the plume are relatively high. As the plume moves, it spreads out in all directions by hydrodynamic dispersion, and pollutant concentrations within the plume decrease over time because the pollutant mass is distributed over a larger volume of water. Many organic pollutants, including most of the smaller hydrocarbons, are susceptible to biodegradation. Naturally-occurring bacteria can use the pollutants as a source of "food" (that is, as a source of carbon for growth and energy for metabolism). The biodegradation process breaks down the hydrocarbon molecules into simpler hydrocarbons or to carbon dioxide and water. The rate of biodegradation depends on the chemical structure of the pollutant molecule, the type of bacteria, the amount of dissolved oxygen present in the ground water, and the availability of nutrients for the bacteria. Biodegradation can be a valuable asset if it works at a fast enough rate. Taken together, the effects of dispersion and biodegradation are often referred to as "natural attenuation".

The ground water pathway in Garfield County. Natural gas operations have the potential to create ground water contamination. One potential source of contamination is an improperly constructed gas well, which can allow the escape of natural gas, drilling fluids, or produced water into the surrounding geologic formation at the breach. Another potential source is seepage from unlined pits used to store water that may be contaminated with hydrocarbons or chemicals used in different stages of the well installation and completion process. Hydraulic fracturing creates fractures having the potential to act as conduits for the flow of water contaminated with hydrocarbons and substances used in the fracturing process. Surface spills or leaks of materials such as condensate can allow hydrocarbons to eventually reach ground water, as described on the preceding page. From the standpoint of evaluating the threat to human health, the key question (as explained in the earlier section on risk assessment) is whether or not a given exposure route is complete.

Rural residents of Garfield County have expressed concern about possible effects on ground water used for drinking and other domestic purposes. With the exception of the well-known contamination problem near West Divide Creek caused by faulty well construction, available

data from sampling and analysis do not show the presence of natural gas-related pollutants in ground water. Ground water characterization required by Garfield County for new subdivisions has not revealed any contamination problems (J. Rada, Garfield County Health Department). Similarly, examination of the ground water data base maintained by the Colorado Oil and Gas Commission revealed no contamination outside the vicinity of the problem in West Divide Creek.

Can ground water be contaminated even though no contamination has been revealed by results from sampling and analysis? Given that there is no exhaustive ground water monitoring program in place, the possibility exists that undetected contaminant plumes may be present. Rural water wells could be an important source of water quality data. However, landowners must bear the cost of analyzing their water, and most landowners likely do not have their water analyzed because of cost.

How likely is it that a plume will affect a water well? The likelihood of a contaminant plume in the drinking water aquifer reaching a private well used by rural residents is strongly dependent on location- and release-specific factors. Most ground water used in rural areas of Garfield County is from 20 to about 250 feet below the land surface (D. Dennison, Garfield County Oil & Gas Liaison). Pollutant releases that occur within this zone do have the potential to reach water wells. Whether the contaminant plume does so depends first on the direction of ground water flow—a well must be in the path of the plume in order to be affected. The vertical location of the release must also be a match for the point where the well draws water. A pollutant release at a given depth can result in a plume that may not travel vertically to a depth that would allow it to enter the well. Even if a well is in the path of the plume, the distance between the release location and the well is also a key factor. The greater the distance that the plume travels, the more the plume spreads out by hydrodynamic dispersion, reducing the maximum pollutant concentrations found in the plume. Biodegradation can cause further reductions in pollutant concentrations within the plume to the extent that the pollutant may no longer be a threat. Therefore the degree of threat posed by a release to ground water depends strongly on the location of the release relative to nearby water wells, in terms of both direction and distance.

There is public concern about the possibility of hydraulic fracturing leading to ground water contamination. Part of this concern is derived from the unknown composition of the materials pumped through the gas well into the gas-bearing formation during the hydraulic fracturing process; the detailed composition of these materials is treated as proprietary information by the natural gas industry. Concern also stems from the possibility that the new fractures may promote the movement of natural gas and hydraulic fracturing fluids toward water wells.

Natural gas wells in Garfield County range in depth from about 2,000 feet below the land surface to as much as 18,000 feet below the land surface (2006 Phase I Hydrogeologic Study by URS, Inc.), with most typically falling in the range from 4,000 to 9,000 feet (D. Dennison, Garfield County Oil & Gas Liaison). Thus, considerable transport must take place to bring hydraulic fracturing chemicals from such great depths up to the surficial aquifer used by rural residents. Given that the gases and fluids in these deep formations are under great pressure,

there is a tendency for upward migration of pollutants towards lower pressure zones at shallower depths. The rate of migration can be very slow because of the low permeability of formations between the gas-bearing zones and the surficial aquifers. However, fractures and faults can provide preferential flow paths that offer less resistance to pollutant transport. Evidence of deep ground water mixing with shallow ground water in the Mamm Creek gas field in southeastern Garfield County was presented in the 2006 Phase I Hydrogeologic Study performed by URS, Inc., demonstrating that the potential for pollutant transport from deep zones to shallow ground water is real. Due to the complexity and heterogeneity of the subsurface across Garfield County, it is difficult to predict with any confidence when and where this kind of migration may occur.

A risk assessment for ingestion of contaminated ground water was not performed. Without data showing contaminant concentrations in water currently used or potentially useable for drinking, there is no basis for calculating risk. Similarly, available information is insufficient to permit the use of modeling to predict contaminant concentrations. However, the maximum contaminant levels described below in the discussion of surface water are also a useful guide for ground water used for drinking. Even though these levels are legally enforceable only for public water systems, residents who monitor their private well may use these levels as a guideline for unacceptable contaminant concentrations.

The surface water pathway in Garfield County. There are several ways in which natural gas operations may contaminate surface waters (i.e., rivers, streams, lakes, ponds, and wetlands). Hydrocarbons and other materials involved in natural gas operations can enter the water directly through spills, such as those that sometimes occur in transportation accidents. Spills or leaks that occur some distance away from surface water may still enter the water as a result of overland flow across the land surface. Spilled or leaked materials that don't flow all the way to surface water on their own may be washed into the water by rain or snowmelt flowing across the land surface. Some bodies of surface water are fed by seepage from ground water. In these situations, ground water contaminant plumes described in the preceding section may also affect surface water. In contrast, some surface waters act as a source of recharge for ground water. In these situations, contaminated surface water can lead to a plume of contaminated ground water.

The Colorado River and certain tributaries are used as a source of drinking water by the public water systems operated by the City of Rifle and the Towns of Parachute and Silt.
Public water systems are regulated by the EPA under the Safe Drinking Water Act and are thus subject to the National Primary Drinking Water Regulations, which can be viewed at http://www.epa.gov/safewater/contaminants/index.html. These regulations set "maximum contaminant levels" for a variety of microorganisms and chemicals in water that is supplied to the public. Four of the most prominent petroleum hydrocarbons have been assigned maximum contaminant levels: benzene at 0.005 milligrams per liter, toluene at 1 milligram per liter, ethyl benzene at 0.7 milligrams per liter, and total xylenes at 10 milligrams per liter. Barium, which is a component of drilling muds, has a maximum contaminant level of 2 milligrams per liter.

Public water systems are required to monitor the water for these contaminants on a regular basis and, if violations occur, provide notice to the public and take corrective action.

The requirements of the Safe Drinking Water Act provide Garfield County residents supplied by public water systems with significant protection from drinking water contaminants associated with natural gas operations. In order for this regulatory system to be effective, it is imperative that the public water systems meet all the requirements for monitoring. Should benzene, toluene, ethyl benzene, xylenes, or barium be discovered at unusually high concentrations through this monitoring, the public water systems should consider additional monitoring for other contaminants that are associated with natural gas operations.

SOIL

Soil can become contaminated by spills, leaks, or overflows onto the land surface. Liquids (both hydrocarbons and water-based liquids) can flow down-slope across the land surface, spreading pollutants across a larger area of surface soil. Some portion of the liquids will infiltrate into the soil, spreading pollutants from the surface downward. Sorption of pollutants to soil results in a residue that persists until rain and snowmelt have leached the pollutants off the soil and carried them farther away across the land surface or farther down into the subsurface. Water soluble solid materials that are spilled or leaked onto the land surface may undergo the same process by dissolving into rain and snowmelt that infiltrates into the soil.

The primary manner in which people are exposed to pollutants in soil is through ingestion. While it is certainly not the case that adults intentionally “eat dirt”, a small amount of incidental ingestion is plausible. For example, soil on hands from gardening or other outdoor activities can be transferred into a person’s mouth. Young children are more likely to ingest soil as a result of their hand-to-mouth habits. The EPA recommends making the assumption that an adult ingests an average of one-tenth of one gram (less than four one-thousandths of an ounce) of soil per day (*Risk Assessment Guidance for Superfund, Volume 1. Human Health Evaluation Manual)*. For children, the recommendation is two-tenths of a gram of soil per day. There is a possibility for dermal absorption of pollutants from soil on hands. However, this is limited to the relatively small number of pollutants that have this ability.

There is little to no information available on pollutants in soil from natural gas operations (R. Chesson, Colorado Oil and Gas Conservation Commission). This precludes the possibility of doing a risk assessment for an actual, polluted site.

The Colorado Oil and Gas Conservation Commission requires that soil contaminated with greater than 1,000 milligrams of total petroleum hydrocarbons per kilogram of soil be treated or removed and properly disposed of. Soil with this level of contamination resulting from a condensate spill was assessed for risk as a way of illuminating what kind of hydrocarbon concentrations would present a significant threat. Only benzene, toluene, and *m,p*-xylenes were included because toxicity values for other hydrocarbons in condensate are not available.

The EPA-recommended values for a reasonable-maximum exposure were used in the calculation, which is shown in Appendix J. The hazard quotients are 0.011, 0.0031, and 0.0014 respectively for benzene, toluene, and *m,p*-xylenes. The sum of the hazard quotients is 0.016. All of these numbers are well under one, which is the threshold for unacceptable exposure leading to non-cancer effects. The cancer risk due to benzene is one chance in one million, which meets the EPA regulatory goal for acceptable cancer risk. That 1,000 milligrams of total petroleum hydrocarbons per kilogram of soil presents an acceptable health threat is not surprising—the level was deliberately set at a "safe" value.

RECOMMENDATIONS

As described in this report, there are numerous gaps and uncertainties in our understanding of pollution from natural gas operations in Garfield County. The motivation for the following recommendations is to reduce these uncertainties and fill data gaps. Better information is needed in order to make a complete and accurate evaluation of threats to human health.

- *Conduct a thorough study of air emissions during drilling*—At least three well pads should be selected for study, with different companies, drilling approaches, and operations represented. A scenario believed to be a worst case from an air emission standpoint should be among the three. Daily 24-hour grab samples of ambient air should be collected at the boundary of the well pad at each of sixteen equally-spaced compass directions. Samples should be analyzed for volatile organic compounds, carbon monoxide, and ozone. The duration of the study at each well pad should cover the drilling and completion of at least three wells. On-site measurements of wind speed, wind direction, and temperature should be made at 15-minute intervals in order to understand elements of the basic meteorology of the site. The results of this study should provide a much-improved picture of air pollutant concentrations representative of drilling operations in general.

- *Identify the components of hydraulic fracturing fluids and other materials used in well installation*—There is considerable public concern about the chemical composition of these materials. The industry maintains that hydraulic fracturing fluids are not a threat but has offered only incomplete evidence in the form of material safety data sheets, which are not required to include the identity of all components. Disclosure of the fracing fluid composition would allow monitoring of ground water for fluid components, evaluation of the potential health threat, and the potential for improved public acceptance of the industry. Similarly, the chemical composition of used drilling muds and produced water should be determined and revealed.

- *Establish a monitoring program for protection of the private well users*—As described in the section on water, Garfield County presents a difficult situation to assess for ground water contamination. The subsurface is complex, and the behavior of any specific contaminant plume may make contamination difficult to locate. It may not be possible

to implement a ground water monitoring network at a feasible cost that would provide a high degree of confidence for detecting contamination.

However, the principal goal is to detect any contamination that may be affecting private wells, where exposure to contaminants would actually take place. The most direct way to accomplish this goal is to collect quarterly or semiannual samples from private wells. The monitoring program should be funded, organized, and operated by either Garfield County or the Colorado Department of Public Health and Environment. Well water should be analyzed for methane, benzene and other volatile organic compounds, and selected components of hydraulic fracturing fluids that have the greatest potential to affect human health.

- *Inspection of surface soils at well pads after drilling activities are complete*—Colorado Oil and Gas Conservation Commission staff should inspect well pads for contamination of surface soil and collect samples of any areas where contamination is suspected based on observation of discolored soil or odor. Inspections should occur frequently and in particular should be timed so as to allow observation of empty pits prior to backfilling when drilling operations area complete. Samples should be analyzed for petroleum hydrocarbons and any metals (such as barium) that are used or occur in drilling fluids. Soils exceeding the spill cleanup criterion for total petroleum hydrocarbons or typical action levels for metals should be remediated. This practice should ensure that landowner exposure to soil contaminants is minimized.

- *Use green completions and applicable best management practices*—The industry can accomplish a significant reduction in pollutant emissions by continuing to adopt more environmentally friendly practices. As described in this report, the capture of gas during flow back should eliminate the most serious pollutant emissions.

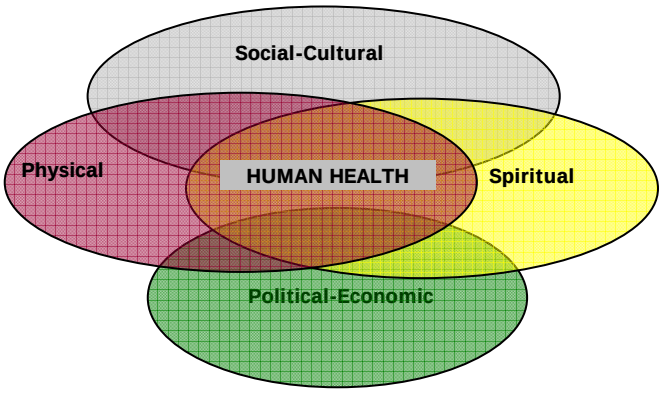
PART 2. HEALTH STUDY

PREMISES OF THE STUDY

We began this study with the premise that we would use the World Health Organization's (WHO) definition of human health; i.e., that health is broader and more inclusive than physical wellness. "Health," by the WHO definition, is inclusive of the social-cultural, spiritual and political-economic conditions of the community and its members. Thus, both quantitative and qualitative data collection included information on socio-economic and behavioral impacts and outcomes. An in-depth study of the socioeconomic impacts of growth taking place on the Western Slope of Colorado was recently published by the Mesa State College Natural Resource and Land Policy Institute (September 2007, Redifer et al.). It is beyond the scope of the current report to describe or significantly add to the information contained in the "Socioeconomics of growth" report.

Figure 8.

World Health Organization Definition of "Human



This study represents a "snapshot" in time of the health of Garfield County residents. This "snapshot" provides a baseline assessment, against which, future changes in health parameters may be measured. Trend data are provided in this report, where possible.

This is a "descriptive study". Statistical analyses are presented when and where appropriate. Whereas, it is possible, in many cases to discuss correlations between health status and residence, it is not possible to make definitive conclusions about causation, given the data that are available at this time.

METHODOLOGY

The Health Study has three major components:

- Qualitative Data: Community perceptions and concerns regarding health and well-being
- Quantitative Data: Health outcomes data
- Self-reported Health Status: Household survey

The overarching questions being asked in this study are the following;

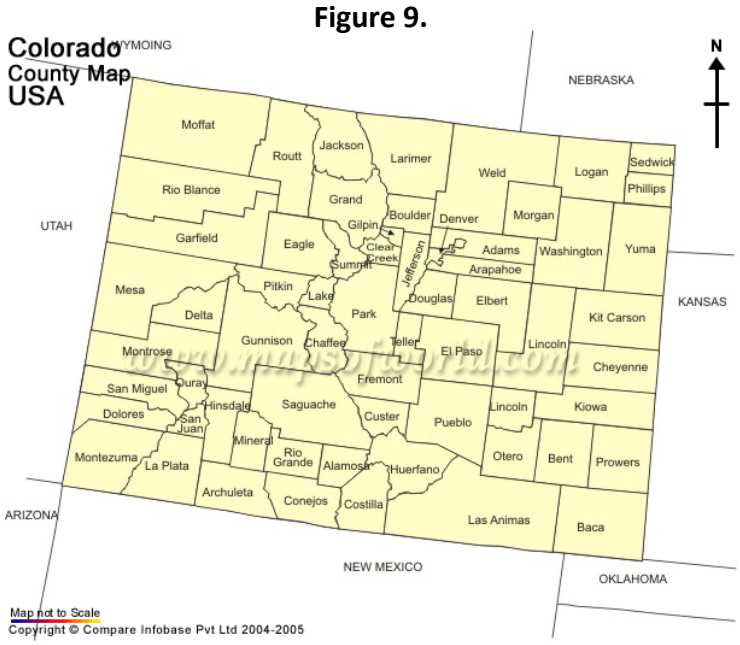
1) Is the health of Garfield County residents different than the health of residents of Delta, Mesa or Montrose Counties?

2) Is the health of residents of areas of Garfield County that are heavily impacted by the natural gas industry different from the health of residents of less impacted areas of Garfield County?

Description of study area and comparison counties. The three comparison counties, Delta, Mesa, and Montrose, were selected for the following reasons:

- All four counties (including Garfield County) are located on the Western Slope of Colorado, and thus, share similar social and political cultures.
- All four counties have experienced energy and mining activities, although to different degrees (see Background section). As a result of the natural cycles of these industries, all four counties have experienced similar economic cycles of growth and recession ("boom and bust"), and the accompanying environmental and social impacts.

Figure 9.



- The somewhat overlapping healthcare networks and service areas allowed us to acquire comparative health data for residents of the four counties.

Demographic data for Garfield County and the three comparison counties were largely obtained from the Colorado Department of Local Affairs, State Demography Office. These data are available online at http://dola.colorado.gov.

Table 8. County Profiles: 2000 & 2006 Data*

County		July Population	Total Households	Average Household Size	Births	Deaths	Birth/Death Ratio	Similarity Ranking
Delta								
	2000	28,009	11,058	2	296	330	0.90	3
	2006	30,676	12,225	2	347	303	1.14	
Garfield								
	2000	44,267	16,229	3	733	242	3.03	--
	2006	53,020	19,587	3	893	273	3.27	
Mesa								
	2000	117,656	45,823	2	1,485	1,109	1.34	2
	2006	135,468	53,416	2	1,853	1,268	1.46	
Montrose								
	2000	33,666	13,043	3	435	296	1.47	1
	2006	38,903	15,261	3	503	361	1.39	

http://dola.colorado.gov/demog_webapps/profile_county; accessed 4/10/2008; Division of Local Government, State Demography Office

*County profile variables
July population: July 1 of each calendar year, prepared by the Demographic Section in cooperation with the U.S. Bureau of the Census.

Total Households: Households (total occupied housing units are estimated from total housing units, household population and persons per household.

Average Household Size: Computed by dividing the household population (at July 1) by the number of households.

Births: These data are received from the Department of Health on a fiscal year (July 1 to June 30) basis.

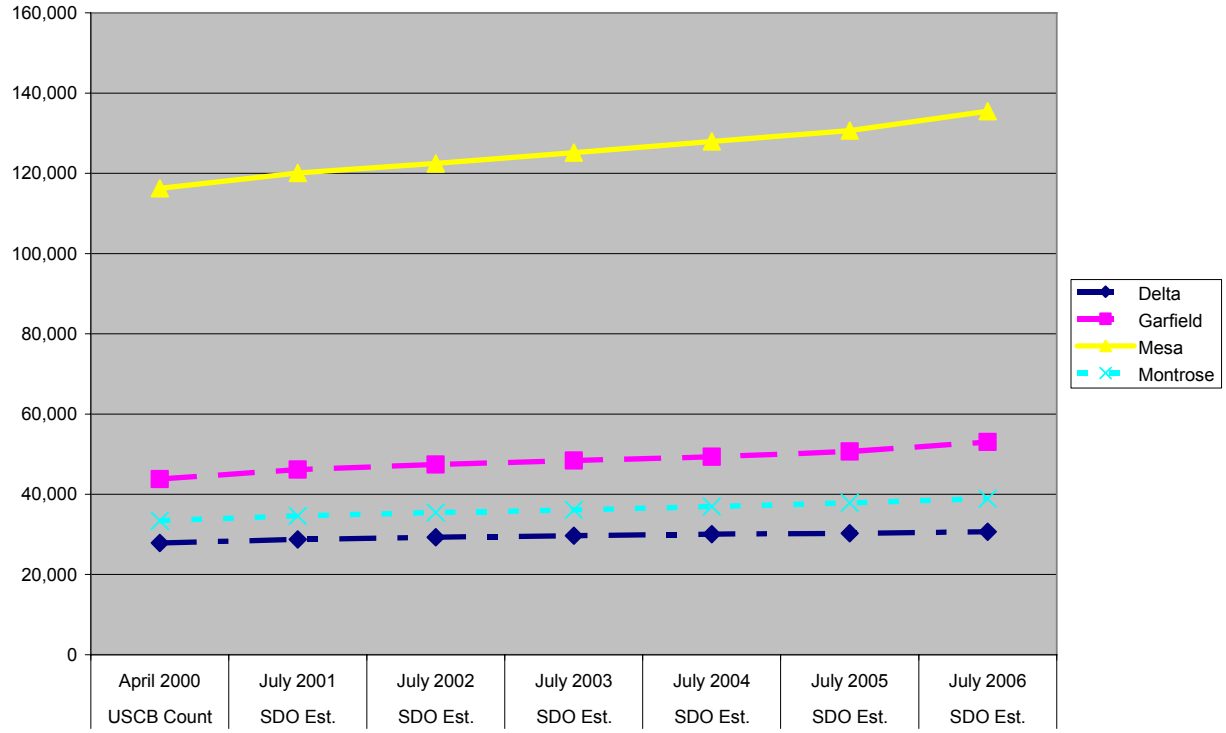
Deaths: These data are received from the Department of Health on a fiscal year (July 1 to June 30) basis.

Birth/Death Ratio: Garfield County had >3X the number of births to deaths in both 2000 and 2006. This was in contrast to the other three counties, all of which had <1.5X the number of births as deaths.

Similarity Ranking: A rank-sum algorithm (JD Boise, Jr. *et al. Rad Res* 167:711-726, 2007) was used to identify which of the three counties is most similar to Garfield County demographically. Rank values for 9 socioeconomic variables (population in 2000, population in 2006, number of households, household size, birth/death ratio, % change in population from 2000 to 2006, median household income, population age groupings, and percentage of children living below poverty) were determined, based on similarity to Garfield County. Rank values for all variables were summed, with the lowest sum representing the most similarity to Garfield County.

Some of the socioeconomic variable comparisons are illustrated in the graphs that follow. All of the data for these graphs were obtained from the Department of Local Affairs, State Demography Office website (see above).

Garfield, Montrose, and Delta County populations are most similar, while Mesa County's population is 2.5 to almost 4.5 times the population of the other counties.

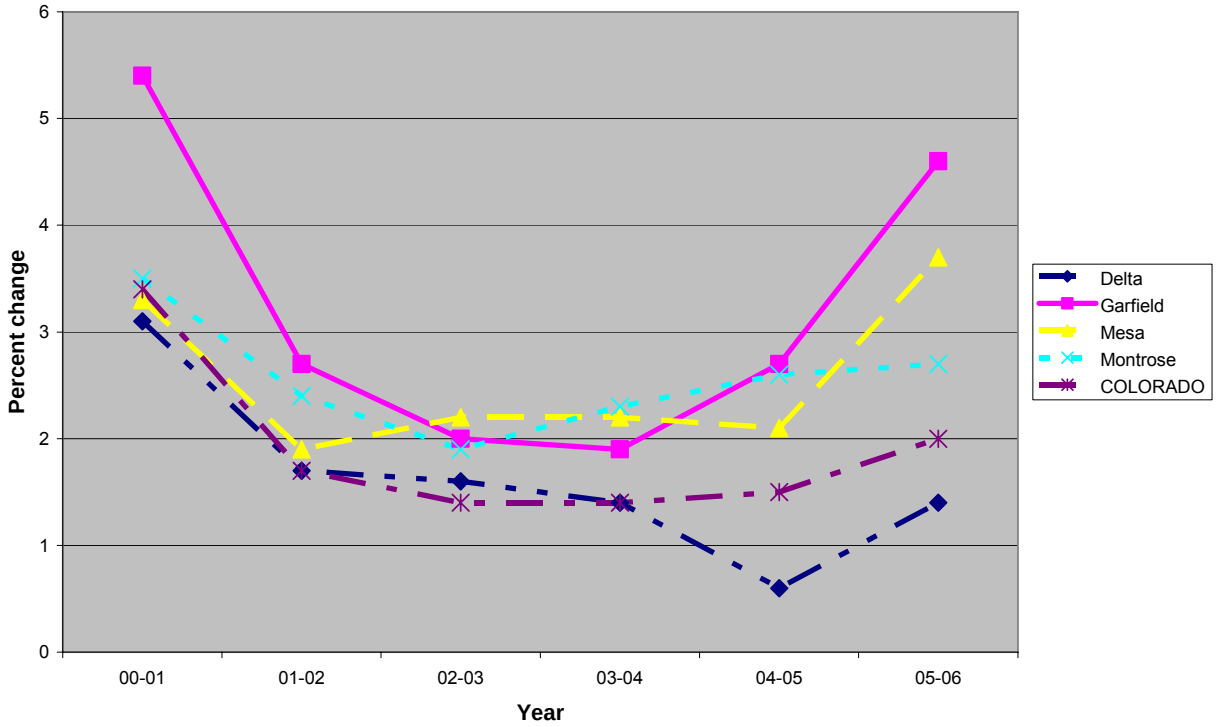


USCB: United States Census Bureau
SDO: State Demographers Office

Figure 10. Population Estimates by County, 2000-2006.

All four counties have undergone decreases, and subsequent increases, in population over the past decade. Currently, all four counties are experiencing population growth.

Figure 11. Average Annual Percent Change in Population, 2000-2006.



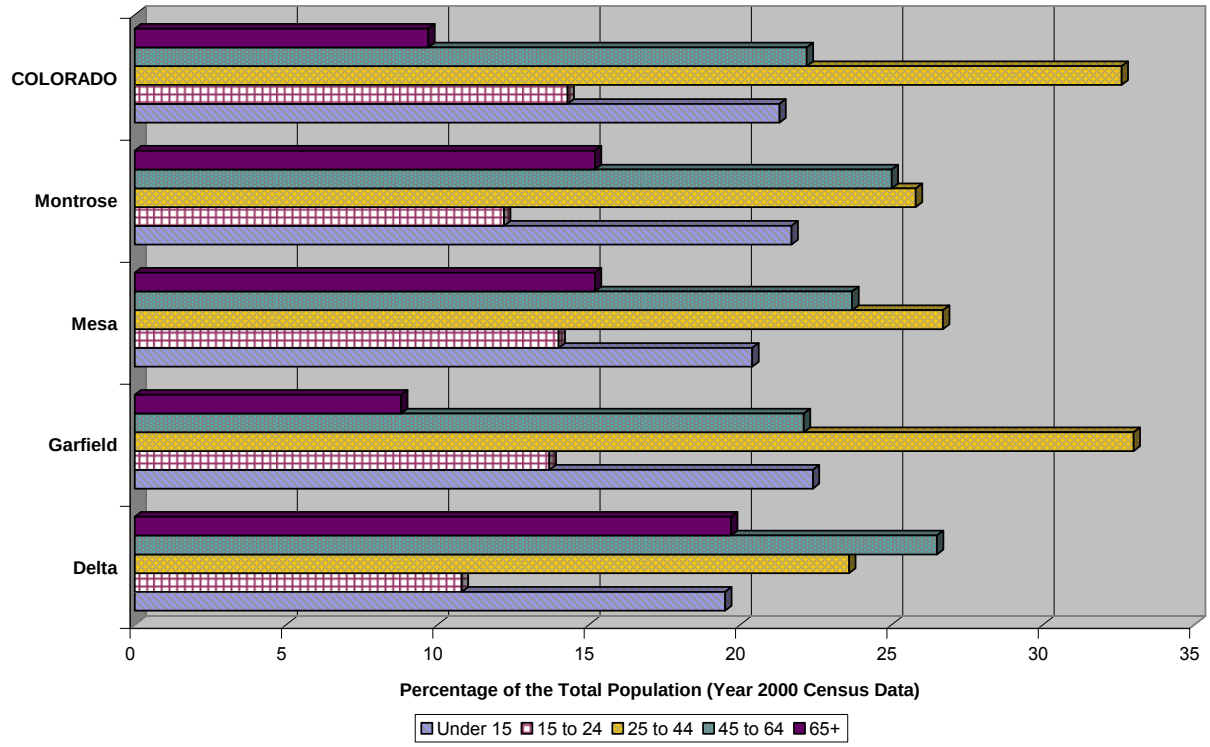
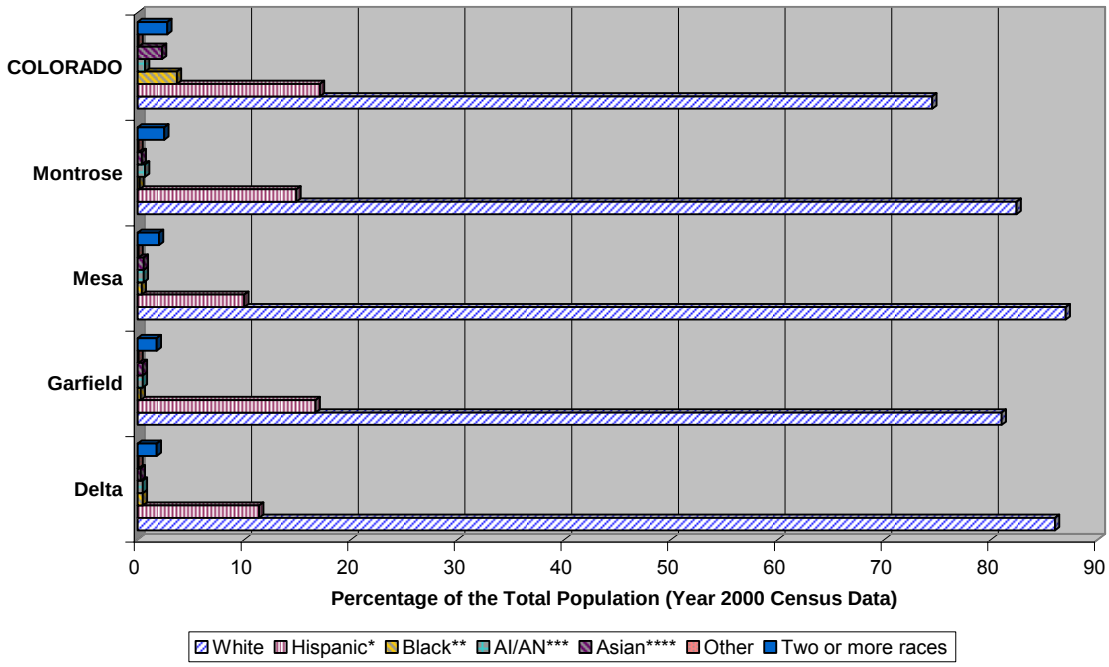


Figure 12. Population Age as a Percentage of Total Population

The largest population by age in Garfield County is the 25- to 44-year old age group. Garfield County tends to have a younger population, overall, than the comparison counties. The age demographic of the Garfield County's population is more similar to that of the state, overall.

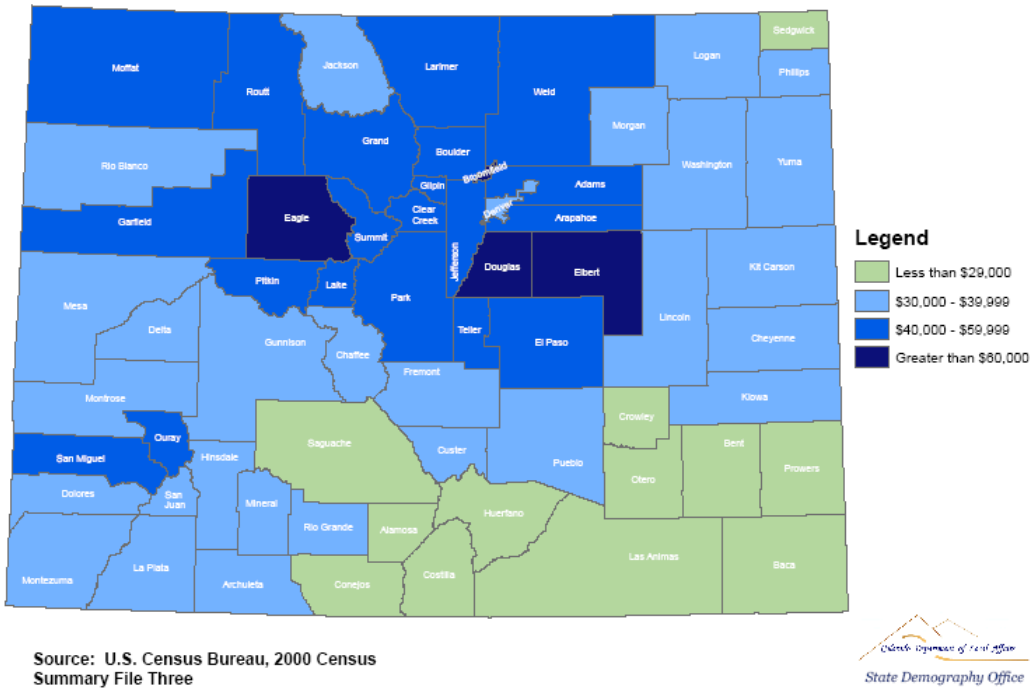
Figure 13. Race and Ethnicity as a Percentage of Total Population



Greater than 80% of the individuals who live in Garfield County are non-Hispanic white, with Hispanic individuals making up <15% of the residents. Garfield County is most similar to Montrose County, with respect to the race and ethnicity makeup of the population.

The following maps illustrate other demographic comparisons among the four counties: (http://dola.colorado.gov/demog_webapps/profile_county; accessed 4/10/2008; Division of Local Government, State Demography Office).

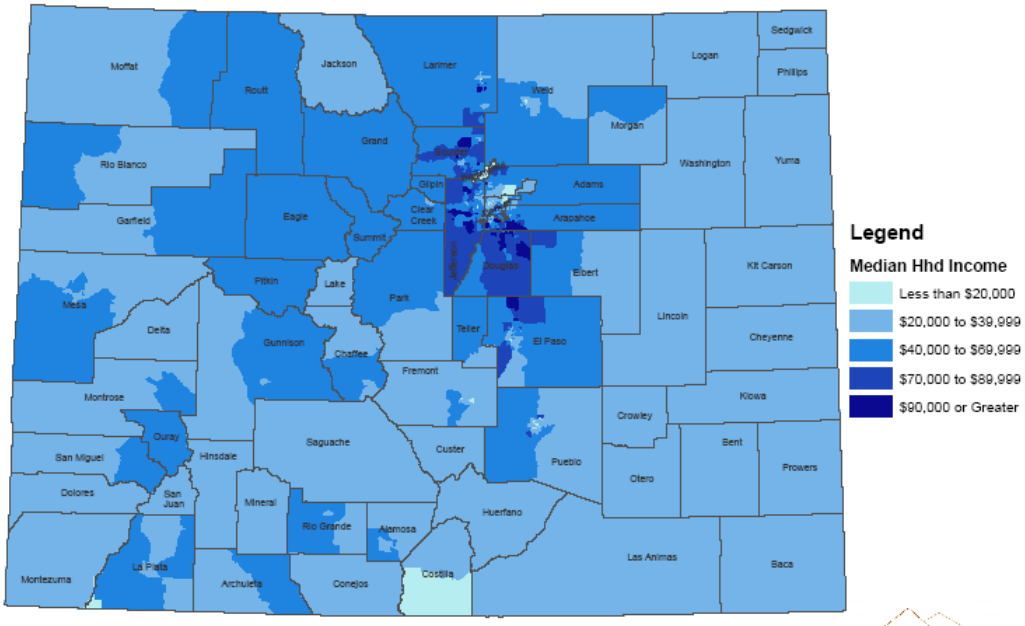
Figure 14. Median Household Income by County, 2000 Census



Source: U.S. Census Bureau, 2000 Census Summary File Three

State Demography Office

Figure 15. Median Household Income by Census Tract, 2000 Census



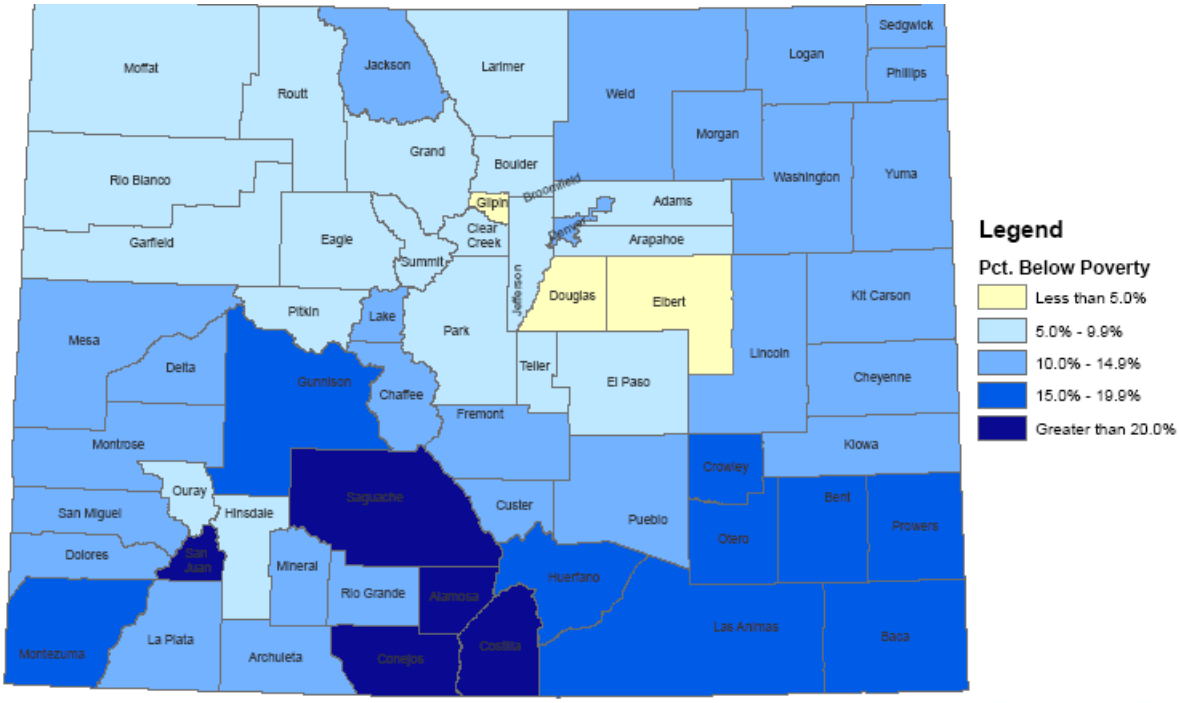
Source: U.S. Census Bureau, 2000 Census Summary File Three

State Demography Office

According to U.S. Census Bureau data for 2000, median household income in Garfield County is higher than in any of the comparison counties. However, the census tract data indicate that the western part of Garfield County, where more of the natural gas activity is located, has lower median household incomes than the eastern half of the county. Census tract data for Mesa County shows higher median household incomes for the southern half of the county. There is less discrepancy for median household incomes among census tracts for Delta and Montrose Counties.

The 2000 U.S. Census showed that fewer people were living below poverty in Garfield County than in Delta, Mesa or Montrose Counties. This is generally true, also for the percentage of children living in poverty, although percentages differ by census tract within the counties (see below).

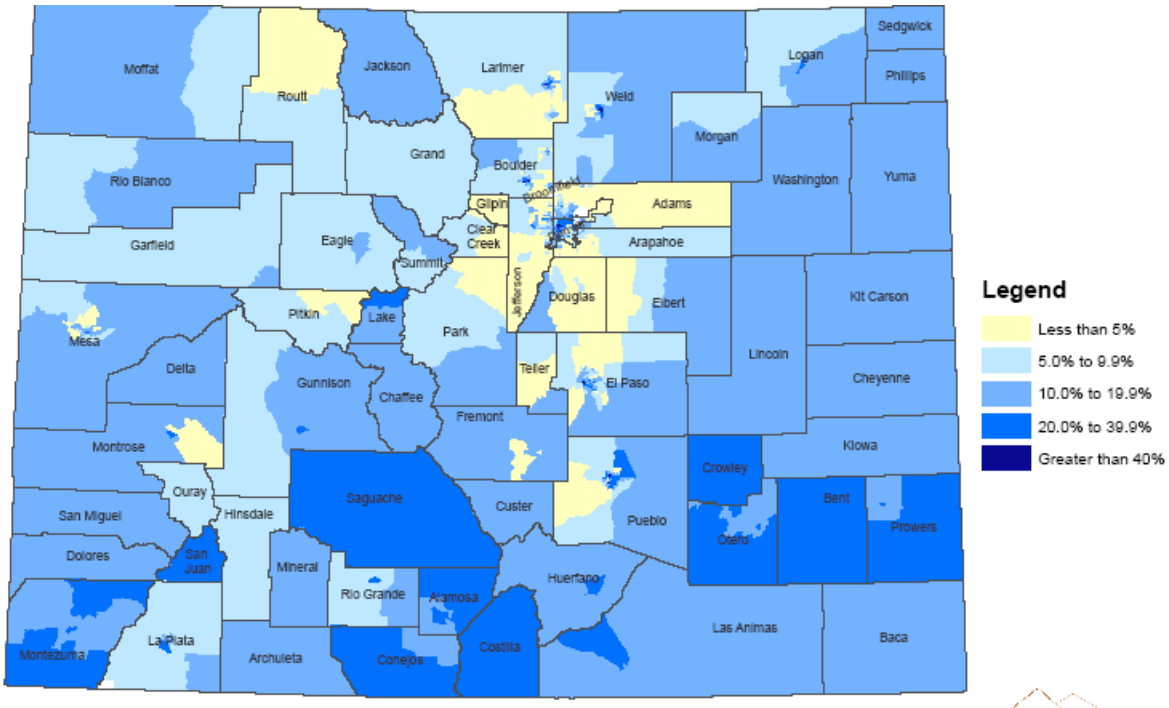
Figure 16. Percent of Persons Below Poverty by County, 2000 Census



Source: U.S. Census Bureau, 2000 Census Summary File Three

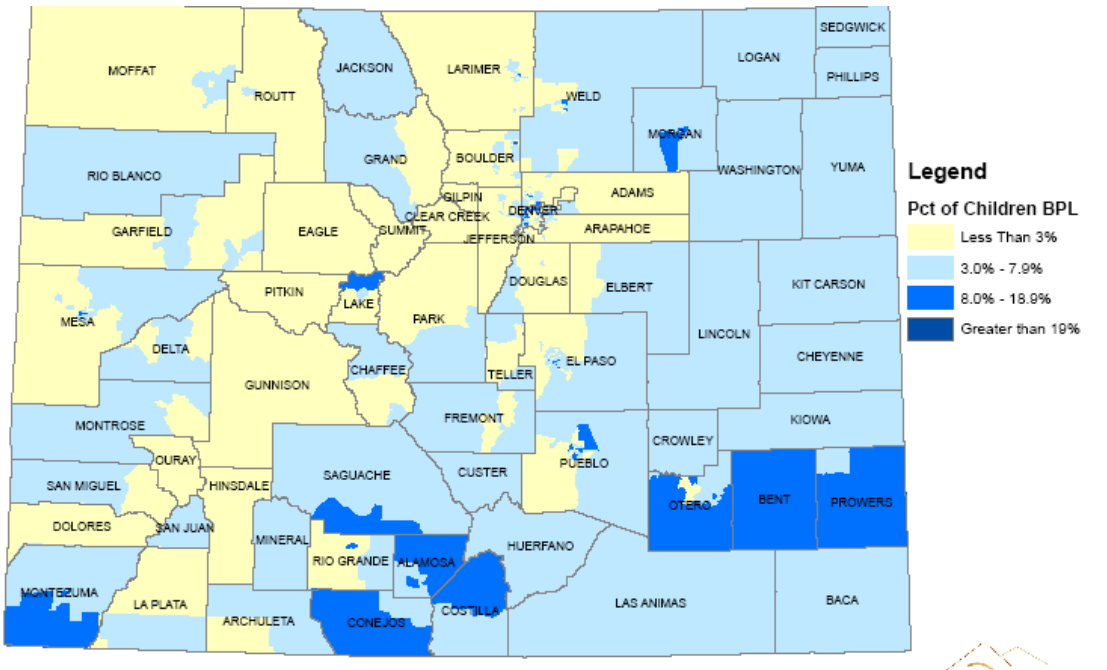
State Demography Office

Figure 17. Percent of Persons Below Poverty by Census Tract, 2000 Census



Source: U.S. Census Bureau, 2000 Census
Summary File Three

Figure 18. Percent of Children Below Poverty by Census Tract, 2000 Census



Source: U.S. Census Bureau, 2000 Census
Summary File Three

Perceptions and Concerns (Qualitative Data Collection).

Data Collection Process

Perceptions about community health and priority health concerns were collected through a process of public meetings, focus groups, and individual interviews that took place over a period of approximately two years. A separate process of collecting complaints and concerns occurred at the Garfield County Health Department, where the Environmental Health Manager kept a running phone log. Information in that log, as it relates to this study's objectives, is included in the data analysis.

Community Meetings

Two public meetings were held early in the data collection process; one each in Rifle (at the Fairgrounds) and in Battlement Mesa (at the Community Center). The Rifle meeting was held during the day on a Saturday, while the Battlement Mesa meeting was held in the evening on a weeknight. The objective was to give community members a choice of venue and time of day/day of the week to allow for greater participation. Both meetings were advertised through several venues; in the local newspapers, through flyers, at the Garfield County Health Department, and through announcements at Grand Valley Citizens Alliance (GVCA) meetings.

A total of 36 individuals (including Garfield County Health Department staff) attended the meetings. The format for the meetings was an initial presentation by Drs. Teresa Coons and Russell Walker, describing the human health assessment study, followed by an opportunity for attendees to ask questions and state concerns.

Key Informant Interviews

Interviews (either in-person or by telephone) were conducted by study staff with individuals who requested the opportunity to "tell their stories". All of these interviews were voluntary and self-selected. Individuals learned of the opportunity to be interviewed and share personal experiences and concerns through newspaper and radio stories about the study, word-of-mouth, and as a result of attending community or GVCA meetings.

Focus Groups

Six focus groups were held, with a total of more than 60 individuals participating. The focus groups were held at different times and locations, over a time period of approximately one year. Individuals attended by invitation. Participants were not compensated, nor did they receive any incentive for their participation. Focus group discussions were recorded and transcribed for analysis. The following groups of community citizens were each represented by a focus group:

Elected officials (municipal and county elected officials and administrators)
Grand Valley Citizens Alliance (local concerned citizens' organization)
Elderly residents (Battlement Mesa Assisted Living facility residents)

Healthcare Providers (The focus group was held at Grand River Medical Center in Rifle and was advertised to all medical staff and allied healthcare providers. Participation in this group was poor; we followed up with a survey of local providers.)

Garfield County Human Services Council (One hour of a regular meeting was devoted to the study focus group. A wide range of county service agencies, both profit and non-profit, were represented.)

Garfield County School Districts (Separate groups were held for School District Re-2, comprising Rifle, Silt and New Castle, and School District Re-16, comprising Parachute and Battlement Mesa. Invitations to participate were coordinated through the district's administrative offices.)

Focus group participants were instructed to think of "health" broadly, i.e., not just physical health, but also psychosocial health and "well-being". All focus groups were "guided discussions" conducted by Dr. Teresa Coons, using a common set of discussion questions.

Focus Group Questions

1. How would you rate the health of people in Garfield County and/or your community relative to the health of people in other Colorado communities or other communities in which you've lived? Note: I am simply asking for your perception, based on your own experience.

2. What do you consider to be the priority health-related issues in your community? Note: I am using the term, health, in the context of not only specific physical ailments, but also the broader concept of "well-being".

3. Who is most affected by health issues in your community? Are there particular age or demographic groups that are more at risk or have more health problems?

4. To what environmental or societal factors (if any) would you attribute any of the priority health issues that you've identified in your community?

5. What health issues concern <u>you</u> the most? (Question asked of each participant individually.)

Note: Healthcare providers were also asked to identify the health conditions that they saw most frequently in their practices.

<u>Complaint Phone Logs</u>

The phone log maintained by the Garfield County Environmental Health Manager documents telephone calls received from early 2003 through 8/2007. Information in the log includes date of call, type of complaint or concern, region or location (if applicable), caller name and address, complaint or concern narrative and resolution of the call. The list of callers overlapped, to some extent, with the list of individuals who asked to be interviewed, and some of the individuals were repeat callers. The health concerns expressed in the phone log reflect the concerns documented in the previously described data collection process.

Quantitative Health Data. Health outcomes data were collected from a number of sources for Garfield County and comparison counties. The search for health outcomes data was driven by two objectives: 1) to complete a "snapshot in time" picture of the health of Garfield County residents in comparison to the health of residents in the comparison counties, and 2) to obtain statistical data that could be used to respond to the concerns voiced by Garfield County residents during the qualitative data collection process. Thus, to the extent that the data were available, we collected statistical information on the prevalence of conditions such as cancer and asthma and the predominant causes of mortality and morbidity in Garfield County.

The following data were obtained from the Colorado Department of Public Health and Environment (datasets represent the most current data available at the time this report was written):

- Death statistics: rates and leading causes of death (1990-2006)
- Birth defects: types and rates (2000-2006)
- Adolescent health measures (2007)
- Reportable conditions (1998-2006)
- West Nile virus (2002-2007)
- Cancer statistics (1992-2005)
- Behavioral Risk Factor Study Survey (BRFSS) data (2000-2005)
    - General health status (physical & mental)
    - Diabetes, asthma
    - Smoking, weight
    - Health insurance
- Injury hospitalization and death: causes and rates (2001-2003)

Hospital and outpatient data were obtained from the following sources:

- Colorado Hospital Association, DRG-based hospital discharge data (2000 through 1st quarter 2006)
- Emergency room data
    - Grand River Medical Center (located in Rifle, CO and serving western Garfield County)

- Valley View Hospital (located in Glenwood Springs, CO; primarily serving eastern Garfield County)
- Rocky Mountain Health Plans* (RMHP) – member data for 4 counties
- St. Mary's Hospital *CareFlight* data

- RMHP hospital inpatient, outpatient and ambulatory member data – 4 county comparison
- By DRG category
- Focus on respiratory conditions

*RMHP is a non-profit, Colorado-based health insurance company that provides healthcare coverage for a significant number of Western Colorado residents. RMHP provides a full range of health plans, including Medicare supplement and Medicaid coverage.

Self-reported Health Status: Household Survey. A targeted health survey was administered to Garfield County residents by trained interviewers. The in-home surveys captured information about the general health and health risk factors of residents, as well as information about specific health conditions that were identified as priority concerns during focus group discussions. This information was intended to provide a more objective measure of the health status of community residents, and a means of conducting within County comparisons.

A randomly selected sample of households from throughout Garfield County was surveyed. The sampling protocol was designed to provide a zip code-based sampling pool of 2-4% of the households in Garfield County that have listed telephone numbers (4% of households in zip code areas that are highly impacted by the presence of natural gas industry operations and 2% of households in the zip code areas that have little or no natural gas activity); a sample that would give a 95% confidence level (±5% error rate) for the study results. Randomly selected phone numbers (and the respective mailing addresses) from each Garfield County zip code area were obtained from infoUSA (infoUsa, Inc., 5711 South 86th Circle, P.O. Box 27347, Omaha, NE 68127), a marketing research firm that specializes in health-related community surveys. In order to achieve the desired number of completed household interviews, we requested 15 phone numbers for each number that we hoped to complete. Drawbacks to this survey approach include the unwillingness of many people to respond to telephone calls from unknown individuals (either because they don't want to be bothered or because they are afraid that the call is from a telephone solicitor), and the fact that many individuals are hard to reach at home during convenient hours. We hoped to avoid the problem of individuals being unwilling to speak with us on the telephone by preceding our initial phone call with a letter to the household that explained the nature of the survey and requested return information on the

best day(s) and time(s) of day to call. A postage-paid return card was included in the letter for this purpose.

Because of the difficulty of reaching people by phone (see above), and a relatively low initial response rate, we also developed a mail survey. We split the sample of randomly selected phone numbers/addresses for each zip code area, and mailed a written survey to half of the selected respondents. Because we used the same randomly selected sample to create a mailing list, we have no reason to suspect that there is any identifiable significant difference between the group that received phone calls from an interviewer and the group that received a survey in the mail. By using the two methods – both of which can have low response rates – we attempted to maximize our ability to reach a representative sample of households in Garfield County. The written survey contained questions that were essentially the same as in the phone survey, modified only to allow the respondent to document their responses on paper. (A copy of the survey documents are provided in Appendix T.)

Telephone surveys were conducted by a limited number of trained interviewers, using an ACCESS (2002) database that allowed direct data entry during the telephone conversation. All sample household information and survey documentation (e.g., attempted phone contacts and outcomes, reasons for refusing to participate in the survey) and written survey responses were entered into the same ACCESS database.

To assure that we achieved a representative cross-section of the population demographic, adult respondents were asked to complete the survey questions for all members of their household, regardless of age or family relationship. The telephone survey required, on average, 20 minutes to complete – depending on the number of household members and the range of reported health conditions.

In addition, to assure that we did not exclude primarily Spanish-speaking individuals from the surveyed population, the survey document was translated into Spanish and then back-translated by a professor of Spanish language, who, in particular, tested for the appropriateness of dialect and idiom for this geographic region. As telephone contact was made with potential survey respondents, interviewers documented households within which the primary language was Spanish. Those households were re-contacted by a native Spanish-speaking public health nurse, who was an employee of the Garfield County Health Department. Standardized interviews were conducted in Spanish, results were recorded in English on survey forms, and the data were entered into the survey database.

ACCESS data tables were downloaded into *EpiInfo* Version 3.4.1, Centers for Disease Control and Prevention for analysis. (Please see Appendix U for data analysis protocols and outcomes.)

RESULTS

Perceptions and Concerns. (Qualitative data from focus groups, interviews, public meetings and complaint reports)

Key Informant Interviews

A total of 23 interviews were conducted between October 2005 and October 2007; 16 (69.6%) were conducted in person, 7 (30.4%) were conducted by telephone.

Table 9. Interviewee Demographics

Gender	Residence	Residence Time in the County	Distance of Residence from Natural Gas Extraction or Production Activities	How Did Individual Hear About Study?
Female: 12 (52.2%)	Rifle: 5 (21.7%)	Range: 9 months to 20 years	Range: 150 feet to 6.5 miles	Meeting (public meeting or GVCA* meeting): 18 (78.3%)
Male: 11 (47.8%)	Parachute: 10 (42.6%) Silt: 8 (34.8%)	Mean: 9.8 years Median: 9.5 years	Mean: 0.93 miles Median: 0.25 miles	Newspaper article: 4 (17.4%) Word of Mouth: 1 (4.3%)

** GVCA: Grand Valley Citizens Alliance*

Key Words and Common Themes Analysis

Transcriptions from the key informant interviews and focus group discussions were reviewed for key words and themes, which were then grouped into thematic categories. The comments and concerns of 119 individuals are represented below.

Physical Health Issues/Concerns. (Note: The following concerns may or may not have been associated with environmental exposures.)

- Increase in or exacerbations of allergies and asthma
    - Related concerns: coughing, wheezing, other respiratory complaints
- Generalized chemical sensitivities
- Fibromyalgia/chronic pain
    - Related concern: chronic fatigue, lethargy
- Chronic colds
    - Related concerns: concern about compromised immune systems

- Headaches, dizziness, burning/itching eyes, nausea/vomiting, sinus problems – most often attributed to odors
- Burning/itching skin
- Mental health issues such as stress, depression, anger, inability to sleep
- Cancer (adrenal cancer, brain tumors, unknown/presumed cancers or "fear of developing cancer")
- Loss of voice or speech problems
- Trauma/work-related injuries
- Age-related illnesses
- Diabetes
- Obesity
- Perceptions that pre-existing health conditions have been exacerbated; people "feeling worse" than in the past

Social/Community Issues and Concerns

- Increase in child and spousal abuse; child neglect; stressed family relationships
- Alcohol abuse (especially among high school students)
- Drug abuse (especially methamphetamine use)
- High suicide rate
- Increase in sexually transmitted diseases related to increase in temporary workers
- Lack of health insurance
    - Related concerns: lack of dental care for children and preventive care
- Access to healthcare and mental health services
- Number of low income families
- Growth issues: Availability of housing and community services, increase in low-income families, cultural clash (long-time residents, industry workers), traffic, public safety

Environmental Concerns

- Noise
- Odors
- Dust
- "Toxic" chemicals in water and air

Wildlife/Domestic Animals

- Reported changes in herd animal reproductive patterns/illnesses
- Decreases in bird, insect, and deer populations

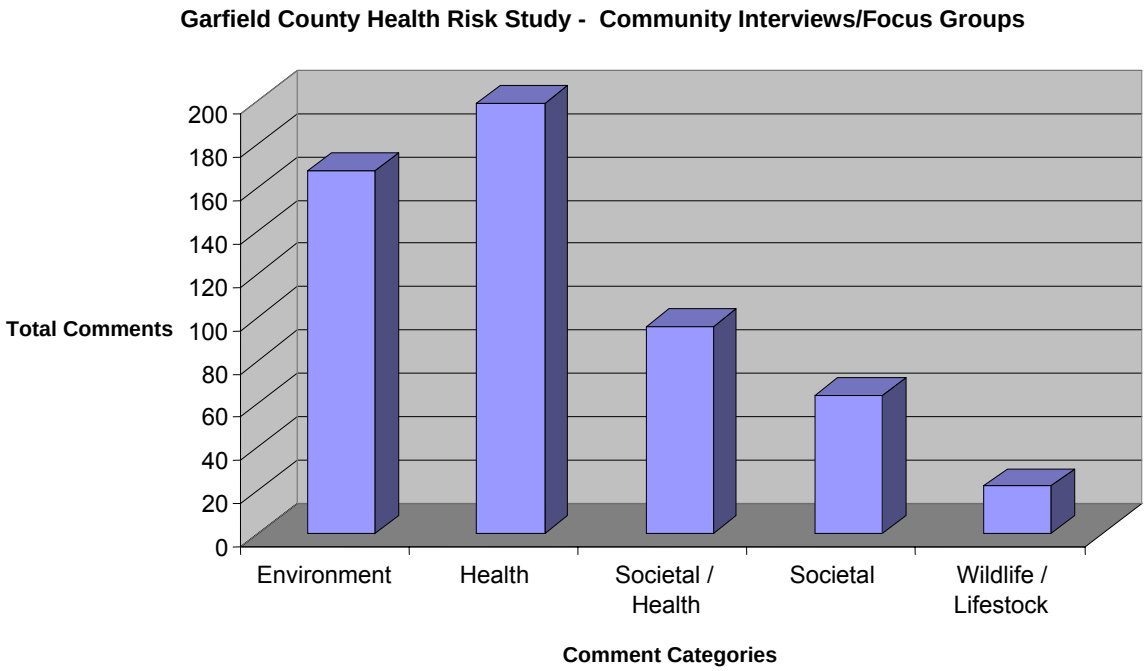


Figure 19. Community Interviews/Focus Group Comments

<u>Garfield County Environmental Health Phone Log Complaints</u>

For the documented time period, the log contains 372 calls. *The largest number of complaints/concerns was related to odors (93 calls).* Other complaints/ concerns included the following:

- Road conditions (31 calls)
- Ground water concerns (25)
- Noise (25)
- Safety (24)
- Dust (23)
- Spills (23)
- Property damage (18)
- Visual appearances (14)
- Permitting (14)
- Surface water concerns (13)
- Specific health concerns (13)
- Traffic (10)
- Trespassing (9)
- Surface use agreements (9)
- Flaring (7)
- General environmental concerns (7)
- Industry worker speeding (5)
- Stormwater (3)

- Fire (2)
- Pit water (production water) containment (2)
- Smoke (1)
- Trash (1)

Quantitative Health Data. Final data collection for this report took place in January 2008, unless otherwise noted. Thus, these data are the most currently available at that point in time.

Vital Statistics

- Tables 8 through 11 present vital statistics data and trends for 1996 and 2002-2006 by county. Table 12 provides selected birth statistics by County for 2006, specifically.
- According to the annual birth rate data for the years 1996 and 2002 – 2006, birth rates for all counties have been essentially stable during this period. The exception is Montrose County, for which there was a drop in the birth rate between 1996 and 2002, after which the birth rate stabilized between 2002 and 2006. Garfield County had the highest average annual birth rate during this period.
- The percentage of teen mothers has been stable over the study period, with the exception of Delta County, which saw a drop in the percentage of mothers who are between the ages of 10 and 17 years between 1996 and 2002. Based on the average annual rate for the period 2002-2006, Garfield County had the lowest rate of teen mothers among the comparison counties.
- The rate of low birth weight (<2,500 grams) babies among the four counties is similar.
- Mesa County had the lowest rate of mothers who did not receive prenatal care during the first trimester of their pregnancies. The rates for the other three counties were similar.
- The highest rate of mothers who had less than 12 years of formal education was in Garfield County.
- Garfield County's rate of neonatal and infant deaths was similar to that of Mesa County, and higher than that of Delta and Montrose Counties.
- The age-adjusted, total death rate for Garfield County was comparable to the age-adjusted, total death rate for Delta County, and lower than the age-adjusted, total death rates for Mesa or Montrose Counties. The graph in the section below provides a comparison of crude, total death rates for the four counties over the period of 1990 – 2006. Garfield County had the lowest crude death rate for the past 2 ½ decades.

Table 10. Vital statistics by County 1996, 2002-2006	Delta County						
	1996	2002	2003	2004	2005	2006	2002-2006 Annual Average
Total population	25,718	29,194	29,666	30,073	30,264	30,672	29,974
Total Births							
Number	312	317	332	350	338	344	336
Birth Rate	12.1	10.9	11.2	11.6	11.2	11.2	11.2
Age of Mother 10-17							
Number	31	18	19	19	14	11	16
Percent of Total Births	9.9	5.7	5.7	5.4	4.1	3.2	4.8
Low Weight Births (<2,500 grams)							
Number	23	24	28	37	26	21	27
Percent of Total Births	7.4	7.6	8.4	10.6	7.7	6.1	8.1
Prenatal Care Later than 1st Trimester							
Number	88	94	74	85	97	103	91
Percent of Total Births	28.8	29.7	22.7	26.6	30.5	32.2	28.3
Mother's Education <12 years							
Number	*89*	84	74	95	77	75	81
Percent of Total Births	28.6	26.8	22.5	28	23.4	22.6	24.7

Infant Deaths								
Number	*	*	5	3	0	*		*
Rate	*	*	15.1	8.6	0	*		
Neonatal Deaths								
Number	*	*	3	*	0	*		*
Rate	*	*	9	*	0	*		*
Total Deaths								
Number	308	316	338	278	331	323		317
Age-Adjusted Rate	798.3	766.1	801.8	652.6	759.5	747.6	745.2	

Source: Health Statistics Section, Colorado Department of Public Health and Environment.

*indicates one or two events

Birth rates are per 1,000 total population.

Infant and neonatal mortality rates are per 1,000 live births. Infant death is death in the first year of life. Neonatal death is death occurring prior to the 28th day of life.

Total death rates are per 100,000 population.

Age-adjusted rates are adjusted to the 2000 U.S. population using the direct method applied to 10-year age groups.

Table 11. Vital statistics by County 1996, 2002-2006	Garfield County						
	1996	2002	2003	2004	2005	2006	2002-2006 Annual Average
Total population	37,678	47,439	48,395	49,319	50,669	52,878	49,740
Total Births							
Number	604	855	871	803	816	945	858
Birth Rate	16	18	18	16.3	16.1	17.9	17.2
Age of Mother 10-17							
Number	22	32	30	25	24	31	28
Percent of Total Births	3.6	3.7	3.4	3.1	2.9	3.3	3.3
Low Weight Births (<2,500 grams)							
Number	37	63	70	65	57	69	65
Percent of Total Births	6.1	7.4	8	8.1	7	7.3	7.6
Prenatal Care Later than 1st Trimester							
Number	157	326	217	197	266	346	270
Percent of Total Births	26.2	38.2	24.9	24.6	32.7	36.7	31.6
Mother's Education <12 years							
Number	144	281	311	276	270	273	282

Percent of Total Births	24	33	35.8	34.6	33.3	29.2	33.1
Infant Deaths							
Number	6	9	5	8	3	3	6
Rate	9.9	10.5	5.7	10	3.7	3.2	6.5
Neonatal Deaths							
Number	5	3	3	6	3	*	3
Rate	8.3	3.5	3.4	7.5	3.7	*	4
Total Deaths							
Number	229	279	310	271	268	289	283
Age-Adjusted Rate	815.8	819	904.3	759.9	729.9	729.4	786.6

Source: Health Statistics Section, Colorado Department of Public Health and Environment.
*indicates one or two events
Birth rates are per 1,000 total population.
Infant and neonatal mortality rates are per 1,000 live births. Infant death is death in the first year of life. Neonatal death is death occurring prior to the 28th day of life.
Total death rates are per 100,000 population.
Age-adjusted rates are adjusted to the 2000 U.S. population using the direct method applied to 10-year age groups.

Table 12. Vital statistics by County 1996, 2002-2006	Mesa County						
	1996	2002	2003	2004	2005	2006	2002-2006 Annual Average
Total population	107,536	122,467	125,077	127,816	130,662	135,473	128,299
Total Births							
Number	1,366	1,553	1,662	1,711	1,819	1,880	1,725
Birth Rate	12.7	12.7	13.3	13.4	13.9	13.9	13.4
Age of Mother 10-17							
Number	99	66	75	69	88	87	77
Percent of Total Births	7.2	4.2	4.5	4	4.8	4.6	4.5
Low Weight Births (<2,500 grams)							
Number	102	123	126	146	141	138	135
Percent of Total Births	7.5	7.9	7.6	8.5	7.8	7.3	7.8
Prenatal Care Later than 1st Trimester							
Number	195	242	257	210	255	292	251
Percent of Total Births	14.3	15.6	15.5	12.3	14	15.6	14.6
Mother's Education <12 years							
Number	295	295	370	276	272	415	366
Percent of Total Births	21.6	19.1	22.4	22.1	20.6	22.2	21.3

Infant Deaths							
Number	16	16	10	12	6	9	11
Rate	11.7	10.3	6	7	3.3	4.8	6.1
Neonatal Deaths							
Number	12	13	7	10	3	7	8
Rate	8.8	8.4	4.2	5.8	1.6	3.7	4.6
Total Deaths							
Number	1,024	1,220	1,232	1,162	1,268	1,268	1,230
Age-Adjusted Rate	952.2	996.2	985	909.1	970.4	936	958.7

Source: Health Statistics Section, Colorado Department of Public Health and Environment.
*indicates one or two events
Birth rates are per 1,000 total population.
Infant and neonatal mortality rates are per 1,000 live births. Infant death is death in the first year of life. Neonatal death is death occurring prior to the 28th day of life.
Total death rates are per 100,000 population.
Age-adjusted rates are adjusted to the 2000 U.S. population using the direct method applied to 10-year age groups.

Table 13. Vital statistics by County 1996, 2002-2006	Montrose County						
	1996	2002	2003	2004	2005	2006	2002-2006 Annual Average
Total population	30,482	35,433	36,122	36,932	37,883	38,908	37,056
Total Births							
Number	484	440	458	496	521	493	482
Birth Rate	15.9	12.4	12.7	13.4	13.8	12.7	13
Age of Mother 10-17							
Number	30	19	23	22	15	19	20
Percent of Total Births	6.2	4.3	5	4.4	2.9	3.9	4.1
Low Weight Births (<2,500 grams)							
Number	41	31	32	46	42	32	37
Percent of Total Births	8.5	7	7	9.3	8.1	6.5	7.6
Prenatal Care Later than 1st Trimester							
Number	146	142	122	176	222	198	172
Percent of Total Births	30.4	32.4	27.2	35.9	42.9	40.5	36.1
Mother's Education <12 years							
Number	143	133	133	138	131	120	131
Percent of Total Births	29.9	31.1	30.4	29.4	26.1	26.3	28.6

Infant Deaths							
Number	3	*	3	*	*	3	*
Rate	6.2	*	6.6	*	*	6.1	*
Neonatal Deaths							
Number	*	0	3	*	0	3	*
Rate	*	0	6.6	*	0	6.1	*
Total Deaths							
Number	304	373	336	339	330	365	349
Age-Adjusted Rate	997.3	1053	930.2	917.9	871.1	938.1	940.1

Source: Health Statistics Section, Colorado Department of Public Health and Environment.

*indicates one or two events

Birth rates are per 1,000 total population.

Infant and neonatal mortality rates are per 1,000 live births. Infant death is death in the first year of life. Neonatal death is death occurring prior to the 28th day of life.

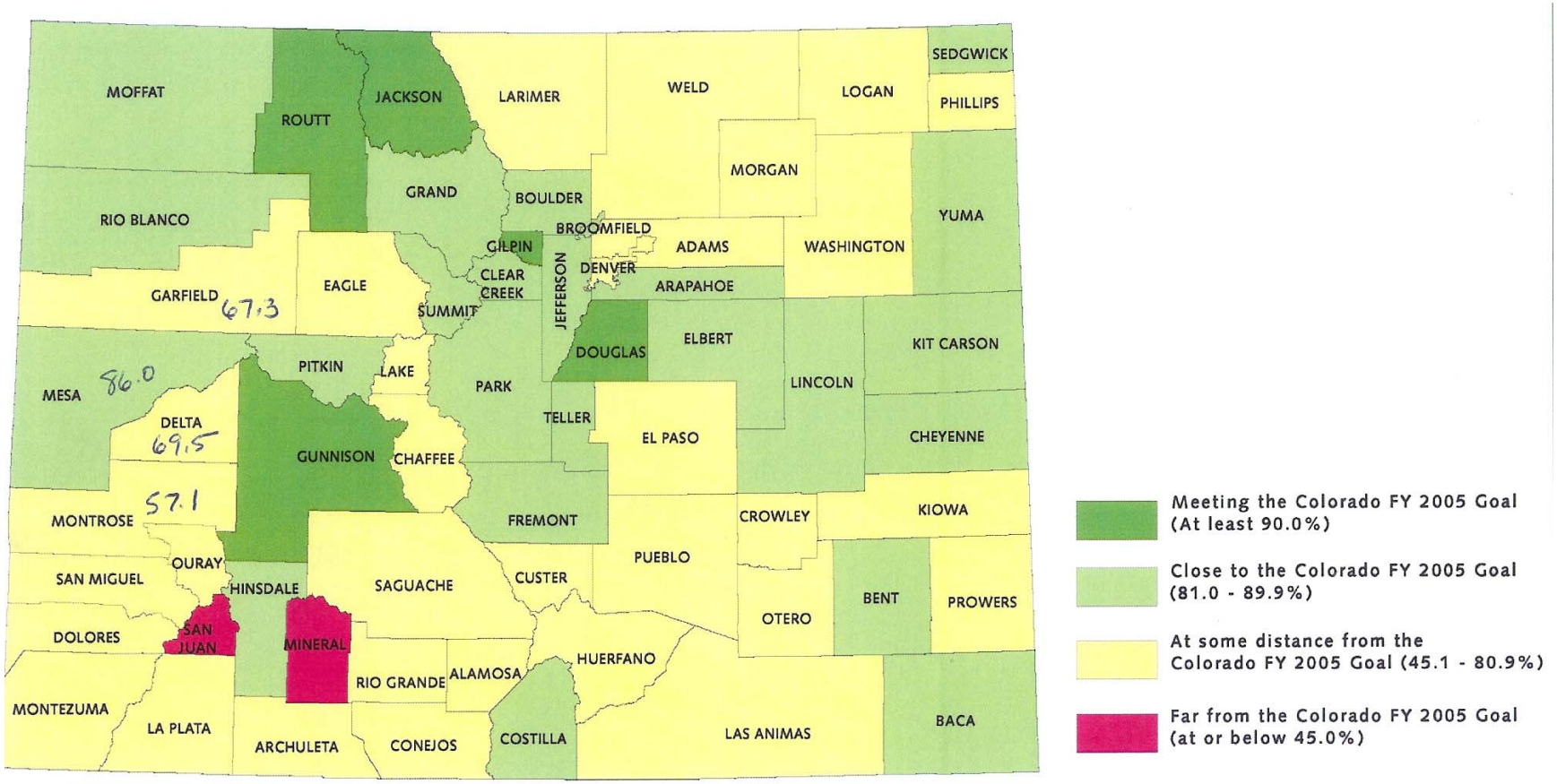
Total death rates are per 100,000 population.

Age-adjusted rates are adjusted to the 2000 U.S. population using the direct method applied to 10-year age groups.

Figure 20. First Trimester Prenatal Care by County (Percent)

Healthy People 2010 Goal: Increase the percent of infants born to pregnant women receiving prenatal care beginning in the first trimester to 90.0 percent.

County rates are for the year 2005. The state rate is 80.1 percent.



Colorado First Trimester Prenatal Care

Figure 21. Low Birth Weight by County (Percent)

Healthy People 2010 Goal: Reduce the low birth weight rate to an incidence of no more than 5.0 percent of all births. County rates are 2003-2005 three-year averages. The state rate is 9.1 percent.

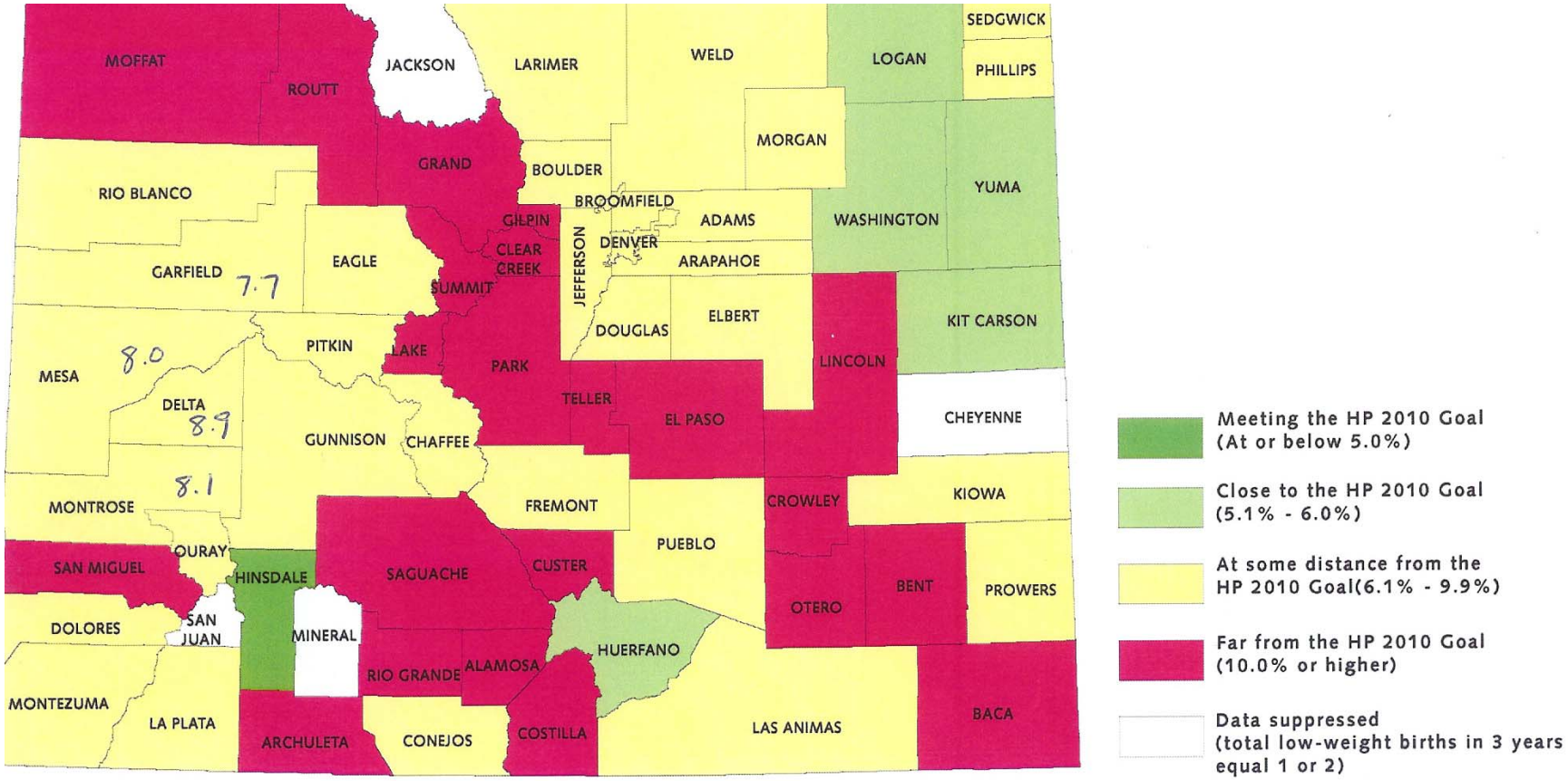


Figure 22. Very Low Birth Weight by County (Percent)

Healthy People 2010 Goal: Reduce the very low birth weight rate to an incidence of no more than 0.9 percent of all births. County rates are 2003-2005 three-year averages. The state rate is 1.3 percent.

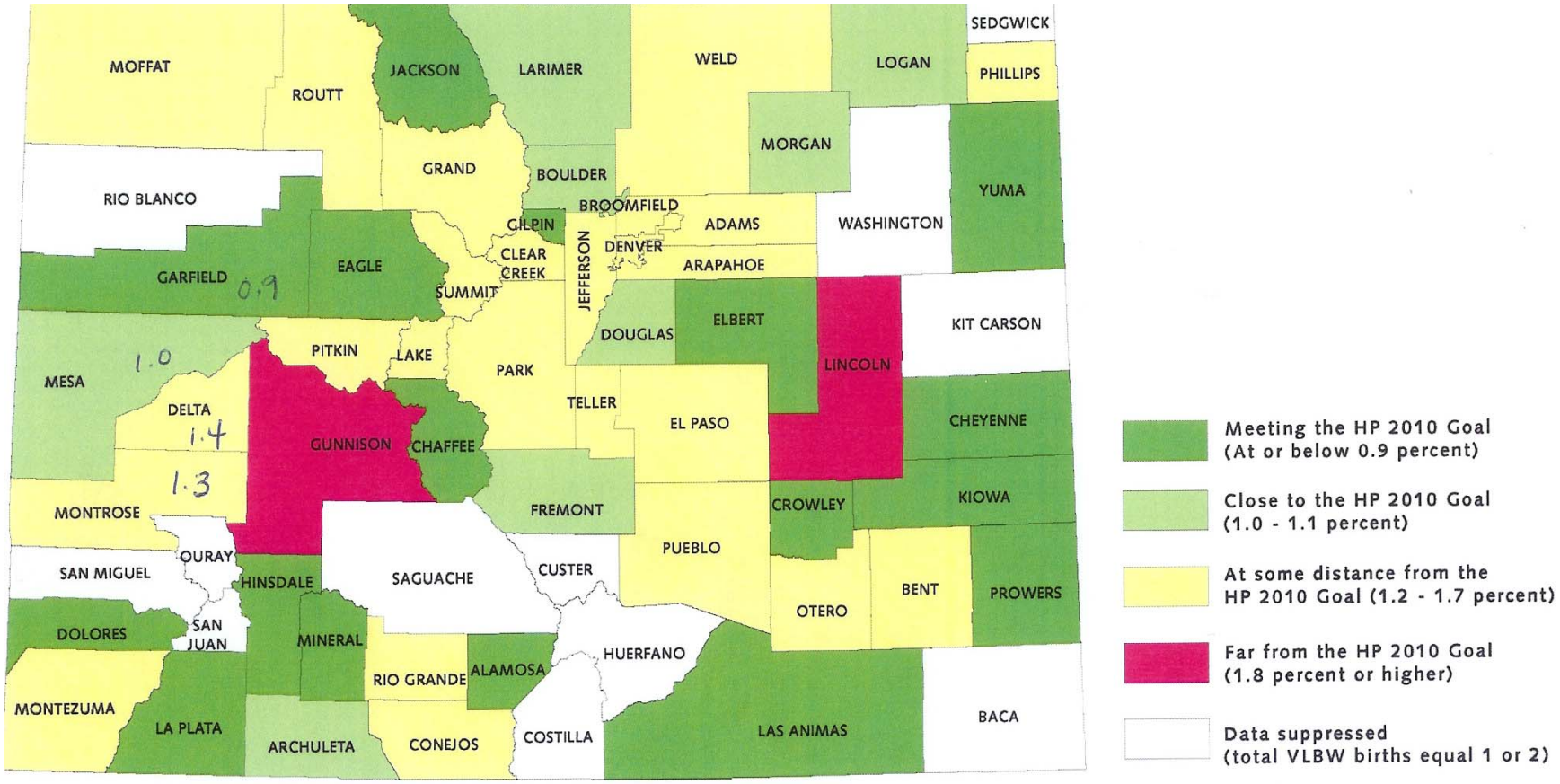


Figure 23. Neonatal Mortality by County (Rate per 1,000)

Healthy People 2010 Goal: Reduce the neonatal mortality rate to no more than 2.9 deaths per 1,000 births.
County rates are 2001-2005 five-year averages, except for Broomfield which is 2002-2005 only.
The state rate is 4.4.

