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Basin fragmented: Coal bed methane development in the Powder River Basin

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A BASIN FRAGMENTED: COAL BED METHANE DEVELOPMENT IN THE POWDER RIVER BASIN

by

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A Basin Fragmented: Coal Bed Methane Development In the Powder River Basin

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The Powder River Basin, located in Montana and Wyoming, is experiencing a higher rate of coal bed methane development than any other region in the United States. The number of wells has increased from 23 in 1989 to 13,279 in 2004. Although coal bed methane is the cleanest burning fossil fuel available, a myriad of concerns accompany its development in the Powder River Basin, including: development on public and private land, water issues (both quantity and quality), landscape fragmentation, air and noise pollution, changes in quality of life, and wildlife impacts.

This thesis focuses specifically on landscape fragmentation, and addresses the question of how much land fragmentation has happened in the Powder River Basin due to coal bed methane development. In this study, landscape fragmentation is defined as the decrease in size of habitat patches and an increase in distance between those patches.

The research encompasses three major components: 1) a patch analysis using remote sensing techniques to quantify landscape fragmentation, 2) an assessment of historical and current energy policies to determine their role in contributing to landscape fragmentation; and 3) a qualitative, local scale perspective. A conceptual model linking landscape fragmentation to policy deduces that the split estate, technology, and current energy sources have direct impacts on landscape fragmentation. The landscape analysis of the study site revealed a 147% increase in the number of road miles representing a change from 117 to 290 miles. The number of patches rose from 41 to 426, which clearly illustrates a fragmented landscape resulting from coal bed methane development. The final chapter discusses what can be expected in terms of landscape fragmentation in the Powder River Basin given the results of the patch analysis and current energy policy findings. The thesis concludes with a set of recommendations directed at federal and state governments and energy development companies.

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CHAPTER ONE: INTRODUCTION

> "By sheer persistence-and attending meetings-Clark got the director of the industry-friendly Wyoming Department of Environmental Quality to visit her ranch. She explained to him that the drilling company had produced 45 acre-feet of water in thirty days. She had him do the numbers: based on fourteen wells, the companies would produce 781 acre-feet of water. 'That's more than they can store in every one of these reservoirs they have planned here. So, you see, it's a *real* big problem.' She persuaded the state agency to suspend the drilling on her ranch until the companies figure out what they're going to do with the water (Ivins and Dubose, 2003, p. 170)."

The problem Patricia Clark, a rancher south of Gillette, Wyoming, refers to in the above quotation is the water pumped to the surface in order to extract methane gas from a coal seam under her ranch. In addition to pumping water to the surface, miles of roads are made to access the wells. The process of coal bed methane extraction raises serious questions concerning the landscape. But how much of an impact coal bed methane activity is having on the landscape in places like Gillette, Wyoming is still an unknown.

The first goal of this thesis is to quantify the extent of landscape fragmentation that has occurred as a result of coal bed methane development in the Powder River Basin. The second goal is to assess the role energy policy has played in contributing to the problem of landscape fragmentation. Specifically, this thesis will address the ways energy policy has contributed to landscape fragmentation as a result of coal bed methane development in the Powder River Basin.

Examining landscape change due to human use and activity has a long tradition in geography. The study of landscape change involves a temporal analysis of a given area to determine the amount and type of change. One way to measure temporal change due to coal bed methane development within the Powder River Basin is to utilize landscape

fragmentation methods. An analysis of the entire Powder River Basin is beyond the scope of this thesis due to the magnitude of the task, time, and resources. However, this research will employ a large scale approach (small area) to a defined region – the Three Mile Creek quadrangle - in order to analyze landscape fragmentation between 1994 and 2002. This time range is employed because of the availability of appropriate data through the Wyoming Geographic Information Advisory Council (WGIAC).

For the purposes of this study, landscape fragmentation means the decrease in size of habitat patches and an increase in distance between those patches (Weller et al. 2002). Habitat patches refers to relatively homogeneous environmental regions with clearly defined edges (Weller et al. 2002). While studies of landscape fragmentation have been conducted in relationship to the impacts of the oil and gas industry in the western United States, no such studies of this kind were found specifically concerning the Powder River Basin.

Pertinent to measuring landscape fragmentation in the Powder River Basin are the linear features created in order to extract the coal bed methane. Specifically, this study uses roads and pipeline paths to determine landscape fragmentation which are two of the most predominant features created during extraction. Dirt roads are created to access well sites and compression stations, while pipeline pathways are generally underground. The land is excavated in order to put the pipelines and other utilities in place, thereby disturbing the delicate landscape in the process.

The Powder River Basin, stretching across two western states, Montana and Wyoming as Figure 1 illustrates, is a prime setting in which to conduct landscape

