Final Report

Garfield County Land Values and Solutions Study

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June 2006

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Prepared for

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Table of Contents

SECTION I.
Introduction

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Introduction

This introductory section describes project objectives, project participants, the study area and the organizational structure of the remaining report.

Project Objectives

The objectives of this analysis are five fold:

- Develop a statistically valid model that documents and quantifies variations in Garfield County residential property values;
- Demonstrate how property characteristics, parcel location or other factors influence residential property value;
- Identify possible industrial land uses that hypothetically impact property values, test these hypotheses and quantify the impact of these uses on residential property values;
- Expand explanation of property value variations with non-statistical, anecdotal information; and
- Identify county policy alternatives that might be employed to mitigate the impact of industrial activities on rural residential property values.

Participants

This project was directed by BBC Research & Consulting (BBC), a Denver-based economic, market and policy research firm. BBC was assisted in this effort by ForeSee Consulting, LLC, which provided assistance in data analysis, mapping and geographic information services, and Mark Chain Consulting, LLC, which provided assistance with local representation, data analysis and site interpretation.

Within Garfield County, Jesse Smith, Assistant County Administrator, and Randy Russell, Long Range Planner, provided oversight, coordination and substantive technical and conceptual assistance.

Study Area

This analysis focuses specifically on residential properties within unincorporated Garfield County. The county is part of a regional economy based on tourism, second home development, recreation, construction and natural gas extraction. Garfield County has six incorporated towns, including Glenwood Springs, the county seat. The Federal government owns and manages over 60 percent of the county's land area.

Report Organization

Following this introduction, Section II provides an overview of Garfield County's economic base as context for understanding the broader economic pressures on Garfield County land values. Section III offers a technical discussion of the hedonic pricing model used to analyze property values and quantify the factors that predict value variation. Section IV summarizes modeling results, emphasizing how industrial activities occurring in close proximity to residential uses can adversely impact values and finally, Section V offers options for better managing land uses to reduce uses and value conflicts.

SECTION II.
Garfield County Economic Base

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Garfield County Economic Base

This section provides a brief overview of recent economic and demographic trends in Garfield County as context for a subsequent analysis of land values and industrial impacts provided in the following sections.

Overview

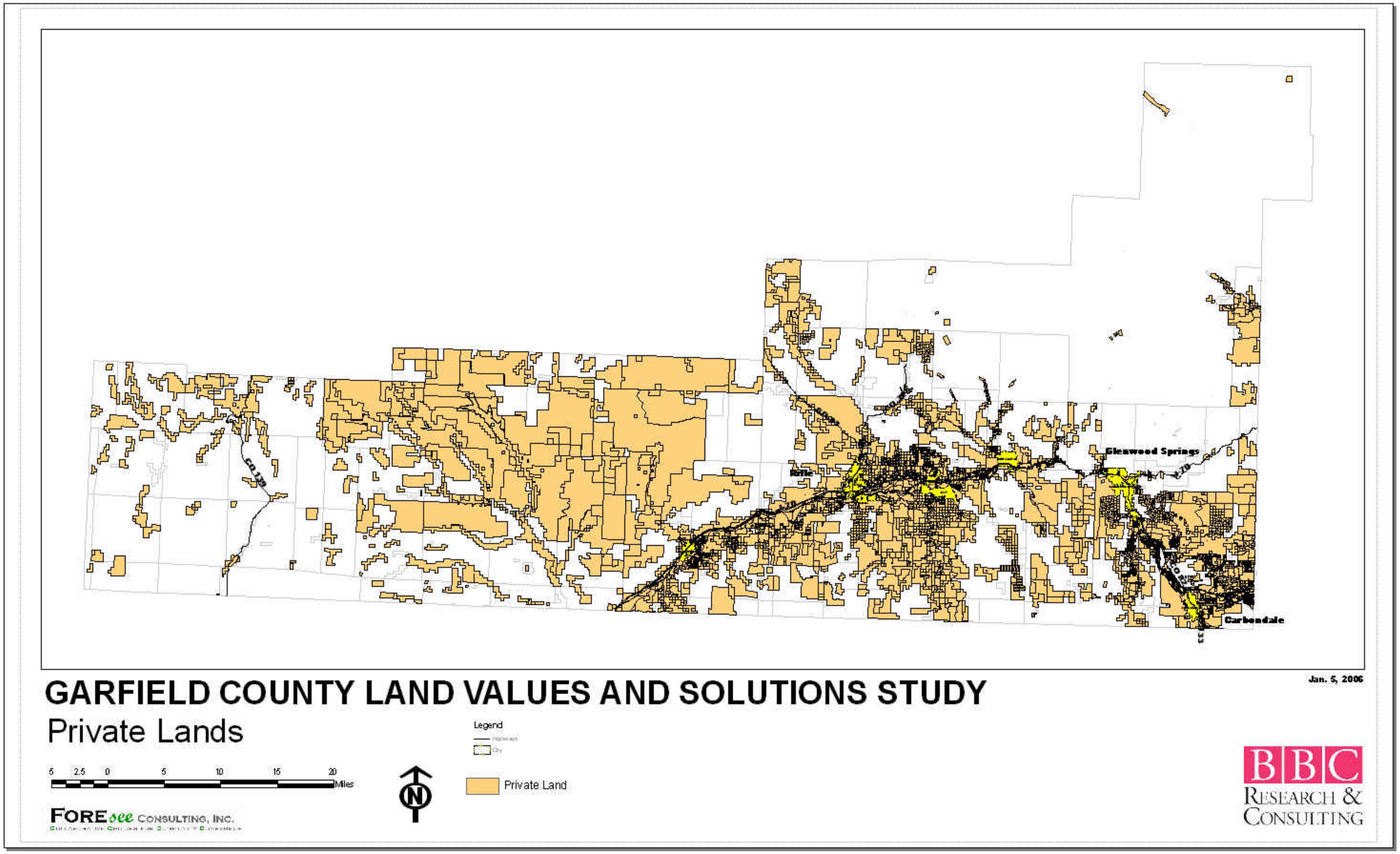
Garfield County is one the most physically and economically diverse counties on Colorado's Western Slope. As shown in Exhibit II-1 on the following page, the Federal government owns over 60 percent of the county's land, which is managed by the United States Forest Service or the Bureau of Land Management (BLM). Exhibit II-1 shows public and private land ownership in Garfield County, the county road system and the local municipalities.

Regional Influences. Garfield County can be viewed as having three distinct socioeconomic regions. The far western portion of the county is sparsely populated, arid and contains mostly public lands. The eastern half of the county contains five municipalities aligned along I-70 and supports the majority of the county's population and economic activity. The southeastern corner of the county has one municipality (Carbondale) that is situated between Glenwood Springs and Aspen on Highway 82. This southeastern area, defined by the Roaring Fork and Crystal River Valleys, is economically aligned with the resort and recreation economy of Aspen and Pitkin County.

Since the mid-1990s, the burgeoning resort and real estate economies of Eagle and Pitkin Counties have stimulated associated economic activity—particularly residential development in Garfield County. Glenwood Springs, the county seat, has traditionally served as a regional retail and services center for west central Colorado, including Eagle, Rio Blanco and Pitkin counties. More recently, as resort and recreation development activity has spread "down valley," Garfield County, with its warmer climate and more reasonably priced housing, has emerged as a residential alternative for Eagle and Pitkin County workers. In the last few years, Garfield County has developed new economic ties with Grand Junction and Mesa County, as natural gas development has spurred economic interrelationships and increased worker commuting between Mesa, Rio Blanco and Garfield counties.

Finally, the prospect of new gas exploration activity on the Roan Plateau, and potential oil shale development in northwest Colorado, suggests that Garfield County will likely develop further economic relationships with Rio Blanco County on its northern border.

Exhibit II-1.



Source: ForeSee Consulting, Inc.

Population growth. Exhibit II-2 compares population for Garfield County and its incorporated municipalities. The county has grown rapidly in recent years as increased housing costs in the Roaring Fork Valley have pushed growth down-valley from Carbondale and Glenwood Springs to New Castle, Silt, Rifle and Parachute, and as local energy development has drawn new workers and households to the area.

Exhibit II-2.
Population, Garfield County, 2000-2004

Municipality	2000	2001	2002	2003	2004	Annual Growth Rate 2000-2004
Carbondale	5,196	5,509	5,565	5,689	5,767	2.6%
Glenwood Springs	7,736	8,135	8,301	8,406	8,517	2.4%
New Castle	1,984	2,268	2,604	2,825	2,949	10.4%
Parachute	1,006	1,269	1,297	1,320	1,338	7.4%
Rifle	6,784	7,079	7,349	7,541	7,760	3.4%
Silt	1,740	1,901	2,039	2,089	2,184	5.8%
Unincorp. Area	19,345	20,012	20,286	20,526	20,810	1.8%
Garfield County	43,791	46,173	47,441	48,396	49,325	3.0%

Source: Colorado Department of Local Affairs.

Garfield County has one of the nation's richest natural gas and oil shale reserves and is anticipating considerable job growth in the next 10 years. Exhibit II-3 below shows recent population projections for Garfield County and its municipalities. Garfield County is projected to grow at nearly 5 percent annually. The fastest growth in the county is expected to occur in the Colorado River Valley, between New Castle and Parachute where the growth pressure from energy development and resort service employment coincide. It is important to note that as a municipality grows in size, its percentage growth rate is less sensitive. For instance, when a town with a population of 2,000 grows by 80 households in one year, it has an annual growth rate of 4 percent. If another town with a population of 4,000 grows by 80 households in one year, its annual growth rate is just 2 percent.

Exhibit II-3.
Projected Population, Garfield County, 2000-2015

Municipality	2000	2005	2010	2015	Annual Growth Rate 2000-2015
Carbondale	5,196	5,863	8,339	10,303	4.7%
Glenwood Springs	7,736	8,632	12,094	14,829	4.4%
New Castle	1,984	3,270	7,157	10,752	11.9%
Parachute	1,006	1,444	2,764	3,971	9.6%
Rifle	6,784	7,926	11,543	14,430	5.2%
Silt	1,740	2,288	3,778	5,031	7.3%
Unincorp. Area	19,345	20,866	26,869	30,975	3.2%
Garfield County	43,791	50,289	72,544	90,291	4.9%

Note: Assumes a continuation of current observed relative growth patterns.

Source: Colorado Department of Local Affairs; RRC Associates Inc.; McCormick & Associates.

Employment. The total labor force in Garfield County has been steadily increasing since 1997, with the exception of a brief dip in 2001. Exhibit II-4 shows the labor force and unemployment in Garfield County from 1997 to 2004.

Exhibit II-4.
Labor Force and Unemployment Rate, Garfield County, 1997-2004

Source: Colorado Department of Local Affairs.

Unemployment has remained constant, as the labor force has increased, reflecting a very strong local economy. Total employment increased from 25,680 jobs in 2003 to 26,920 jobs in 2004, an increase of nearly 5 percent.

Projected job growth. According to the Colorado Department of Local Affairs, Garfield County will add 8,740 jobs between 2005 and 2015, representing job growth at 31 percent. Assuming that the multiple job holding remains constant, there will be an increase of 7,600 persons needed to fill those jobs. Exhibit II-5 shows projected job and workforce projections for Garfield County from 2000 to 2015.

A large portion of Garfield County's projected job growth is dependent on job growth in neighboring Pitkin and Eagle Counties. A significant amount of jobholders in Pitkin and Eagle Counties reside in Garfield County, and a fair amount of local service jobs in Garfield County are supported by commuting workers. Jobs that provide services to a workforce housed in Garfield County but working in neighboring counties is a significant portion of the projected Garfield County job base.

Exhibit II-5.
Job and Workforce Projections, Garfield County, 2000 to 2015

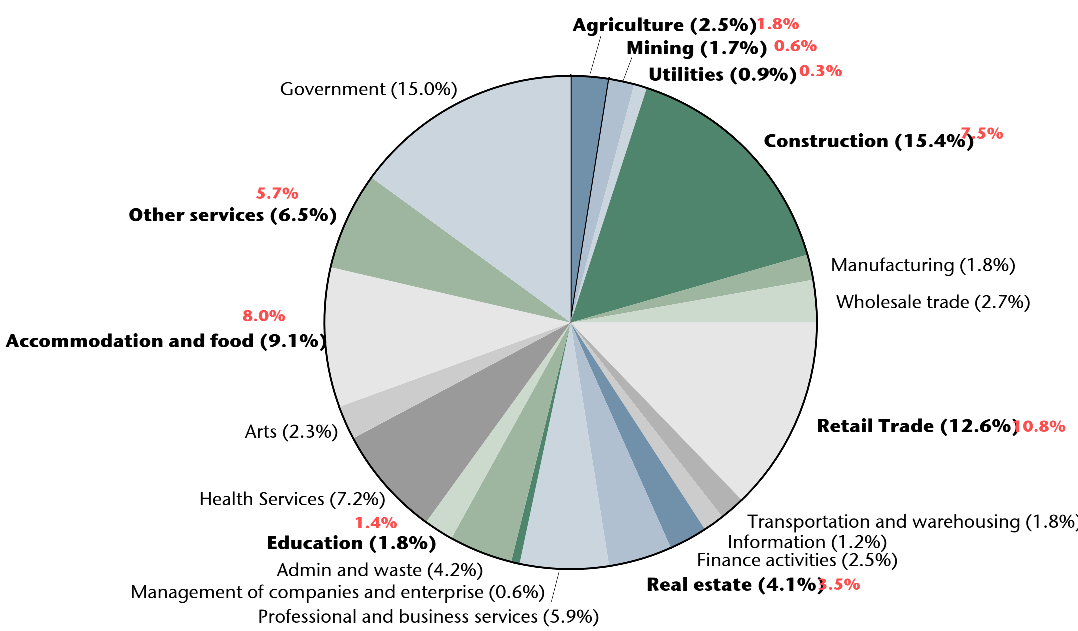
	2000	2005	2010	2015
Total Garfield County Jobs	26,091	28,260	34,000	37,000
Jobs Held by Residents	26,896	30,377	44,109	53,016
Multiple Job Holding Rate	1.15	1.15	1.15	1.15
Residents Holding Jobs	23,388	26,415	38,356	46,101
Residents Commuting Out	-6,000	-6,704	-14,236	-20,143
Remaining Local Employees	17,388	19,711	24,120	25,958
Employees Needed to Fill Jobs*	22,688	24,574	29,565	32,174
Workers Commuting In	5,300	4,863	5,446	6,216

Note: * Assumes a 1.15 multiple job holding rate.

Source: Colorado Department of Local Affairs; RRC Associates Inc.; McCormick & Associates.

Employment by sector. Exhibit II-6 shows employment by sector for Garfield County in 2003. Bold sectors indicate a larger share of employment in Garfield County than the state in that particular sector. The red figures show the state's share of employment in that sector.