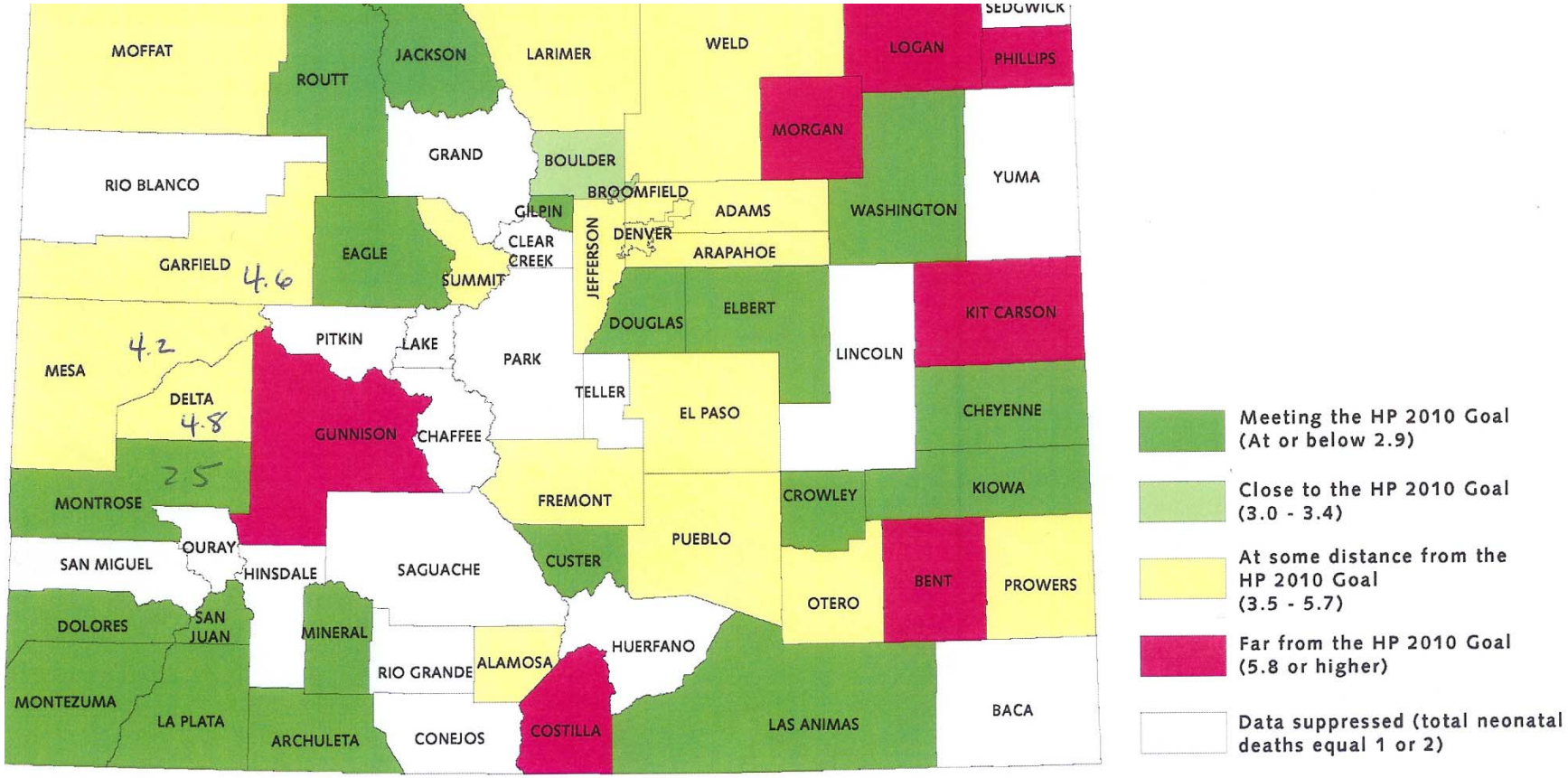
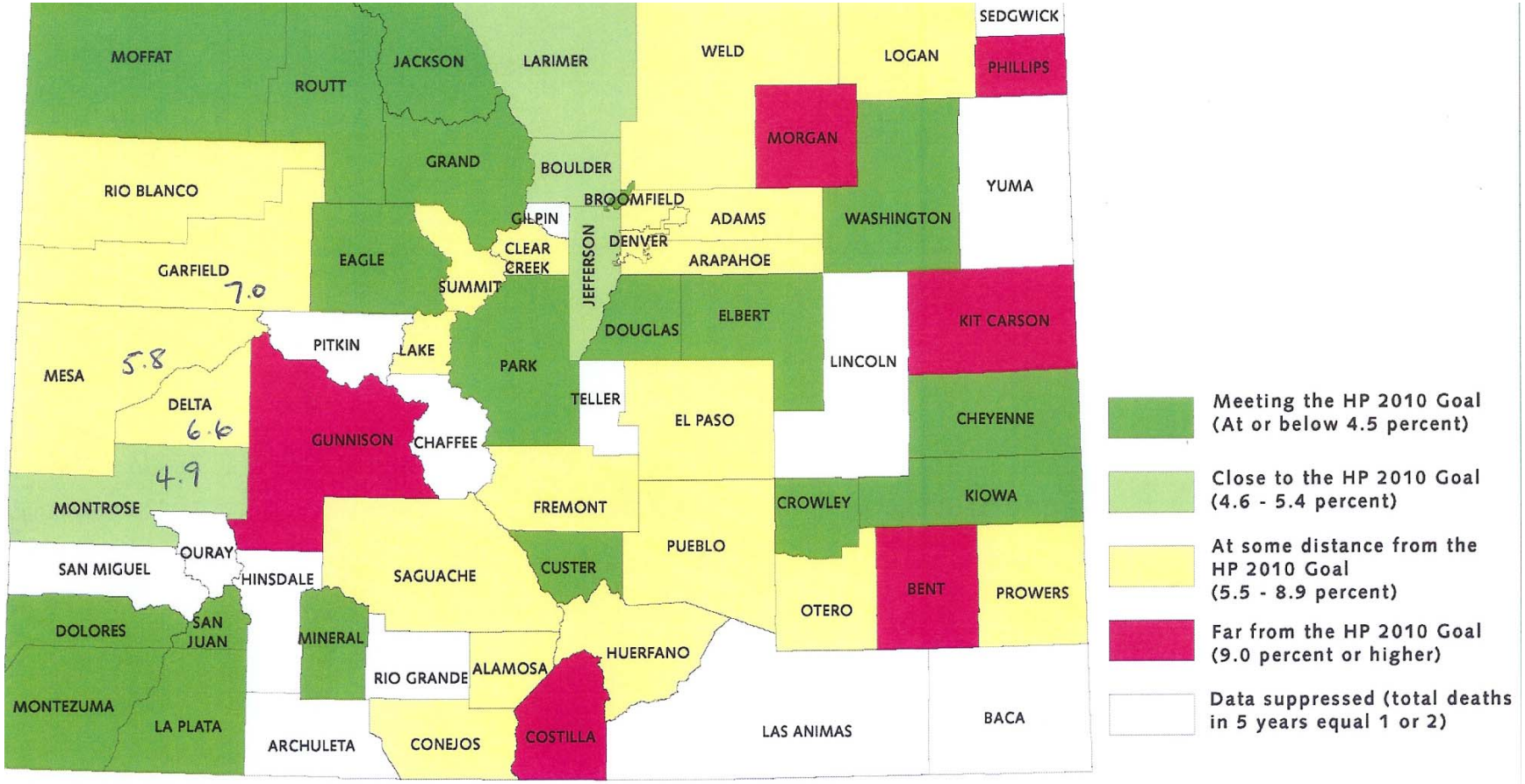


Figure 24. Infant Mortality by County (Rate per 1,000 births)

Healthy People 2010 Goal: Reduce the infant mortality rate to no more than 4.5 deaths per 1,000 births.
County rates are 2001-2005 five-year averages, except for Broomfield which is 2002-2005 only.
The state rate is 6.1.



Colorado Infant Mortality Rates

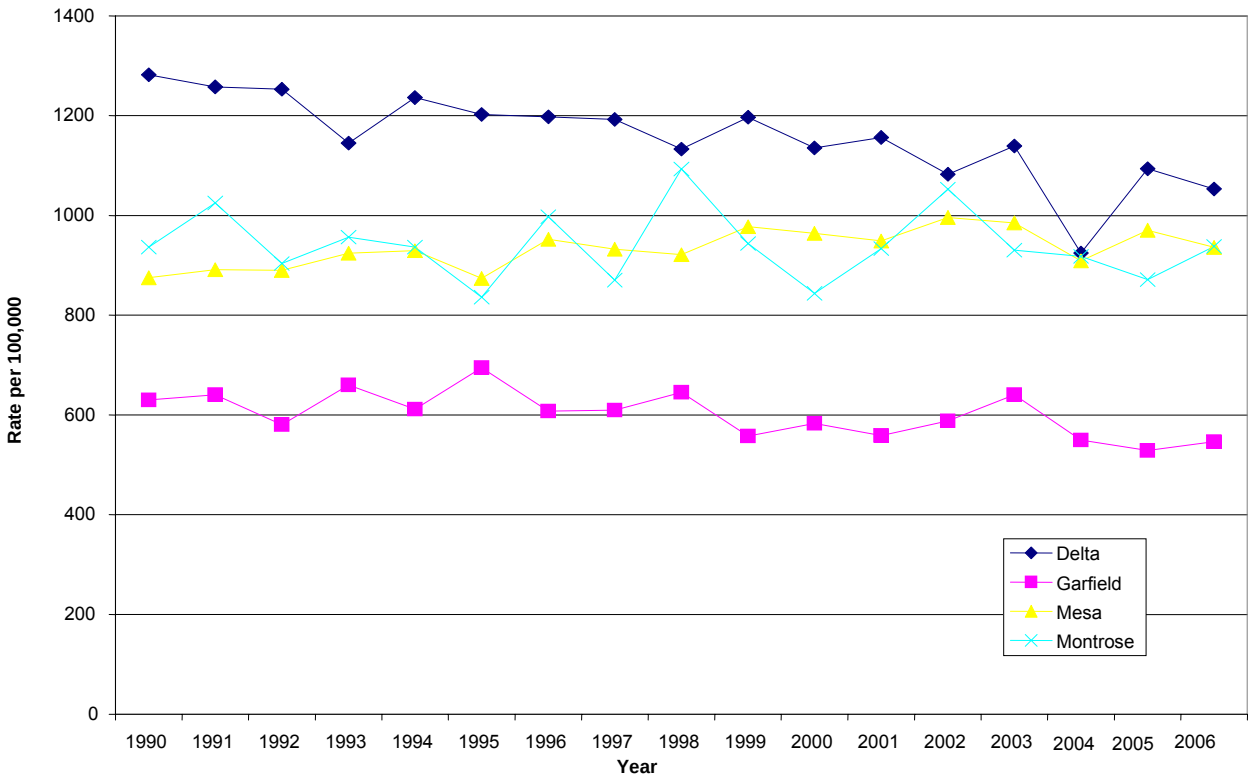
Table 14. Selected birth characteristics by County, 2006

County	Total Live Births	Age of Mother (%)				Low Birth Weight (%)	Very Low Birth Weight (%)
		10-17	18-19	20-29	30+	<2,500 grams	<1,500 grams
Delta	344	3.2	9.3	66.3	21.2	6.1	*
Garfield	945	3.3	7.5	59	30.2	7.3	1
Mesa	1,880	4.6	8.2	61.9	25.2	7.3	0.9
Montrose	493	3.9	8.3	59	28.8	6.5	2

*indicates one or two events

County	Prenatal Care (%)		Pre-term births (%)	Education of mother (%)	Smoking during Pregnancy (%)
	after 1st trimester	No care	<37 weeks	<12 years	
Delta	32.2	1.9	7.8	21.8	11.7
Garfield	36.7	1.8	8.5	28.9	13.8
Mesa	15.6	0.9	7.6	22.1	17.5
Montrose	40.5	0.8	9.1	24.3	8.9

Figure 25. Crude Total Death Rates - Delta, Garfield, Mesa, Montrose Counties



Average, annual, age-adjusted death rates by cause of death are shown in Figure 26 below for the four counties. Cardiovascular disease is the biggest cause of death in all four counties, followed by other heart-related disease and cancer. The rates among the four counties are similar. Please see the "Cause of death" table in Appendix K for the numbers of actual deaths by county and cause.

Figure 26. Average Annual Age-adjusted Death Rates by Cause, 2003-2006

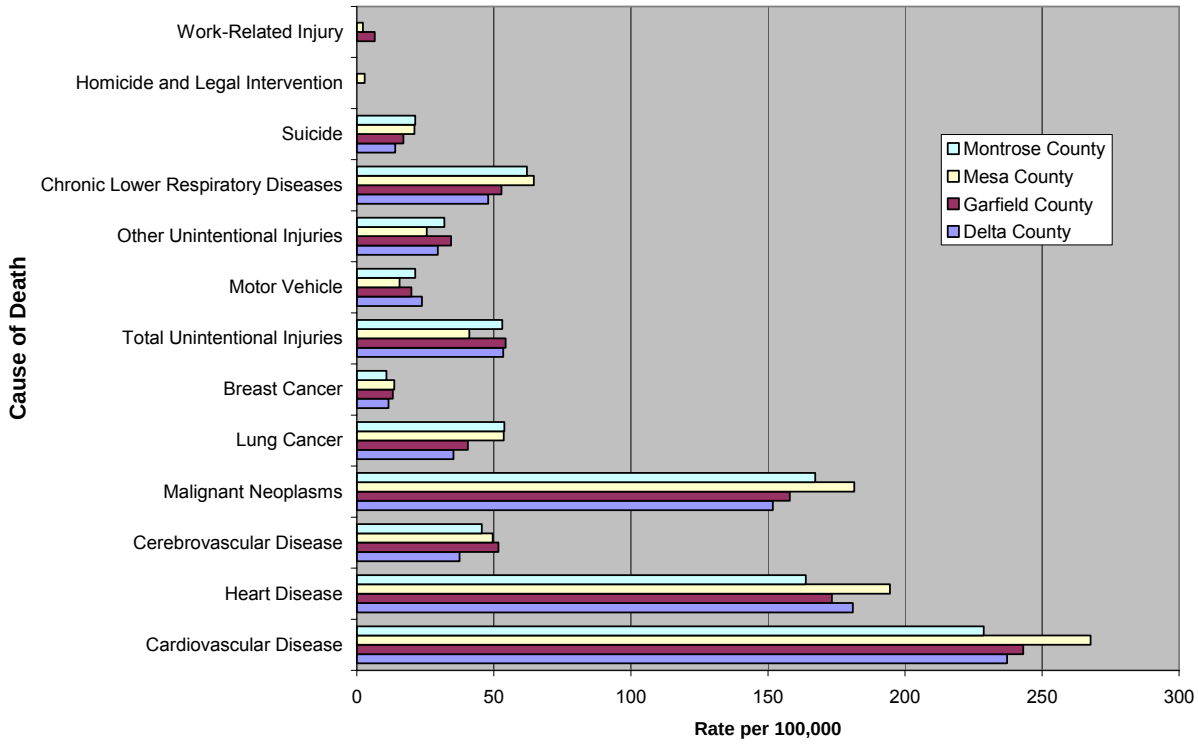


Table 15 provides information on the 2006 age-specific death rates for the four counties. The age distribution of deaths is similar.

Table 15. Age-specific death Rates by County – 2006

	Delta County			Garfield County		
Age	Deaths	Population	Age-Specific Death Rate	Deaths	Population	Age-Specific Death Rate
1-14	*	5,321	*	*	11,290	*
15-24	4	4,159	1	10	7,031	1.4
25-64	58	15,157	3.8	88	29,181	3.0
65+	259	5,708	45.4	187	4,497	41.6
All Ages	323	30,672	10.5	289	52,878	5.5

	Mesa County			Montrose County		
Age	Deaths	Population	Age-Specific Death Rate	Deaths	Population	Age-Specific Death Rate
1-14	7	24,507	0.3	0	7,636	0
15-24	19	21,127	0.9	6	5,342	1.1
25-64	263	68,064	3.9	60	19,480	3.1
65+	970	19,954	48.6	296	5,920	50
All Ages	1,268	135,473	9.4	36	38,908	9.4

*indicates one or two events

Age-adjusted rates are adjusted to the 2000 U.S. population using the direct method applied to 10-year age groups. Source: Health Statistics Section, Colorado Department of Public Health and Environment.

The figures on this page portray death rates by age group and gender for Garfield County residents over the period 1990 through 2006.

Figure 27. Death Rates for Garfield County Males by Age Groups

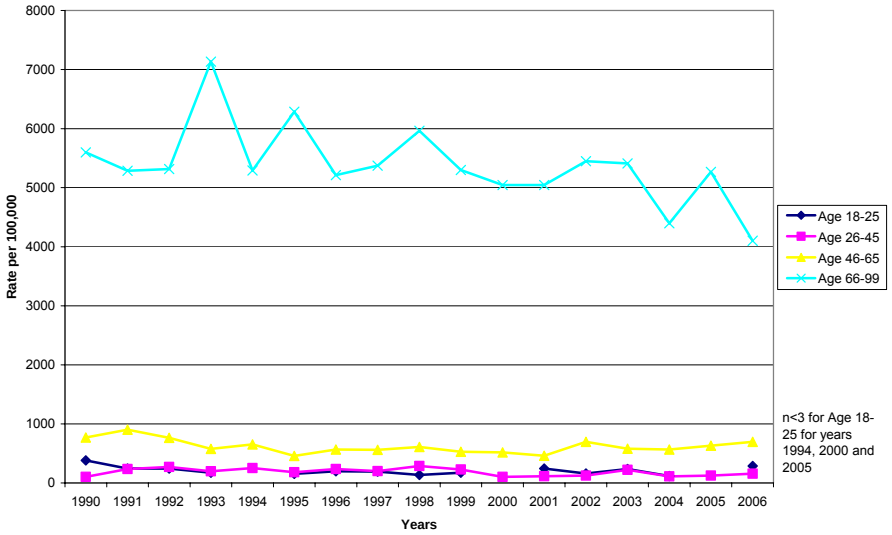
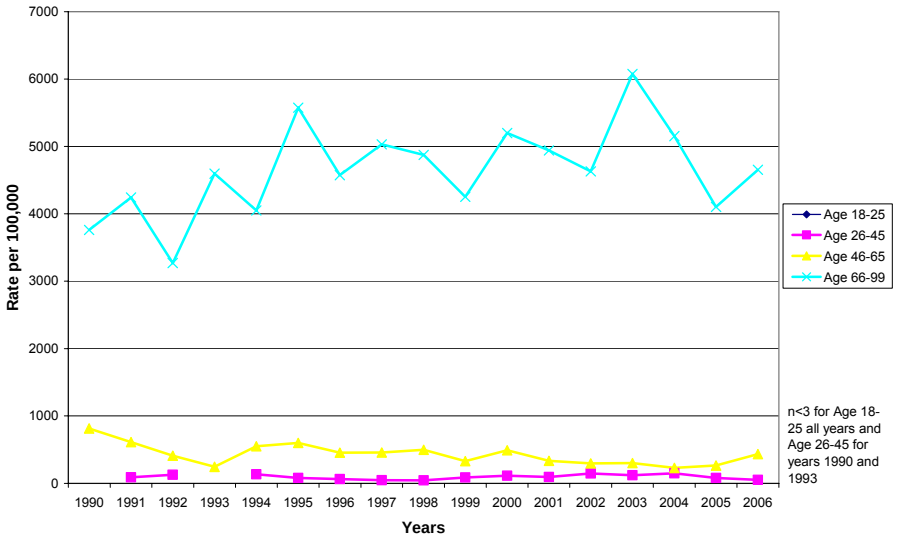


Figure 28. Death Rates for Garfield County Females by Age Groups

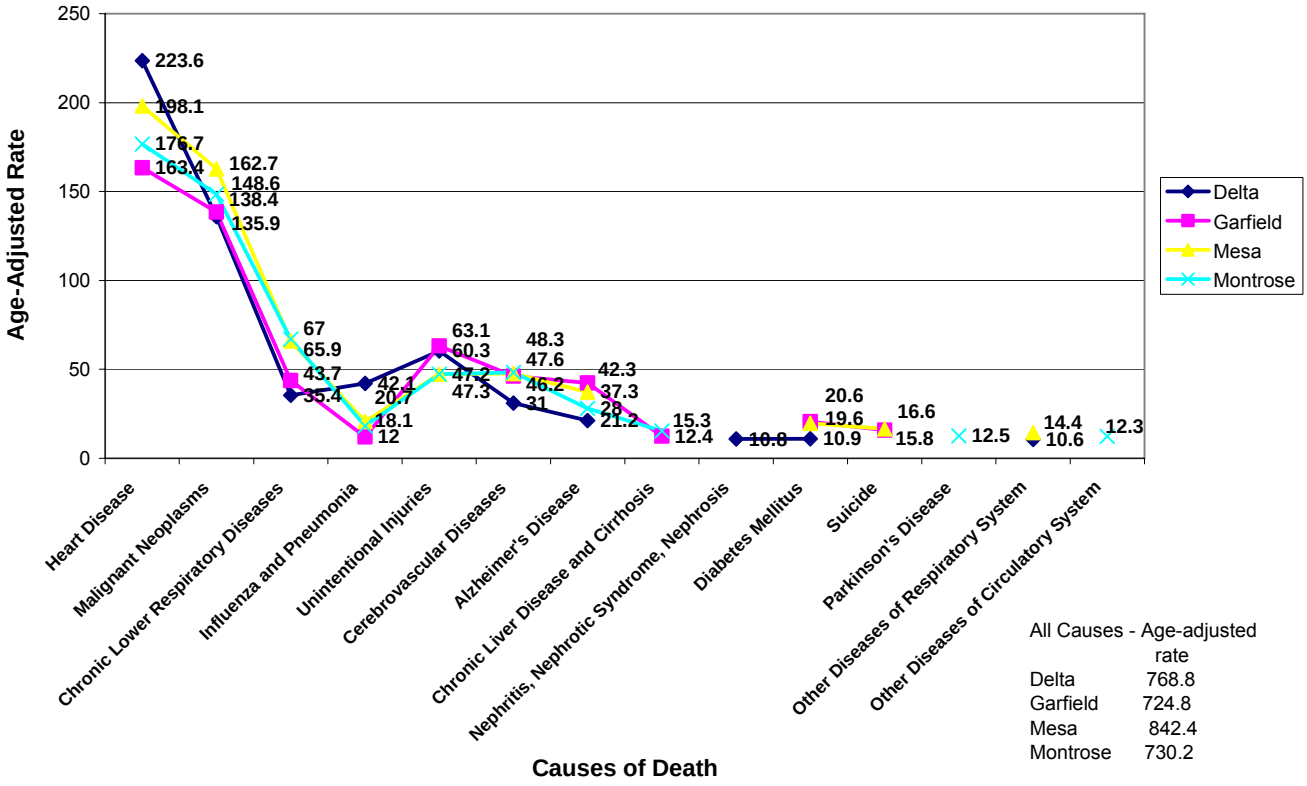


Appendix L provides statistical information on cause of death by race/ethnicity for 2006. Only data for "all races", non-Hispanic Whites and Hispanic Whites are shown in this table. Individuals with other racial or ethnic backgrounds are a relatively small percentage of the population of the four comparison counties, and thus, make a correspondingly small contribution to the overall death statistics. Generally speaking, the distribution of cause of death for Hispanic Whites is either lower than or similar to that of

non-Hispanic Whites in all counties. One notable exception is fact that unintentional injuries accounted for a higher percentage of total deaths for Hispanic Whites than for non-Hispanic Whites in Garfield County.

The figure below shows the leading causes of disease-related death by county for 2006.

Figure 29. Leading Causes of Death by County, 2006



Birth Defects

Birth defects data by county for the years 2000-2005 was obtained from "*Colorado Responds to Children with Special Needs (CRCSN)*, Colorado's birth defects monitoring and prevention program. This organization is located within the Colorado Department of Public Health and Environment. To be included in CRCSN, a child must be a Colorado resident diagnosed prenatally to three years of age with an eligible condition. Eligible conditions include medical conditions, medical risk factors for developmental delay, or one of two environmental (i.e., maternal) risk factors for delay. Children who meet these criteria are identified, using information from hospitals, vital records (birth, death, and fetal death certificates), from the Newborn Screening Program, the Newborn Hearing Screening Program, laboratories, physicians, and specialty clinics (e.g., genetic or developmental clinics)

Table 16 shows the number of live births identified in Garfield County by year of birth for the time period 2000-2005.

Table 16. Number of Resident Live Births in Garfield County: 2000-2005

YEAR	LIVE BIRTHS
2000	786
2001	782
2002	855
2003	871
2004	803
2005	816
Total	4,913

Table 17 shows that Garfield County's overall rates for major congenital anomalies (birth defects) are no higher than those observed for a comparison area of all counties in Colorado excluding Garfield County.

TABLE 17. RATES OF BIRTH DEFECTS 2000-2005

DIAGNOSIS CATEGORY	Garfield County					Colorado excluding Garfield County			
	Count	Rate	Lower Limit	Upper Limit		Count	Rate	Lower Limit	Upper Limit
MAJOR CONGENITAL ANOMALIES	261	531.2	470.2	597.7		21,445	532.6	525.7	539.6
CENTRAL NERVOUS SYSTEM	21	42.7	26.5	65.3		1,067	26.5	24.9	28.1
ANENCEPHALUS AND SIMLAR ANOMALIES	1	2.0	0.1	11.3		18	0.4	0.3	0.7
ENCEPALOCELE	1	2.0	0.1	11.3		27	0.7	0.4	1.0
MICROCEPHALUS	5	10.2	3.3	23.7		226	5.6	4.9	6.4
CONGENITAL HYDROCEPHALUS WITHOUT SPINA BIFIDA	8	16.3	7.0	32.1		281	7.0	6.2	7.8
EYE	7	14.2	5.7	29.3		599	14.9	13.7	16.1
MAJOR EYE	5	10.2	3.3	23.7		463	11.5	10.5	12.6
MICROPHTHALMOS	1	2.0	0.1	11.3		44	1.1	0.8	1.5
CONGENITAL CATARACT AND LENS ANOMALIES	1	2.0	0.1	11.3		130	3.2	2.7	3.8
CARDIOVASCULAR	103	209.6	171.4	253.7		7,231	179.6	175.5	183.7
MAJOR CARDIOVASCULAR	95	193.4	156.7	235.9		6,803	169.0	165.0	173.0
TRANSPOSITION OF GREAT VESSELS	3	6.1	1.3	17.8		147	3.7	3.1	4.3
COMMON VENTRICLE	1	2.0	0.1	11.3		34	0.8	0.6	1.2
VENTRICULAR SEPTAL DEFECT	28	57.0	37.9	82.3		1,670	41.5	39.5	43.5
OSTIUM SECUNDUM TYPE ATRIAL SEPTAL DEFECT	45	91.6	66.9	122.4		2,846	70.7	68.1	73.3
ENDOCARDIAL CUSHION DEFECTS	1	2.0	0.1	11.3		154	3.8	3.2	4.5
CONGENTIAL STENOSIS OF AROTIC VALVE	3	6.1	1.3	17.8		152	3.8	3.2	4.4
HYPOPLASTIC LEFT HEART SYNDROME	1	2.0	0.1	11.3		110	2.7	2.2	3.3
PULMONARY VALVE STENOSIS AND ATRESIA	4	8.1	2.2	20.8		430	10.7	9.7	11.7

TABLE 17 (CONTINUED). RATES OF BIRTH DEFECTS 2000-2005									
DIAGNOSIS CATEGORY	Garfield County					Colorado excluding Garfield County			
	Count	Rate	Lower Limit	Upper Limit		Count	Rate	Lower Limit	Upper Limit
COARCTATION OF AORTA	10	20.4	9.8	37.4		377	9.4	8.4	10.4
ANOMALIES OF PULMONARY ARTERY	16	32.6	18.6	52.8		1,029	25.6	24.0	27.2
RESPIRATORY	17	34.6	20.2	55.3		1,231	30.6	28.9	32.3
AGENESIS,HYPOPLASIA,DYSPLASIA OF LUNG	5	10.2	3.3	23.7		180	4.5	3.8	5.2
OROFACIAL	12	24.4	12.6	42.6		769	19.1	17.8	20.5
CLEFT PALATE WITHOUT CLEFT LIP	7	14.2	5.7	29.3		360	8.9	8.0	9.9
CLEFT LIP WITH/WITHOUT CLEFT PALATE	6	12.2	4.5	26.6		450	11.2	10.2	12.3
GASTROINTESTINAL	18	36.6	21.7	57.8		2,055	51.0	48.9	53.3
MAJOR GASTROINTESTINAL	15	30.5	17.1	50.3		1,810	45.0	42.9	47.1
TRACHEOESOPHAGEAL FISTULA, ESOPHAGEAL ATRESIA AND STENOSIS	1	2.0	0.1	11.3		182	4.5	3.9	5.2
CONGENITAL HYPERTROPHIC PYLORIC STENOSIS	4	8.1	2.2	20.8		665	16.5	15.3	17.8
ATRESIA,STENOSIS OF THE LARGE INTESTINE,RECTUM,ANAL CANAL	3	6.1	1.3	17.8		211	5.2	4.6	6.0
HIRSCHSPRUNG DISEASE AND OTHER COLON DISORDERS	2	4.1	0.5	14.7		89	2.2	1.8	2.7
GENITOURINARY	97	197.4	160.4	240.3		7,389	183.5	179.4	187.7
MAJOR GENITOURINARY	97	197.4	160.4	240.3		7382	183.3	179.2	187.5
RENAL AGENESIS AND DYSGENESIS	5	10.2	3.3	23.7		162	4.0	3.4	4.7
ARM/HAND LIMB REDUCTION	1	2.0	0.1	11.3		123	3.1	2.5	3.6
LEG/FOOT LIMB REDUCTION	1	2.0	0.1	11.3		59	1.5	1.1	1.9

Table 17 (continued). Rates of Birth Defects 2000-2005									
DIAGNOSIS CATEGORY	**Garfield County**					**Colorado excluding Garfield County**			
	Count	Rate	Lower Limit	Upper Limit		Count	Rate	Lower Limit	Upper Limit
REDUCTION DEFORMITY	2	4.1	0.5	14.7		172	4.3	3.7	5.0
ANOMALIES OF DIAPHRAGM (INC DIAPHRAGMATIC HERNIA)	2	4.1	0.5	14.7		136	3.4	2.8	4.0
ANOMLIES OF ABDOMINAL WALL	2	4.1	0.5	14.7		238	5.9	5.2	6.7
CHROMOSOMAL	15	30.5	17.1	50.3		1,131	28.1	26.5	29.8
TRISOMY 21 (DOWN SYNDROME)	3	6.1	1.3	17.8		529	13.1	12.0	14.3
TRISOMY 13 (INCLUDING PATAU SYNDROME)	1	2.0	0.1	11.3		35	0.9	0.6	1.2
TRISOMY 18 (INCLUDING EDWARDS SYNDROME)	2	4.1	0.5	14.7		40	1.0	0.7	1.4

Rates are per 10,000 live births / Lower and upper limits are 95% confidence limits based on a binomial distribution. Denominator: study area n=4,913 live births, Comparison Area n=402,643

Table 18 shows the major congenital anomaly rates by year of birth in Garfield County. These data do not indicate that the rate of major congenital anomalies was either increasing or decreasing over this time period (Cochran-Armitage Trend Test p=0.68).

Table 18. Major Congenital Anomaly Rates Garfield County : 2000-2005			
Year of birth	Number of Major Anomalies	Number of Births	Major Congenital Anomaly Rate
2000	36	786	458.0
2001	46	782	588.2
2002	53	855	619.9
2003	37	871	424.8
2004	38	803	473.2
2005	51	816	625.0
Total	261	4,913	531.2

Rates are per 10,000 live births

Child and Adolescent Health

The following table and maps provide information on how Garfield County ranks relative to the comparison counties and the State of Colorado on selected measures of child and adolescent health. We chose to look at some of these measures because of concerns expressed during focus group discussions with Garfield County human services providers, school district personnel, healthcare providers, and citizens about these important determinants of health. (Please see the *Qualitative Data* section, above.)

The following measures are portrayed in Table 19:

Teen Fertility. This measure is the rate of births per 1,000 teens ages 15-17 for 2003-2005. The numerator is the total number of births to teens in 2003, 2004, and 2005. The denominator is the sum of the estimated population of females ages 15 through 17 for the same years. The result is multiplied by 1,000 to obtain the average rate for the 3-year period. Data are calculated by the county of residence of the teen. DS indicates data that are suppressed for confidentiality when the numerator or denominator has a value of 1 or 2. The national, *Healthy People 2010* goal refers to pregnancies, not births. The Colorado 2010 goal is 21 births per 1,000 teens. Data source: Numerator -- Health Statistics and Vital Records, Colorado Department of Public Health and Environment. Denominator -- Demography Section, Colorado Department of Local Affairs.

Teen Injury Hospitalizations. This measure is the rate of hospitalization for injuries per 100,000 teens ages 15-19 for the period 2000-2005. The numerator is the sum of all hospitalizations for injuries of teens ages 15-19 in 2000, 2001, 2002, 2003, 2004, and 2005. The denominator is the sum of the estimated population of teens ages 15 through 19 for the same years. The result is multiplied by 100,000 to yield the average rate for the 6-year period. Rates can be affected by small numbers, and caution should be used with these data. While there is no *Healthy Persons 2010 goal* for this measure, the Colorado 2010 goal is a rate of 450.0. Data Source: Injury Epidemiology, Prevention Services Division, Colorado Department of Public Health and Environment.

Teen Suicide. This measure is the rate of suicide deaths per 100,000 teens ages 15-19 for 2001-2005. The numerator is the total number of teen suicide deaths in 2001, 2002, 2003, 2004, and 2005. The denominator is the sum of the estimated population of teens ages 15 through 19 for these same years. The result is multiplied by 100,000 to obtain the average rate for the five-year period. DS indicates that data are suppressed for confidentiality when the numerator or denominator has a value of 1 or 2. Data Source: Numerator -- Health Statistics and Vital Records, Colorado Department of Public Health and Environment. Denominator -- Demography Section, Colorado Department of Local Affairs.

Teen Motor Vehicle Deaths. This measure is the rate of deaths per 100,000 teens ages 15-19 that were caused by motor vehicle crashes for 2003-2005. The numerator is the total number of deaths to teens in 2003, 2004, and 2005. The result is multiplied by 100,000 to obtain the average rate for the 3-year period. DS indicates that data are suppressed for confidentiality when the numerator or denominator has a value of 1 or 2. Data Source: Numerator -- Health Statistics and Vital Records,

Colorado Department of Public Health and Environment. Denominator -- Demography Section, Colorado Department of Local Affairs.

Child Abuse. This measure is the rate of maltreatment (including physical abuse, sexual abuse, emotional abuse and/or neglect) of children younger than18 in calendar year 2005. The value shown reflects the number of unique substantiated cases per 1,000 children less than 18 years of age in a county. Data source: Numerator – Colorado Central Registry, Colorado Department of Human Services. Denominator – Demography Section, Colorado Department of Local Affairs.

Child Deaths. This measure is the rate of child deaths per 100,000 children ages 1-14 for 2001-2005. The numerator is the sum of all child deaths among children ages 1 through 14 in 2001, 2002, 2003, 2004 and 2005. The result is multiplied by 100,000 to obtain the average five-year rate for child deaths. While there is no *Healthy People 2010* goal for this measure, the Colorado goal is 19.0. Data Source: Health Statistics and Vital Records, Colorado Department of Public Health and Environment. Denominator -- Demography Section, Colorado Department of Local Affairs.

Child Motor Vehicle Deaths. This measure is the rate of deaths per 100,000 children ages 0-14 caused by motor vehicle crashes for 2003-2005. The numerator is the sum of all deaths among children ages 0-14 in 2003, 2004, and 2005. The denominator is the sum of the estimated population of children ages 0 through 14 for the same years. The result is multiplied by 100,000 to obtain the average 3-year rate for child motor vehicle deaths. DS indicates data are suppressed for confidentiality when the numerator or denominator has a value of 1 or 2. The *Healthy People 2010* goal is for ages, not specifically for ages 0-14. Data Source: Health Statistics and Vital Records, Colorado Department of Public Health and Environment. Denominator -- Demography Section, Colorado Department of Local Affairs.

Child Injury Hospitalizations. This measure is the rate of hospitalization for injuries per 100,000 children ages 0-14 for 2000-2005. The numerator is the sum of all hospitalizations for injuries of children ages 0-14 in 2000, 2001, 2003, 2003, 2004 and 2005. The denominator is the sum of the estimated population ages 0 through 14 for the same years. The result is multiplied by 100,000 to obtain the average 6-year rate for child injury hospitalizations. Rates can be affected by small numbers, and caution should be used with these data. While there is no *Healthy People 2010* goal for this measure, the Colorado 1020 goal is a rate of 150.0. Data Source: Injury Epidemiology, Prevention Services Division, Colorado Department of Public Health and Environment.

Children with Social Emotional Difficulties. This measure is the estimated percent of children ages 1-14 who have difficulties with emotions, concentration, behavior, or being able to get along with other people. The data combine two years of results from the Colorado Child Health Survey and are specific to children ages 1 through 14 in Colorado in 2004-2005. Numerators and denominators are not provided. Data for Garfield and Mesa Counties are Planning and Management Region data. No data are available for Delta and Montrose Counties. Data Source: Child Health Survey, Health Statistics Section, Colorado Department of Public Health and Environment.

Dental Care Received. This measure is the estimated percent of children ages 1-14 who received needed dental care in the 12 months before the survey. The data combine two years of results from the Colorado Child Health Survey and are specific to children age 1 through 14 living in Colorado in 2004-2005. Numerators and denominators are not provided. Planning and Management Region data are used for Garfield and Mesa Counties. No data are available for Delta and Montrose Counties. There are no *Healthy People 2010* or Colorado goals for this measure. Data Source: Child Health Survey, Health Statistics Section, Colorado Department of Public Health and Environment.

Health Insurance Coverage. This measure is the estimated percent of children ages 1-14 who had any kind of health care coverage, including health insurance, pre-paid plans, or government plans. The data combine two years of results from the Colorado Child Health Survey and are specific to children ages 1 through 14 living in Colorado in 2004-2005. Planning and Management Region data are shown for Garfield and Mesa Counties. No data are available for Delta and Montrose Counties. Numerators and denominators are not provided. Data Source: Child Health Survey, Colorado Department of Public Health and Environment.

Medical Care Received. This measure is the estimated percent of children ages 1-14 who received all the medical care they needed in the 12 months before the survey. The data combine two years of results from the Colorado Child Health Survey and are specific to children ages 1 through 14 living in Colorado in 2004-2005. Planning and Management Region data are shown for Garfield and Mesa Counties. No data are available for Delta and Montrose Counties. Numerators and denominators are not provided. There are no *Healthy People 2010* or Colorado 2010 goals for this measure. Data Source: Child Health Survey, Colorado Department of Public Health and Environment.

Personal Doctor or Nurse. This measure is the estimated percent of children ages 1-14 who have a personal doctor or nurse. The data combine two years of results from the Colorado Child Health Survey and are specific to children ages 1 through 14 living in Colorado in 2004-2005. Planning and Management Region data are shown for Garfield and Mesa Counties. No data are available for Delta and Montrose Counties. Numerators and denominators are not provided. There are no *Healthy People 2010* or Colorado 2010 goals for this measure. Data Source: Child Health Survey, Colorado Department of Public Health and Environment.

Overweight. This measure is the percentage of children, ages 2-14, who's BMI (body mass index) is at or above 85 percent of normal weight for height. The data combine two years of results from the Colorado Child Health Survey and are specific to children ages 1 through 14 living in Colorado in 2004-2005. Planning and Management Region data are shown for Garfield and Mesa Counties. No data are available for Delta and Montrose Counties. Numerators and denominators are not provided. Data Source: Child Health Survey, Health Statistics Section, Colorado Department of Public Health and Environment.

Table 19. Child and Adolescent Health by County

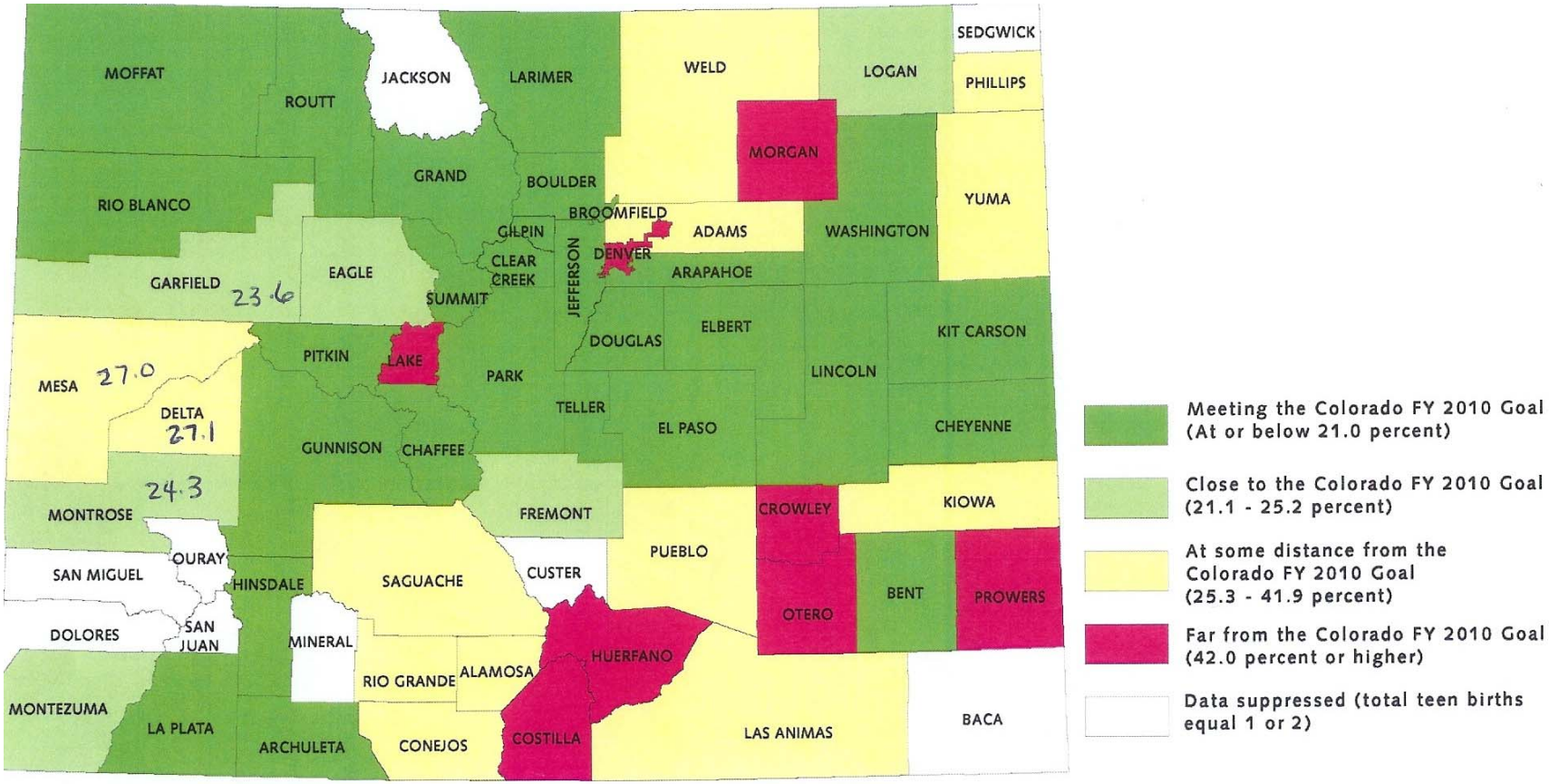
Measure	Delta County			Garfield County		
	Numerator	Denominator	County Measure	Numerator	Denominator	County Measure
Teen Fertility (15-19)	52	1,921	27.1	77	3,258	23.6
Teen Injury Hospitalizations (15-19)	95	12,476	761.5	134	21,175	632.8
Teen Suicide	4	10,752	37.2	0	18,185	12.1
Teen Motor Vehicle Deaths (15-19)	DS	6,510	DS	3	11,059	27.1
Child Abuse	46	6,933	6.6	78	13,833	5.6
Child Deaths (1-14)	9	26,204	34.3	18	50,698	35.5
Child Motor Vehicle Deaths (0-14)	N/A	N/A	N/A	N/A	N/A	91.9
Injury Hospitalizations (0-14)	93	33,264	279.6	121	64,738	186.9
Children with Social Emotional Difficulties	N/A	N/A	N/A	N/A	N/A	34.5
Dental Care Received	N/A	N/A	N/A	N/A	N/A	79.5
Health Insurance Coverage	N/A	N/A	N/A	N/A	N/A	79.5
Medical Care Received	N/A	N/A	N/A	N/A	N/A	98.4
Personal Doctor or Nurse	N/A	N/A	N/A	N/A	N/A	76.8
Overweight	N/A	N/A	N/A	N/A	N/A	16.3

	Mesa County	Montrose County	Colorado	People 2010

Measure	Numerator	Denominator	County Measure	Numerator	Denominator	County Measure		Goal
Teen Fertility (15-19)	224	8,284	27	59	2,430	24.4	24.4	43
Teen Injury Hospitalizations (15-19)	464	58,924	787.5	81	16,021	505.6	573.3	N/A
Teen Suicide	7	50,268	13.9	DS	13,661	DS	12.1	5
Teen Motor Vehicle Deaths (15-19)	7	30,520	22.9	4	8,168	49	26.2	9.2
Child Abuse	412	31,026	13.3	76	9,630	7.9	9.2	10.3
Child Deaths (1-14)	26	115,227	22.6	7	36,012	19.4	20	N/A
Child Motor Vehicle Deaths (0-14)	N/A	N/A	91.9	N/A	N/A	N/A	91.6	N/A
Injury Hospitalizations (0-14)	364	146,958	247.7	73	45,499	160.4	198.3	N/A
Children with Social Emotional Difficulties	N/A	N/A	34.5	N/A	N/A	N/A	28.9	N/A
Dental Care Received	N/A	N/A	79.5	N/A	N/A	N/A	87.9	100
Health Insurance Coverage	N/A	N/A	79.5	N/A	N/A	N/A	87.9	100
Medical Care Received	N/A	N/A	98.4	N/A	N/A	N/A	98.5	N/A
Personal Doctor or Nurse	N/A	N/A	76.8	N/A	N/A	N/A	77.6	N/A
Overweight	N/A	N/A	16.3	N/A	N/A	N/A	14.5	5

Figure 30. Teen Fertility (Ages 15-17)

Colorado FY2010 Goal: Reduce fertility rate among females age 15-17 to 21.0 births per 1,000 females.



County rates are for 2003-2005 three-year averages. The state rate is 40.9.

Figure 31. Teen Injury Hospitalizations

Colorado FY2010 Goal: Reduce the rate of injury hospitalization among children age 15-19 to 450.0 per 100,000.

County rates are 2000-2005 six-year averages, except for Broomfield which is averaged over the three-year period 2004-2005. The Colorado rate is 573.3.

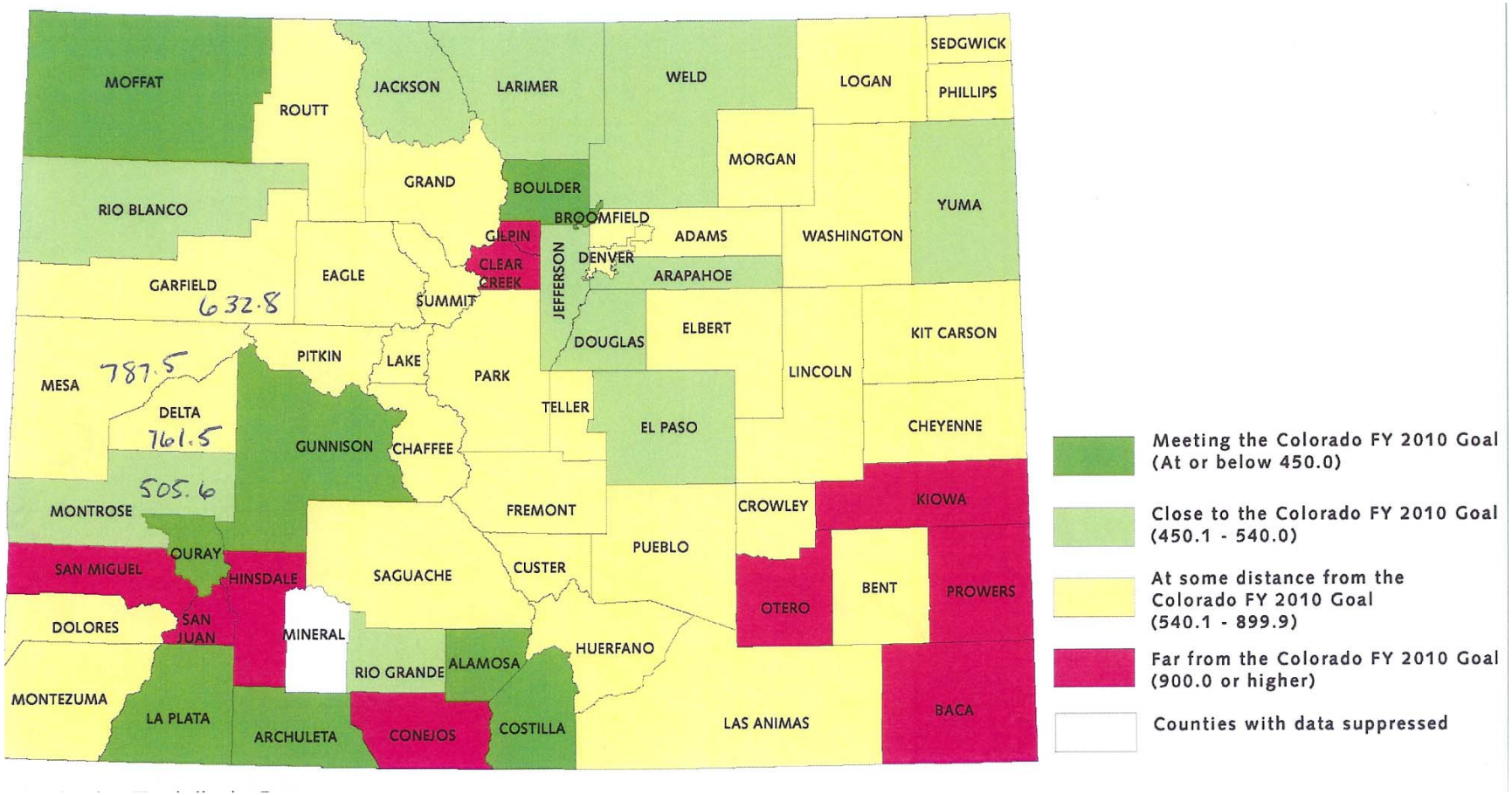


Figure 32. Teen Motor Vehicle Deaths (Ages 15-19)

Healthy People 2010 Goal: Reduce the rate of deaths among adolescents age 15-19 caused by motor vehicle crashes to no more than 9.2 deaths per 100,000 teens.

County rates are 2004-2005 three-year averages. The state rate is 26.2.

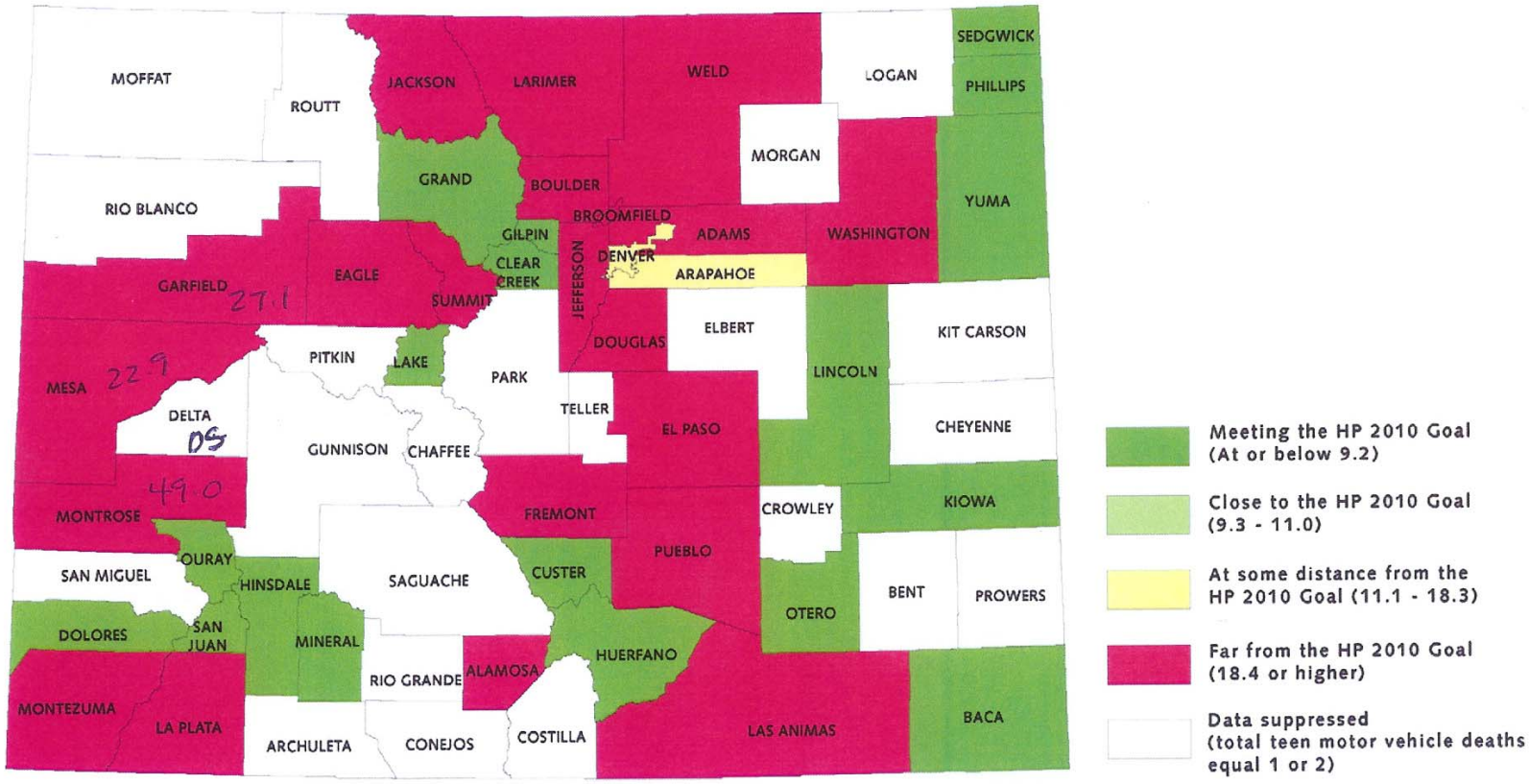
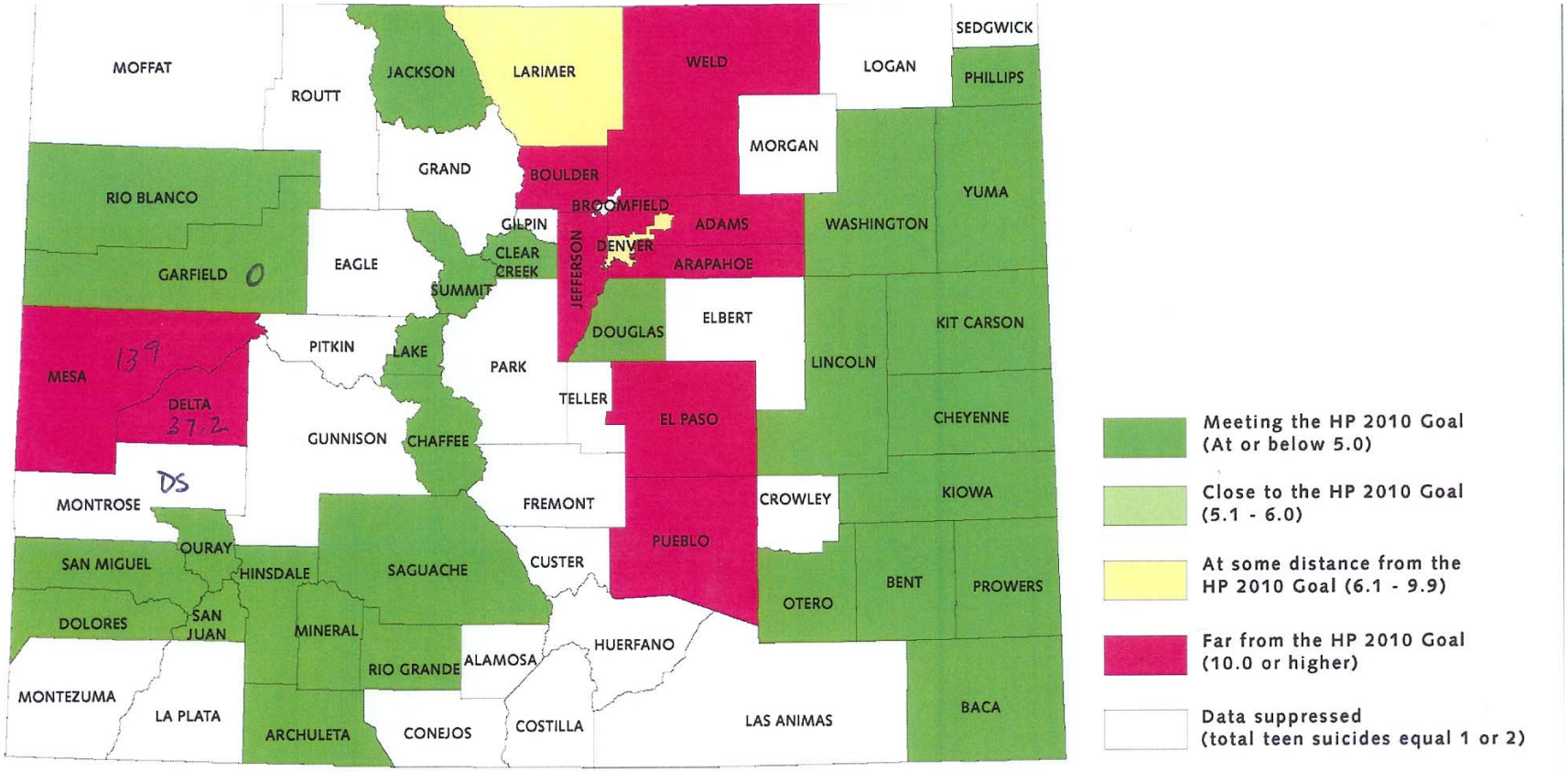


Figure 33. Teen Suicide (Ages 15-19)

Healthy People 2010 Goal: Reduce suicides to no more than 5.0 per 100,000 youth aged 15-19.

County rates are 2001-2005 five-year averages, except for Broomfield which is 2002-2005 only.

The state rate is 12.1.



Colorado Teen Suicide Rates

Figure 34. Child Abuse (Number per 1,000)

Healthy People 2010 Goal: Reduce the incidence of maltreatment of children younger than 18 (including physical abuse, sexual abuse, emotional abuse, and/or neglect) to 10.3 or below.

County rates are for calendar year 2005. The state rate is 9.2 per 1,000.

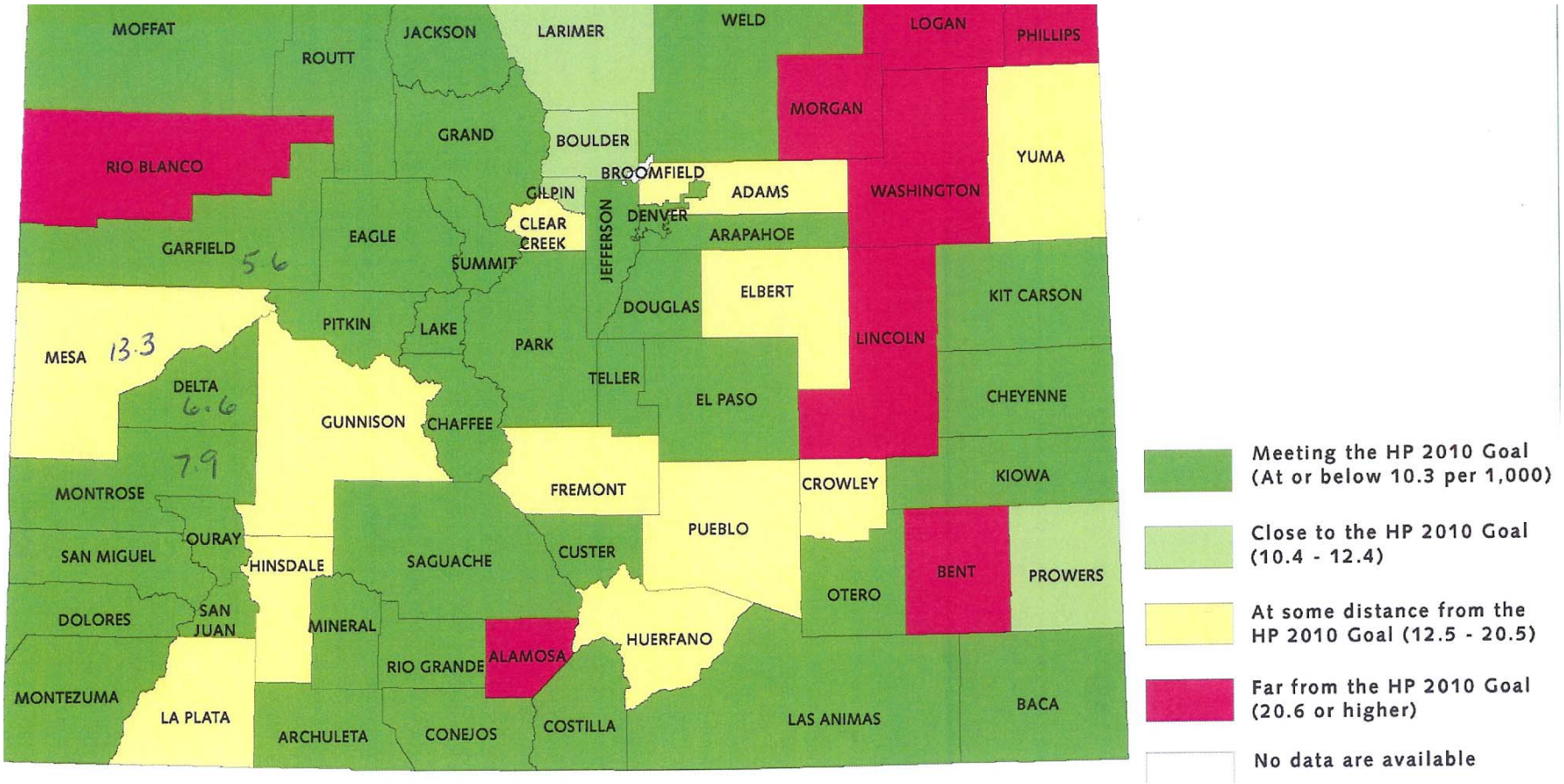
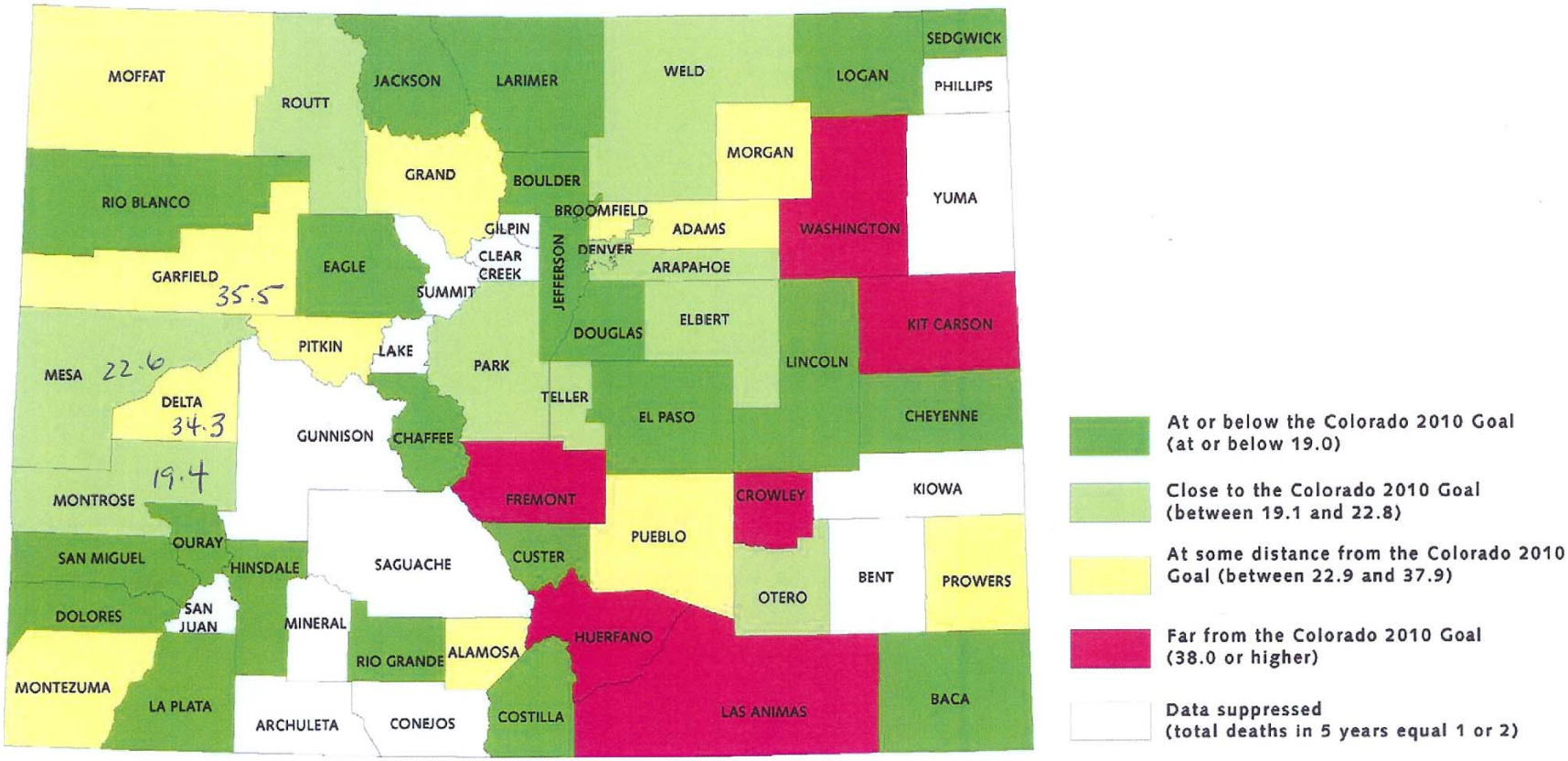


Figure 35. Child Deaths (Ages 1-14)
Number per 100,000

Colorado 2010 Goal: Reduce the death rate of children to no more than 19.0 deaths per 100,000 children aged 1-14.

County rates are 2001-2005 five-year averages, except for Broomfield which is 2002-2005 only.

The state rate is 20.0.



Injury-Related Hospitalizations and Deaths

The Colorado Department of Public Health and Environment tracks injury-related hospitalizations. Although there are many ways by which these data may be sorted and reported (e.g., by age, gender, mechanism of injury, etc.), for the purposes of this report, we have chosen to review only a couple of categories by county: injury hospitalizations by intent, and injury hospitalizations by injury type. Tables 20a and 20b and the accompanying graphs show the relationship of Garfield County to the state and comparison counties in these categories.

Table 20A. Injury Hospitalizations by County, 2001 - 2003
Total – Intention Categories
Age-Adjusted Rates per 100,000

	Total Hospitalizations	Unintentional Injury	Intentional Injury
Delta	812.6*	721.2*	61.9**
Garfield	654.9	574.4	57.3**
Mesa	746.1*	579.2	153.6*
Montrose	607.4**	514.8**	71.6
Colorado	694.0	591.6	81.5

*significantly higher than Colorado rate
**significantly lower than Colorado rate

Figure 36.

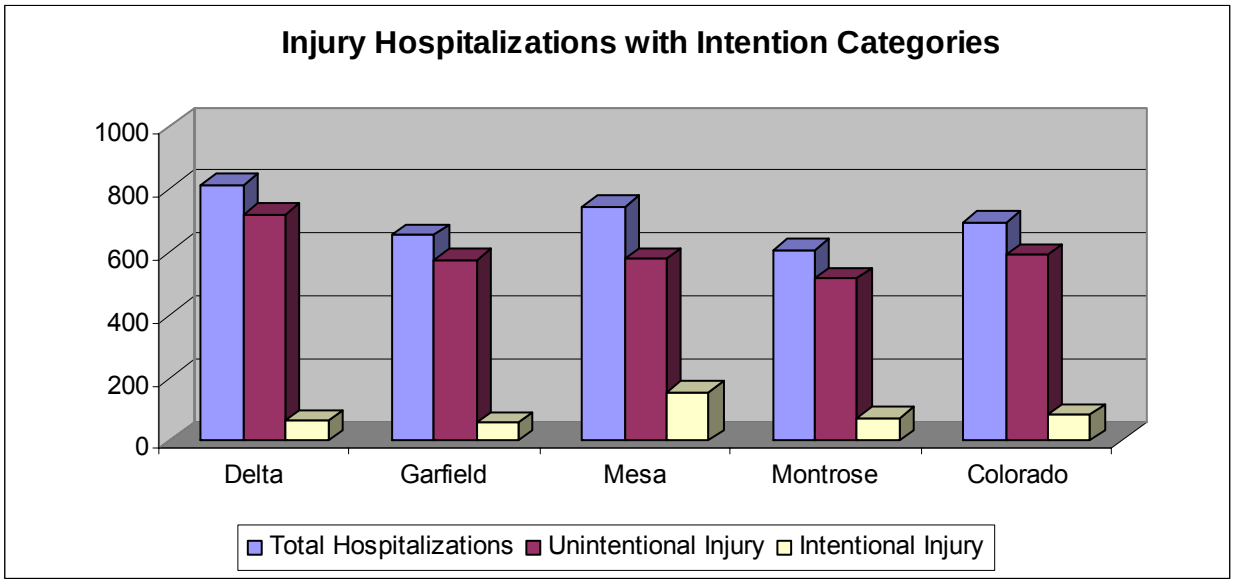
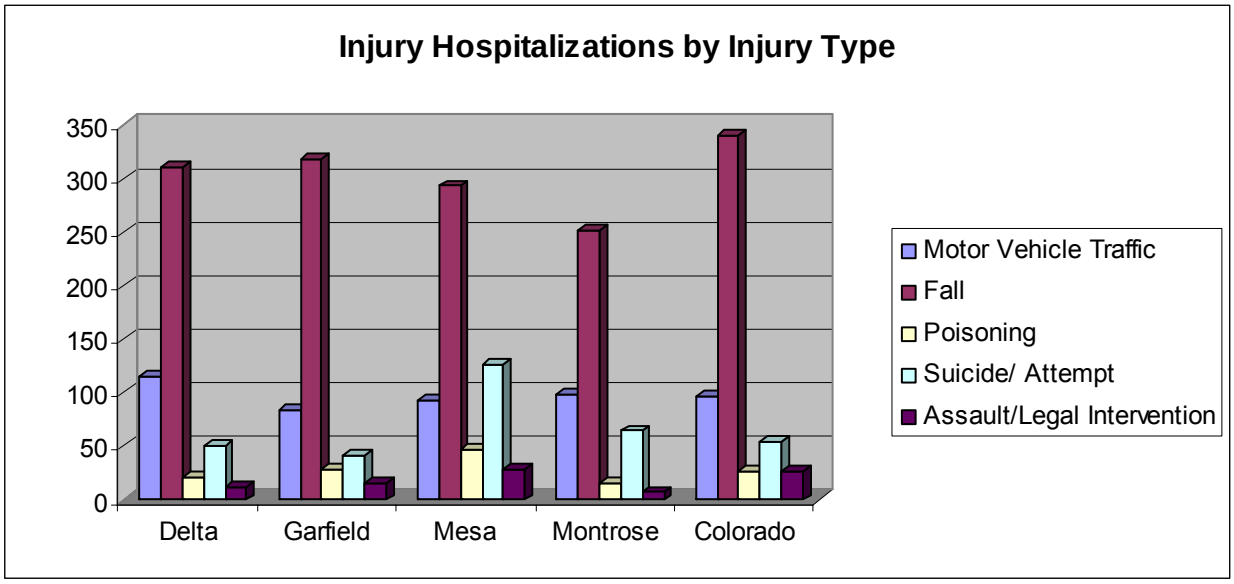


Table 20B. Injury Hospitalizations by County, 2001 - 2003
Total – Injury Type
Age-Adjusted Rates per 100,000

	Motor Vehicle Traffic	Fall	Poisoning	Suicide/ Attempt	Assault/Legal Intervention
Delta	114.4	309.7	20.8	50.8	12.4**
Garfield	83.2	318.4	28.2	41.9**	15.4**
Mesa	93.5	292.8**	46.5*	126.2*	28.0
Montrose	98.9	252**	15.8**	64.3	7.3**
Colorado	96.5	340.6	26.7	54.7	27.1

*significantly higher than Colorado rate
**significantly lower than Colorado rate

Figure 37.



Similarly, the CDPHE records and tracks injury-related deaths. For the purposes of this report, county and state comparisons are shown only for "injury deaths by intention" and "injury deaths by injury type. This information is presented in Tables 21a and 21b and the accompanying graphs.

Table 21A. Injury Deaths by County, 2001 - 2003
Total – Intention Categories
Age-Adjusted Rates per 100,000

	Total Injury Deaths	Unintentional Injury	Intentional Injury
Delta	76.9	47.4	28.1
Garfield	82*	56.1*	22.0
Mesa	65.6	38.2	21.8
Montrose	82.3	57.2*	24.0
Colorado	63.9	41.6	20.1

*significantly higher than Colorado rate
**significantly lower than Colorado rate

Figure 38.

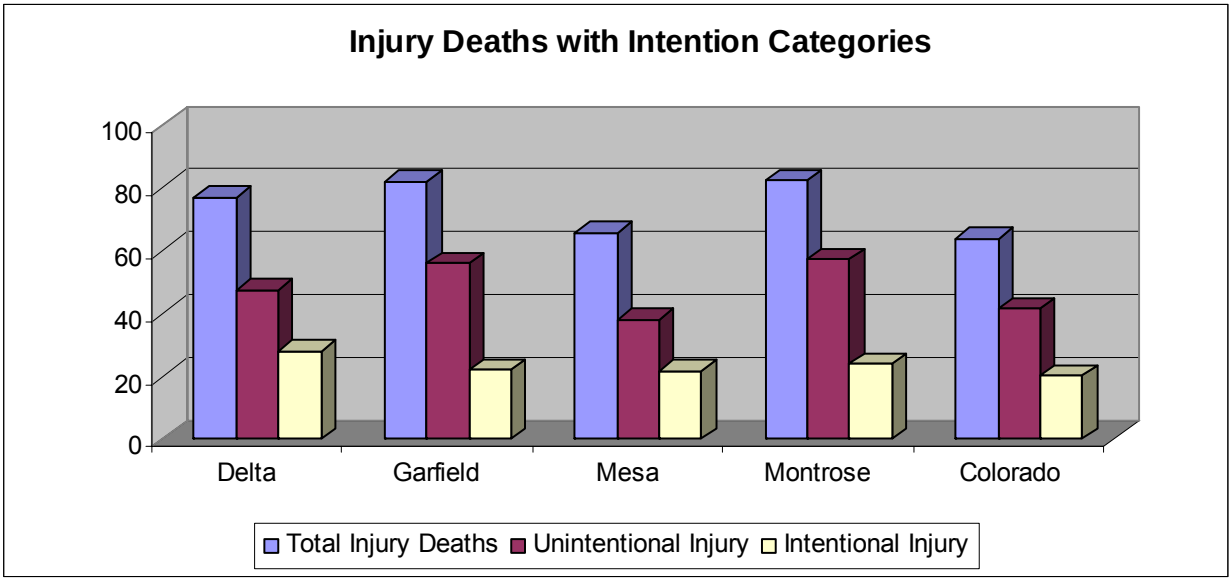
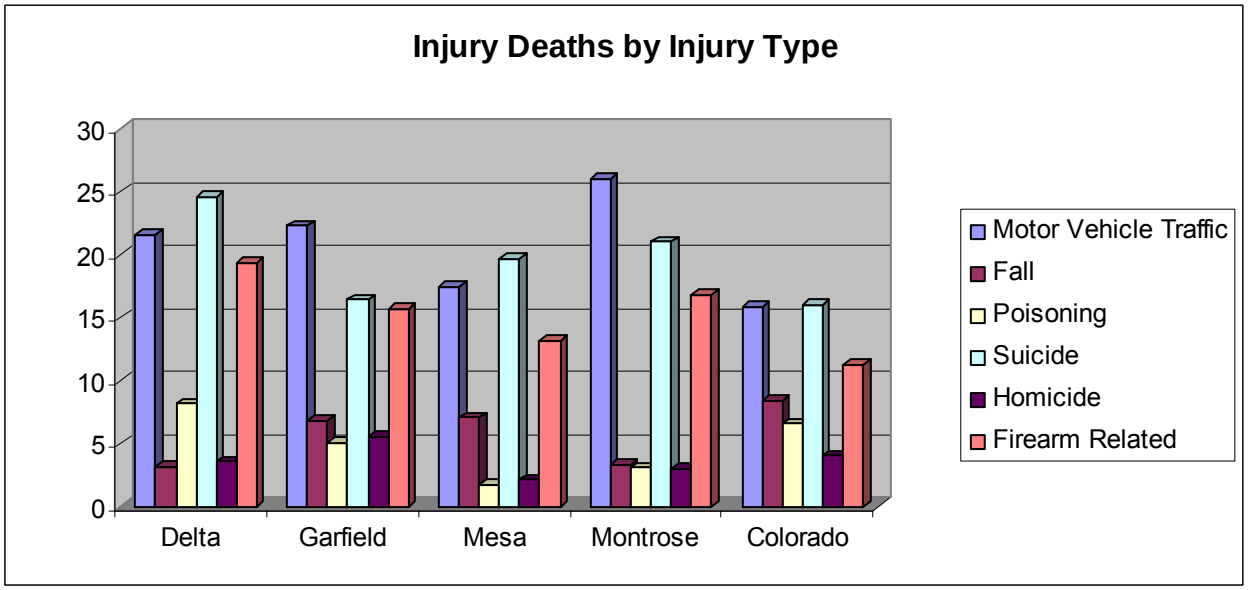


Table 21B. Injury Deaths by County, 2001 - 2003
Total – Injury Type
Age-Adjusted Rates per 100,000

	Motor Vehicle Traffic	Fall	Poisoning	Suicide	Homicide	Firearm Related
Delta	21.6	3.2**	8.2	24.6	3.6	19.4
Garfield	22.3	6.8	5.1	16.4	5.6	15.7
Mesa	17.5	7.1	1.8**	19.7	2.2**	13.2
Montrose	26.0	3.4**	3.1	21.0	3.0	16.8
Colorado	15.9	8.4	6.6	16.0	4.1	11.3

*significantly higher than Colorado rate
**significantly lower than Colorado rate

Figure 39.



Behavorial Risk Factor Study Survey (BRFSS) Data

The annual Centers for Disease Control and Prevention Behavioral Risk Factor Study (a random sample, telephone-based survey of health risk factors and behaviors) provides information on the health of a representative sample of adults. Table 22 provides the results of selected 2004-2005 survey questions by county.

Table 22. 2004-2005 BRFSS	Delta County		Garfield County		Mesa County		Montrose County		Colorado	
Topic	%	95% CI*	%	95% CI*	%	95% CI*	%	95% CI*	%	95% CI*
Diagnosed with diabetes	2.8	0.0-5.8	2.6	0.0-5.1	5.4	3.0-7.8	6.4	1.6-11.2	4.6	3.4-5.0
Current smoker	23.9	14.1-33.7	18.7	9.6-27.7	20.7	15.2-26.3	21.8	12.5-31.1	19.9	18.9-20.9
Currently have health insurance	67.6	56.8-78.4	79.2	20.8-87.6	80.1	74.3-85.9	71.3	60.3-82.3	84.4	83.4-85.3
Ever had asthma	17.2	7.9-26.5	16	8.1-23.9	10.6	7.0-14.2	15	5.2-24.7	17.2	7.9-26.5
Overweight BMI** 25.0-29.9	60.7	49.2-72.2	41.8	31.1-52.5	57.3	50.8-63.8	56.3	44.8-67.8	60.7	49.2-72.2
Obese BMI** >30	14.1	5.4-22.7	12.6	4.9-20.2	20.9	15.5-26.3	21.3	12.2-30.3	14.1	5.4-22.7

*Confidence Interval

**Body Mass index (BMI) is defined as weight in kilograms divided by height in meters squared

Percents are weighted to the total population.