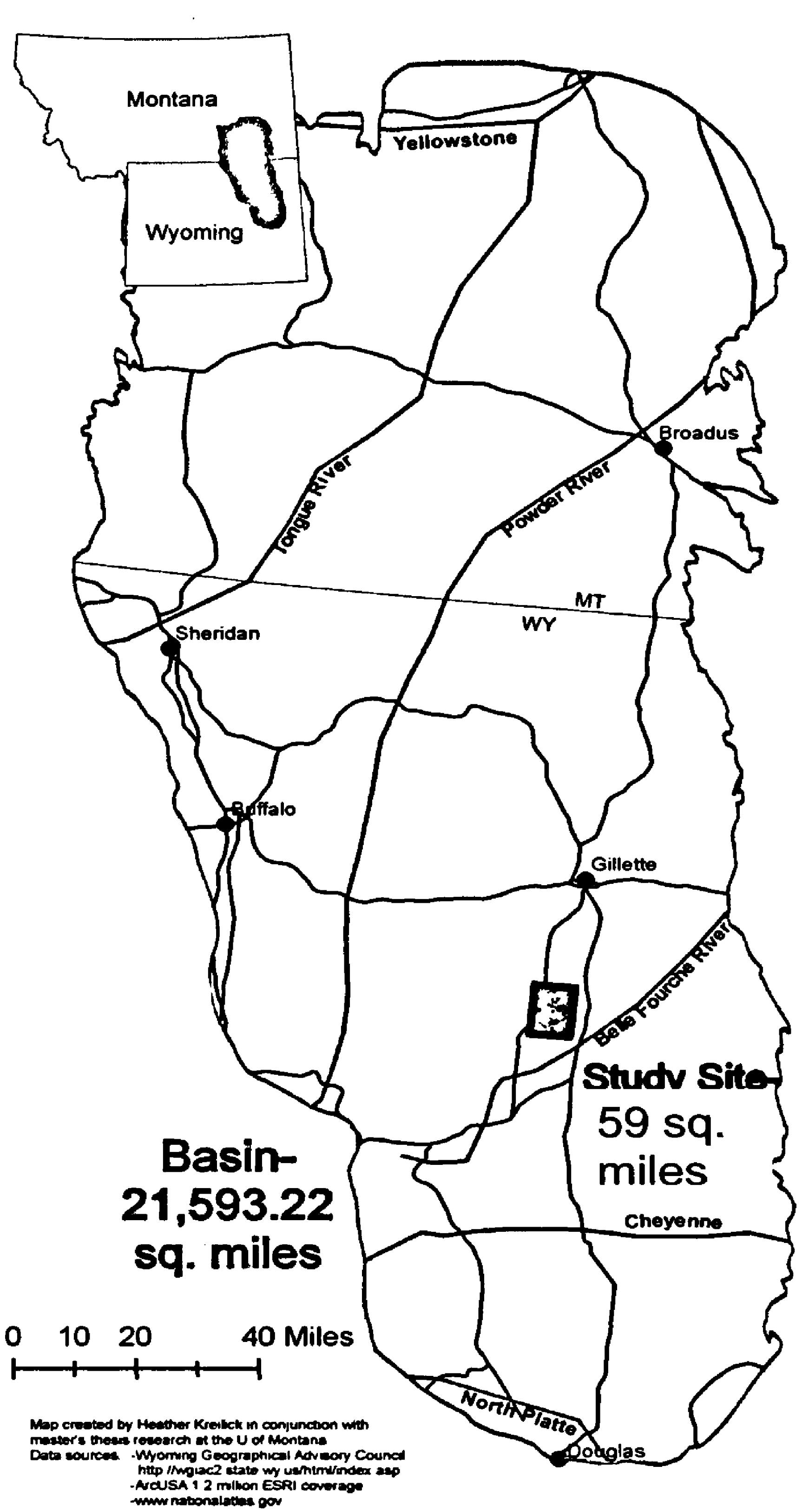

Figure 1 Location Map- Powder River Basin, Kreilick, 2005.

fragmentation research related to coal bed methane development. The Powder River Basin is home to one of the fastest growing energy industries in the nation, the development of coal bed methane gas (All Consulting, 2004; U.S. Department of Energy, 2003). Amidst this semi-arid, western landscape emerge an endless network of roads, miniature beige well houses, electrical lines, underground pipelines, and scattered compression stations. Due to an increasing national demand for natural gas (Energy Information Administration, 2003) and the fact that neighboring mineral leaseholders can extract gas lying under adjacent properties, a sense of urgency to expedite the permitting process permeates both federal and private leases, according to the Permitting Official and the Rancher (persons interviewed are referenced with a generic title rather than a formal citation).

The Research Problem

Coal bed methane gas is the cleanest burning and most abundant fossil fuel available, and it is easily accessible in the Powder River Basin and several other regions throughout the United States (Bryner, 2005, USGS, 2000). Natural gas combustion, which includes coal bed methane, produces 28% less carbon dioxide than oil and 45% less than coal (Skov and Myers, 2004). While coal bed methane is a preferable form of energy to burn because it is cleaner than traditional counterparts, it brings a quagmire of problems to the communities from which it is extracted, including livelihood, cultural, environmental, ecological, economic, and wildlife impacts.

The Powder River Basin is an excellent place to explore coal bed methane development because of a myriad of impacts and concerns. Conflict over land use arises due to the complexities of the split estate, the instance where a property has both surface and mineral ownership and the owners are typically not the same entity. Additional uneasiness arises with water issues, public land management, and the overall infrastructure involved with coal bed methane development.

A voluminous amount of water is pumped from the coal bed seam in which the methane gas resides, creating a water quality and quantity dilemma. Although the amount is not static, coal bed methane wells pump 2.5 to 12 gallons per minute of water to the surface (EWG, 2004). If the basin is brought to full production, this would equate to 450 cubic feet of water per second (Stanford and Hauer, 2003). The depletion of water from coal aquifers has extensive ramifications, including the drawing down of domestic water wells (Stark, 2004, Zugel, 2005) and in some cases the transport of methane gas instead of water in domestic water pipes (USGS, 2003). Another concern with the coal bed methane water, according to the Hydrologist, is that much of it has a high sodium absorption rate (SAR) and if used for irrigation can alter the composition of the soil, creating a permanent hardpan that is impenetrable for crops. Water issues related to coal bed methane development are discussed extensively in Chapter Two.

Coal bed methane development infrastructure is clearly evident while driving across the Powder River Basin. In addition to the roads, well houses, electrical lines, underground pipelines, and scattered compression stations is an increase in traffic, dust, and air and noise pollution (Bryner, 2005). The transformation arising from the rate of coal bed methane development is discussed in depth in Chapters Five and Six.