Exhibit II-6.
Employment by Sector, Garfield County, 2003



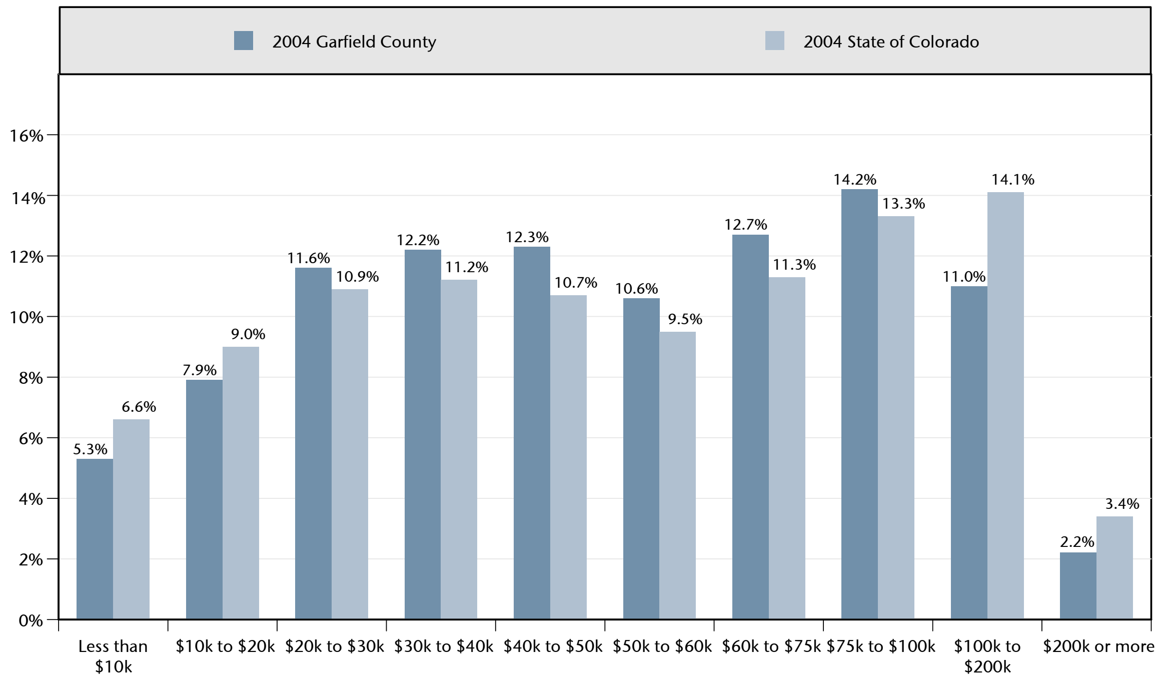
Note: Figures in Red show the comparable state share of employment in selected sectors.

Source: Colorado Department of Local Affairs.

Garfield County has a larger share of its employment in the service, retail, real estate, construction, agricultural and mining sectors. This distribution reflects Garfield County's three major industries: tourism, ranching and resource extraction.

Household income. Exhibit II-7 shows household income in Garfield County in 2004. Approximately 13 percent of Garfield County households earn less than $20,000 compared to about 16 percent in Colorado overall. Nearly 28 percent of Garfield County households earn more than $75,000. Statewide, approximately 31 percent of households earned more that $75,000 in 2004.

Exhibit II-7.
Household Income Distribution, State of Colorado and Garfield County, 2004



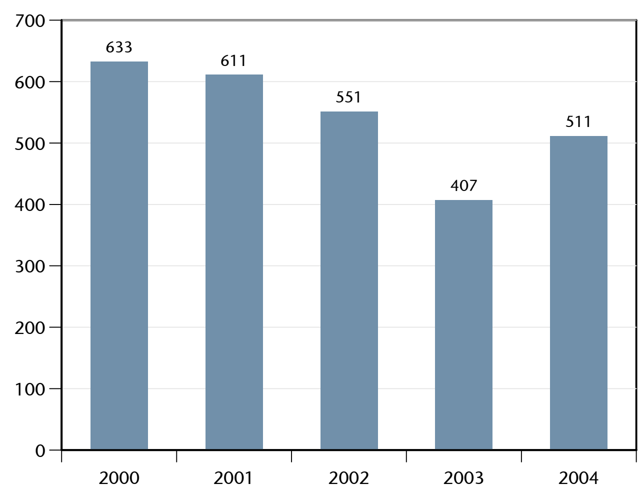
Note: Data is estimated.

Source: PCensus 2004.

Building permits. Building permits declined in 2002 and 2003, as the economy softened after 9/11, but development has rebounded along with gas exploration, construction and tourism. Exhibit II-8 shows net building permits in Garfield County from 2000 to 2004.

Exhibit II-8.
Building Permits, Garfield County, 2000-2004

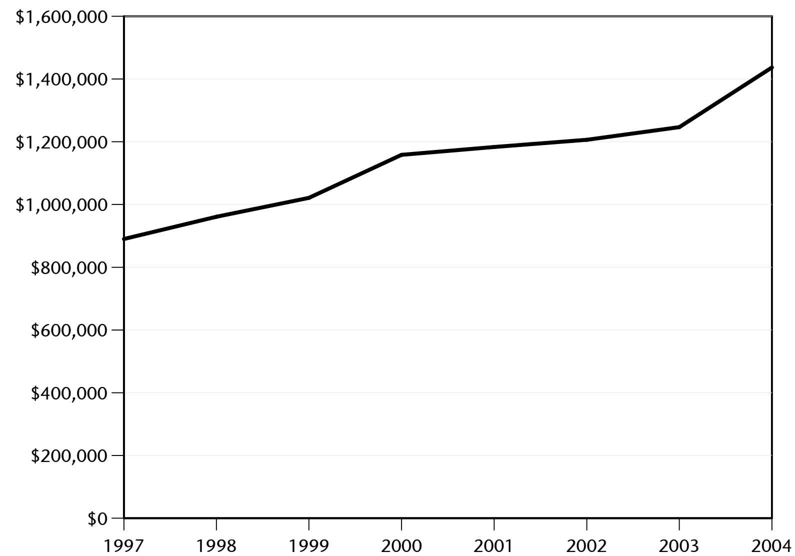
Source:
Colorado Department of Local Affairs.



Retail sales. Retail sales in Garfield County have steadily increased in the last seven years. Exhibit II-9 shows retail sales in Garfield County from 1997 to 2004.

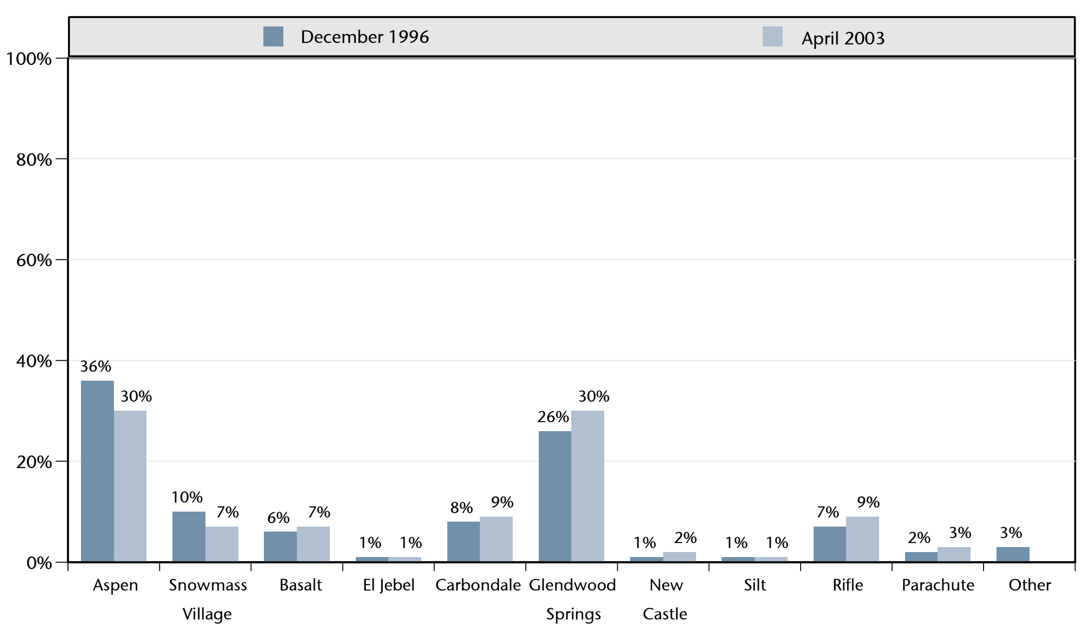
Exhibit II-9.
Retail Sales, Garfield Country, 1997-2004

Source:
Colorado Department of Local Affairs.



Job location. Exhibit II-10 shows regional job location in Garfield and Pitkin County. The migration of jobs and residents down valley is evident as Aspen and Snowmass Village have lost market share and the Colorado River Valley has gained share.

Exhibit II-10.
Job Location in the Roaring Fork/Lower Colorado Valley, December 1996 and April 2005

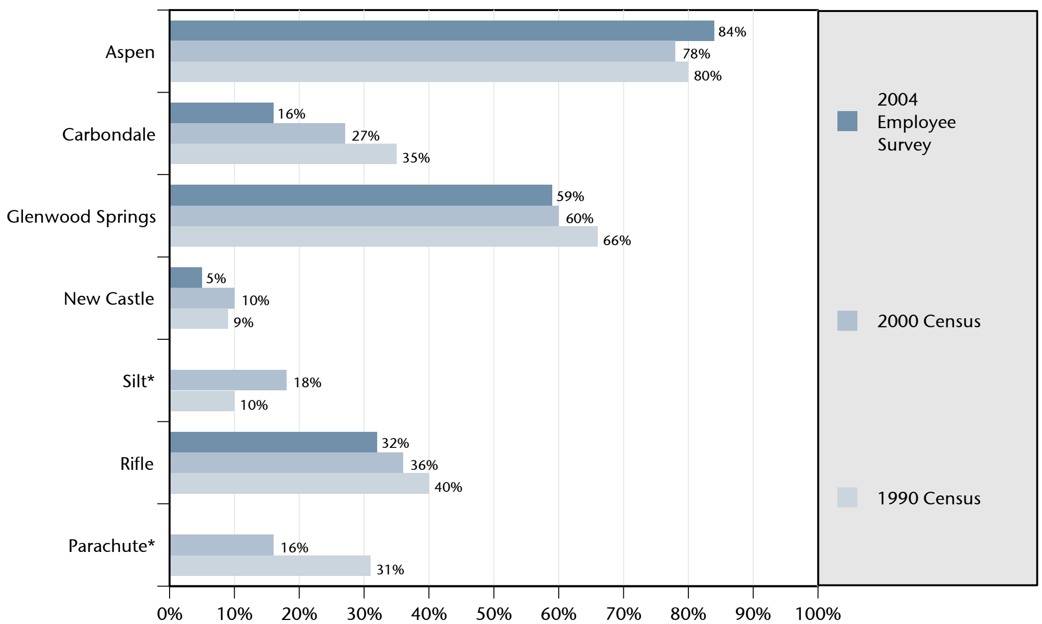


Source: 2004 Local & Regional Travel Patterns Study.

In 1995, Aspen and Snowmass Village held 45 percent of regional jobs. In 2003, only 37 percent of jobs in the region were located in Aspen and Snowmass Village. Glenwood Springs and Rifle have increased their share of regional jobs over the same period, from 33 percent in 1996 to 39 percent in 2003.

Commuting patterns. Exhibit II-11 shows the percent of residents who work in the same community in which they live and trends in commuting behavior. With the exception of Apen, commuting is increasing. Despite the increasing distribution of jobs more equitability across the area, increasing numbers of Colorado River Valley residents still commute away fromtheir home to their jobs.

Exhibit II-11.
Percent of Residents that Work in the Same Community in Which They Live, 1990 Census, 2000 Census, 2004 Employee Survey



Note: * Incorporated Silt and Parachute responses to the 2004 survey are less than 40.

Source: Bureau of Transportation Statistics, 2000 US Census, RRC Associates, Inc.

Summary

Garfield County is a physically and economically diverse community with distinct economic sub-regions. A large share of the county is held in remote public lands, although current and future gas development on these public properties has shaped, and will continue to influence, local employment and commuting patterns. A large share of the unincorporated county remains in agricultural use. The central county contains the I-70 corridor, the core population base and the most rapidly growing communities. The southeastern portion of the county, encompassing the town of Carbondale, the Crystal River Valley and the Roaring Fork River Valley is economically tied to resort and second home development in neighboring Pitkin County. Glenwood Springs is the county seat, largest community and the county's regional service center.

Garfield County's economy is tied to tourism, construction, natural gas development and what might be termed "quality of life migrants" who are drawn to the area by local recreation opportunities,, climate and the attractive landscape. In recent years, the economy, population and employment has grown rapidly as both the recreation/retirement and the natural gas industry have expanded. Home and land values have increased proportionally. In this environment of limited private lands and rapid employment growth, one would anticipate rapid growth in residential values and considerable variation in property values across the breadth of the county.

SECTION III.
Technical Approach

SECTION III.
Technical Approach: Property Values Analysis

This section examines trends in Garfield County land values and uses statistical analysis to document and quantify the factors that influence local residential land values. This section begins with a summary of hedonic pricing analysis—the methodological basis of this analysis—and continues with a detailed description of pricing model experimentation and development. The next section includes findings and observations regarding residential land value trends and industrial influences in Garfield County.

Analytical Options

The primary objective of this study was to develop an authoritative economic model of Garfield County land values and to quantify the factors that determine valuation variations between similar sized and similarly located parcels. There are a number of analytical approaches that have the potential to support these objectives. In undertaking this study, the consulting team's first task was to evaluate analytical options and suggest an appropriate methodology. The initial screening of methodological options employed four key criteria: data availability, statistical validity of outcomes, modeling flexibility, and prospects for effective visual and spatial display. Ultimately, the project team concluded that the original proposed approach, a hedonic pricing model, remained the best option and offered the most promising means of satisfying project objectives. This method allows investigation of numeric variables, such as house size or the property area, in addition to binary variables, such as whether the property has a garage.

Background on Hedonic Pricing Analysis

Hedonic pricing analysis is a method of explaining demand or prices for a particular good (e.g. a housing unit) by attaching estimates of value to each of its component characteristics (e.g. size of structure, ago quality of construction). Hedonic pricing analysis is commonly used in real estate economics and consumer price index (CPI) calculations.

For example, in real estate economics, hedonic pricing can used to explain changes in value for a housing unit that has many characteristic variations. Because homes are so different, it is difficult to estimate the demand for houses generically. Instead, it is assumed that a house can be "decomposed" into characteristics, such as number of bedrooms, size of parcel, or distance to urban services. A hedonic regression equation treats these attributes (or bundles of attributes) separately, and estimates values (in the case of an additive model) or price elasticity (in the case of a log model) for each characteristics.

An extensive literature review in the disciplines of economics, land use and real estate identified numerous studies since the early 1970s that have investigated the effect on property values of proximity to special, distinguishable features and activities. These special features, near but not necessarily part of the real estate to be valued, are referred to as "externalities." These have included both positive and negative attributes, from beaches to power lines to hog farms. Most studies of externalities have used a valuation technique called hedonic pricing.

The literature on hedonic pricing of residential real estate falls into two general categories. The first—the theoretical literature—focuses on identification of housing supply and demand equations and comparisons among equations of differing forms. The second category is the empirical literature. The empirical papers describe specific hedonic pricing investigations where the measurements of value are the implicit prices of structural and physical characteristics of properties, plus at least one additional characteristic drawn from the surroundings, such as the community, the neighborhood or an external amenity or disamenity.