According to the results of this survey, fewer Garfield County residents have diabetes, smoke or are overweight or obese than in the state, as a whole, or in the comparison counties. The percentage of adults in Garfield County who have asthma is similar to the state, as a whole, and to two of the three comparison counties.

Cancer Statistics

Cancer statistics for Colorado and the four comparison counties were obtained from the Colorado Department of Public Health and Environment, Colorado Central Cancer Registry, Prevention Services Division (www.cdphe.state.co.us). Mr. Jack Finch, (Statistical Analyst III) provided the most recently available data (through 2005) for the most frequently observed cancers in Colorado, as well as for several other cancers that are of interest because of their potential link to exposure to benzene or to radionuclides. For cancers that have sufficiently high rates of occurrence to provide meaningful trend data, trends in incidence and mortality rates are provided for the four comparison counties for the years 1992 through 2005. (Please see Appendix M for data tables.) Table 23 (below) shows comparisons of selected cancer incidence rates to the state incidence rates for the same time periods. Blank cells indicate that there was no significant difference from the state rate.

Table 24 provides the same information for mortality rates. It is important to note that mortality rates – more so than incidence rates – may reflect differences in socio-economic status and/or healthcare access (i.e., access to "state-of-the-art" treatment), rather than differences in risk factors for developing cancer. The latter may include an individual's genetic background, lifestyle choices, and/or exposures to a wide range of environmental toxins (chemical, biological, or radiological). One of the difficulties of observing relatively recent trends in cancer incidence statistics and trying to draw conclusions about possible changes in risk factors, is that, with respect to carcinogenic exposures, these trends reflect events that happened 10- 20 years ago or are cumulative over a lifetime. Generally speaking, the appearance of clinical cancer has a "lag" time of up to two decades following initiation of carcinogenesis. (Childhood cancers and some rare cancers are exceptions.) Thus, with the exception of changes in cancer screening practices that often artifactually inflate cancer rates, short-term trends may not reflect changes in the potential for exposure to carcinogenic materials.

Incidence and mortality trends among the comparison counties have also been portrayed graphically (see below). Incidence rates for all cancers have changed little over time, although cancer rates in males dropped slightly for Delta, Garfield, and Montrose counties for the most recent time period. There is relatively little difference among the counties for either male or female cancer incidence rates across the designated time periods. In addition to the county-specific cancer statistics, the information on Colorado and National incidence rates and risk factors was obtained from the "*Cancer in Colorado 1998-2003*" report (www.cdphe.state.co.us/pp/cccr/1998-2003/index.html) and "*Cancer Facts and Figures 2008*" (American Cancer Society, www.cancer.org).

Selected cancers.

Prostate cancer – Although Garfield County's average annual incidence rates for the period of 1992-1998 were higher than those of Delta, Mesa and Montrose Counties, there has been a steady downward trend in prostate cancer rates in Garfield County. For the most recent time period, prostate cancer rates were lower than those for the other three counties. It is important to note that incidence rates are a reflection of "detection" rates. Changes in rates may be an artifact of screening practices (which, in turn, reflect "standards of practice", health insurance coverage, and public acceptance).

Female Breast cancer – A similar downward trend in female breast cancer incidence is seen for Garfield County. Incidence rates among the comparison counties are not significantly different from each other or from the state rate.

Colorectal cancer – Colorectal cancer rates in males for Garfield County have decreased since 1992, and are now similar to those in Montrose County and lower than those in Delta and Mesa Counties and in the state, as a whole. Female colorectal cancer incidence has been highly variable, and is currently similar to the rates in Delta and Montrose Counties and in the state, as a whole (which are all higher than the most recent incidence rate for Mesa County).

Lung cancer – There has been a significant drop in the male lung cancer incidence rates in Garfield County over the most recent tracking period (2003-2005). Garfield County has the lowest incidence rate among the comparison counties and the state of Colorado for this period. Female lung cancer rates in Garfield County have essentially remained stable since 1992. The most recent rates are similar to the state rates, are higher than those for Delta County, and are lower than those for Mesa and Montrose Counties.

Bladder cancer – Bladder cancer incidence rates have been highly variable in Garfield County for both males and females. All of the comparison counties saw a spike in male bladder cancer incidence for the 2001-2002 period (true also for female bladder cancer, with the exception of Delta County, for which no female bladder cancers were reported during this period). The most recent tracking period showed decreases in the incidence rates for all counties, except Montrose County (continued upward trend in male bladder cancer) and Delta County (increase in female bladder cancer). State rates have remained stable for both male and female bladder cancer over the 1992-2005 time period.

Melanoma – Melanoma rates for Garfield County do not differ significantly from those in the comparison counties or the state as whole. Male melanoma rates have tended to decrease since 1999, while female rates have been more variable, although relatively low.

Leukemias – The incidence rates for all male leukemias in Garfield County were lower than those in the comparison counties and the state during 2003-2005 (the only period for which county-specific data were available). Female leukemia incidence rates for Garfield County were essentially the same as for the state, as a whole, slightly lower than for Montrose County, and higher than those for Mesa and Delta Counties.

Thyroid cancer – In all cases, incidence rates for male thyroid cancer were lower than for thyroid cancer in females, during 2003-2005, the only period for which county-specific data were available. In Garfield County, male thyroid cancer rates were lower than in Montrose County and the state, but higher than in Mesa and Delta Counties (No thyroid cancer was recorded for males in Delta County). Thyroid cancer rates for females in Garfield County were only higher than the rates for female residents of Mesa County.

Cervical cancer – Garfield County had the lowest incidence rates for cervical cancer among the comparison counties and the state, as a whole.

TABLE 23. COMPARISON OF COUNTY RATES WITH STATE RATES - INCIDENCE

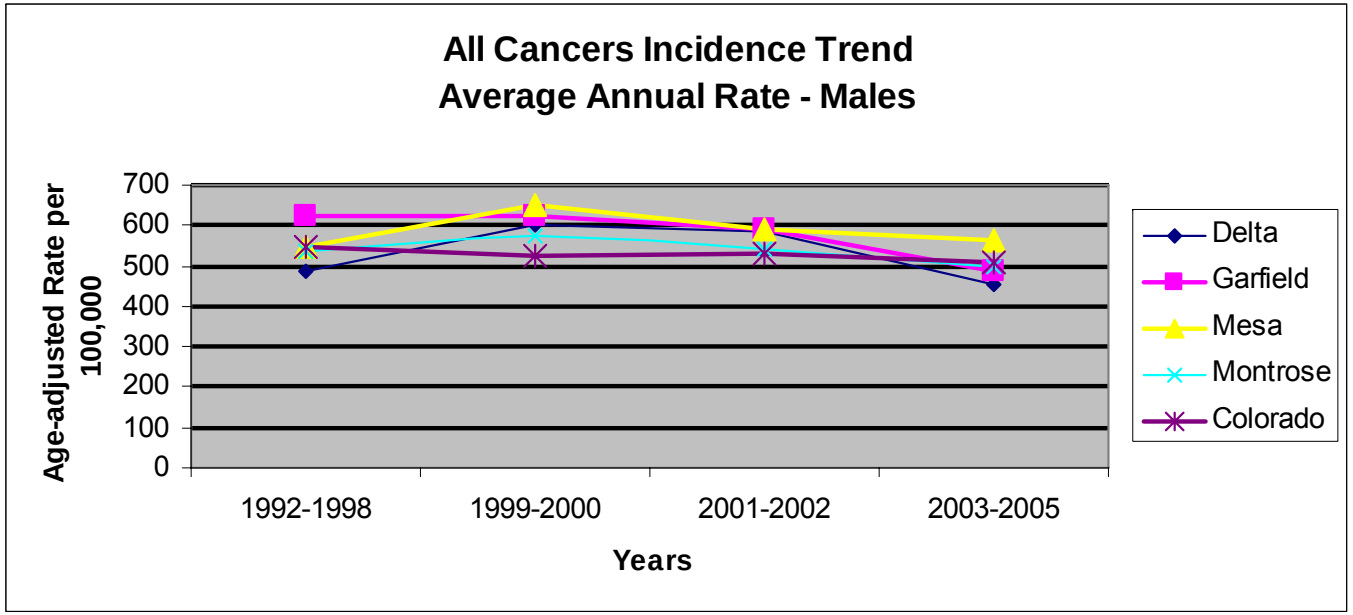
Male	Delta				Garfield				Mesa				Montrose			
	1992-1998	1999-2000	2001-2002	2003-2005	1992-1998	1999-2000	2001-2002	2003-2005	1992-1998	1999-2000	2001-2002	2003-2005	1992-1998	1999-2000	2001-2002	2003-2005
Prostate	↓				↑	↑			↓	↑	↑	↑		↑		
Lung									↑	↑		↑				
Colo-rectal																
Melan-oma										↑						
Bladder														↓		
Leuke-mias																
Thyroid																
All Cancers	↓				↑	↑				↑	↑	↑				
Female																
Breast			↓													
Lung									↑	↑		↑				
Colo-rectal																
Melan-oma	↑		***													
Thyroid												↓				
Leuke-mias																
Bladder			***			***					↑					
Cervix		***	***			***	***									
All Cancers					↑	↓										

. Rate is significantly higher than Colorado rate.
. Rate is significantly lower than Colorado rate.
***Indicates fewer than 3 events in this category.

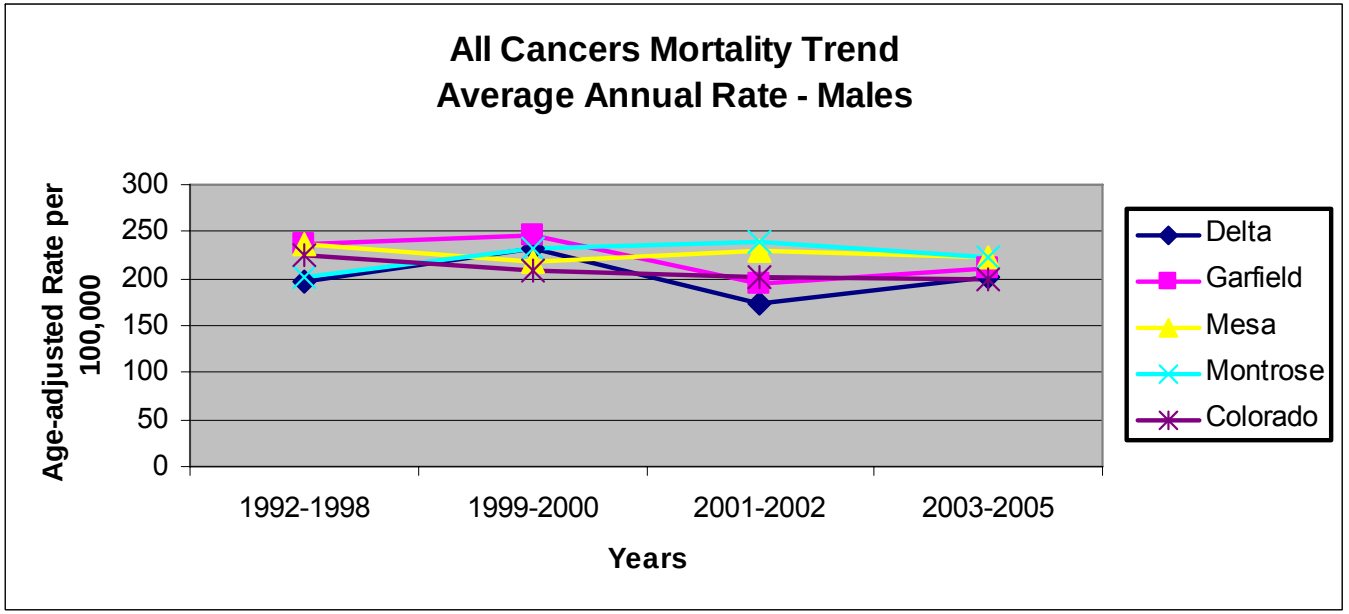
TABLE 24. COMPARISON OF COUNTY RATES WITH STATE RATES - MORTALITY

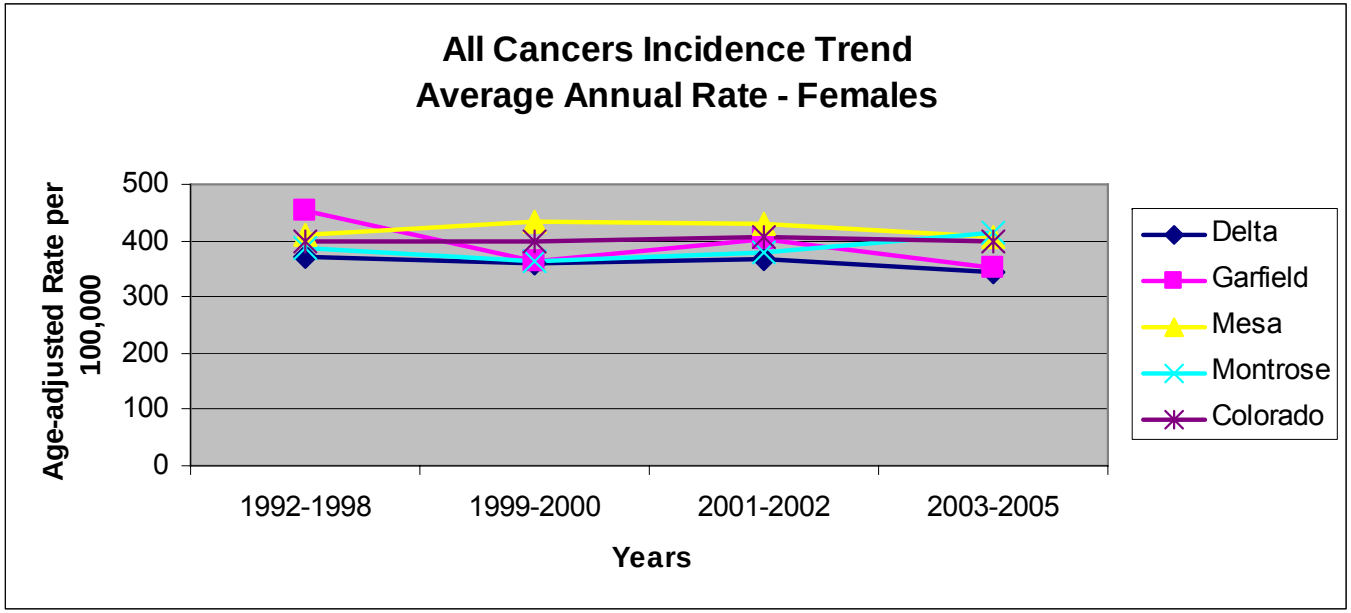
Male	Delta				Garfield				Mesa				Montrose			
	1992-1998	1999-2000	2001-2002	2003-2005	1992-1998	1999-2000	2001-2002	2003-2005	1992-1998	1999-2000	2001-2002	2003-2005	1992-1998	1999-2000	2001-2002	2003-2005
Prostate									↓			↓				
Lung												↑				
Colo-rectal	↓						***									
Melan-oma		***					***	***					***	***		
Bladder	***	***			***		***	***		***				***		
Leuke-mias																
Thyroid				***				***				***				***
All Cancers	↓											↑				↑
Female																
Breast																
Lung				↓								↑				
Colo-rectal												↓				
Melan-oma		***	***	***	***	***	***	***				↓	***	***	***	
Thyroid				***				***					***	***	***	
Leuke-mias								***								***
Bladder		***	***	***	***	***	***	***					***		***	***
Cervix		***	***	***		***	***	***			***		***	***	***	***
All Cancers								***	↑			↑				↑

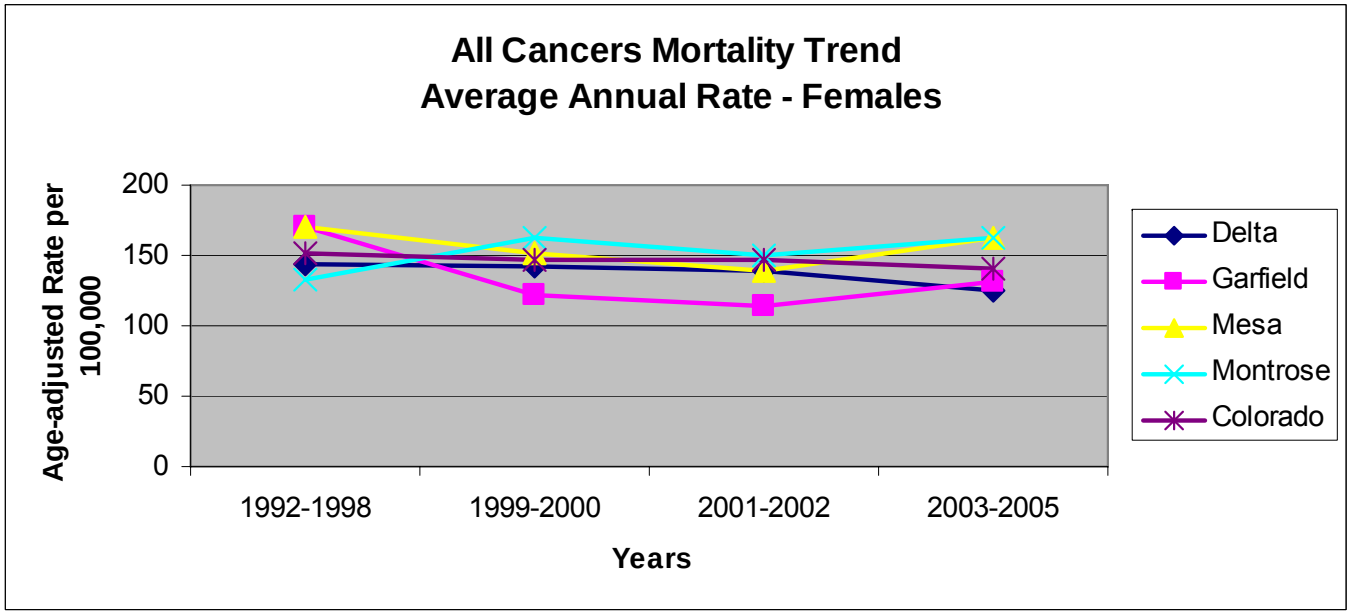
↑Rate is significantly higher than Colorado rate.
↓Rate is significantly lower than Colorado rate.
***Indicates fewer than 3 events in this category

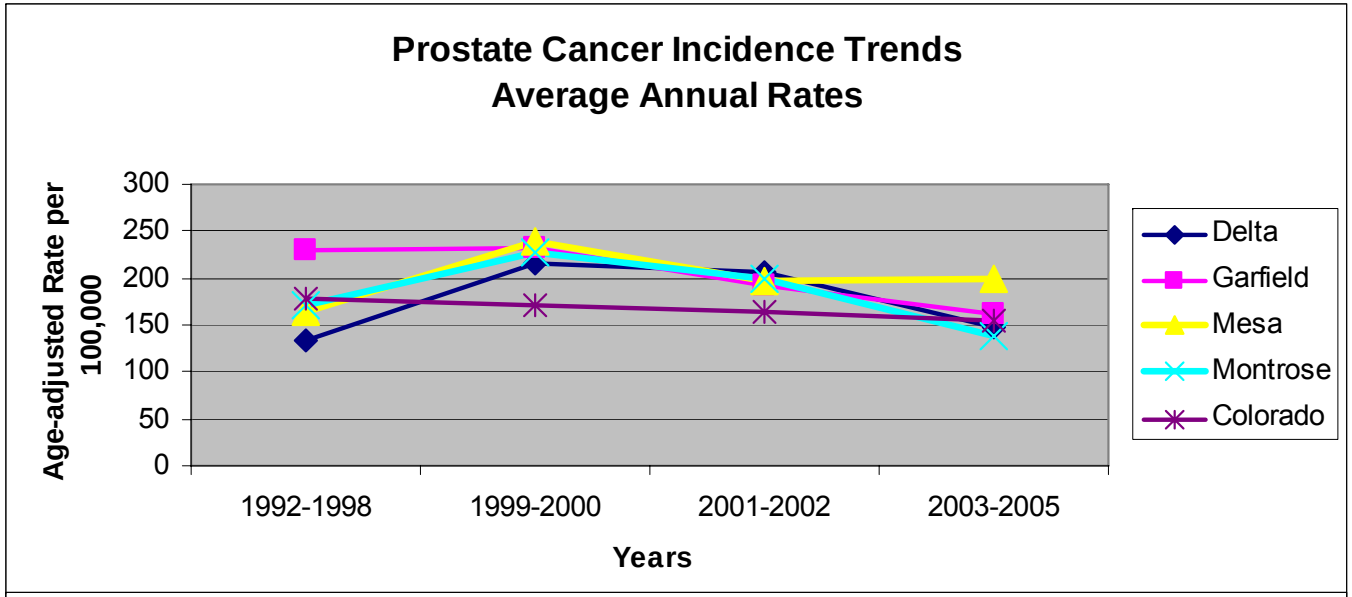


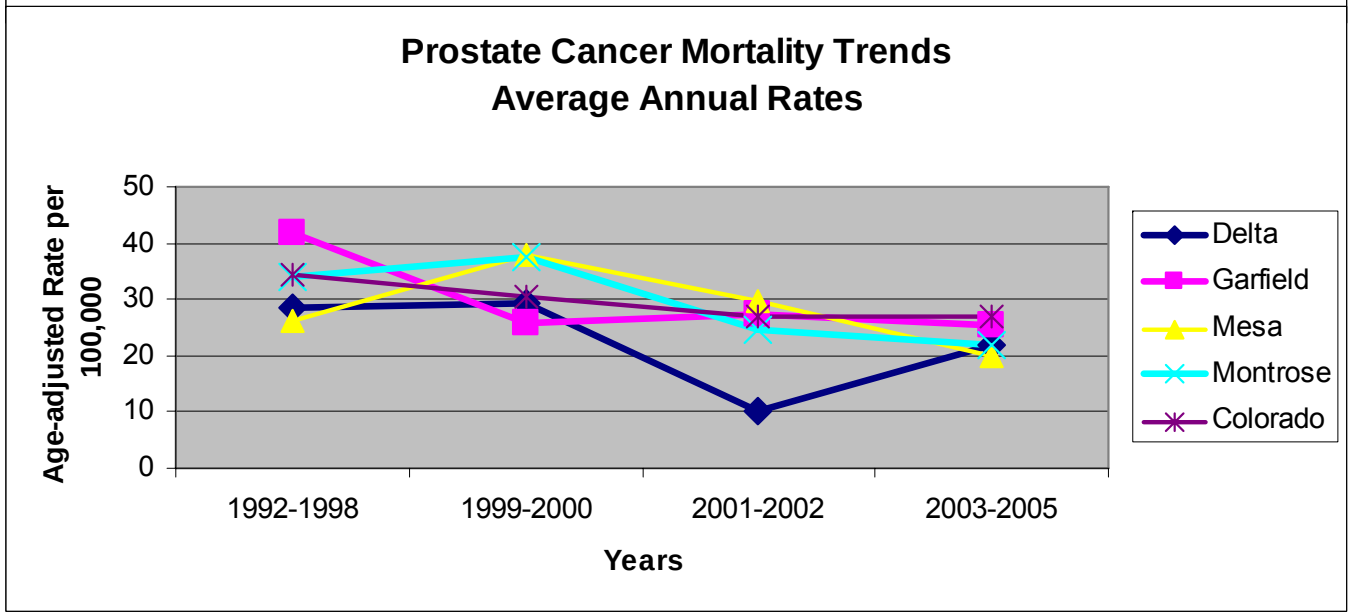
Figures 40a-d. In Colorado, the cummulative lifetime risk for developing cancer of any type is 1 in 2 for males and 2 in 5 for females.



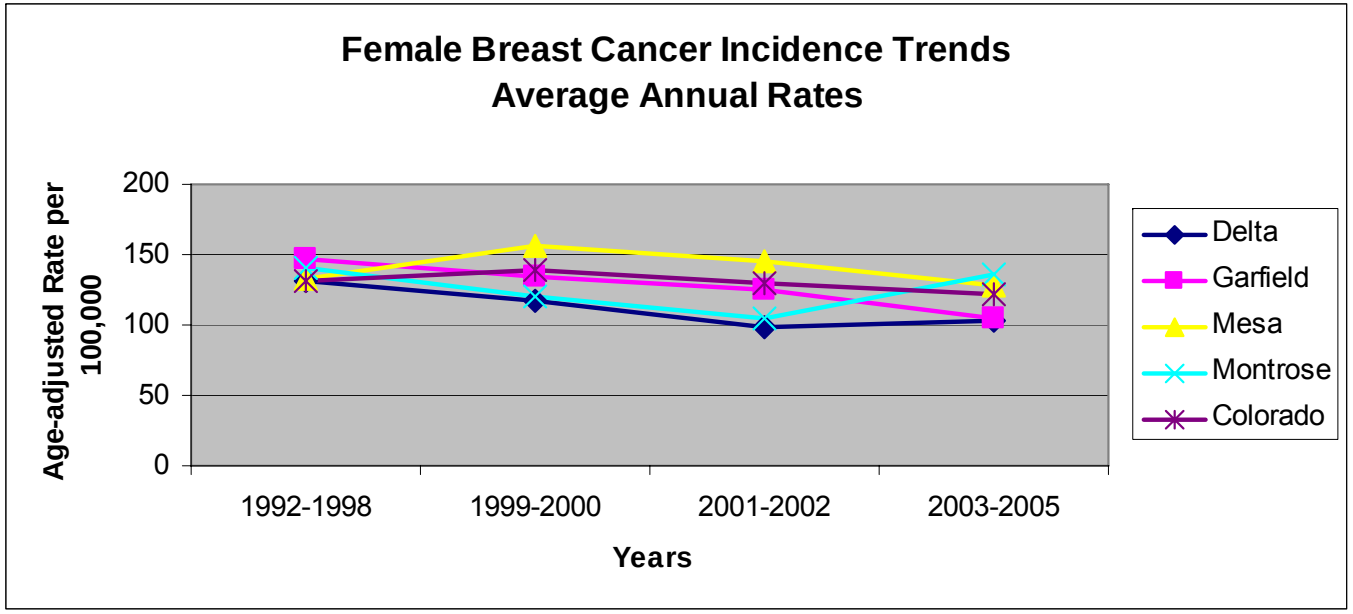

All Cancers Incidence Trend
Average Annual Rate - Females
Age-adjusted Rate per 100,000
500
400
300
200
100
0
1992-1998
1999-2000
2001-2002
2003-2005
Years
Delta
Garfield
Mesa
Montrose
Colorado

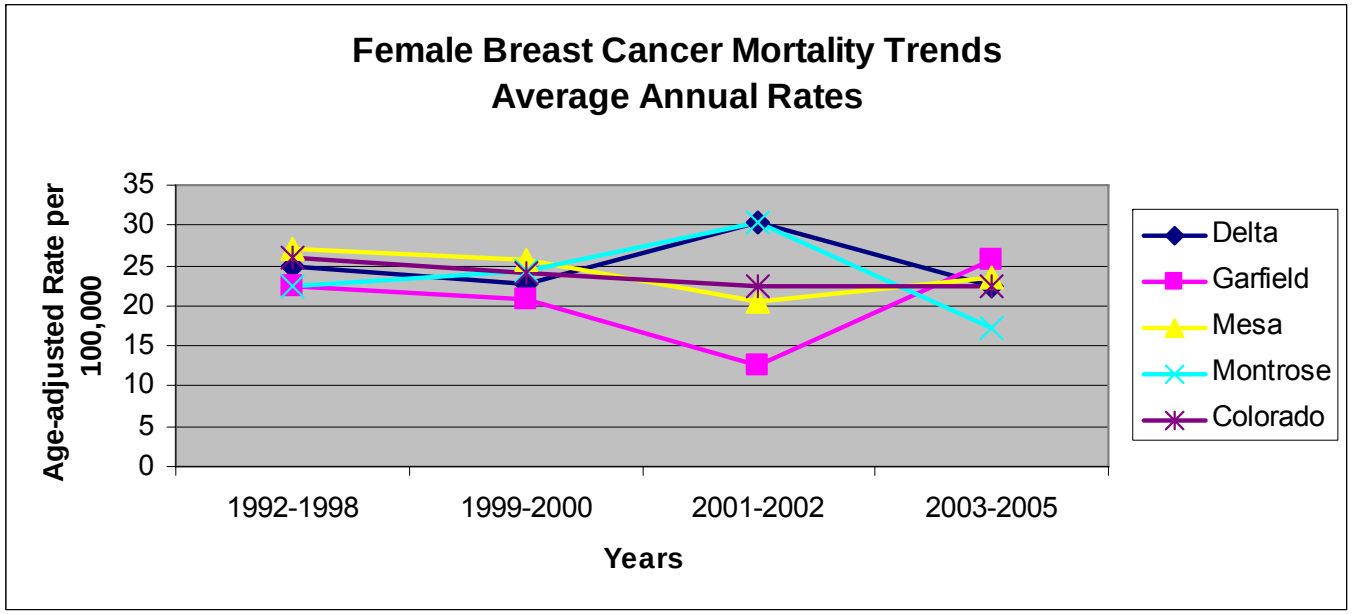

All Cancers Mortality Trend
Average Annual Rate - Females
Age-adjusted Rate per 100,000
200
150
100
50
0
1992-1998
1999-2000
2001-2002
2003-2005
Years
Delta
Garfield
Mesa
Montrose
Colorado



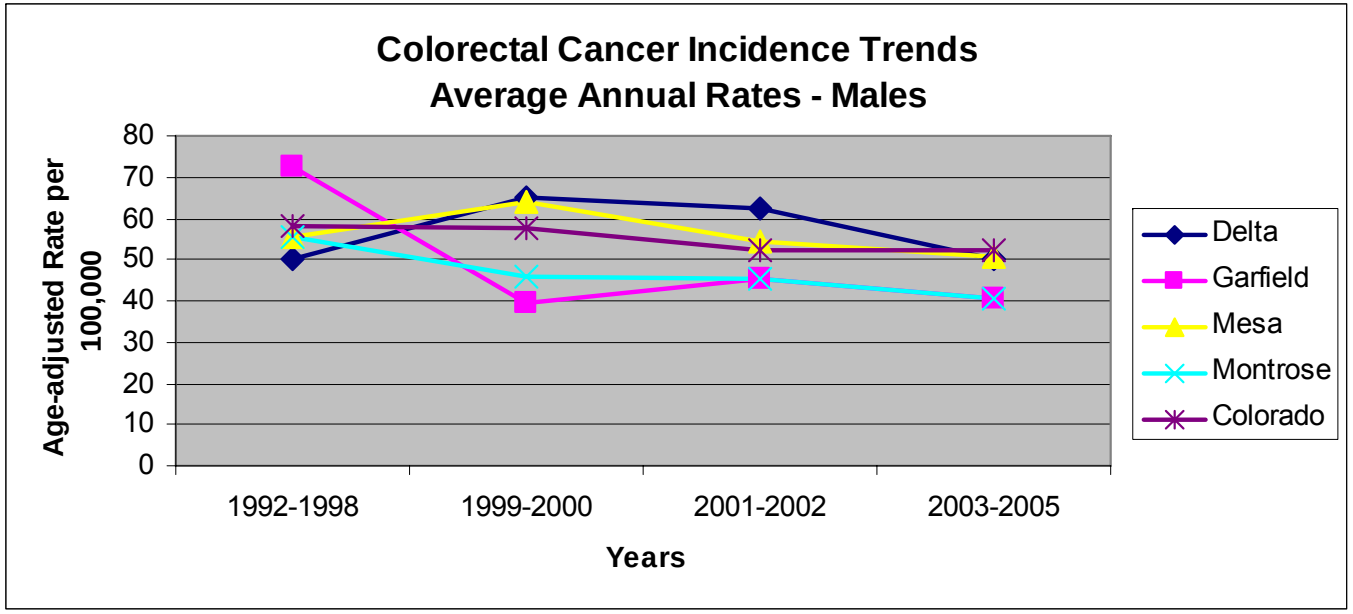


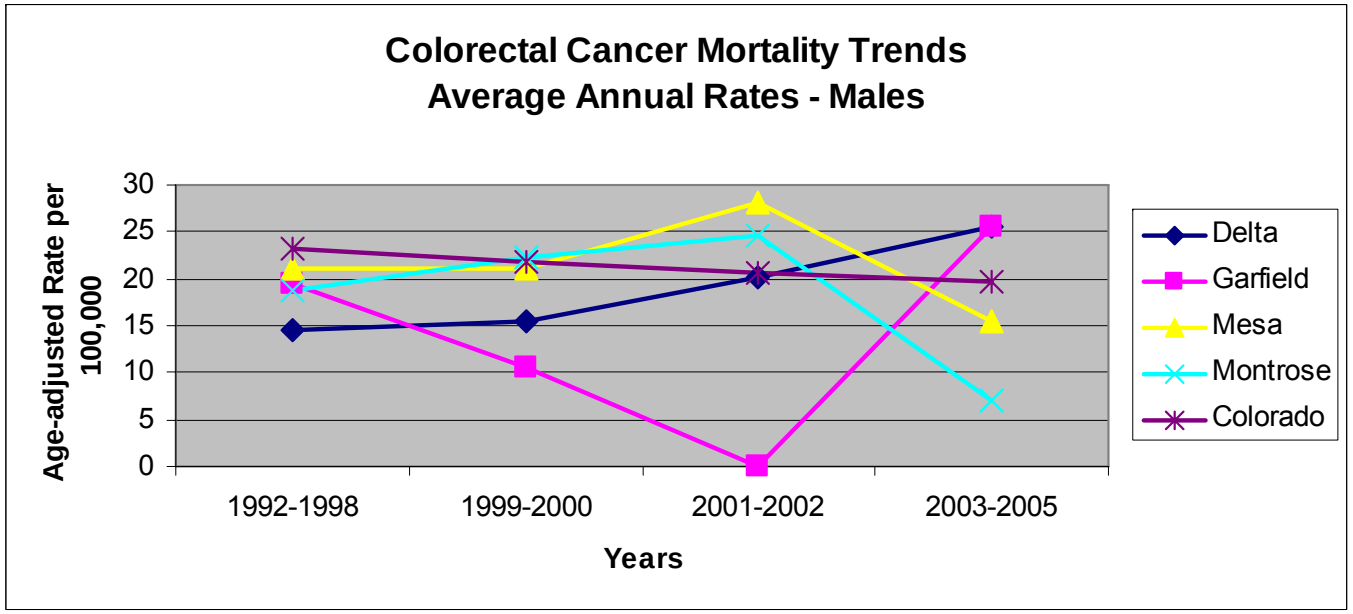
Figures 41a and 41b. Prostate cancer is the most frequently diagnosed cancer in men. In Colorado, 1 in 5 males is likely to develop prostate cancer during their lifetime. The only well-established risk factors for prostate cancer are age (>65 years), ethnicity (incidence rates are highest among African American men), and family history of the disease. Some studies suggest that a diet high in saturated fat may also be a risk factor.



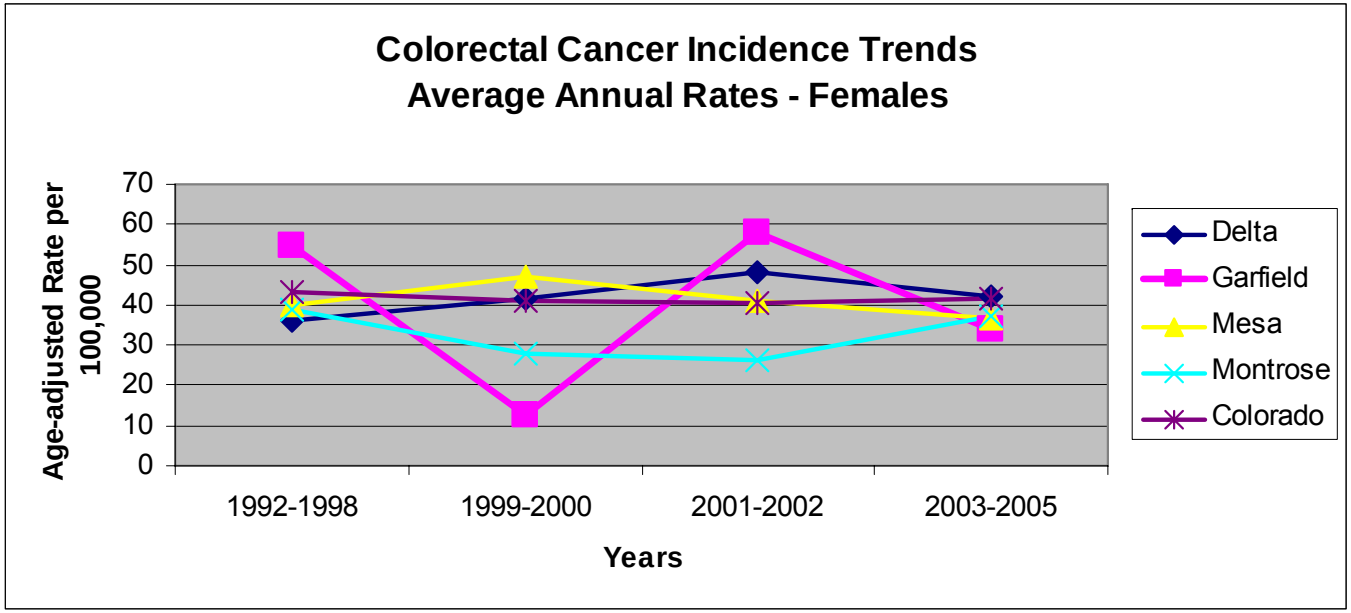


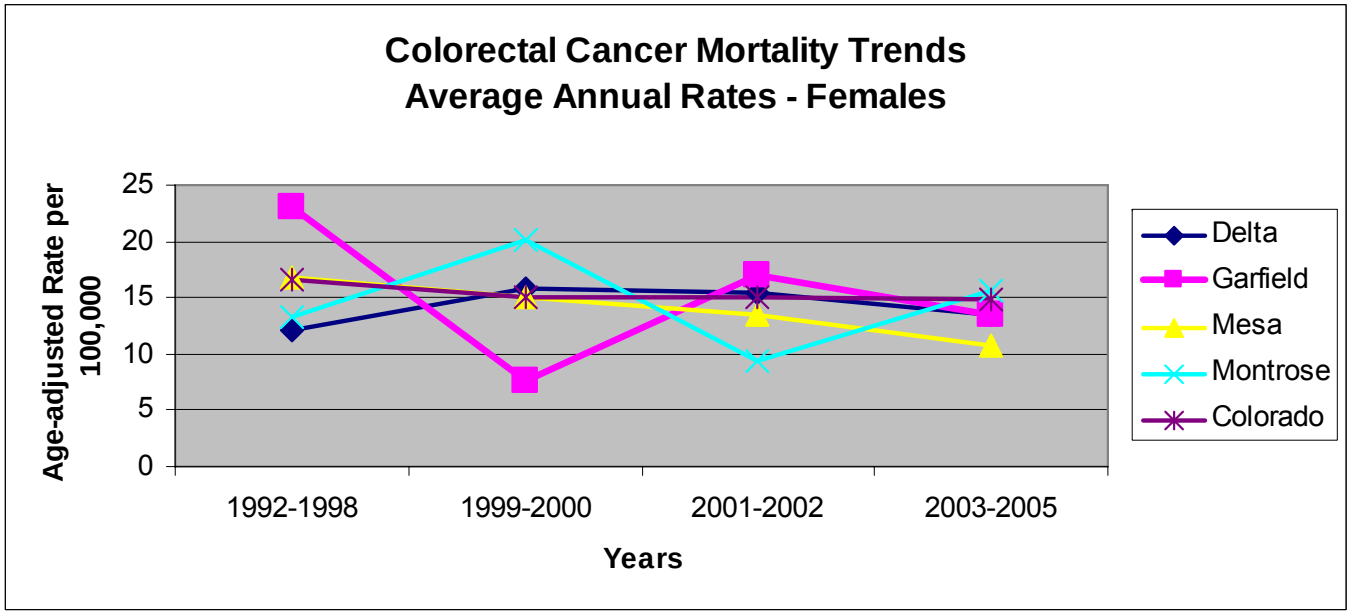
Figures 42a and 42b. Breast cancer is the most frequently diagnosed cancer in women. In Colorado, it is likely that 1 in 7 women develop breast cancer during their lifetime. Age is the most important risk factor for female breast cancer. Other risk factors include genetic background (inherited mutations in the BRCA1 and BRCA2 genes; a personal or family history of breast cancer), and reproductive factors such as a long menstrual history, never having children or having a first child after age 30, and recent use of oral contraceptives. Other factors such as obesity, postmenopausal hormone therapy, physical inactivity and alcohol use may play a role in the development of breast cancer.

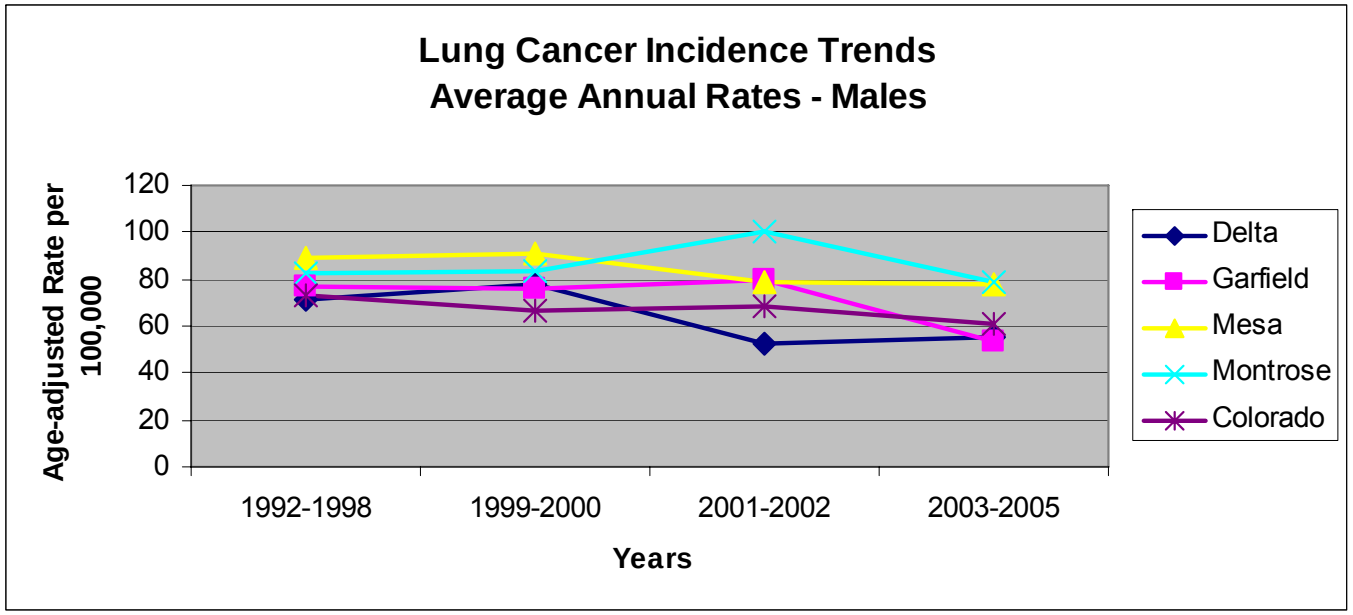


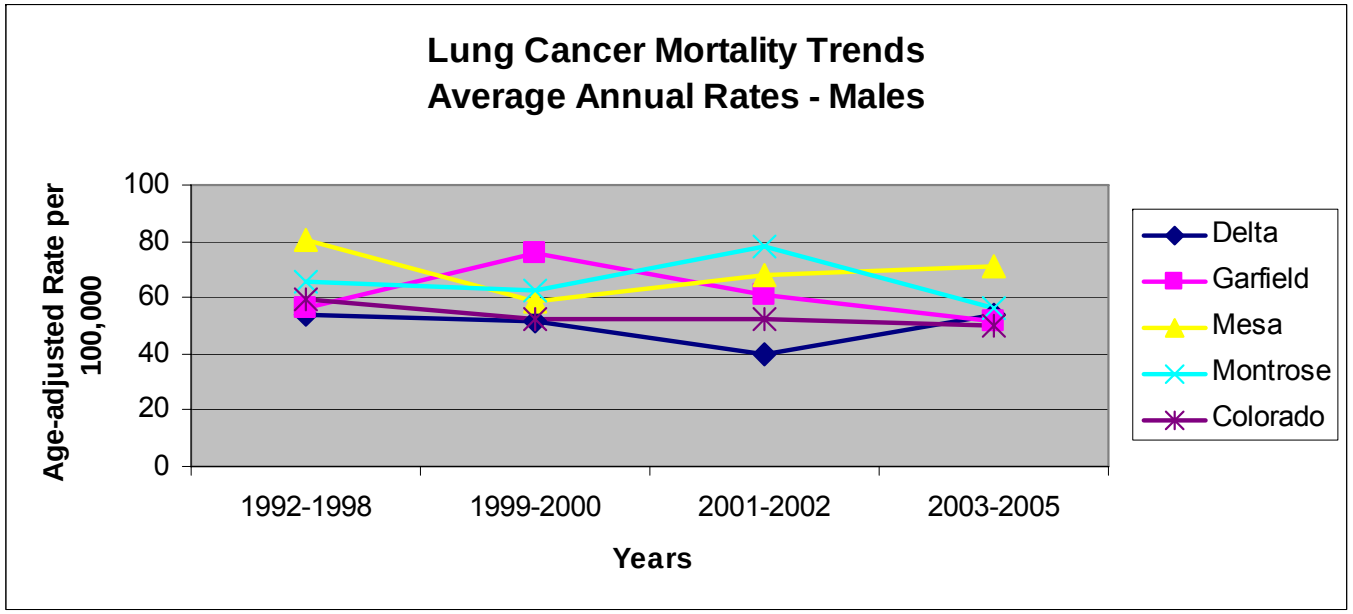


Figures 43a-d. Nationally, colorectal cancer is the third most common cancer in both men and women. In Colorado the lifetime risk for developing colorectal cancer is 1 in 14 for males and 1 in 18 for females. Risk factors for developing colorectal cancer include increasing age, certain genetic mutations or a personal or family history of colorectal cancer, polyps, or chronic inflammatory bowel disease. Other risk factors include obesity, physical inactivity, smoking, alcohol consumption, and a diet high in red or processed meat and low in fruits and vegetables.

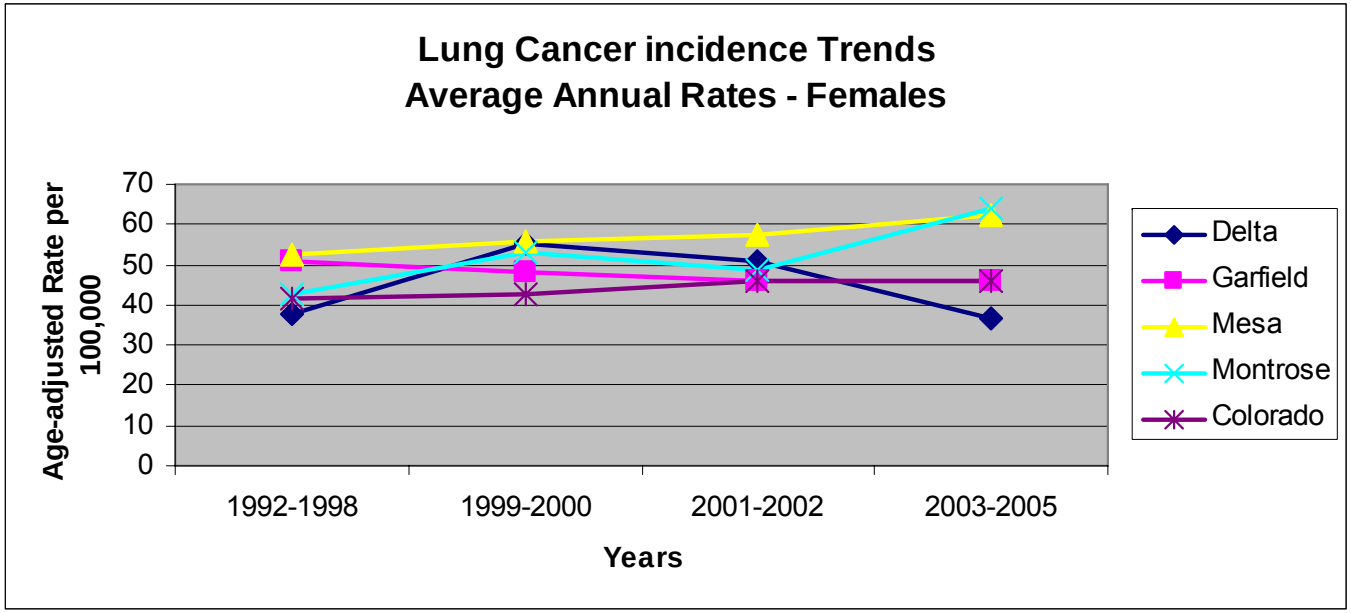

Colorectal Cancer Incidence Trends
Average Annual Rates - Females
Age-adjusted Rate per 100,000
70
60
50
40
30
20
10
0
1992-1998
1999-2000
2001-2002
2003-2005
Years
Delta
Garfield
Mesa
Montrose
Colorado

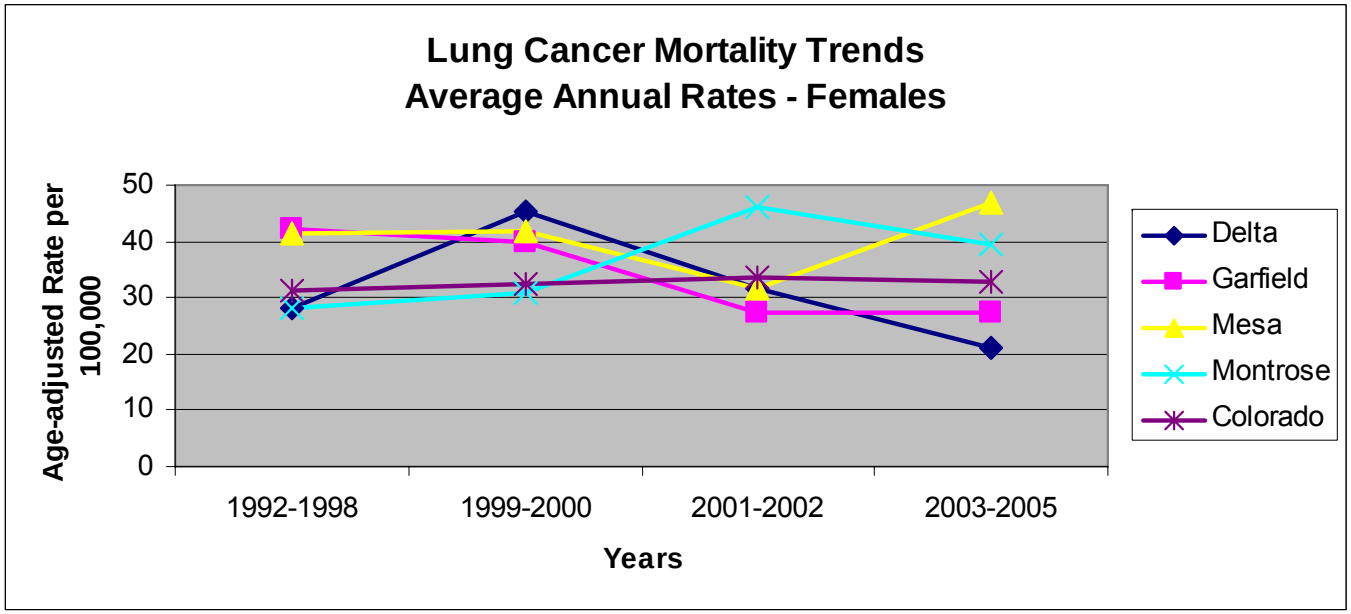

Colorectal Cancer Mortality Trends
Average Annual Rates - Females
Age-adjusted Rate per 100,000
25
20
15
10
5
0
1992-1998
1999-2000
2001-2002
2003-2005
Years
Delta
Garfield
Mesa
Montrose
Colorado

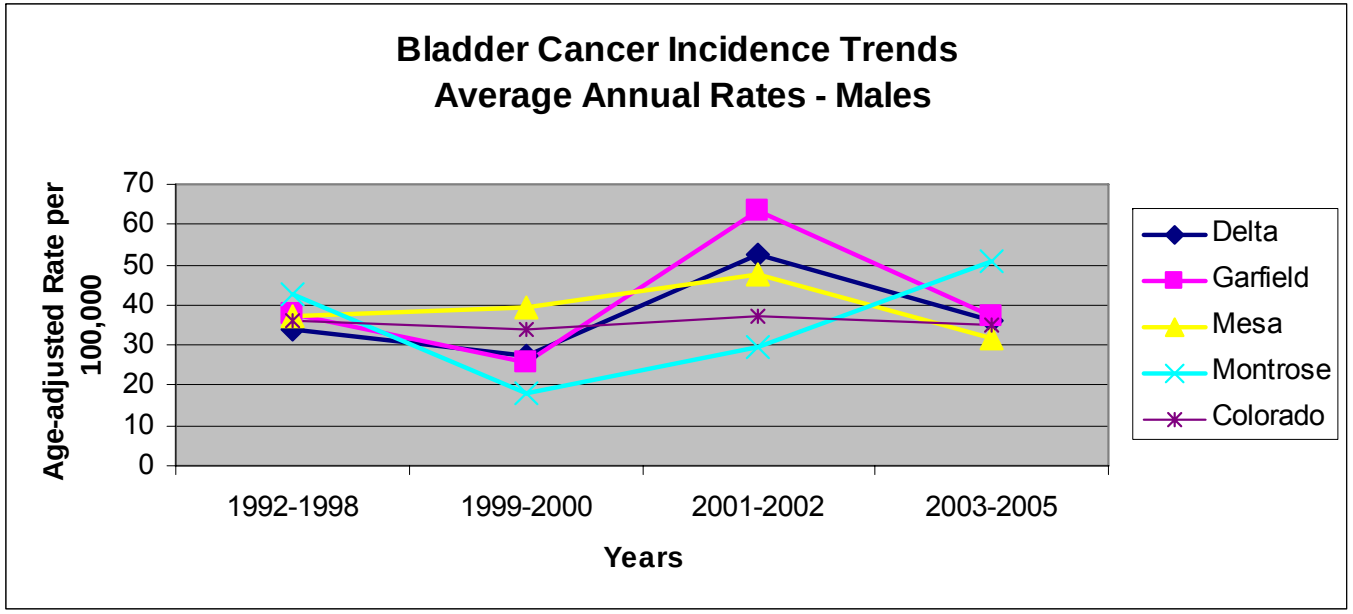


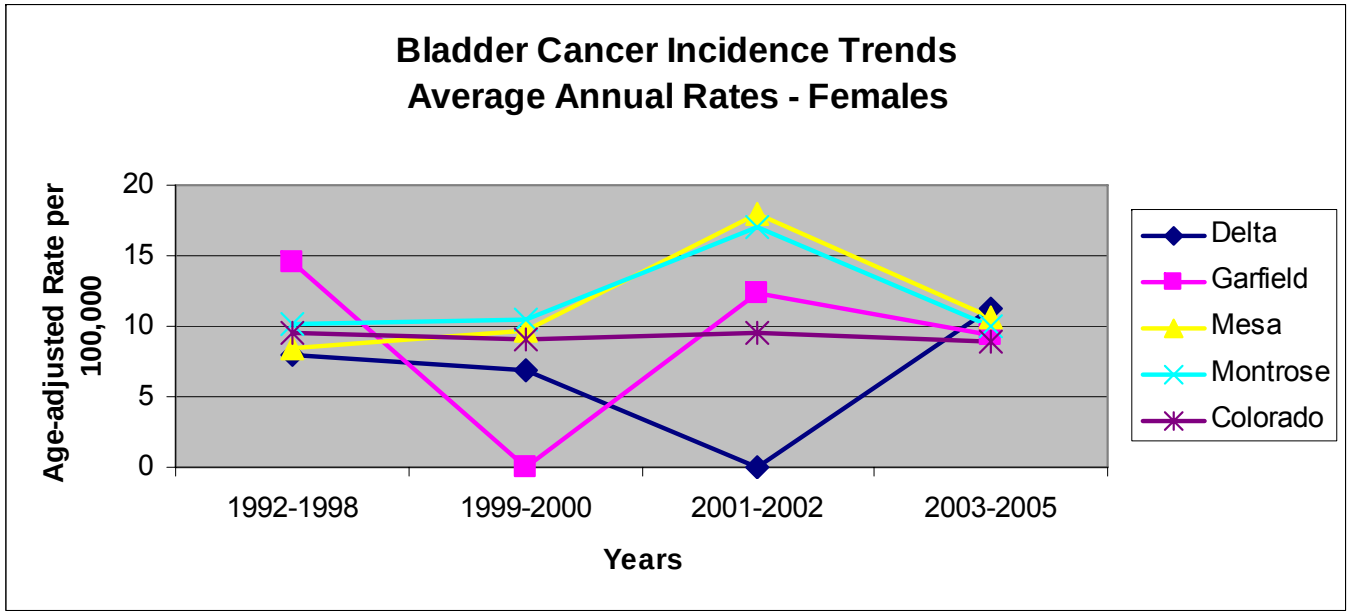


Figures 44a-d. Although the incidence rates for lung cancer are declining, it is still the second most frequently diagnosed cancer in both men and women, and accounts for the most cancer-related deaths. In Colorado, the lifetime risk of lung cancer is 1 in 10 for males and 1 in 15 for females. Cigarette smoking is by far the most important risk factor for developing lung cancer. Other risk factors include genetic background history of tuberculosis and occupational or environmental exposure to secondhand smoke, radon, asbestos, certain metals, organic chemicals, and other air pollutants, and radiation.

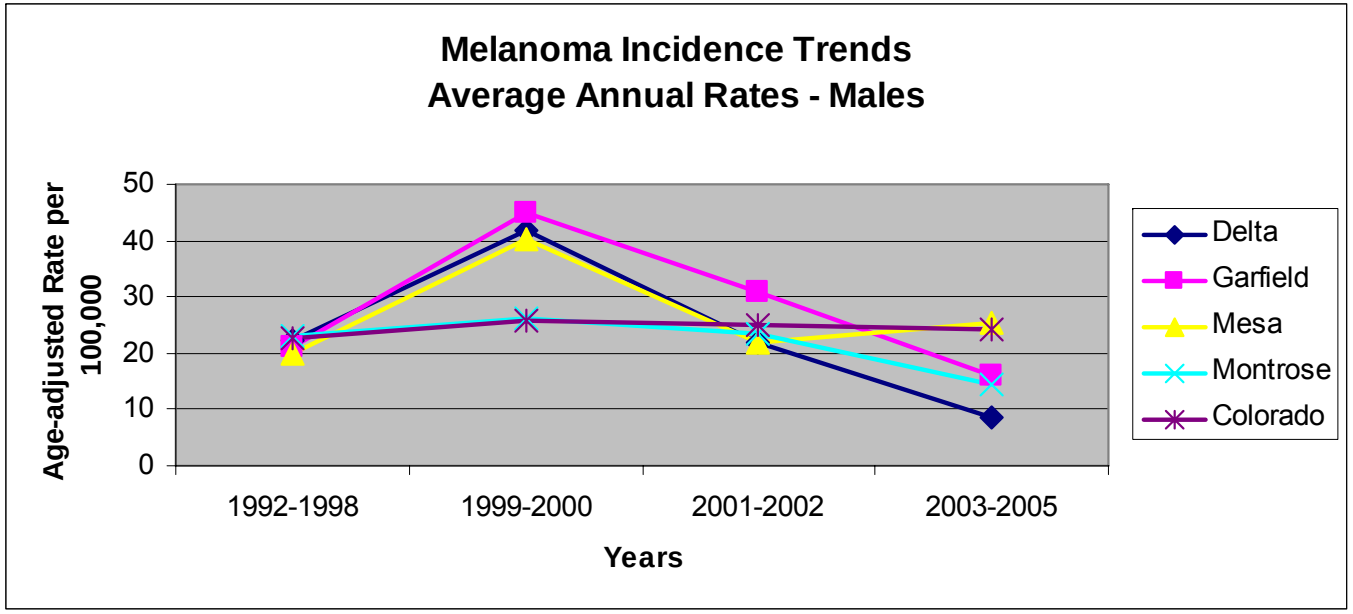

Lung Cancer incidence Trends
Average Annual Rates - Females
Age-adjusted Rate per 100,000
70
60
50
40
30
20
10
0
1992-1998
1999-2000
2001-2002
2003-2005
Years
Delta
Garfield
Mesa
Montrose
Colorado

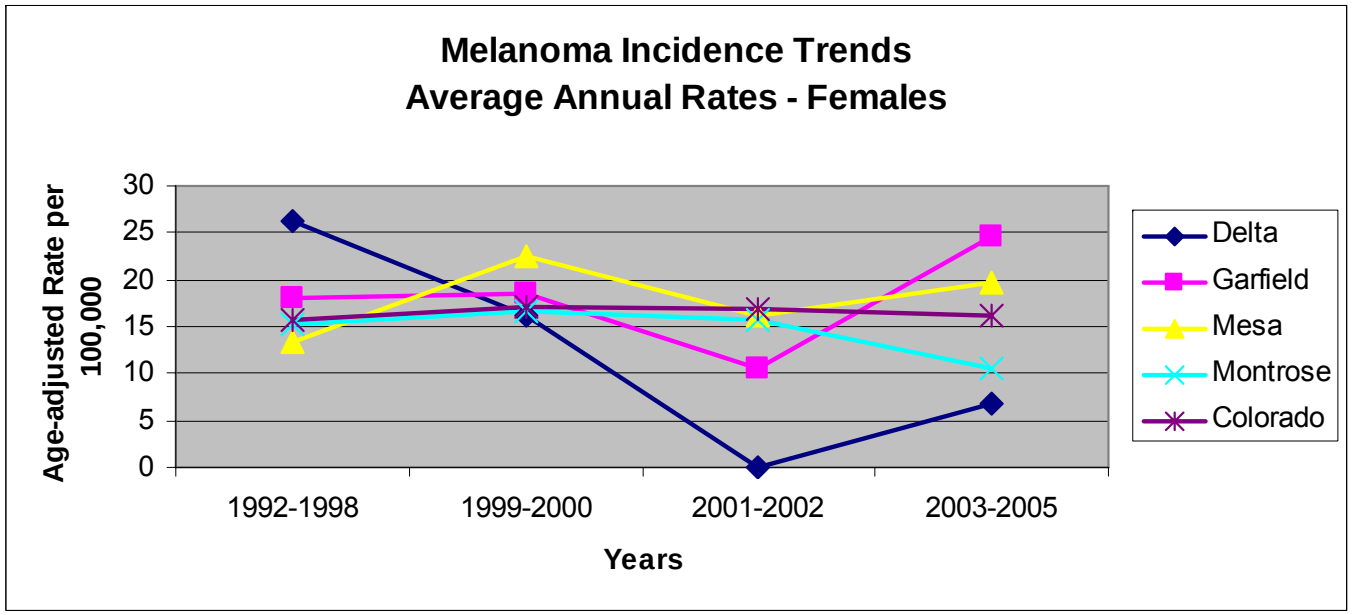

Lung Cancer Mortality Trends
Average Annual Rates - Females
Age-adjusted Rate per 100,000
50
40
30
20
10
0
1992-1998
1999-2000
2001-2002
2003-2005
Years
Delta
Garfield
Mesa
Montrose
Colorado



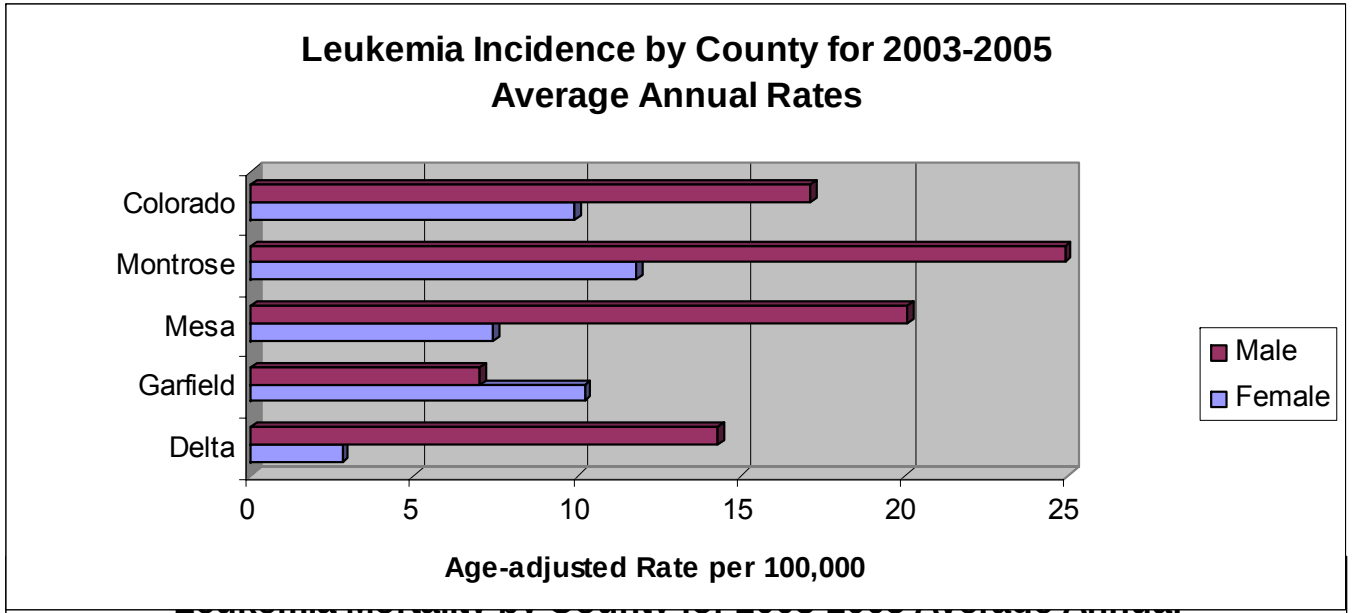


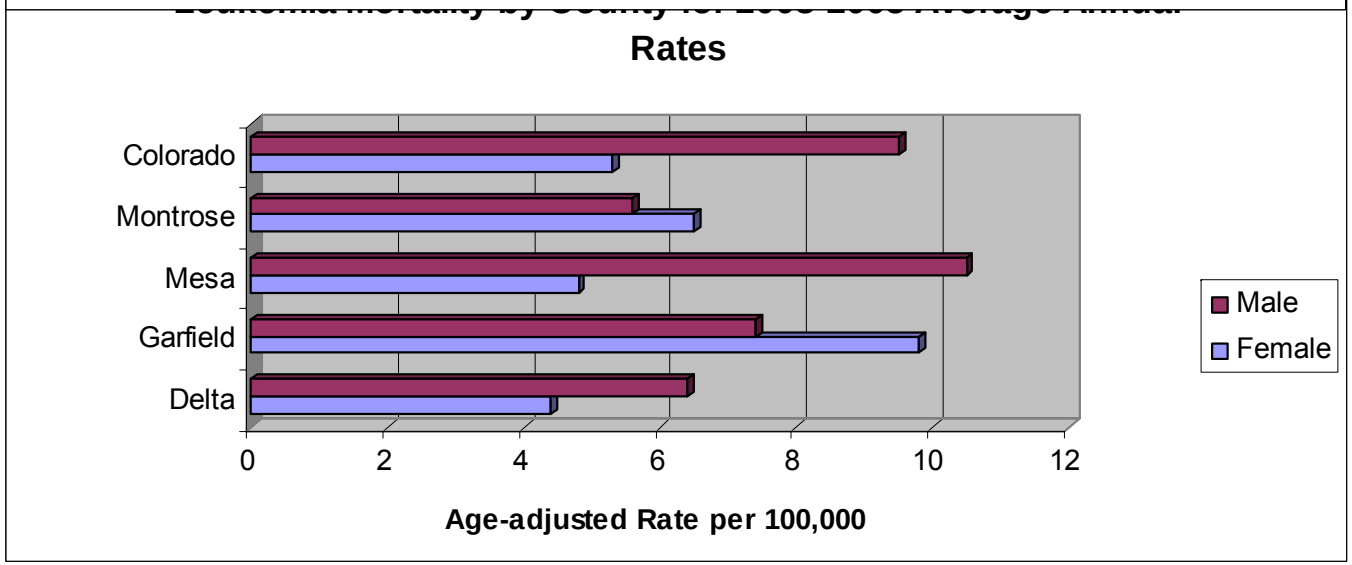
Figures 45a and 45b. Nationally, bladder cancer incidence rates are nearly four times higher in men than in women. In Colorado, the lifetime risk for bladder cancer is 1 in 20 for males and 1 in 76 for females. Smoking is the most important risk factor for developing bladder cancer. Workers in the dye, rubber or leather industries and individuals who live in communities that have high levels of arsenic in their drinking water are also at increased risk for developing bladder cancer.





Figures 46a and 46b. Melanoma is the most common, serious form of skin cancer, and occurs primarily (although not exclusively) in whites. The major risk factors for melanoma are personal or family history and the presence of large numbers or atypical moles. Other risk factors include a history of excessive sun or ultraviolet light exposure; sun sensitivity (light or red hair and light skin); diseases that suppress the immune system; and occupational exposure to coal tar, pitch, creosote, arsenic compounds, or radiation.





Figures 47a and 47b. Although leukemia is diagnosed 10 times more often in adults than in children, it is often thought of as primarily a childhood disease. The most common types of leukemia diagnosed in adults are acute myeloid leukemia and chronic lymphocytic leukemia. Leukemia occurs more frequently in males than in females. In Colorado, the lifetime risk of developing leukemia is 1 in 45 for males and 1 in 79 for females. Individuals with Down Syndrome and certain other genetic abnormalities have higher rates of leukemia. Cigarette smoking and exposure to radiation and to chemicals like benzene are also risk factors for leukemia.

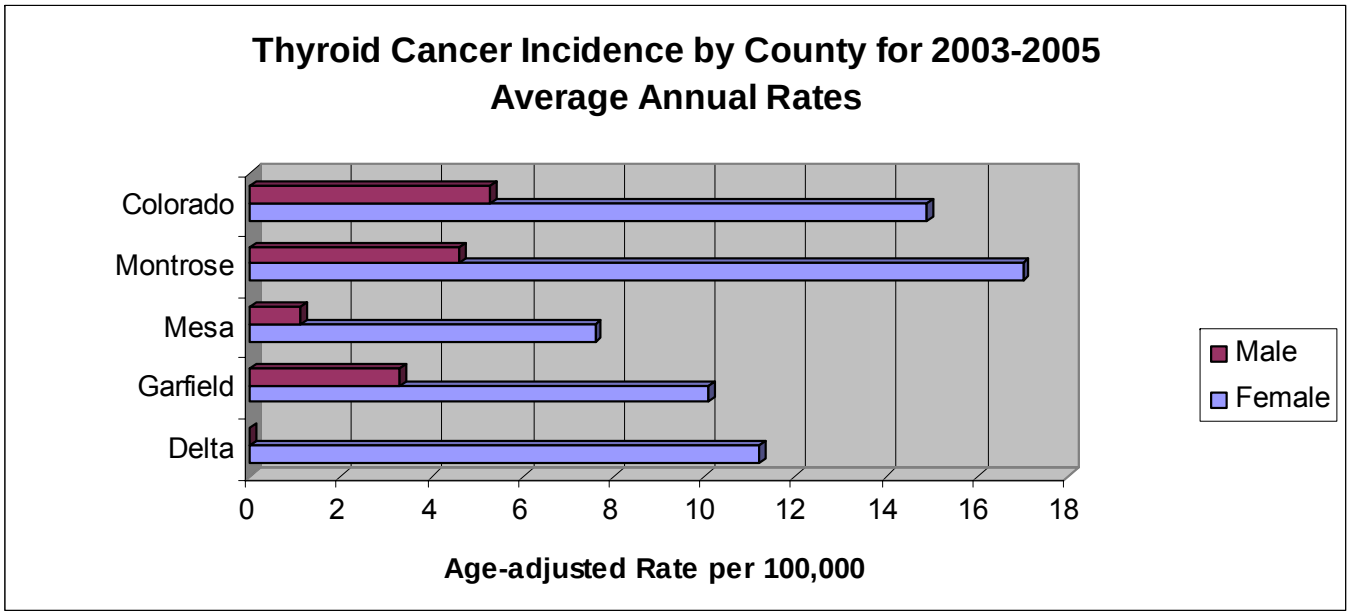


Figure 48. Nationally, thyroid cancers occur about 3 times more often in women than in men, and they are more frequent in younger adults. In Colorado, the lifetime risk of developing thyroid cancer is 1 in 204 for males and 1 in 92 for females. Major risk factors for developing thyroid cancer are a diet low in iodine, exposure to radiation, and certain inherited medical conditions.

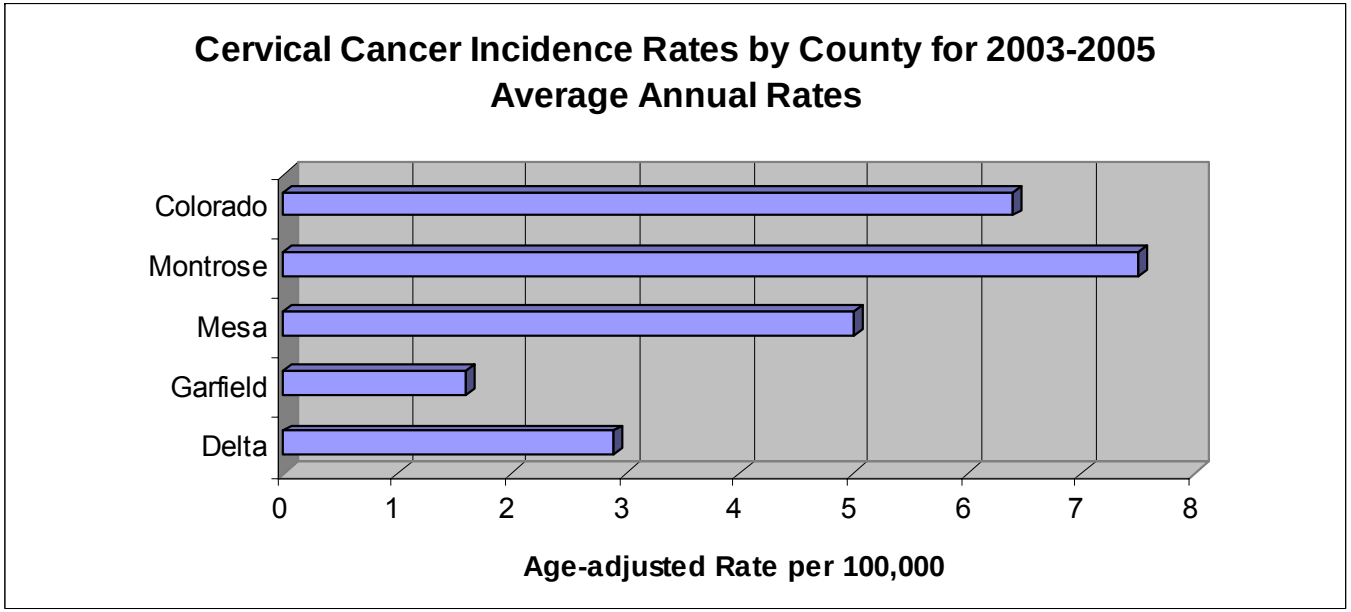


Figure 49. Incidence rates for cervical cancer have decreased significantly, and as Pap screening has become more common, cervical cancer is more often detected before it becomes invasive. In Colorado, 1 in 154 women develop invasive cervical cancer over their lifetime. The primary cause of cervical cancer is infection with human papillomavirus (HPV). The ability of the infection to progress to cancer is related to factors such as suppressed immunity, having many children, cigarette smoking, and nutrition. Long-term use of oral contraceptives is also associated with an increased risk of cervical cancer.

West Nile Virus

There are two reasons for looking at county-based statistics for West Nile virus — both are related to concerns voiced by Garfield County residents. First, in public meetings, focus groups, and interviews, citizens have expressed the concern that birds appeared to be fewer in number in certain areas of Garfield County than remembered. Birds are the reservoir host for West Nile virus. They may become ill and die as a result of the viral infection.

Second, many of the symptoms associated with human West Nile virus infection mimic those reported by Garfield County residents and attributed to exposures related to natural gas industry activities.

West Nile virus was first observed in Colorado in 2002. It was not until 2003, however, before the virus had a significant Western Slope presence. The coincidence of the presence of this virus and the beginnings of the surge in natural gas industry activities on the Western Slope make it important to consider the possibility that West Nile virus infection could be the cause of some of the human physical symptoms and animal impacts that have been reported by Garfield County residents. At this point, it would be extremely difficult to either rule out West Nile virus as the cause of at least some of these impacts or to prove conclusively that it was the virus and not exposure to volatile organic compounds or other toxicants present in the environment as a result of natural gas activity.

Natural History of West Nile Virus (www.cdphe.state.co.us/dc/Zoonosis/zoonosis.asp)

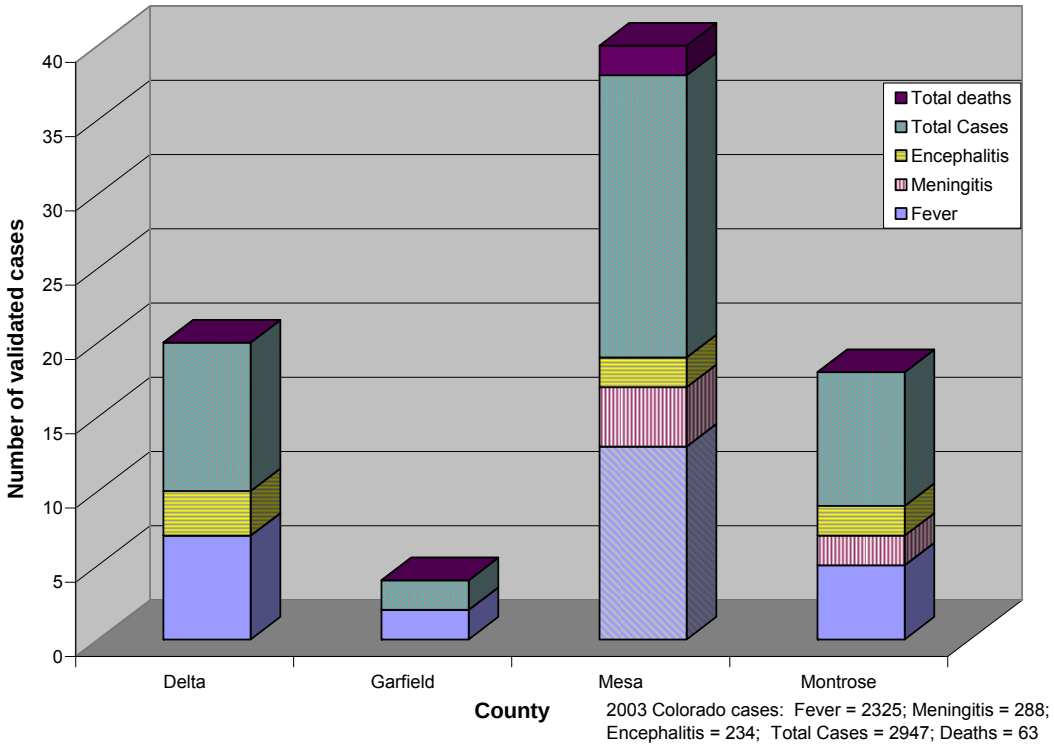
West Nile virus is maintained in a bird-mosquito-bird cycle. Mosquitoes are infected by feeding on an infected bird; virus is then transmitted to a new host when the mosquito bites a person or other animal. Humans and horses are the most frequent, "dead-end" hosts (i.e, they cannot infect other mosquitoes). Viruses are prevalent from May to September, when mosquitoes are most abundant.

West Nile virus infection has been detected in more than 70 wild bird species. The highest death rates are seen among birds in the corvid family. Horses are susceptible to infection with West Nile virus and can die as a result of the infection. Other clinical signs include lack of coordination or muscle control, weakness of limbs, and inability to rise. Other mammalian species may be susceptible to infection with this virus (e.g., there have been reports of infection in dogs).

Most people who are infected with West Nile virus do not become ill and have no symptoms. For those who do become ill, the onset of symptoms occurs 5-15 days after being bitten by an infected mosquito. The clinical symptoms of West Nile virus infection range from a flu-like syndrome (West Nile fever) to meningitis and encephalitis. The symptoms of West Nile fever have been reported to last significantly longer than the usual flu. Individuals who have developed West Nile fever report "not feeling well" for many months after the onset of the illness. In some cases, infection with the virus results in inflammation of the brain, resulting in either meningitis or encephalitis. In these cases, symptoms begin with a high fever and headache that may progress to stiff neck, disorientation,
tremors, coma and death. Severe infections have resulted in long-lasting neurological syndromes that resemble polio.

The following graphs and maps illustrate the time trends for West Nile Virus in Colorado from 2002 through 2007 (Colorado Department of Public Health and Environment). Information is provided for both human and animal infections. It is important to note that the numbers for human cases represent only those that were clinically validated (either by blood tests or by the fact that the individual was hospitalized as a result of their infection). Because of the tendency of individuals suffering "flu-like" symptoms NOT to be tested for West Nile virus (due to cost or unavailability of the test) and to either be treated by their doctors or to treat themselves symptomatically, it is very likely that the actual numbers of individuals who developed West Nile Fever were much higher than those listed in the official records (CDPHE; www.cdphe.state.co.us) and reported here.