An increasing concern over the impacts of coal bed methane extraction in the Powder River Basin is also abundantly clear in recent mass media and local and national newspaper articles on the subject. The production of two documentary films in the last year - "Powder River Country" and "Gassing the Big Sky" - depict the hardships confronted by residents of the basin as a result of coal bed methane development.

The Research Setting

The Powder River Basin spans over thirteen million acres. The Basin is bordered to the west by the Bighorn Mountain Range, with Cloud Peak looming at 13,167 feet. The Black Hills border the eastern edge in the distance, with Bear Lodge Mountain at 6,650 feet representing the highest point.

Sheridan lies near the Montana border at 3,745 feet and Gillette to the southeast at 4,544. Sheridan is a quaint western town with a community college and a lively main street. Sheridan has a strong mining history, but it is not as obvious to the casual observer as Gillette's mining background. Gillette lies in the middle of mining activity, with a billboard claiming Gillette as the "Energy Capitol of the World." Vast coal pits lie directly north and south of town and coal bed methane wells are in full production on the outskirts of town. The first oil well was drilled in 1941 by Texas Gulf just north of Gillette, and oil is still produced in the region. Pumping oil derricks still dot the landscape south of Gillette and throughout the Basin.

Energy development is not a new concept in the Powder River Basin. Conventional oil and gas and strip coal mining are well-established industries in the

basin. Coal was discovered just east of Gillette in 1924, and the Wyodak Mine was built 1928. The mine, the largest strip coal mine in the world for many years, continues to produce coal. Coal production in Wyoming peaked in 1981. Several coal mines surrounding Gillette and throughout the basin continue to produce coal (Wright Area Chamber of Commerce, 2004).

The Powder River Basin is a prime setting in which to measure landscape fragmentation and impacts of energy policy at local and national scales for a number of reasons. First, recent landscape change related to coal bed methane extraction in this area is evident (Barlow, 2005, Stark, 2004). Of the studies addressing landscape change in and around the Powder River Basin, the focus is primarily on wildlife impacts (Weller et al, 2002; Naugle et al. 2005). None of the studies, however, specifically quantify landscape fragmentation or the effect of energy policy on the landscape. In order to address this void, this study will examine landscape fragmentation applicable at various scales – small area to large area - and also look at how energy policy shapes the process of landscape change.

Second, the region is under transition. While coal, uranium, and conventional oil extraction have prospered in the Basin for decades, coal bed methane production is expanding across the landscape at an alarming rate, as Figure 2 indicates. In 1989, there were 23 producing coal bed methane wells; six years later there were 125. The years between 2000 and 2004 saw a leap from 3,875 to 13,279 producing wells (Wyoming Oil and Gas Conservation Commission, 2005). The data suggest a 242% increase in number of wells in a four year span. This growth rate is in part due to the geology and the physical accessibility of coal seams, but is also related to the historical frameworks and

energy policies that facilitate the level of development indicated. In addition, 51,000 wells are expected to be drilled in the Basin over the next ten years (BLM Record of Decision, 2003).

Third, there is much local concern expressed over the trend toward coal bed methane development in regards to the multitude of potential physical, cultural and economic impacts. Admittedly, ranching is still a predominant land use (see Figure 3); however, one cannot ignore the industrial presence of coal bed methane development nor not wonder how land use changes in the Powder River Basin are transforming the resource base and livelihood systems of rural communities and families. Lastly, the availability of data and the accessibility of the study area make the Powder River Basin an ideal study site.

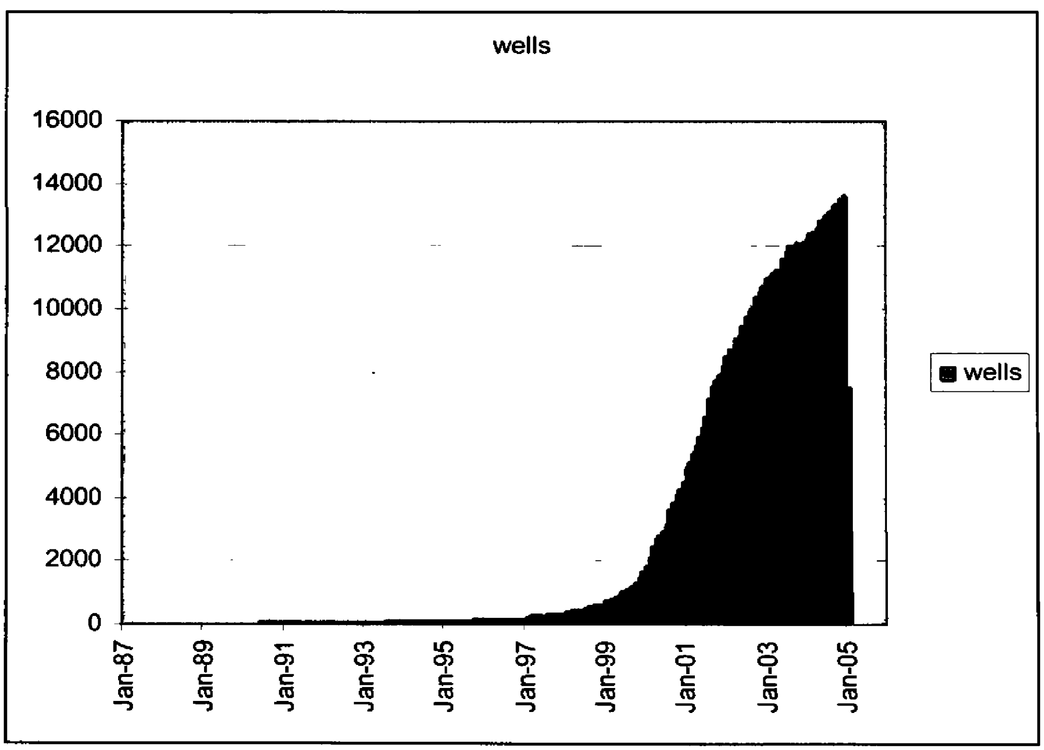

Figure 2 Number of Wyoming Wells between 1987 and 2005, data from the Wyoming Oil and Gas Conservation Commission, 2005.