Before one can evaluate the impact of an external characteristic, effects must be controlled for other factors of importance. For example, *Palmquist, Roka and Vukina* (1997) controlled for the characteristics that contributed to a home's sale price in order to estimate the effect of the proximity of a hog farm.

There is a consensus among economists as to the general factors that explain the market price of a property. For example one well know study *Pompe and Rinehart* (1995) investigated the impact of beach quality on the purchase price of single-family homes with and without water frontage in South Carolina. The authors used a standard hedonic pricing model:

$$P_i = f(s_i, n_i, x_i).$$

where *P* is the selling price of a property. The expression includes structural characteristics (*s*), neighborhood characteristics (*n*), and external effects (*x*). The structural characteristics were age of house, size of living area, number of bathrooms, and having a fireplace. The neighborhood characteristics were distance to Myrtle Beach and whether the property sold after Hurricane Hugo in 1989. To measure the externality of interest, beach quality from the perspective of the property, the model included both width of the nearest beach at high tide and distance to the nearest beach multiplied by the width of the nearest beach at high tide. The model also controlled for a property's ocean views, being on the water, and having a dock; all attributes expected to impact property values.

The hedonic pricing model developed by *Pompe and Rinehart* is similar to that used across the economics and planning literature. For other representative examples, see *Palmquist, Roka* and *Vukina* (1997); *Palmquist* (1992); *Graves, et a*l. (1988); *Ridker and Henning* (1967) and *Levesque* (1994). *Levesque* 1994 specifies the following form for the pricing model, which incorporates the effect of time:

$$P = f(z_1, z_2 \ldots, z_m, a_1, a_2 \ldots, a_m, t).$$

In this expression:

- *P* is the market price of a house;
- The *z*'s are continuous variables like the duration or intensity of a disamenity (e.g., distance to a waste site, frequency or level of noise events, etc.) or a housing characteristic (e.g., square footage, lot size, distance to town, etc.);
- The *a*'s are a series of specific attributes that either do or do not exist (e.g., on the waterfront, has a garage, etc.); and
- The *t* is the period when the property sold.

Most studies apply log-likelihood ratio tests to select the best among competing models. Four functional forms are typically tested: linear, semi-logarithmic, log-linear, and exponential (*Palmquist* 1984; *Levesque* 1994; *Dickie et a*l. 1997).

BBC reviewed 13 studies that included empirical estimations of implicit prices to arrive at guidelines for this study. The structural characteristics incorporated in these models may include: age of house, size of living area, size of lot, number of bathrooms, existence of a porch or deck, existence of a fireplace, type of heating, type or size of garage, hardwood floors, landscaping, house construction, and date of sale. Similarly, there was consistency in the use of location effects. These tended to include some measure of commuting time or accessibility, and one or more neighborhood or community effects (e.g., socioeconomics, public safety, recreation, etc.). The studies considered a range of externalities, among them are distance to the beach, existence of a nice view, highway noise, distance to a noxious site (e.g., a landfill), and airport noise.

One model created by *Boxall, Chan and Mc Millan* (2005) investigated the effect of oil and natural gas facilities on rural residential properties near the city of Calgary in Alberta, Canada. Due to the presence of sour gas (gas with at least 1 percent Hydrogen Sulfide) in Alberta and the associated potential health risks, *Boxall, Chan and McMillan* used a cumulative index related to the presence of emergency plan response zones near sour gas facilities as well as the volumes of gas flared at nearby flaring batteries. *Boxall, Chan and McMillan* found statistically significant results for variables related to sour gas and found that sour wells had twice the marginal impact on property values as sweet wells.

Hedonic studies are complex and have limitations. Many factors may contribute to the perceived value of any individual property. Not all of these factors can be measured. No model can “explain” 100 percent of the variation in the sale price of a home. The portion of the variation explained by hedonic pricing models of housing values is typically in the range of 70 to 90 percent.

In addition, housing markets vary substantially from place to place. Because of this, analysts generally do not transfer estimated magnitudes of a variable measured in one market to other markets not considered in a study. For example, the square footage of a house is statistically significant in explaining valuation differences in every model identified by the study team. While specific quantitative measurements of the effect of square footage on the total sales price cannot be generalized from one geographic area to another, it is reasonable to expect that square footage will be significant in future studies and should be included in the analysis.

Despite limitations, hedonic analysis provides an established and practicable basis for the pricing of specific property characteristics in a complex housing market like Garfield County for a number of reasons. First, because this method relies upon actual market data, such models can incorporate techniques to explicitly measure appreciation over time instead of relying on external measures of inflation. Secondly, the large body of empirical studies provides benchmarks for the evaluation of new studies. Finally, hedonic analysis is a practical approach in most housing markets because adequate, usable data is generally available from standardized Assessor’s records. Competing methods include contingent valuation and discrete choice modeling. Each of these alternatives involves surveying numerous individuals in experimental settings that attempt to simulate the relevant market and would have measured intended rather than actual behavior. In addition, competing methods tend to focus on situations involving a few instead of many attributes.

Analysis Framework

Recognizing the varied characteristics of property markets across Garfield County, and after some experimentation, BBC created two models to describe the variation in property sales prices: one for the Roaring Fork Valley, and one for the Colorado River Valley. Both BBC models follow the standard framework found in the literature, with some modification to reflect this specific analysis:

$$P = bS + cW + dY + b'TS + u$$

Or

Price=structural characteristics + property characteristics + time of sale + external factors+ unexplained factors

The *S*-term in this expression represents an array of general characteristics of the structure and the property. After exploring the measures available in the dataset, a number of variables were selected for consideration based on past studies. These structural characteristics include total square footage of the house; number of bedrooms; number of bathrooms; modular or traditional stick builtconstruction; condominium or single family home; type of wastewater system; property acreage: effective house age; the number of outbuildings associated with the parcel; the amount of heated space in the outbuildings; the distance to the city of Glenwood Springs; the distance to Pitkin County; the distance to the nearest paved Garfield County road; and whether the property had a view of Mount Sopris or was situated north of the Colorado River. Distances were measured from the center of a property to the center of the object in question as reflected in GIS maps collected from Garfield County. Additional acreage, square footage and the presence of outbuildings were expected to positively influence property values.

The model controls for the year a property sold through a dummy variable *(Y)* associated with the period in which the property was sold. Six periods were chosen for the study with the earliest including all properties sold in or prior to 1990 and the remaining categories including properties sold in each of the subsequent three-year intervals. In addition, the model addresses the possibility of an interaction between certain property attributes and time through the term *TS*. The interaction variables are calculated by multiplying each variable (e.g., acreage) times the number of years after 1987—the beginning of the study period—that the property was sold. The value of *T* ranges from zero for 1987 to 18 for 2005.

The *W*-term represents three dummy variables used to represent the presence of a potentially value-affecting industrial use, such as a gravel pit, the presence of high voltage power lines, proximity to I-70 or railroad tracks, or the presence of a natural gas well on the property.

BBC expected the majority of these industrial impacts to have a negative impact on property value. For gravel pits, high voltage lines, I-70, and railroad lines, BBC used a simple distance calculation from the center of parcels to the industrial externality. These distances were measured in miles and were calculated using the GIS information from the Garfield County Information Technology Office.

Natural gas development posed a slightly different challenge as members of the Energy Advisory Board hypothesized that the impact from this development varies substantially over time. It was expected that the most recently drilled wells would have the greatest impact on property value and that the impact would diminish over time. The three periods were:

- Well completed within ninety days of the sale date;
- Well completed within the two years prior to the sale date; and
- Well completed more than two years prior to the sale date .

Finally, the *u*-term is an element of regression models that accounts for random error unexplainable by any other means.

Exhibit III-1 shows a list of variables tested for use in the models. The variables listed as tested and rejected were not included in the model because BBC was unable to quantify a statistically significant impact for these property characteristics. These variables may have a substantial influence of property value that was not captured in the data set or was closely correlated with other variables. For example, there is close correlation between the number of bedrooms in a residence and the size of the home in square feet and therefore it was unlikely that our model would produce a statistically significant result for both variables.

Exhibit III-1.
Variables Considered for Hedonic Property Value Model

Variables Included in Model	Variables Tested and Rejected
Land Characteristics:	
Size (acreage)	South facing percentage
Presence of water features	All flat
Presence of "good" vegetation (CRV only)	Acreage Squared
Structural characteristics	
Size of home	Number of bedrooms
New home (less than 10 years old)	Number of bathrooms
Presence of garage (CRV only)	Construction type (e.g. modular, condominium, etc.)
Presence of outbuildings	Additional house age groupings (e.g., 10 to 20 years old)
Heated space in outbuildings	Water system other than a private well
On a non-septic wastewater system (RFV only)	
Locational characteristics/industrial proximity	
Distance from Glenwood Springs (CRV only)	Distance to nearest town
Distance from Pitkin County (RFV only)	Adjoins Federal land
North of Colorado River (CRV only)	Distance to I-70
View of Mt. Sopris (RFV only)	Distance to railroad
Distance to nearest paved road	Proximity of high voltage lines
Distance to nearest gravel pit (CRV only)	Proximity of land fill
Gas well completed within 90 days after sale (CRV only)	
Gas well completed < 2 years prior to sale (CRV only)	
Gas well completed > 2 years prior to sale (CRV only)	
Value appreciation over time	
Increase in value per acre by year	
Increase in value per square foot by year	

Note: CRV only indicates variables used only the in the Colorado River Valley model.
RFV only indicates variables used only in the Roaring Fork River Valley model.

Source: BBC Research and Consulting.

Data Sources

BBC used data from the following sources to construct the models describing Garfield County property values:

- **Garfield County Assessor's Office**: The Assessor's office provided sales records from 1987 until early 2005 in addition to assessed property descriptions and characteristics.

- **Garfield County IT Department**: Rob Hykys, the Garfield County Geographic Information Systems (GIS) specialist, provided BBC the latest GIS parcel layer for Garfield County. These data helped establish properties for the model such as distances to landmarks or industrial locations.

- **Garfield County Planning Department**: The planning department provided information on amenities available in various subdivisions within Garfield County. Information included the type of water and sewer systems.

- **Foresee Consulting**: Foresee provided GIS-based attributes for Garfield County parcels including distances to paved roads, gravel pits, utility lines, Pitkin County, I-70 and other attributes such as the percentage of desirable vegetation, the view of Mount Sopris, percentage of the property facing south and whether the parcel is flat.

- **Colorado Oil and Gas Conservation Commission**: BBC accessed the public COGCC records for location, completion date and status of natural gas wells in Garfield County.

BBC refined the data in the assessor's database limiting the scope of the investigation to rural residential properties on parcels smaller than 160 acres. The exclusion of municipal residential transactions and to a lesser extent, eliminating large properties reduced the sales used for analysis from 34,000 to 7,500.

The assessor's data is updated on an eighteen-month basis and thus some attributes of properties for sales between June 2004 and December 2005 may not be complete. In addition, the 2005 sales records may not reflect all sales conducted in 2005, as there is a lag between the date of sale and entry of the data in the database. Finally, the property attributes related to the GIS position of a parcel (distance to Glenwood Springs, view of Mount Sopris, etc.) rely on the parcel map layer created by the Garfield County IT Department. This parcel map layer is a hand conversion from Garfield County Autocad maps, and at the time of use was not entirely correct.

Summary

A hedonic pricing model is used to explain and quantify what factors determine land values in Garfield County. The model accepts data on individual parcel structural and locational characteristics to identify effects on real estate prices. Hypothetically, the BBC model can express, in dollar terms, what portion of a home's selling price is due to various factors, ranging from measures of property isolation to the presence of a garage or other outbuilding. The hedonic model approach was chosen because it can be input with real sales transaction data, which is the best measure of prevailing real estate market prices. Additionally, the model should be able to demonstrate how a home's value rise or falls with its proximity to an industrial use, such as a gravel pit or a natural gas well.

SECTION IV.
Modeling Results

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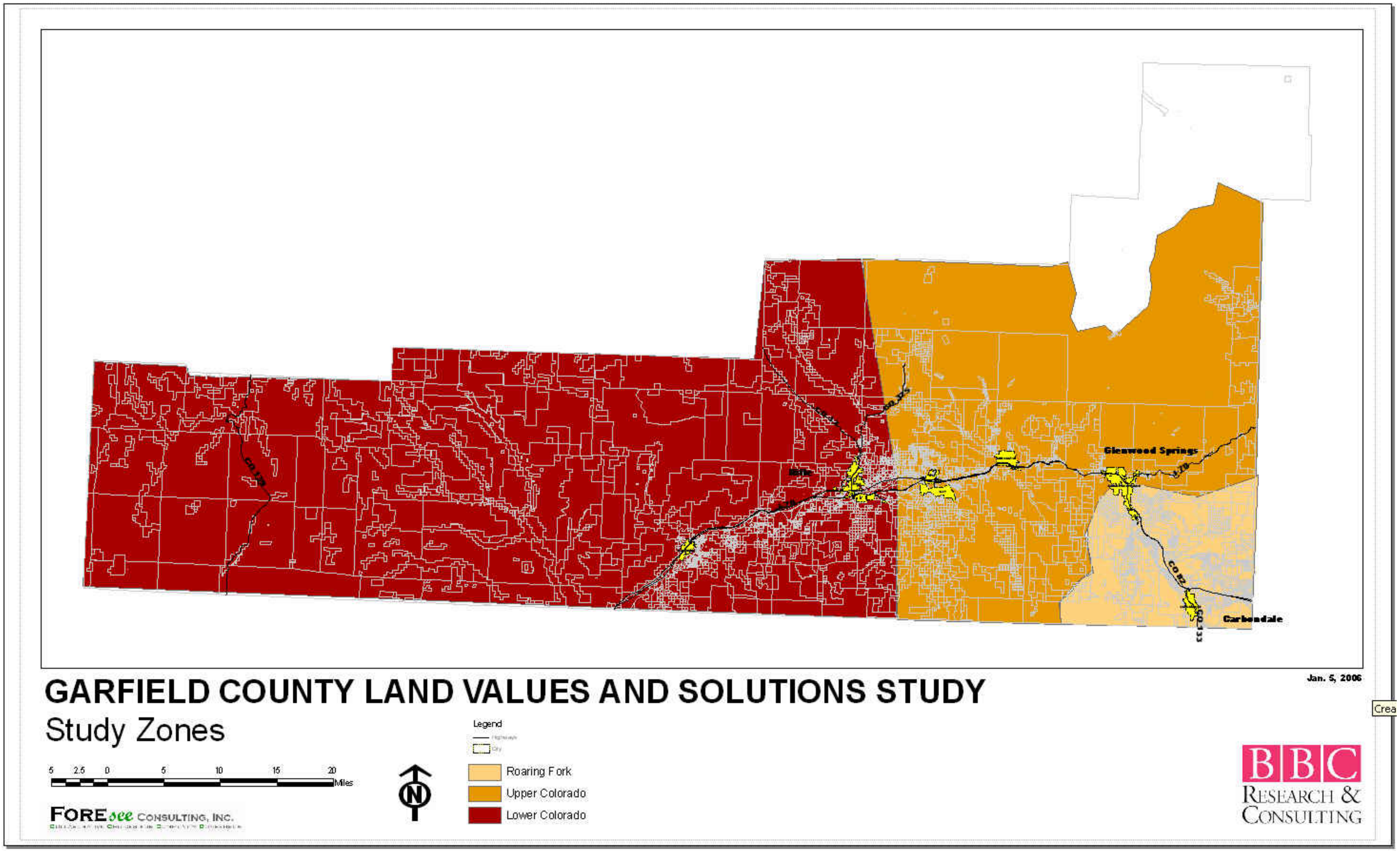
Modeling Results

The prior section reviewed the decision to use a hedonic pricing model and the model's attributes. This section discusses model development and testing, and presents the results of BBC's hedonic pricing analysis of rural residential property values in Garfield County.