Figure 50. West Nile Virus Infections – 2003



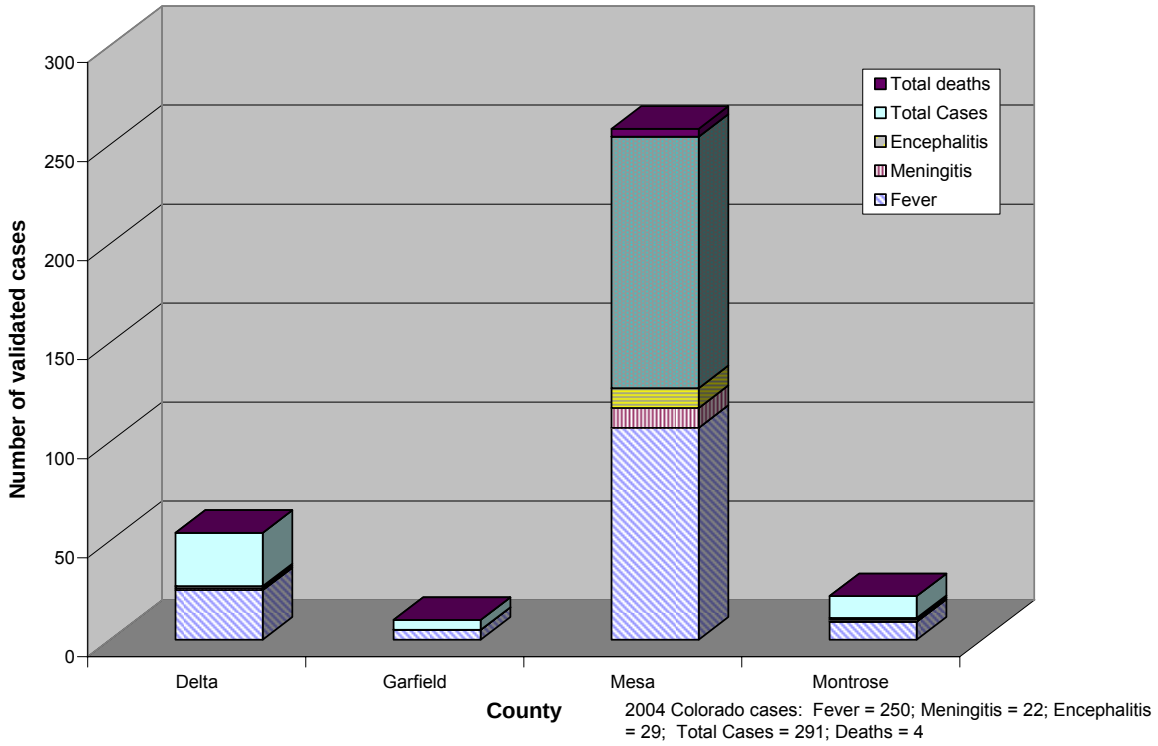


Figure 51. West Nile Virus Infections – 2004

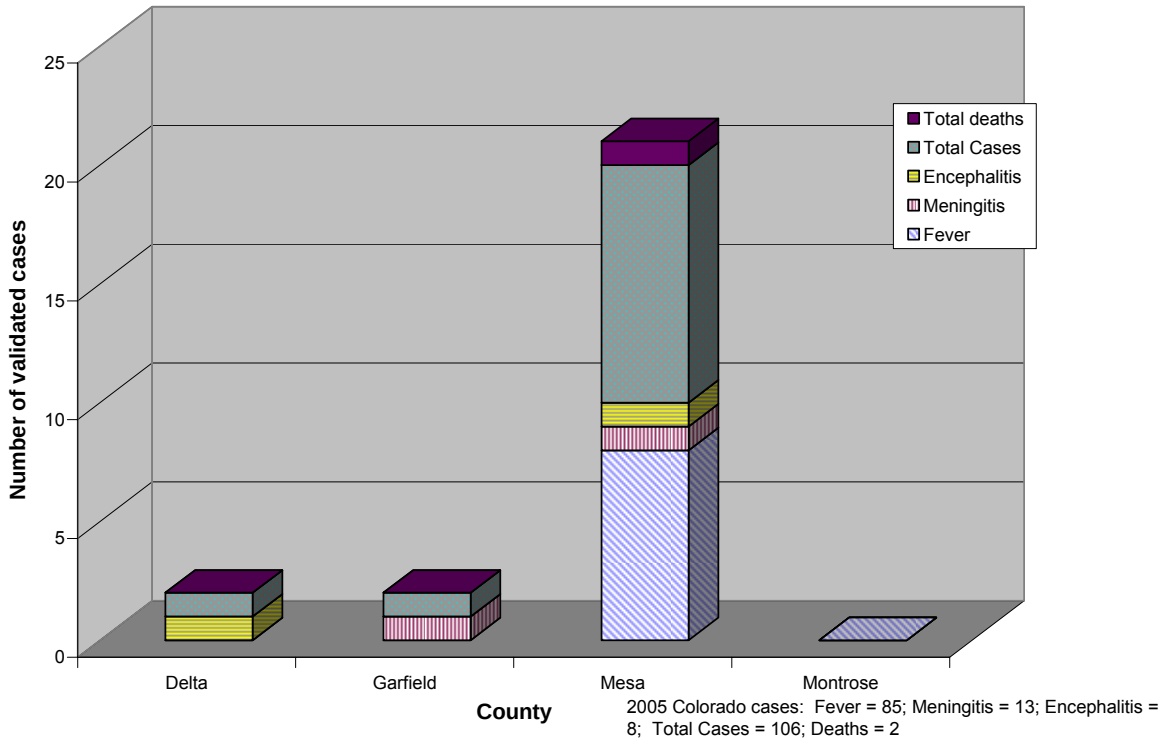


Figure 52. West Nile Virus Infections – 2005

Figure 53. West Nile Virus Infections – 2006

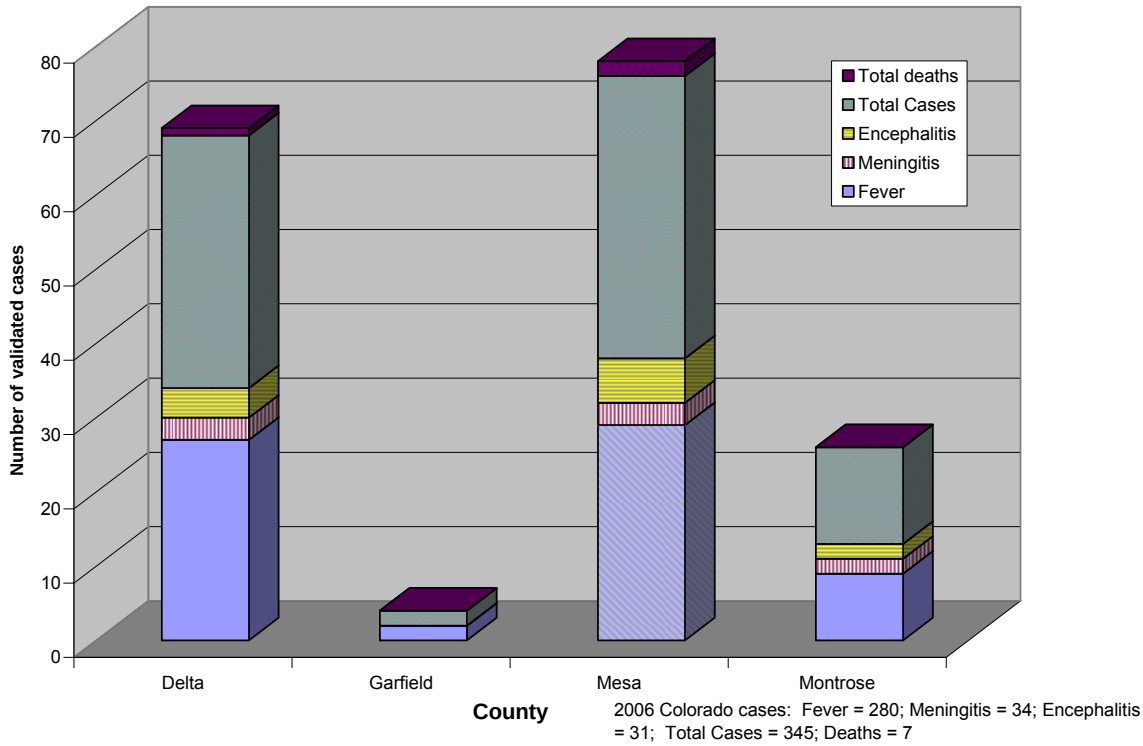


Figure 54. West Nile Virus Infections – 2007

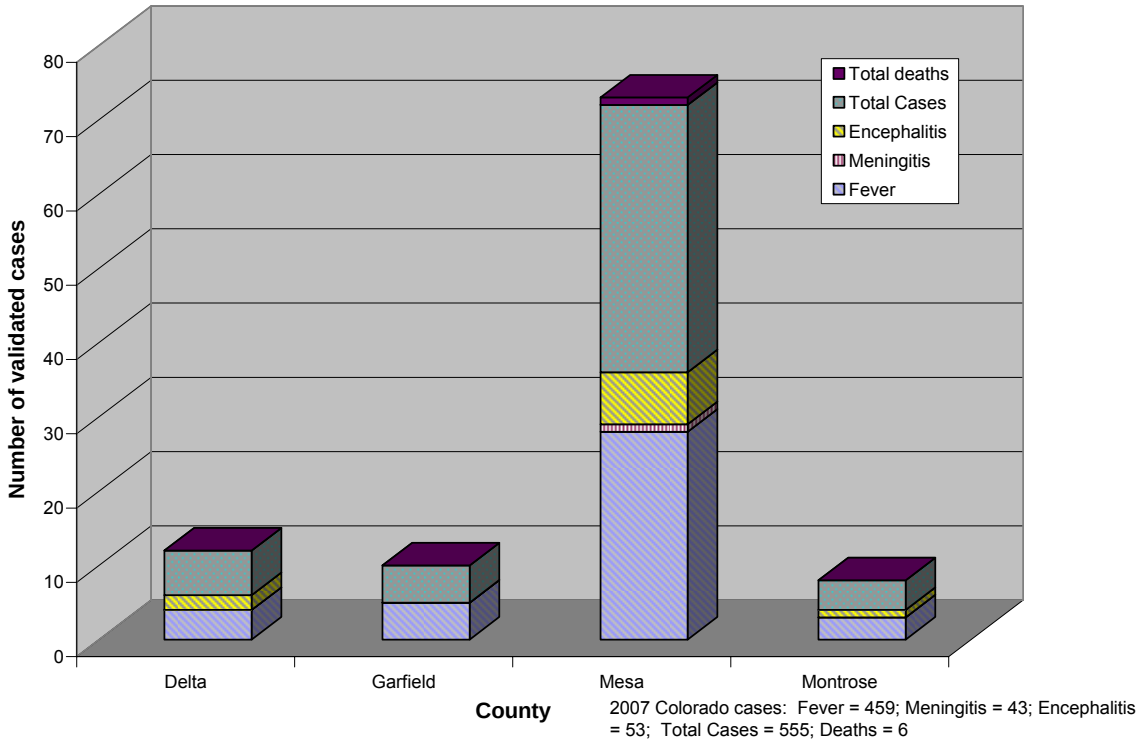
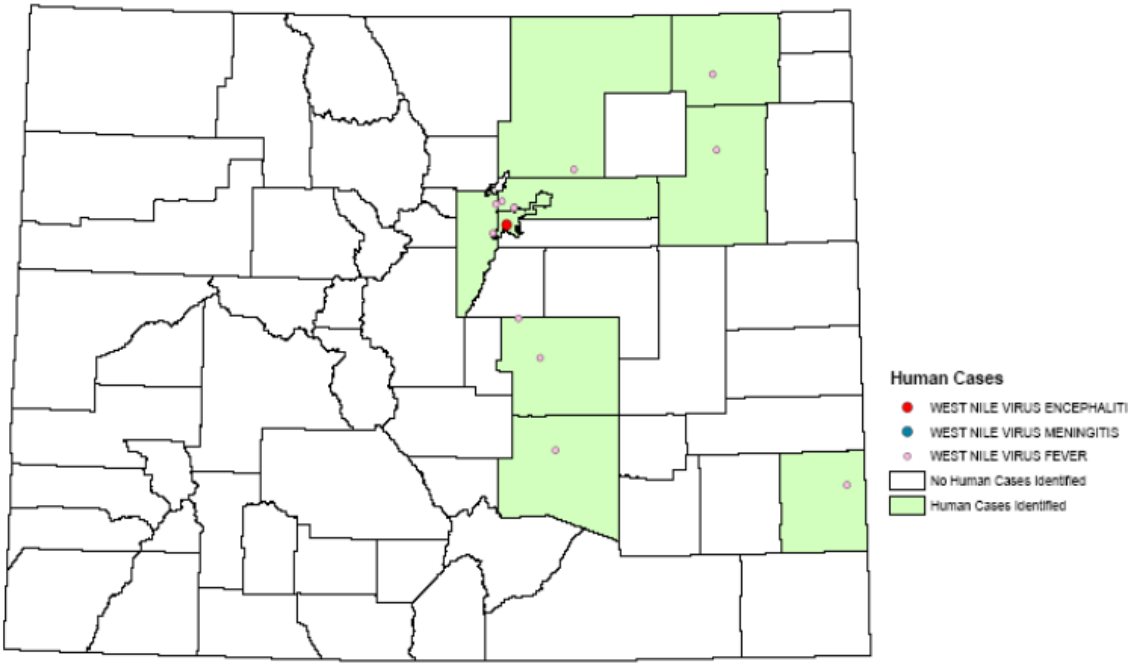
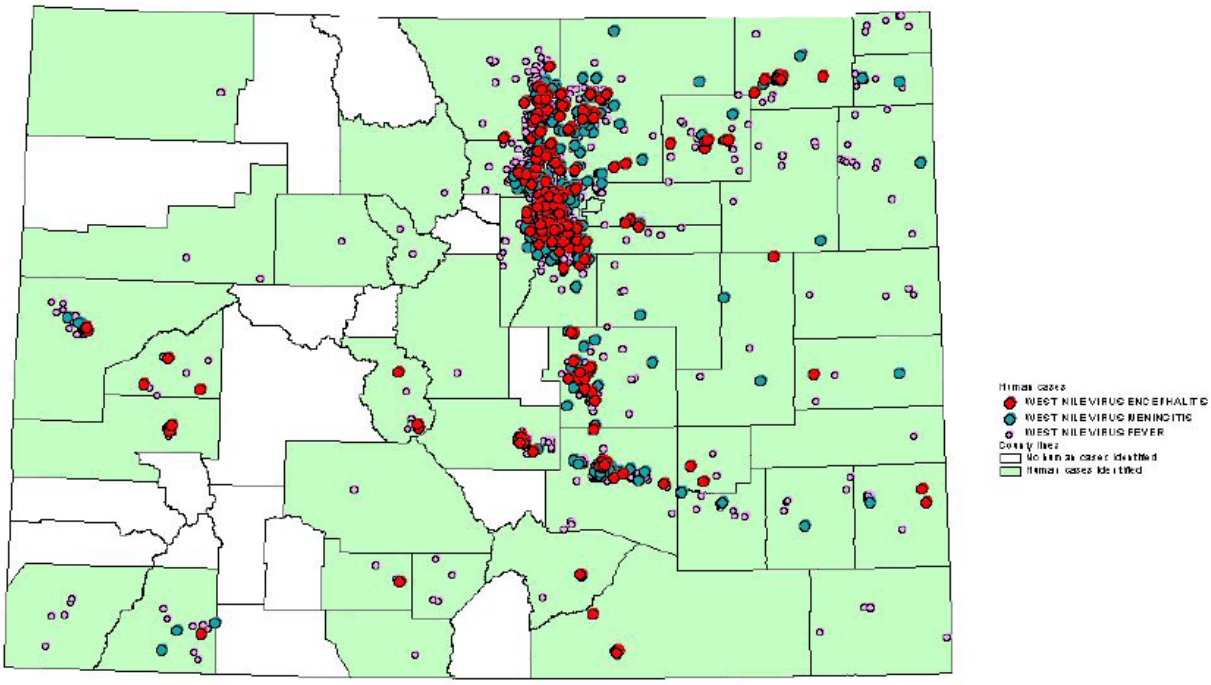


Figure 55. Colorado West Nile Virus Human Cases – 2002



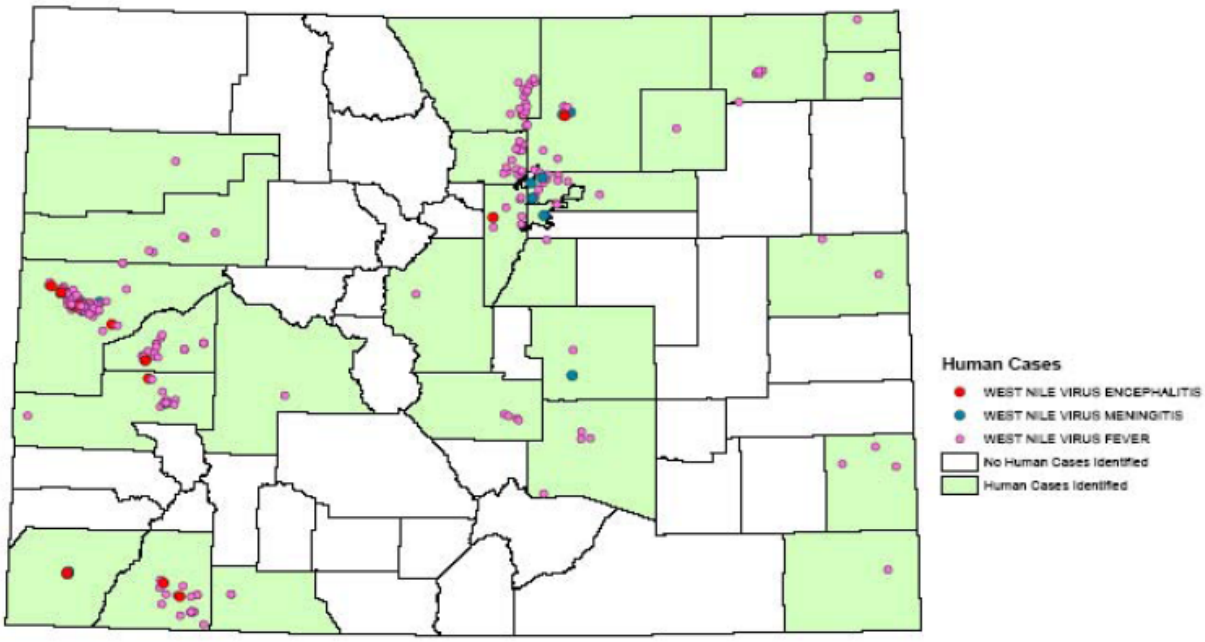
N = 14



N = 2,944

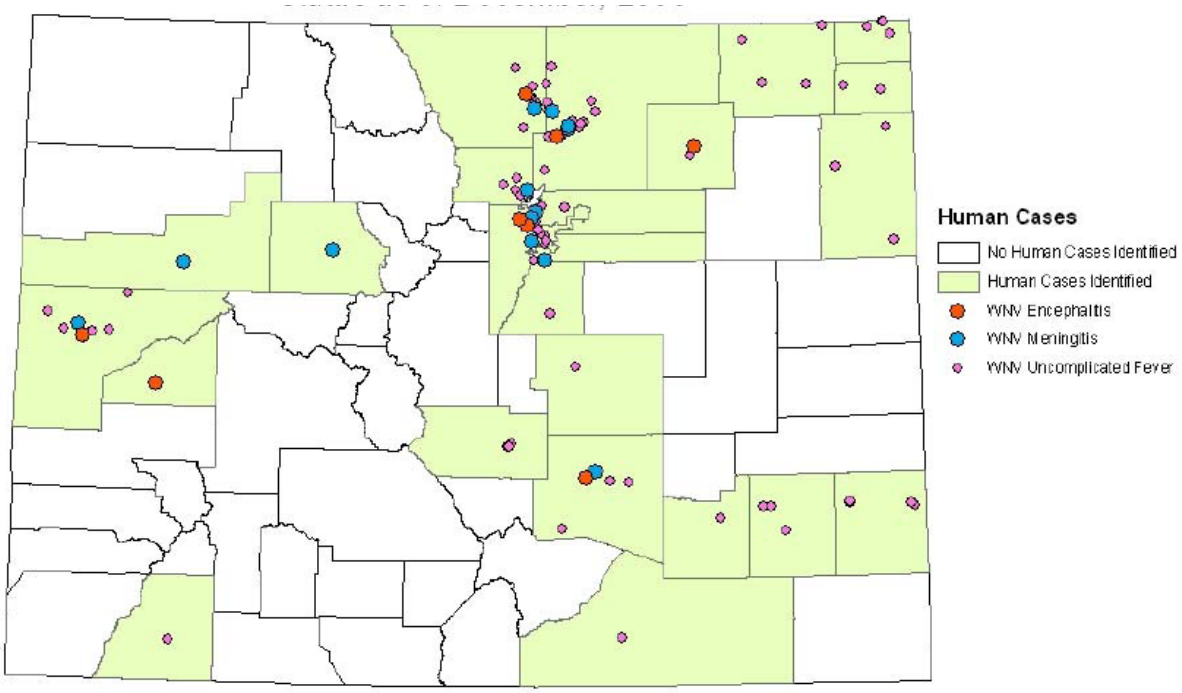
Figure 56. Colorado West Nile Virus Human Cases – 2003

Figure 57. Colorado West Nile Virus Human Cases – 2004



N = 289

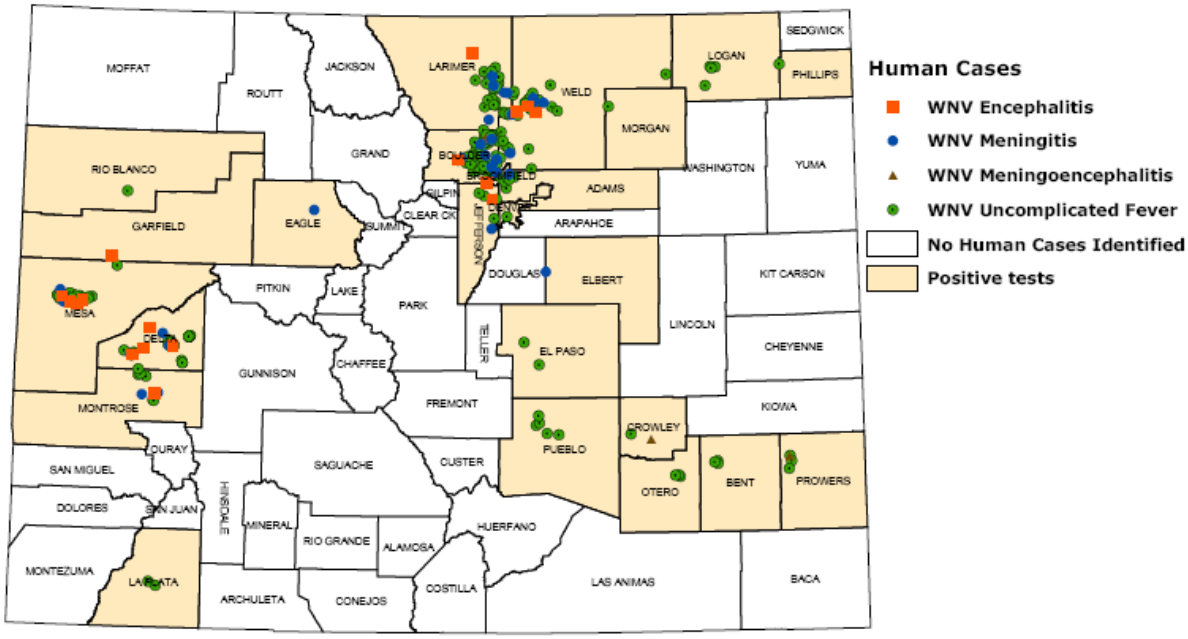
Figure 58. Colorado West Nile Virus Human Cases – 2005



N=106

NOTE: Points have been displaced from actual location to protect confidentiality

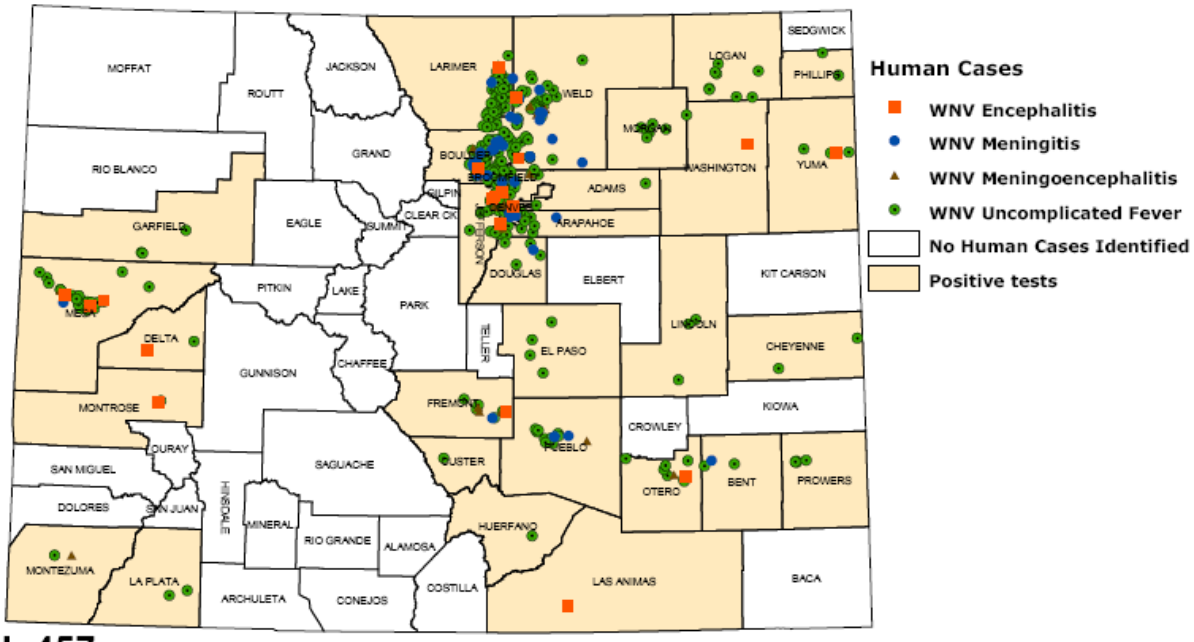
Figure 59. Colorado West Nile Virus Human Cases – 2006



N=282

Note: Points have been displaced from actual locations to protect confidentiality.

Figure 60. Colorado West Nile Virus Human Cases – 2007



N=457

Note: Points have been displaced from actual locations to protect confidentiality.

Figure 61. Colorado West Nile Virus Surveillance Map – 2002

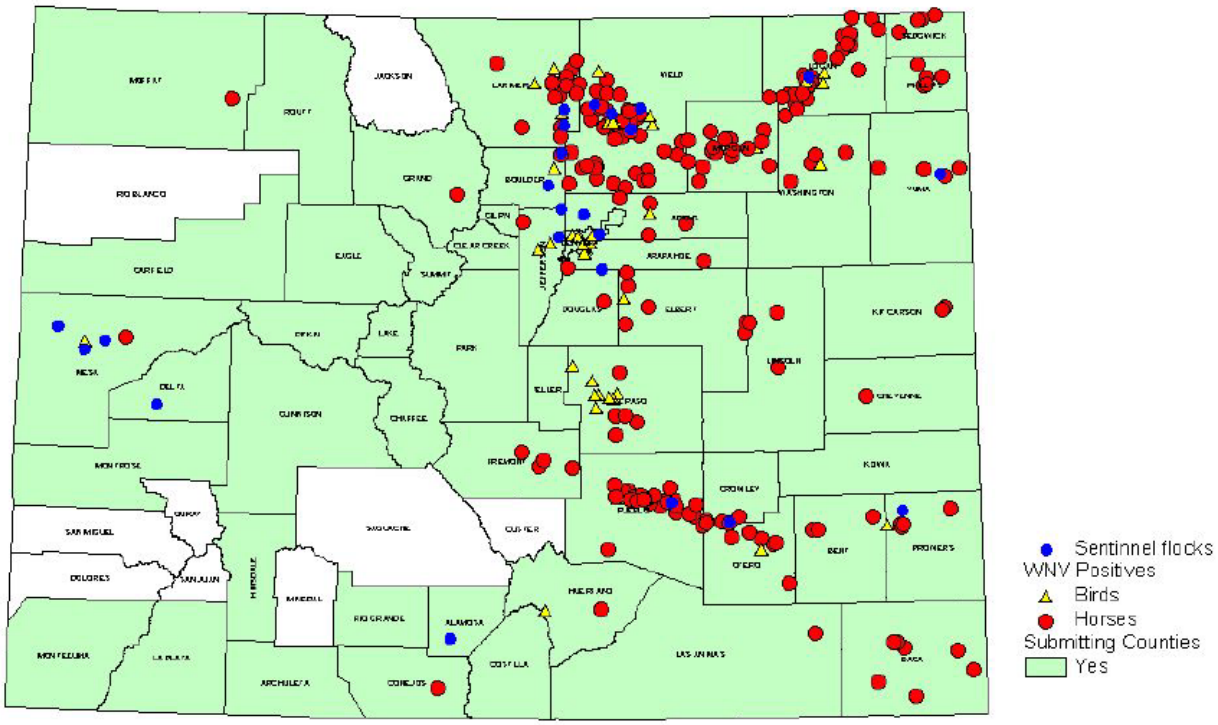


Figure 62. Colorado West Nile Virus Surveillance Map – 2003

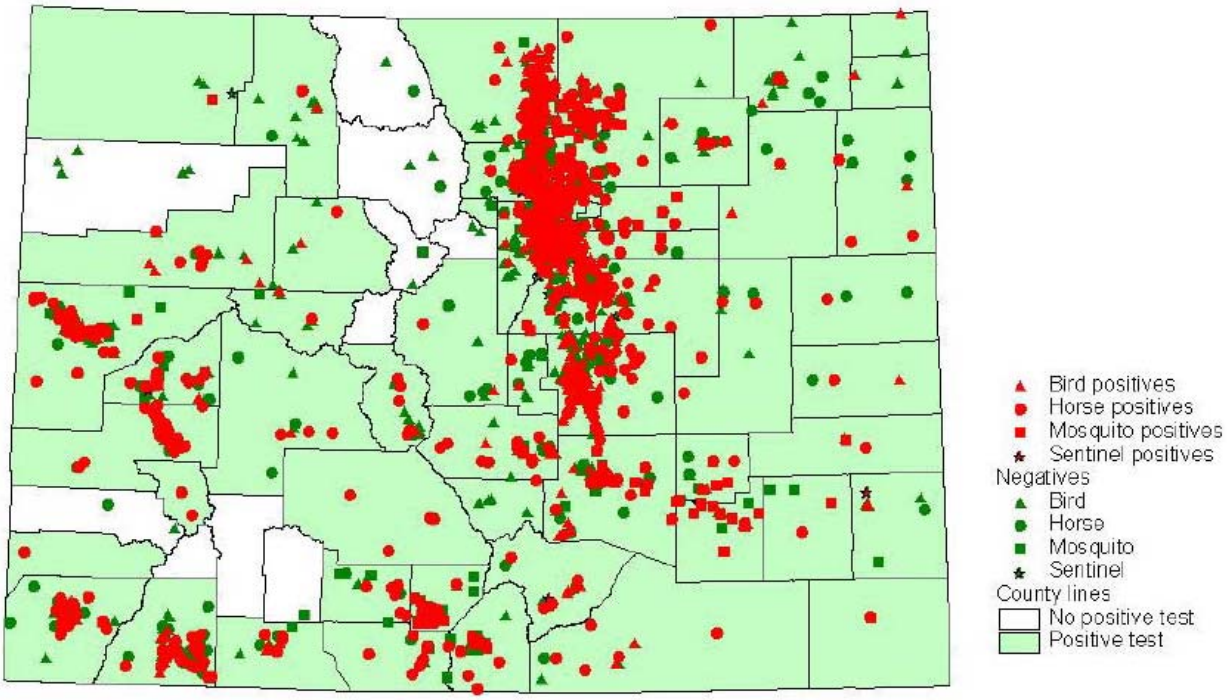


Figure 63. Colorado West Nile Virus Surveillance Map – 2004

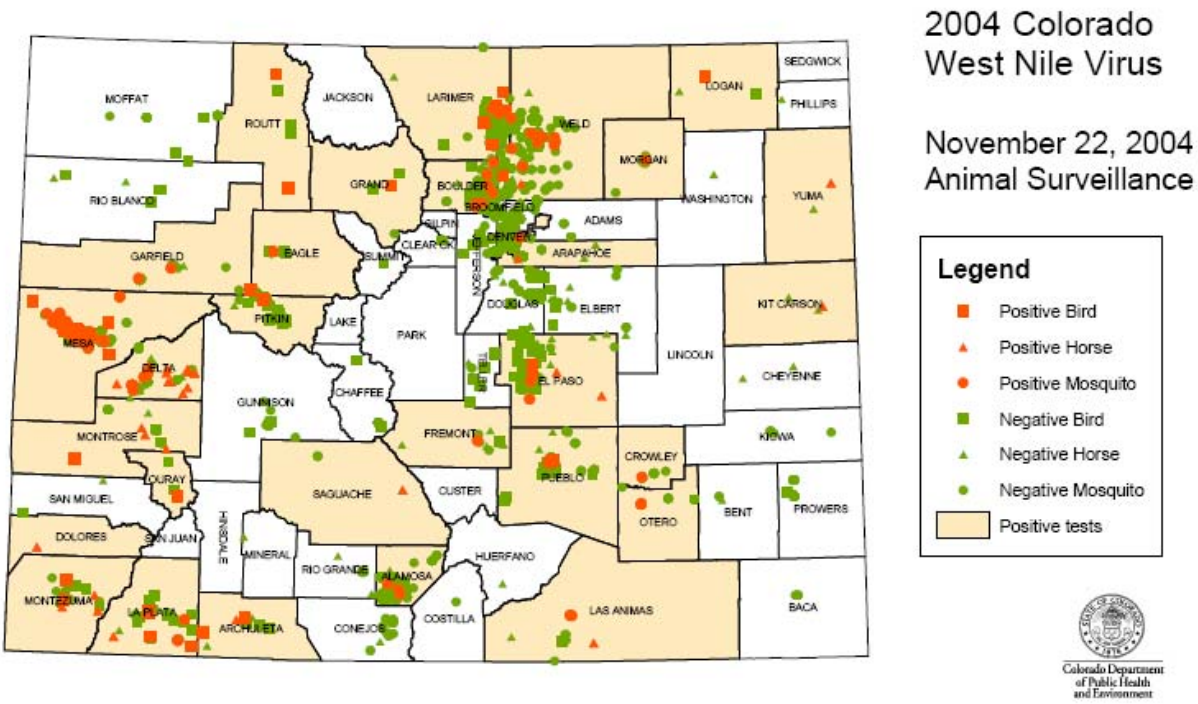


Figure 64. Colorado West Nile Virus Surveillance Map – 2005

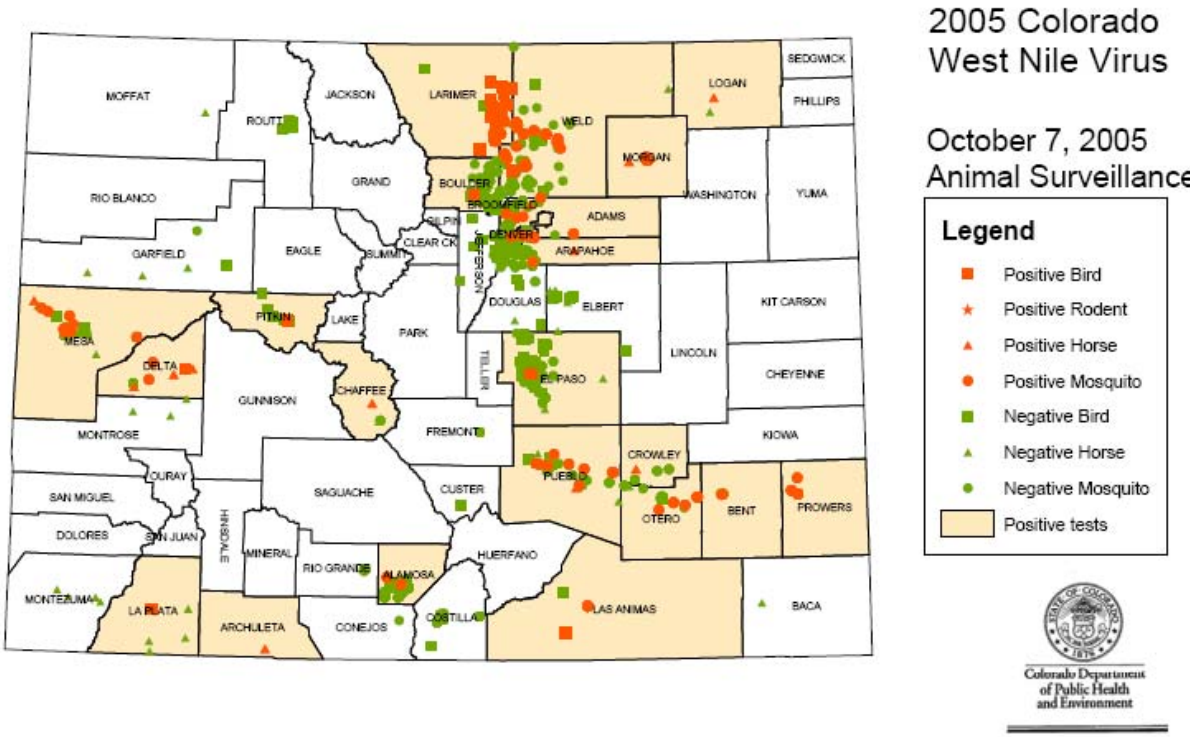


Figure 65. Colorado West Nile Virus Surveillance Map – 2006

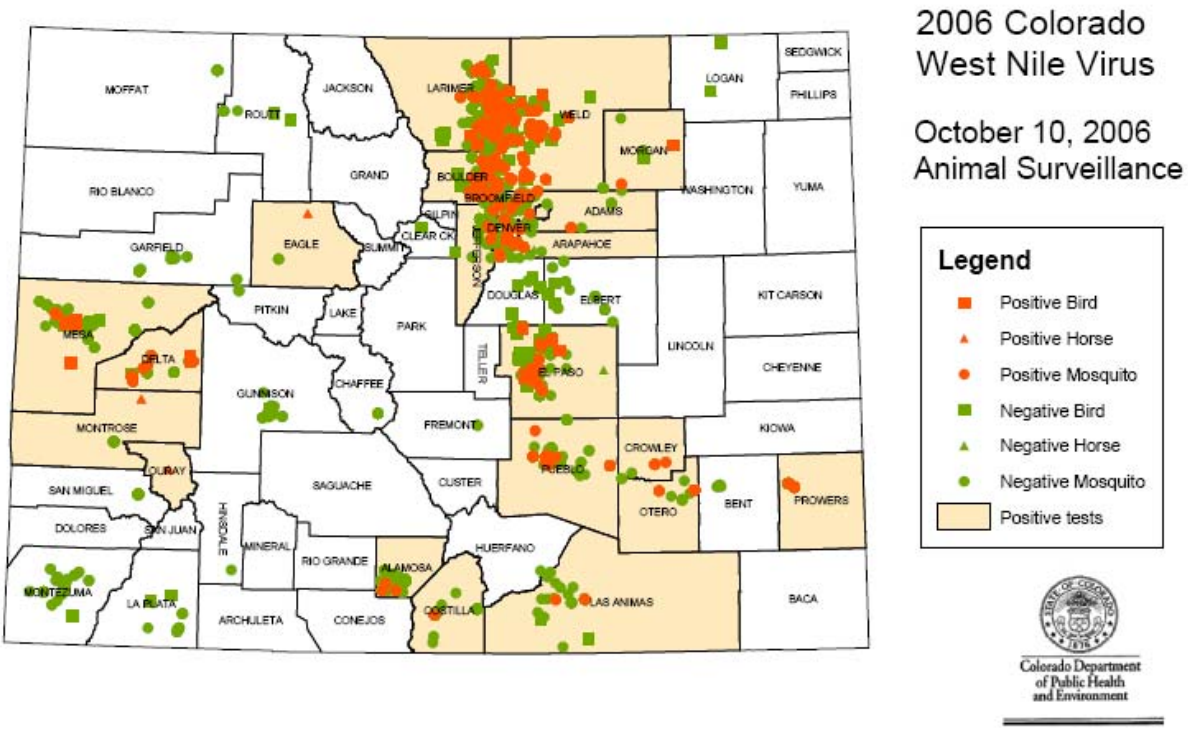
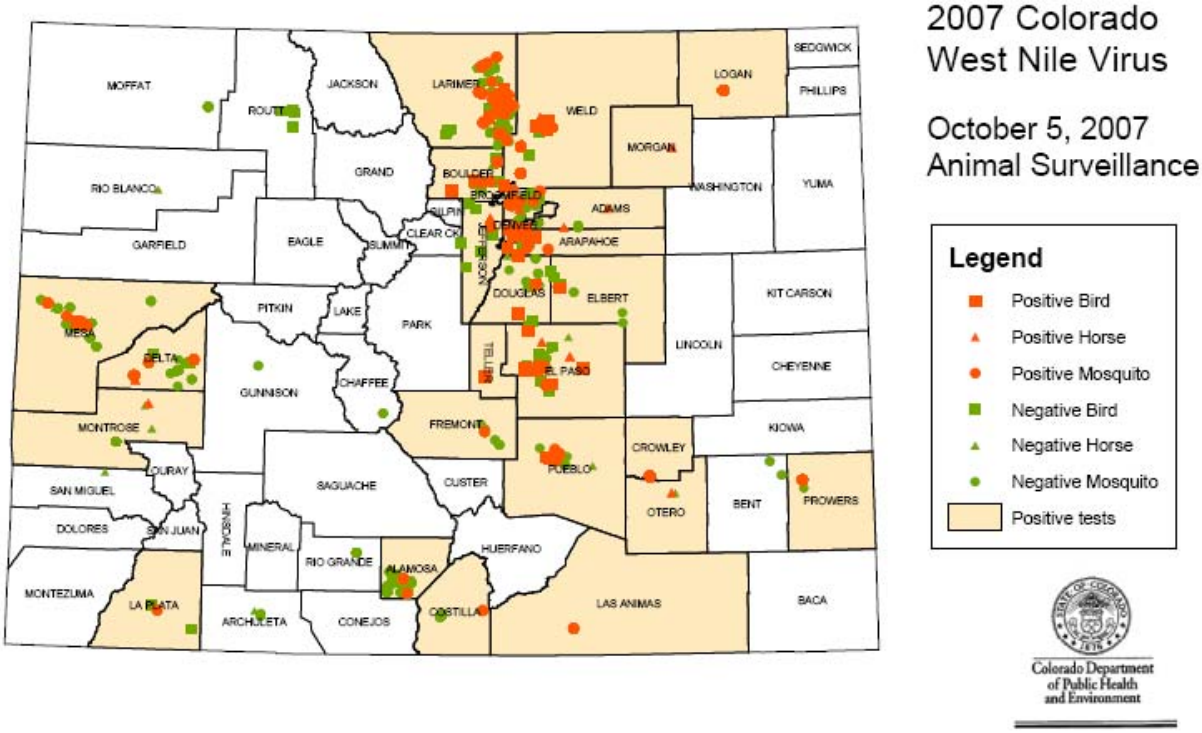


Figure 66. Colorado West Nile Virus Surveillance Map – 2007



Reportable Conditions

The Colorado Department of Public Health and Environment, by state statute, collects data on a variety of "reportable conditions", including a number of infectious diseases and cancer. Reportable conditions for which Garfield County, at least one of the comparison counties, or another county in the state reported one or more cases of the condition are detailed in Tables 25A through 25G for each of the years 2000, 2001, 2002, 2003, 2004, 2005, and 2006. Numbers of cases and rates (per 1,000 population, 2000 census data) for the four counties and the state are given. Garfield County cases are highlighted to allow easier comparison with the other county data.

- In 2000, none of the rates for reportable conditions in Garfield County were ranked highest, when compared to the state and comparison county rates.
- In 2001, the only reportable condition for which Garfield County had the highest rate was giardiasis.
- In 2002, Garfield County's rates were highest for influenza, meningitis, and invasive strep pneumonia.
- In 2003, Garfield County's rates for giardiasis, hepatitis A, and influenza were the highest.
- In 2004, Garfield County's rates for encephalitis, salmonellosis, and shigellosis were the highest. The rate for meningitis was the same as Mesa County's rate, and was higher than for the state and the other two comparison counties.
- In 2005, Garfield County's rates were the highest for encephalitis (1 case out of only 8 in the state that year), hepatitis A, malaria, meningitis, shigellosis, and varicella (chicken pox).
- In 2006, Garfield County's rates for hanta virus pulmonary syndrome, hepatitis A and C, salmonellosis, and shigellosis were the highest.

At least one case of the following diseases was reported during each year of the period, 2000-2006:

- camphylobacter
- giardiasis
- influenza
- salmonella
- shigellosis
- hepatitis C
- hepatitis A was reported in five of the seven years
- hepatitis B was reported in six of the seven years.

Table 25A. 2000 Reportable Conditions	Delta Cases	Delta Rate	Garfield Cases	Garfield Rate	Mesa Cases	Mesa Rate	Montrose Cases	Montrose Rate	Colorado Total	Colorado Rate
AMEBIASIS	0	0.00	0	0.00	3	0.25	1	**	42	0.10
CAMPYLOBACTER	6	2.14	6	1.36	16	1.36	2	**	592	1.36
CRYPTOSPORIDIOSIS	1	**	0	0.00	0	0.00	0	0.00	72	0.17
E0COLI	1	**	3	0.68	7	0.59	1	**	157	0.36
ENCEPHALITIS	0	0.00	0	0.00	2	**	0	0.00	15	0.03
GIARDIASIS	2	**	5	1.13	11	0.93	4	1.19	695	1.60
HAEMOPHILUS INFLUENZAE	0	0.00	0	0.00	0	0.00	0	0.00	33	0.08
HANTAVIRUS PULMONARY SYNDROME	1	**	0	0.00	0	0.00	0	0.00	8	0.02
HEMOLYTIC UREMIC SYNDRM	0	0.00	0	0.00	0	0.00	0	0.00	11	0.03
HEPATITIS A	0	0.00	1	0.23	4	0.34	1	0.30	223	0.51
HEPATITIS B	2	**	1	0.23	4	0.34	3	0.89	831	1.92
HEPATITIS C	8	2.86	18	4.07	60	5.10	2	**	6802	15.68
INFLUENZA	3	1.07	2	**	64	5.44	2	**	592	1.36
LISTERIOSIS	0	0.00	2	**	0	0.00	0	0.00	11	0.03
MALARIA	1	**	0	0.00	2	**	0	0.00	30	0.07
MENINGITIS	0	0.00	1	0.23	5	0.42	0	0.00	211	0.49
MENINGOCOCCAL DISEASE	0	0.00	0	0.00	1	**	0	0.00	35	0.08
MUMPS	0	0.00	0	0.00	0	0.00	0	0.00	1	**
PERTUSSIS	0	0.00	0	0.00	31	2.63	0	0.00	487	1.12
SALMONELLOSIS	6	2.14	7	1.58	15	1.27	12	3.56	692	1.59
SHIGELLOSIS	1	**	4	0.90	3	0.25	0	0.00	269	0.62
STREP PNEUMO INVASIVE	0	0.00	0	0.00	0	0.00	0	0.00	226	0.52
TOXIC SHOCK-STREP	0	0.00	0	0.00	0	0.00	0	0.00	2	**
TYPHOID FEVER	0	0.00	0	0.00	0	0.00	0	0.00	2	**
Column Total	32	11.42	50	11.30	228	19.38	28	8.32	12039	27.75

Rates per 1,000 population, based on county population according to 2000 census data.

*** rates not calculated for fewer than 3 cases.*

Table 25B. 2001 Reportable Conditions	Delta Cases	Delta Rate	Garfield Cases	Garfield Rate	Mesa Cases	Mesa Rate	Montrose Cases	Montrose Rate	Colorado Total	Colorado Rate
AMEBIASIS	1	**	1	0.22	1	**	0	0.00	34	0.08
CAMPYLOBACTER	6	2.09	8	1.73	19	1.58	8	2.31	766	1.72
CRYPTOSPORIDIOSIS	0	0.00	0	0.00	2	**	0	0.00	44	0.10
E0COLI	1	**	1	0.22	2	**	0	0.00	95	0.21
ENCEPHALITIS	0	0.00	0	0.00	1	**	0	0.00	10	0.02
GIARDIASIS	4	1.39	10	2.17	15	1.25	2	**	632	1.42
HAEMOPHILUS INFLUENZAE	0	0.00	0	0.00	1	**	0	0.00	38	0.09
HEMOLYTIC UREMIC SYNDRM	1	**	0	0.00	0	0.00	0	0.00	11	0.02
HEPATITIS A	0	0.00	1	0.22	1	**	0	0.00	89	0.20
HEPATITIS B	1	0.35	0	0.00	10	0.83	2	**	748	1.68
HEPATITIS C	15	5.22	24	5.20	104	8.66	11	3.18	5708	12.84
INFLUENZA	5	1.74	12	2.60	25	2.08	1	**	1743	3.92
LISTERIOSIS	0	0.00	0	0.00	0	0.00	0	0.00	10	0.02
MALARIA	0	0.00	1	0.22	0	0.00	0	0.00	25	0.06
MENINGITIS	1	**	2	**	9	0.75	0	0.00	388	0.87
MENINGOCOCCAL DISEASE	0	0.00	0	0.00	2	**	0	0.00	38	0.09
MUMPS	0	0.00	0	0.00	0	0.00	0	0.00	3	0.01
PERTUSSIS	0	0.00	0	0.00	14	1.17	1	**	389	0.87
SALMONELLOSIS	1	**	3	0.65	9	0.75	4	1.16	593	1.33
SHIGELLOSIS	0	0.00	1	0.22	2	**	0	0.00	245	0.55
STREP PNEUMO INVASIVE	0	0.00	0	0.00	2	**	0	0.00	317	0.71
TOXIC SHOCK-STREP	0	0.00	0	0.00	0	0.00	0	0.00	2	**
TYPHOID FEVER	0	0.00	0	0.00	0	0.00	0	0.00	1	**
Column Total	36	12.54	64	13.86	219	18.23	29	8.38	11929	26.83

Rates per 1,000 population, based on county population according to 2000 census data.

*** rates not calculated for fewer than 3 cases.*

Table 25C. 2002 Reportable Conditions	Delta Cases	Delta Rate	Garfield Cases	Garfield Rate	Mesa Cases	Mesa Rate	Montrose Cases	Montrose Rate	Colorado Total	Colorado Rate
AMEBIASIS	0	0.00	0	0.00	0	0.00	0	0.00	32	0.07
CAMPYLOBACTER	2	**	3	0.63	3	0.24	1	**	616	1.36
CRYPTOSPORIDIOSIS	1	**	0	0.00	5	0.41	0	0.00	57	0.13
E0COLI	0	0.00	1	**	1	**	1	**	109	0.24
ENCEPHALITIS	0	0.00	0	0.00	0	0.00	0	0.00	15	0.03
GIARDIASIS	2	**	8	1.69	7	0.57	9	2.54	578	1.28
HAEMOPHILUS INFLUENZAE	0	0.00	0	0.00	0	0.00	0	0.00	36	0.08
HANTAVIRUS PULMONARY SYNDROME	0	0.00	0	0.00	0	0.00	0	0.00	1	**
HEMOLYTIC UREMIC SYNDRM	0	0.00	1	**	1	**	0	0.00	14	0.03
HEPATITIS A	1	**	0	0.00	2	**	0	0.00	75	0.17
HEPATITIS B	0	0.00	1	**	14	1.14	0	0.00	789	1.74
HEPATITIS C	11	3.77	34	7.17	96	7.84	6	1.69	6128	13.55
INFLUENZA	35	11.99	126	26.56	259	21.15	5	1.41	3363	7.44
LISTERIOSIS	0	0.00	0	0.00	0	0.00	0	0.00	7	0.02
MALARIA	0	0.00	0	0.00	0	0.00	0	0.00	25	0.06
MENINGITIS	1	**	5	1.05	3	0.24	0	0.00	254	0.56
MENINGOCOCCAL DISEASE	2	**	0	0.00	0	0.00	0	0.00	25	0.06
MUMPS	0	0.00	0	0.00	0	0.00	0	0.00	2	**
PERTUSSIS	6	2.06	0	0.00	8	0.65	0	0.00	464	1.03
SALMONELLOSIS	4	1.37	4	0.84	7	0.57	6	1.69	615	1.36
SHIGELLOSIS	3	1.03	4	0.84	3	0.24	0	0.00	213	0.47
STREP PNEUMO INVASIVE	0	0.00	6	1.26	0	0.00	0	0.00	392	0.87
TOXIC SHOCK-STREP	0	0.00	0	0.00	0	0.00	0	0.00	7	0.02
TYPHOID FEVER	0	0.00	0	0.00	0	0.00	0	0.00	5	0.01
WEST NILE VIRUS	0	0.00	0	0.00	0	0.00	0	0.00	12	0.03
Column Total	68	23.29	193	40.68	409	33.40	28	7.90	13834	30.59

Rates per 1,000 population, based on county population according to 2000 census data.

*** rates not calculated for fewer than 3 cases.*

Table 25D. 2003 Reportable Conditions	Delta Cases	Delta Rate	Garfield Cases	Garfield Rate	Mesa Cases	Mesa Rate	Montrose Cases	Montrose Rate	Colorado Total	Colorado Rate
AMEBIASIS	0	0.00	0	0.00	0	0.00	0	0.00	25	0.05
CAMPYLOBACTER	8	2.70	1	**	10	0.80	2	**	605	1.32
CRYPTOSPORIDIOSIS	0	0.00	0	0.00	7	0.56	0	0.00	38	0.08
E0COLI	1	**	1	**	3	0.24	0	0.00	78	0.17
ENCEPHALITIS	0	0.00	0	0.00	0	0.00	0	0.00	3	0.01
GIARDIASIS	0	0.00	8	1.65	7	0.56	2	**	458	1.00
HAEMOPHILUS INFLUENZAE	1	**	0	0.00	3	0.24	0	0.00	39	0.09
HANTAVIRUS PULMONARY SYNDROME	0	0.00	0	0.00	0	0.00	0	0.00	5	0.01
HEMOLYTIC UREMIC SYNDRM	0	0.00	1	**	0	0.00	0	0.00	8	0.02
HEPATITIS A	0	0.00	8	1.65	0	0.00	1	**	59	0.13
HEPATITIS B	4	1.35	1	**	14	1.12	1	**	684	1.49
HEPATITIS C	27	9.10	36	7.44	120	9.59	13	3.60	5977	13.03
INFLUENZA	144	48.54	444	91.75	413	33.02	41	11.35	14880	32.44
LISTERIOSIS	0	0.00	0	0.00	0	0.00	0	0.00	9	0.02
MALARIA	0	0.00	1	**	0	0.00	0	0.00	22	0.05
MENINGITIS	2	**	1	**	10	0.80	0	0.00	709	1.55
MENINGOCOCCAL DISEASE	0	0.00	0	0.00	1	**	1	**	27	0.06
MUMPS	0	0.00	0	0.00	0	0.00	0	0.00	1	**
PERTUSSIS	1	**	0	0.00	3	0.24	1	**	368	0.80
SALMONELLOSIS	1	**	3	0.62	17	1.36	0	0.00	492	1.07
SHIGELLOSIS	2	**	3	0.62	2	**	0	0.00	331	0.72
STREP PNEUMO INVASIVE	3	1.01	3	0.62	1	**	1	0.28	365	0.80
TOXIC SHOCK-STREP	0	0.00	0	0.00	0	0.00	0	0.00	3	0.01
TYPHOID FEVER	0	0.00	0	0.00	0	0.00	0	0.00	4	0.01
WEST NILE VIRUS	10	3.37	2	**	19	1.52	9	2.49	2947	6.42
Column Totals	204	68.77	513	106.00	630	50.37	72	19.93	28137	61.34

Rates per 1,000 population, based on county population according to 2000 census data.
*** rates not calculated for fewer than 3 cases.*

Table 25E. 2004 Reportable Conditions	Delta Cases	Delta Rate	Garfield Cases	Garfield Rate	Mesa Cases	Mesa Rate	Montrose Cases	Montrose Rate	Colorado Total	Colorado Rate
AMEBIASIS	0	0.00	0	0.00	0	0.00	0	0.00	15	0.03
CAMPYLOBACTER	7	2.33	9	1.82	5	0.39	3	0.81	827	1.78
CRYPTOSPORIDIOSIS	0	0.00	0	0.00	3	0.23	3	0.81	59	0.13
E0COLI	0	0.00	0	0.00	4	0.31	0	0.00	52	0.11
ENCEPHALITIS	0	0.00	3	0.61	0	0.00	0	0.00	8	0.02
GIARDIASIS	6	1.99	5	1.01	12	0.94	7	1.90	517	1.11
HAEMOPHILUS INFLUENZAE	1	**	0	0.00	1	**	1	**	44	0.09
HANTAVIRUS PULMONARY SYNDROME	0	0.00	0	0.00	0	0.00	0	0.00	4	0.01
HEMOLYTIC UREMIC SYNDRM	0	0.00	0	0.00	0	0.00	0	0.00	6	0.01
HEPATITIS A	1	**	1	**	1	**	0	0.00	51	0.11
HEPATITIS B	4	1.33	1	**	5	0.39	0	0.00	578	1.24
HEPATITIS C	30	9.97	49	9.93	153	11.97	34	9.21	4818	10.35
INFLUENZA	0	0.00	1	**	0	0.00	0	0.00	26	0.06
LISTERIOSIS	0	0.00	0	0.00	1	**	0	0.00	13	0.03
MALARIA	0	0.00	1	**	0	0.00	0	0.00	19	0.04
MENINGITIS	1	**	8	1.62	21	1.64	0	0.00	424	0.91
MENINGOCOCCAL DISEASE	0	0.00	0	0.00	0	0.00	0	0.00	15	0.03
MUMPS	0	0.00	0	0.00	0	0.00	0	0.00	3	0.01
PERTUSSIS	26	8.64	1	**	112	8.76	1	**	1185	2.55
SALMONELLOSIS	3	1.00	6	1.22	4	0.31	1	**	542	1.16
SHIGELLOSIS	0	0.00	2	**	1	**	1	**	161	0.35
STREP PNEUMO INVASIVE	11	3.66	10	2.03	13	1.02	1	**	332	0.71
TOXIC SHOCK-STREP	0	0.00	1	**	0	0.00	0	0.00	2	**
TYPHOID FEVER	0	0.00	1	**	0	0.00	0	0.00	3	0.01
VARICELLA(CHICKEN POX)	1	**	41	8.31	28	2.19	44	11.91	2040	4.38
WEST NILE VIRUS	27	8.98	5	1.01	127	9.94	11	2.98	296	0.64
Total	118	39.23	145	29.40	491	38.42	107	28.97	12040	25.88

Rates per 1,000 population, based on county population according to 2000 census data.

*** rates not calculated for fewer than 3 cases.*

Table 25F. 2005 Reportable Conditions	Delta Cases	Delta Rate	Garfield Cases	Garfield Rate	Mesa Cases	Mesa Rate	Montrose Cases	Montrose Rate	Colorado Total	Colorado Rate
AMEBIASIS	0	0.00	0	0.00	1	**	1	**	17	0.04
CAMPYLOBACTER	4	1.32	10	1.97	10	0.77	6	1.58	868	1.84
CRYPTOSPORIDIOSIS	0	0.00	0	0.00	5	0.38	1	**	50	0.11
ENCEPHALITIS	0	0.00	1	**	0	0.00	0	0.00	8	0.02
GIARDIASIS	2	**	5	0.99	11	0.84	4	1.06	534	1.13
HAEMOPHILUS INFLUENZAE	1	**	1	**	4	0.31	0	0.00	42	0.09
HANTAVIRUS PULMONARY SYNDROME	0	0.00	0	0.00	0	0.00	0	0.00	11	0.02
HEMOLYTIC UREMIC SYNDRM	0	0.00	0	0.00	0	0.00	0	0.00	10	0.02
HEPATITIS A	0	0.00	2	**	0	0.00	0	0.00	49	0.10
HEPATITIS B	0	0.00	1	**	2	**	1	**	435	0.92
HEPATITIS C	24	7.93	36	7.10	127	9.74	28	7.39	4235	8.97
INFLUENZA	10	3.31	11	2.17	36	2.76	1	**	1032	2.19
LISTERIOSIS	0	0.00	0	0.00	1	**	0	0.00	6	0.01
MALARIA	0	0.00	1	**	0	0.00	0	0.00	25	0.05
MENINGITIS	1	**	4	0.79	5	0.38	0	0.00	322	0.68
MENINGOCOCCAL DISEASE	0	0.00	0	0.00	1	**	0	0.00	19	0.04
MUMPS	0	0.00	0	0.00	0	0.00	0	0.00	6	0.01
PERTUSSIS	5	1.65	15	2.96	81	6.21	3	0.79	1383	2.93
SALMONELLOSIS	5	1.65	5	0.99	13	1.00	5	1.32	582	1.23
SHIGELLOSIS	0	0.00	6	1.18	0	0.00	0	0.00	170	0.36
STEC (shiga toxin producing E0coli)	1	**	1	**	6	0.46	0	0.00	83	0.18
STREP PNEUMO INVASIVE	2	**	4	0.79	16	1.23	0	0.00	421	0.89
TOXIC SHOCK-STREP	0	0.00	0	0.00	3	0.23	0	0.00	6	0.01
TYPHOID FEVER	0	0.00	0	0.00	0	0.00	0	0.00	7	0.01
VARICELLA(CHICKEN POX)	7	2.31	57	11.25	89	6.83	33	8.71	1797	3.81
WEST NILE VIRUS	1	**	1	**	10	0.77	0	0.00	110	0.23
Total	63	20.82	161	31.77	421	32.29	83	21.91	12228	25.89

Rates per 1,000 population, based on county population according to 2000 census data.

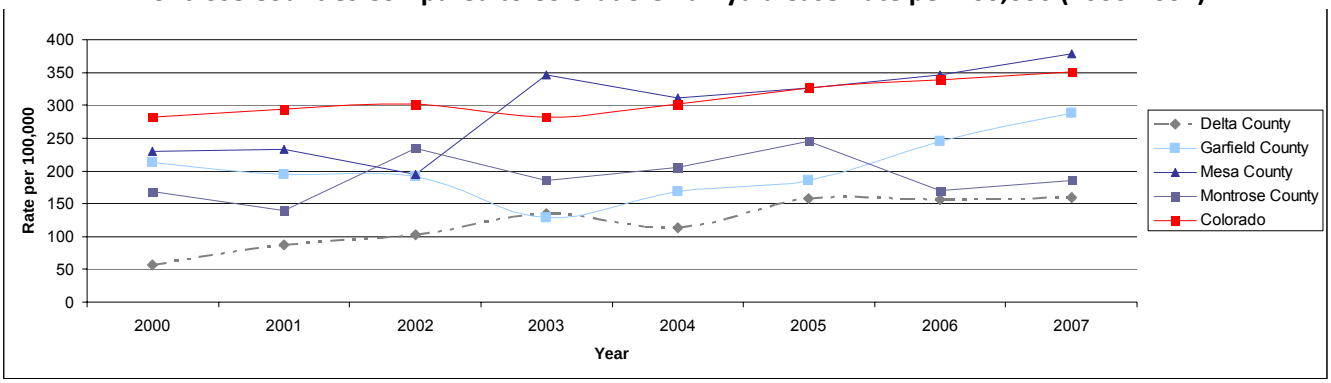
*** rates not calculated for fewer than 3 cases.*

Table 25G. 2006 Reportable Conditions	Delta Cases	Delta Rate	Garfield Cases	Garfield Rate	Mesa Cases	Mesa Rate	Montrose Cases	Montrose Rate	Colorado Total	Colorado Rate
AMEBIASIS	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
CAMPYLOBACTER	6	1.93	0	0.00	8	0.60	5	1.41	830	1.73
CRYPTOSPORIDIOSIS	0	0.00	0	0.00	2	**	0	0.00	77	0.16
ENCEPHALITIS	0	0.00	0	0.00	1	**	0	0.00	11	0.02
GIARDIASIS	3	0.97	3	0.57	7	0.53	3	0.84	554	1.15
HAEMOPHILUS INFLUENZAE	0	0.00	1	**	5	0.38	0	0.00	51	0.11
HANTAVIRUS PULMONARY SYNDROME	0	0.00	1	**	0	0.00	0	0.00	6	0.01
Hemolytic Uremic Syndrm	0	0.00	0	0.00	0	0.00	0	0.00	8	0.02
HEPATITIS A	0	0.00	1	**	0	0.00	0	0.00	44	0.09
HEPATITIS B	1	**	2	**	10	0.75	2	**	521	1.08
HEPATITIS C	27	8.71	51	9.77	115	8.63	22	6.19	3490	7.26
INFLUENZA	11	3.55	1	**	17	1.28	5	1.41	775	1.61
LISTERIOSIS	0	0.00	1	**	0	0.00	0	0.00	12	0.02
MALARIA	0	0.00	0	0.00	0	0.00	0	0.00	25	0.05
MENINGITIS	0	0.00	4	0.77	5	0.38	5	1.41	241	0.50
MENINGOCOCCAL DISEASE	0	0.00	1	**	2	**	0	0.00	22	0.05
MUMPS	0	0.00	1	**	0	0.00	0	0.00	51	0.11
PERTUSSIS	17	5.48	12	2.30	9	0.68	15	4.22	710	1.48
SALMONELLOSIS	6	1.93	12	2.30	9	0.68	3	0.84	625	1.30
SHIGELLOSIS	2	**	6	1.15	2	**	0	0.00	238	0.50
STEC (shiga toxin-producing E0coli)	0	0.00	0	0.00	1	**	1	**	109	0.23
STREP PNEUMO INVASIVE	6	1.93	7	1.34	10	0.75	3	0.84	422	0.88
TOXIC SHOCK-STREP	0	0.00	0	0.00	0	0.00	0	0.00	1	**
TYPHOID FEVER	0	0.00	0	0.00	0	0.00	0	0.00	7	0.01
VARICELLA(CHICKENPOX)	15	4.84	23	4.41	50	3.75	14	3.94	1504	3.13
WEST NILE VIRUS	34	10.96	2	**	38	2.85	13	3.66	345	0.72
Total	128	41.28	129	24.72	291	21.85	91	25.60	10679	22.22

Sexually Transmitted Diseases (STDs). Of the conditions that are reportable to the state health department, other than cancer, a recent trend in the frequency of STD diagnoses is worth noting. The worksheets and data to support the graphs shown below are provided in Appendix N; data are from the STD/HIV Surveillance Program, Disease Control and Environmental Epidemiology Division, Colorado Department of Public Health and Environment.

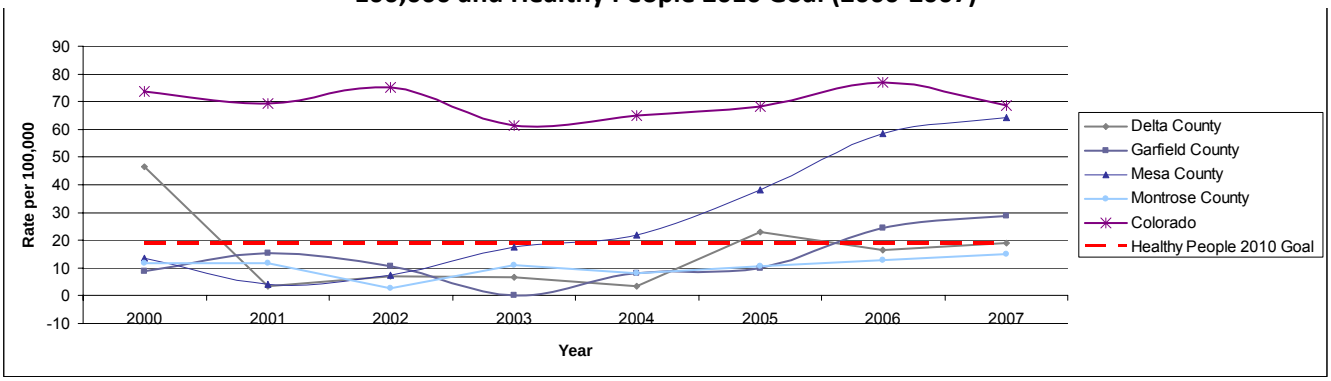
- For the time period, 2003 through 2007, the rate of reported cases of Chlamydia in both Garfield and Mesa Counties has steadily increased. It is not clear, at this time, whether this rate increase is due to an actual increase in disease or is an artifact of changes in screening patterns in the two counties. Overall, Garfield County's rates are lower than those for Mesa County and the state, but higher than those for Delta and Montrose Counties. Both Delta and Montrose Counties show an increase in reported cases for 2004-2005, but then the rates are flat (Delta) or decrease (Montrose) from 2005 through 2007.

Figure 25H. Rate per 100,000 Population of Reported Chlamydia Cases in Delta, Garfield, Mesa and Montrose Counties Compared to Colorado Chlamydia Case Rate per 100,000 (2000-2007)



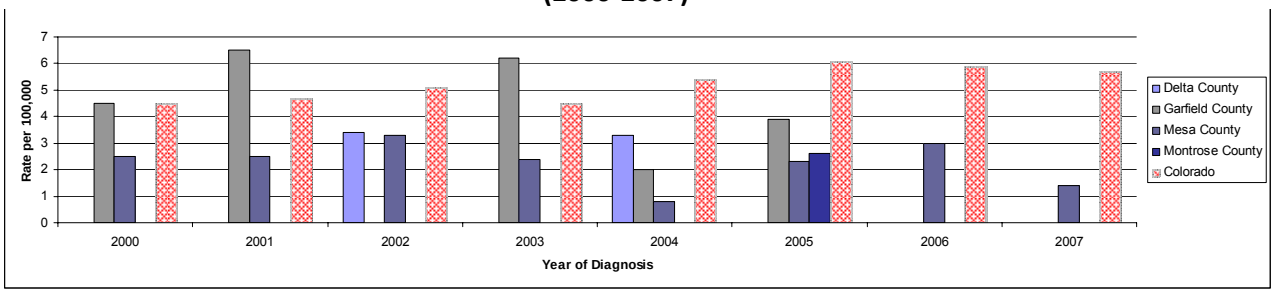
- Similarly, the rate of reported cases of Gonorrhea in Garfield and Mesa Counties steadily increased from 2003 through 2007. Garfield County's rates are again lower than those for both Mesa County and the state, but higher than those for Delta and Montrose Counties. Delta County's Gonorrhea cases showed the same pattern as for Chlamydia; Montrose County's Gonorrhea cases increased slightly over the period 2004 through 2007.

Figure 25I. Rate per 100,000 Population of Reported Gonorrhea Cases in Delta, Garfield, Mesa and Montrose Counties Compared to Colorado Gonorrhea Case Rate per 100,000 and Healthy People 2010 Goal (2000-2007)



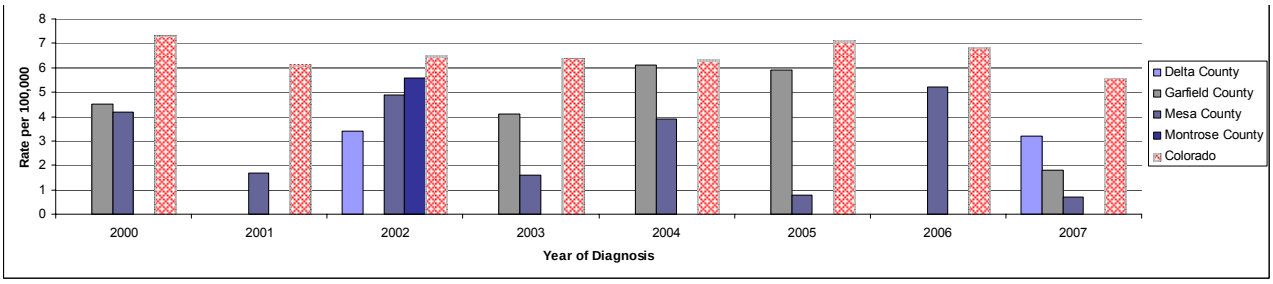
- Garfield County had the highest rate of reported HIV cases among the four counties for the years 2000, 2001, 2003, and 2005. These rates were higher than the state rate for the years 2001 and 2003. (There were no cases reported in 2002, 2006, or 2007.)

Figure 25J. Rate per 100,000 Population of Reported HIV Cases in Delta, Garfield, Mesa and Montrose Counties Compared to Colorado HIV Case Rate per 100,000 (2000-2007)



- Garfield County had the highest rate of reported AIDS cases among the four counties for the years 2000, 2003, 2004, and 2005. (There were no cases reported in 2001, 2002, or 2006.)

Figure 25K. Rate per 100,000 Population of Reported AIDS Cases in Delta, Garfield, Mesa and Montrose Counties Compared to Colorado AIDS Case Rate per 100,000 (2000-2007)



Hospital and Insurance Provider Data. Several other data sources were used to expand the picture of the health of Garfield County residents. Hospital discharge data and emergency room visit data provided comparative information on the more serious conditions for which Garfield County residents sought medical care. Health insurance claims data from a major health insurance provider operating on the Western Slope was another resource for information regarding health and healthcare usage among the comparison counties. Unfortunately, our attempts to obtain primary care provider information were not successful.

Hospital Discharge Data

Table 26 provides information on hospitalization rates and hospital choice for Garfield County residents during 2005 and 2006. Out of more than 4,000 hospitalizations of Garfield County residents during both 2005 and 2006, approximately 60% of those patients were hospitalized at Valley View Hospital in Glenwood Springs. Approximately 16% and 12% of the patients were hospitalized in St. Mary's Hospital and Medical Center (Grand Junction) or Grand River Hospital District (Rifle), respectively. The rest were hospitalized in other area or regional hospitals.

Table 27 shows the top 10 DRG (Diagnosis-Related Group) categories for Garfield County residents hospitalized in 2000 through 2005. "Diagnosis-Related Group" is a system that was developed for the U.S. Health Care Finance Administration to classify hospital cases into one of approximately 500 groups (DRGs) expected to have similar hospital resource use. The system is used by Medicare and Medicaid as part of a prospective payment plan. It takes into account diagnoses, procedures, age, gender and the presence of complications or co-existing medical conditions.

For the purposes of this study, the approximately 500 DRG categories were collapsed into 130 consolidated categories for which data were obtained. These 130 categories were then further grouped into larger, relationship categories, the contents of which, are described below.

During this six-year period, with the exception of 2003, circulation disorders and bone and joint disorders were either the first or second most common reasons for hospitalization (in 2003, birthing and pregnancy disorders was number one, and circulation disorders was third). Because of the frequency with which respiratory and nervous system concerns were mentioned by Garfield County residents, and the potential for air quality issues to cause or exacerbate respiratory conditions, these two DRG categories are highlighted. Respiratory disorders were either the fourth or fifth most common reason for hospitalization in all years; nervous system disorders were ranked either seventh or eighth each year. Digestive disorders ranked third in four out of the six years. Neonatal disorders were sixth in frequency during the entire six-year period.

Table 26. Hospital Utilization, Garfield County Residents 2005-2006 (Colorado Hospital Association)

Patient Origin Garfield County	Valley View Hospital		Saint Marys Hospital and Medical Center		Grand River Hospital District		Aspen Valley Hospital		University Hospital		Presbyterian Saint Lukes Medical Center		Vail Valley Medical Center	
FY 2005	Cnty Cases	Cnty Share	Cnty Cases	Cnty Share	Cnty Cases	Cnty Share	Cnty Cases	Cnty Share	Cnty Cases	Cnty Share	Cnty Cases	Cnty Share	Cnty Cases	Cnty Share
TOTAL	2,384	55.9%	668	15.7%	515	12.1%	277	6.5%	79	1.9%	69	1.6%	62	1.5%
GLENWOOD SPRINGS	914	80.0%	65	5.7%	9	0.8%	28	2.5%	34	3.0%	19	1.7%	20	1.8%
RIFLE	415	42.9%	206	21.3%	261	27.0%	5	0.5%	11	1.1%	14	1.4%	9	0.9%
CARBONDALE	519	57.0%	65	7.1%	4	0.4%	224	24.6%	15	1.6%	18	2.0%	16	1.8%
PARACHUTE	95	17.9%	229	43.2%	172	32.5%	-	0.0%	1	0.2%	3	0.6%	4	0.8%
NEW CASTLE	294	68.4%	48	11.2%	22	5.1%	14	3.3%	7	1.6%	9	2.1%	9	2.1%
SILT	146	52.7%	49	17.7%	46	16.6%	5	1.8%	11	4.0%	6	2.2%	4	1.4%
BATTLEMENT MESA	1	10.0%	6	60.0%	1	10.0%	1	10.0%	-	0.0%	-	0.0%	0	0.0%

FY 2006	Cnty Cases	Cnty Share	Cnty Cases	Cnty Share	Cnty Cases	Cnty Share	Cnty Cases	Cnty Share	Cnty Cases	Cnty Share	Cnty Cases	Cnty Share	Cnty Cases	Cnty Share
COUNTY TOTAL	2,346	55.8%	674	16.0%	513	12.2%	272	6.5%	66	1.6%	76	1.8%	62	1.5%
GLENWOOD SPRINGS	863	78.8%	84	7.7%	4	0.4%	26	2.4%	21	1.9%	25	2.3%	21	1.9%
RIFLE	371	38.7%	237	24.7%	280	29.2%	6	0.6%	6	0.6%	11	1.1%	14	1.5%
CARBONDALE	543	58.7%	40	4.3%	2	0.2%	229	24.8%	23	2.5%	17	1.8%	17	1.8%
PARACHUTE	103	19.6%	217	41.3%	157	29.8%	-	0.0%	6	1.1%	4	0.8%	2	0.4%
NEW CASTLE	292	74.9%	42	10.8%	25	6.4%	5	1.3%	6	1.5%	4	1.0%	6	1.5%
SILT	171	57.2%	49	16.4%	43	14.4%	6	2.0%	4	1.3%	15	5.0%	2	0.7%
BATTLEMENT MESA	3	27.3%	5	45.5%	2	18.2%	-	0.0%	-	0.0%	-	0.0%	0	0.0%

Table 26. Hospital Utilization, Garfield County Residents 2005-2006 (continued)

Patient Origin Garfield County	The Childrens Hospital		Other Hospitals		Total
FY 2005	**Cnty Cases**	**Cnty Share**	**Cnty Cases**	**Cnty Share**	**Total Cases**
TOTAL	37	0.9%	176	4.1%	4,267
GLENWOOD SPRINGS	15	1.3%	38	3.3%	1,142
RIFLE	4	0.4%	43	4.4%	968
CARBONDALE	8	0.9%	41	4.5%	910
PARACHUTE	2	0.4%	24	4.5%	530
NEW CASTLE	7	1.6%	20	4.7%	430
SILT	1	0.4%	9	3.2%	277
BATTLEMENT MESA	0	0.0%	1	10.0%	10
FY 2006	**Cnty Cases**	**Cnty Share**	**Cnty Cases**	**Cnty Share**	**Total Cases**
COUNTY TOTAL	35	0.8%	161	3.8%	4,205
GLENWOOD SPRINGS	14	1.3%	37	3.4%	1,095
RIFLE	9	0.9%	25	2.6%	959
CARBONDALE	3	0.3%	51	5.5%	925

PARACHUTE		4	0.8%	33	6.3%	526
NEW CASTLE		2	0.5%	8	2.1%	390
SILT		2	0.7%	7	2.3%	299
BATTLEMENT MESA		1	9.1%	0	0.0%	11

Table 27. Top 10 DRG categories by year in Garfield County (Colorado Hospital Association)

2000		2001		2002		2003		2004		2005	
DRG category	per 1000	DRG category	per 1000	DRG category	per 1000	DRG category	per 1000	DRG category	per 1000	DRG category	per 1000
Circulation Disorders	9.87	Circulation Disorders	9.72	Bone and Joint Disorders	9.55	Birthing and Pregnancy Disorders	8.86	Circulation Disorders	8.98	Circulation Disorders	8.96
Bone and Joint Disorders	8.74	Bone and Joint Disorders	9.05	Circulation Disorders	8.87	Bone and Joint Disorders	8.82	Bone and Joint Disorders	8.96	Bone and Joint Disorders	8.11
Birthing and Pregnancy Disorders	8.54	Digestive Disorders	7.78	Digestive Disorders	8.39	Circulation Disorders	8.64	Digestive Disorders	7.85	Digestive Disorders	7.76
Respiratory Disorders	8.45	Birthing and Pregnancy Disorders	7.52	Respiratory Disorders	8.24	Digestive Disorders	7.67	Birthing and Pregnancy Disorders	7.52	Birthing and Pregnancy Disorders	7.56

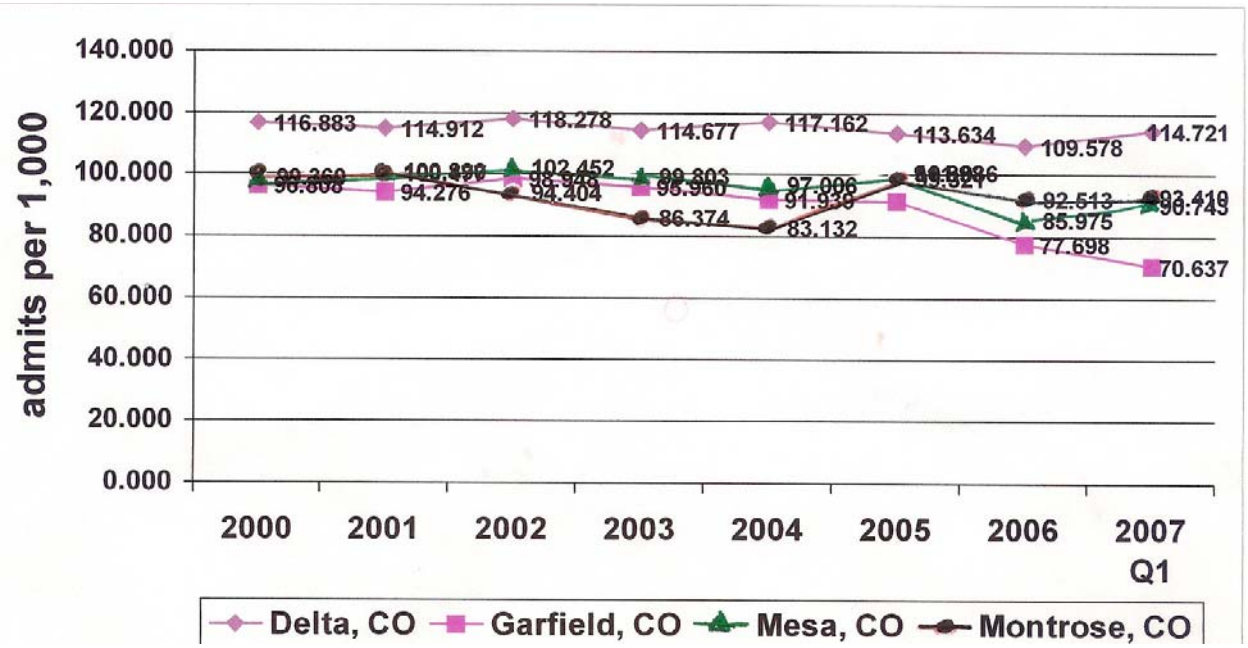
Digestive Disorders	8.38	Respiratory Disorders	6.89	Birthing and Pregnancy Disorders	7.74	Respiratory Disorders	7.36	Respiratory Disorders	6.73	Respiratory Disorders	6.93
Neonatal Disorders	6.21	Neonatal Disorders	6.04	Neonatal Disorders	6.07	Neonatal Disorders	5.29	Neonatal Disorders	5.09	Neonatal Disorders	4.78
Nervous System Disorders	3.82	Female Reproductive Disorders	3.92	Nervous System Disorders	3.96	Nervous System Disorders	3.51	Nervous System Disorders	4.22	Nervous System Disorders	3.59
Female Reproductive Disorders	3.77	Nervous System Disorders	3.66	Female Reproductive Disorders	3.86	Female Reproductive Disorders	3.37	Female Reproductive Disorders	3.22	Female Reproductive Disorders	3.53
Nutritional, Metabolic and Thyroid Disorders	2.58	Pancreas and Liver Disorders	2.95	Nutritional, Metabolic and Thyroid Disorders	2.51	Pancreas and Liver Disorders	3.14	Pancreas and Liver Disorders	2.88	Pancreas and Liver Disorders	2.51
Pancreas and Liver Disorders	2.12	Nutritional, Metabolic and Thyroid Disorders	2.69	Urinary Tract Disorders	2.49	Urinary Tract Disorders	2.52	Urinary Tract Disorders	2.47	Nutritional, Metabolic and Thyroid Disorders	2.49

A more detailed analysis of the hospitalization DRGs **by county of residence** for the years 2000 through 2006 and for the first quarter of 2007 follows. The rates referred to and shown in the graphs are per 1,000 individuals, based on the 2000 census data for county population. (The complete data set and more detailed subcategory graphs may be found in Appendix O.)