Figure 3 Cattle Ranch Visible on the Landscape, Kreilick, 2005.

Research Questions

The following three questions are addressed in this study:

1. Can landscape fragmentation between 1994 and 2002 be quantified and can a repeatable method be employed to determine this basin-wide?

2. How has energy policy at the state and national levels impacted landscape fragmentation change as it relates to the coal bed methane industry?

3. Based on current trends, what do the findings from the first two questions suggest on a basin-wide?

The approach applied to the research problem is unique because it uses a combination of quantitative and qualitative methods to address different aspects of the

questions. Though a rigorous analysis of all facets of coal bed methane development is beyond the scope of this study, patch analysis - a fundamental component of landscape fragmentation - is employed to a selected area of the basin. The patch analysis includes mean patch size and number for two time periods to depict pre- and post-coal bed methane development impacts. Chapters Three and Four describe this process in detail. To address the second question, an examination of historical acts and trends and present energy policy is undertaken. The last question is approached through a synthesis of the results of the previous two analyses.

Organization of Thesis

In order to effectively answer the previously stated research questions, Chapter Two is devoted to providing a background on coal bed methane extraction. A discussion of previous and current research concerning the process of coal bed methane extraction and its impacts are included. In addition, a discussion of the geographical context in which the questions are addressed is provided.

Chapter Three presents the methodology and describes the data sources used in the study. Chapter Four discusses the outcomes of the quantitative aspect of the research, namely landscape fragmentation analysis and results. Chapter Five focuses on the qualitative findings stemming from the analysis of the relevant laws and policies and their impacts on energy development in the West today, split-estate intricacies, the role of federal energy policy, and field observations.

Finally, Chapter Six provides conclusions regarding the relationship between landscape fragmentation and energy policy and future prospects for coal bed methane development impacts in the Powder River Basin. Also included in the final chapter are recommendations for the state of Montana, coal bed methane mining companies and suggestions for future research.

CHAPTER TWO: CONCEPTUAL BACKGROUND

Introduction

This chapter provides background on the conceptual and theoretical framework guiding this research and is organized into three sections: 1) an overview of coal bed methane extraction, 2) the geographical literature on energy geography, and 3) the political basis of energy policy and a conceptual model that describes the inter-relationship between energy development and policy. Section one begins with a broad background on coal bed methane and its growing use and development in the US. Coal bed methane impacts as they relate to energy development within the Powder River Basin are then delineated into three parts: water related problems, development of public and private land, and industry infrastructure.

Section two describes a geographical paradigm in which to study coal bed methane development, relying heavily on the field of energy geography and remote sensing. Drawing on the literature, the general structure and variables of energy development are introduced. This is followed by a proposal to use geography as a discipline in which to contribute to discussions on energy policy because of the discipline's eclectic approach to solving problems. Delving further into energy geography, the idea of a "Power Landscape" is introduced, and the technological transformation that accompanies such a landscape is discussed. And lastly, a remote-sensing study by Weller et al. (2002) is described to provide a background of patch analysis concepts that are applied in the quantitative portion of this research.

Section three presents the political nature of energy policy and a conceptual model that focuses on energy policy impacts. Subsequent chapters are then designed to "test" whether this model holds true.

Section 1: Coal Bed Methane Background

Coal bed methane is an extractable gas found in Colorado, Utah, Alabama, New Mexico, and in both Montana and Wyoming (Figure 4). Methane gas was once thought to be undesirable and dangerous as it was the cause of fires and explosions while mining coal. In addition, methane gas contributes to greenhouse gases if left in the atmosphere. In 1981 it was discovered that the coal bed gas could be captured and utilized and is now the fastest growing domestic source of natural gas (All Consulting, 2004, Bryer, 2002, Skov and Myers, 2004).

Methane gas is the most desirable of the fossil fuel energy sources because it is the cleanest burning from an air quality perspective, creating less carbon dioxide than both coal and oil (USGS, 2000, Bryner, 2002). Twenty-four percent of total energy used in the US is in the form of natural gas, and demand and production is certain to increase (ALL Consulting and MBOGC, 2004, Bryner, 2002). In 2000, coal bed methane gas accounted for six to seven percent of total natural gas consumed in the United States (Rice et al. 2000) and later estimates suggest nine percent in 2002 (Pinsker, 2002). The United