Data Overview

BBC performed regression analysis on 7,453 property transactions between 1980 and 2005 after excluding sales involving multiple parcels, non-rural residential parcels and parcels greater than 160 acres. After experimentation with the model, BBC divided Garfield County into three separate areas based on localized economic influences. Ultimately these three sub-areas were consolidated into two regions—the Roaring Fork River Valley, and the Colorado River Valley—each of which demonstrated distinct economic variations. BBC created separate models for each area. Exhibit IV-1 on the following page shows the three original the subject sub-areas.

Exhibit IV-1.



Source: ForeSee Consulting, Inc..

Exhibit IV-2 presents summary statistics for the parcel data used for the two regional models and highlights the variations between the two areas.

Exhibit IV-2. Descriptive Statistics of the Property Sales Data for the Study Area

Note:

1. Values include properties with no home and thus zero residential square feet.
2. Variable was not included in the model.

Source:

BBC Research & Consulting.

Attributes of Properties Analyzed	Roaring Fork River Valley N = 2,726	Colorado River Valley N = 4,727
Average Square Footage	1,116[1]	1,145[1]
Average Heated Square Footage of Outbuildings	175	108
Average Number of Outbuildings	1.4	1.5
Average Acreage	6.1	9.9
Average Percentage of Good Vegetation	–[2]	2%
Percentage with Presence of Water Features	5%	5%
Percentage with a Garage	–[2]	49%
Percentage North of the Colorado River	–[2]	35%
Percentage with a View of Mount Sopris	74%	–[2]
Percentage of "New" Houses	18%	26%
Percentage of Houses on Community Sewer	24%	–[2]
Percentage Sold Prior to 1990	19%	15%
Percentage Sold Between 1991-1993	12%	15%
Percentage Sold Between 1994-1996	19%	20%
Percentage Sold Between 1997-1999	17%	19%
Percentage Sold Between 2000-2002	18%	16%
Percentage Sold Between 2003-2005	14%	15%
Average Distance to Paved Garfield County Road (miles)	0.3	0.4
Average Distance to Glenwood Springs (miles)	–[2]	26.3
Average Distance to Pitkin County (miles)	6.6	–[2]
Average Distance to the Nearest Gravel Pit (miles)	2.3	5.0
Percentage with a Gas Well Completed more than 2 years prior to the sale	–[2]	0.5%
Percentage with a Gas Well Completed less than 2 years prior to the sale	–[2]	0.1%
Percentage with a Gas Well Completed within 90 days of the sale	–[2]	0.1%

Note that there were no sales of properties with natural gas wells in the Roaring Fork River Valley. Thirty-two properties in the Colorado River Valley database had wells completed before or within ninety days of the sales transaction.

The average size in square feet for sold properties is lower than the average home size for the two data sets due to the inclusion of land-only parcels in the calculations. Fifty-four percent of sales in the Roaring Fork Valley and thirty-five percent of the sales in the Colorado River Valley included parcels with no home. Thus, the average home size for properties was 2,400 square feet and 1,760 square feet respectively for the Roaring Fork Valley and the Colorado River Valley.

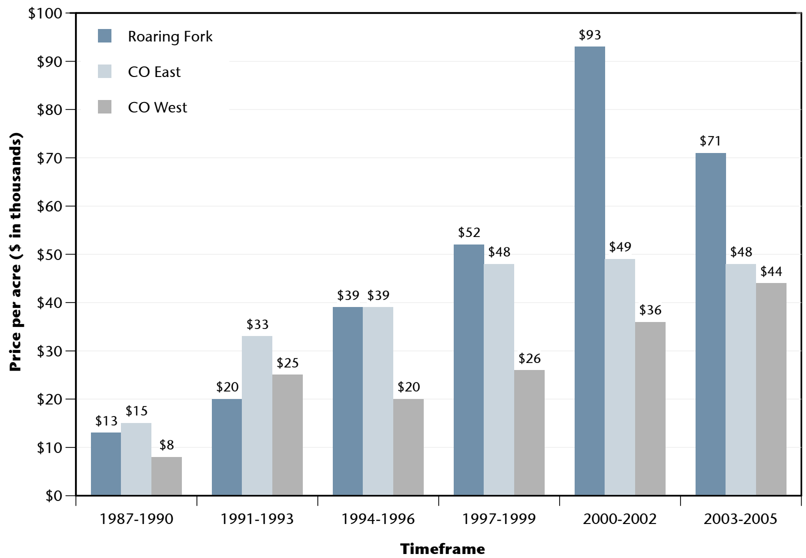
Exhibit IV-3 on the following page shows the location of parcels by date of home construction. Perhaps surprisingly, there is little change in the location of development over time, except for a modest increase in sales activity in the Rifle – Silt area in recent years.

Exhibit IV-4 shows the increase in price per acre for small, land-only properties (1-5 acres) sold in the east and west Colorado River Valley as well as the Roaring Fork River Valley. Property values have risen over the study period and remain highest for parcels in the Roaring Fork River Valley.

Exhibit IV-4. Property Value Per Acre Over Time—Small Parcels Without Structures

Source:

BBC Research & Consulting.



Similarly, Exhibit IV-5 shows the price per acre for larger land-only parcels (20-40 acres) in the three regions of the county.

Exhibit IV-5. Property Value Per Acre Over Time—Larger Parcels Without Structures

Source:

BBC Research & Consulting.

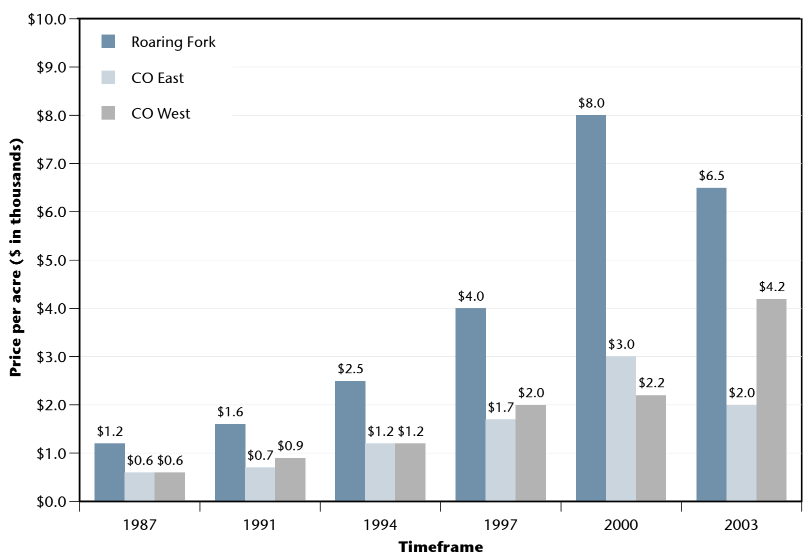
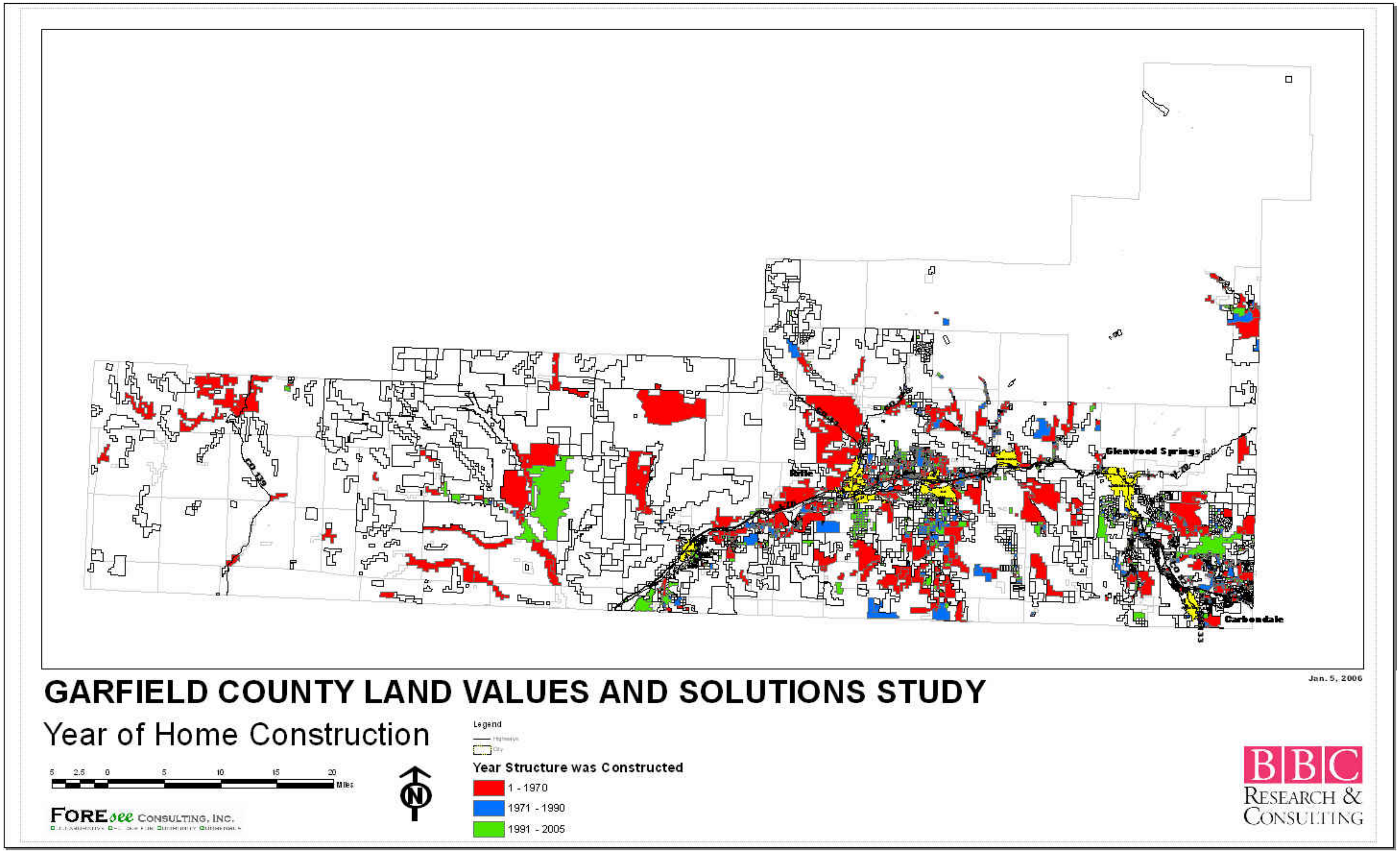


Exhibit IV-6 on page 6 shows the price per acre of land only parcels by size for properties sold between 2003 and 2005. The price per acre increases as the size of the parcel diminishes, indicative of the inherent value of being able to locate a structure.

Exhibit IV-3.

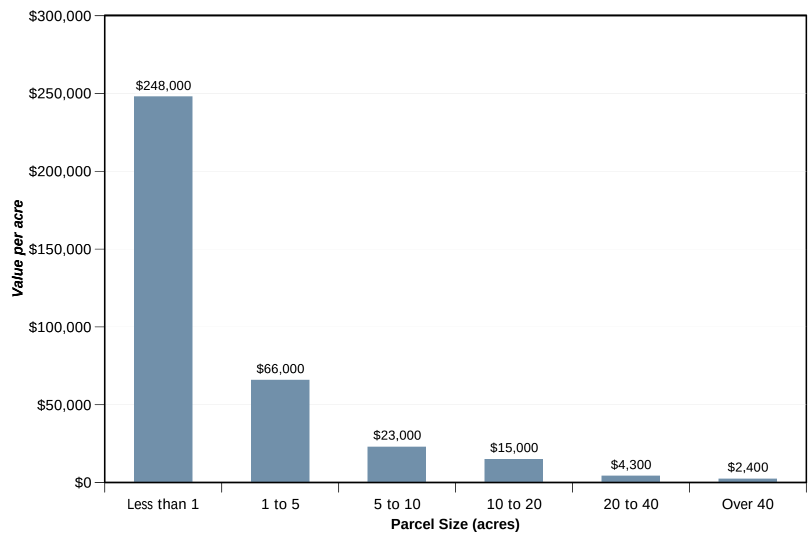


Source: ForeSee Consulting, Inc.

Exhibit IV-6. Property Value Per Acre by Parcel Size (2003-2005 Without Structures)

Source:

BBC Research & Consulting.



Roaring Fork Valley Model Results

After considerable experimentation, BBC created two distinct models to describe property values in Garfield County. The model for the Roaring Fork Valley contained 2,726 observations and explained approximately 76 percent of the variation of sales prices. Exhibit IV-7 details the coefficients for the model describing Roaring Fork Valley properties.

Exhibit IV-7. Roaring Fork Valley Property Value Coefficients

Note:

**** Statistically different from zero at a 99 percent confidence level.

*** Statistically different from zero at a 95 percent confidence level.

** Statistically different from zero at a 90 percent confidence level.

* Coefficients are not statistically different from zero at a 90 percent confidence level.

Source:

BBC Research & Consulting.

Property Attributes	Coefficient
Impact of Structure and Location	
Home Square Feet x T	$7.6 per square foot times years since 1987****
Acreage x T	$547 per acre time years since 1987****
Number of Outbuildings	$13,746 per outbuilding****
Heated Outbuilding Square Feet	$46.9 per heated square foot****
Property Has Water Feature	$75,820 per property****
View of Mount Sopris	$51,570 per property****
Effective Age of House Under 10 years	$75,452 per property****
Non-septic Sewer System	$101,829 per property****
Miles to CO 82 and Pitkin County Line	-$8,093 per mile****
Miles to Paved County Road	-$57,934 per mile****
Impact of Sales Period	
Sold between 1987 and 1990	$37,852 per property****
Sold between 1991 and 1993	$33,511 per property***
Sold between 1994 and 1996	$106,505 per property****
Sold between 1997 and 1999	$145,691 per property****
Sold between 2000 and 2002	$191,163 per property****
Sold between 2003 and 2005	$179,888 per property****

The Roaring Fork Valley model yielded the following results:

- Fifteen of the sixteen variables are statistically significant at a 99 percent confidence level and the remaining variable is significant at a 95 percent confident level.
- The coefficients for the view of Mount Sopris, effective age of house under 10 years, non-sewer septic system, and whether the property was near a water feature were all numerically large, positive and statistically significant at a 99 percent confidence level.
- The coefficients for acreage times years since 1987; and house size in square feet times years since 1987 were both positive and statistically significant at a 99 percent confidence level.
- The coefficients for variables measuring distance in miles from paved roads and the intersection of State Highway 82 and the Pitkin County line were negative and statistically significant at a 99 percent confidence level.
- All of the date-of-sale coefficients were statistically positive and statistically significant at a 95 percent confidence level. These coefficients, in general, were larger for sales dates representing later years.