- **All Hospitalizations**

Delta County has the highest rate over the 6.25-year period for hospitalizations. Garfield County has either the lowest or the next-to-lowest rate for this period, and showed a downward trend in hospitalization rate from 2005 into the first quarter of 2007.

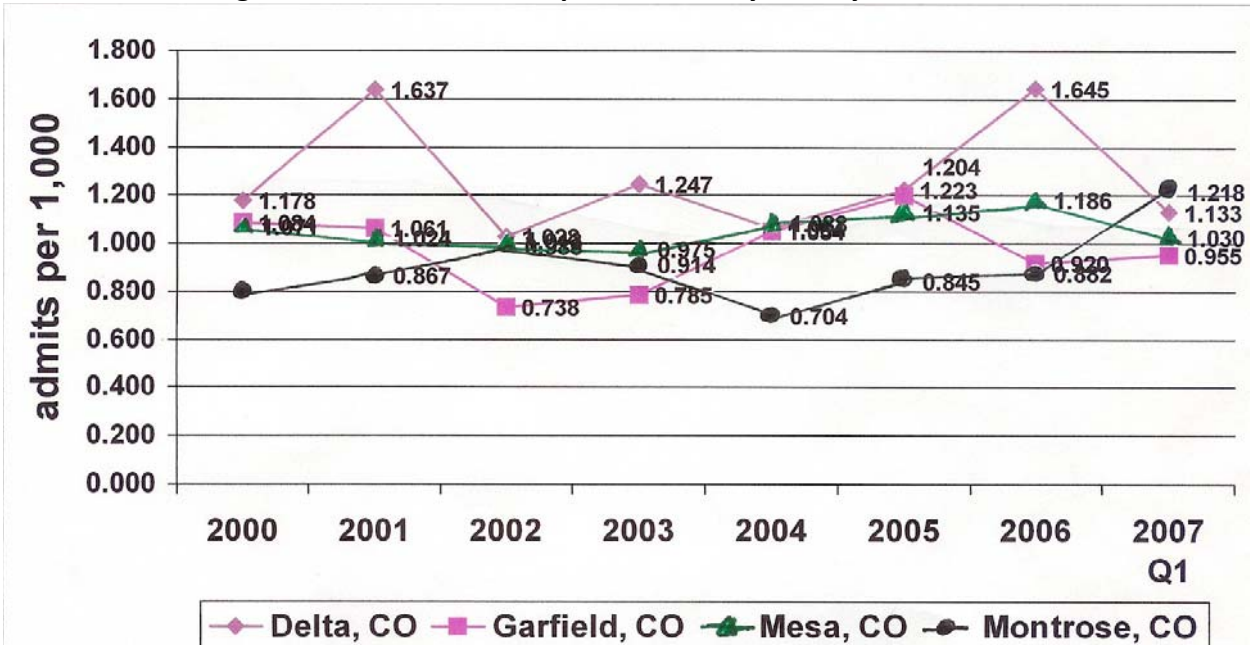
Figure 67. All Hospitalizations by County of Residence



- **All Trauma**

Garfield County's trauma rates were generally the same as or lower than the rates for the comparison counties for the 6.25-year time period.

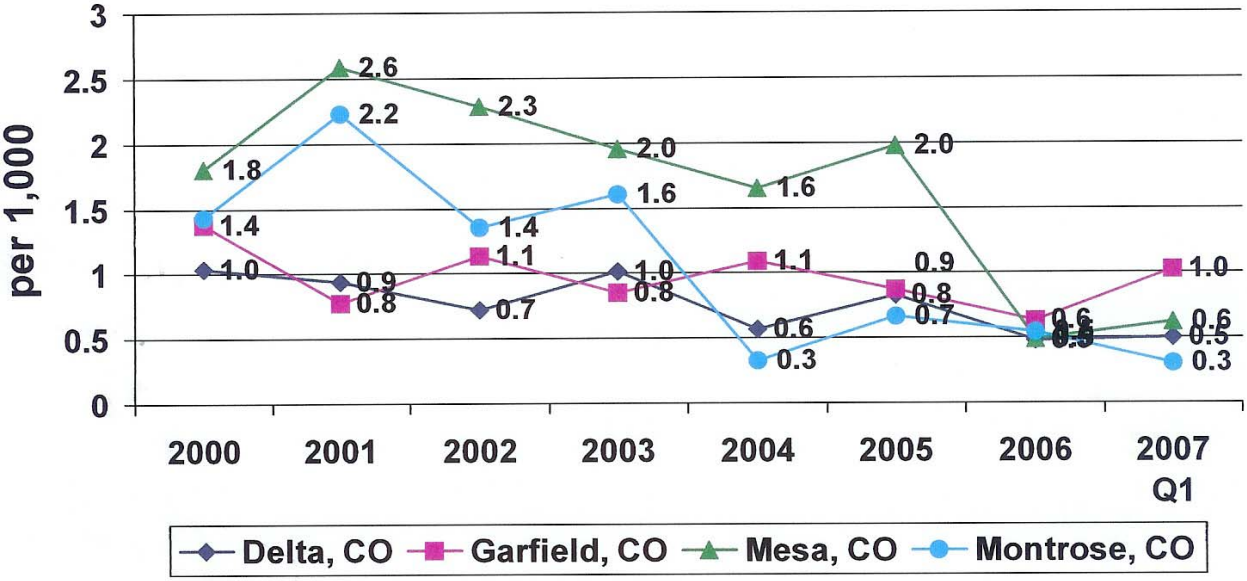
Figure 68. All Trauma Hospitalizations by County of Residence



- **Alcohol and Drug Disorders**

This area was of concern to some Garfield County residents because of a perception that an influx of natural gas industry workers could result in an increase in the use and abuse of alcohol and drugs. With respect, specifically, to hospitalization as a result of alcohol and drug-related disorders, Mesa County has the highest rates for the study period, although their rate dropped in 2006 to essentially the same as for the other counties. Garfield County's rates were similar to those Delta County and lower than the rates for Montrose County through 2003. In 2003, Montrose saw a decrease in alcohol and drug hospitalizations, which brought their rate to one that was similar to those of Garfield and Delta Counties. Garfield County's rate appeared to be increasing in 2007, at which time it had the highest rate of the four counties. *Caution: one-quarter's data is not generally sufficient to safely predict a trend.*

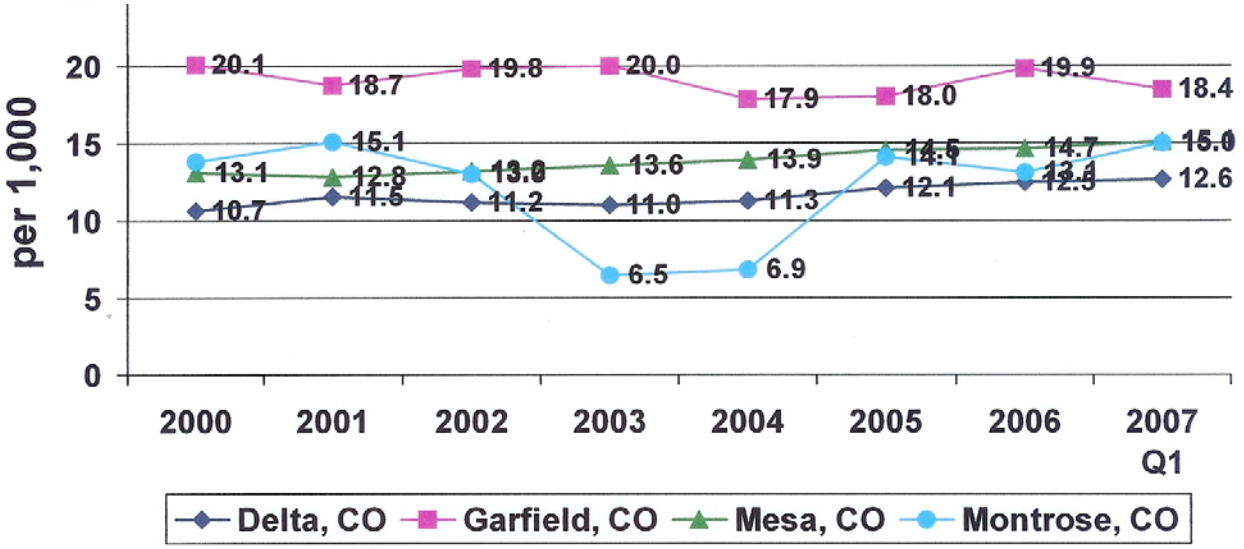
Figure 69. Alcohol and Drug Disorders Hospitalizations by County of Residence



- **Birthing and Pregnancy Disorders**

Garfield County's overall rates for this category were consistently higher than those for the comparison counties. The percentages of complicated births, out of all births, for Delta, Garfield, Mesa, and Montrose Counties were 53.4, 58.0, 61.4, and 53.0, respectively. Postpartum complications, in particular have been steadily increasing in Garfield County since 2004. This category also includes abortions, cesarean sections, ectopic pregnancies, false labor, other antepartum diagnoses with or without surgical procedures, threatened abortion, and vaginal deliveries with and without complications. Further breakdown of information for this category is provided below.

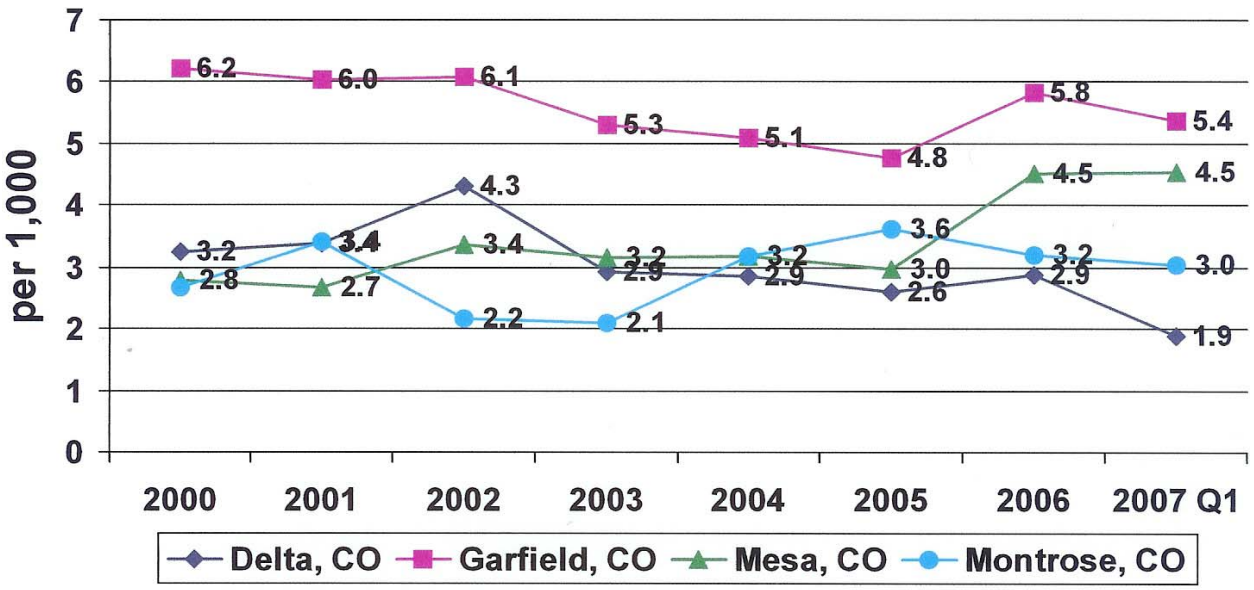
Figure 70. Birthing and Pregnancy Disorders Hospitalizations by County of Residence



- Neonatal Disorders

Neonatal disorder hospitalization rates in Garfield County have been relatively stable, and generally lower than the rates for Mesa and Montrose Counties and similar to the rates for Delta County. Mesa County's neonatal disorder hospitalization rates have been consistently higher than for the other three counties. This category includes extreme immaturity or respiratory distress at birth, prematurity, full-term neonates with significant problems, and neonatal death or transfer to another facility for care.

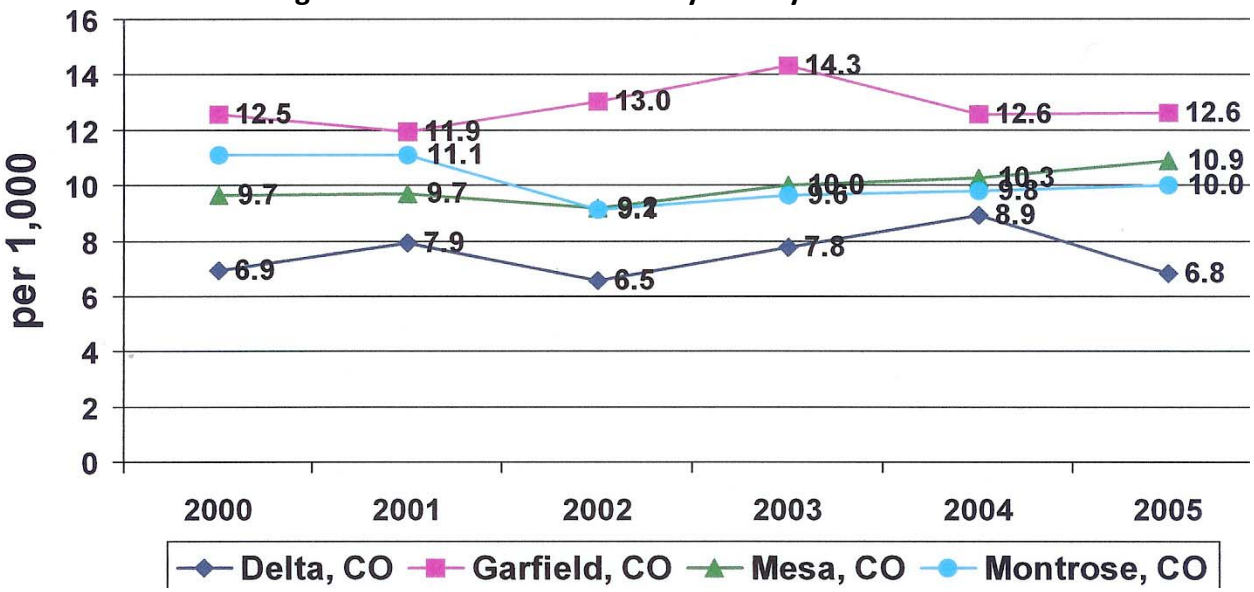
Figure 71. Neonatal Disorders Hospitalizations by County of Residence



- **Normal Newborn Hospitalizations**

On the other hand, Garfield County also has the highest rates for normal newborns born in the hospital. These higher rates for both normal and abnormal births most likely reflect the fact that Garfield County has the highest birth rates among the four counties for the years studied (Tables 10-13. Vital Statistics).

Figure 72. Normal Newborns by County of Residence



- **Female and Male Reproductive Disorders Hospitalizations**

To complete the picture of factors that might influence pregnancy and birth outcomes, the following graphs show data for hospitalizations related to hospitalizations for treatment of reproductive organ disorders. Garfield County hospitalization rates for female reproductive disorders were generally the same as or lower than the rates for the other three counties. Montrose County had the highest rates for this category for all years, with the exception of the Year 2000, in which Delta County had the highest rate. This category includes infections and malignancies of the female reproductive organs, menstrual disorders, surgical procedures involving female reproductive organs, and tubal ligations.

Garfield County hospitalization rates for male reproductive disorders were generally the same as or lower than the rates for the other three counties. Delta County had the highest rates for this category for all years. This category includes complications of benign prostatic hypertrophy, transurethral prostectomy, inflammation and malignancies of the male reproductive organs, and other surgical procedures involving male reproductive organs.

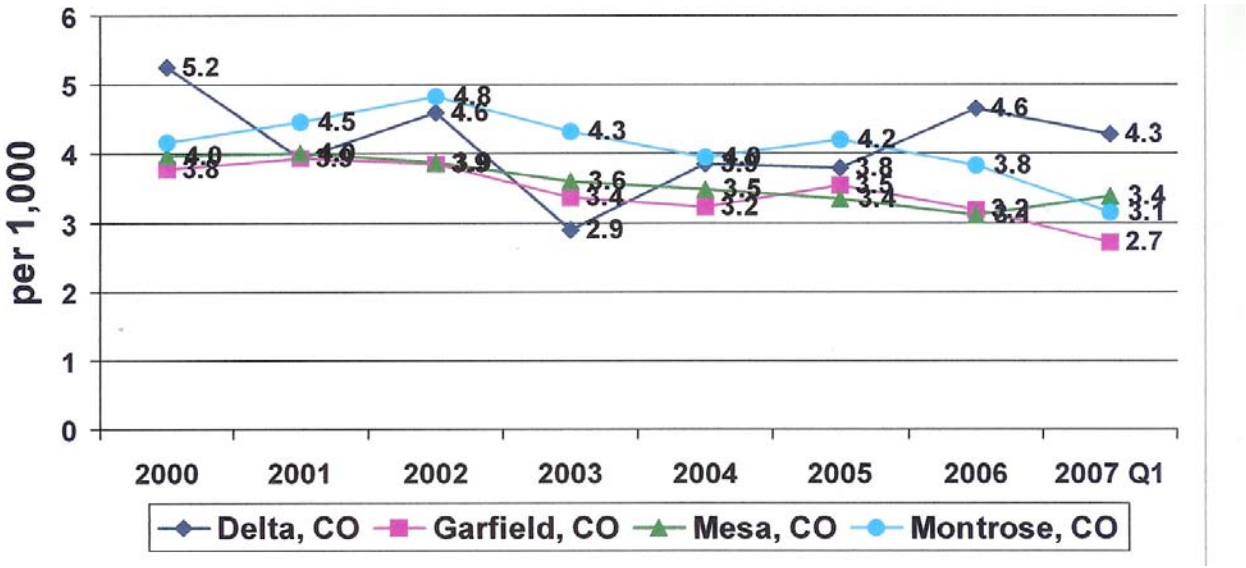
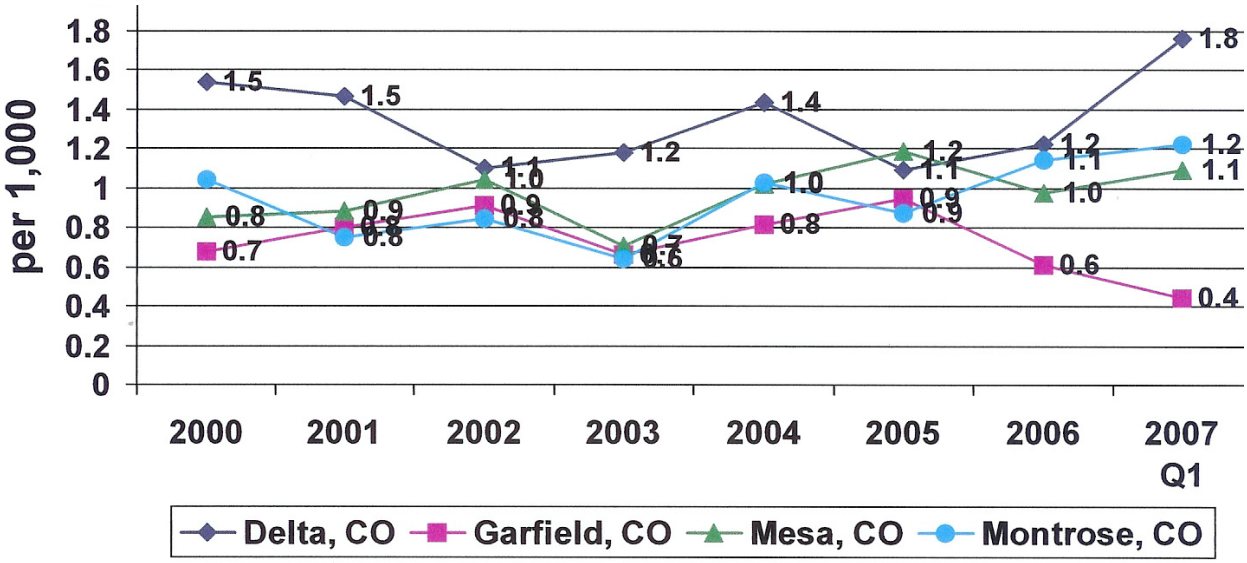


Figure 73. Female Reproductive Disorders Hospitalizations by County of Residence

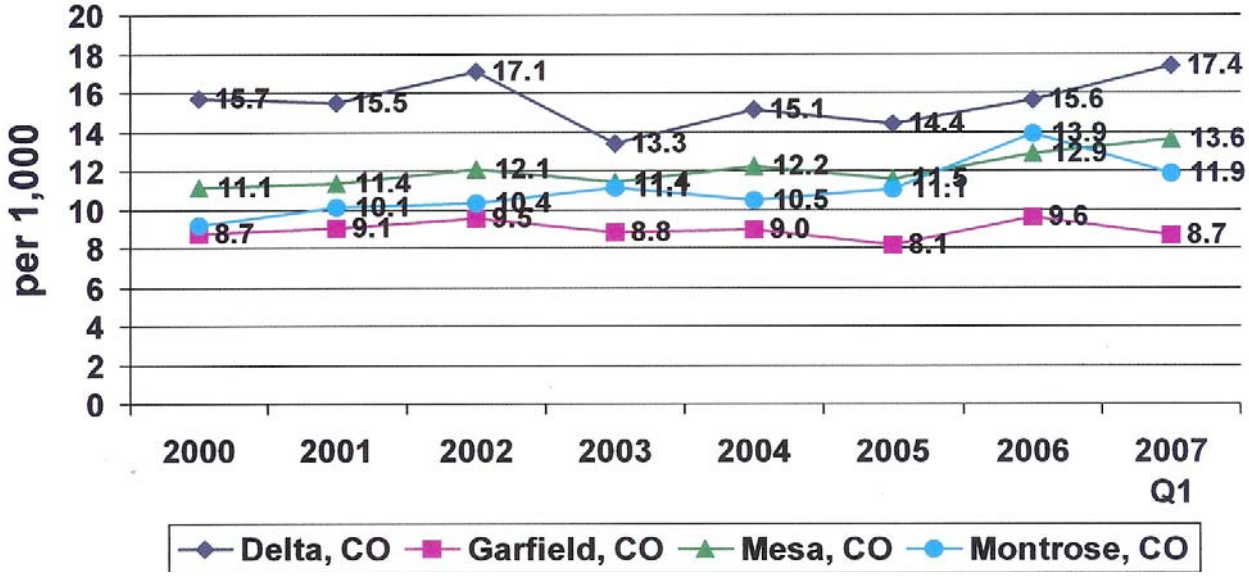
Figure 74. Male Reproductive Disorders Hospitalizations by County of Residence



- **Bone and Joint Disorders**

Delta County has the highest rates throughout the 6.25-year period. Garfield County's rates were the lowest of the four counties, and were generally stable. This category includes back and neck and other joint procedures, fractures, strains, sprains and dislocations, and musculoskeletal and connective tissue disorders.

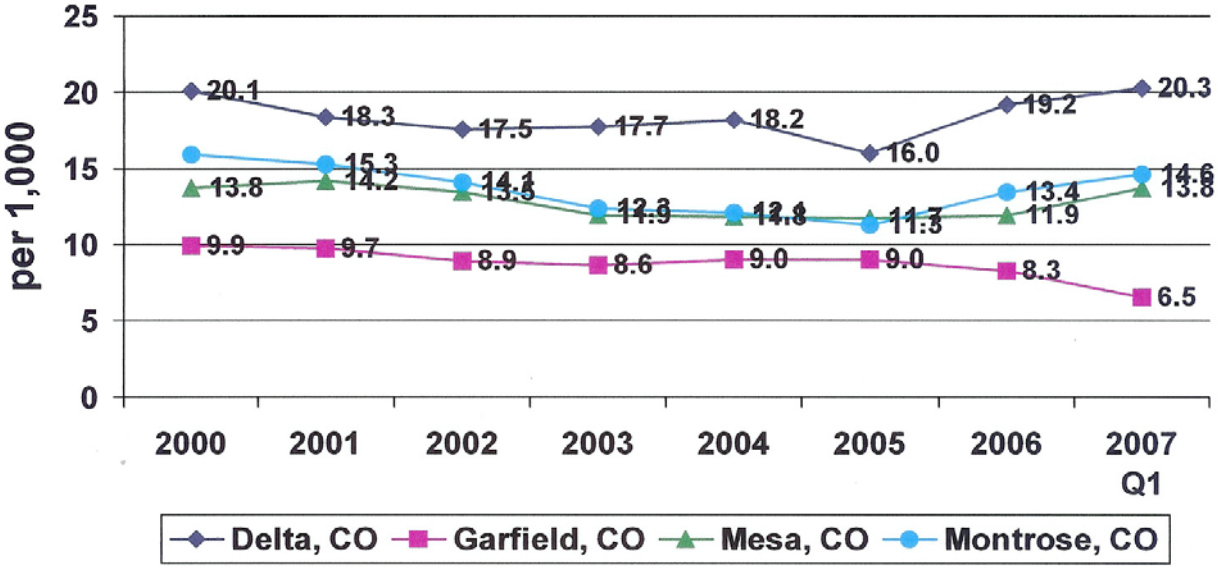
Figure 75. Bone and Joint Disorders Hospitalizations by County of Residence



- **Circulation Disorders**

Delta County has the highest rates throughout the 6.25-year period for this category. Garfield County's rates were the lowest of the comparison counties and were generally consistent over the period. There was a slight downward trend in 2007, at which time, the rates for the other three counties were trending up. This category includes acute myocardial infarction, angina pectoris, atherosclerosis, cardiothoracic procedures, cardiovascular disorders and procedures, chest pain, circulatory system disorders, coronary bypass, heart failure and shock, hypertension, peripheral vascular disorders, and syncope and collapse.

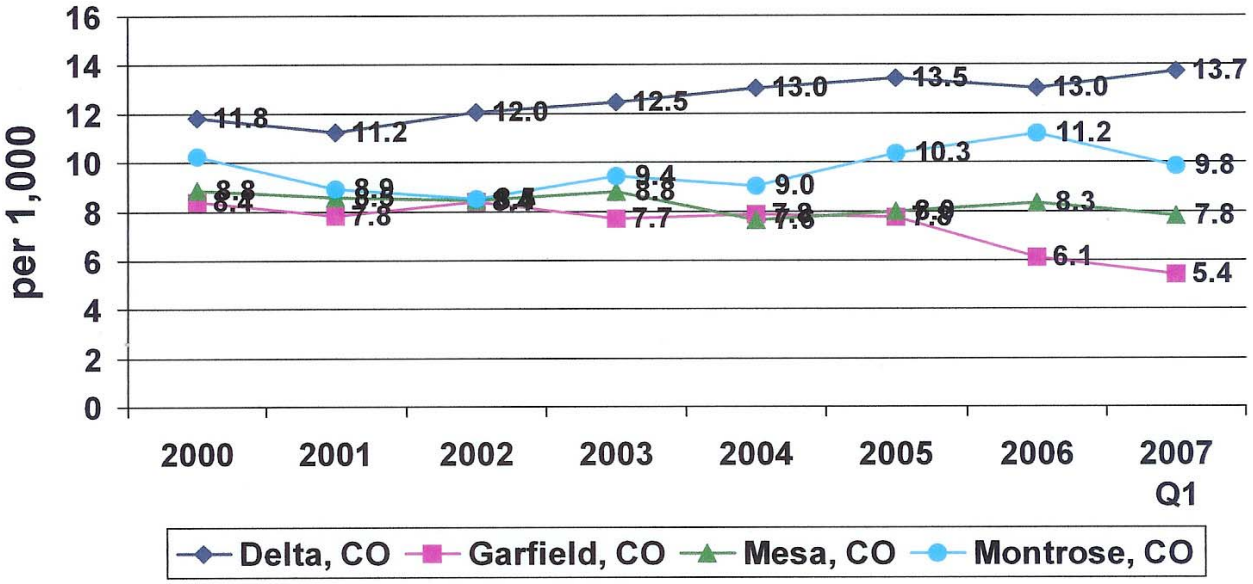
Figure 76. Circulation Disorders Hospitalizations by County of Residence



- **Digestive Disorders**

Mesa County has the highest overall rates for this category. Garfield County's overall rates are essentially the same as those in Delta and Montrose Counties until 2005, when Montrose County began to see an increasing trend in these disorders. Garfield County's rate began a downward trend for the same time period. This category includes appendectomy; digestive malignancy; gastrointestinal hemorrhage; gastrointestinal obstruction; hernia procedures; peptic ulcer; small and large bowel procedures; stomach, esophageal and duodenal procedures; and other digestive syndrome diagnoses. For some of these subcategories, Garfield County's rates were the lowest of the four counties; Garfield County's rates were never highest for any subcategory.

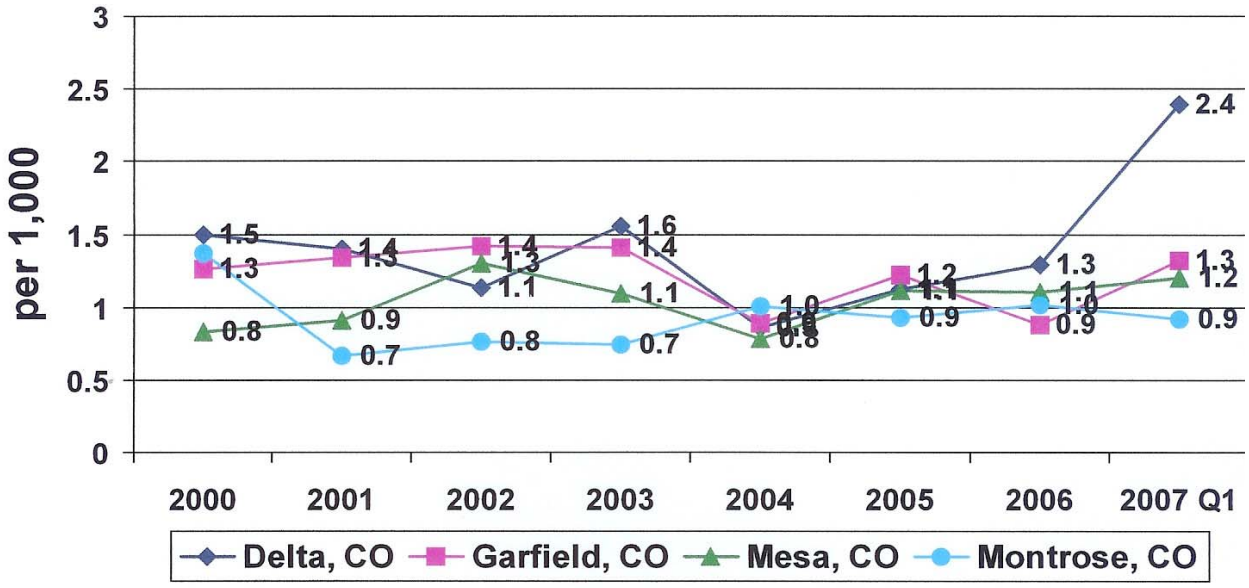
Figure 77. Digestive Disorders Hospitalizations by County of Residence



- **Ear, Nose, Throat Disorders**

Overall, and in general, the hospitalization rates for this group of disorders were similar among the four counties, although Delta County has a peak in the first quarter of 2007. When looking at the subcategories, however, Garfield County's hospitalization rates for otitis media and upper respiratory infections for children, ages 0-17 years, are the highest among the four counties. This is also true for the hospitalization rates for bronchitis and asthma in children. In contrast, the hospitalization rates for otitis media, upper respiratory infection, bronchitis and asthma in adults are the lowest among the four counties. Garfield County also has the lowest rate of COPD hospitalizations. This category includes dysequilibrium; ear, nose, mouth and throat diagnoses; otitis media an upper respiratory infection.

Figure 78. Ear, Nose, Throat Disorders Hospitalizations by County of Residence



- **Infectious and Parasitic Diseases**

Hospitalizations for infectious and parasitic diseases were highest in Delta County throughout the majority of the time period studied. Rates for all counties appear to be decreasing from a high in 2005, with the exception of rates for Montrose County, which have remained essentially stable. Garfield County's hospitalization rates for these diseases were generally lower than for the other three counties, increasing to a peak in 2005, and then dropping steadily through the 1st quarter of 2007. This category includes postoperative and post-traumatic infections, fevers of unknown origin, viral illnesses, septicemia, and other infectious or parasitic disease diagnoses.

Figure 79. Infectious and Parasitic Diseases Hospitalizations by County of Residence

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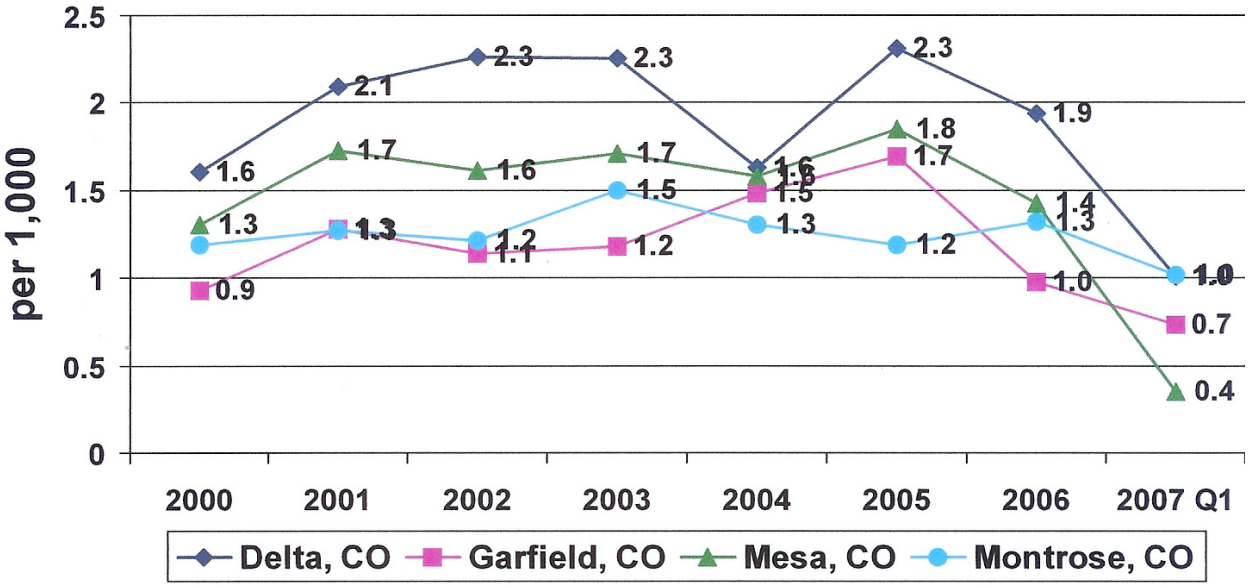
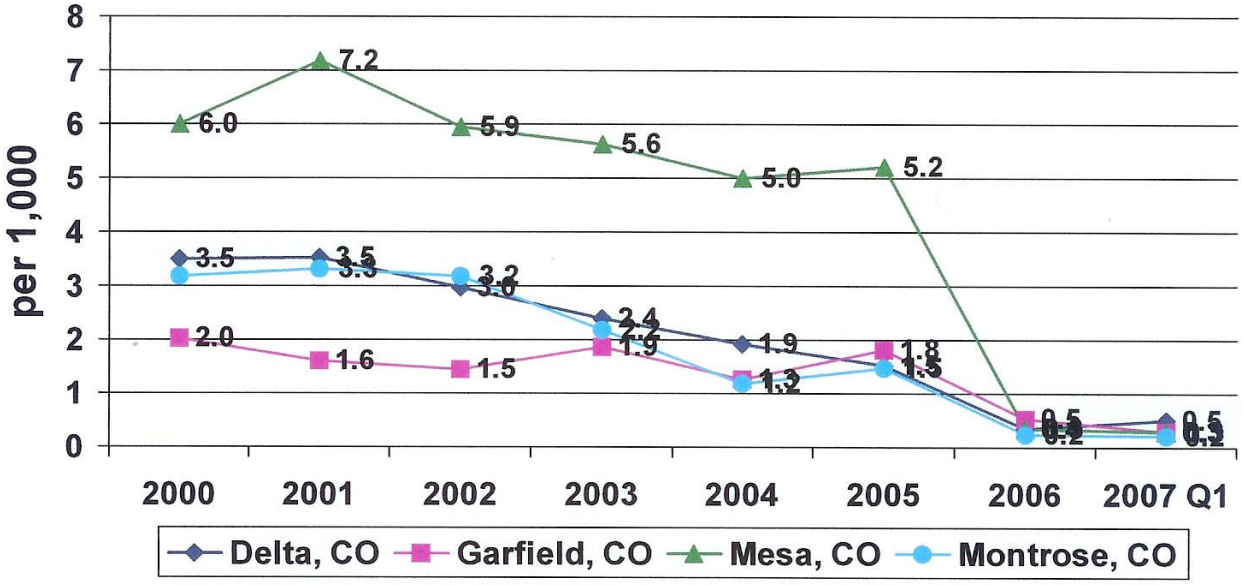


- **Mental Disorders**

Garfield County's hospitalization rates for mental disorders are the lowest among the four counties through 2003; the rates remain stable through 2005, after which there is a downward trend in the rate through the first quarter of 2007. Mesa County's rates are highest among the four counties. After a significant drop in the rate in 2006, the Mesa County rate becomes essentially that same as for the other counties. This category includes acute adjustment reaction and psychosocial dysfunction, childhood mental disorders, depressive neuroses, other neuroses, psychoses, and other mental disorders.

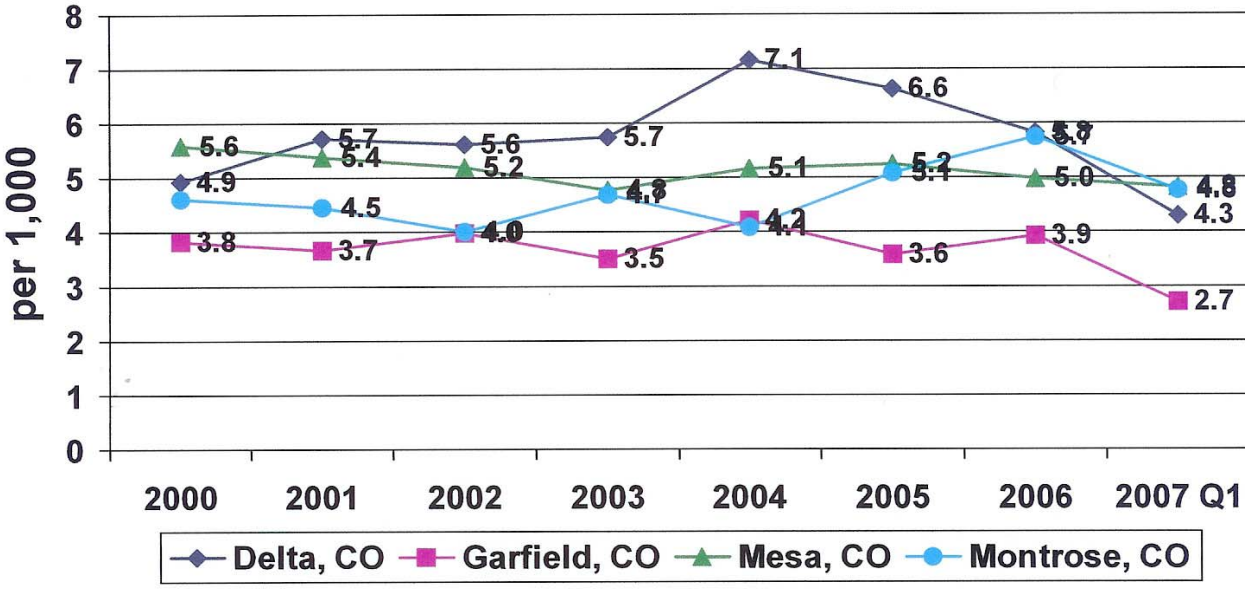
Figure 80. Mental Disorders Hospitalizations by County of Residence



- **Nervous System Disorders**

Garfield County has the overall lowest rates for the 6.25-year period; Delta County's rates are the highest for the years 2001 through 2005. With respect to the subcategory, seizure and headache for children (ages 0-17), Garfield County's rates show an upward trend since 2004, with a big jump in the first quarter of 2007. Seizure and headache hospitalization rates for individuals over 17 years of age show a downward trend since 2004, and are similar to those of the other counties. [Subcategory data are not shown here, but are provided in Appendix N. This category includes cerebrovascular disorders, concussion, cranial and peripheral nerve disorders, craniotomy, extracranial procedures, intracranial hemorrhage or cerebral infarction, nervous system infection except viral meningitis, nervous system neoplasms, seizure and headache, spinal disorders and injuries, stupor and coma (nontraumatic and traumatic), transient ischemia, viral meningitis, and other nervous system disorders.

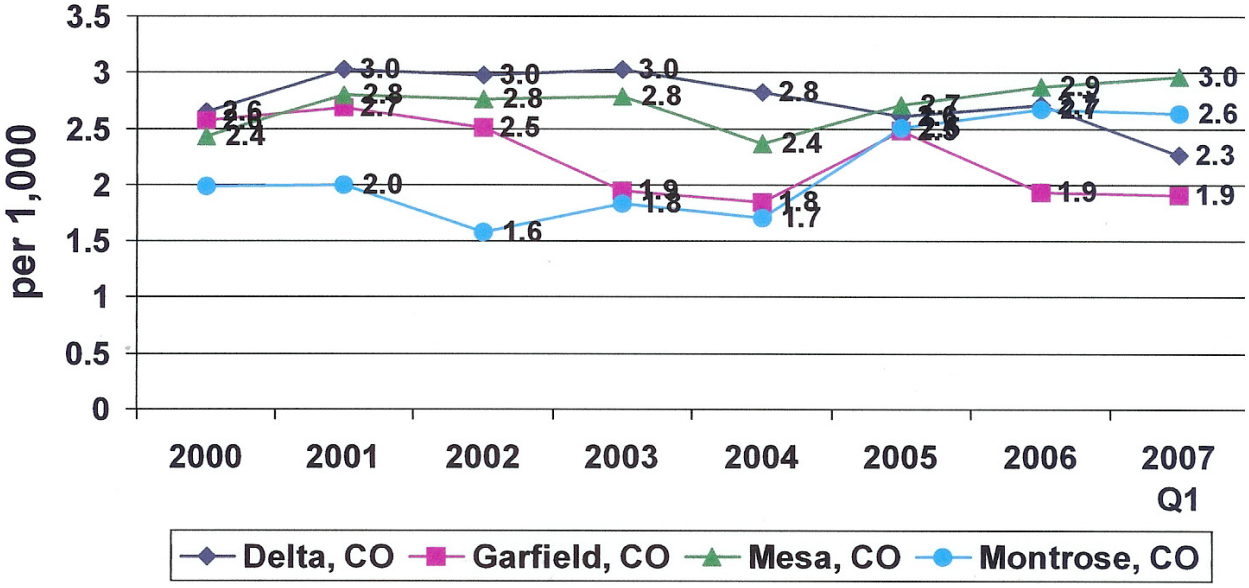
Figure 81. Nervous System Disorders Hospitalizations by County of Residence



- **Nutritional, Metabolic and Thyroid Disorders**

Montrose County has the lowest rates until 2005; rates increased between 2004 and 2005, then leveled off. Garfield County's rates showed a downward trend between 2002 and 2003, a spike in 2005, and decreases again in 2006. Garfield County's diabetes rates are the lowest among the counties for both children and adults. This category includes diabetes (ages 0-35 and >35); endocrine, nutritional and metabolic disorders, nutritional and miscellaneous metabolic disorders (ages 0-17 and >17), and obesity procedures.

Figure 82. Nutritional, Metabolic and Thyroid Disorders Hospitalizations by

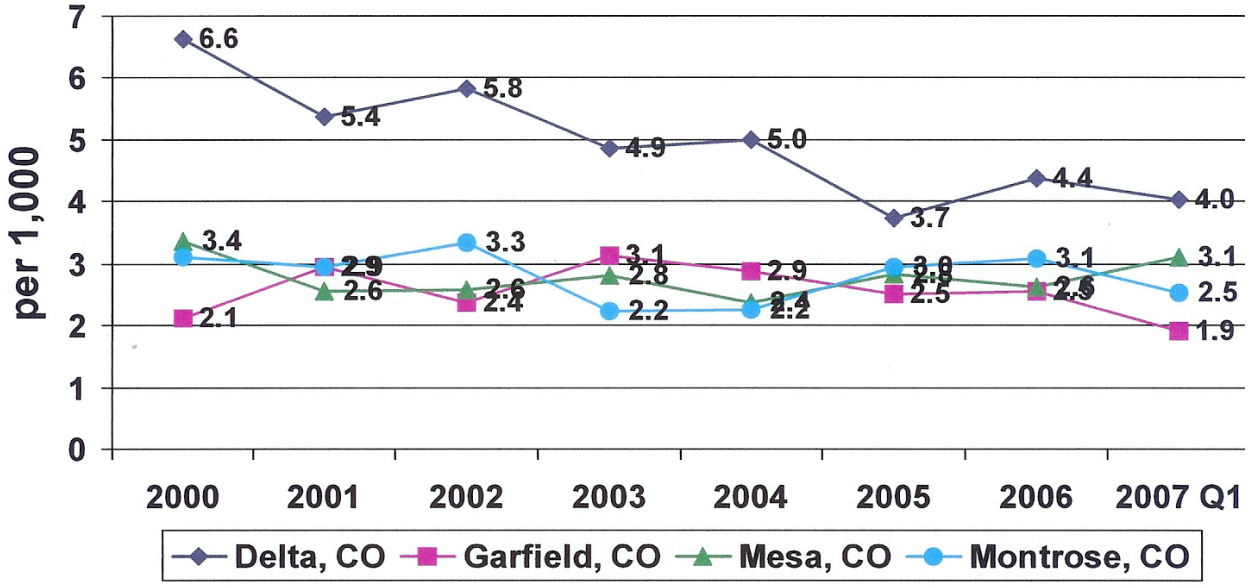


County of Residence

- **Pancreas and Liver Disorders**

Delta County's rates are consistently the highest among the four counties. Rates for the other counties across the time period are similar. This category includes cirrhosis and alcoholic hepatitis, malignancy of hepatobiliary system or pancreas, and pancreas and liver disorders. Garfield County's hospitalization rates are the highest among the counties for most years, surpassed only by Delta County in 2003 and 2006.

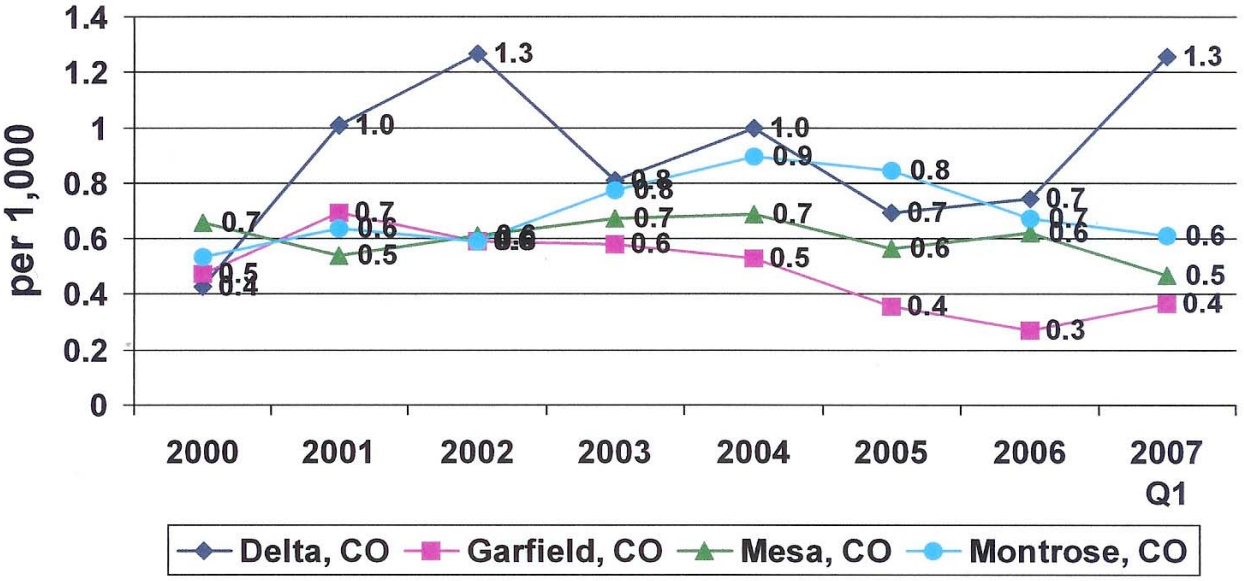
Figure 83. Pancreas and Liver Disorders Hospitalizations by County of Residence



- **Red Cell and Clotting Disorders**

Garfield County's rates show a steady downward trend from 2001- through 2006, with a slight increase in the first quarter of 2007. Garfield County's rates are generally lower than those for the other three counties.

Figure 84. Red Cell and Clotting Disorders Hospitalizations by County of Residence



- **Respiratory Disorders**

Overall, Garfield County rates for respiratory disorders are lower than for the other counties; Delta County's rates are the highest. Subcategory data comparisons are more variable, however. (Subcategory data by age are not shown here, but are available in Appendix N.) Garfield County has the lowest rates for bronchitis and asthma in individuals >17 years, but the highest rates for children (ages 0-17). Childhood bronchitis and asthma rates in Garfield County took a big drop in 2005, but increased to 2004 levels in the first quarter of 2007. Chronic obstructive pulmonary disease (COPD) rates in Garfield County are the lowest among the four counties. Garfield County rates for respiratory infections and inflammations for both adults and children are the lowest for the four counties. Rates for simple pneumonia and pleurisy were the lowest among the four counties for adults (>17 years), but highest for children (0-17) through 2005. (Childhood rates in other counties surpassed those for Garfield County from 2005 through the first quarter of 2007.) The other disorders included in this category are major chest procedures, interstitial lung disease, major chest trauma, pulmonary embolism, respiratory neoplasms, and other pulmonary disorders.

Figure 85. All Respiratory Disorders Hospitalizations by County of Residence

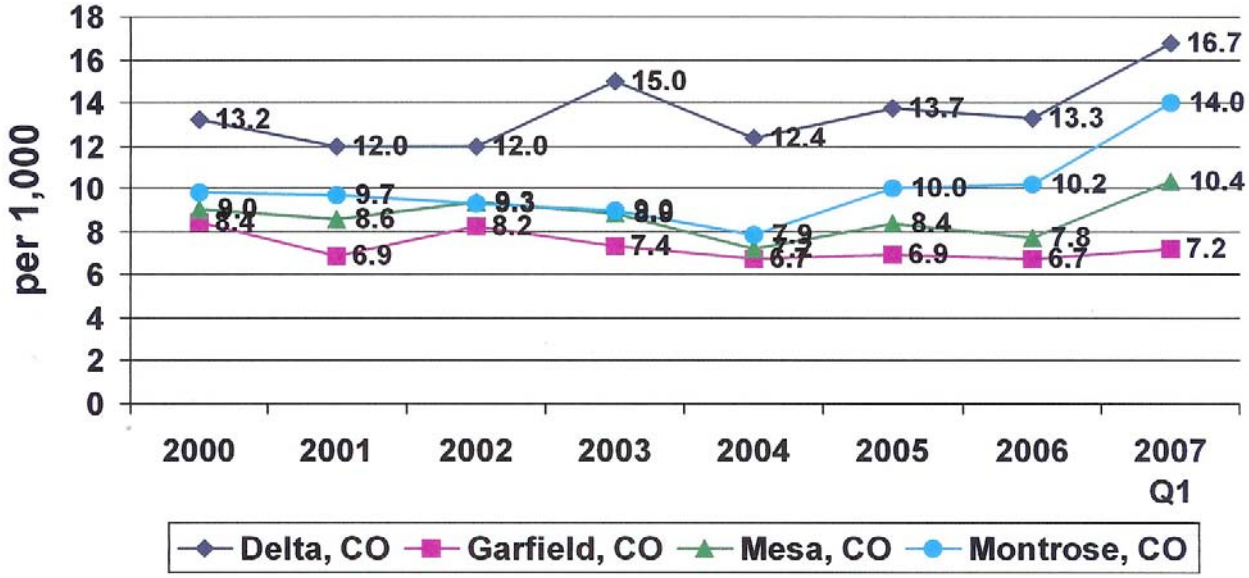
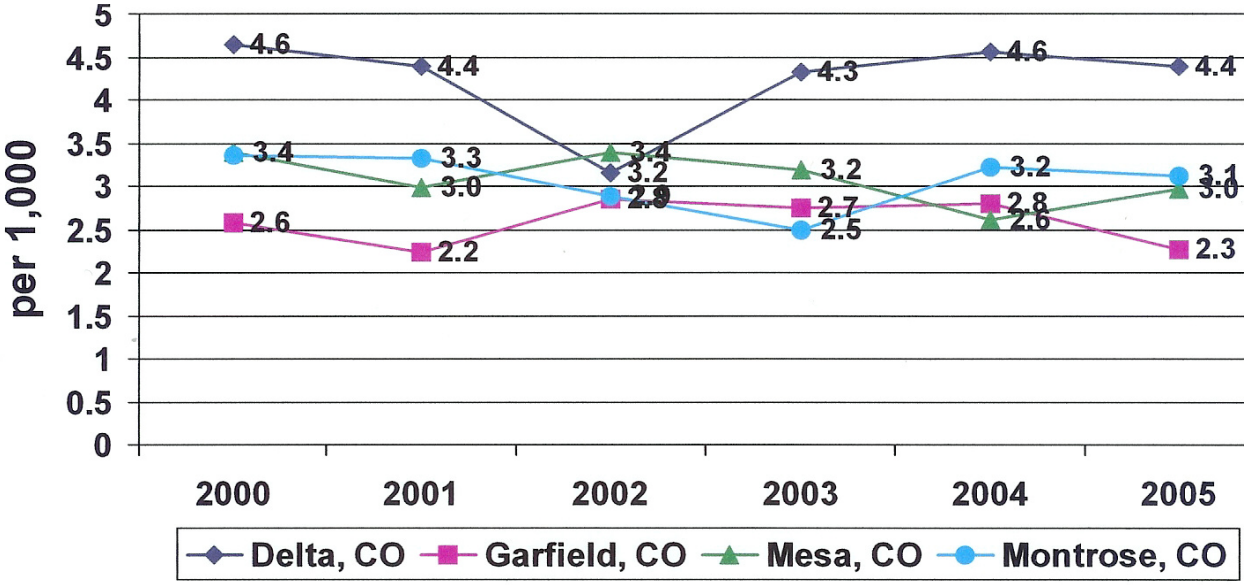


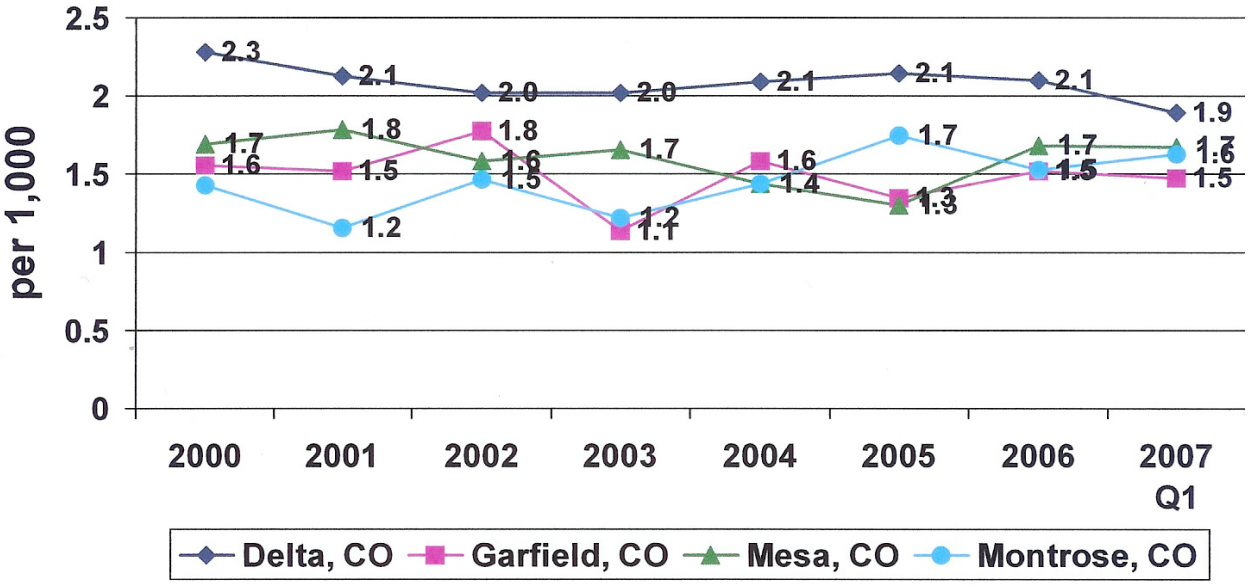
Figure 86. Respiratory Disorders Hospitalizations by County of Residence – Bronchitis, Asthma, COPD and Respiratory Infections and Inflammation



- **Skin Disorders**

Delta County has the highest rates among the four counties; the rates for the other counties are similar across the time period. This category includes cellulitis; malignant breast disorders; skin graft or debridement; skin ulcers; trauma to skin, subcutaneous tissue and breast; and other skin disorders.

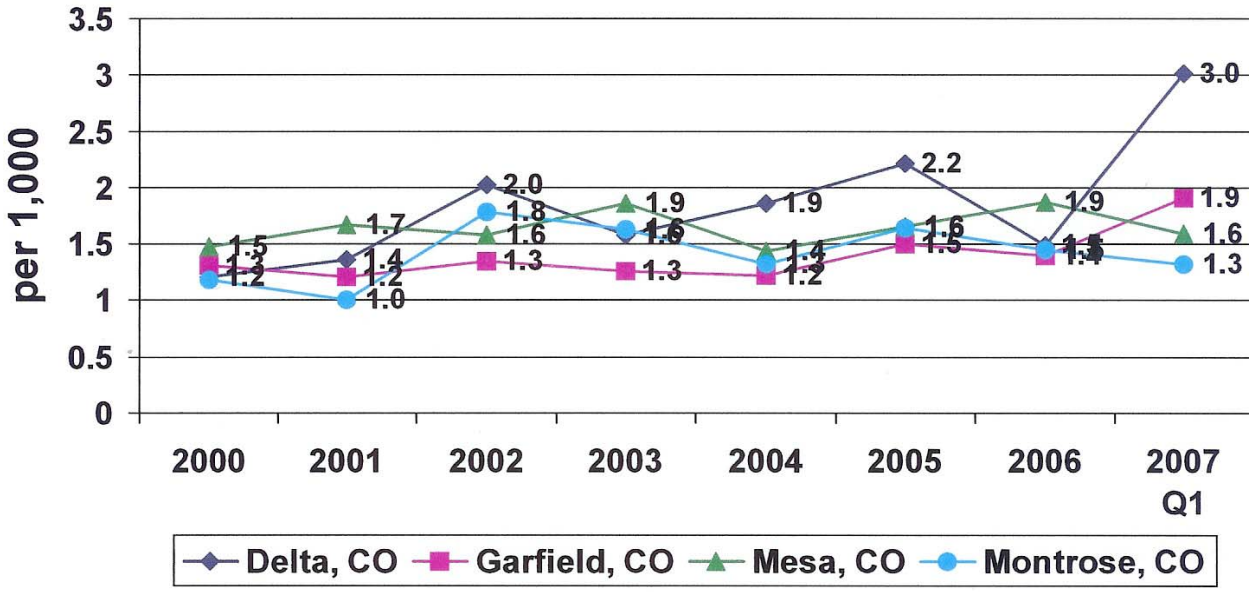
Figure 87. Skin Disorders Hospitalizations by County of Residence



- **Skin grafts, trauma, poisoning and allergic reactions**

Garfield County's hospitalization rates for this category are generally the lowest among the four counties, although Garfield County saw a jump in traumatic injury hospitalization for the first quarter of 2007. This category includes allergic reactions injury, poisoning and toxic effect diagnosis; surgical procedures for injuries; poisoning and toxic effects of drugs; traumatic injury; wound debridement for injuries.

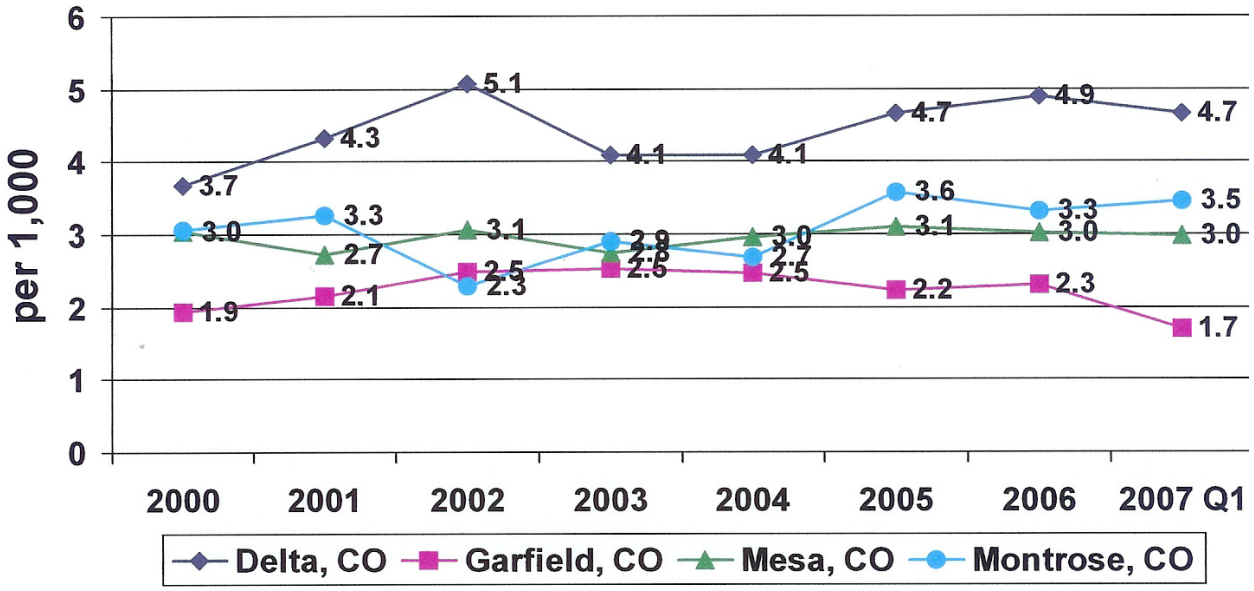
Figure 88. Skin Grafts, Trauma and Poisoning Hospitalizations by County of Residence



- **Urinary tract disorders**

Delta County's rates are the highest across the 6.25-year period; Garfield County's rates are the lowest. This category includes kidney and urinary tract disorders and infections, kidney and urinary tract neoplasms, kidney transplant, and renal failure.

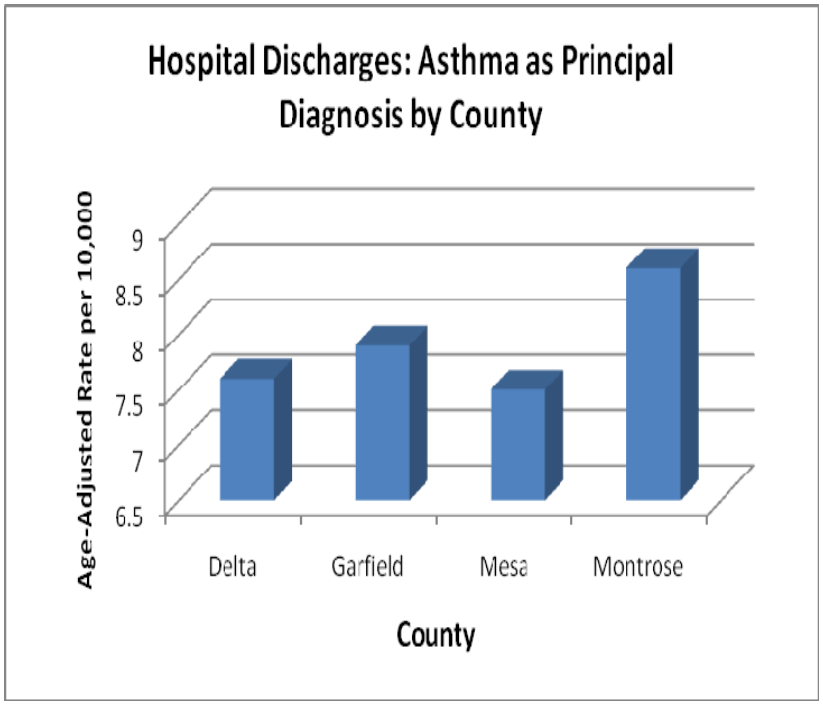
Figure 89. Urinary Tract Disorders Hospitalizations by County of Residence



- **Asthma Hospitalization Rates**

Colorado state data for county rates of hospitalization discharges with a principal diagnosis of asthma for the years 1993-2001 are provided in the graph below (Health Statistics Section, Colorado Department of Public Health and Environment). The age-adjusted rates are per 10,000 county residents. Rates were adjusted to the 2000 U.S. population using the direct method applied to 10-year age groups.

Figure 90.



<u>Rocky Mountain Health Plans Member Data for Health Plan Usage by County; Grand River Health District and Valley View Hospital Emergency Room Admissions Data by Zip Code</u>

Rocky Mountain Health Plans (RMHP) is a non-profit health insurance provider, operating in Colorado. The company's main office is in Grand Junction, Colorado. RMHP provides health insurance to a large proportion of insured individuals in the four comparison counties, although only about 7% of the population of Garfield County is insured by RMHO. We were able to obtain ambulatory, emergency room, inpatient and outpatient hospital visit data for RMHP members in all four counties for the years 2000 through 2007. The limitations of these data, with respect to providing valid comparative information are the fact that fewer individuals are insured by RMHP in Garfield County than in the other three counties (although all rates are adjusted to member months), and the demographics of the RMHP-insured populations most likely varies among the counties. Thus, these comparisons should be viewed with caution. Complete datasets and graphs may be found in the Appendix P.

Only those DRG disorder categories that had at least 200 visits per 1000 Member Months were included in the analysis. Rates are per 1,000 member months.

The Grand River Hospital District (located in Rifle, CO) provided emergency room admission data for the years 2004, 2005, and 2006. These data were organized into the same DRG categories as used for the RMHP member data. Admissions data were sorted by community of residence. As might be expected by the location of the hospital relative to communities within Garfield County, there are few admissions recorded for residents of Carbondale, Glenwood Springs, or New Castle. Thus, only the data for residents of Parachute, Rifle, and Silt are usable and will be discussed in this report. Where Grand River ER visit data differed substantively from the RMHP data for Garfield County, as a whole, the Grand River data are highlighted. Please note that, because of the limitations described above for these data, it is not reasonable to directly compare rates, but it is possible to compare and observe rate trends. A change in rate over a one-year period is NOT sufficient to determine whether an apparent trend is significant or an "outlier". Tables 28-31 discuss these relative trends in the data. Rates are per 1,000 visits. Complete datasets and graphs may be found in the Appendix Q. Of note is the fact that Garfield County residents had the lowest usage rates for annual physical exam visits (adults) and well check-ups (children) of all of the comparison counties over the entire 8-year period. With regard to these low rates, it is also important to note that these rates are for an insured population for which annual physical exams and well-child check-ups are provided.

Valley View Hospital in Glenwood Springs provided emergency room data by zip code of residence for visits that occurred between January 1, 2004 and December 31, 2006. These data were also organized into the DRG categories used for Grand River Hospital District and RMHP member data. Similar to what is described above for the other emergency room data, there are limitations to the possible use and interpretation of the Valley View Hospital data. By far, the largest numbers of emergency room visits were from residents of the Glenwood Springs zip codes. Because the rate calculations (visits by DRG category per 1000 persons) use an estimate of the population residing in each zip code area – and the margin of error increases inversely with the size of the area (i.e., the smaller the geographic area the larger the margin of error in the population estimate) – the rates calculated for each population should only be taken as estimates. To add to the uncertainty of comparing rates among these zip code populations, the data are subdivided into Adult and Child categories. The age categories for data provided by Valley View Hospital were different than those for data provided by Grand River Hospital District and RMHP; Valley View Hospital categorized 0-25 year old individuals as children, while RMHP and Grand River Hospital District designated 0-18 year old individuals as children. Thus, the age categories are not entirely comparable. Finally, the time periods for data provided by Valley View Hospital and the other data sources are not completely overlapping. Because of these limitations in comparing and interpreting the Valley View Hospital emergency room data, with respect to the other two emergency room data sources – and because of the relatively small numbers of emergency room visits for residents of zip code areas other than Glenwood Springs, only the data for the Glenwood Springs zip codes (81601 and 81602) are discussed in the report. It is also important to note that, in the case of smaller populations and shorter time periods (e.g., the September through December 2006 period), a single visit has a greater impact

on the rate, thus making the rates unreliable and the data sets useful only for estimating trends. The complete Valley View Hospital data set and analysis are available in Appendix R.

Table 28. Emergency Room Admissions Data **DRG Category**	**CHA data (2000-1st Q 2007)**	**RMHP (2000-2007)** **Inpatient Hospital**	**Outpatient/Ambulatory**	**Emergency Room**	**GRHD ER (2004-2006)**	**Valley View ER* (2004-2006)**
Accident, Injury, Trauma	Garfield County's injury hospitalization rates increased for adults (>18 years) after 2005, but still remained lower than the rates for Mesa and Delta Counties. Accident, injury and trauma hospitalization rates for children (<18 years) residing in Garfield County are the lowest among the four counties.	Garfield County's rates were the lowest among the four counties until 2005 for both adults and children, and remained the lowest for children through 2007.	Same as for inpatient visit rates.	Adult emergency room visits related to accident, injury or trauma increased from 2003 through 2005, then slightly decreased through 2007.	Emergency room visit data for Grand River Hospital District show increasing rates for Silt, Parachute/Battlement Mesa, and Rifle residents for the period 2004-2006.	Adult ER visit rates were stable throughout the period. Rates for children/young adults decreased between 2004 and 2005, then remained stable for the rest of the period.
Annual Physicals/Well Child Check-ups	Not applicable.	Not applicable.	Garfield County's rates are the lowest among the four counties. **Note: These are RMHP data for insured individuals!**	Not applicable.	Not applicable.	Not applicable.
Birthing, Pregnancy, GYN	Rates are consistently higher for Garfield County than for Delta, Mesa and Montrose Counties.	Garfield County residents had lower utilization rates than did residents of Delta, Mesa and Montrose Counties. *This is likely a reflection of the difference in utilization patterns of insured and uninsured populations.*	Same as for inpatient visits.	Same as for inpatient visits.	Data show an increase in birthing and pregnancy-related patient visits for 2005 through 2006 for Silt, Parachute/Battlement Mesa and Rifle residents.	Adult ER visit rates were stable over the period; ER visit rates for this category decreased among young adults. ER visits for conditions in the perinatal period increased through the time period.

Abbreviations: DRG = Diagnosis-Related Group; CHA = Colorado Hospital Association; RMHP = Rocky Mountain Health Plans; GRHD = Grand River Hospital District. *Data presented for Glenwood Springs zip code areas only.

DRG Category	CHA data (2000-1st Q 2007)	RMHP (2000-2007) Inpatient Hospital	Outpatient/Ambulatory	Emergency Room	GRHD ER (2004-2006)	Valley View ER* (2004-2006)
Circulation/Cardiac	Garfield County's rates are the lowest among the four counties.	Garfield County's rates are the lowest among the four counties for both adults and children. Rates show an increasing trend from 2003-2006.	Same as for inpatient visits.	Same as for inpatient visits.	Rates for Silt, Parachute/Battlement Mesa and Rifle residents show an increasing trend for the time period.	Adult ER visits for this category were stable over the period; child/young adult visits decreased.
Endocrine/Metabolic	Overall, Garfield County hospitalization rates for these disorders are not different than the rates for the other three counties. However, diabetes-related hospitalization rates for both adults and children in Garfield County are the lowest among the four counties.	Rates are consistent with the CHA data for both adults and children.	Same as for ER visits.	ER visit rates for these disorders are generally lower for both adult and child residents of Garfield County than for the other three counties; rates show a slight increasing trend over the time period.	Rates for Silt, Parachute/Battlement Mesa and Rifle residents show an increasing trend for the time period.	Adult ER visits decreased between 2004 and 2005, then remained stable for the remainder of the period. Child/young adult rates increased between 2004 and 2005, then decreased from 2005 through 2006.

Abbreviations: DRG = Diagnosis-Related Group; CHA = Colorado Hospital Association; RMHP = Rocky Mountain Health Plans; GRHD = Grand River Hospital District. *Data presented for Glenwood Springs zip code areas only.

DRG Category	CHA data (2000-1st Q 2007)	RMHP (2000-2007)			GRHD ER (2004-2006)	Valley View ER* (2004-2006)
		Inpatient Hospital	Outpatient/Ambulatory	Emergency Room		
Ear, Nose, Throat, Respiratory	Garfield County has the highest rate for otitis media, upper respiratory infections, bronchitis, and asthma in children. *Asthma hospitalizations have been higher than in either Mesa or Delta Counties since 1993, but were lower than in Montrose County for the period, 1993-2001.* Garfield adult hospitalization rates for these conditions were lowest among the counties, as were the rates for COPD and other respiratory infections and inflammations for both adults and children. Exceptions are simple pneumonia and pleurisy in children, which, until 2005, were highest among the four counties.	Hospitalization rates for adult ENT and respiratory conditions were the lowest among the four counties for adults and similar to the other counties for children.	Garfield County outpatient/ambulatory visits for adults were the lowest among the four counties, but highest among the four counties for children. Garfield County rates decreased for both adults and children from 2005 through 2007.	Garfield County ER visit rates for adults were the lowest among the four counties and were stable over the 8-year period. Rates for children in Garfield County increase steadily from 2000-2003, but are similar to those for the other three counties.	ER visit rates for Silt, Parachute/Battlement Mesa, and Rifle residents are variable, but generally increasing over the time period.	Adult ER visits for otitis media increased between 2004 and 2005, then decreased from 2005 through 2006. Rates for respiratory conditions, in general, and asthma, specifically, were stable throughout the time period. Child/young adult ER visits for otitis media decreased steadily through the time period. Rates for respiratory conditions, overall, were stable, however asthma rates increased.

Abbreviations: DRG = Diagnosis-Related Group; CHA = Colorado Hospital Association; RMHP = Rocky Mountain Health Plans; GRHD = Grand River Hospital District. *Data presented for Glenwood Springs zip code areas only.

DRG Category	CHA data (2000-1st Q 2007)	RMHP (2000-2007) Inpatient Hospital	RMHP (2000-2007) Outpatient/Ambulatory	RMHP (2000-2007) Emergency Room	GRHD ER (2004-2006)	Valley View ER* (2004-2006)
Eye	No data for this category.	Garfield County's rates are the lowest among the four counties for both adults and children.	Same as for hospitalization rates.	Same as for hospitalization rates.	Rates for Silt increased sharply between 2004 and 2005; rate increases for Parachute and Rifle were more gradual for the same time period. Rifle's rates continued to increase through 2006, while Parachute and Silt showed decreasing rates.	Adult ER visits were low and stable throughout the period. Child/young adult rates showed a steady decrease over the time period.
Gastrointestinal/Urinary	Garfield County's rates are either the lowest among the four counties, or are similar to those of the other counties for this group of disorders.	Rates are consistent with the CHA data for both adults and children.	Rates are consistent with the CHA data for both adults and children.	ER visit rates for these disorders are lower for adults in Garfield County than for the other three counties, and also generally lower for children, but increasing over the time period.	Rates for Silt, Parachute/Battlement Mesa and Rifle residents show an increasing trend for the time period.	Adult ER visits for this category were stable throughout the period. Child/young adult visits increased between 2004 and 2005, then decreased between 2005 and 2006.
Infection	No data for this category.	Garfield County rates are similar to those for the other counties.	Garfield County outpatient/ambulatory visits for adults were the lowest among the four counties, but highest among the four counties for children during the time period 2000 through 2002.	ER rates for Garfield County adults were inconsistent, without a sustained trend in either direction, but similar to those for the other counties. Child ER visits for infection-related conditions were generally higher than other counties.	Rates for infection-related ER visits were variable over the time period, without consistent trends for the communities of Parachute/Battlement Mesa, Silt and Rifle.	Adult ER visits for infections decreased throughout the period, as did child/young adult visits.

DRG Category	CHA data (2000-1st Q 2007)	RMHP (2000-2007) Inpatient Hospital	Outpatient/Ambulatory	Emergency Room	GRHD ER (2004-2006)	Valley View ER* (2004-2006)
Mental	Garfield County's rates are the lowest among the four counties.	Garfield County rates are lower than for the other counties and steadily decreasing over the time period.	Same as for hospitalization rates.	Same as for hospitalization rates.	Rates for Rifle and Silt show a gradual increase; rates for Parachute/Battlement Mesa increased steeply between 2005 and 2006.	Overall adult ER visit rates decreased between 2004 and 2005, then increased to 2004 levels between 2005 and 2006. Drug/alcohol-related visits showed a steady increase over the period. The same pattern was seen for children and young adults.
Musculoskeletal	Garfield County's rates are the lowest among the four counties.	Rates are consistent with the CHA data for both adults and children.	Same as for inpatient visits.	Same as for inpatient visits.	No data for this category.	Adult ER visits were stable over the time period, as were child/young adult visits.
Nervous System	Overall, Garfield hospitalization rates for these disorders are lower than for the other counties. For the subcategory of seizure and headache, rates for children in Garfield County have increased since 2004, while decreasing in adults.	Rates are consistent with the CHA data for both adults and children.	Rates are consistent with the CHA data for both adults and children.	Garfield County ER visit rates, overall, were the lowest among the four counties.	Rates for Silt, Parachute/Battlement Mesa and Rifle residents show an increasing trend for the time period.	Adult ER visits, including those related to headaches or migraines, were stable over the period. Child/young adult visits overall increased between 2004 and 2005, then decreased through 2006. Visits related to headaches or migraines increased.