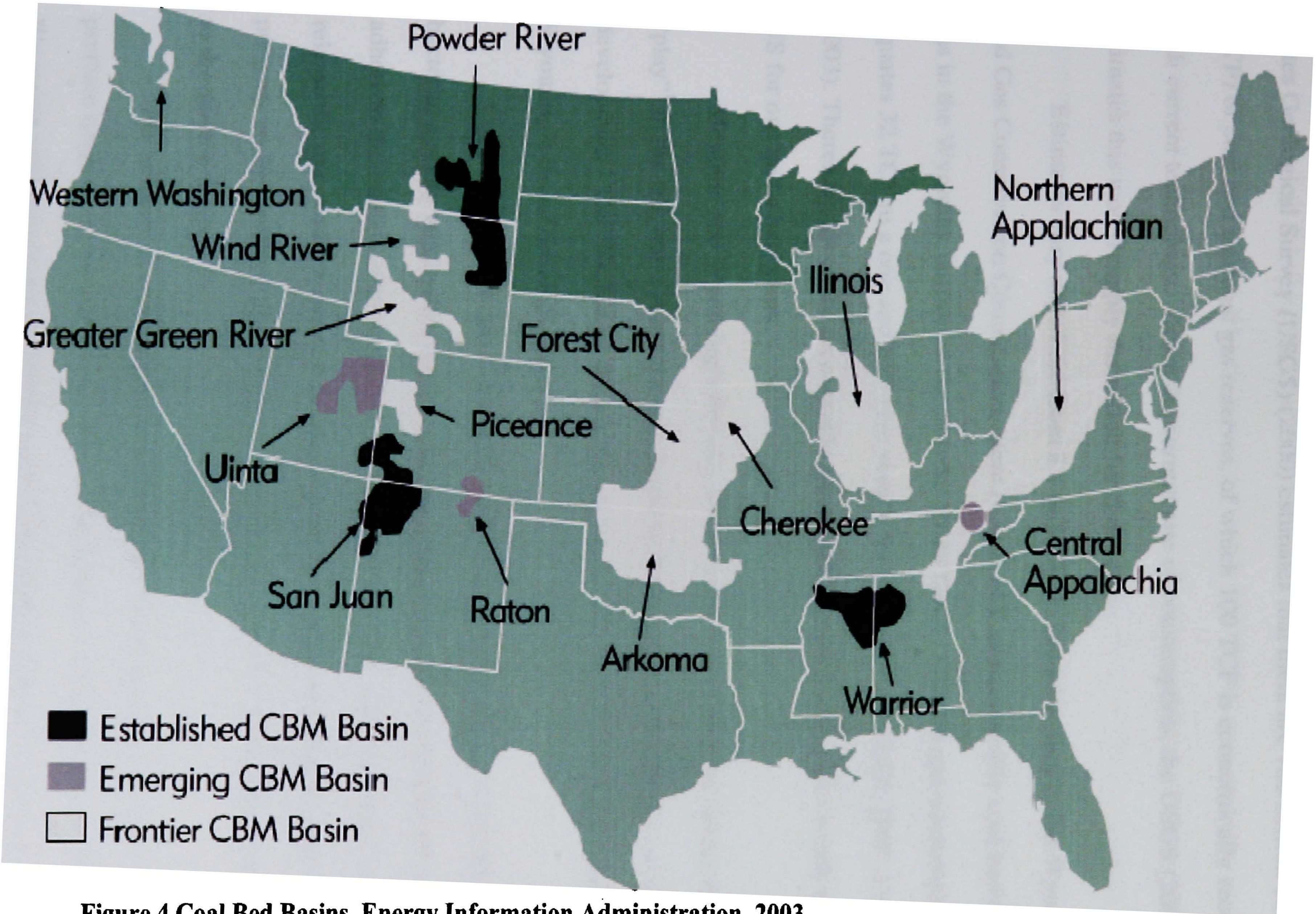

Figure 4 Coal Bed Basins, Energy Information Administration, 2003.

States Geological Survey (USGS) (2000) estimates that there are 700 trillion cubic feet (TCF) of coal bed methane gas reserves, of which 100 TCF is economically recoverable with current technology. Given the current rate of consumption, the USGS (2000) estimates this would supply the nation for five years.

Estimates vary anywhere from 8.1 to 39 TCF, but according to the Wyoming Oil and Gas Conservation Commission, there is 31.8 TCF of recoverable coal bed methane gas in the Wyoming portion of the Powder River Basin. Current gas consumption equates 32 TCF to a one and half year supply for the nation (US DOI, 2003, Cleveland, 2003). Therefore, all of the recoverable gas in the Powder River Basin would supply the US for one and a half years.

Montana and Wyoming's Powder River Basin is currently the fastest developing "play"[1] in the US, but it is not the only basin in Wyoming experiencing coal bed methane development. The Washakie, Hanna, Green River and Wind River Basins are included in Wyoming's list of developing basins.

Coal bed methane gas is made by chemical reactions or is a by-product of bacterial activity within the coal bed (Bryner, 2002). Coal bed methane gas molecules adhere to the surface of the coal and are held in place with water pressure. In order to release the gas, water in the coal aquifer must first be removed, thereby releasing the pressure on the methane gas, which is then able to escape (or is desorbed) and is funneled to the surface (Figure 5).

The amount of water pumped to the surface is outstanding. A typical well can produce roughly 12,000 gallons of water a day (Bryner, 2002). In September 1989, 23 Wyoming wells produced 40,340 42-gallon blue barrels (Bbls) of water and 90,113 one

[1] A group of strata characterized by similar aspects of methane occurrence (USGS, 2000)

thousand cubic feet (Mcf) of coal bed methane for the month. In September 2004, 13,275 wells produced 44,240,272 Bbls of water and 7,236,598 Mcf of coal bed methane for one month (WOGCC, 2005). The quantity of water and methane produced varies throughout the life of the well, which is typically seven to ten years (Bryner, 2002), and both actually drop toward the end of the well's life, as Figure 6 demonstrates.