Exhibit IV-8 shows the property value for a typical property with a house in the Roaring Fork Valley sold in 2005.

Exhibit IV-8.
Typical Roaring Fork Valley Property Value Model Components

Source:
BBC Research & Consulting.

T=time of sale

Property Attributes	Variable Value	Resulting Property Value
Year of Sale	Between 2003 and 2005	$179,888
Acreage x T since 1987	6 acres times 18 years	$59,076
House size x T since 1987	2200 square feet times 18 years	$298,980
Number of Outbuildings	1.4	$19,244
Heated Square Feet in Outbuildings	175	$8,206
Effective Age of House Less Than 10 years	Yes	$75,452
Miles to Pitkin County	7	-$56,651
Miles to Paved County Road	0.28	-$16,222
Has Water Feature on Property	No	$0
Has a View of Mount Sopris	Yes	$51,570
Has Non-Septic Sewer System	No	$0
Total Property Value		**$619,543**

Colorado River Valley Model Results

The model for the Colorado River Valley contained 4,727 observations and explained approximately 81 percent of the variation of sales prices. Exhibit IV-9 details the coefficients for the model describing Colorado River Valley properties.

**Exhibit IV-9.
Colorado River Valley Property Value Model Coefficients**

Property Attributes	Coefficient
Impact of Structure and Location	
Home Square Feet x T	$3.1 per square foot times years since 1987****
Acreage x T	$166 per acre time years since 1987****
Property Has a Garage	$9,279****
Number of Outbuildings	$12,714per outbuilding****
Heated Outbuilding Square Feet	$24.1 per heated square foot****
Property Has Water Feature	$15,077 per property***
Property is North of the Colorado River	$27,541per property****
Effective Age of House Under 10 years	$21,449per property****
Percentage of Good Vegetation	$39,476 per percentage point**
Miles to Glenwood Springs	-$800 per mile****
Miles to Paved County Road	-$11,867 per mile****
Impact of Sales Period	
Sold between 1987 and 1990	$10,815 per property**
Sold between 1991 and 1993	$12,943 per property***
Sold between 1994 and 1996	$28,201 per property****
Sold between 1997 and 1999	$38,827 per property****
Sold between 2000 and 2002	$59,732 per property****
Sold between 2003 and 2005	$77,767 per property****

Note:

**** Statistically different from zero at a 99 percent confidence level.

*** Statistically different from zero at a 95 percent confidence level.

** Statistically different from zero at a 90 percent confidence level.

* Coefficients are not statistically different from zero at a 90 percent confidence level.

Source:

BBC Research & Consulting.

A review of the Colorado River Valley model yields the following results:

- Thirteen of seventeen coefficients were statistically significant at a 99 percent confidence level. Two coefficients were statistically significant at a 95 percent confidence level and the remaining two variables were statistically significant at a 90 percent confidence level.

- The coefficients for acreage times years since 1987; and house size in square feet times years since 1987 were both positive and statistically significant at a 99 percent confidence level.

- The coefficients representing the impact of a effectively new house, a garage on the property, a water feature on the property, a property located north of the Colorado River and an increase in the percentage of good vegetation were numerically large and positive.

- The coefficients representing the impact of a property located further from Glenwood Springs and paved county roads were both negative and statistically significant at a 99 percent confidence level.

- The coefficients for the date-of-sales bins were all positive and increased over time.

In addition, a comparison of the models for the Roaring Fork Valley and Colorado River Valley shows an increase in magnitude of all comparable effects for the Roaring Fork Valley model.

Exhibit IV-10 shows a typical property with a house in the Colorado River Valley and the predicted 2005 value from the model.

Exhibit IV-10. Typical Colorado River Valley Residential Property Value Components.

Source:
BBC Research & Consulting.

Property Attributes	Variable Value	Resulting Property Value
Year of Sale	Between 2003 and 2005	$77,767
Acreage x T since 1987	40 acres times 18 years	$119,239
House size x T since 1987	1500 square feet times 18 years	$83,430
Number of Outbuildings	1.2	$15,257
Heated Square Feet in Outbuildings	16	$385
Effective Age of House Less Than 10 years	Yes	$21,449
Property Has a Garage	0	$9,279
Miles to Paved County Road	1	-$11,867
Distance to Glenwood Springs	29	-$23,200
Has Water Feature on Property	No	$0
North of the Colorado River	No	$0
Percentage of Property with Good Vegetation	2%	$790
Total Value		**$283,250**

The above hypothetical property is used as the baseline example for testing characteristic alternatives and the impact of industrial uses.

General Results

The results of both the Colorado River and Roaring Fork Valley models conformed with BBC's expectations based on previous analyses, traditional real estate sales data and anecdotal information from community members. Both models show an increase over time in property values, an increase for each additional acre of property size, and an increase for additional square footage of house size. Both models show an increase in value of homes over time, although it is interesting to note that the value of property sales in the Colorado River Valley has increased steadily since 2000 while the value of Roaring Fork property sales decreased slightly in the period 2002-2004. Possible explanations for this difference include the increase in natural gas related jobs in the Colorado River Valley and the modest economic downturn of the second home and retirement markets following the World Trade Center bombing.

The attached Exhibit IV-11 on the following page shows variations in county land values by location. Because the county is so large and because there is such a wide range of per acre values, these variations are difficult to present graphically.

In sum, BBC developed a hedonic pricing model that utilized over 7,000 samples of property sales data to correlate rural county property characteristics with recoded sales values. The resultant model allows the operator to demonstrate how changes in any single property characteristic or collection of characteristics would theoretically alter a property's market value. The models—there are two, each covering different parts of the county—have a high degree of statistical validity and generally present data that are in accord with the observations of local Realtors and land owners.

Industrial Impacts

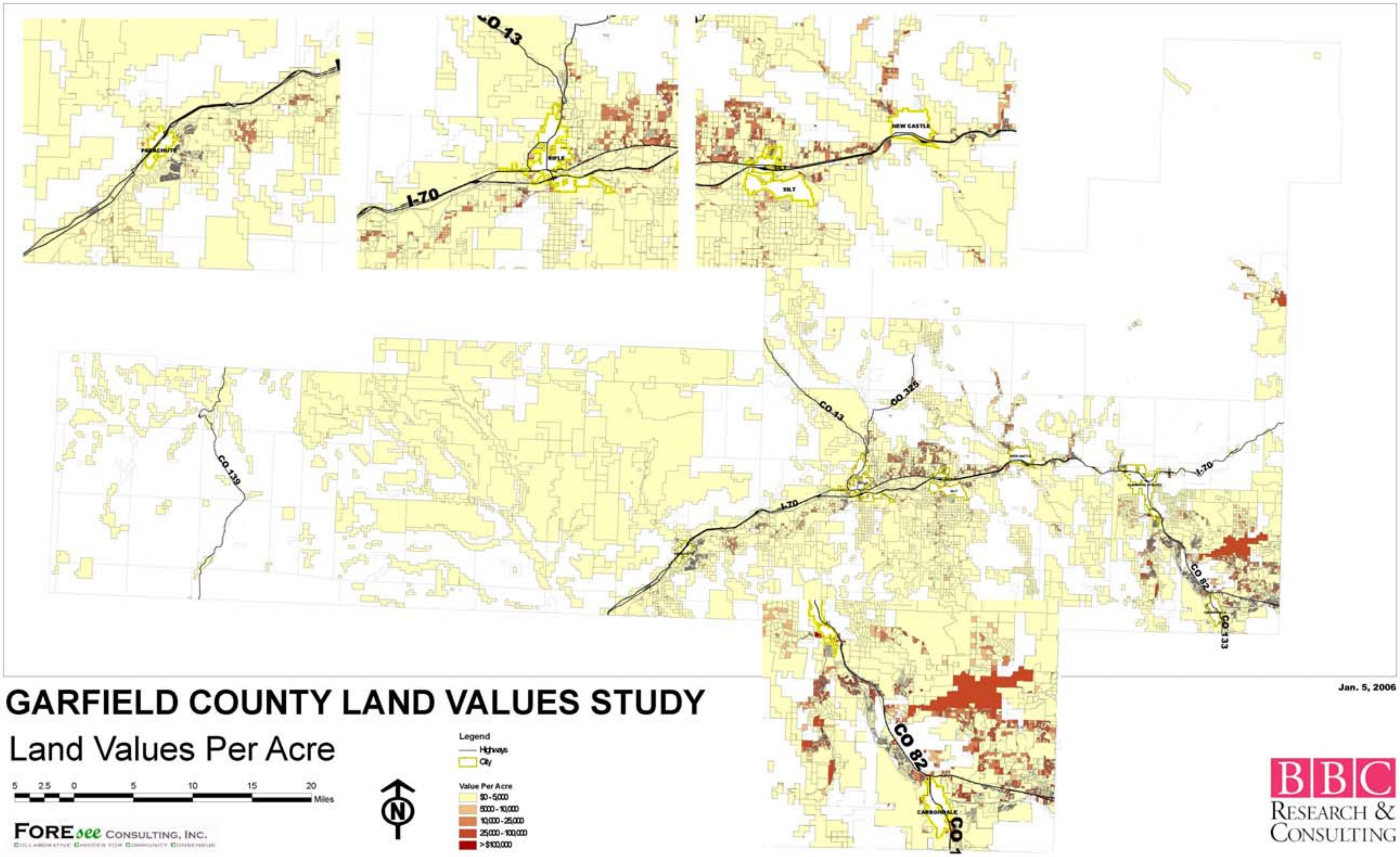
The primary impetus behind the land value models created for Garfield County was an investigation of industrial impacts on property values. BBC used data gathered from industry and county sources, as well as field surveys to analyze the value effects of landfills, railroad lines, high voltage power lines, gravel pits, the presence of I-70, and natural gas well drilling activity. The results of these investigations are discussed below.

Landfills. BBC obtained landfill locations from the Garfield County Information Technology Department. Foresee Consulting Inc. used the Garfield County parcel map to determine the distance from the center of each parcel to the closest landfill. After including the distance to the closest landfill in both the Roaring Fork Valley model and the Colorado River Valley model, BBC was unable to quantify the effect of landfills on property value as statistically different from zero.

Interstate 70. ForeSee consulting provided GIS data indicating a distance from each parcel in the county to I-70. It was hypothesized that living closer to I-70 would prove to be a disamenity and result in lower land values. The statistical analysis failed to prove that the impact of the distance of a property to I-70 was statistically different from zero.

Railroad lines. BBC received a GIS layer of railroad tracks from the Garfield County Information Technology Department. Foresee Consulting, Inc. used this layer to calculate the distance from the center of each parcel to the closest railroad track. BBC used this information in models for the Roaring Fork Valley and the Colorado River Valley, but was unable to find that the impacts of railroad tracks were statistically different from zero.

Exhibit IV-11.



Source: ForeSee Consulting, Inc.

High voltage power lines. The Garfield County Information Technology Department provided BBC locations of all utility lines in Garfield County. ForeSee Consulting, Inc. used this information to determine the distance of each parcel to the nearest high voltage power line. BBC included this information in models for both the Roaring Fork Valley and the Colorado River Valley, but was unable to find the coefficient for the variable to be statistically different from zero.

Gravel pits. The consulting team collected information on major gravel pits in Garfield County with assistance from the Garfield County Information Technology Department and the Garfield County Assessors Office. Using GIS software BBC calculated the distance between the closest gravel pit and the center of each parcel in Garfield County. BBC tested the explanatory value of this information on property sales in both the Roaring Fork Valley model and the Colorado River Valley model. Although the coefficient in the Roaring Fork Valley model was not statistically significant, it was statistically significant in the Colorado River Valley model.

Exhibit IV-12 shows the impact of the distance to a gravel pit on the typical property. As shown, the value of a typical $283,250 property increases by $4,096 for every additional mile between the property and a gravel pit. For example, a hypothetical property located two miles from a gravel pit, could be expected to see a $8,192 increase from the value of an otherwise identical property located adjacent to the gravel pit.

Exhibit IV-12.
Adjusted Property Value for Gravel Pit Effects (Colorado River Valley)

Property Attribute	Value
Gravel pit valuation impact	$4,096 per mile****
Property Value of typical property located adjacent to a gravel pit	$283,250
Increase in property value due to 2 miles distance from the closest gravel pit	$8,192
Total Property Value including gravel pit effects	$291,442*

Note:
**** Statistically different from zero at a 99 percent confidence level.
*** Statistically different from zero at a 95 percent confidence level.
** Statistically different from zero at a 90 percent confidence level.
* Coefficients are not statistically different from zero at a 90 percent confidence level.

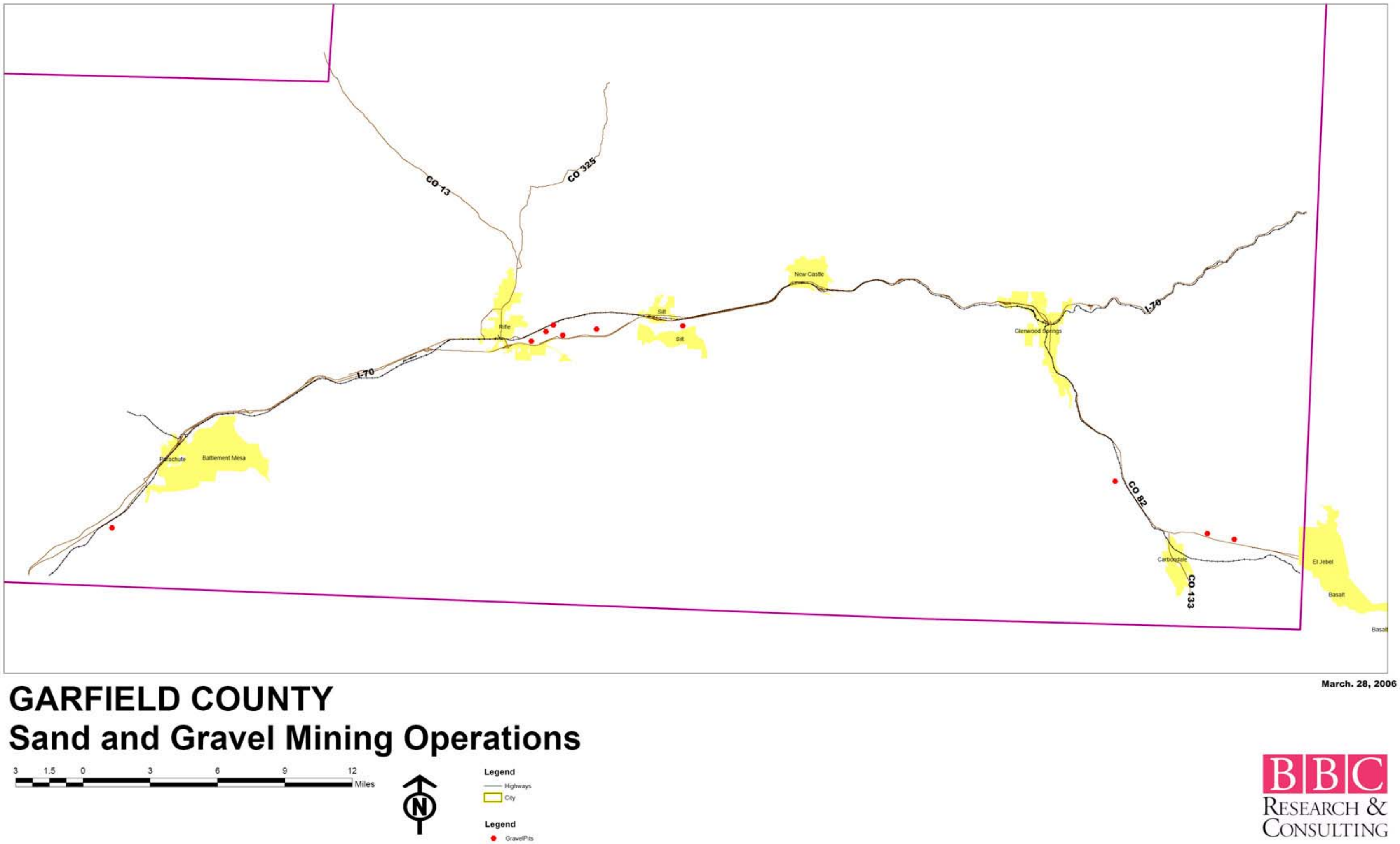
Source:
BBC Research & Consulting.