DRG Category	CHA data (2000-1st Q 2007)	RMHP (2000-2007) Inpatient Hospital	RMHP (2000-2007) Outpatient/Ambulatory	RMHP (2000-2007) Emergency Room	GRHD ER (2004-2006)	Valley View ER* (2004-2006)
Pancreas/Liver	Rates for these conditions for Delta County were consistently the highest among the four counties. Garfield County's rates were not different from those of Mesa and Montrose Counties.	No data for this category.	No data for this category.	No data for this category.	No data for this category.	Included with "Gastrointestinal/urinary" category.
Red Cell/Clotting	Garfield County's rates steadily decreased from 2001through 2006.	No data for this category.	No data for this category.	No data for this category.	No data for this category.	Adult ER rates increased between 2004 and 2005/ Child/young adult rates were stable through 2005, then decreased through 2006.
Skin/Allergy	Rates for these conditions for Delta County were consistently the highest among the four counties. Garfield County's rates were not different from those of Mesa and Montrose Counties.	Garfield County's rates are the lowest among the counties, showing periods of moderate rate decrease (2001-2003) and increase (2003-2005).	Garfield County's rates are the lowest among the four counties, increasing slightly from 2003 to 2004, then decreasing from 2005 through 2007.	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period, except for an increase between 2003 and 2004, decreasing to previous rates in 2006. (Rates for children in Garfield County decreased steadily from 2005 through 2007.)	Rates for Silt, Parachute/Battlement Mesa and Rifle residents show an increasing trend for the time period.	Adult ER rates were stable. Child/young adult rates decreased through the period.

Table 29. Inpatient Hospital Admissions Data

DRG Category	RMHP Member Data: 2000-2007* Adult (≥18 years)	Child (<18 years)
Accident, Injury & Trauma	Garfield County's rates are the lowest among the counties until 2005, when the rates rise to become higher than those for Montrose County (but still lower than for Delta or Mesa Counties. Garfield County rates remain stable through 2007.	Garfield County's rates are the lowest among the counties, and are relatively stable across the 8-year period.
Cardiac	Garfield County's rates are the lowest among the counties, slightly increasing from 2004 to 2006.	
Ear, Nose & Throat	Garfield County's rates are the lowest among the counties, slightly decreasing from 2001 through 2006	Garfield County's rates are similar to those of Delta and Montrose Counties for most of the time period, increasing in 2001, then decreasing through 2007.
Endocrine	Garfield County's rates are generally the lowest among the counties, and remain relatively stable.	Garfield County's rates are relatively stable and lower than those of the other counties, with the exception of being higher than Delta County's rates in 2002, 2003, and 2006.
Eye	Garfield County's rates are the lowest among the counties, and are stable across the time period.	
Gastrointestinal & Urinary	Garfield County's rates are the lowest among the counties, and are relatively stable across the 8-year time period.	Garfield County's rates have increased during the 8-year time period, but are generally lower than those of the other counties
Infection	Garfield County's rates were highly variable over	Garfield County's rates peaked in 2003, dropping

	the 8-year time period, as were those for the other counties.	steadily through 2006, the rising again in 2007. These rates were generally similar to those of the other counties.
Mental Health	With the exception of 2000 and 2001, Garfield County's rates were lower than those for the other counties, and decreased steadily from 2001 to 2007.	Garfield County's rates were lower or the same as rates for the other counties throughout the 8-year time period. There was a spike in rates during 2004.
Musculoskeletal	Garfield County's rates are the lowest among the counties, and are relatively stable across the 8-year time period.	Garfield County's rates are low and similar to those of the other counties, with the exception of Montrose County, which had a spike in rates for 2005, then dropping to return to the low rates of the other counties by 2007.
Neurological	Garfield County's rates are the lowest among the counties, and are relatively stable across the 8-year time period.	
Pregnancy/Gynecological	Garfield County's rates are the lowest among the counties, and are relatively stable across the 8-year time period, with a moderate increase from 2002 to through 2004, dropping again in 2005.	
Respiratory Condition	Garfield County's rates are the lowest among the counties, and are relatively stable across the 8-year time period, following an increase from 2000 to 2001.	Garfield County's rates increased steadily from 2000 through 2002, remaining stable through 2005, and then decreasing steadily through 2007. These rates are generally similar to those for the other counties, and follow the same trends.
Skin/Allergy	Garfield County's rates are the lowest among the counties, showing periods of moderate rate decrease (2001-2003) and increase (2003-2005).	

Table 30. Outpatient Hospital Visits or Lab Work

DRG Category	RMHP Member Data: 2000-2007*	
	Adult (≥18 years)	Child (<18 years)
Accident, Injury & Trauma	Garfield County's rates are the lowest among the comparison counties until 2005, when there was an an increase in rates, making Garfield County's rates higher than those of Montrose County, but still lower than those for Delta and Mesa Counties. All of the counties showed a decrease in rates between 2006 and 2007 except Garfield County, whose rates remained stable.	Garfield County's rates were among the lowest for the four counties, remaining essentially stable over the 8-year period.
Annual Physical Well Check-ups (child)	Garfield County's rates are the lowest among the four counties for annual physical usage. **NOTE: This rate is for an insured population, for which annual physicals are provided.**	Garfield County's rates were the lowest among the four counties for annual physical usage. **NOTE: This rate is for an insured population, for which well check-ups are provided.**
Cardiac	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period.	
Ear, Nose & Throat	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period.	Garfield County's rates tend to fall in the middle of the rates for the four comparison counties, increasing between 2000 and 2001, then increasing through 2007.
Endocrine	With the exception of 2001, Garfield County's rates are the lowest among the four counties, and are generally stable throughout the 8-year period.	Garfield County's rates increased from 2001 through 2003, during which time they were higher than those for Delta County but lower than those for Mesa and Montrose Counties. After 2003, Garfield County's rates were stable through 2006, dropping in 2007, and are lower than the other counties for Garfield County's rates increased from 2001 through 2003, below Garfield rates for 2006 only.

Eye	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period.	Garfield County's rates are the lowest among the four counties, and show a downward trend from 2005 through 2007.
Gastrointestinal & Urinary	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period.	From 2001 until 2003, Garfield County's rates are lower than those for the other counties. After 2003, the rates are higher and more similar to those for Delta and Montrose Counties (Mesa County's rates are higher). Rates increase sharply in 2007 for Garfield and Delta Counties, decreasing for Mesa and Montrose Counties.
Infection	Garfield County rates are generally in the middle of the rates for the four counties, and are relatively stable except for an increase in 2001 and a decrease in 2006.	Garfield County's rates increased steeply between 2000 and 2001, remaining high (relative to the other counties) through 2002, then decreasing through 2006. In 2007, Garfield County's rate was again higher than that for the other counties.
Mental Health	With the exception of a spike in 2001, Garfield County's rates are lower than those for the other counties, and steadily decreased through 2007.	Garfield County's rates are generally lower than those for the other counties. Rates increase between 2000 and 2001, again between 2003 and 2004, decrease through 2006, and turn upward slightly in 2007.
Musculoskeletal	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period.	With the exception of steep increase in Montrose County rates in 2005 (followed by a steep downward trend through 2007), rates for all counties are low.
Neurological	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period.	
Pregnancy/Gynecological	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period.	With the exception of a steep increase in rates for Montrose County in 2007, rates for all counties are low.

Respiratory Condition	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period.	Rates for Garfield County are among the highest for the four counties (rates for Montrose County are generally higher). Rates increase from 2000 through 2002, then decrease from 2006 through 2007.
Skin/Allergy	Garfield County's rates are the lowest among the four counties, increasing slightly from 2003 to 2004, then decreasing from 2005 through 2007.	Garfield County's rates are generally the lowest among the four counties, increasing from 2003 to 2004, then decreasing from 2005 through 2007.

Table 31. Ambulatory Office Visits

DRG Category	RMHP Member Data: 2000-2007* Adult (≥18 years)	Child (<18 years)
Accident, Injury & Trauma	Until 2005, Garfield County's rates are the lowest among the four counties. An increase in rates between 2004 and 2005 puts Garfield County's rates higher than those for Montrose County, but lower than Delta and Mesa Counties, for 2006 through 2007. Garfield County's rates for 2005 through 2007 are stable, while the other counties show decreasing rates for the same period.	Garfield County's rates go up and down during the 8-year period, but are still generally lower than those for the other four counties.
Annual Physical Well Check-ups (child)	Garfield County's rates are the lowest among the four counties for annual physical usage. **NOTE: This rate is for an insured population, for which annual physicals are provided.**	Garfield County's rates were the lowest among the four counties for annual physical usage. **NOTE: This rate is for an insured population, for which well check-ups are provided.**
Cardiac	Garfield County's rates are the lowest among the four counties for the entire 8-year period, despite a gradual increase in rates from 2004 through 2006.	
Ear, Nose & Throat	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period.	Garfield County's rates generally fall in the middle among the four counties, increasing between 2000 and 2001, then generally decreasing for the remainder of the time period.
Endocrine	With the exception of 2001, when Delta County's rates are lower, Garfield County's rates are the lowest among the four counties for the 8-year time period.	Garfield County's rates are higher than those of Delta County for 2000 through 2003 and again in 2006. Otherwise, Garfield County's rates are the lowest among the four counties.
Eye	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period.	Garfield County's rates are the lowest among the four counties, with decreasing trends from 2005 through 2007.
Gastrointestinal & Urinary	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year	Garfield County's rates are generally lower or similar to those of the other counties, increasing between 2003 and 2004, and

	period.	again between 2006 and 2007.
Infection	Garfield County's rates are highly variable over the 8-year time period, remaining in the middle of those for the other counties for every year except 2006. In 2006, Garfield Counties rates are lower than those for the other counties.	Garfield County's rates increased sharply between 2000 and 2001, making them the highest among the counties for 2001 and 2002. Between 2002 and 2006, rates decreased continuously, putting Garfield County in the middle of the other counties. In 2007, rates again increased, making Garfield County the highest among the four counties.
Mental Health	Garfield County rates increased between 2000 and 2001, then decreased steadily through 2007. After 2002, Garfield County's rates are the lowest among the four counties.	Garfield County rates increased between 2000 and 2001 and again in 2004, then decreased between 2004 and 2006, increasing slightly in 2007. Over the 8-year time period, Garfield County rates are either lower than or similar to the rates for the other counties. Mesa County has the highest rates for the entire period.
Musculoskeletal	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period.	With the exception of Montrose County's rates for 2005 through 2006, rates for all counties are low and essentially similar. Montrose County's rates rose steeply between 2004 and 2005, then decreased through 2007.
Neurological	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period.	
Pregnancy/Gynecological	Garfield County's rates are the lowest among the four counties, increasing gradually through 2004, decreasing from 2004 through 2005, and increasing again in 2007.	With the exception of a spike in Montrose County's rates for 2007, all counties have low rates over the 8-year time period.
Respiratory Condition	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period, except for an increase between 2000 and 2001.	Garfield County's rates increase from 2000 to 2002, remain stable through 2005, then decrease steadily through 2007. These rates are generally in the middle of the rates for the four counties.

Skin/Allergy	Garfield County's rates are the lowest among the four counties, and were generally stable throughout the 8-year period, except for an increase between 2003 and 2004, decreasing to previous rates in 2006.	Garfield County's rates are the lowest among the four counties except for 2001, when Delta County's rates were lower. Garfield County's rates increased between 2003 and 2004, decreasing steadily from 2005 through 2007.

Careflight Data

One other measure of traumatic injury rates (and potentially of serious work-related injuries), is statistical information from St. Mary's Hospital "Careflight" emergency flight ambulance service. Complete data sets are available in Appendix S.

Figure 91 shows emergency service for residents of the four counties for all types of emergencies. Figure 92 shows emergency calls to drill rigs in two counties, Garfield and Rio Blanco, both of which have seen a significant increase in natural gas activity over the past four years.

These numbers give a comparison of worker-related, serious injuries between the two counties.

Figure 91. *CareFlights*: Rates by County

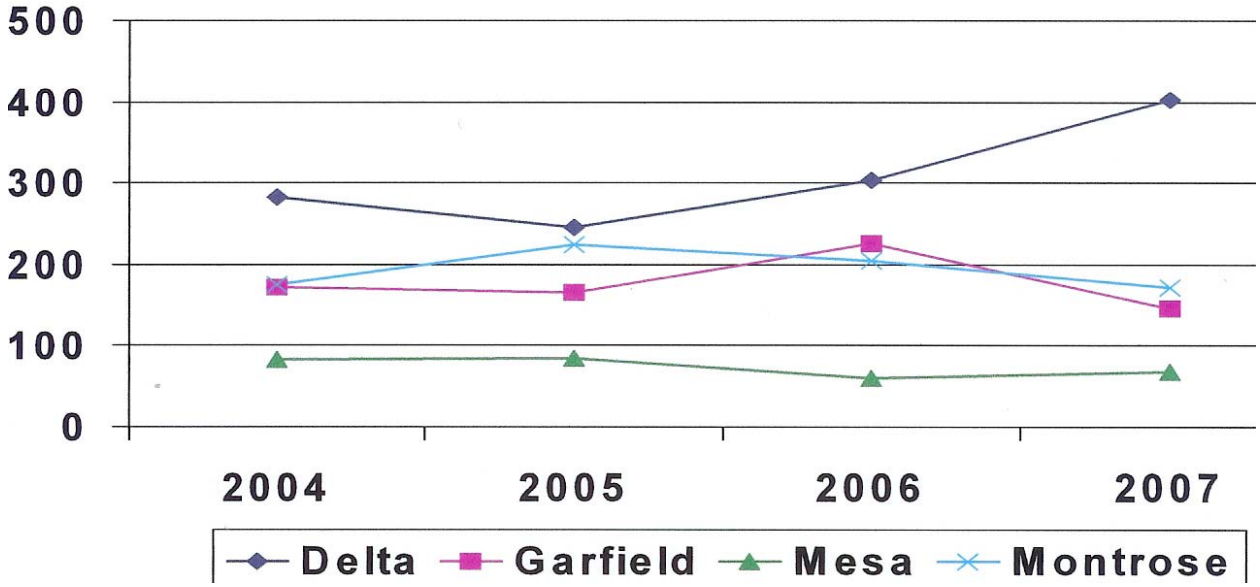
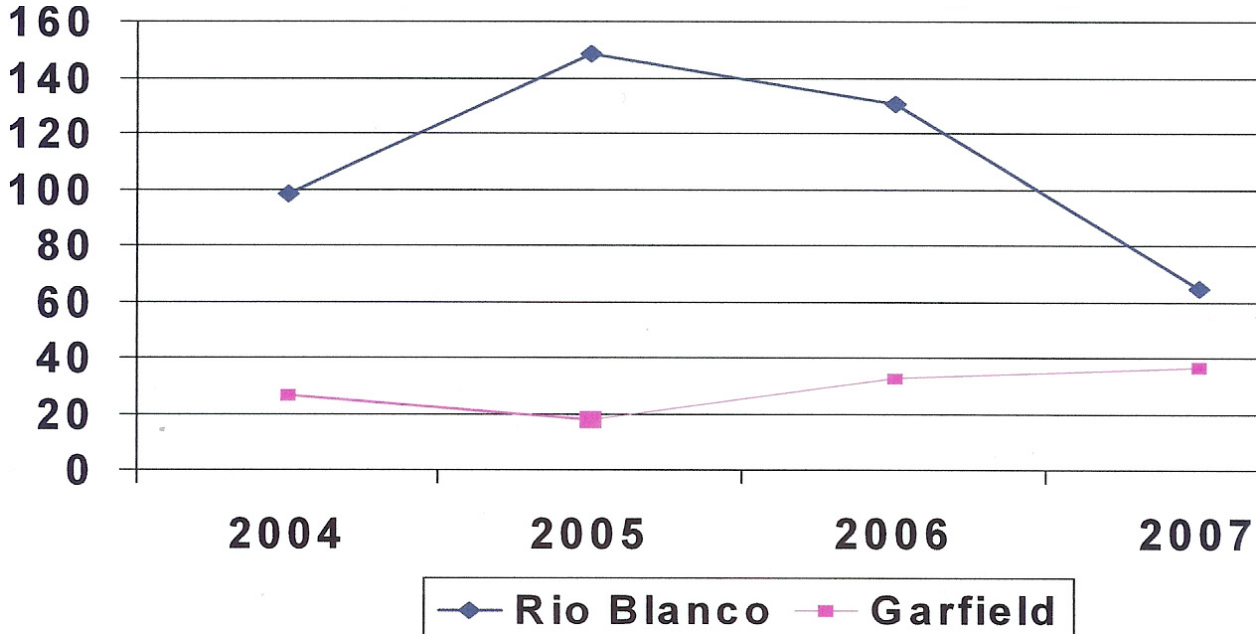


Figure 92. *CareFlights*: Rates of Drill Rig Flights



Household Survey. The full ACCESS database containing responses to the household survey, *EpiInfo* analysis of the survey responses and Excel spreadsheets used to collate and chart the data are provided in Appendix U. The following discussion contains the highlights and most significant results from this phase of the study. In most cases, the graphic results are portrayed by zip code area and for Garfield County, overall. Please note that *"SL"* in all of the graphs and tables refers to households in which Spanish is the primary language. These interviews and surveys were conducted in Spanish.

Respondent Demographics

Table 32 provides an overview of the sample population, numbers of surveys attempted and completed, and the percentage of the population surveyed, by zip code area. Table 33 provides information on response rates and reasons for refusing to participate in the survey.

Table 32. Household Survey Demographics

Zip Code	Census pop.	Households (with "land lines")	Sample		Surveys Completed	% of households completed	Individuals "surveyed"**	% of population surveyed
81601*	12,768	4,680	Mail	440	49	1.05	135	1.06
			Phone	438	56	1.20	151	1.18
81623	13,008	4,784	Mail	362	26	0.54	63	0.48
			Phone	355	48	1.00	140	1.08
81635	5,041	1,947	Mail	186	24	1.23	52	1.03
			Phone	186	22	1.13	57	1.13
81647	4,410	1,672	Mail	170	11	0.66	25	0.57
			Phone	170	23	1.38	84	1.90
81650	10,319	3,752	Mail	401	35	0.93	87	0.84
			Phone	401	50	1.33	147	1.42
81652	3,107	1,632	Mail	172	21	1.29	54	1.74
			Phone	169	20	1.23	53	1.71
Totals	48,653	18,467		3,450	385	2.08	1,048	2.15

* The city of Glenwood Springs includes zip codes 81601 and 81602. For the sake of simplicity, in this report, the data for these two zip codes are combined and referred to collectively as zip code 81601.

** This number includes the number of total individuals (household members) for whom data were collected as a result of completing the designated number of household surveys.

Table 33. Household Survey Response Rate – Telephone Survey

Respondent Location	Total Number Refused	Hung Up	Reason given for not participating: Too busy	Survey too long	Not interested	Other	Gender**: Male	Female	Age**: Young	Middle-aged	Elderly
Carbondale (81623)	25 (34.2%)*	16	1	1	5	2	8	7	6	6	1
Glenwood Springs (81601 & 81602)	42 (42.8%)	17	7	0	12	6	7	16	4	5	3
New Castle (81647)	11 (32.4%)	3	1	0	3	4	0	5	1	4	1
Parachute (81635)	12 (35.3%)	4	1	0	1	6	2	2	1	1	0
Rifle (81650)	37 (43.5%)	16	5	3	3	5	7	8	5	4	2
Silt (81652)	16 (44.4%)	4	3	0	3	6	3	5	2	5	0
Battlement Mesa (81635)	1 (4.3%)				1						

* Percentage of actual telephone contacts (does not include attempted calls to numbers no longer in service or household contacts that were unsuccessful as a result of repeated calls to a phone number that resulted in “no answer” or answering machine response only. With the exception of Battlement Mesa (which is largely a retirement community), there are no significant trends among “impacted” and “non-impacted” communities with respect to refusal to participate in the telephone survey.

** It was often not possible to definitively identify the gender and age of the person who answered the phone and refused to complete the survey. Thus, these numbers are given for rough information only, and are not intended to provide a reliable description of the population that refused to participate in this survey.

Figure 93 demonstrates graphically that the quality of the vast majority of completed household surveys was good, with a minimal number that were "marginal", with respect to the reliability of the collected data, or had significant levels of missing data.

Figure 93. Quality of Household Survey Interviews

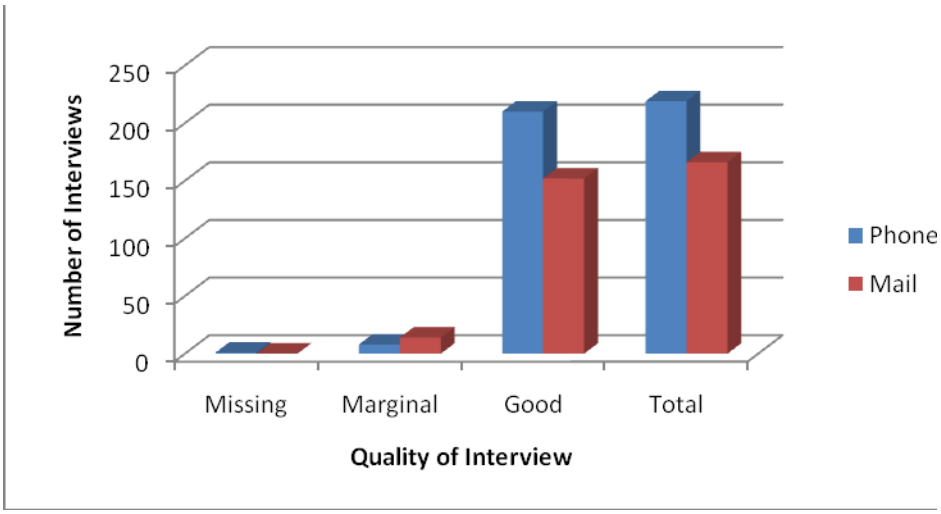


Figure 94 shows the length of residence in Garfield County for survey respondent households. The vast majority of respondents from every zip code area have lived in Garfield County for more than five years, and more than 90% have lived in their current residence for more than one year (Figure 95). Figures 96 and 97 show the location of respondent residences and the number of persons residing in the respondent households as a percentage of the households surveyed. Figures 98 through 103 provide information on other demographic characteristics of the surveyed households and respondents, such as age, gender, ethnicity, percentage of ethnicity, education and health insurance. The majority of the respondents were married.

Figure 94. Length of residence in Garfield County

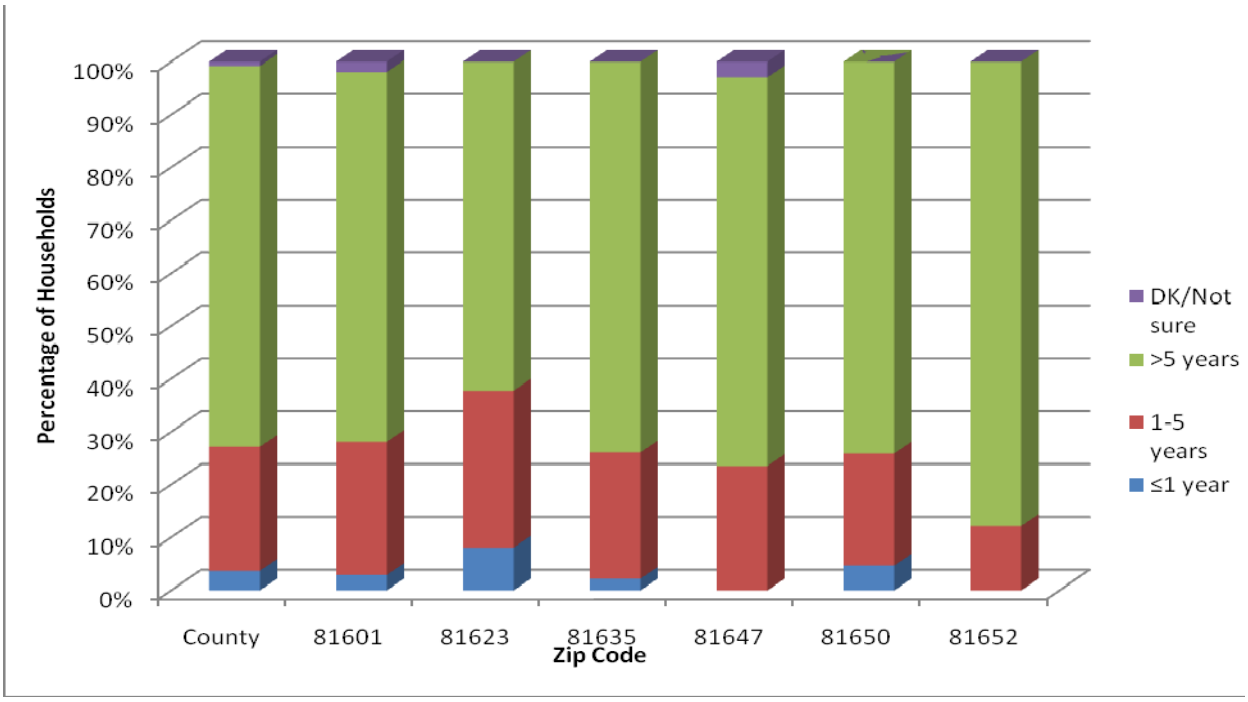


Figure 95. Length of time in current residence

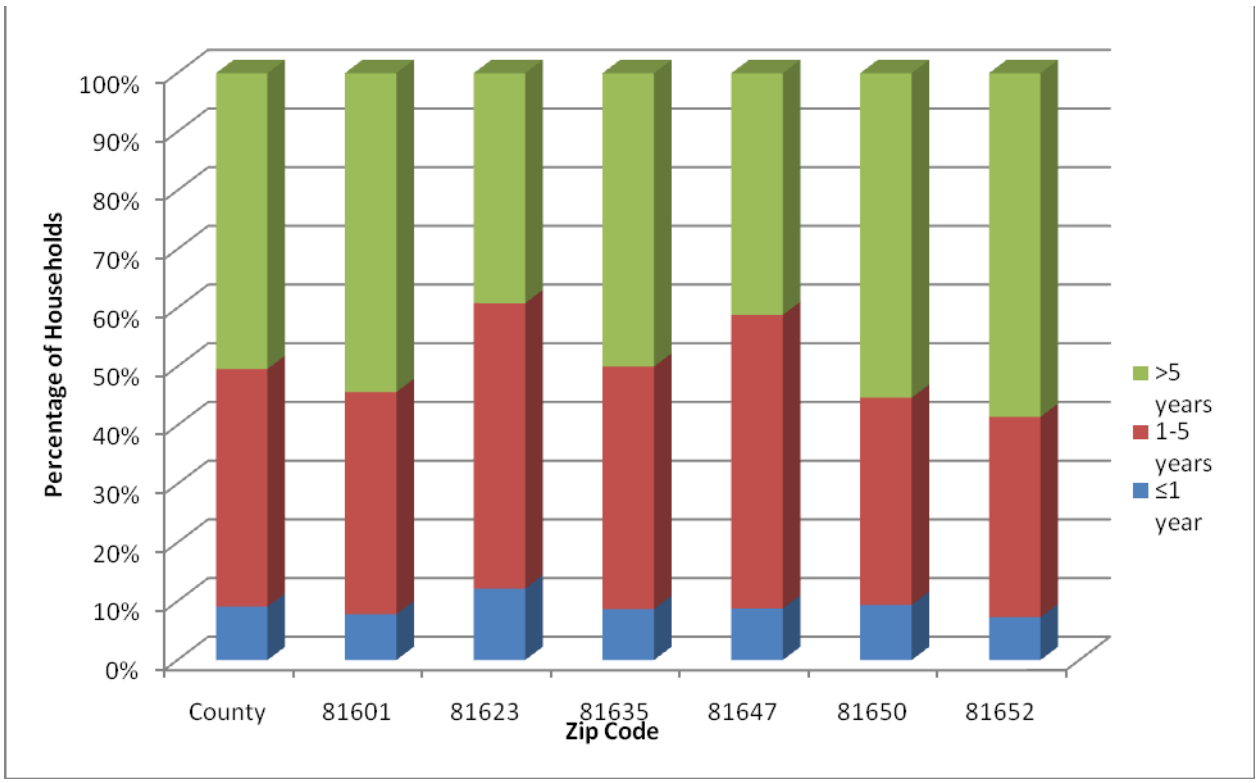


Figure 96. Location of residence in Garfield County

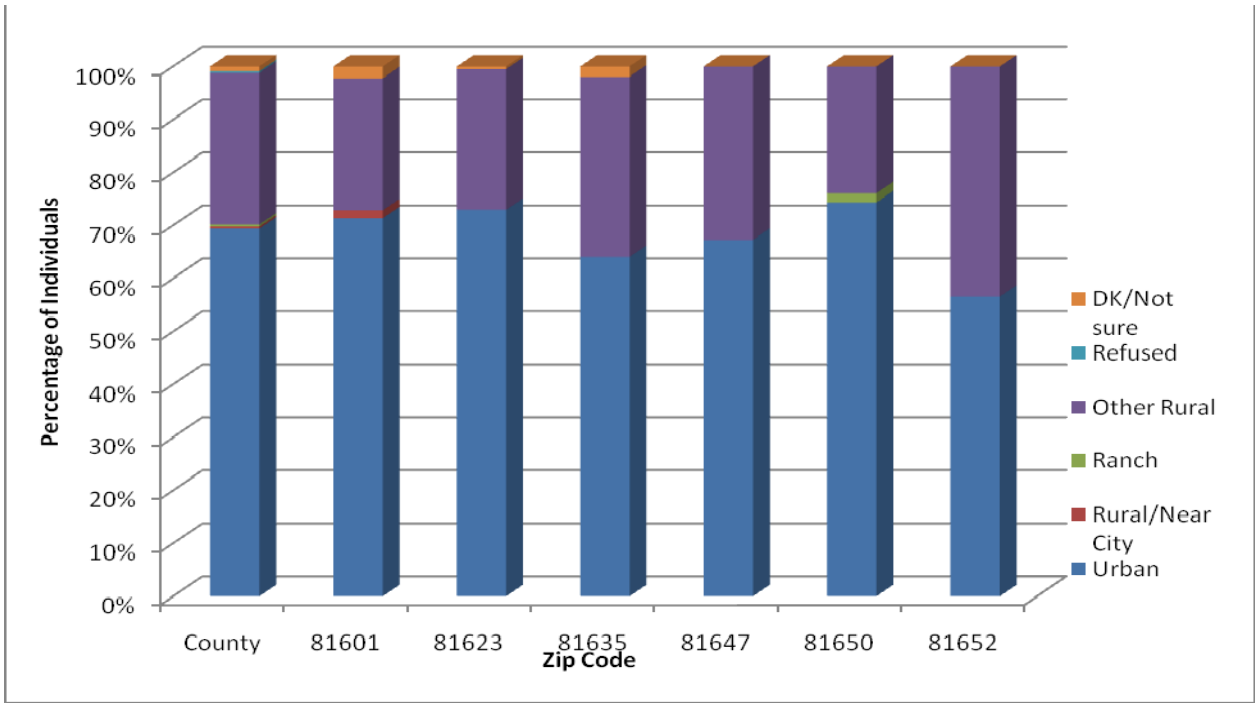
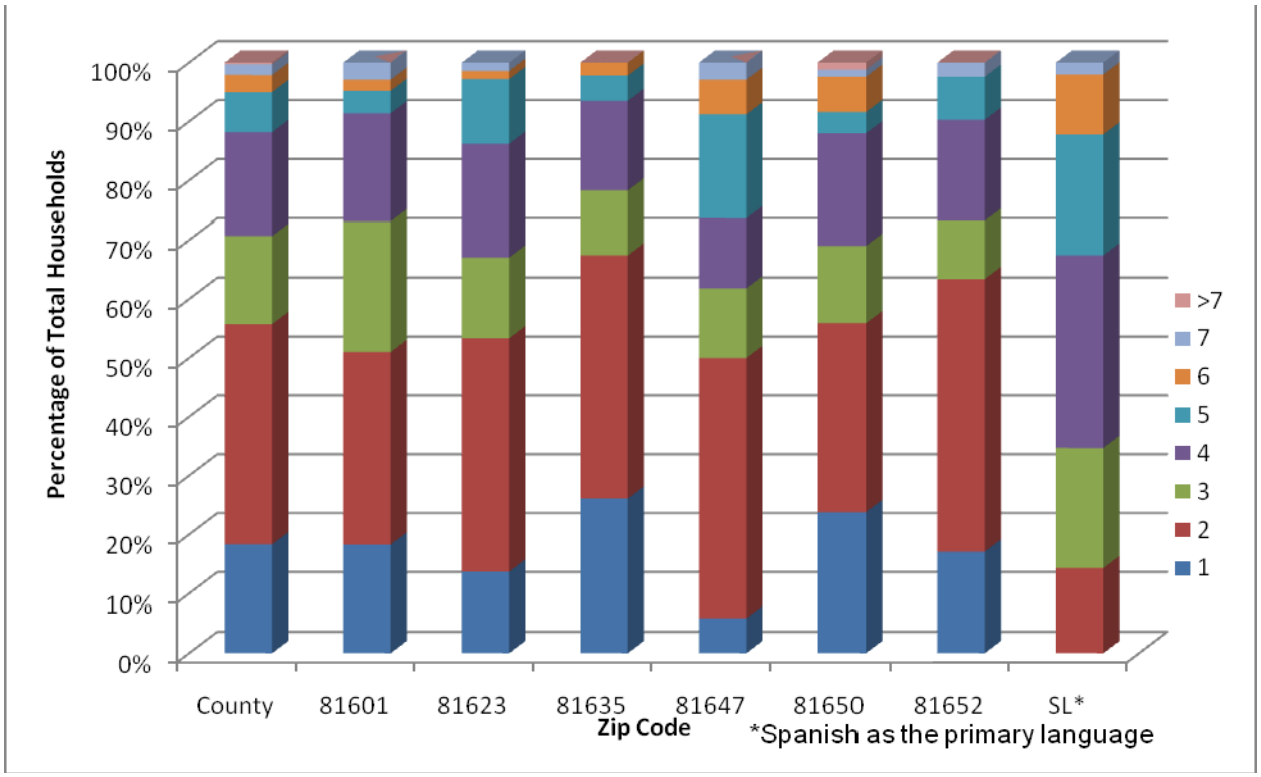


Figure 97. Household Size (residents per household)



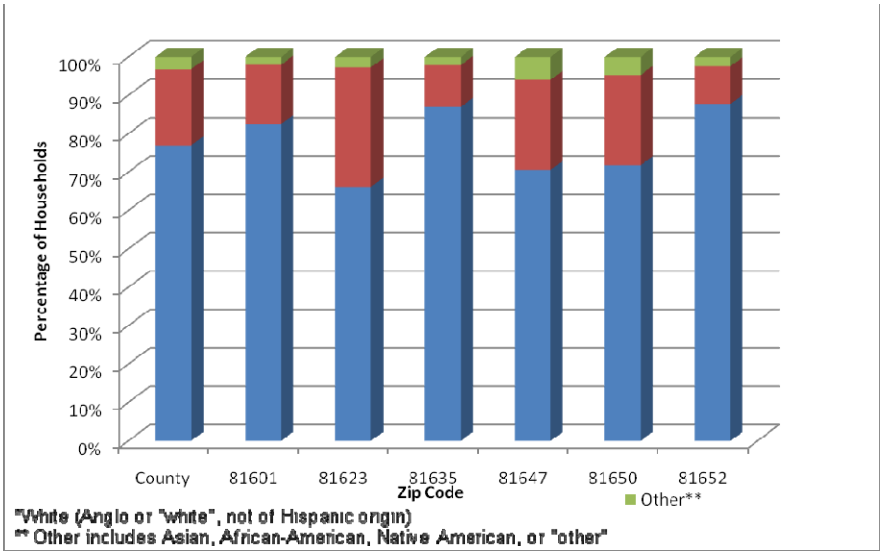
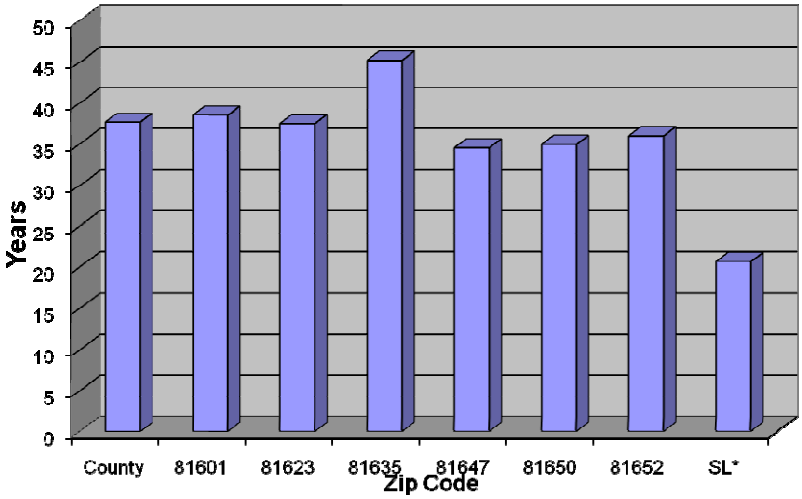


Figure 98. Household Ethnicity

Figure 99. Mean Age of Household Residents



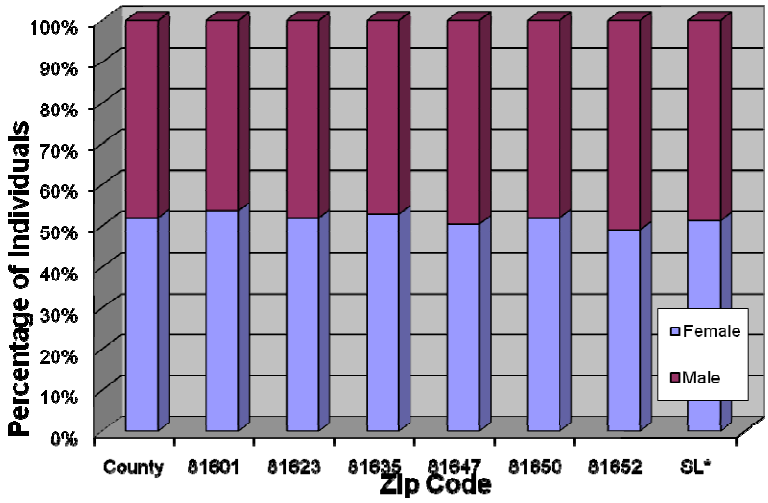


Figure 100. Gender of Residents

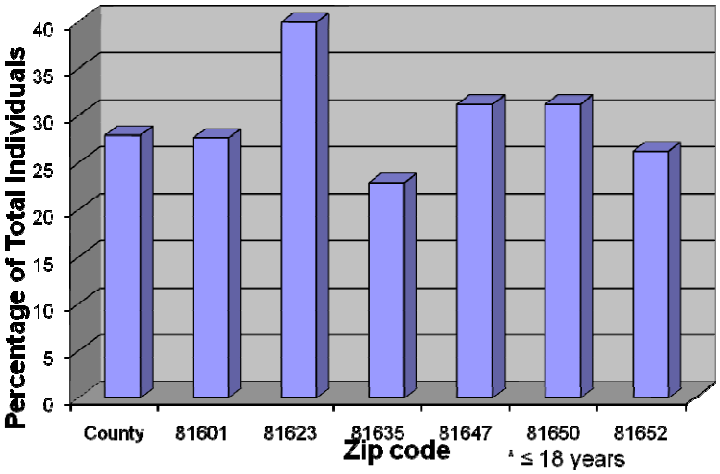
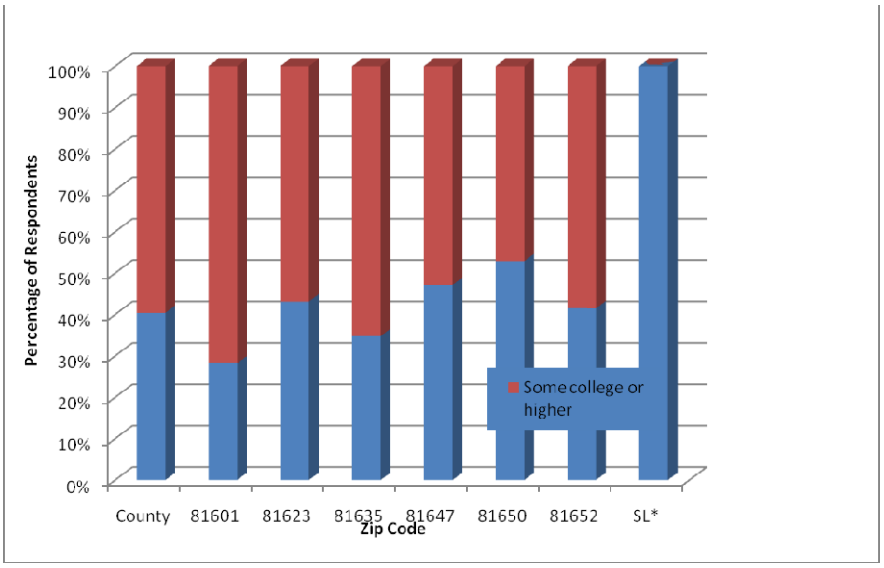


Figure 101. Percentage of Children in Respondent Households

Figure 102. Education level of Survey Respondent



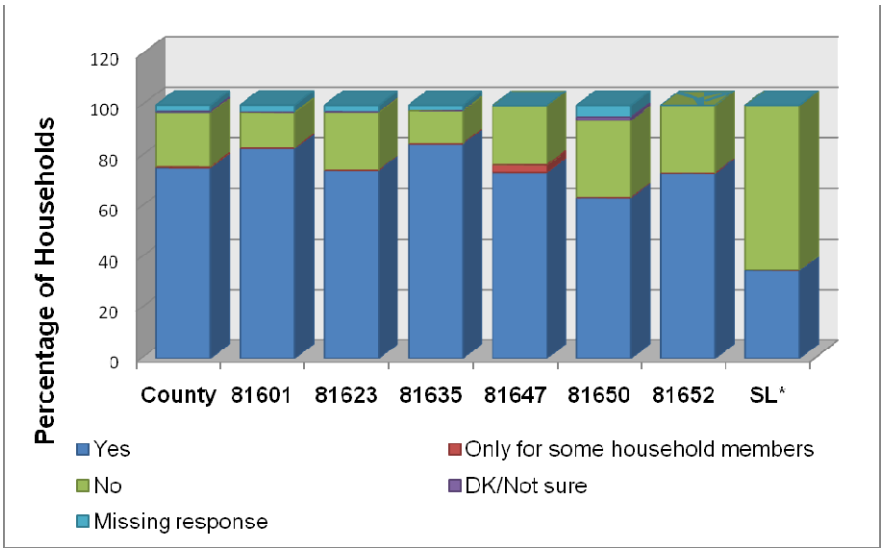


Figure 103. Percentage of Households with Health Insurance

Household Survey Outcomes

Greater than 80% of individuals from every zip code area in Garfield County rated their current health as either excellent or good, and less than 10% of individuals in every zip code area felt that their current health is somewhat worse or much worse than it was one year ago.

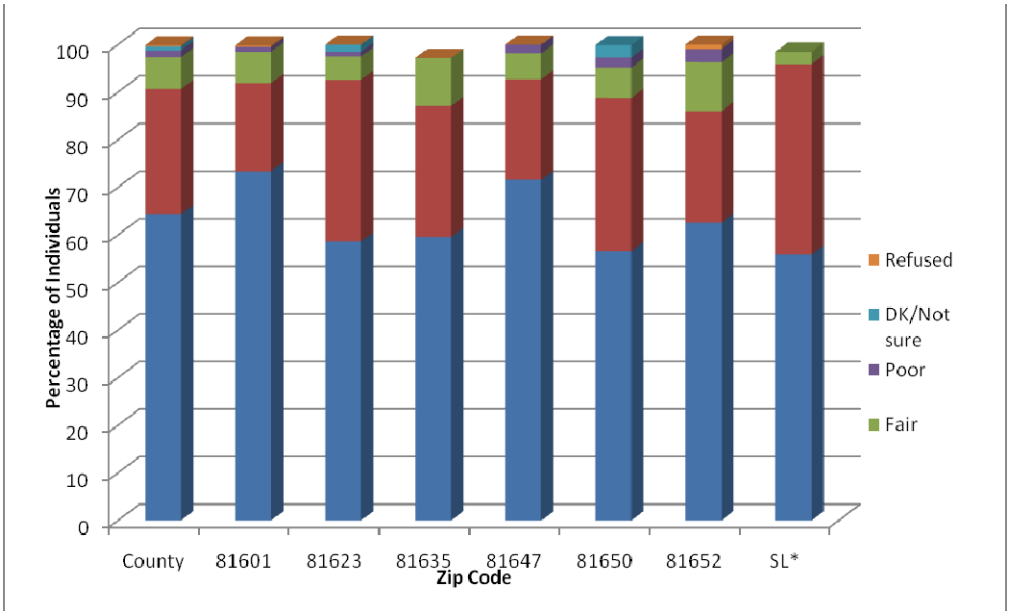


Figure 104. Current Health

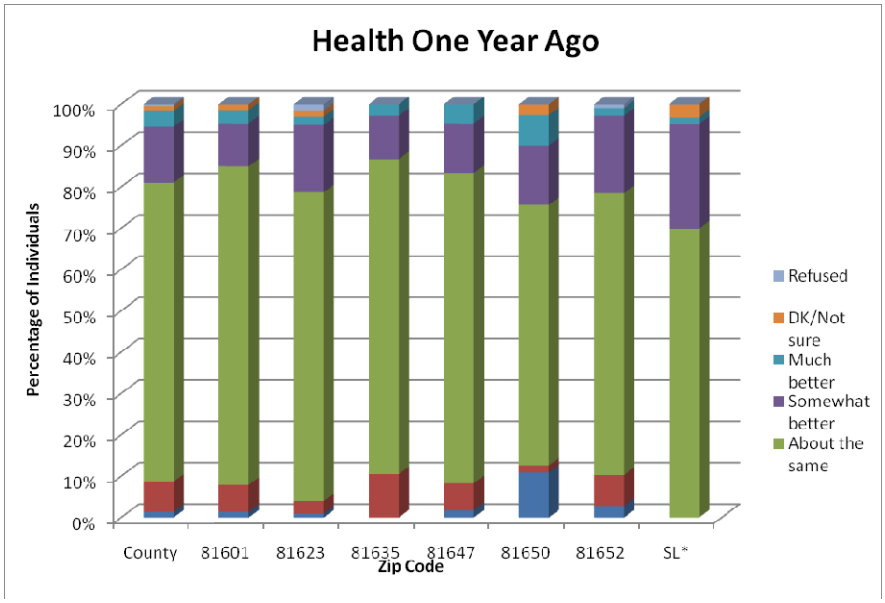


Figure 105. Health One Year Ago

Approximately 12% of individuals, county-wide, reported that they had suffered an illness or injury during the past year that had affected their health for greater than 5 days.

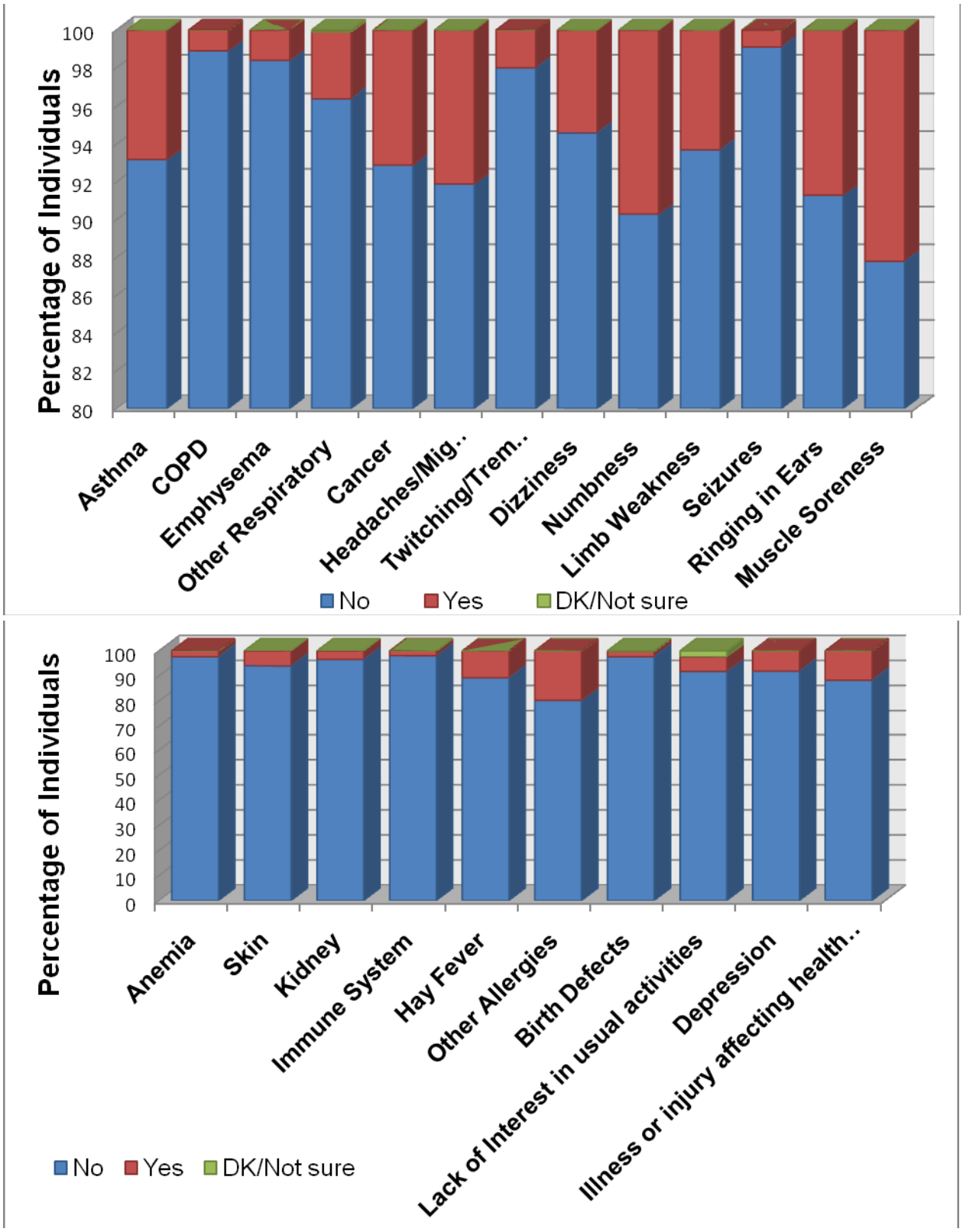


Figure 106. Percentage of individuals reporting selected diseases and symptoms: Garfield County Overall

- Approximately 8% of individuals, county-wide, reported suffering from depression.

- 20% of individuals reported suffering from a variety of allergies, including hay fever.

- 8% of individuals suffer from frequent headaches or migraines; a zip code comparison shows that the lowest frequency of headache sufferers live in zip code 81623 (4%), while the highest frequency was reported from zip codes 81635 and 81647 (8.3% each). Please note that these data are NOT age-adjusted.

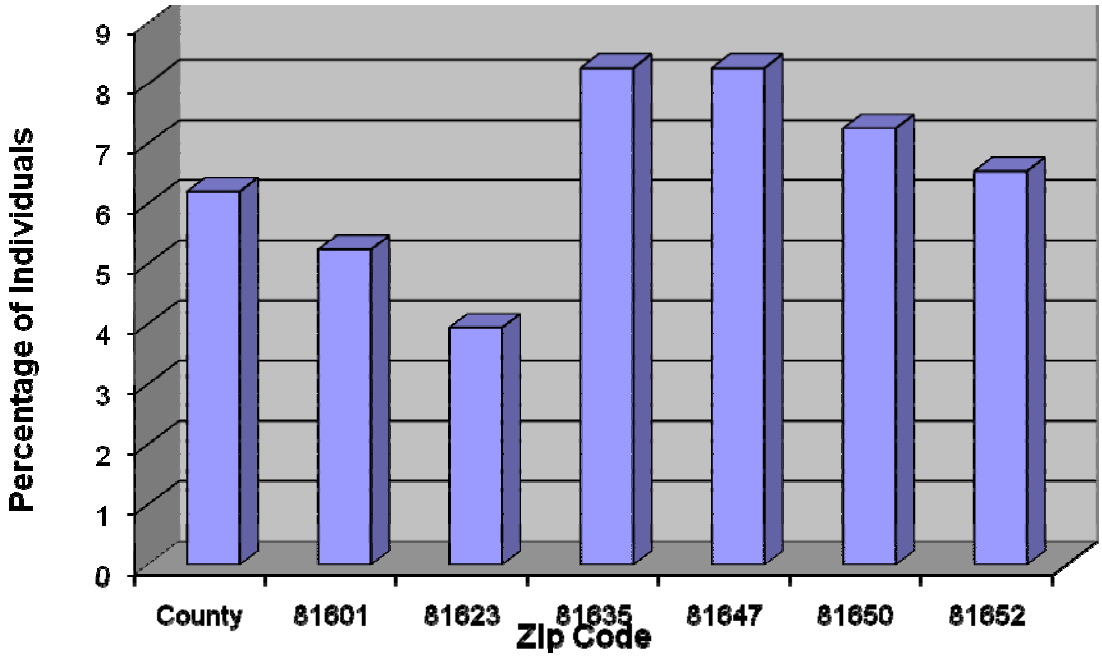


Figure 107. Percentage of individuals suffering from frequent headaches or migraines by zip code

We made some attempt to look at any correlation with home drinking water supply and neurological symptoms or complaints such as frequent headaches (see Figure 107 below), dizziness, "twitching", and weakness, and lung or kidney diseases For a complete set of symptoms or conditions that were correlated with home water supply, please see Appendix U. Those respondents who live in the 81647, 81650 and 81652 zip code areas were more likely to be using bottled or vended water as a home drinking water source. In all cases, the numbers of individuals reporting these conditions were too small to show statistical significance for any correlation. However, the majority of respondents in all zip code areas used filtered or unfiltered tap water (municipal water supplies) as their primary drinking water source. Despite the fact that municipal drinking water sources are required to meet Federal drinking water standards, many respondents living in the 81647, 81650 and 81652 reported concerns about a

relationship between their health conditions and their drinking water source (Figure 110). Please see our recommendation regarding testing for private wells and small homeowner association drinking water sources.

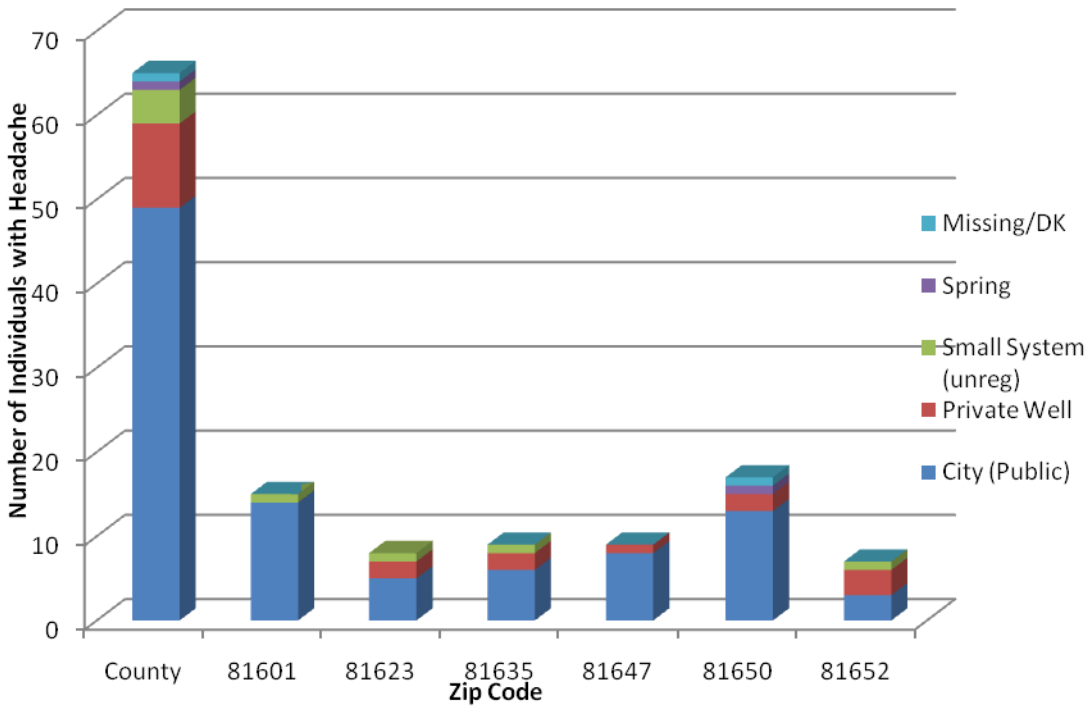


Figure 108. Main water supply and number of individuals reporting frequent headaches

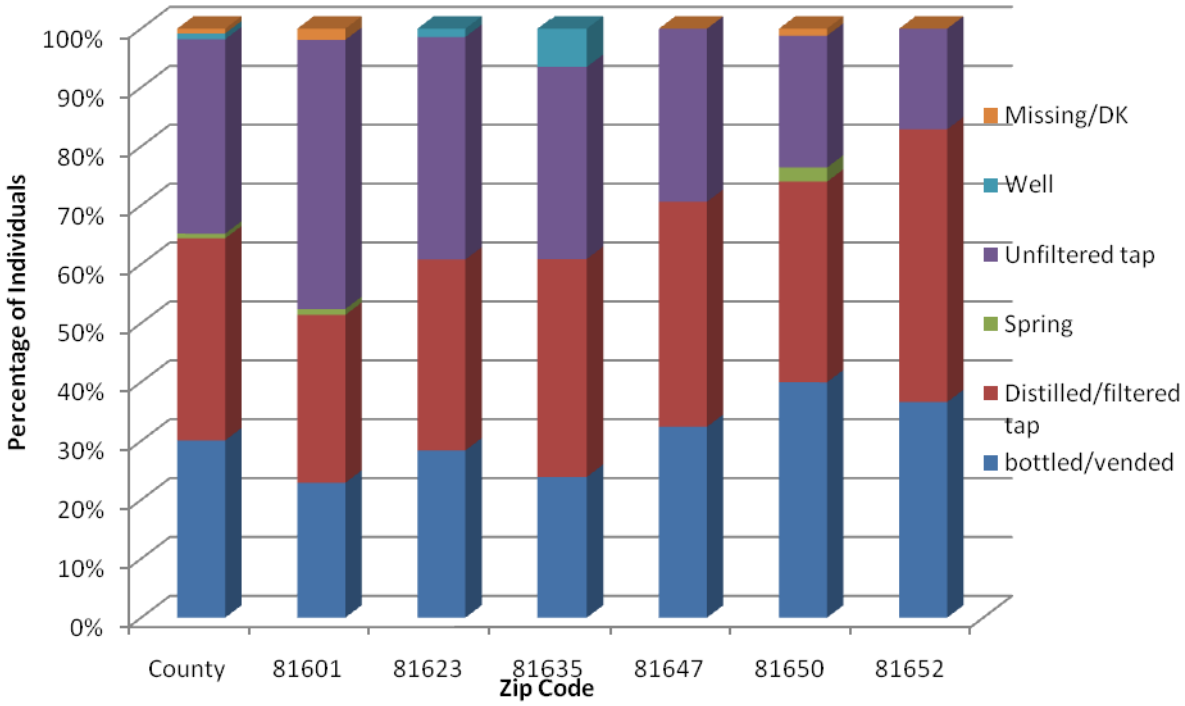


Figure 109. Primary source of drinking water at home

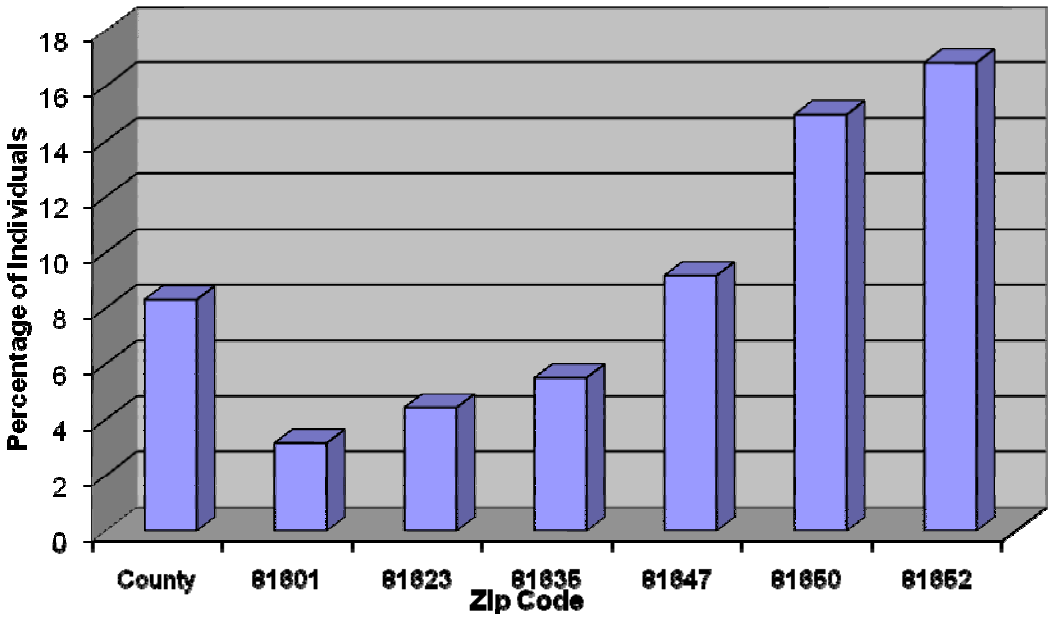


Figure 110. Percentage of Individuals Concerned about Health Problems Related to Water Supply

We also asked questions about personal behaviors that could influence respondent health; e.g., alcohol, tobacco, and recreational drug use. These responses were stratified by zip code and age. (Please see Appendix U for complete data sets.) Figures 110 through 112 provide data on frequency and amount of alcohol and recreational drug use reported for the County, overall.

Figure 111. Days Per Month of Alcohol Consumption by Age: County Overall

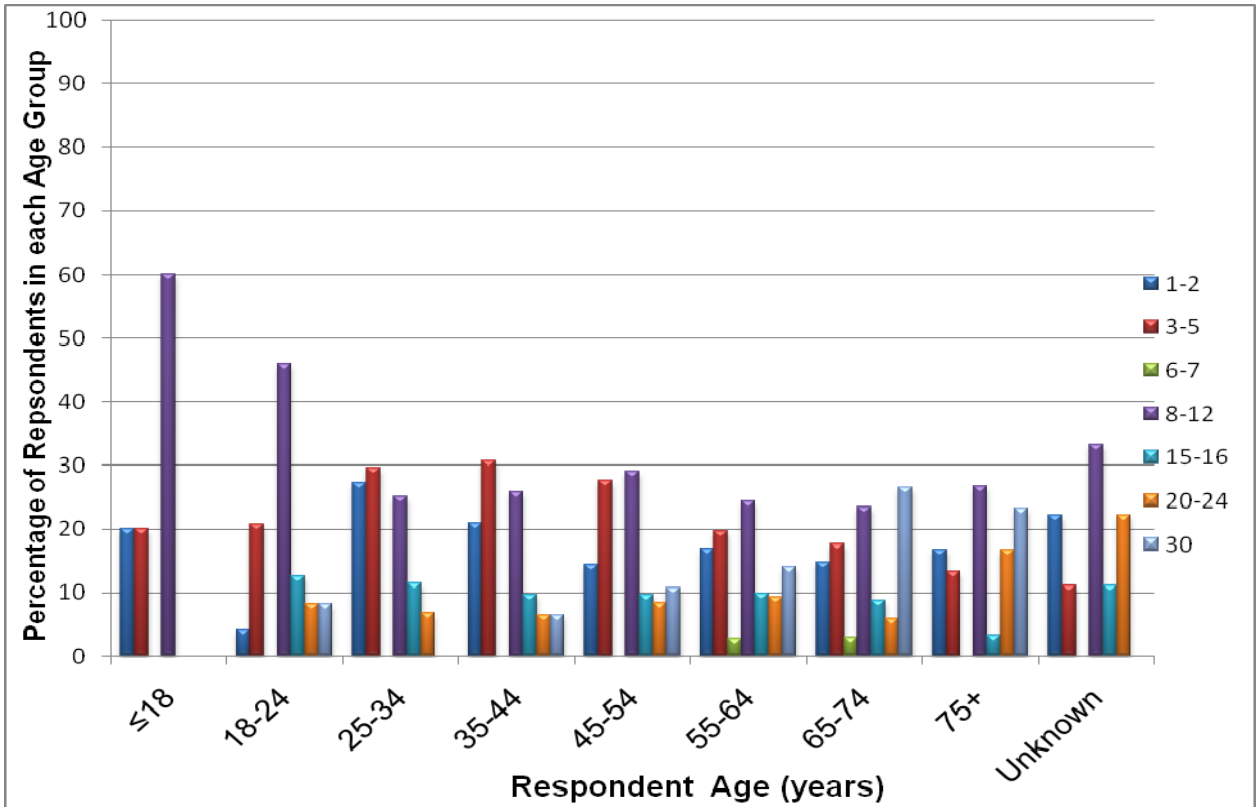
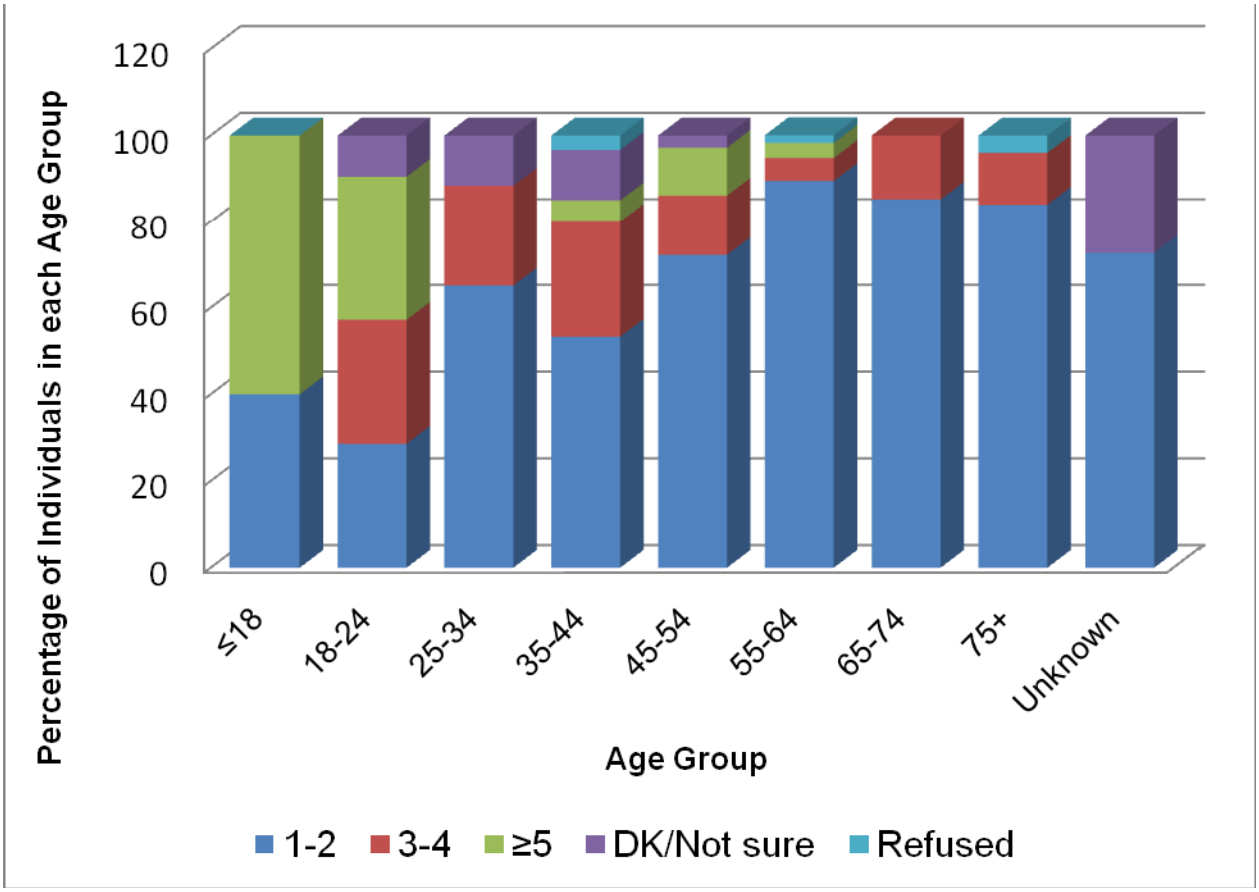


Figure 112. Number of Drinks Per Day for Individuals Who Consumed Alcohol During the Past 30 Days: County Overall by Age



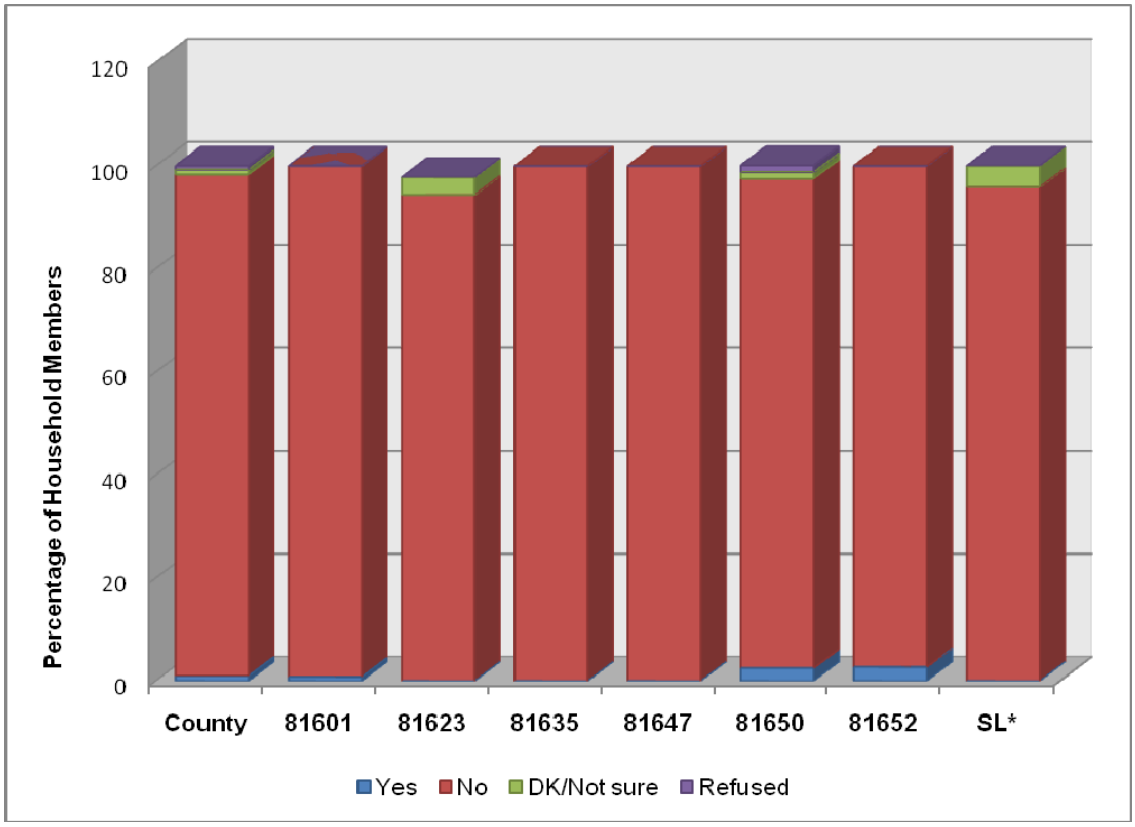


Figure 113. Percentage of Household Members Who Reported Using Recreational Drugs During the Previous 30 Days by Zip Code

Figures 114 through 116 provide information on cigarette smoking within Garfield County by zip code, age group and frequency.

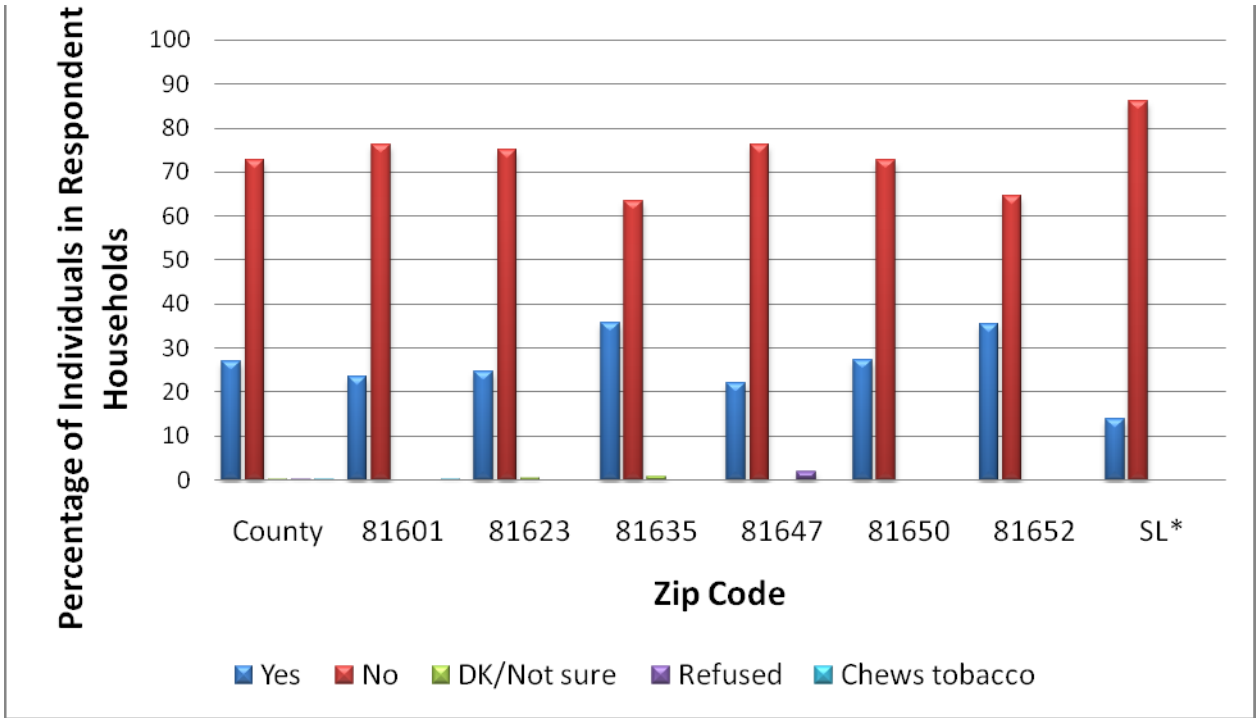


Figure 114. Percentage of Individuals Who Have Smoked More than 100 Cigarettes by Zip Code

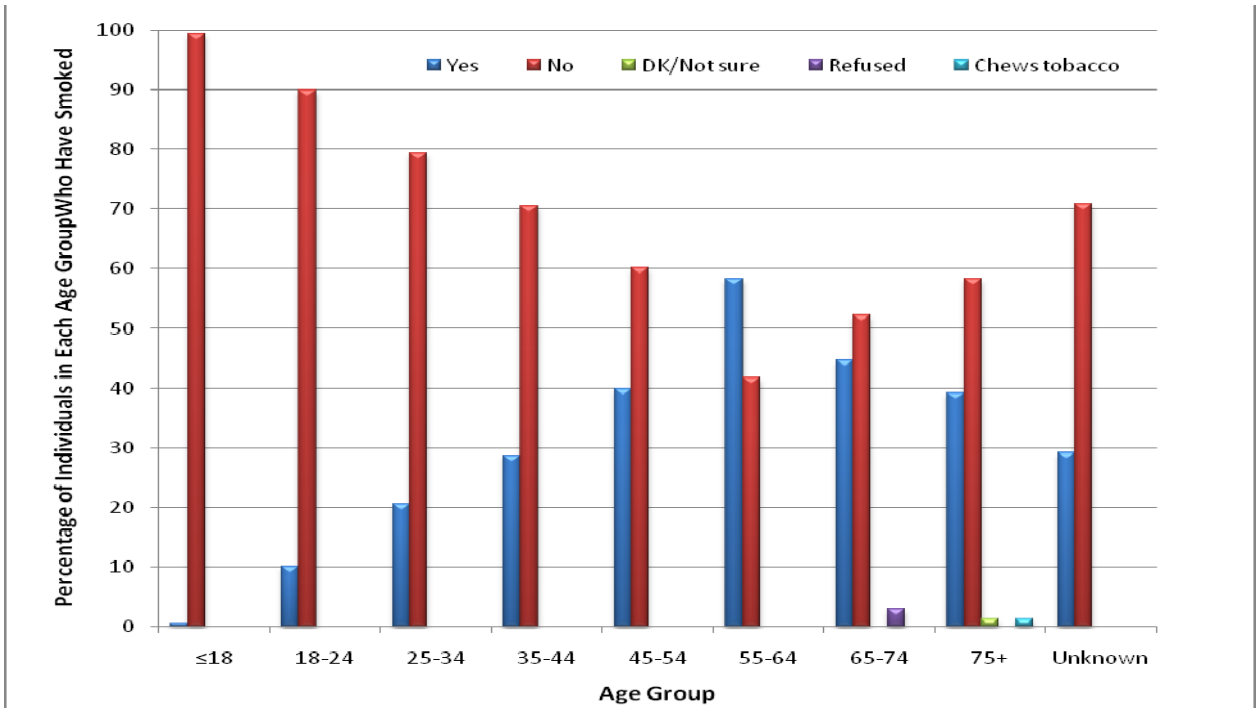


Figure 115. Percentage of Individuals Who Have Smoked More Than 100 Cigarettes by Age Group: County Overall

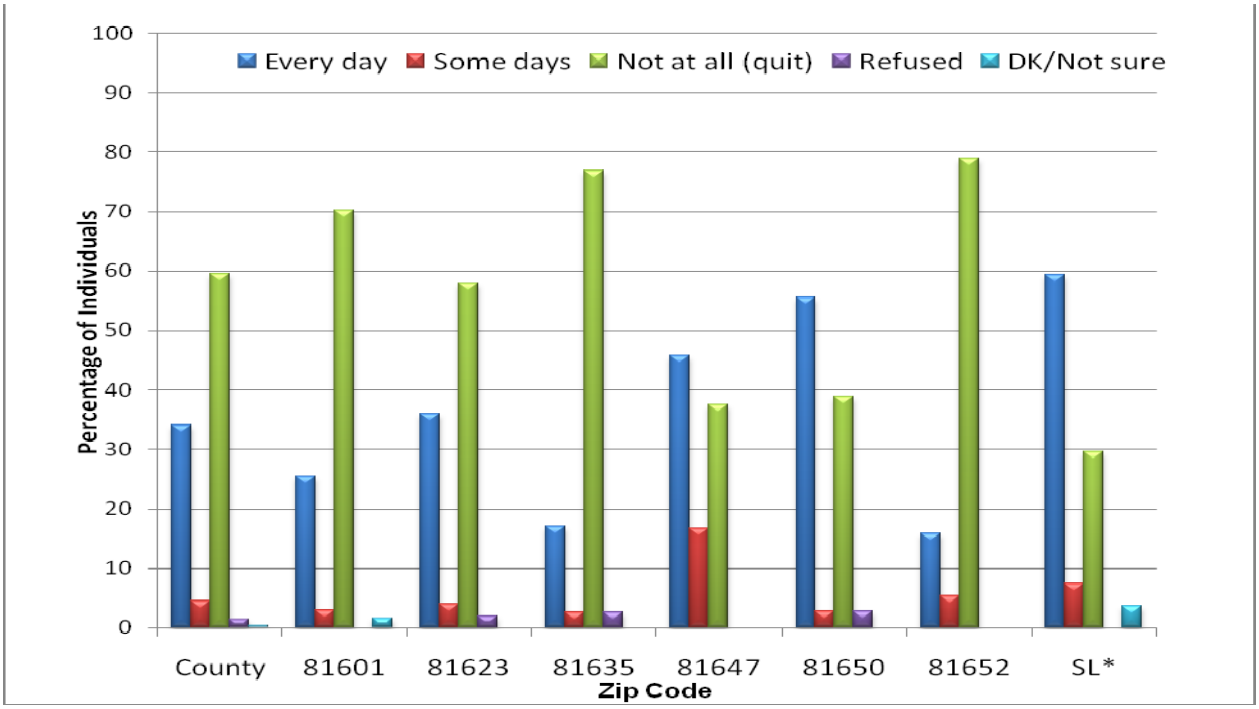


Figure 116. Frequency of Smoking for individuals Who Have Smoked More Than 100 Cigarettes in Their Lives: by Zip Code

Because respiratory complaints were expressed so frequently in interviews and focus groups, we asked a number of specific questions about respiratory conditions and contributing factors such as smoking. Figures 117 through 122 show correlations by zip code, between self-reported smoking frequency and self-reported respiratory conditions. Figures 123 through 126, and the accompanying discussions, provide additional information on self-reported respiratory conditions by zip code.