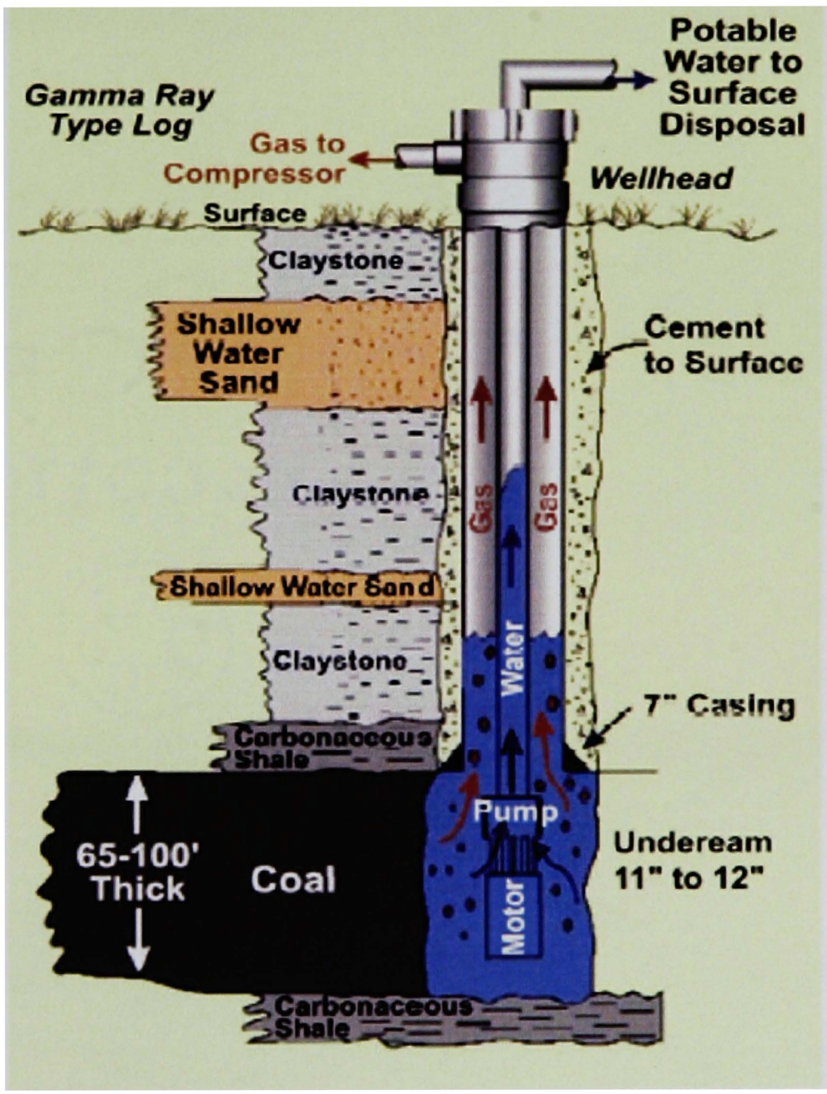

Figure 5 Typical Well, Department of Energy, 2005.

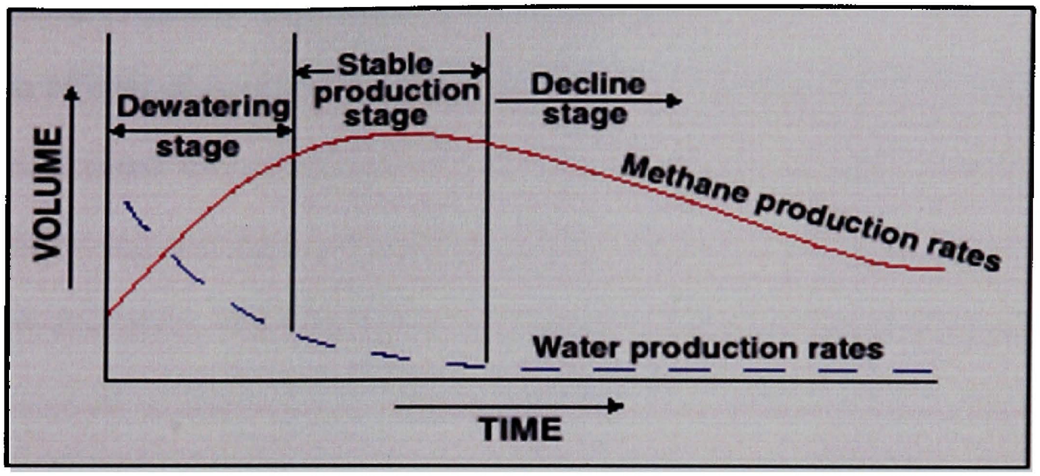

Figure 6 Water and Gas Production over the Life of a Well, USGS, 2000.

However, not all of the water is pumped from the coal seam. According to the Hydrologist, water pressure needs to be reduced by approximately four percent which equates to ten to fifteen feet below the top of the coal seam. Ideally, the space between the fractures within the coal seams is one eighth of an inch. If too much pressure is released, the space between the fractures becomes greater than one eighth of an inch and the crack collapses.

Impacts Related to Coal Bed Methane Development in the Powder River Basin

Several major impacts associated with coal bed methane development in the Powder River Basin have been documented. The categories of impacts which stand out include: water-related problems and trans-boundary effects, development on public and private lands, and industry infrastructure.

Water-Related Problems and Trans-Boundary Effects

The effects of coal bed methane extraction extend beyond the immediate well site, impoundment pond, or access road. Water pressure drops on neighboring properties, air pollution from dust and diesel generators can be seen for miles and increased traffic is felt by all in the basin. Though there are still many unknowns regarding the extent and final results of these impacts, several are specifically related to water. These concerns include the effects on aquifers, methane migration, water quality, wildlife impacts and the methods used to distribute the water.

The Powder River Basin lies in a semi-arid climate. The mean annual precipitation for Dead Horse Creek (a primary drainage in the Basin) for 1962 to 1992 was 11.3 inches (High Plains Regional Climate Center, 2004). The landscape is sensitive to drought and removing water in the aquifers may have lasting and unexpected ramifications. The range is great, but in some cases it is estimated to take 800 to 1,500 years to replenish depleted aquifers (Bryner, 2002).