Exhibit IV-13 on the following page shows the location of active gravel pits in Garfield County.

The gravel pit analysis suggests that properties proximate to gravel pit extraction activities will witness a diminution of value. Anecdotally, this loss of value appears to be due to the noise, dust, lights, truck traffic and environmental degradation associated with gravel activity. It is likely that impacts extend along access roads where traffic is increased, but our sample of property sales did not allow that representation. Some gravel pits have spurred other industrial activity on site, such as equipment storage, a change of use that might contribute to these losses.

These issues and mitigation strategies are discussed in detail in the next section of this report.

Exhibit IV-13.



Source: ForeSee Consulting, Inc.

Natural gas well impacts. The Garfield County Energy Advisory Board (GCEAB) suggested that BBC use a slightly different methodology when looking at impacts on property values from natural gas well drilling activity. Gas drilling, in contrast with other industrial land uses, has temporal quality—most impacts occur over a relatively short period. The majority of disruptive activity associated with natural gas development occurs during the initial well drilling stage. GCEAB suggested that this phase of gas development would likely have the largest impact on property value. After the drilling period, GCEAB hypothesized that the value would rebound closer to the value of an identical property without a natural gas well. BBC used data from the Colorado Oil and Gas Conservation Commission (COGCC) to determine locations and completion dates for active wells in Garfield County. BBC then determined if a property had a well in the drilling phase, a newly completed well, or a well that was completed prior to two years before the sale. BBC only used this information in Colorado River Valley model, as there were no parcels sold with natural gas wells in the Roaring Fork Valley during the study period.

As of December, 2005, COGCC reported 5,010 gas well permits for Garfield County. BBC used COGCC-reported well status codes to eliminate plugged or abandoned wells and only included completed wells in our analysis. The remaining 2,674 operational wells in Garfield County exist on 354 parcels of land. Only 144 of these properties sold during the study period. BBC excluded sales of multiple parcels in addition to sales marked invalid (non arms length transactions) in the Assessors database. This process resulted in 64 sales of properties with gas wells, of which 32 were larger than 160 acres and thus excluded from the sample analysis.

Of 32 sales included in the model, fifteen had a home built on the property before the sale or during the year of sale. Sixty percent of all included sales in the Colorado River Valley involved properties with a home built before or during the sale year. While the impact of gas development most likely differs between properties with and without a residence, quantifying this impact would not have been possible given the limited number of sales directly affected by gas wells.

Exhibit IV-14 shows a more detailed outline of the numbers of Garfield County gas wells and sales of properties with wells during the study period.

Exhibit IV-14.
Garfield county gas wells and sales included in land issues model.

Source:

Well data from the Colorado Oil and Gas Conservation Commission (COGCC) website as of 12/16/05. Sales data from Garfield County Assessor's Office for sales between January, 1987 and September 2005. BBC Research & Consulting.

Description	Number
Natural gas well permits	5,010
Natural gas well completions	2,918
Operational wells (not plugged or abandoned)	2,674
Parcels with operational wells	354
Parcels sold with wells	144
Sales transactions of parcels with wells	242
Valid sales transactions of parcels with wells	201
Valid single parcel sales of parcels with wells	140
Total sales with well completed before or within 90 days of sale	64
Number of transactions where well was drilled prior to 2 years before sale	50
Number when limited to parcels under 160 acres	23
Number of sales where well was drilled within 2years prior to sale	10
Number when limited to parcels under 160 acres	6
Number of sales where well was completed within 90 days of sale	4
Number when limited to parcels under 160 acres	3
Total sales included in model with "well-impacts"	32

Exhibit IV-15 shows the impact of the three different well-completion periods on the typical property shown in prior Exhibits IV-8 and IV-9. Although the findings appear to support the initial hypothesis, the sample size is small and the correlation lacks statistical significance. One possible reason for the lack of statistical significance is the dearth of data for rural-residential properties sold with natural gas wells. As indicated above, of the 4,727 sales used in the Colorado River Valley model, only 32 properties had sold with active or completed wells.

Exhibit IV-15.
Natural Gas Well Impacts (Colorado River Valley).

Note:

**** Statistically different from zero at a 99 percent confidence level.

*** Statistically different from zero at a 95 percent confidence level.

** Statistically different from zero at a 90 percent confidence level.

* Cofficients are not statistically different from zero at a 90 percent confidence level.

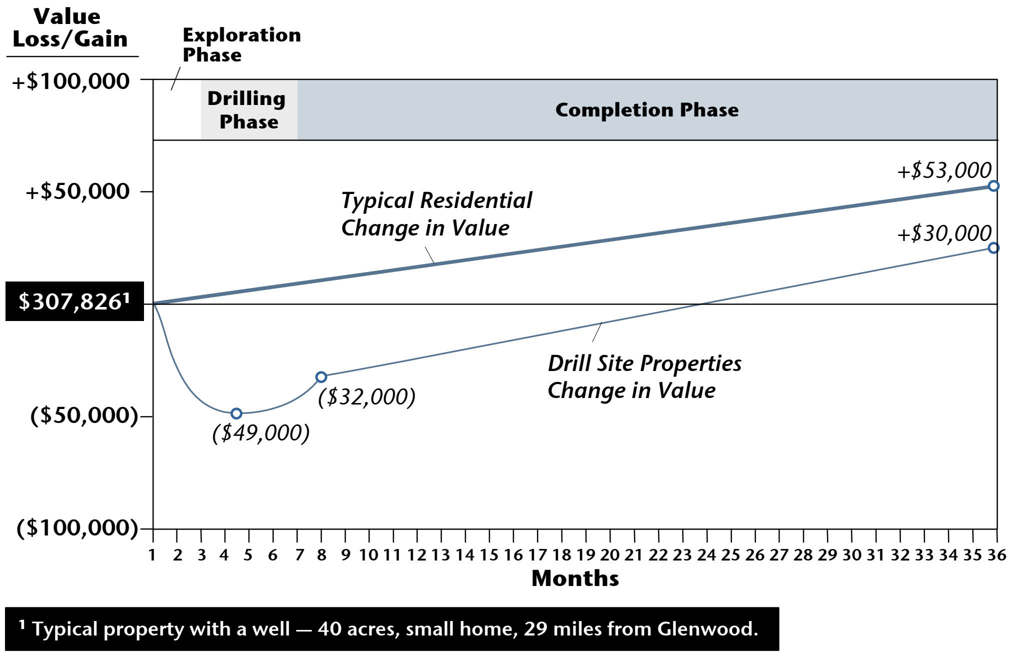
Source:

BBC Research & Consulting.

Property Attribute	Well completed 90 days or less after the sale	Well completed in the two years prior to the sale	Well completed prior to two years before the sale
Initial Property Value	$307,826	$307,826	$307,826
Impact of well on property	-$48,343*	-$31,816*	-$23,009*
Percentage Impact	-15%	-10%	-7%
Final Property Value	$259,483	$276,010	$284,817

Exhibit IV-16 offers a plausible representation of the property value curve suggested by the GCEAB and the data developed in Exhibit IV-15. The curve shown assumes continued baseline property appreciation as witnessed over the past decade.

Exhibit IV-16.
Hypothesized Impact Curve for Natural Gas Wells



Source: BBC Research & Consulting.

Although sample sizes and price correlations lack authoritative, statistical reliability, which limits broader application, the land valuation impact shown in Exhibit IV-16 offers the consultants' best representation of how gas drilling activity impacts property values in the Colorado River Valley of Garfield County.

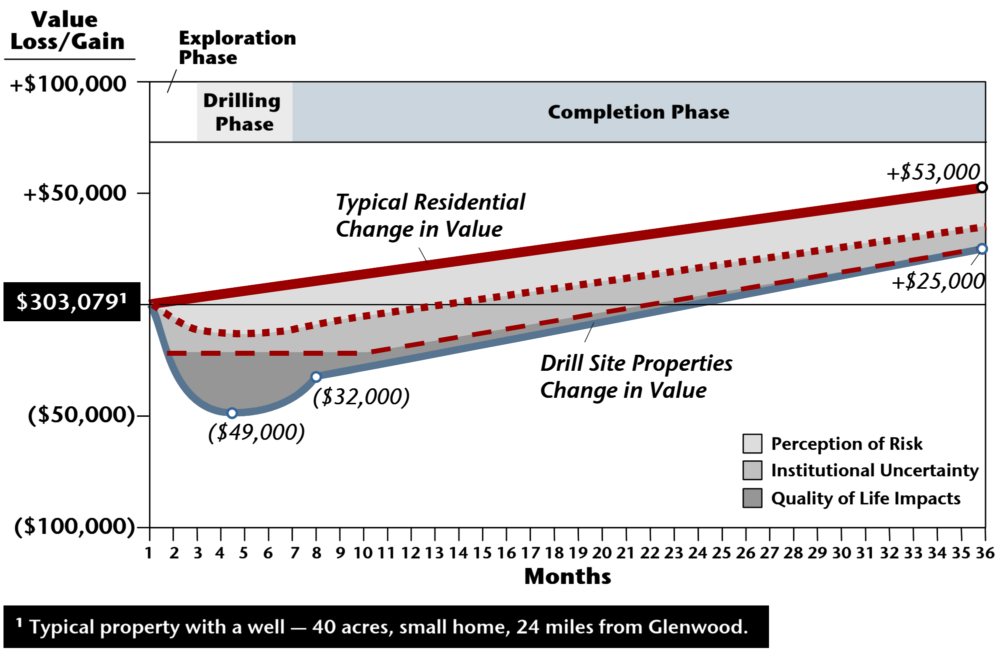
On average, property owners who sell their homes during the active drilling phase of gas exploration can expect to bear a 15 percent loss of value for a typical Garfield County parcel valued at about $308,000. The length of the most significant financial loss can vary depending on the nature and length of the drilling activity and a variety of associated factors. As drilling activity and accompanying impacts diminish and the project enters a completion phase, most property values will begin to return to prior levels, although property values may never achieve the same level of appreciation garnered by similar properties that do not have wells on site.

The loss of value shown in Exhibit IV-15 can be tied to the cumulative impact of three contributory factors that are detailed in Exhibit IV-16. The shaded regions shown in Exhibit IV-17 represent the consultants' best representation of the components of property value loss and recovery caused by gas well drilling.

The first component of property value loss, shown in dark gray is the loss of property value caused by quality of life impacts on the parcel affected by gas drilling. Quality of life impacts include all the physical impacts of gas well drilling, including noise from drilling, increased heavy truck traffic and odor. These impacts are largest during the drilling period and diminish quickly as projects are completed and on-site activities diminish.

The second component of property value loss is shown below in Exhibit IV-17 as the region shaded medium-gray, in between the solid and dotted lines. Institutional uncertainty is the loss of value associated with the perceived uncertainty of drilling effects, and sometimes the reluctance of Realtors, lending institutions, or mortgage companies to accept the uncertain impacts of gas drilling activity. While most well drilling activity has little long-term impact, some wells are problematic—producing noise, odors, fires or environmental disruption. There is also the possibility of redrilling the field at some future date. Regardless of the most likely scenario, appraisers, lenders and Realtors understand risk and some institutions would rather avoid the complications all together and thus will avoid recommending or accepting properties for borrowing purposes if gas drilling is present.

Exhibit IV-17.
Hypothesized Impact Curve With Value Loss Components

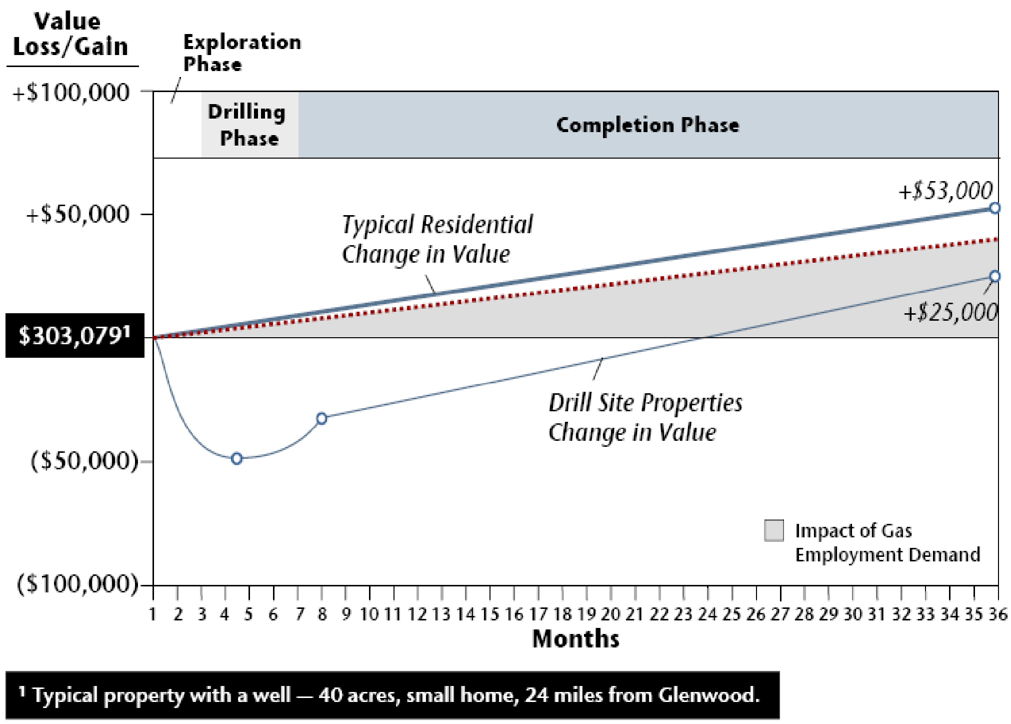


Source: BBC Research & Consulting.

The final component of potential property value loss associated with drilling activity is the potential buyer's perception of risk, which is represented above in Exhibit IV-17 in light-gray. Similar to lending institutions and Realtors, potential buyers wish to avoid a property at risk for continued on site gas development. The geology of the gas field alone dictates the size, density and duration of gas harvesting operations and therefore potential buyers and the lending community are faced with an uncertain situation when evaluating property with or adjacent to gas wells. Risk aversion does not disappear as quickly as do quality of life impacts after the drilling period is over. There is continued uncertainty that new gas development may take place in the immediate vicinity of completed gas wells, due to possible technological advances or new discoveries of subterranean gas deposits.