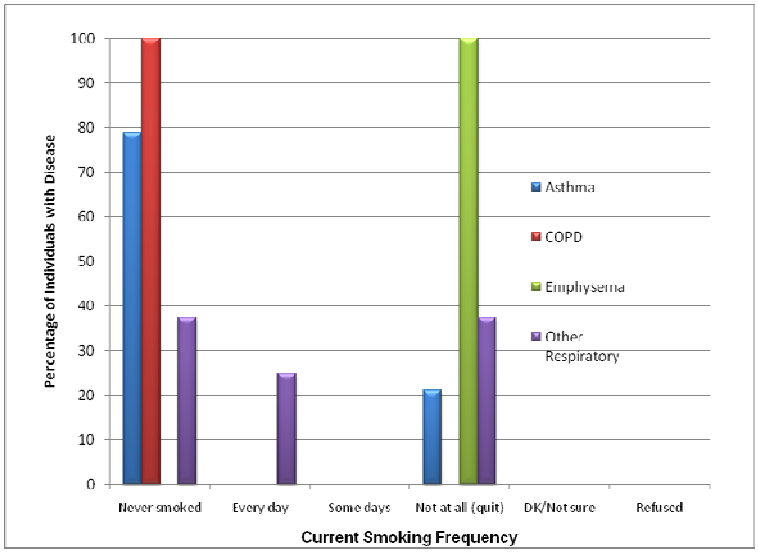
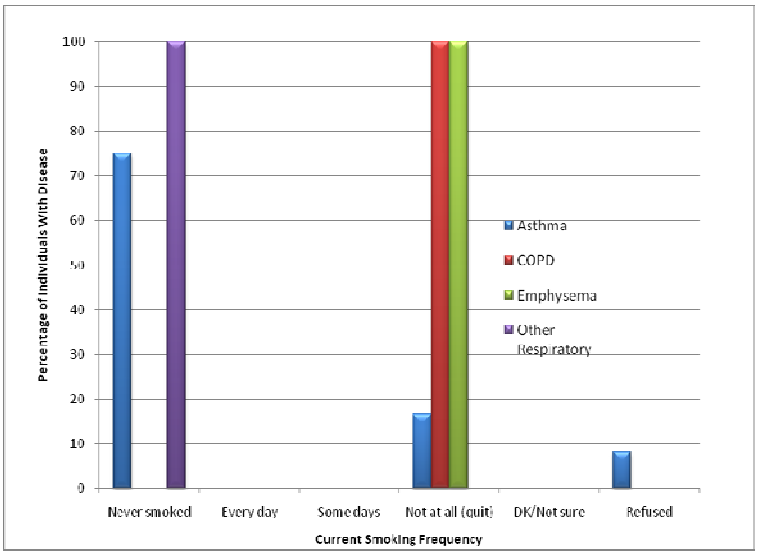


Figure 117. Smoking Frequency of Individuals Who Have Respiratory Conditions: Zip Code 81601

Figure 118. Smoking Frequency of Individuals Who Have Respiratory Conditions: Zip Code 81623



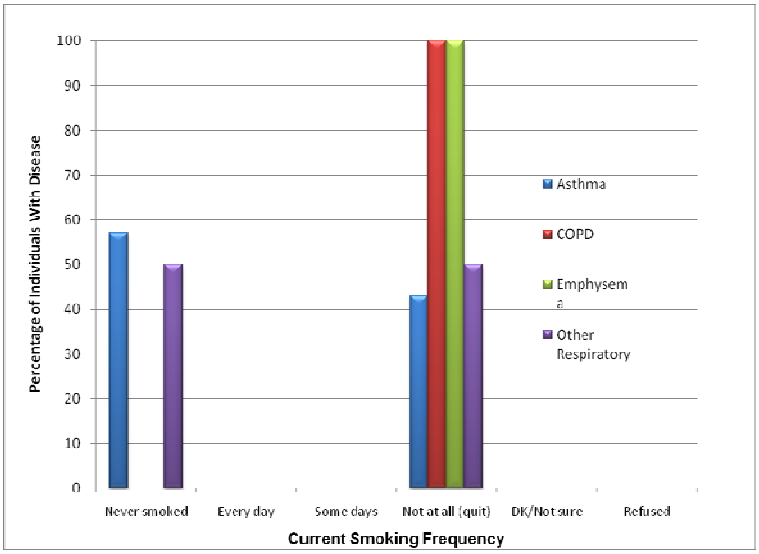


Figure 119. Smoking Frequency of Individuals Who Have Respiratory Conditions: Zip Code 81635

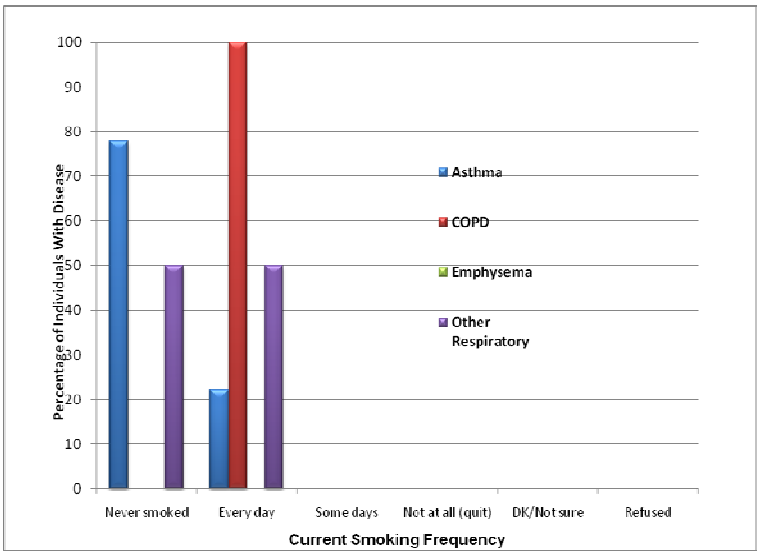
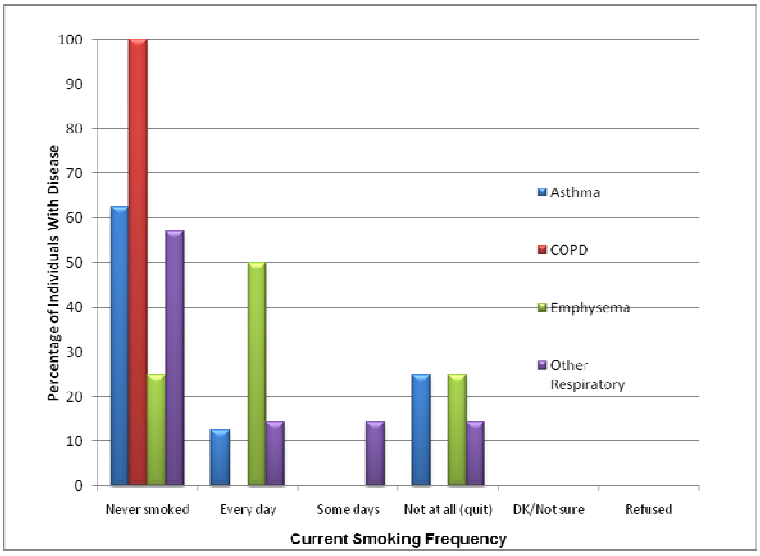


Figure 120. Smoking Frequency of Individuals Who Have Respiratory Conditions: Zip Code 81647

Figure 121. Smoking Frequency of Individuals Who Have Respiratory Conditions: Zip Code 81650



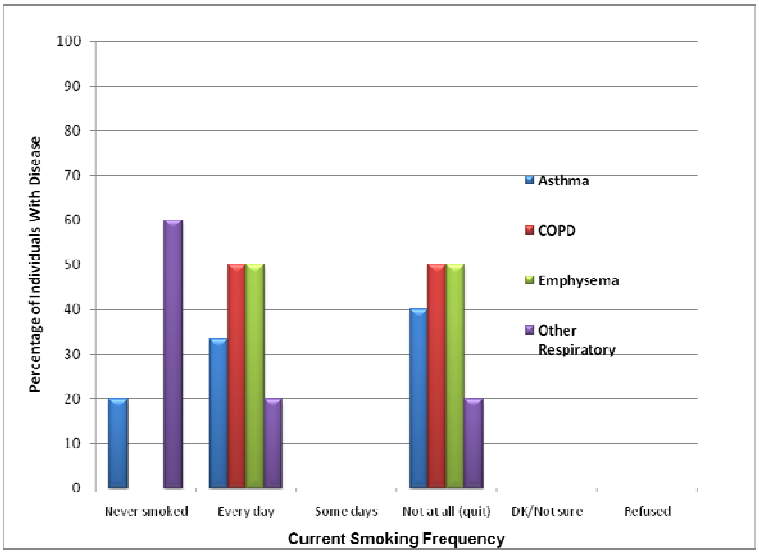


Figure 122. Smoking Frequency of Individuals Who Have Respiratory Conditions: Zip Code 81652

- 6.5% of individuals, county-wide, reported having a diagnosis of asthma; the highest frequency of individuals with asthma was in zip code area 81647 (8.3%), while the lowest frequency of individuals with asthma was in zip code area 81652 (4.7%). Both zip code areas have significant natural gas industry activity.

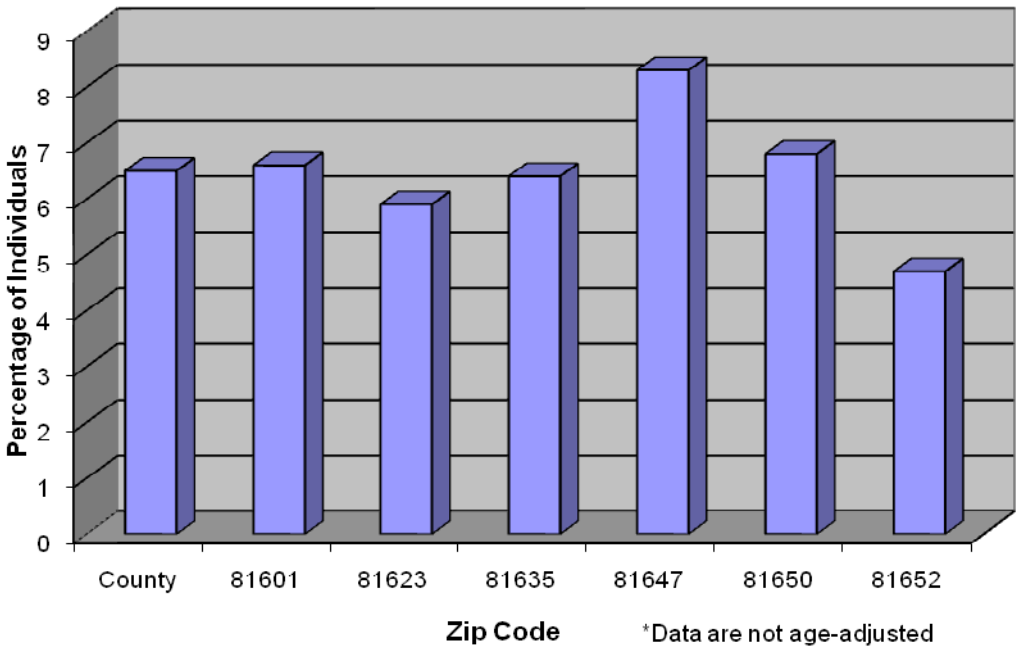


Figure 123. Percentage of Household Members with Asthma by Zip Code

- Similar to what was observed for asthma, the zip code area having the highest frequency of other respiratory conditions, such as Chronic Obstructive Pulmonary Disease (COPD), emphysema and other lung or breathing problems, was among those most highly impacted by natural gas industry activity, but the lowest or next to lowest frequency was also found among these impacted zip code areas (Figures 125 through 127).

- Age and smoking are factors that clearly influence the incidence of these conditions. With the exception of asthma, individuals who reported having lung conditions tended to be older (e.g., 65+ for COPD and emphysema). These data are not shown here, but are available in Appendix U. 27% of county residents, overall, reported having smoked at least 100 cigarettes during their lifetime; 60% of these have quit smoking (Figure 116 above). 85% of respondents reported that smoking is NOT allowed within the home

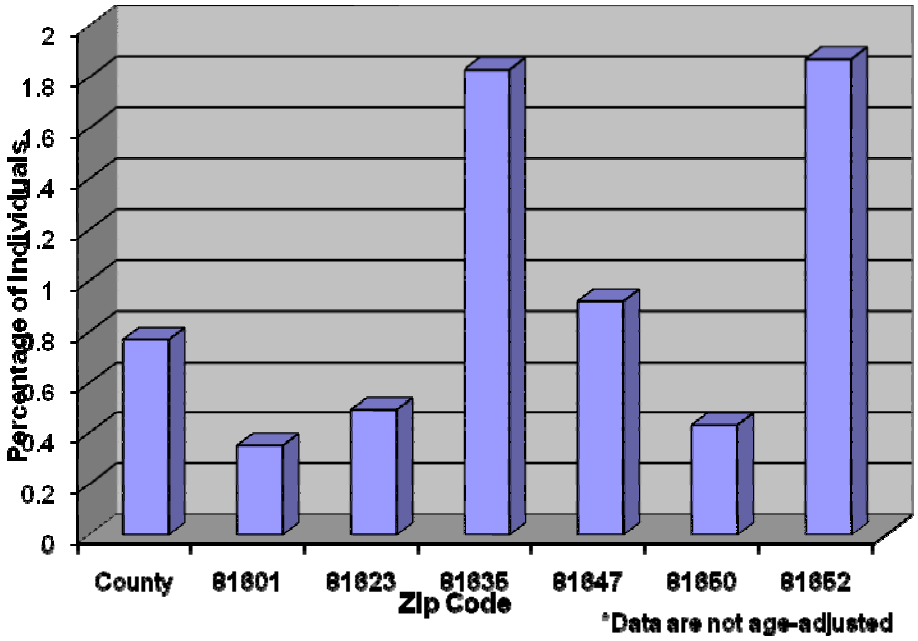
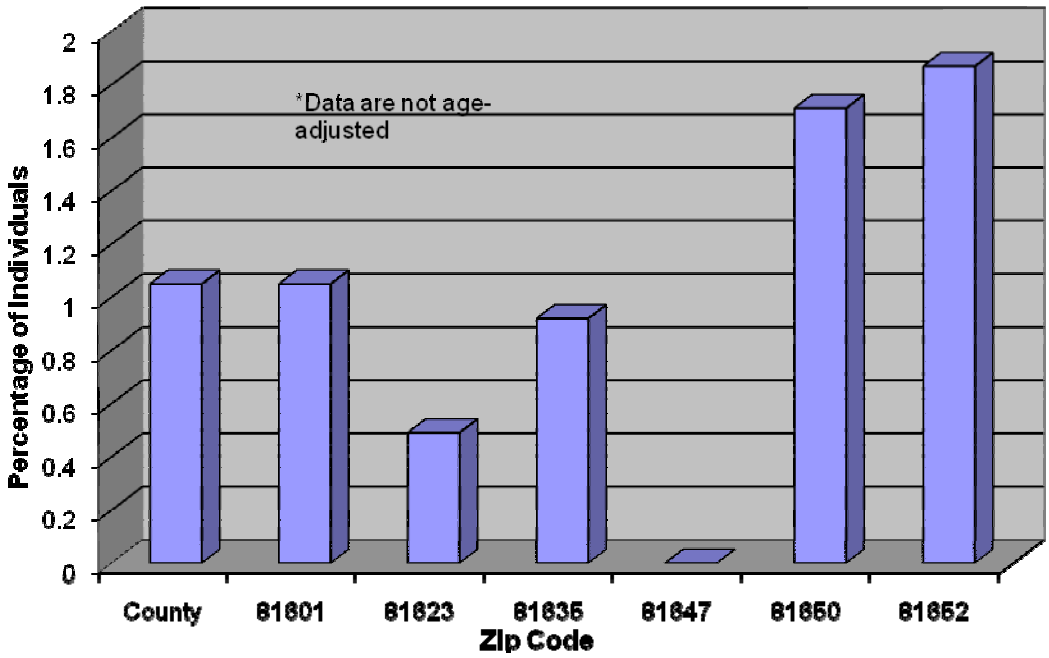


Figure 124. Percentage of Household Members with COPD by Zip Code

Figure 125. Percentage of Household Members with Emphysema by Zip Code



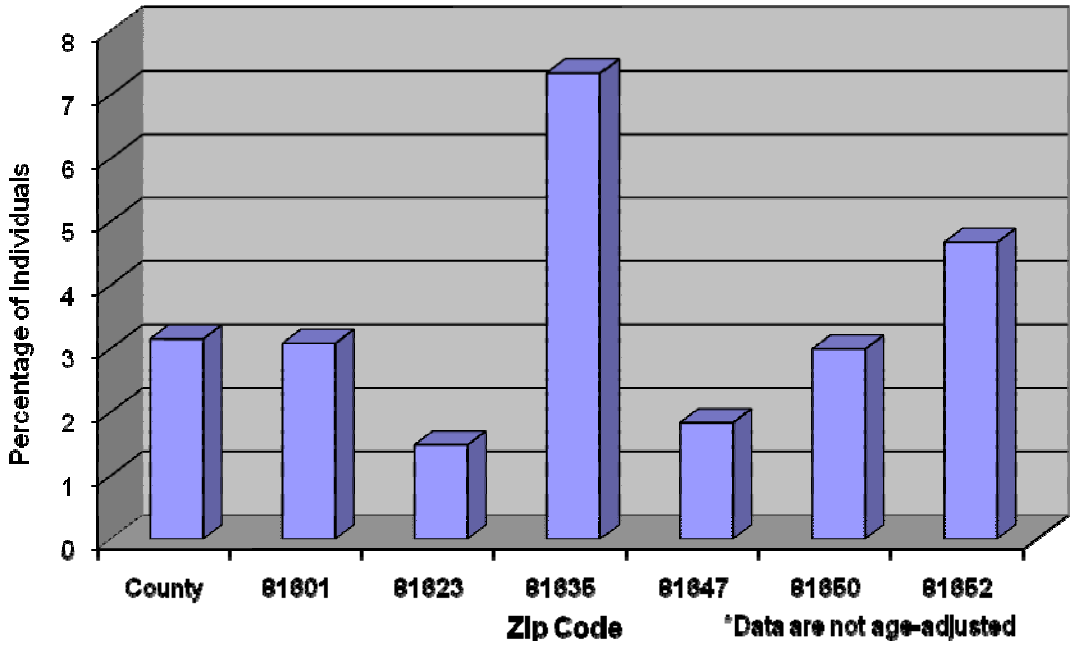


Figure 126. Percentage of Household Members with Other Lung Problems by Zip Code

- 3.8% of individuals report living with diabetes and its side effects such as kidney problems, loss of feeling or pain in hands and feet, and eye problems. There was no statistically significant difference among the zip code areas for frequency of diabetes. Complete data, including age breakdown for individuals with diabetes, may be found in Appendix U. Figure 127 provides survey data on the prevalence of diabetes by zip code.

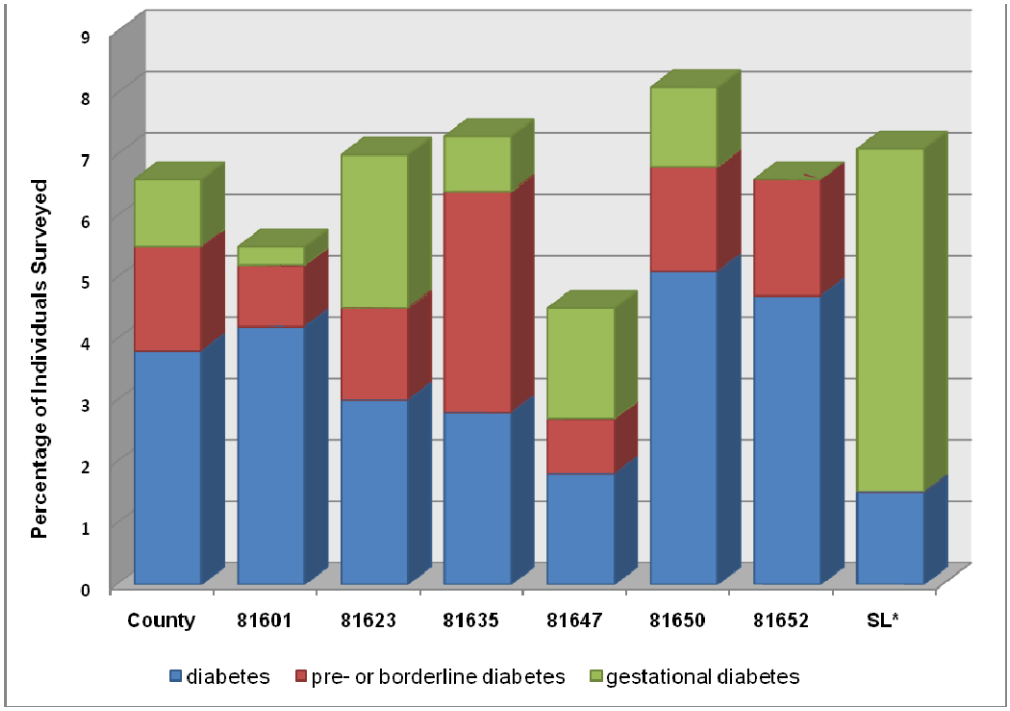


Figure 127. Percentage of Individuals with Diabetes by Zip Code

In order to address causes of physical symptoms, such as loss of peripheral nerve function, pain in hands and feet, eye problems, and/or kidney problems, that could be related to exposure to emissions from natural gas industry activities, we correlated the self-reported occurrence of these symptoms with self-reported diabetes among household survey respondents. All of these symptoms are possible complications of having diabetes (Figures 128 through 131).

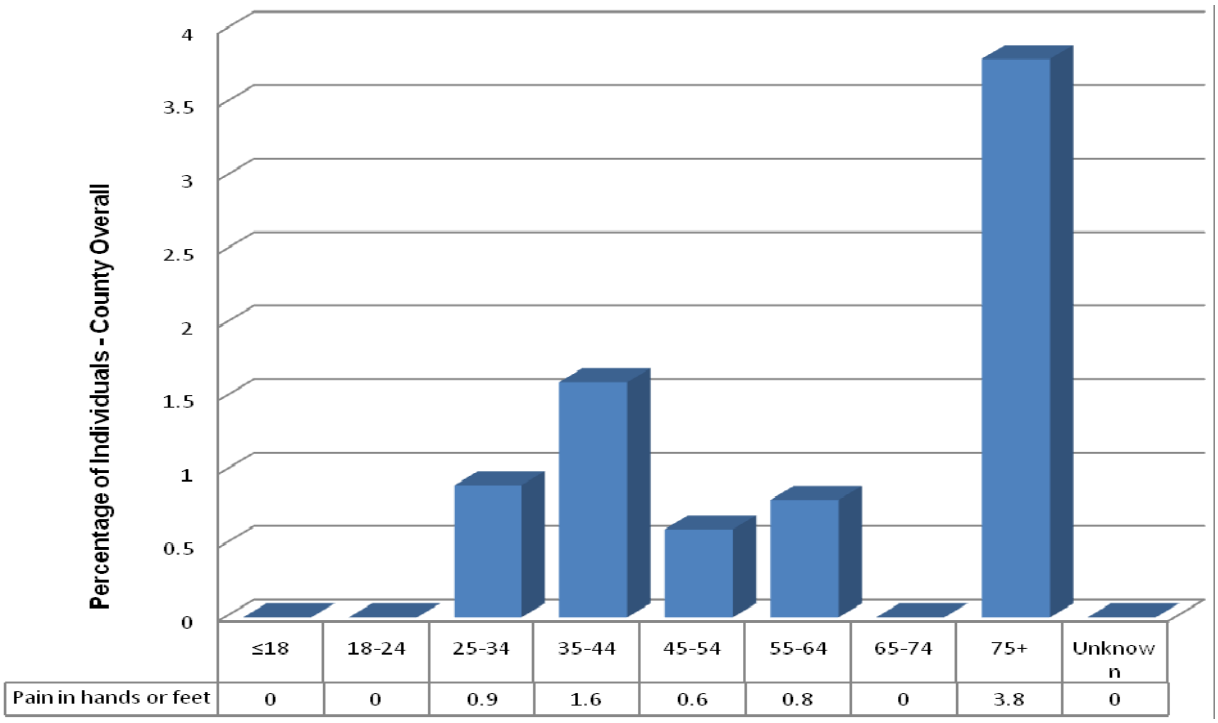
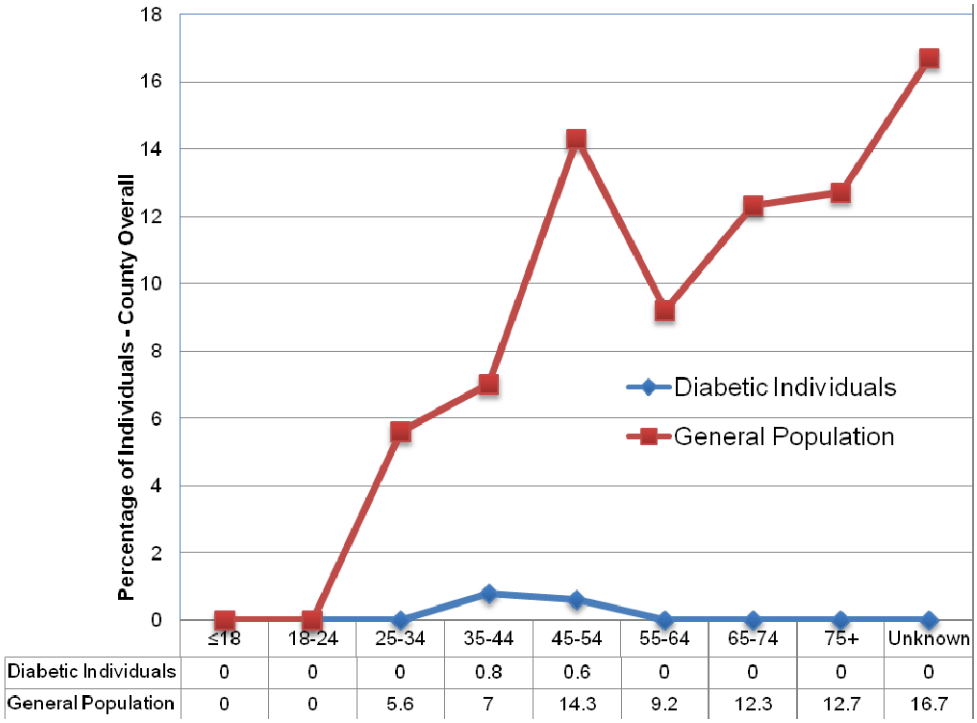
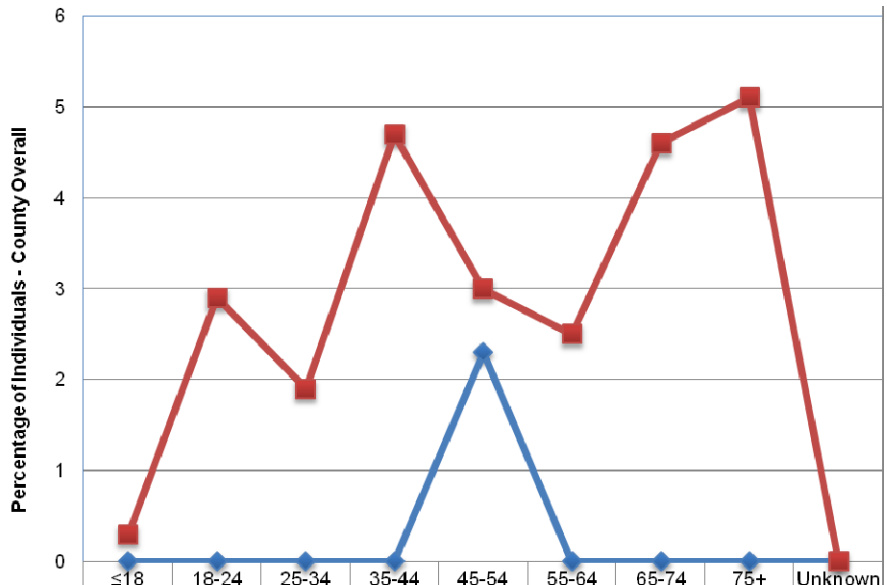


Figure 128. Diabetes Complications: Percentage of Individuals with Diabetes AND Pain in Hands or Feet

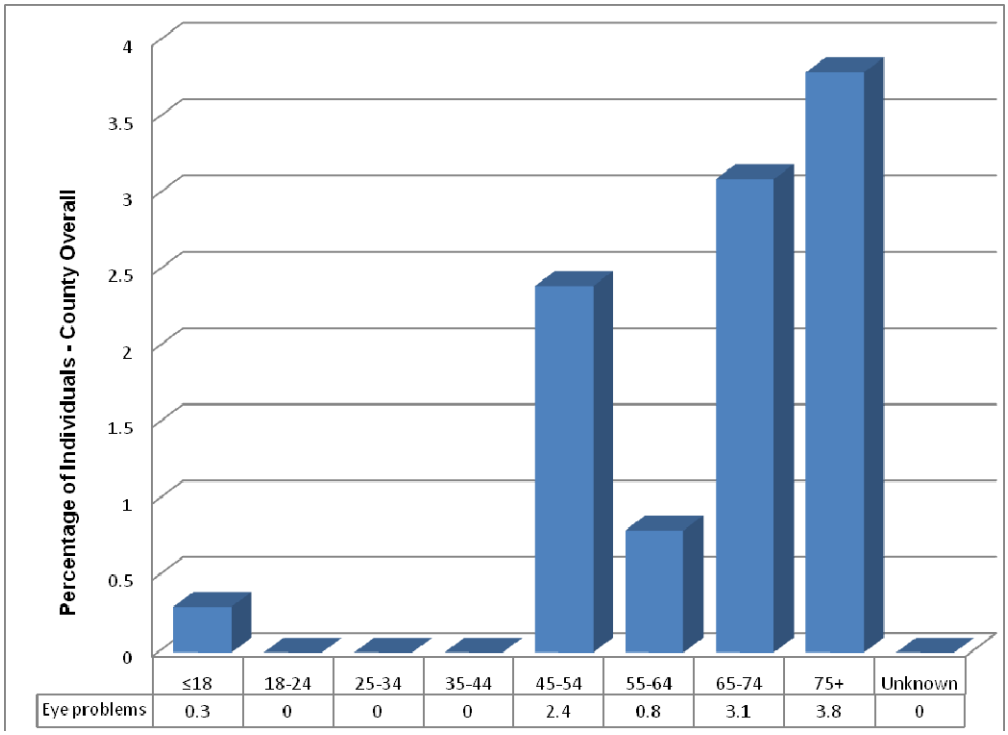
Figure 129. Diabetes Complications: Percentage of Individuals with Diabetes AND Loss of Feeling in Hands or Feet, County Overall (Comparison with "Loss of Feeling" in Non-Diabetic, Survey Population)





	≤18	18-24	25-34	35-44	45-54	55-64	65-74	75+	Unknown
Diabetic Individuals	0	0	0	0	2.3	0	0	0	0
General population	0.3	2.9	1.9	4.7	3	2.5	4.6	5.1	0

Figure 130. Diabetes Complications: Percentage of Individuals with Diabetes AND Kidney Problems/Protein in Urine, County Overall (Comparison with "Kidney Problems" in Non-Diabetic, Survey Population)



	≤18	18-24	25-34	35-44	45-54	55-64	65-74	75+	Unknown
Eye problems	0.3	0	0	0	2.4	0.8	3.1	3.8	0

Figure 131. Diabetes Complications: Percentage of Individuals with Diabetes AND Eye Problems

- 24% of individuals have coronary disease, a category that includes heart attack or heart surgery, high blood pressure, stroke and angina. There were no statistically significant differences among the zip code areas for frequency of coronary disease. (Figures 132 and 133. Complete data are available in Appendix U.)

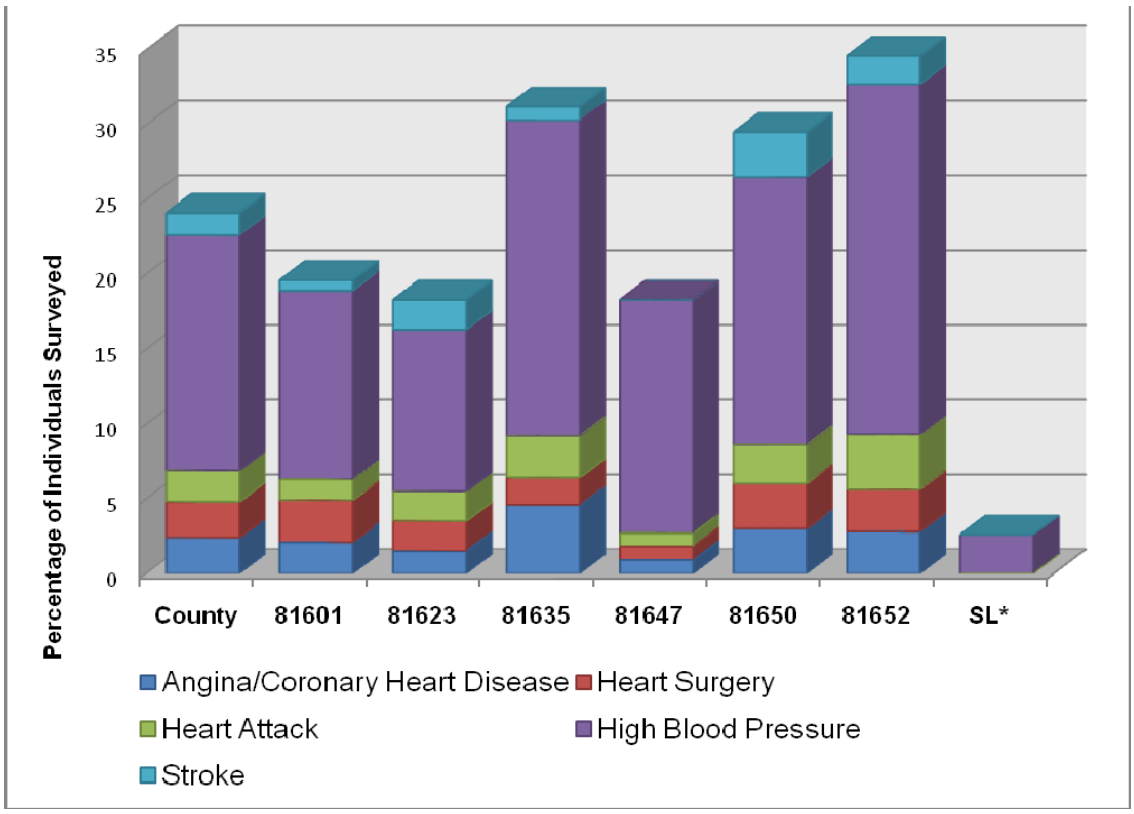
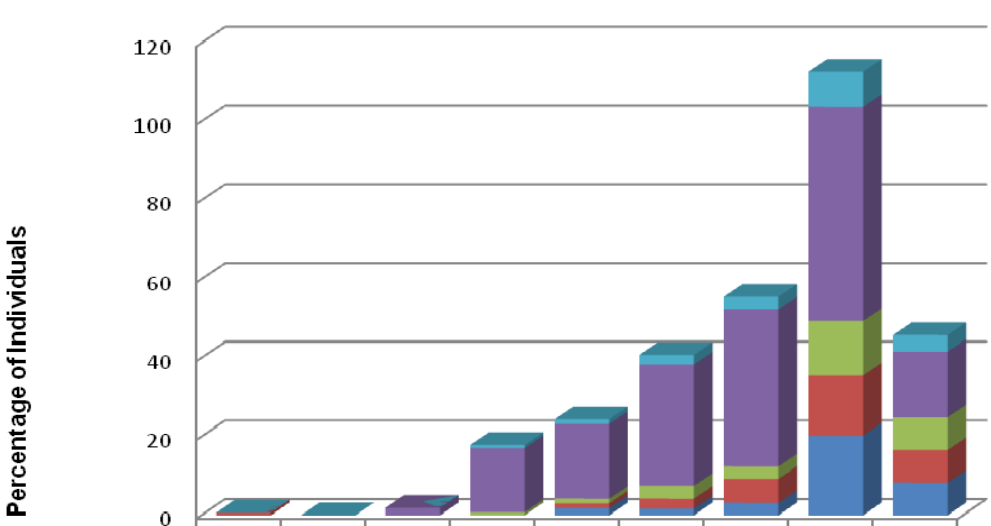


Figure 132. Percentage of Individuals with Coronary Disease by Zip Code

Figure 133. Percentage of Individuals with Coronary Disease by Age Group: County Overall



	≤18	18-24	25-34	35-44	45-54	55-64	65-74	75+	Unknown
Stroke	0	0	0	0.8	1.2	2.5	3.1	8.9	4.2
High Blood Pressure	0	0	1.9	16.3	19	30.8	40	54.4	16.7
Heart Attack	0	0	0	0.8	1.2	3.3	3.1	13.9	8.3
Heart Surgery	0.7	0	0	0	1.2	2.5	6.2	15.2	8.3
Angina/Coronary Heart Disease	0	0	0	0	1.8	1.7	3.1	20.3	8.3

- One series of questions in the household survey dealt with reproductive issues. Figure 134 provides data on the relative number of pregnancies per adult female household members by zip code (women living in Garfield County ≥ 1 year, and ≥18 and ≤54 years of age).

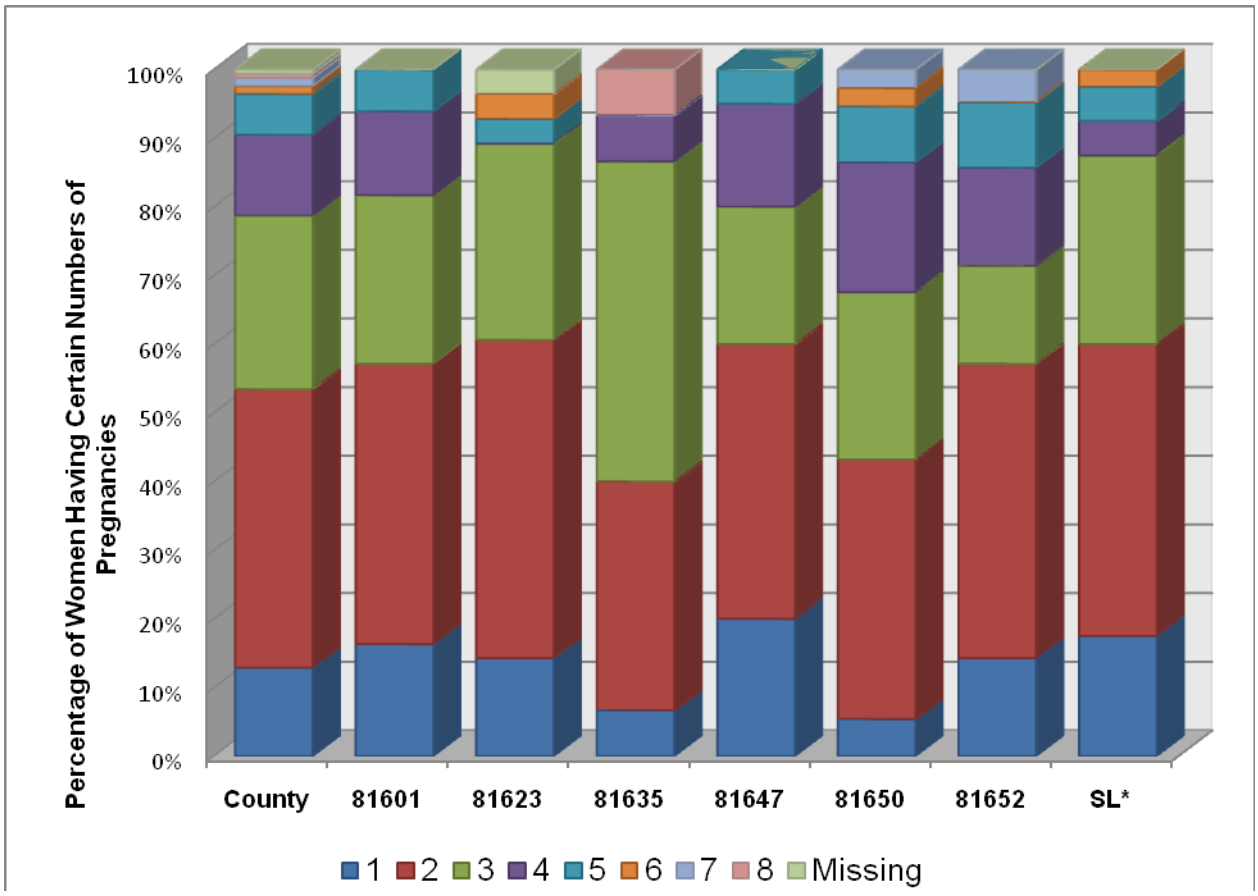
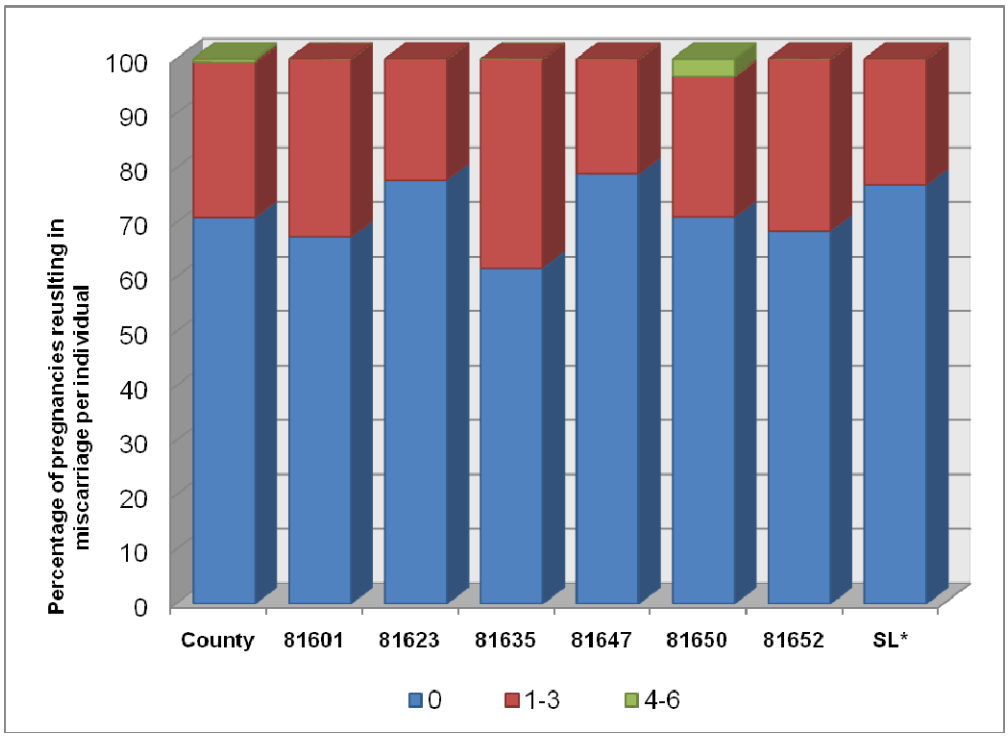


Figure 134. Number of Pregnancies Per Woman for Women Who Became Pregnant

Figure 135. Percentage of Pregnancies that Resulted in Miscarriages by Zip Code



6% or less of children born in any zip code area of Garfield County had birth defects (as defined by the survey respondent). 10% or less of children born in any zip code area of Garfield County were reported to have developed health or developmental problems within 5 years of their birth. (Figures 136 and 137; complete data are available in Appendix U.)

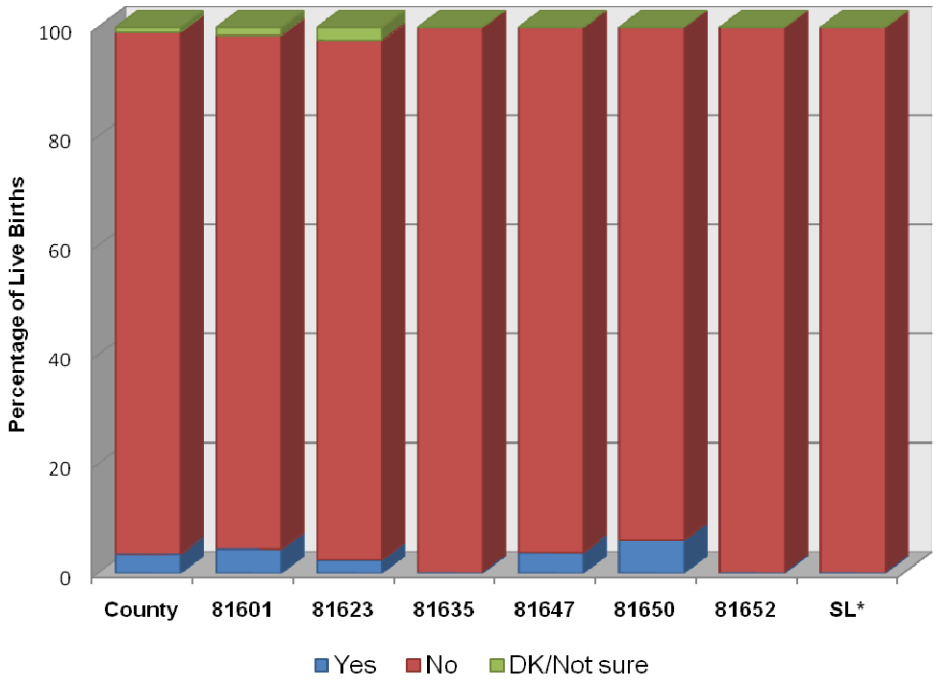
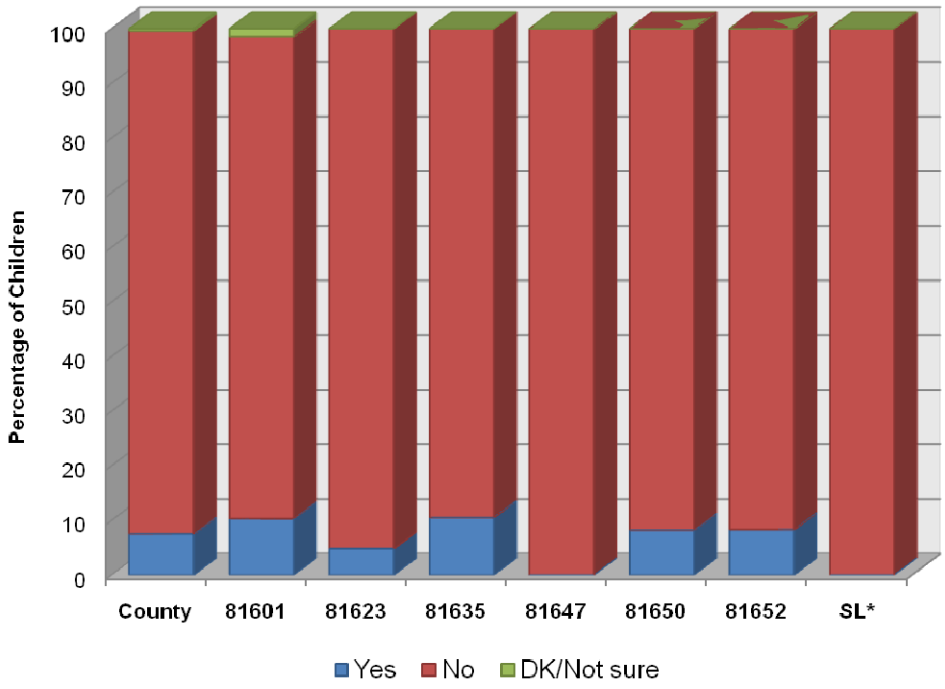


Figure 136. Percentage of Children Born With Birth Defects (Self-Defined) by Zip Code

Figure 137. Percentage of Children Developing Health or Developmental Problems Within 5 Years of Birth by Zip Code



- 5% of individuals, county-wide, reported having some kind of cancer during their lifetime. These data are summarized in Figures 138 through 140. The complete data are available in Appendix U.
    - ~2X as many individuals residing in zip code area 81635 reported having cancer than was reported for the county overall. *It is important to note, however, that the average age of the respondents from this zip code area was considerably older than for the other zip code areas.*

    - 53.3% of the reported cancers were diagnosed in individuals who were 55 years or older; There were NO cancers reported in individuals under age 25.

    - The most frequently reported cancers were female breast cancer (20.7%), non-melanoma skin cancers (26.4%), prostate cancer (15.1%), cervical cancer (9.4%), and colon cancer (7.5%). Malignant melanoma and lymphoma each accounted for 3.8% of the reported cancers. Uterine, thyroid, liver, kidney, and bladder cancers, along with leukemia, glandular carcinoma, made up the remainder of the cancers reported (1.9% each).

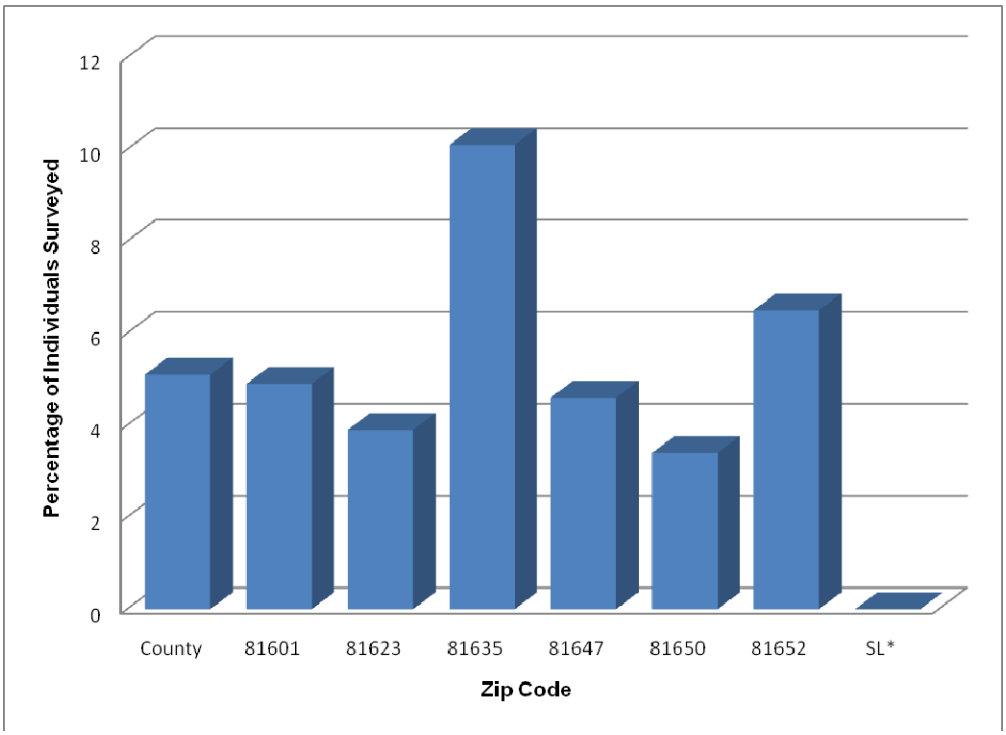
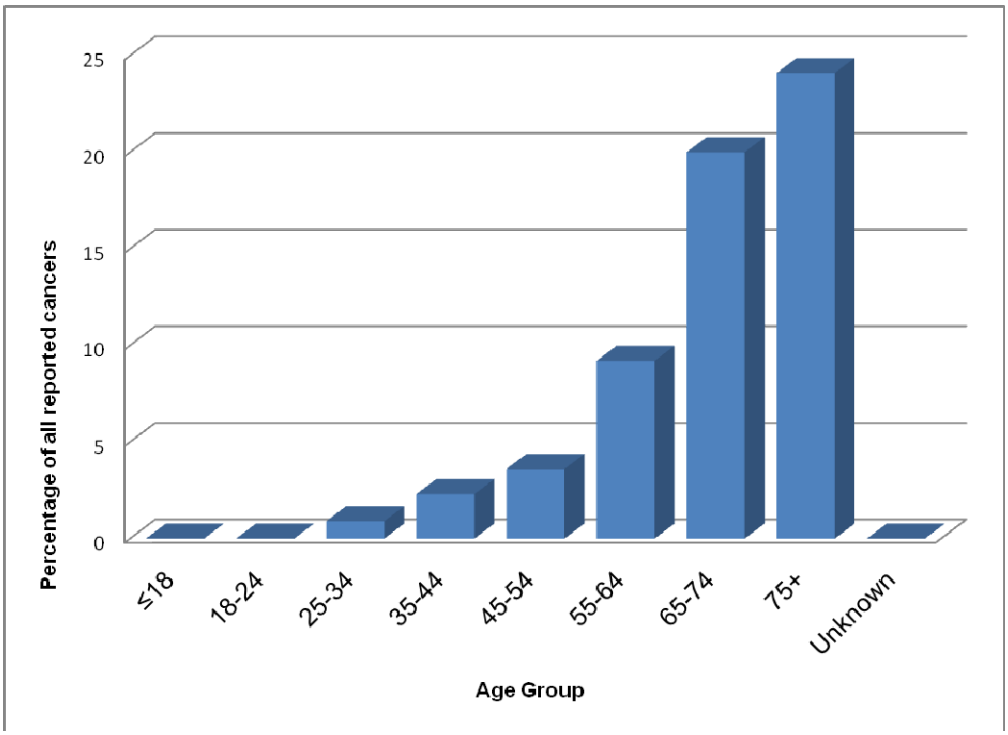


Figure 138. Percentage of Individuals Reporting Cancer by Zip Code

Figure 139. Percentage of reported Cancers by Age: County Overall



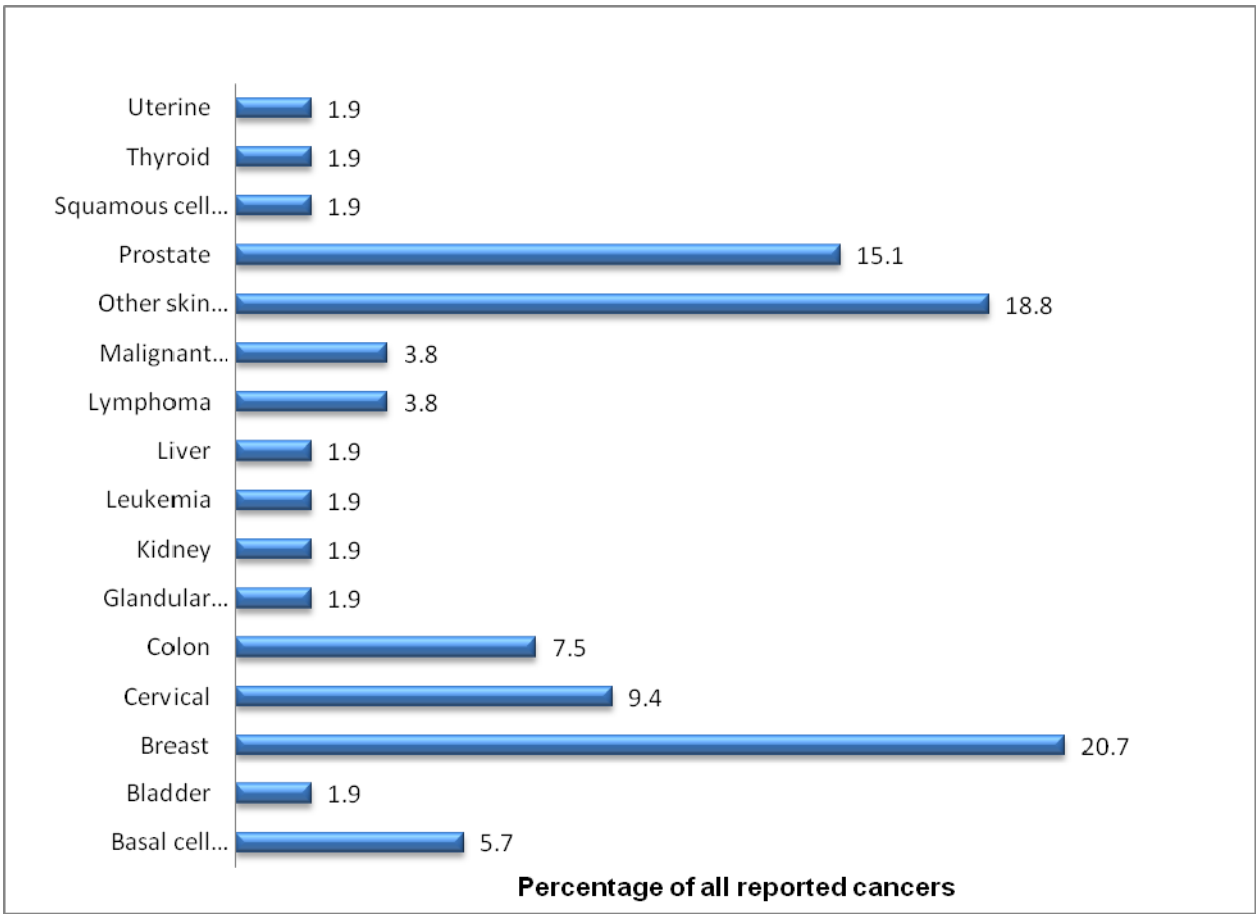


Figure 140. Reported Cancer Types: County Overall

Occupation and Disease

- Responses to questions about occupational history (current and longest job titles and industry affiliations) allowed correlations with diseases and symptoms reported by survey respondents. Figures 140 through 149 provide a graphical description of the long-term occupations and current job categories for household survey respondents and household members. There was broad representation of types of jobs, both in the "white-collar" and "blue-collar" occupations, giving us confidence that no one occupational or job demographic was over- or under-represented in this survey. Some individuals did refuse to report either their job or the industry for which they work. Jobs and industries were categorized using standard National Institute for Occupational Health and Safety (NIOSH) categories.

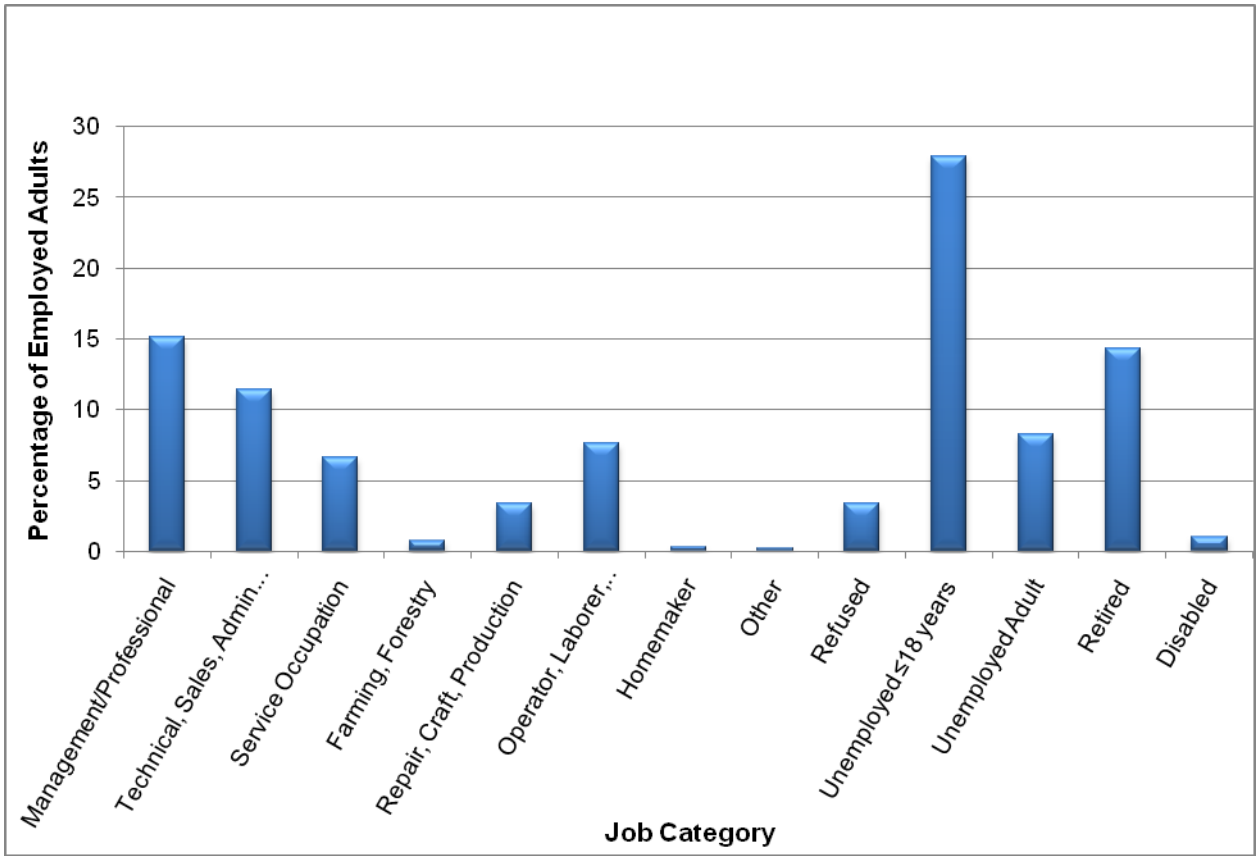


Figure 141. Current Occupation: County Overall

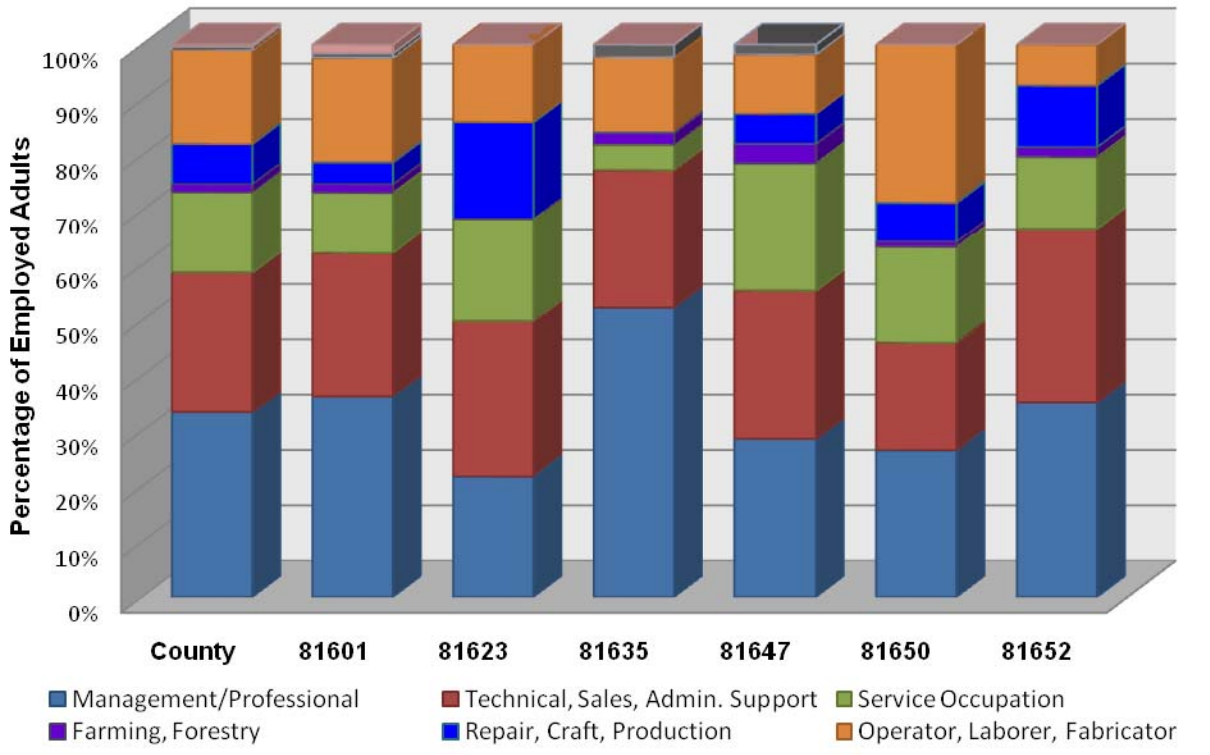


Figure 142. Current Occupation by Zip Code

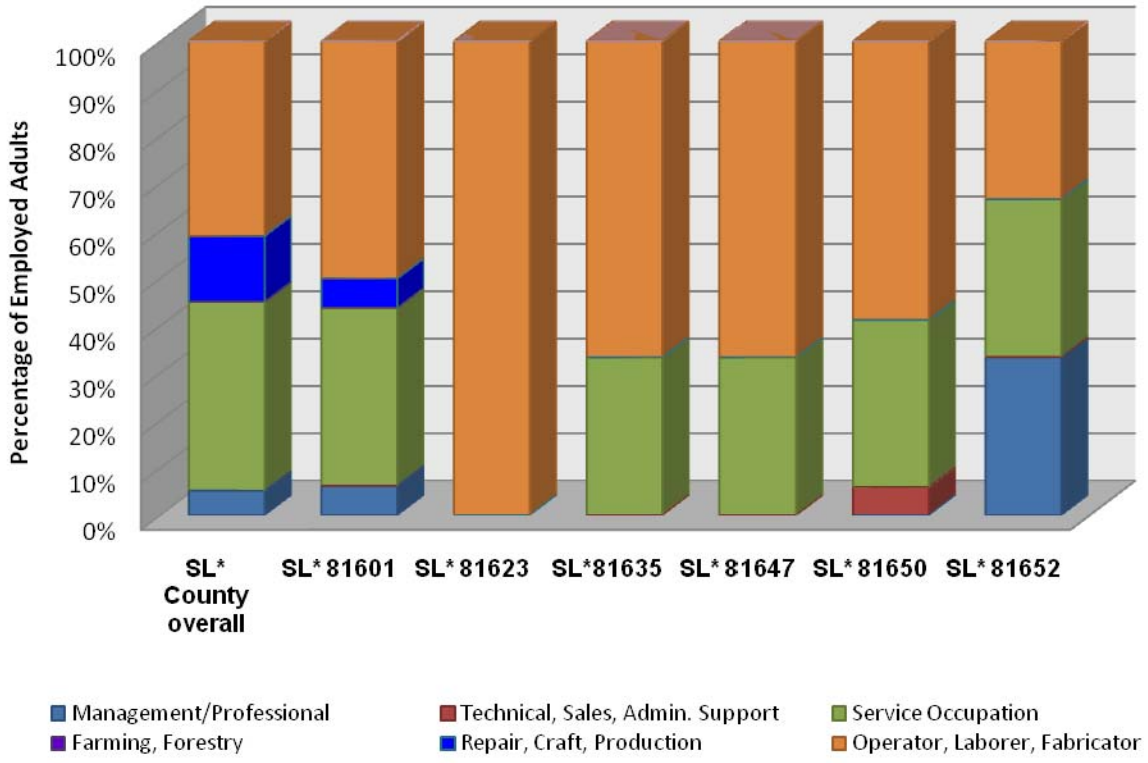


Figure 143. Current Occupation by Zip Code: Primarily Spanish-Speaking Households

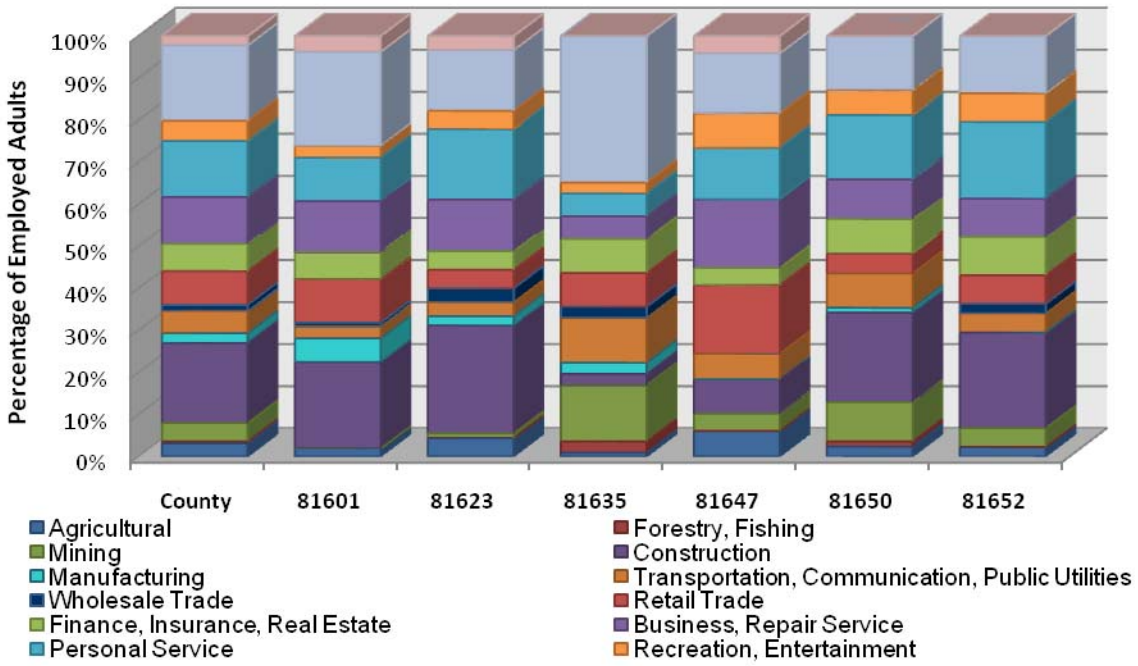


Figure 144. Current Industry Employment by Zip Code

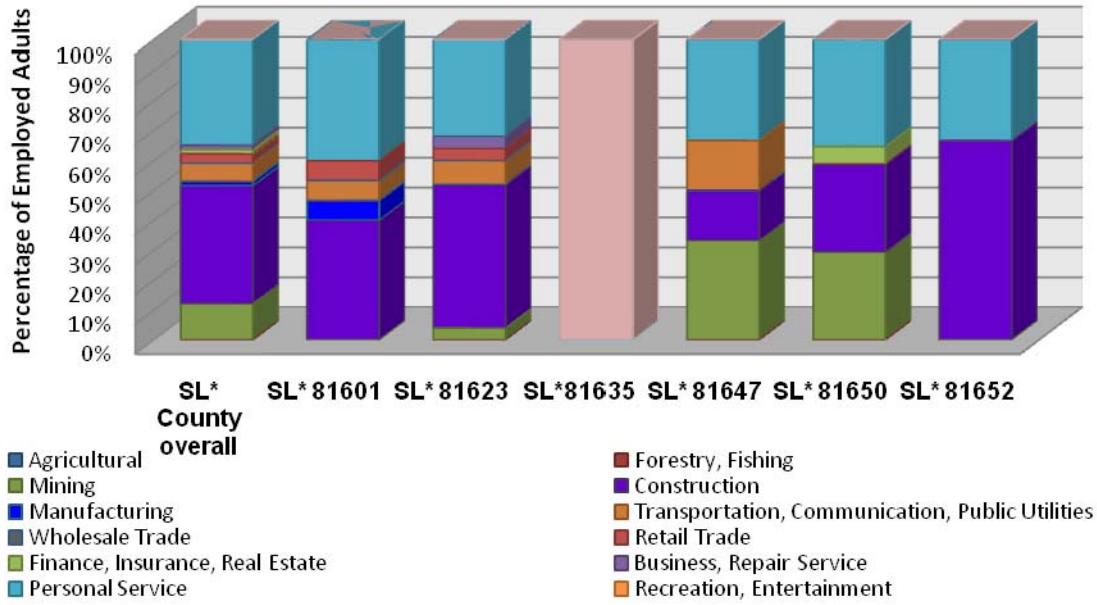


Figure 145. Current Industry Employment by Zip Code: Primarily Spanish-Speaking Households

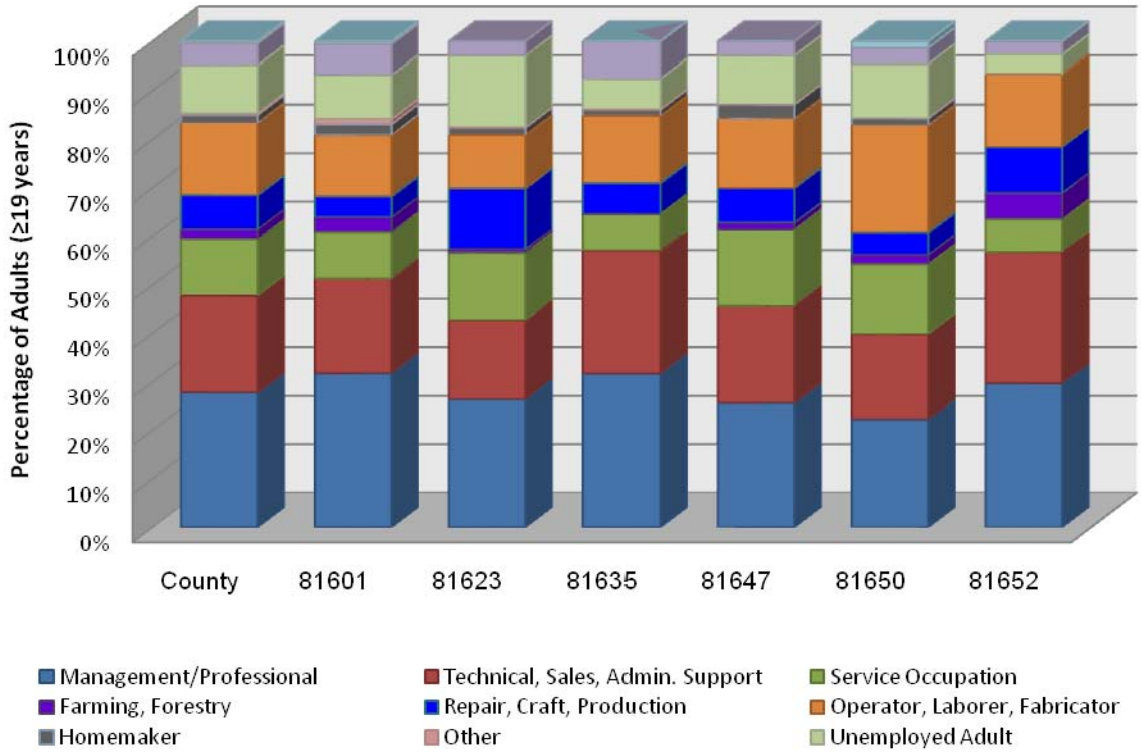


Figure 146. Longest Occupation by Zip Code

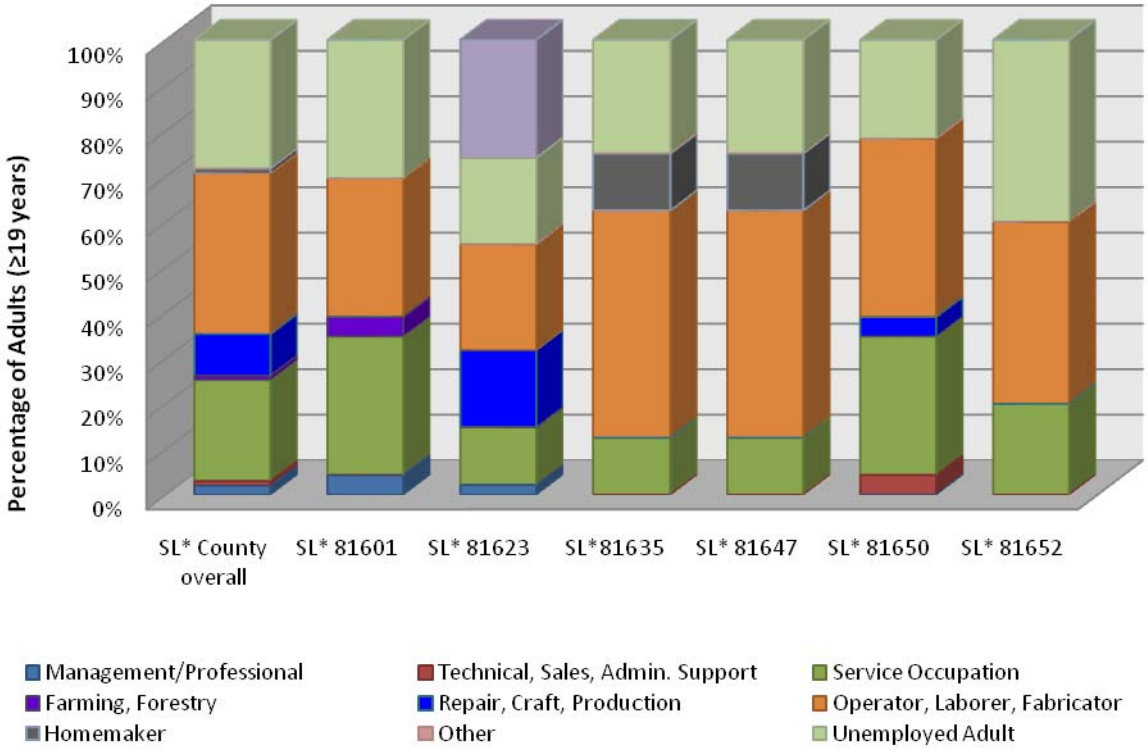


Figure 147. Longest Occupation by Zip Code: Primarily Spanish-Speaking Households

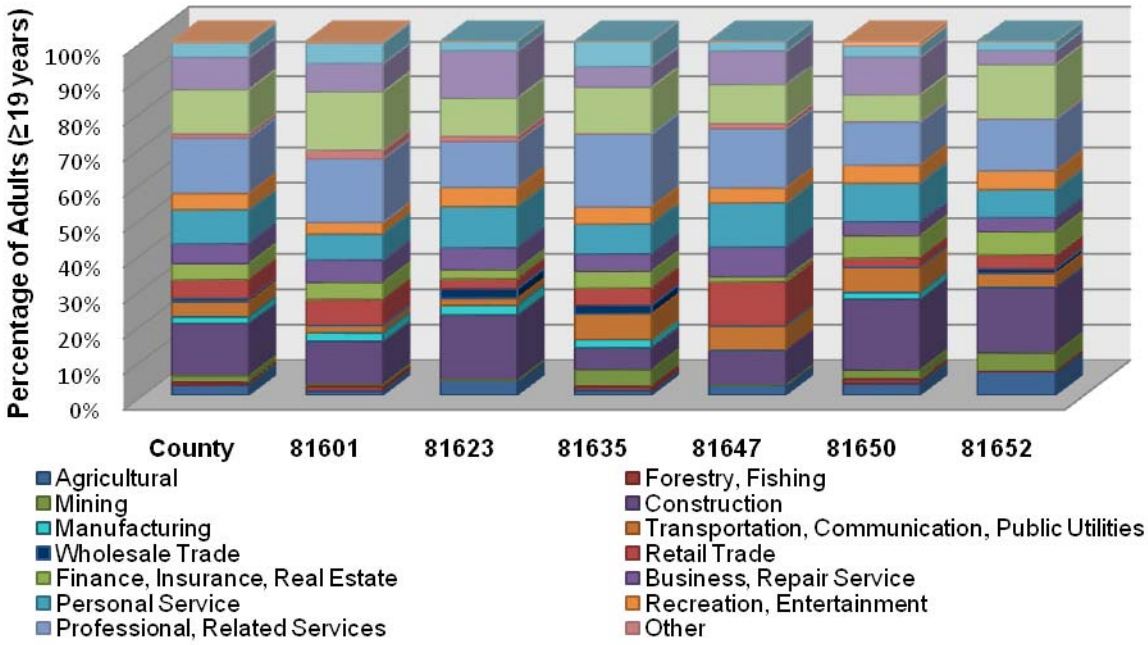


Figure 148. Longest Industry Employment by Zip Code

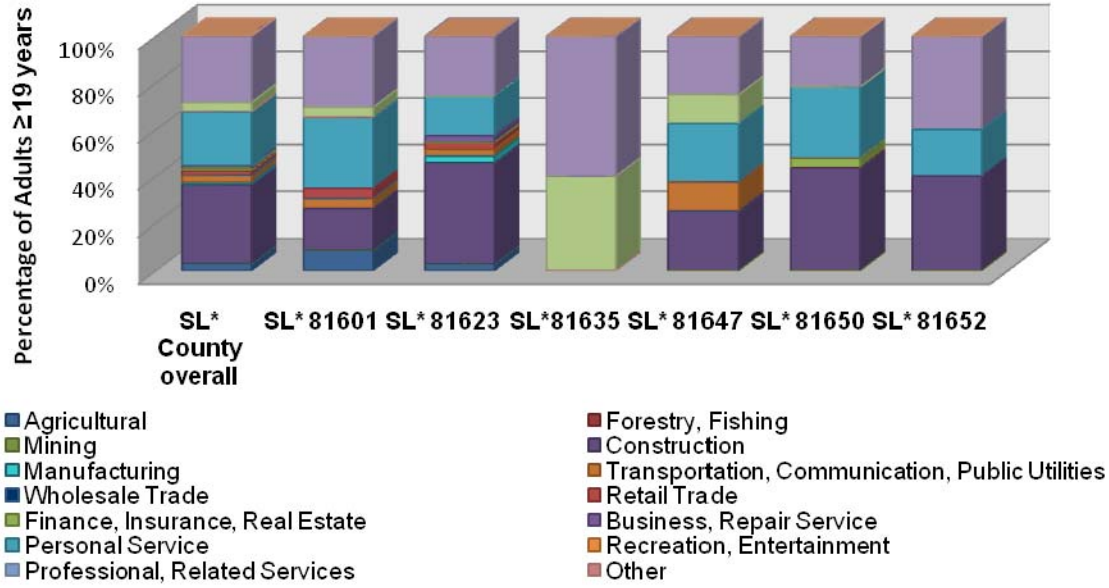


Figure 149. Longest Industry Employment by Zip Code: Primarily Spanish-Speaking Households

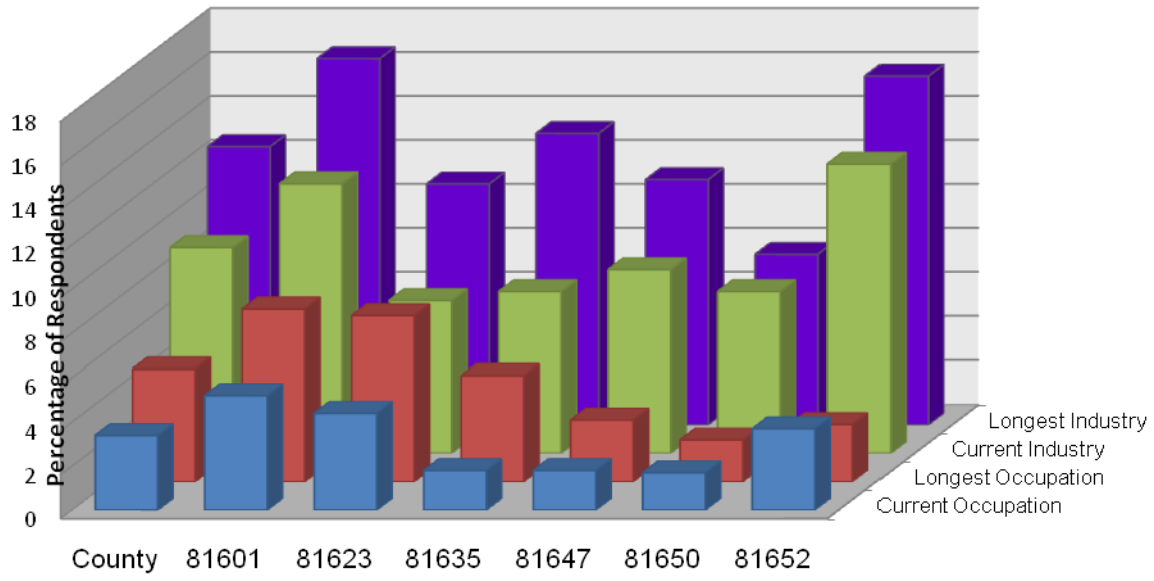


Figure 150. Percentage of Individuals Who "Didn't Know" or Refused to Answer Occupation or Industry Employment Questions by Zip Code

- It is important to note that this study was not designed as an occupational health study, and thus, no conclusions may be drawn regarding occupational exposures and disease outcomes. The numbers of individuals within any occupational category that report having a particular disease or condition are too low for statistical significance. However, the following observations may be made:
  - Individuals who reported that their current and/or longest occupation was in the professional and related services industries (e.g., healthcare providers, attorneys, etc.), personal services occupations (e.g., housekeepers, hair stylists, etc.), construction industries or transportation (including truck drivers), communications and public utilities industries were most likely to have reported having respiratory conditions; neurological symptoms such as dizziness, numbness, weakness; skin problems; and frequent headaches/migraines.