Coal bed methane development will drop the water level in aquifers, according to the Hydrologist. In addition, surrounding aquifers may also be affected and experience drops in water and/or water pressure, resulting in trans-boundary effects (Montana Department of Natural Resources, 1999). Water pressure will likely drop on the property where the development is happening, and the water level and pressure on neighboring properties that do not have coal bed methane development will also drop. The Hydrologist also states that artesian wells that previously pumped water without pumps generally will require pumps after coal bed methane development is in the area due to a lack of water and/or water pressure. Some speculate that all artesian wells in the Powder

River Basin will quit, which include those wells beyond the circle of impact (Zugel, 2005). There is evidence of a decrease in water levels in the Powder River Basin when residents near Sheridan, Wyoming reported that their wells went dry (Stark, 2004, Zugel, 2005).

Land subsidence is another direct effect of water removal that may result outside the circle of influence, or beyond the land being developed. The drop in water levels, or water pressure, allows this to happen and can be an additional cost for neighboring, according to Coordinator B.

Methane migration is another trans-boundary effect related to water removal. Once the water pressure is removed, the methane gas will travel to spaces with the least amount of pressure. Ideally, it travels up the methane pipe next to the water pump releasing the pressure and is processed as natural gas. But methane migration cannot always be controlled, and the potential for methane to migrate through other sources and in other directions is present.

Methane migration can occur on a landscape level and little is known about how coal bed methane development accelerates this process (All Consulting, 2004, USGS, 2000) Methane migration includes methane flowing through basin residents' water pipes, animal burrows and possibly causing underground combustible fires (USGS, 2003, Bernofsky, 2005, Zugel, 2005) . In some cases, the pressure from the gas actually pushes heavily sedimented water up the pipes, followed by spurts of methane gas (Bernofsky, 2005). According to Coordinator A, methane migration is another effect that can happen beyond the circle of influence, and create unexpected hardships for residents of the basin.

Coal bed methane water brought to the surface may be having negative impacts on the sage grouse population. Research conducted by David Naugle (2004) at the University of Montana has suggested that a decline in the sage grouse population is due to the West Nile Virus. The presence of the West Nile Virus in Wyoming may be due to the concentration of coal bed methane impoundment ponds located in the Powder River Basin. Degradation of habitat and impoundment ponds are a direct effect of coal bed methane development. Current research in this area is ongoing.

The sodium absorption ratio (SAR)[2] of water from the coal seams, especially in this region, can be high. Water quality is site specific and is affected seasonally. Water with a high SAR is generally safe for livestock, but there is not enough livestock to drink even a fraction of the coal bed methane water. If water with a high SAR is used for irrigation, changes to the chemical composition of the soil results, creating a hardpan and rendering the soil unproductive (Stanford and Hauer, 2003) and more susceptible to invasive species.

There are a number of approaches to deal with the coal bed methane water (Keith et al. 2003). The most common and least expensive approach discharges the water directly into streams and rivers (Energy Information Administration, 2003). This method, also known as surface discharge, is how 99.9% of the coal bed methane water is dealt with in the Powder River Basin (Bryer, 2003). Many of the naturally ephemeral streams where the coal bed methane water flows are turned into perennial streams. This

[2] SAR is the measure of the relative amount of sodium compared to calcium and magnesium. Calcium and magnesium play a pivotal role in holding soils together, particularly with clay soils. Sodium can displace calcium and magnesium, resulting in impermeable soils. When such soil is wet, it erodes easily, and when it is dry, the soil creates a hardpan. Average values in the region are: Tongue River 1-3; Powder River 5; CBM discharge water ~40-60 (WPCAC, 2005). Though acceptable SAR values are dependent on its use, a SAR of 8 is acceptable, whereas a SAR over 12 is harmful to soil (Clark in Ivins and Dubose, 2003).

change from seasonal to permanent flows can have long lasting impacts on ranching operations in terms of stream crossings and diversion structures. The volumes of water can further increase erosion and can potentially pollute existing groundwater wells (Hart, Holland and Long, 2002).

Another method is to reinject the water below the coal bed, thereby avoiding surface discharge. This is not very common and would be cost prohibitive in the Powder River Basin, though it is the most common method in other regions such as the San Juan Basin (USGS, 2000; Hart, Holland and Long, 2002). Ion removal, which lowers the SAR level of the water, is yet another approach, though also costly and not generally practiced in the Powder River Basin (Stanford and Hauer, 2003).

A fourth method is to leave the extracted water in holding ponds or infiltration ponds. Lined ponds are intended to allow the water to evaporate. Unlined ponds allow seepage into the subsurface (Keith et al. 2003). Water held in infiltration ponds then travels underground horizontally across the landscape. The soil has an accumulation of salts six to ten feet underground due to the arid climate. The traveling water will dissolve and concentrate these underground salts and will at some point flow to the surface, creating a saline seep[3], according to the Hydrologist. The cumulative, long term effects of water moving through the subsurface and collecting salt could potentially modify the geomorphology of the Basin, though the ultimate effects are largely unknown, according to Coordinator B.

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[3] A saline seep is where water that is flowing horizontally underground picks up salts as it travels. Eventually this water surfaces or creates a blowout on a hillside thereby transforming the soil into a hard clay pan where no vegetation will grow.

Development of Private and Public Land

Coal bed methane development has implications for landscape change on both private and public lands. Coal bed methane development has been facilitated on private lands due to the split estate, mineral rights precedence, raising many concerns for the landowner. Landowners argue that they are often left out of the development process, and have little say in how their land is developed. Landowners contend that the placement of infrastructure, such as roads, compression stations, and wells, greatly challenges their ability to manage their land in a sustainable manner. This often leaves the landowner with a feeling of powerlessness over the management of their property (Bryner, 2002). A thorough discussion addressing the consequences of the split estate is included in Chapter Five.