It is important to acknowledge that property values in Garfield County have appreciated in large part because of housing demand generated by gas employment activity. Estimates of the gas industry contribution to Garfield County's employment and subsequent housing demand is shown in Exhibit IV-18 as the shaded gray area.

Exhibit IV-18.
Hypothesized Impact Curve With Impact of Gas Employment Demand



Source: BBC Research & Consulting.

The increased natural gas harvesting activity has caused an increase in jobs available in Garfield County. Workers are moving to Garfield County to fill those jobs and need housing, thus driving housing demand, and property values up. The net effect of gas development in Garfield County has driven property values up, even for those persons who own property in close proximity to gas wells. For the great majority of persons living in the Colorado River Valley, the economic stimulation and housing value appreciation brought on by gas drilling has proved to be a significant benefit.

Limitations and Caveats

Although hedonic pricing models are valuable tools for analyzing pricing effects of various property characteristics, it is important to note the limitations of this method in general, and of these results in particular.

Land value trends reflect numerous factors, property characteristics and changing buyer preferences. Many property characteristics are not captured in the database used in this analysis. For instance, the availability, quality and reliability of water sources is known to significantly influence property values in unincorporated areas, and even subtle characteristics, such as the quality of views and vegetation at a particular building site, can greatly alter a parcel's value. Generally, a large sample size will ameliorate some of these discrepancies but ultimately a statistical model is only as accurate as the data supporting the work. In this process, BBC used the best data available for Garfield County, but these data are still incomplete and contain inaccuracies. For example, the parcel map for Garfield County is still being refined and has errors associated with parcel locations. Although BBC worked with the Garfield County Information Technology Department to eliminate many of these problems it is doubtful that the data conflicts are entirely resolved. In addition, the sales data may not have contained all sales for late 2004 and early 2005. Given the pace of natural gas development and paucity of properties sold with natural gas wells, these data would have helped clarify the property value impacts of natural gas wells.

The industrial impact analysis presented a number of additional challenges. Many intrusions, which were thought to impact land values, did not demonstrate any reliable effect. Although gravel pit operations and gas drilling activity did reveal a negative impact, other activities, such as power lines, railroads and highways, which have demonstrated negative value impacts in other hedonic valuation studies, did not demonstrate significant impacts in this analysis in this county. This finding does not mean that these activities have no property value impact, simply that the data and process employed here did not demonstrate that such an impact existed in the particular circumstances of Garfield County. It may be that the data set had flaws; the specific set of sales data were influenced by other factors; or the sample was too small to be conclusive. It also may be true that the hypothesis was simply wrong. Certainly, one would expect to demonstrate a diminution of value from the presence of say, large electric power lines, and such impacts have been demonstrated in other situations, but no such demonstrable effect was revealed in Garfield County. This may be because most properties were ranchlands where power lines were of little consequence, or because the remainder of the ranch had valuable characteristics that overcame the modest impact of remote power lines.

Not surprisingly, some industrial activity in rural areas does result in adverse impacts to residential property owners. In Garfield County, gravel pit operations and gas drilling activity showed a demonstrable negative impact on property values. Oil and gas drilling activity and gravel pit operations do appear to have an impact on property value, perhaps a temporary effect, but the sample size here does not allow conclusion with statistical authority.

It appears that gas drilling has a negative impact on affected land values for the period that drilling activity, and associated quality of life measures, is disrupted. As drilling is replaced with an operating well, valuation impacts diminish and property value rise. Over time, values appear to return toward baseline conditions, but the perception of possible environmental and operating risks remain, and property values lag those of equivalent properties without wells. It is also notable that over time the impact of gas drilling activity, and the employment and household demands it creates, probably drives home values higher, even for gas well affected homes, than the negative impacts diminish property value. For the great majority of Garfield County homeowner, gas drilling has had a significantly beneficial impact on home values.

The next section of this report discusses these conclusions and policy implications in detail.

SECTION V.
Impact Mitigation and Best Practices

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This section draws upon findings from the prior sections, local interviews, and anecdotal data from research in Garfield County and the experience of other counties in similar situations to develop impact mitigation strategies and best practices that can lessen the impact of industrial development on rural residential land values.

Context

Anecdotal data support the analytical findings of BBC land valuation models:

- Garfield County has enjoyed rapid growth in property values over the past decade. Initially, the impetus for growth came from employment demands in Pitkin County and second home growth in the Roaring Fork Valley. More recently, employment in the gas drilling industry and well field services has spurred a new round of indigenous demand within the county.

- The county is realistically described as two “economic watersheds”: the Roaring Fork Valley and the Colorado River Valley. Property values respond to different factors in these two areas with the former driven by proximity to the Pitkin County resorts and the esthetic value of the subject parcels, and the latter determined more by site suitability for housing and recent growth in the energy industry.

- Although many factors can adversely influence rural residential property values, two industrial factors were statistically verifiable in Garfield County: gravel pits and gas drilling activity. Many other factors, such as power lines and proximity to the Interstate, did not show the expected land value impacts.

- Generally, gravel extraction facilities present a predictable, fairly uniform and consistent impact on the enjoyment and value of nearby property. This effect is well recognized, intuitive, and occurs in virtually every county in Colorado.

- Gas drilling activity is a far more complicated, less predictable, less uniform phenomenon with uncertain impacts. Since mineral rights and gas field management is a matter of state interest, the county has fewer tools available to mitigate drilling-related impacts.

- Gas drilling has a demonstrable impact on housing values for those properties experiencing drilling activity. On average, significant losses in value are temporary and the average property returns to near normal values after activity subsides. There is always some loss of value associated with well presence, in part the result of a perception of health and environmental risk by the buyer.

Gravel Extraction

Aggregate materials mined at gravel pits are a fundamental element of urban infrastructure development and is used in making concrete, asphalt and other stone-based building materials. Growth of demand for gravel is likely as gravel is needed to meet the demands of all urban growth and is an important component in the development of gas field platforms and roads. The location of gravel pits in populated areas is a frequent cause of concern for local residents and environmental advocates. Local governments have long standing review processes that attempt to mitigate impacts or disallow development where it is deemed inappropriate. However, potential gravel extraction sites are often limited, due to transportation cost concerns and the existence of productive aggregate deposits.

Gravel extraction operations involve heavy machinery, noise, truck traffic and possible blasting, which often affect the lifestyle and environmental quality of neighbors and nearby communities. There are also environmental concerns including threats to groundwater quality; impacts to fisheries and stream habitat; disruption of wildlife; and increased noise and dust pollution.

In Colorado, gravel pit location is generally subject to county and municipal land use codes and can be regulated effectively through zoning statutes and performance monitoring. Gravel pits are usually characterized as an industrial use and are generally located in the appropriate zones.

In these cases, adverse impacts can be mitigated by special use permits that generally require the following:

- Comprehensive noise mitigation plans, such as setbacks, acceptable traffic patterns, regular business hours, scheduled blasting;
- Complicity with all applicable county, state, and federal water and air pollution regulations;
- Detailed closure and reclamation plans that indicate the time frame and methods to effectively meet regulations for site abandonment; and
- An appropriate bond to secure the performance of the closure requirements and reclamation plan.

Although their presence does impact land values in the area, gravel extraction poses only a limited liability for local landowners because activity is locally regulated. The local land use planning process also offers an opportunity for citizen involvement in determining zoning statutes and future land use codes.

Gas Drilling Activity

Gas drilling activity at the scale currently underway in Garfield County, is a relatively new phenomenon and a challenging activity to manage.

Gas well drilling activity poses several problems similar to gravel extraction, including noise impacts, truck traffic and environmental concerns. Unlike gravel extraction, gas drilling activity is not a uniform or an entirely standardized process. Individual wells can have different drilling requirements and differing impacts. Some well platforms will serve as a site for multiple wells and thus remain in the drilling stage for many months. Other drilling platforms will serve only one well and will produce very short-term effects. Wells can be small operations at very isolated sites, or multiple, simultaneous activities encompassing large areas, or in close proximity to urban areas. Most importantly exploratory drilling and well development is a process that has multiple phases, each with their own set of impacts. Finally, some wells are abandoned and some wells remain active for many decades.

The uncertainty of well drilling effects, and thus the non-uniform impact on property values, particularly in comparison with gravel extraction, can be summarized as follows:

- **Well clustering.** One individual well may be quite benign and have very little impact on property values. Conversely, a field of activity, or continuous drilling in the same area, may have substantial effects on residential property enjoyment and values. Land value impacts are not always the same for every well and the impact of multiple wells may be more exponential than cumulative. Although it is environmentally preferable to cluster wells into one pad where possible, those landowners in the immediate vicinity of the clustered well pad may experience more significant property value impacts than other landowners further away from the clustered pad.

- **Specific well location.** Not all drilling platforms interfere with residential uses or enjoyment of property. If a well is out of sight and accessed by a separate road, it may produce little value effect, but a well in close view and accessed by a shared road may have a very serious impact on property value.

- **Temporary effects.** Generally, the negative impact of drilling activity is associated with the early phases of exploration and initial drilling, while the far longer operation of the well may have limited impacts. Thus, land value effects tend to be severe in the early months of activity but diminish thereafter.

- **Risk.** Some loss of value occurs from the simple risk associated with an uncertain phenomenon. While often well drilling and post drilling operations produce little immediate or long-term environmental impacts, problems do occur—including odors, contamination or other environmental disruption. Regardless of the most likely scenario, buyers understand risk and will try to avoid putting themselves in a risky position, if possible. Risk is not just a buyer issue, but also acknowledged by appraisers, lenders and re-finance companies.

The loss of value curve produced in the prior section incorporates most of these concepts, but ultimately the statistical loss of value curve describes an average or typical situation. Unfortunately, in gas drilling anomalous situations are commonplace. Additionally, the previously developed curve does not entirely address the variability of property value impacts on contiguous landowners. For instance, a landowner whose neighbor has a gas well on their property, which is in plain view across property lines, may experience a greater loss in value than if the gas well was on their own property and screened from view by topographical features.

Gas well impacts on property values are highly variable and some property owners may experience greater dips in their property values over longer periods of time than others, since the geology of the gas field dictates the size, density and duration of gas harvesting operations. The hypothesized impact curve might also vary substantially if a property was located on the edge of an area of natural gas development, or was one of the first or last properties in an area to have a well drilled. Given the current and projected pace of natural gas development in the region, the impact on property values will most likely continue to change for the near future.

Finally, it should be acknowledged that there is also evidence that a large portion of the increase in property values in the Colorado River Valley is due to the increased demand for residential housing created by natural gas industry employees. For many county residents, gas development is a double-edged sword stimulating home appreciation but diminishing values in close proximity.

General Loss of Property Value

Property value loss as a result of natural gas drilling activity is most significant during the drilling phase. Best practices are a strategy for mitigating impacts, but value losses will occur regardless. Generally but not always, property values partially recover once a well is completed and the physical impacts of gas development subside. Property value loss is caused by a combination of quality of life impacts resulting in less owner enjoyment of the property, lending institution uncertainty and buyer risk aversion. The loss of value curve shown in prior Section IV shows the average or typical case. However, anecdotal evidence collected from landowner, Realtor and lender interviews in Garfield County indicate that in certain cases value loss can be far more severe than the averages shown in this report.

Uneven impacts. The problem is that property owners who own land in Garfield County but not near gas well activity are seeing their property values appreciate while those who own land in close proximity to gas activity experience a diminution of value more dramatic than what was shown in the loss of value curve in Section IV. In addition, the unpredictable nature of where and when new gas activity will occur is causing risk averse buyers and lenders to be cautious about where they do business in the Colorado River Valley. Thus, owners in close proximity to current gas activity are completely unable to sell their homes or must sell them at significant losses.

Best management practices. Garfield County officials have considered organizing a publicly administered fund that under certain circumstances, would provide financial aid to property owners adversely affected by gas development. The consultants were unable to find another locale where this method was used. While this notion has some merit, it also presents some difficulties, especially with the administration and distribution of funds. It will be difficult to justify the exact amount of aid given to one landowner when his neighbor may get a different amount of aid. Return of land values is not certain, thus land banking concepts have a high degree of risk. Funding sources are also uncertain; perhaps funds can be supplied through severance tax distributions, but these funds may already be earmarked for other priorities.

Educating lenders, appraisers and Realtors about the property value impacts of gas development and the subsequent value recovery period is another mitigation measure under consideration by the county. The education program has the potential to ease some of the fears felt in the lending community, but the consultants do not believe that uninformed lenders, Realtors and buyers are the core problem. Based on our interviews, in many cases, lenders and buyers are quite well-informed and their aversion to risky property acquisition is a response to real market conditions. Arguably, some mortgage lenders have overreacted and entirely red-lined the area. This would appear to create a favorable market opportunity for more aggressive lenders and perhaps an educational effort to showcase this business opportunity and an aggressive effort to identify willing lenders and brokers would suffice. Education and continued manufacturing and land value impacts is an appreciate task for the energy coordinator or ombudsman.

Land issues and solutions committee best practices. In June of 2005, the Garfield County Land Values and Solutions Committee (Committee), a subcommittee of the Energy Advisory Board, focused on defining the major problems for surface owners caused by gas development in Garfield County. The following is a list of the 4 most significant problems as they relate to surface land values identified by the Committee:

- Odor;
- Truck traffic;
- Environmental pollution;
- Visual impacts of the drilling rig; and
- Perception of risk.

Mitigation measures for these effects are discussed in the following section devoted to identifying the phases of gas development and providing physical mitigation measures that may lessen the impact of gas extraction operations.

The perception of risk in an area with gas development present causes most of the institutional friction that leads to property value loss. The Committee recognized that Realtors, appraisers and secondary-market lenders are declaring areas with gas development to be too risky for capital investment even though they may not be completely informed regarding the impacts of gas operations.

To mitigate the institutional problem, the Committee suggested an education program that is focused on informing local Realtors and appraisers regarding the stages of gas development and the associated impacts of each stage—emphasizing the temporary nature of the most significant effects. This program would include classes, tours of well pads in various stages of production along with fact sheets and possibly historical sales data. The Committee also discussed publishing a directory of industry contacts so that Realtors, appraisers and prospective buyers can inquire about current and future plans for gas development in the region and identify lenders who are active in the area.

The secondary lending market could also be a target of an educational campaign aimed at adding some flexibility to their lending policies. However, there is evidence that at least some institutional lenders are becoming more receptive to servicing properties near gas development and that as appraisers have more evidence of value recovery, this situation will further improve.

A final recommendation raised by the advisory committee involved the possible institution of a well compliance certification program, perhaps overseen by the Colorado Department of Health, which would provide current and prospective owners as well as appraisers, with assurances that well development had been completed in a satisfactory manner and inspected by a knowledgeable third party. Additional debate is needed to determine what standards could be imposed and how inspections would be accomplished, recorded and certified, but the sense of the committee was that a process similar to issuing a building permit would go a long way toward satisfying third party interests, and could reduce the perception of risk currently affecting buyers and institutional lenders.

The following sections discuss the phases of oil and gas development, document environmental and community impacts, and highlight prospective strategies to mitigate adverse quality of life impacts related to field development and reclamation.