  - Those individuals who refused to answer questions about their occupation and/or industry affiliation were most likely to have reported having frequent headaches/migraines; neurological symptoms such as dizziness, numbness, weakness; anemia; seizures; skin problems; and cancer (but no bladder, kidney, liver, lymphoma or thyroid cancers or leukemia).

  - Figures 151 through 168 provide a summary of these data. Please note that the Y axis scales differ among the graphs.

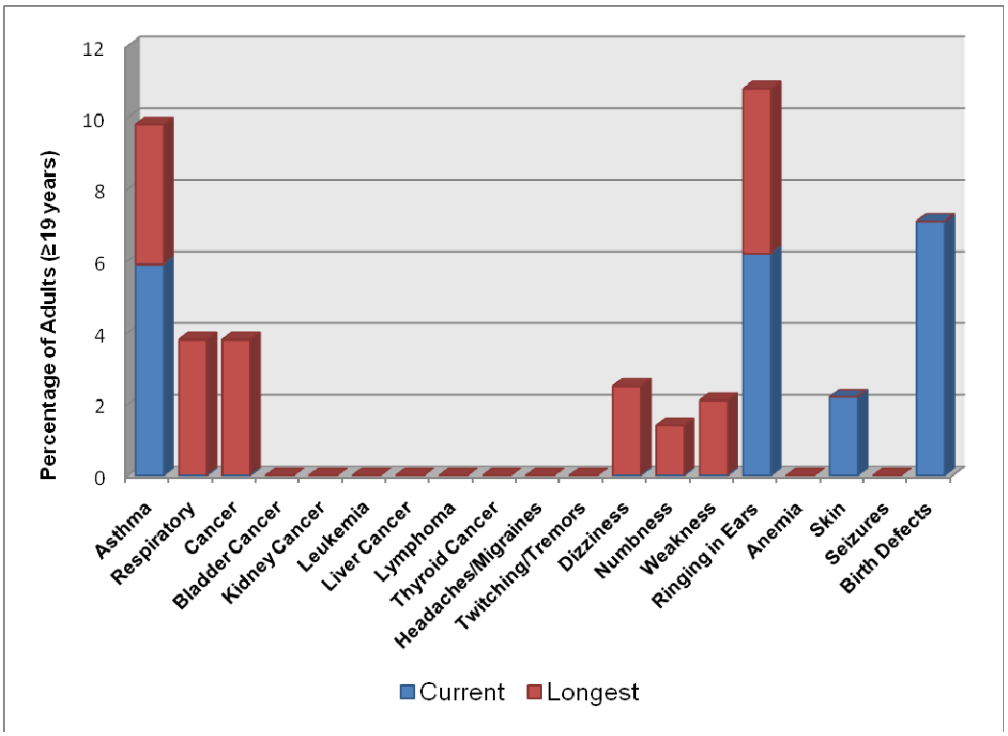
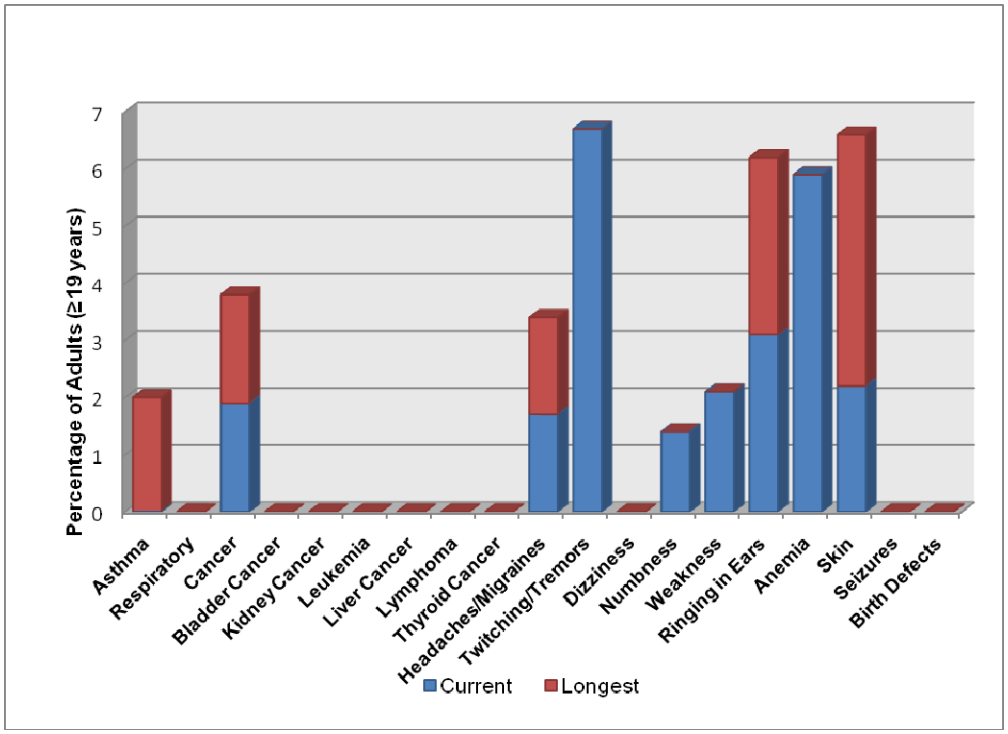


Figure 151. Percentage of Individuals Employed in the Agricultural Industry Reporting Selected Diseases and Symptoms: County Overall

Figure 152. Percentage of Individuals Employed in the Mining Industry Reporting Selected Diseases and Symptoms: County Overall



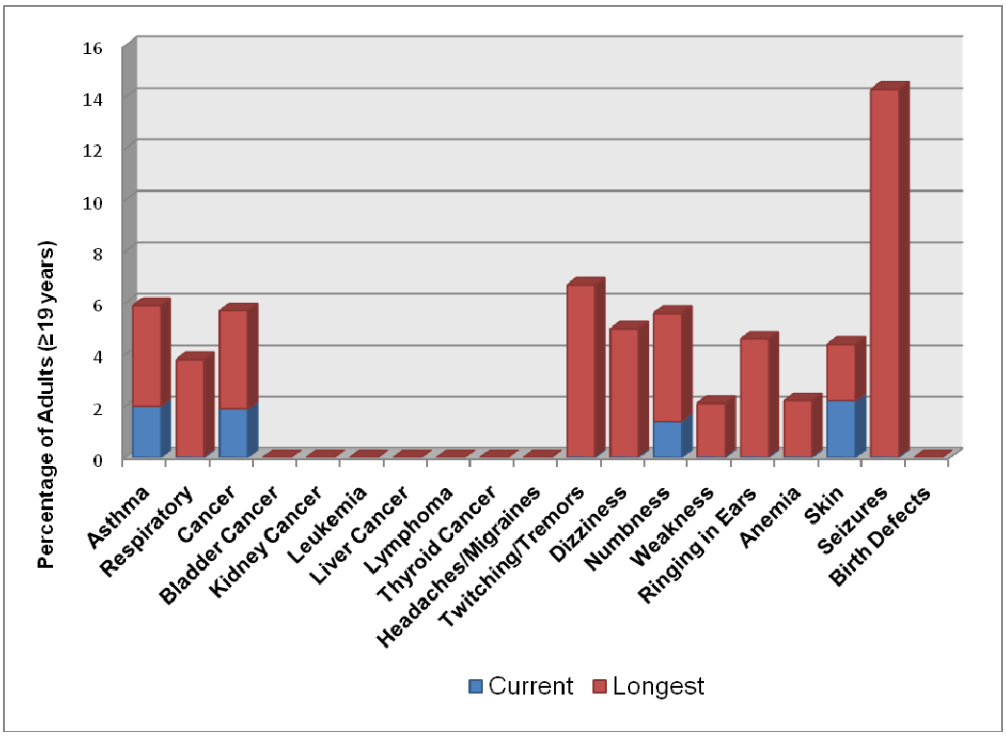
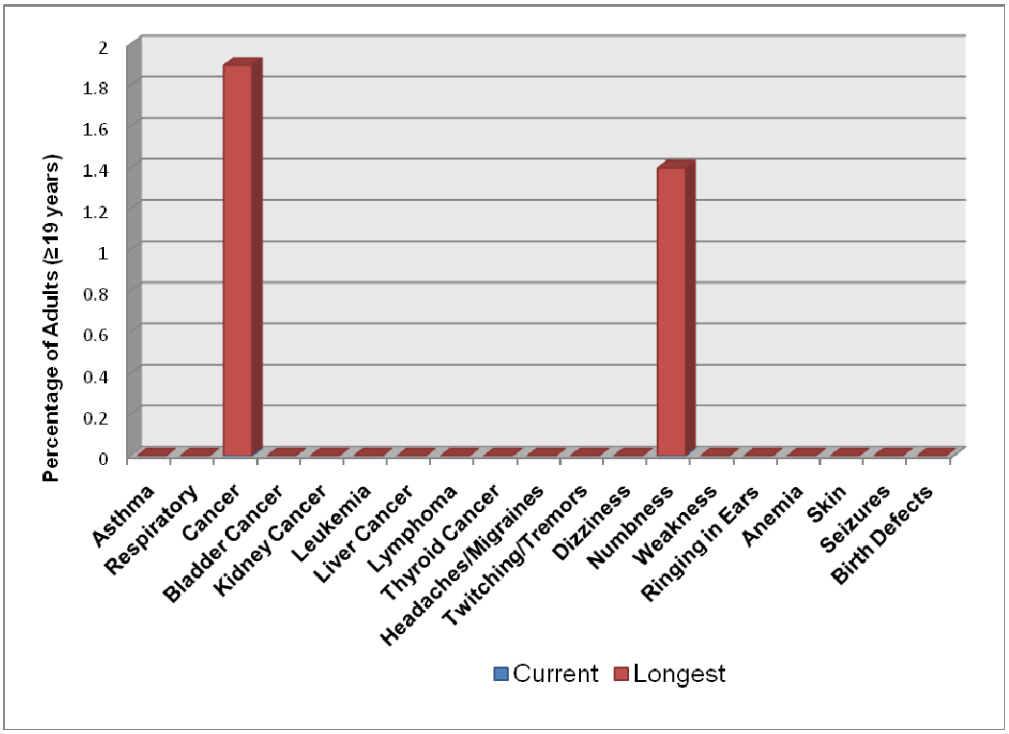


Figure 153. Percentage of Individuals Employed in the Manufacturing Industry Reporting Selected Diseases and Symptoms: County Overall

Figure 154. Percentage of Individuals Employed in the Wholesale Trade Industry Reporting Selected Diseases and Symptoms: County Overall



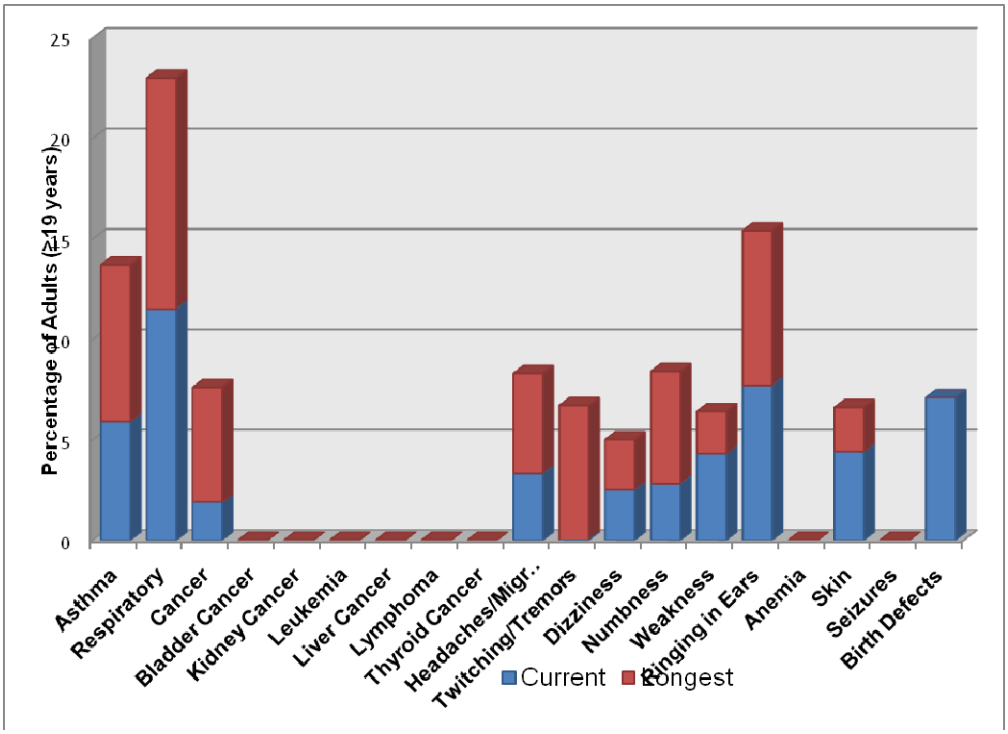
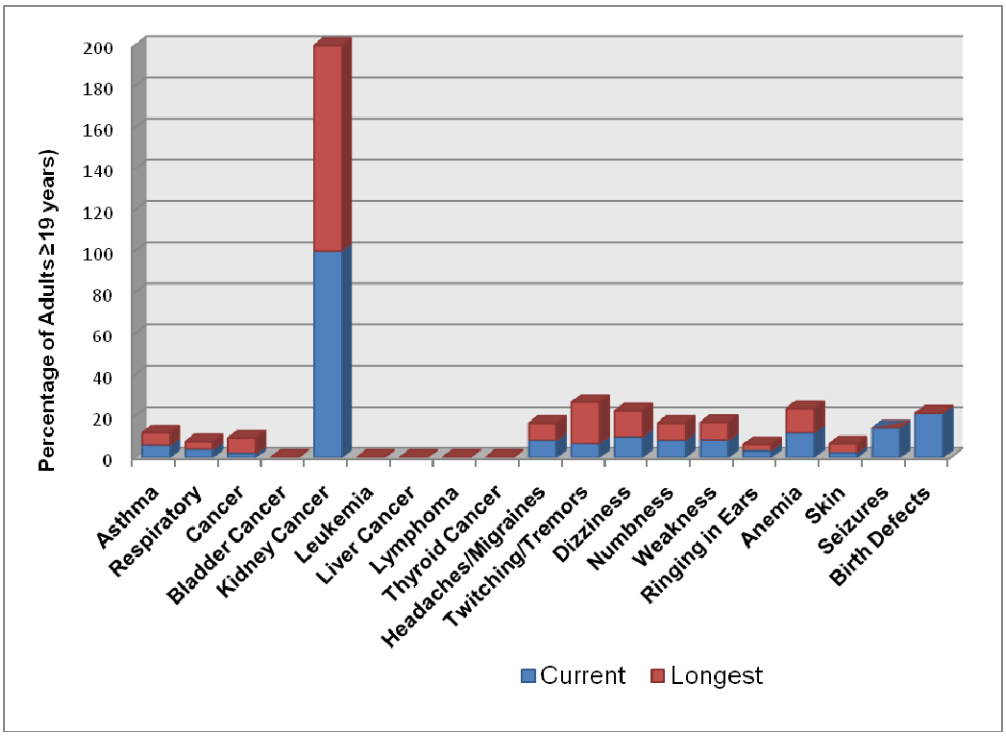


Figure 155. Percentage of Individuals Employed in the Finance, Insurance or Real Estate Industry Reporting Selected Diseases and Symptoms: County Overall

Figure 156. Percentage of Individuals Employed in the Personal Services Industry Reporting Selected Diseases and Symptoms: County Overall



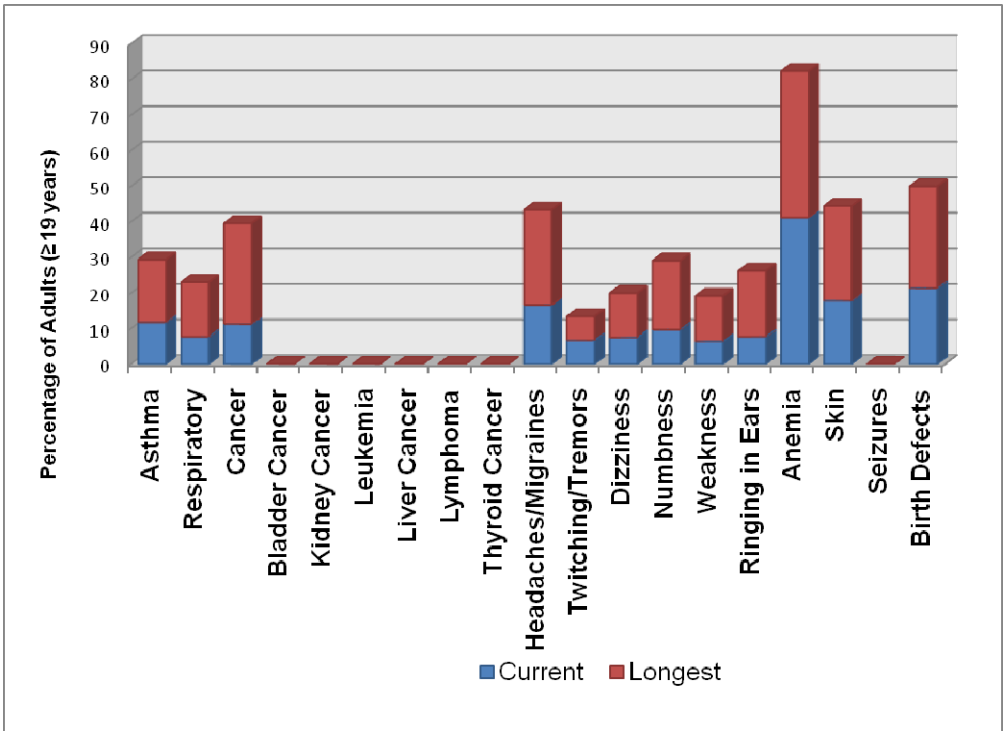
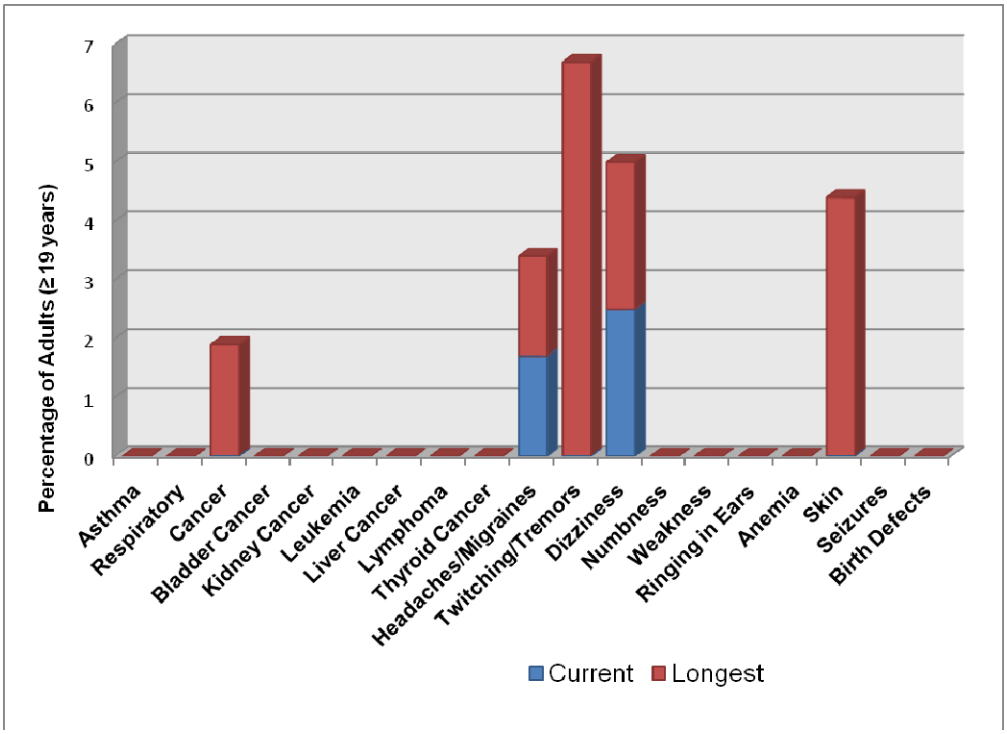


Figure 157. Percentage of Individuals Employed in the Professional and Related Services Industries Reporting Selected Diseases and Symptoms: County Overall

Figure 158. Percentage of Individuals Employed in the Forestry or Fisheries Industries Reporting Selected Diseases and Symptoms: County Overall



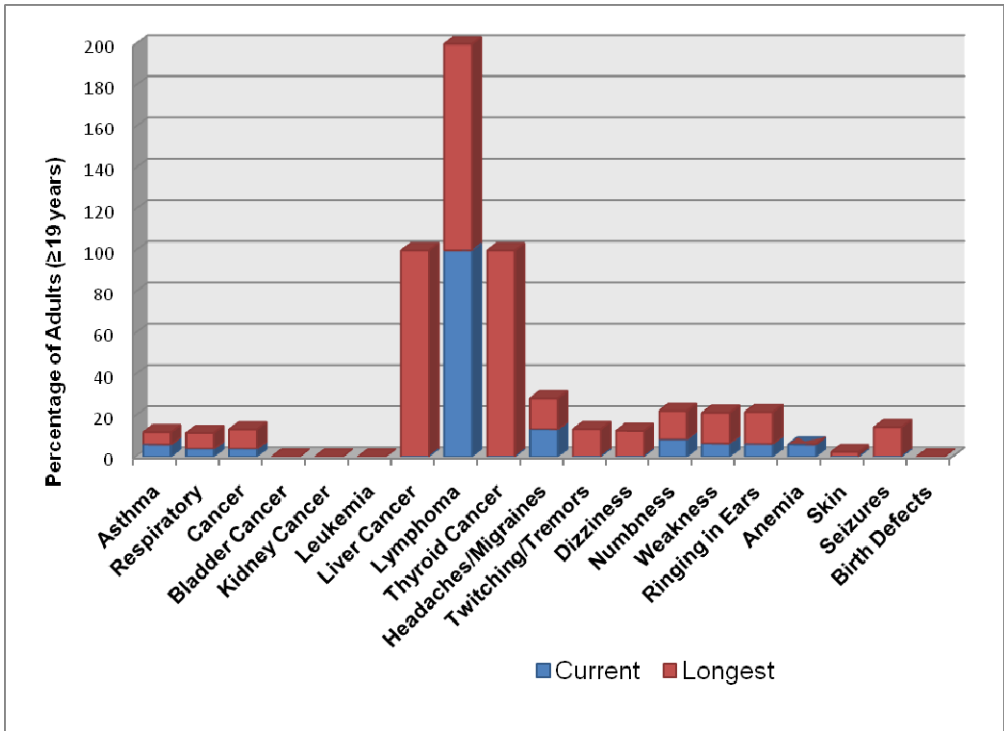
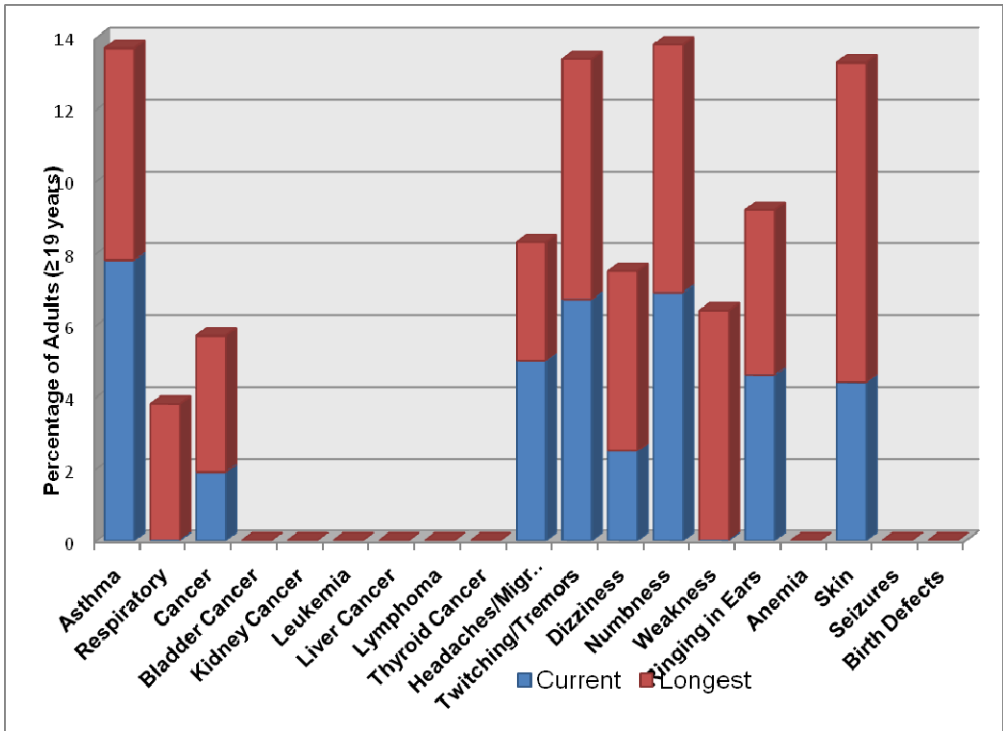


Figure 159. Percentage of Individuals Employed in the Construction Industry Reporting Selected Diseases and Symptoms: County Overall

Figure 160. Percentage of Individuals Employed in the Transportation, Communications or Public Utilities Industries Reporting Selected Diseases and Symptoms: County Overall



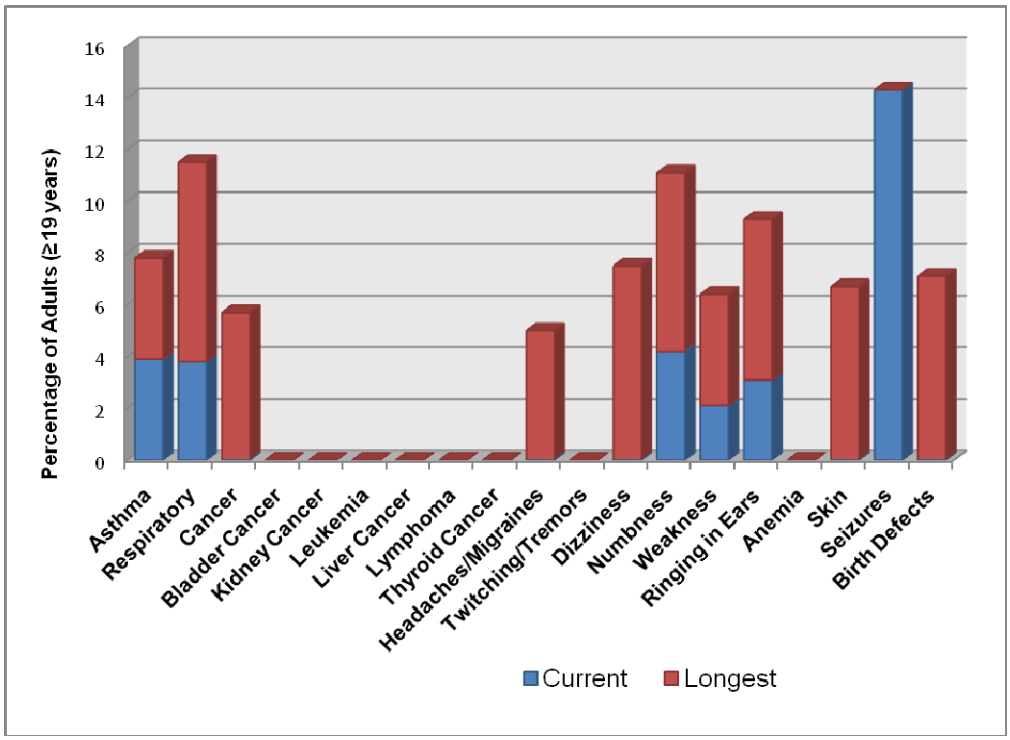
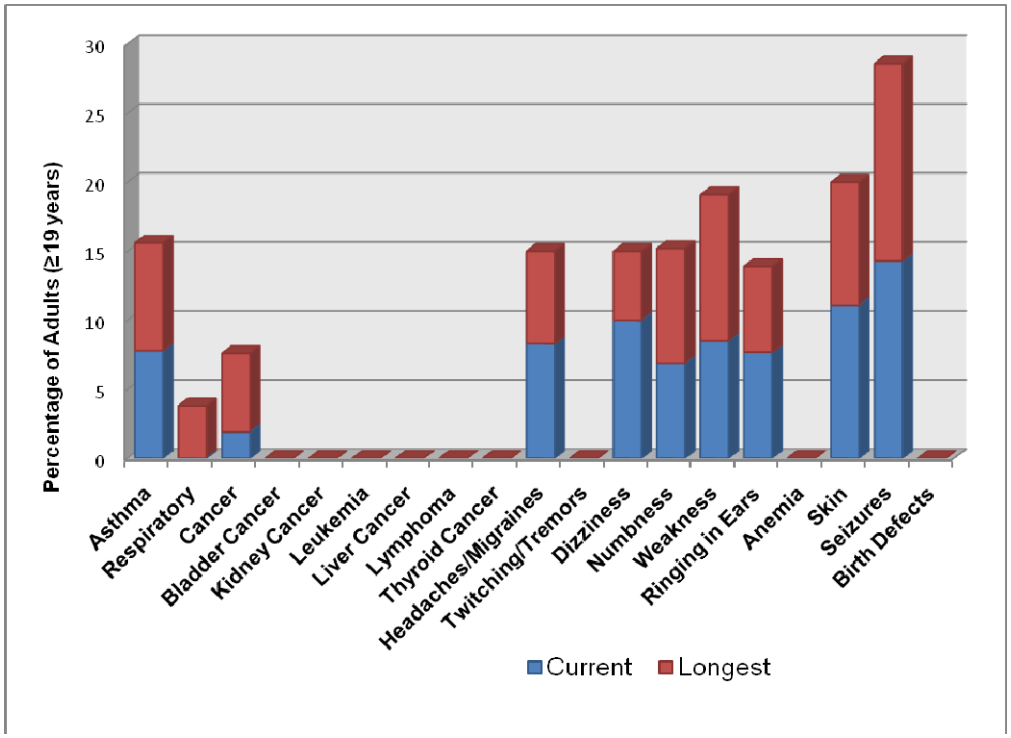


Figure 161. Percentage of Individuals Employed in the Retail Trade Industry Reporting Selected Diseases and Symptoms: County Overall

Figure 162. Percentage of Individuals Employed in the Business and Repair Services Industries Reporting Selected Diseases and Symptoms: County Overall



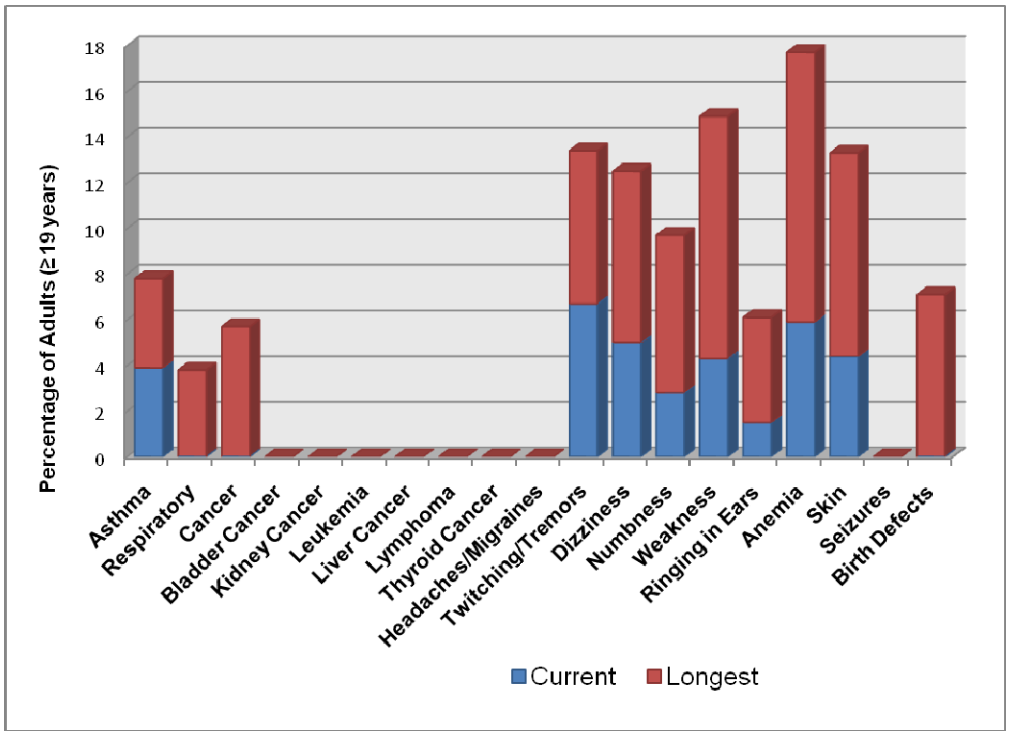
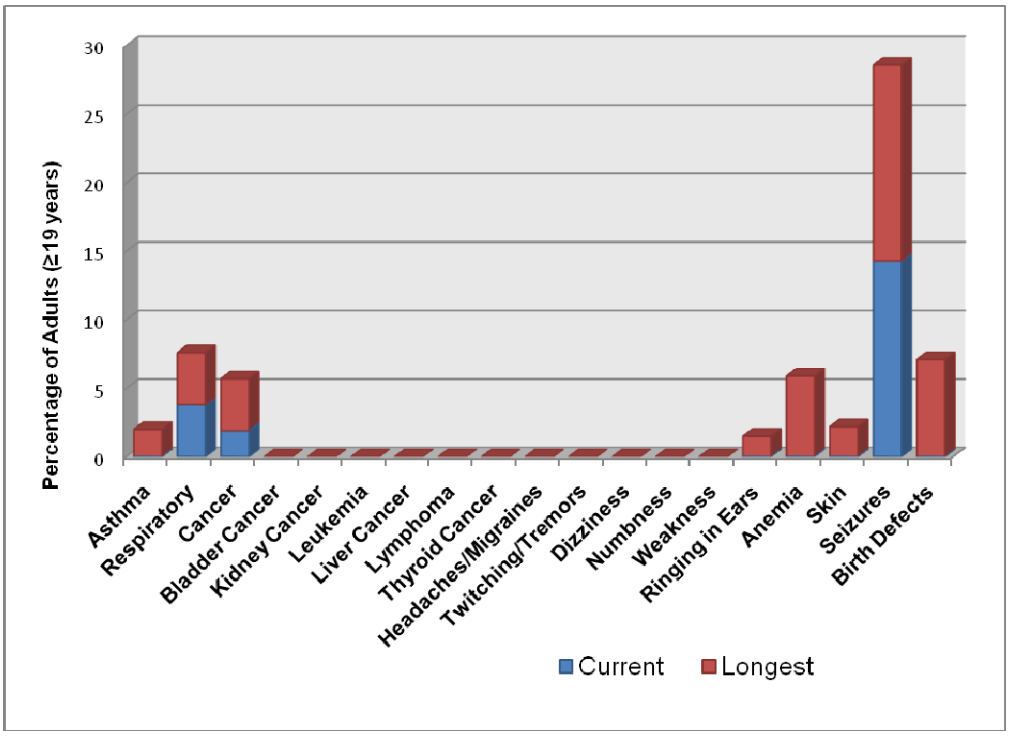


Figure 163. Percentage of Individuals Employed in the Recreation and Entertainment Industries Reporting Selected Diseases and Symptoms: County Overall

Figure 164. Percentage of Individuals Whose Industry Employment Could Not Be Classified Reporting Selected Diseases and Symptoms: County Overall



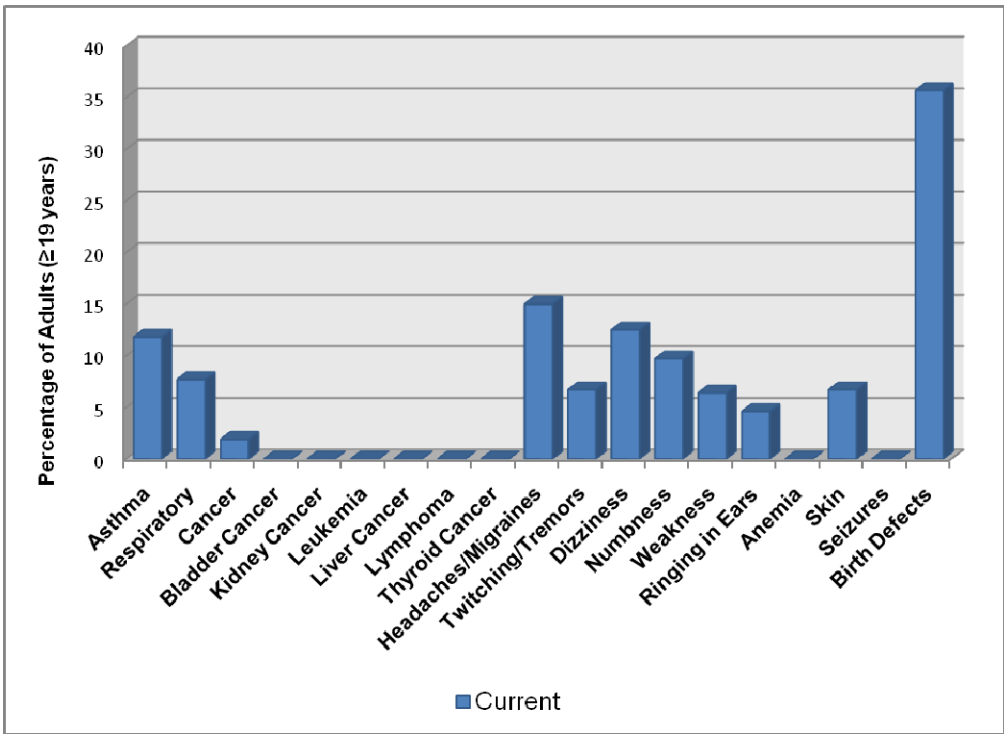
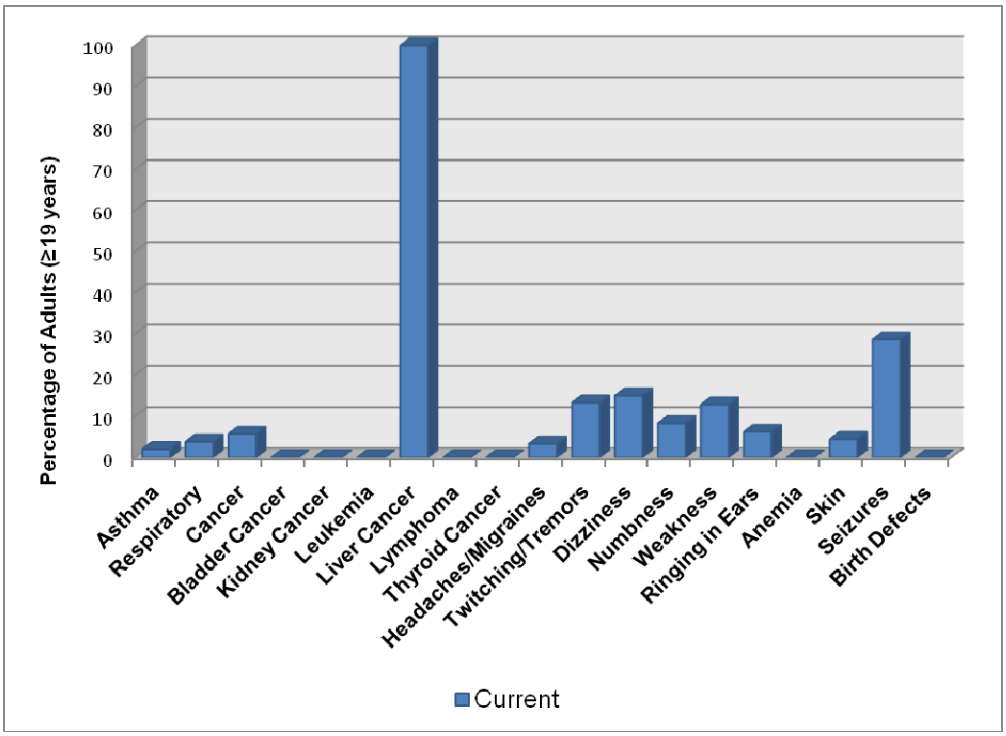


Figure 165. Percentage of Currently Unemployed Individuals Reporting Selected Diseases and Symptoms: County Overall

Figure 166. Percentage of Currently Disabled Individuals Reporting Selected Diseases and Symptoms: County Overall



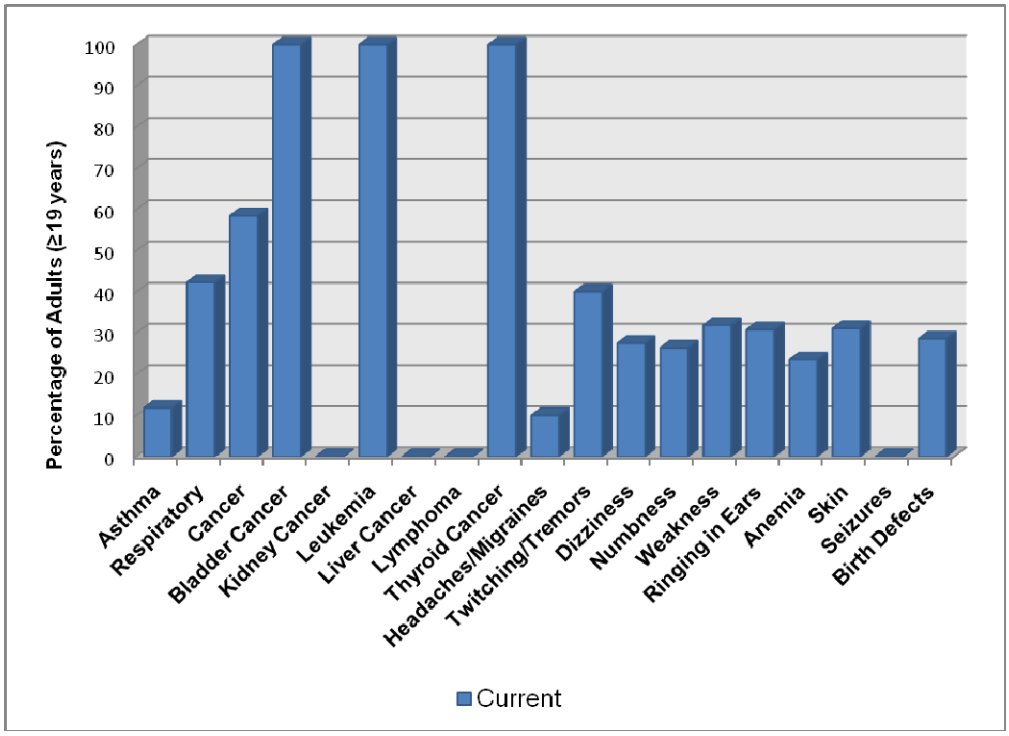
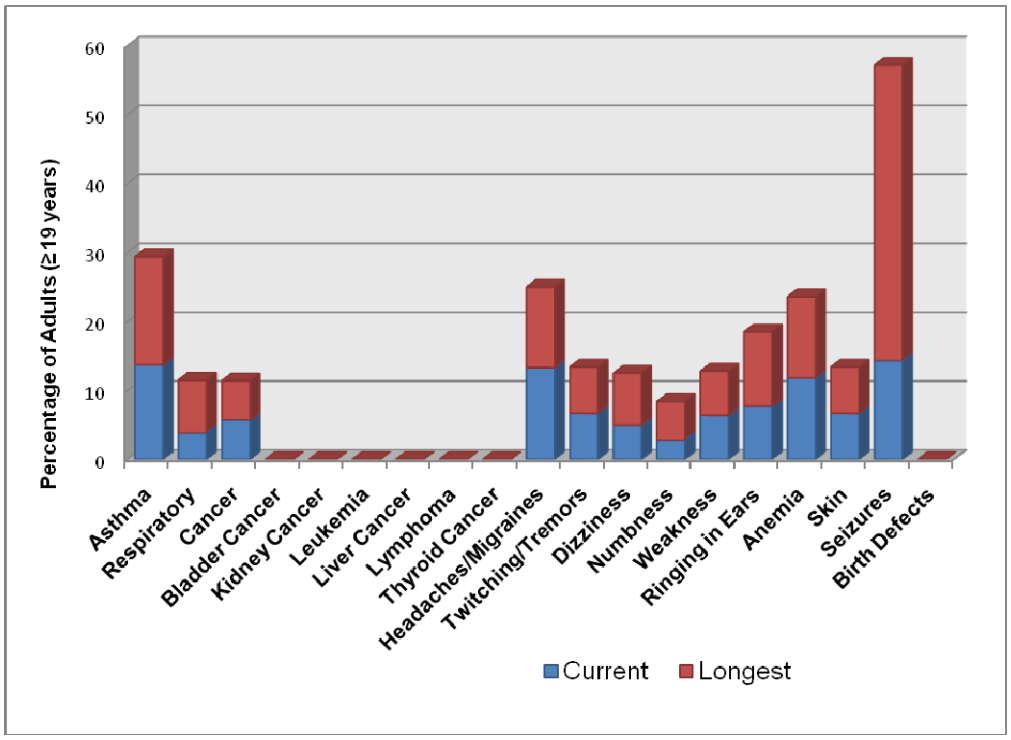


Figure 167. Percentage of Currently Retired Individuals Reporting Selected Diseases and Symptoms: County Overall

Figure 168. Percentage of Adults Who Didn't Know or Refused to Provide an Industry Affiliation Reporting Selected Diseases and Symptoms: County Overall



Relationships Between Health and Environmental Exposures: Household Member Concern

A series of questions regarding perceptions of risk related to home and outside environmental exposures and their relationship to health outcomes were asked at the end of the survey. These questions were intended to serve as measures of concern and perceptions among a randomly selected population within Garfield County (as opposed to the more self-selected population that provided comments during focus groups, interviews, and public meetings), and to provide some measure of the potential bias with which survey respondents might have responded to questions about their health.

- When asked whether or not they are concerned that their home drinking water source was related to any of their health problems, between 5.5 and 17% of individuals who live in areas with high natural gas industry activity (zip code areas 81635, 81647, 81650, and 81652) responded that they are concerned, while only 3-5% of individuals who live in the areas least impacted by natural gas industry activity (zip code areas 81601 and 81623) responded in the same manner (Figure 169).

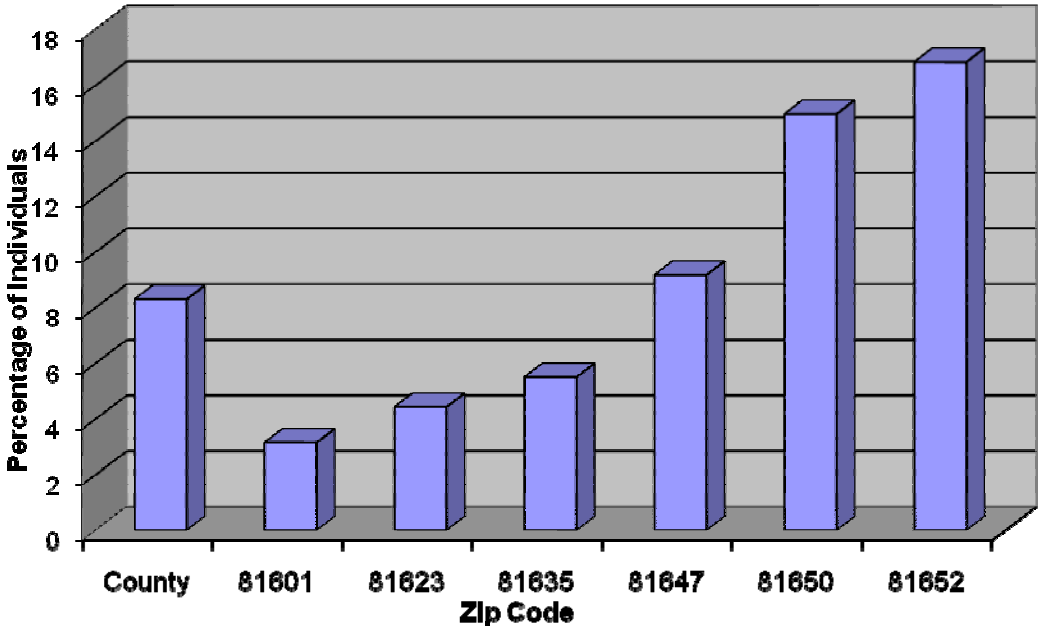
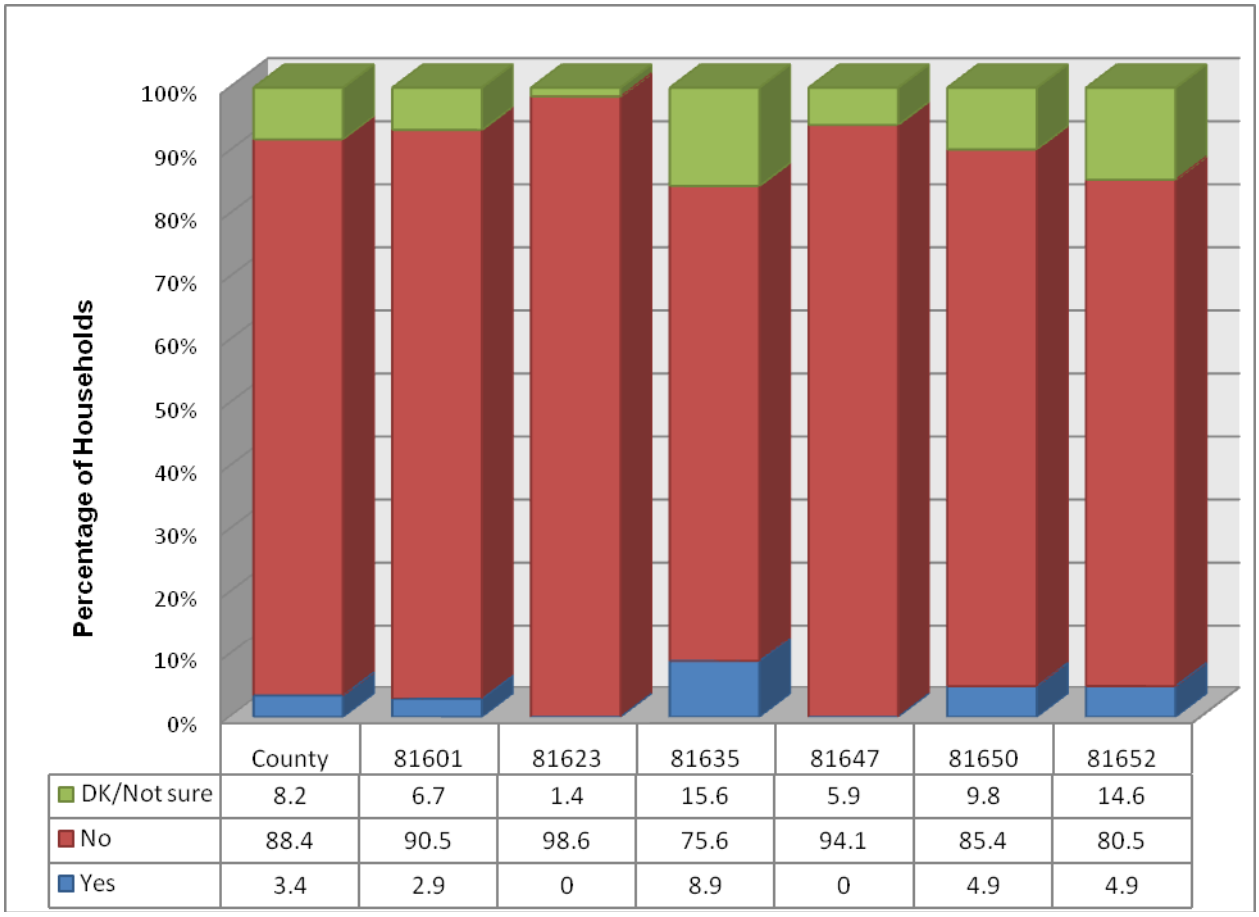


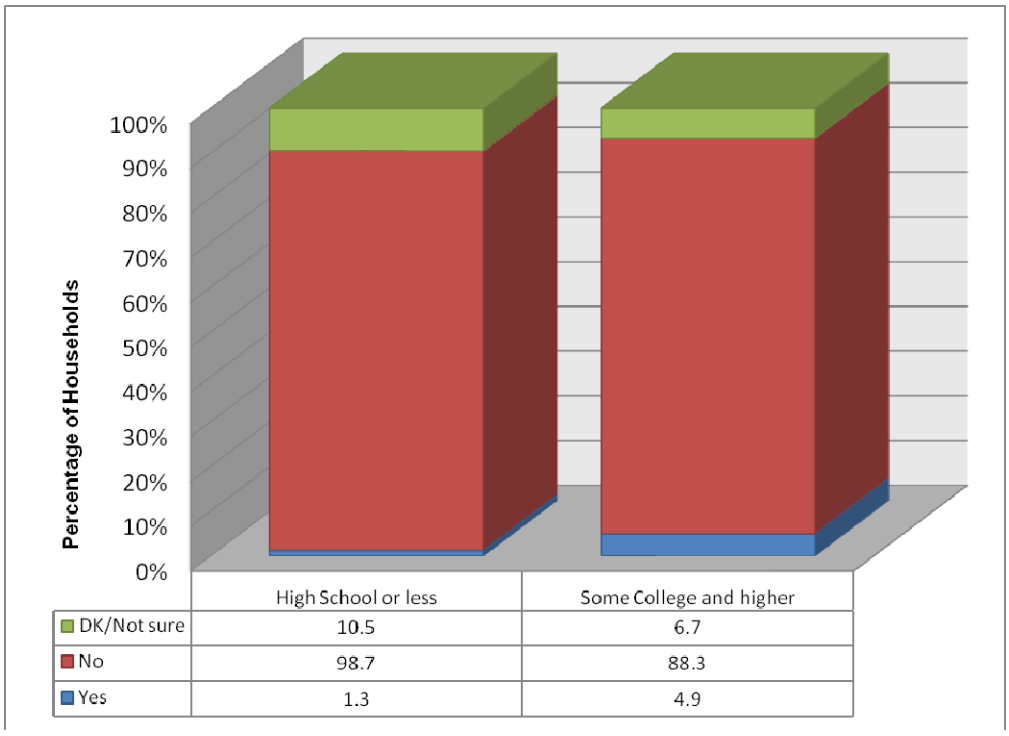
Figure 169. Percentage of Individuals Concerned About Health Problems Related to Home Drinking Water Supply by Zip Code

- When asked whether or not they are concerned that their health problems may be related to chemicals in or near their homes, between 6 and 16% of individuals who live in areas with high natural gas industry activity (zip code areas 81635, 81647, 81650, and 81652) responded that they are concerned; between 1.4 and 7% of individuals who live in the areas least impacted by natural gas industry activity (zip code areas 81601 and 81623) responded in the same manner (Figure 170). There was no correlation between level of education and concern about a relationship between chemicals in or near the home and health problems (Figure 171).



	County	81601	81623	81635	81647	81650	81652
DK/Not sure	8.2	6.7	1.4	15.6	5.9	9.8	14.6
No	88.4	90.5	98.6	75.6	94.1	85.4	80.5
Yes	3.4	2.9	0	8.9	0	4.9	4.9

Figure 170. Percentage of Households Concerned that Health Problems May Be Related to Chemicals In or Near the Home by Zip Code

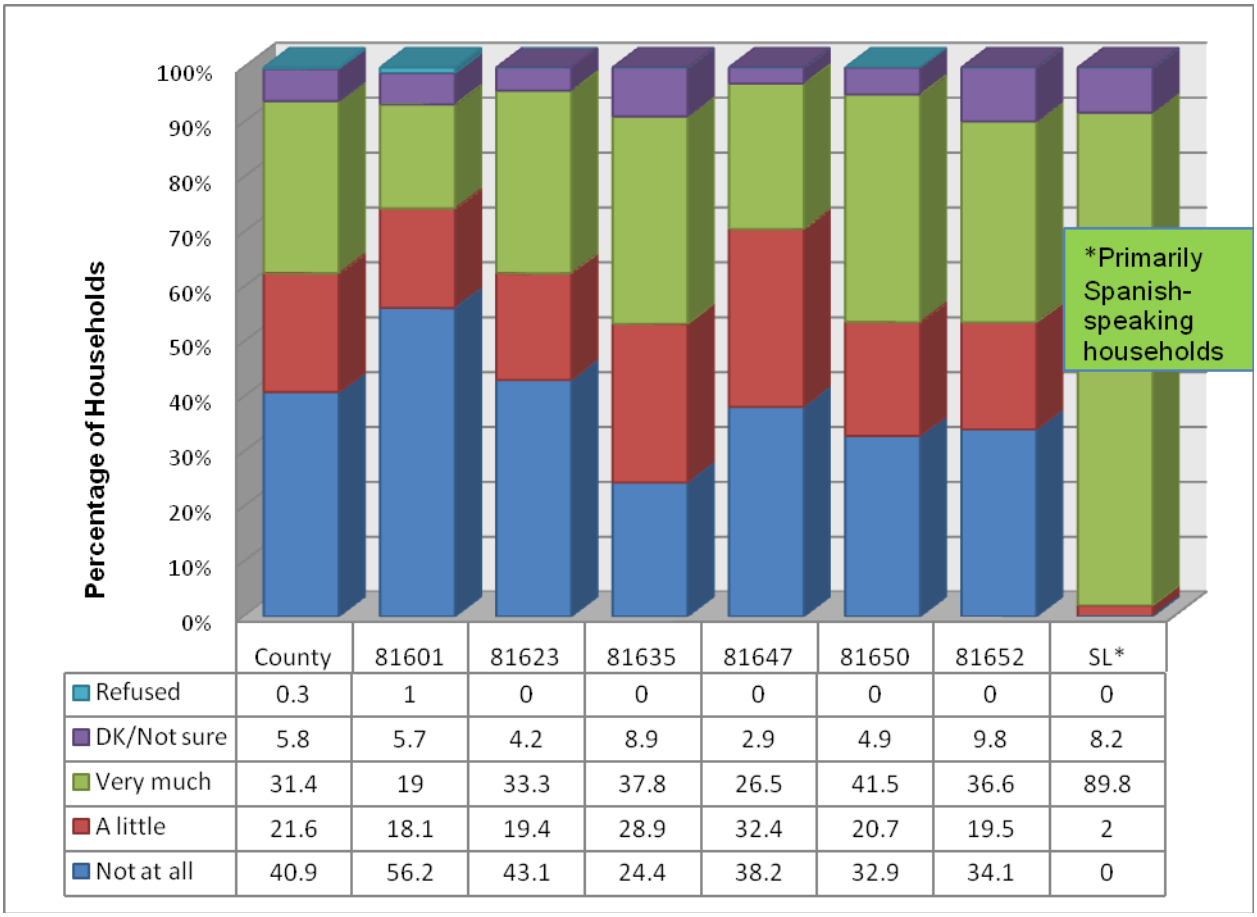


	High School or less	Some College and higher
DK/Not sure	10.5	6.7
No	98.7	88.3
Yes	1.3	4.9

Figure 171. Concern that Chemicals In or Near the Home May Be related to Health Problems: Correlation With Education.

- When asked if they are concerned that either environmental or chemical hazards in their neighborhoods may be related to health problems (Figure 172),
    - Between 24 and 38% of individuals residing in zip code areas 81635, 81647, 81650, and 81652 responded that they are not worried at all. Between 76 and 62% of individuals in these zip code areas responded that they are "a little worried", "very much worried", or "don't know/not sure".

    - Between 56 and 43% of individuals residing in zip code areas 81601 and 81623 responded that they are not worried at all. Between 44 and 57% of individuals in these zip code areas responded that they are "a little worried", "very much worried", or "don't know/not sure".



	County	81601	81623	81635	81647	81650	81652	SL*
Refused	0.3	1	0	0	0	0	0	0
DK/Not sure	5.8	5.7	4.2	8.9	2.9	4.9	9.8	8.2
Very much	31.4	19	33.3	37.8	26.5	41.5	36.6	89.8
A little	21.6	18.1	19.4	28.9	32.4	20.7	19.5	2
Not at all	40.9	56.2	43.1	24.4	38.2	32.9	34.1	0

Figure 172. Percentage of Households Concerned that Health Problems May be Related to Environmental or Chemical Hazards in Their Neighborhoods by Zip Code

- County-wide, individuals who have a high school education or less are slightly less worried about the relationship between their health and environmental or chemical hazards in their neighborhoods (Figure 173).

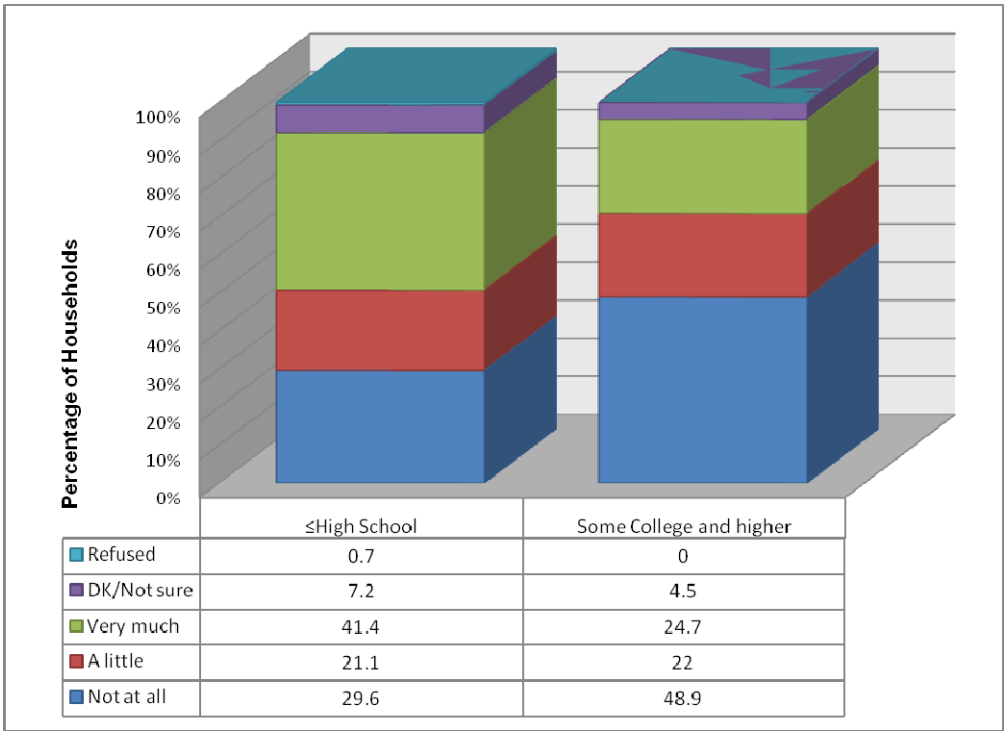
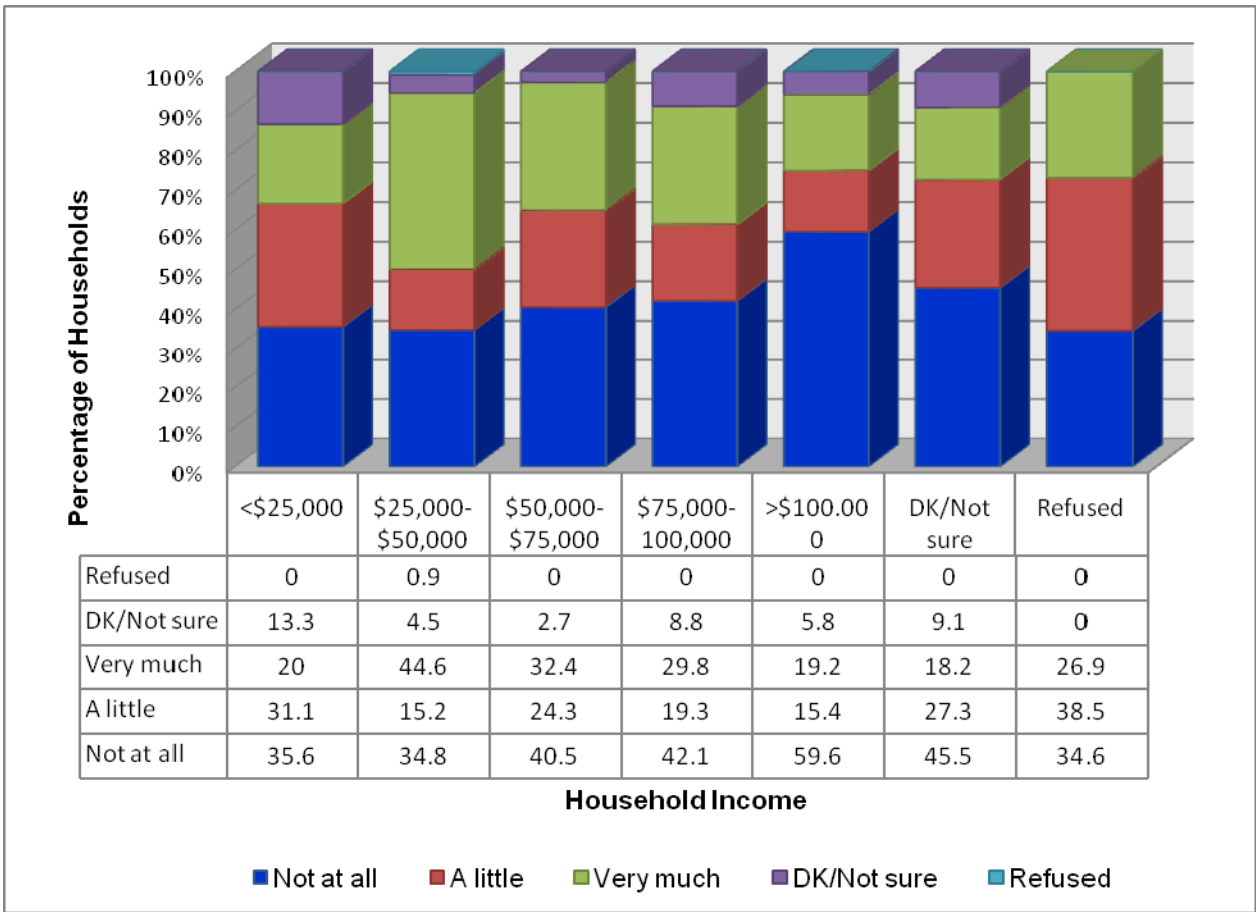


Figure 173. Concern that Environmental or Chemical Hazards in the Neighborhood May Be Related to Health Problems: Correlation with Education

- Individuals with higher incomes (>$100,000 per year) tended to be less worried about a relationship between environmental or chemical hazards in their neighborhoods and health problems. Those who refused to report an income level tended to express "a little" concern more often that individuals who reported an income at any level. Respondents in those households with reported incomes of between $25,000 and $50,000 were most likely to report that they are "very concerned" about environmental or chemical hazards and an impact on human health (Figure 174).



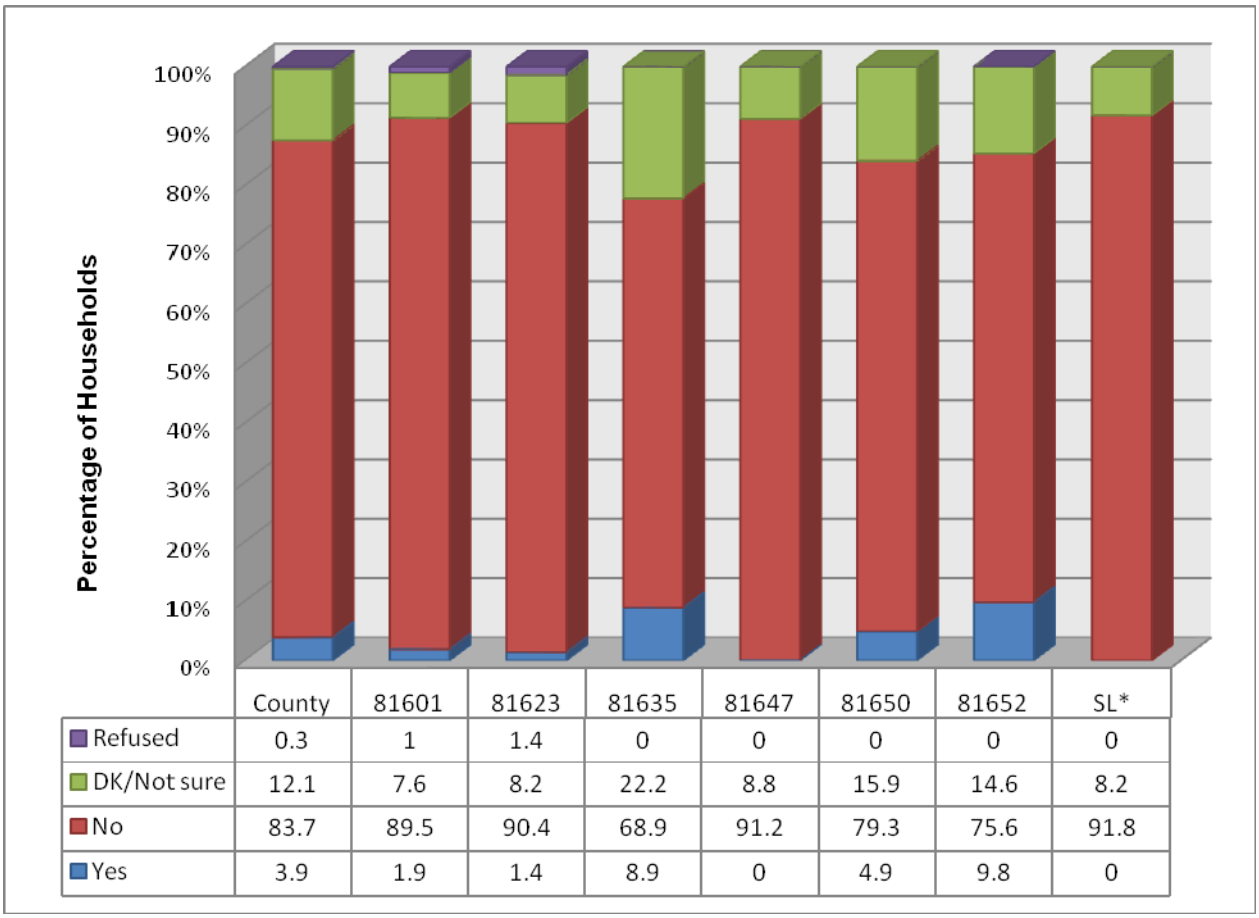
	<$25,000	$25,000-$50,000	$50,000-$75,000	$75,000-100,000	>$100.000	DK/Not sure	Refused
Refused	0	0.9	0	0	0	0	0
DK/Not sure	13.3	4.5	2.7	8.8	5.8	9.1	0
Very much	20	44.6	32.4	29.8	19.2	18.2	26.9
A little	31.1	15.2	24.3	19.3	15.4	27.3	38.5
Not at all	35.6	34.8	40.5	42.1	59.6	45.5	34.6

Figure 174. Concern that Environmental or Chemical Hazards May Be Related to Health Problems: Correlation with Household Income

- When asked specifically whether they are concerned that natural gas industry activities may be related to health problems (Figure 175),
  - Between 69 and 92% of individuals residing in zip code areas 81601 and 81623 responded that they are not concern. Between 8 and 31% of individuals in these zip code areas responded either that they are concerned or that they "don't know or are not sure".

  - 90% of individuals residing in zip code areas 81601 and 81623 responded that they are not worried at all. 10% of individuals in these zip code areas responded that they either that they are concerned or that they "don't know or are not sure".

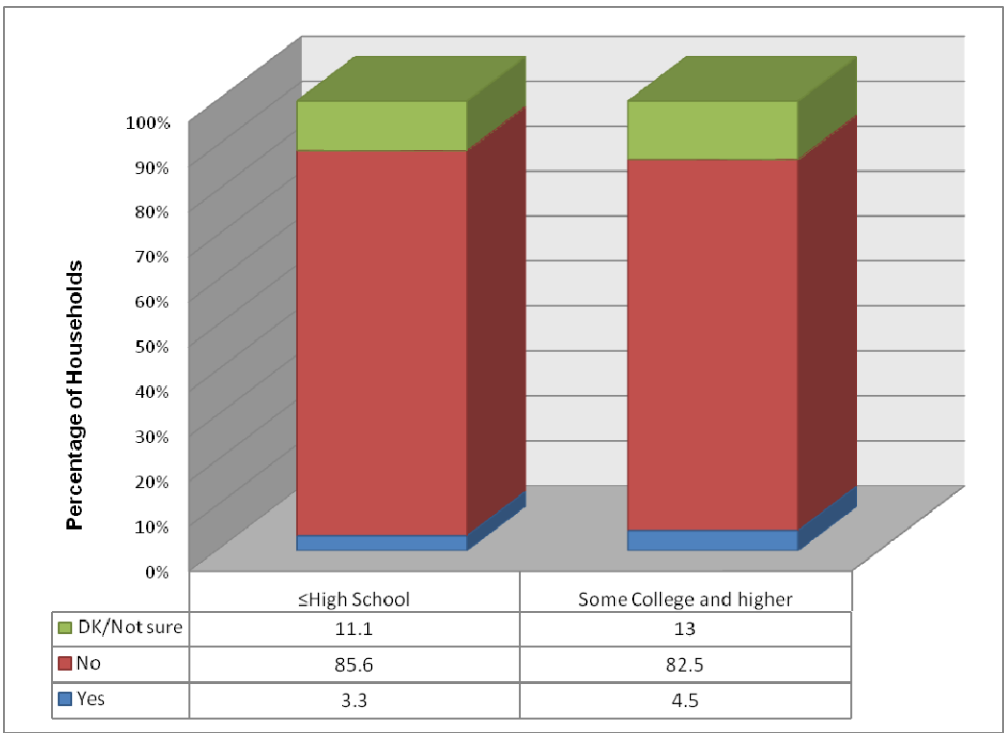
  - There was essentially no difference related to education between individuals who responded that they are concerned about health-related impacts of the natural gas industry and those who are not concerned or are not sure (Figure 176).



	County	81601	81623	81635	81647	81650	81652	SL*
Refused	0.3	1	1.4	0	0	0	0	0
DK/Not sure	12.1	7.6	8.2	22.2	8.8	15.9	14.6	8.2
No	83.7	89.5	90.4	68.9	91.2	79.3	75.6	91.8
Yes	3.9	1.9	1.4	8.9	0	4.9	9.8	0

Figure 175. Percentage of Households Concerned that the Natural Gas Industry May Be Related to Health Problems by Zip Code

Figure 176. Concern that the Natural Gas Industry May Be Related to Health Problems: Correlation with Education



	≤High School	Some College and higher
DK/Not sure	11.1	13
No	85.6	82.5
Yes	3.3	4.5

STUDY CONCLUSIONS AND RECOMMENDATIONS

Based on the data available to us from state, hospital association, and healthcare provider sources, the health of people in Garfield County is not different from the health of residents of other Western Slope counties. However, citizen perception, as evidenced by focus group and interview data and the household survey, indicates that at least some individuals in impacted areas of Garfield County believe otherwise. Citizens express concern and experience frustration and stress over activities that they fear could have negative impacts on their health and environment. Such stress, frustration and the fear of the unknown can, of itself, lead to health problems. Paul Slovic's research (Slovic P. Science 1987;236:280-285) on risk perception documents that individuals tend to fear and react most negatively to situations for which there are considerable unknowns regarding the outcomes, both current and future, and over which they feel they have little control. Energy-related activities in Western Colorado present such a situation for many individuals.

As described in this report, there are numerous gaps and uncertainties in our understanding of pollution from natural gas operations in Garfield County. The motivation for the following recommendations is to reduce these uncertainties and fill data gaps. Better information is needed in order to make a complete and accurate evaluation of threats to human health.

RECOMMENDATIONS.

- Establish a medical monitoring system – especially through primary care networks – to identify any changes in baseline data or trends and/or anomalies in medical practices.

- Conduct a thorough study of air emissions during drilling, including enough sites to cover the range of drilling approaches.
    - Collect 24-hour samples daily around the perimeter of the drill pad to achieve continuous monitoring during several cycles of well installation.

    - Monitor meteorological conditions.

- Identify the components of hydraulic fracturing fluids.
    - Would allow open evaluation of degree of threat.

    - Would improve public acceptance of natural gas operations.

- Inspect surface soils at completion of drilling operations.
    - Minimize possible exposure of landowners to residual soil contamination.

    - Sample and analyze areas suspected to be contaminated.

    - Clean up areas exceeding action levels.

- Use "green completions" and applicable best management practices, including locating drilling and production facility operations far enough from public buildings and residences to reduce the risk of exposure to air toxics, such as benzene, toluene, and xylenes.

- Establish a monitoring program for private wells
    - Provides the most direct way to assess contamination of drinking water resources

    - Analyze for methane, benzene and other volatile organic compounds, and selected components of hydraulic fracturing fluids having the greatest potential to affect human health

STUDY LIMITATIONS

In addition to limitations and data gaps discussed in the body of this report, the following study limitations are worth pointing out:

- "RARE CANCERS" – Cancers that occur very rarely within a population cannot be identified through the state's Tumor Registry, because of requirement to protect individual identity. Thus, the occurrence of rare cancers in persons living in Garfield County, whether or not those cancers could have some relationship to environmental exposures, were not likely to have been picked up through this study. Those incidences could be identified through a county-based medical monitoring system.

- PRIMARY CARE DATA – As noted earlier, we were not able to acquire primary care data directly, despite an attempt to survey local primary care practices. Primary care practice data are the most reliable source of information on unusual occurrences of diseases or symptoms, especially if the data from all local practices can be combined for analysis. This requires, however, that local care providers are networked electronically or have some other means of sharing patient data in a de-identified (to protect individual identities), but nearly real-time manner.

- AVAILABLE DATA SETS -- Because the health data used for this study (other than the Household Survey data) were not collected specifically for research purposes, they are limited in scope, have significant gaps, and may not be comparable with other datasets. This is a common limitation for studies of this type. However, the datasets used for this study are often the only data available, and thus, are often used to describe community health with the qualifications noted.