Phase I: Exploration

Once ownership of minerals has been determined and an appropriate surface use agreement instituted, an individual or company may begin exploring for subsurface oil and gas deposits. Remote sensing techniques, such as aerial photography, infrared imaging, radar and microwave frequency receivers, are used to preliminarily identify prospective oil and gas reserve locations. Once the field has been narrowed, geophysical exploration is used to physically locate the oil and gas deposits, commonly accomplished with seismic testing.

Seismic testing. Seismic tests are conducted by bouncing acoustic or seismic waves off the different layers of subsurface rock. The waves travel through, reflect, or are absorbed differently by the various layers under the surface, potentially revealing the location of oil and gas. Seismic waves are generated using the following methods:

- Blasting dynamite in a subsurface cavity (shothole);
- Dropping a heavy weight from a truck (thumper truck) that strikes the ground producing seismic waves; or
- Shaking the ground with a vibrasizer.

Once produced, the seismic waves are reflected back at different speeds and intensities and recorded at the surface by geophones. New technology has allowed for three-dimensional underground mapping, which if used, requires the tight spacing of thumper trucks as they explore an area, leading to increased surface disturbance.

Impacts of seismic testing. Most impact issues associated with seismic testing are a result of surface disturbances from the heavy machinery and subsurface explosions. Possible impacts of seismic testing include:

- Thumper trucks may cause the destruction of surface vegetation and topsoil erosion;
- Dynamite shot-holes may intercept the water table, causing groundwater contamination and seepage problems; or

- Work crews may leave behind waste such as fuel spills, survey stakes, or food and human wastes.

Best management practices. The extent to which conflicts between surface estate and mineral estate owners can be avoided largely depends on the conditions of the surface use agreement. The following is a list of best management practices that landowners and local government could encourage operators to use during seismic testing:

- The mineral owner must make a good faith effort to notify the surface owner before any seismic testing begins.

- Thumper trucks should avoid steep slopes and ecologically sensitive areas to minimize soil erosion and vegetation destruction.

- Landowners may want to negotiate stronger surface damage provisions if there will be three-dimensional seismic tests on their property.

- Shot-holes should be properly plugged and reclaimed, noting if there is any water seeping to the surface.

Seismic testing cannot directly identify oil and gas deposits; it only indicate the potential for reserves. Oil and gas accumulations must be confirmed through exploratory well drilling.

Exploratory drilling. Once a promising oil or gas deposit has been found, an operator will select a drill site, build roads to access the selected site, prepare a drill pad, and erect a drilling rig. It is at this stage of the oil and gas extraction process that there is a significant amount of traffic, noise, and heavy machinery present at the drilling site.

Impacts of drilling. The following issues may arise during oil and gas drilling operations:

- Surface Disturbances
  - Gravel access roads adding dust, noise, and traffic.
  - Loss of surface vegetation to prepare a drilling pad.
  - Waste pits dug to store drilling fluid and waste.
  - Productive agricultural land used for the drill pad.
- Wastes and Emissions
  - Emissions are produced from drilling operations that include nitrogen oxide, particulates, volatile organic compounds, carbon monoxide, and hydrogen sulfide.
  - Breached well casings can allow oil, gas, or drilling fluid to seep into nearby aquifers.

- Drilling fluids that circulate through the well may contain dissolved or suspended contaminants including lead, mercury, and arsenic.

- Toxic drilling fluids can be discharged into unlined pits, where there is potential for groundwater contamination.

- Disposed drill cuttings can be buried onsite or spread over the surface of the drill site.

- There is the potential for fuel, drilling fluid, or other chemical spills at the drill site.

- Noise, Traffic and Lights

  - There is noise associated with drilling operations; the actual drilling rig often operates on a diesel engine.

  - There is truck traffic during the drilling stage, creating noise and dust.

  - Rig construction and operation may occur throughout the day and night; potentially creating a nuisance for nearby landowners.

Best management practices. The following is a list of possible best management practices to mitigate the impacts listed above:

- The mineral owner makes a good faith effort to notify the surface owner before any drilling begins.

- Where possible, operators use pitless drilling to eliminate hazardous fluid pits and reduce the risk of groundwater contamination.

- Directional drilling, while expensive, allows for multiple wells at one pad (clustered development), reduces surface disturbances, and increases production efficiency.

- Slim hole drilling reduces the amount of drill cuttings and drilling fluid used.

- Reconditioning drilling fluid allows it to be reused at multiple wells, thus minimizing waste.

After an operator has drilled a well bore, they analyze the drill cuttings to determine whether oil and gas are present and if they exist in enough quantity to warrant the investment necessary for full-scale production. An operator may drill several times before they decide a well is fit for production.

Phase II: Field Organization

In this primarily administrative phase of oil and gas development, operators organize wells in one region to create a system that efficiently extracts oil and gas. Organizational techniques used in the phase include well spacing, unitization and mineral pooling.

Operators use well spacing to maximize the amount of oil or gas that can be extracted from an underground deposit. They determine the volume that can be harvested with a single well, and then estimate how many wells are needed to drain the entire underground deposit. The State of Colorado's current well spacing requirements indicate that wells that access the same geological formation must be at least 1,200 linear feet apart from each other, however exemptions are allowed if good cause can be shown.

Well spacing issues arise generally only if state or local government decides to change spacing requirements. Operators may petition for tighter well spacing, which is sometimes granted.

Phase III: Production

Once an economically feasible well has been identified and the drilling field has been consolidated, the well is ready to be completed. An additional casing, usually a steel pipe, is inserted into the well bore. Cement is then pumped down the casing to fill the space between the casing and the walls of the drilled hole to prevent oil and gas from seeping into the ground.

The drilling rig is removed from the well pad and a completion rig is placed over the well bore to perforate the casing where it touches formations that contain oil and gas. Next, a well head is installed to regulate the flow of oil and gas to the surface. The well head has valves that connect the well to equipment that separates the oil, gas, water, and any impurities. The oil or gas is then either stored on site and removed by truck, or connected to a pipeline system for transport to another location. In the case of natural gas, which is not easily stored, a pipeline connection must be in place before a well is placed into production.

If there is not enough pressure in the well for oil or gas to naturally flow to the surface, pumping is often necessary. There are several different types of pumps, the most common being the beam pump, which are often powered by a gas or diesel engine or an electric motor.

Several pits may be constructed during this stage to separate oil or gas from water or other impurities.

Production stage impacts. The following issues may arise during oil and gas production:

- Emissions and Waste
  - There are contaminants that may be released into the air during the production phase, including nitrogen oxide, hydrogen sulfide, benzene, toluene, particulates, and methane.
  - Venting and flaring of natural gas wells can cause air pollution and odors.
  - Produced water is sometimes high in salinity and compounds and is usually disposed of by re-injection into a disposal well.
  - There are various wastes associated with production operations, including lube oil, treating chemicals, and paraffin, which may also be injected into disposal wells.

- Proper maintenance is important since production spills can come from leaking storage tanks, valves, or joints.

- Seepage from open pits may contaminate groundwater.

- Noise and Traffic

  - Pumps usually run on a diesel or gas engine, which can produce a constant noise.

  - While not as heavy as during the drilling phase, routine maintenance and product hauling causes traffic to persist.

Best management practices. The following is a list of prospective best management practices to mitigate the impacts listed above:

- Minimizing the well pad footprint lessens surface disturbance impacts.

- Landscaping around well pads can be used to lessen the visual impact.

- Setback requirements can mitigate excessive noise and visual impacts.

- Requiring crews to work only during certain hours can mitigate nuisance issues.

- The use of remote telemetry can reduce truck traffic around well pads.

- Pneumatic pumps are much quieter than conventional pumps.

- Pit lining requirements and groundwater testing procedures can be used to prevent point source water pollution.

In certain cases, a gas deposit may have large reserves but a poor flow rate due to low permeability. Several stimulation techniques are employed to encourage better flows.

Stimulation techniques. Stimulation may be necessary during several periods in the productive lifespan of a well. They may be used prior to production, or as part of maintenance operations during production. Most often, stimulation techniques are used as flow rates at a well start to decline, towards the end of its productive life. Hydraulic fracturing or "fracing" is the most common form of well stimulation.

Fracing is an operation in which a specially blended liquid is pumped down a well and into a formation under pressure high enough to cause the formation to crack open, forming passages through which gas can flow into the well bore. Some fracing fluids are pumped out of the ground during the gas extraction process, but studies have shown that between 20 and 40 percent of the fluid may remain underground.[1]

Stimulation technique impacts. Fracing is a relatively new process and therefore, the full spectrum of its effects are uncertain. The following is a list of impacts associated with hydraulic fracturing:

- Operators have been known to use diesel fuel and other chemicals as fracing fluids, which may cause groundwater contamination.

- Recovered fracing fluids are often stored in open pits, which if unlined, may contribute groundwater contamination.

Best management practices. The following is a list of possible best management practices to mitigate the adverse effects of hydraulic fracturing:

- In sensitive areas, water quality testing can be conducted before and after fracing operations to ensure against aquifer contamination.

- An alternative to water- and chemical-based fracing is a "dry" stimulation technique that uses a pressurized mixture of carbon dioxide and sand to induce production.

- Where possible, "green" fracing fluids can be used to minimize adverse environmental impacts.

- Landowners should be notified when fracing techniques are employed near to domestic water sources.

Separation and purification. The fluid that flows to the surface at oil and gas wells is often a blend of oil, gas, and impurities such as water, and dissolved solids. As a result, the impurities must be separated from the oil or gas.

If crude oil is being recovered, the oil mixture is piped to an on site treatment facility, which separates gases from oil and water. The separated gas is sometimes captured and processed, or it may be treated like a waste product and vented or flared. The oil and water then are heated to separate the oil from the water and other impurities that may be present. The oil is then stored on site until it is hauled off by pipeline or truck. The produced water and other impurities are either piped to a pit where the water is evaporated, or it may be injected into an underground disposal well.

Natural gas must also undergo a purification process once it is extracted from the ground. The gas is conditioned to remove impurities, such as water and hydrogen sulfide. Chemical separation and purification processes are employed to separate water and hydrogen sulfide from the natural gas. The gas is then compressed and transported, usually by pipeline, to a processing plant.

Impacts of separation and purification. The following is a list of the potential impacts of oil and gas purification processes.

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[1] US EPA 2002: Evaluation of impacts to underground sources of drinking water by hydraulic fracturing of coalbed methane reservoirs.

- Natural gas compressors are noisy and may create a nuisance for nearby landowners.
- Produced water and other byproducts stored in pits can be a potential threat to groundwater.

Best management practices. The following is a list of possible best management practices to mitigate the impacts described above:

- Compressors can be housed in structures to reduce nuisance value.
- Proper disposal techniques should be employed to prevent groundwater contamination.

Phase IV: Site Abandonment and Reclamation

When a well is no longer economically feasible to operate, it is abandoned. Proper abandonment procedures include well plugging, conversion to an injection well, and site reclamation.

Once an operator decides to permanently leave a well site, the well must be plugged to prevent oil or gas from migrating to nearby groundwater or the surface. Wells are plugged using three 100 to 200-foot cement plugs at different depths in the well bore. The casing is then cut off below the surface and capped with a steel plate to seal the well.

If the well is located near other productive wells, the operator may convert it to an injection well. Injection wells may be used to dispose of produced water and other associated wastes, or to stimulate production, such as with hydraulic fracturing.

The purpose of site reclamation is to return the land, air and water around a well to the same condition as before oil or gas development. Reclamation activities typically include the removal of all extraction-related equipment, removal of trash and debris, closure and remediation of pits and contaminated soils, and site revegetation. Reclamation efforts generally take place after wells have been abandoned, but there are interim reclamation activities that are required to be performed at other stages of extraction.

Abandonment and reclamation impacts. Most issues that arise in this stage are due to improperly plugged and abandoned wells. Impacts of improper reclamation and abandonment include:

- Improperly capped wells may allow agricultural contaminants, such as pesticides, to migrate from the surface to groundwater.
- Oil, gas, contaminated water, and other pollutants can leak from improperly abandoned wells and contaminate groundwater or pool at the surface of the well.
- Improperly abandoned pits can pose a danger to livestock, wildlife and humans.

Best management practices. The following is a list of practices that will ensure proper abandonment and reclamation practices:

- Landowners should work with local and state agencies to ensure that abandonment is properly completed.
- Native vegetation and topsoil should be used in reclamation efforts to stem the spread of noxious weeds.
- Groundwater should be tested well after abandonment to ensure that water quality has not been compromised.
- All production and waste pits should be reclaimed properly to prevent any surface or groundwater pollution.

In sum, counties have limited ability to manage gas well extraction activities and limit the economic impact of value losses. However, with cooperation and acceptance of best management practices, the negative impact of drilling on property values can be greatly diminished.

APPENDIX A.
Regulatory Case Studies

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Regulatory Case Studies

This appendix presents examples of how other counties and municipalities are employing strategies to mitigate the impacts of increased oil and gas development.

La Plata County, Colorado

Gas well permit conditions require oil and gas firms to:

- Monitor domestic water wells within a half-mile of a gas well before and after drilling
- Build an earthen berm with trees to screen the well from sight
- Only work between 8 AM and 6 PM after drilling is completed
- Replace the traditional pump with a low-profile, quieter electric pump shortly after production begins

Las Animas County, Colorado

County regulations require oil and gas companies to:

- Go through a planning review process involving elected county officials to determine whether a drilling permit is granted based on demonstrated need, suitability of location, adequacy of existing roads, and compatibility of existing uses.
- Devise an emergency preparedness plan.
- Supply a detailed plan outlining methods to mitigate noise, traffic, wildlife and visual impacts of the well pad.

Moffat County, Colorado

County-authored surface use agreement requires:

- Negotiated well, road, and pipeline location between surface and mineral owners.
- Limitations on nighttime operations.
- The use of low-profile tanks and pumping units, noise suppression devices, and earthen berms to minimize visual and noise impacts.
- Detailed reclamation, traffic minimization, fire and emergency, dust control and weed control plans.

Town of Frederick, Colorado

City ordinances require oil and gas companies to:

- Submit plans to the town of all facilities, pipelines, flow lines and gathering lines
- Devise an emergency response plan
- Comply with a municipal-level inspection process
- Consult the Colorado Division of Wildlife to mitigate impacts of well location in migration corridors

City of Lovington, New Mexico

A local drilling ordinance requires oil and gas companies to:

- Use closed-loop drilling systems
- Cease drilling new disposal wells
- Dispose of all drill cuttings and fluid off-site
- Notify the city engineer within 15 days of any effluent leak or spill
- Submit an annual leakage survey
- Obtain a city-issued drill permit

Township of Filer, Michigan

A health protection ordinance requires energy companies to:

- Conduct a health risk analysis of proposed new pipelines, processing plants and compression stations
- Implement an emergency warning system for effluent leaks and spills
- Inform the township about any hazardous materials used on the well pad

City of Farmington, New Mexico

City ordinances have created the following:

- A remediation requirement that all reserve and waste pits be properly removed within 30 days of well completion
- A municipal-level inspection and advisory board with regulatory authority over well location and safety compliance

City of Norton, Ohio

City ordinances require oil and gas companies to:

- Obtain the written approval of 51 percent of surface owners within 1,000 feet of a proposed well before any drilling can occur
- Carry liability insurance of not less than $500,000 for property damage and $1 million for personal injury
- Use pumps with explosion-proof, electric motors
- Regularly test fresh water wells within 1,000 feet of the well pad for quality