Increasing energy development such as coal bed methane, coal, and oil drilling on public lands is a major component of the National Energy Policy. Ninety-six percent of public lands in Wyoming are open to development, while six percent are in partial or complete restrictions, such as land designated to wilderness (Bryner, 2002). Specifically, conflict arises over whether to protect public lands or allow the development of energy resources on these public lands.

Some argue that the choice over public land management is to preserve the inherent value of the land or extract the resources which lie under it. Others contend that a balance can be found between the two choices. It is difficult to quantify solitude, recreation, biodiversity, and habitat protection (Bryner, 2002). In either event, the choice is one of values, and whether the American public wants an inexpensive (though non-renewable) energy source or a pristine, untouched backyard.

The fact that an extractive industry such as coal bed methane is booming in the Powder River Basin is not necessarily surprising, though conflicts of interests certainly exist. The West has traditionally thrived on extractive policies and economies including logging, mining, and cattle ranching. It is important to know that resource extraction dominated western economies and policies in the 19th century and up to the 1960s. And it was in the late 19th century when natural resources were at the peak of their abundance that many public policies were created, such as the General Mining Law of 1872, the Desert Land Act of 1877, the Reclamation Act of 1902, and the Stock Raising Homestead Act of 1916 (of which the latter is discussed in detail in Chapter Three) (Baden, 1997).

Industry Infrastructure

Additional concerns related to coal bed methane extraction are associated with infrastructure. Air quality concerns stemming from dirt road travel and exhaust from related activities, especially with compressor engines pose potential hazards to humans and wildlife (ALL Consulting and MBOGC, 2004). Night lights near wells and compression stations and noise from generators and production equipment are a constant reminder of continued development (Clifford, 2001).

In the documentary "Powder River Country", Mickey Steward (2005), a contractor for the Coal Bed Methane Coordination Coalition, talks about the land's intrinsic and aesthetic value being lost to industrialization. The land use is changing from a primarily agricultural use to that of industrial and commercial. Pipelines, compressor stations, roads and electric lines make this transformation apparent (Figure 7).
The volume of traffic is another impact of infrastructure. The wells often require daily checks. Prairie Dog Creek Road just outside of Sheridan can have as many as 3000

vehicles drive on the road per day, an increase from the previous average of ten vehicles a day. According to Coordinator A, the Powder River Road has had up to 10,000 per day.

Figure 7 Compressor Stations near Sheridan, Wyoming, Kreilick, 2005.

A study conducted by the Weller et al. (2002) found that land fragmentation as a result of coal bed methane development roads has several impacts, including: wildlife mortality due to collision, wildlife mortality due to consumption of toxins, removal of vegetation, degradation of aquatic habitats, interruption of wildlife life-history functions such as mating patterns, increase in off-road vehicle use, habitat exposure by humans, noise, air and water pollution and an increase in invasive species. A decline in agricultural production and loss of privacy for residents are additional impacts with road and coal bed methane operations development and is also the primary focus of this study.

Section 2: Geographical Paradigm

This study is situated within the tradition of human-environment interactions within the discipline of geography (Gaile and Wilmont, 2003; Chapman, 1989; Wilbanks, 1985). The focus of this study is energy extraction and measuring to what extent the landscape has been fragmented due to such extraction. Intertwined with energy extraction is energy policy, which is a key component of energy geography discussions. The study draws substantially on the geographic literature on energy geography and particularly approaches that integrate remote-sensing techniques.

Historically, the field of geography has utilized the biophysical (the location of) and the economics of energy development. Wilbanks (1985) suggests that a broader audience could be had in terms of energy geography if geographers would address the real issues associated with energy development, and that in so doing, would have the impact of influencing energy policy. Wilbanks (1985) further suggests geographers tend to examine the essence of an issue, or to take an immersion approach to a subject is what will allow the field of geography to contribute most to energy studies, and thereby contribute to energy policy. In addition, geography as a field is able to apply a cross section of the sciences, rather than taking a departmentalized approach. It is for these reasons that geography is a fantastic lens with which to examine coal bed methane development in the Powder River Basin.

By understanding the relationship of energy within our societies and economies, geographers will increase their ability to help solve energy problems (Wilbanks, 1985;

Chapman, 1989). The following table presents a framework in which to approach a study of energy (Figure 8).

Structure	Variables
1. Functional	1. Technology
2. Economic	2. Benefits and costs
3. Organizational	3. Regulation
4. Spatial	4. Values and perceptions
5. Environmental	5. Resources and residuals
6. Social	6. Distances and density

Figure 8 The Structural Components and Determining Variables of Energy Systems, Chapman, 1989.

In a general sense, *functional* represents the technology and facilities associated with energy development; the *economic* refers to the gains and losses; operational and regulatory entities are the *organizational* component; the *spatial* deals with the biophysical aspects of the energy source and its production and consumption; the interaction of all stages of energy production and consumption on the physical environment represent the *environmental* component; and lastly, the *social* refers to impacts and influences of and by the populations interacting with any aspect of the energy production/consumption cycle (Chapman, 1989). While much overlap exists with all six of the structural components of coal bed methane development in the Powder River Basin, the functional, organizational, and environmental will have emphasis over others in this study.

At any given point in the production and consumption of energy, the structures can be influenced by variables. The following bulleted list provides a brief description of each variable.

- The *technology* associated with an energy system is highly dependent on scientific knowledge and development. In addition, the level and availability of skill needed for the technology varies depending on the complexity of the energy system.
- Energy systems employed are those with the greatest *benefits* and the lowest *costs*. The challenge to this method is that it is difficult to measure the intangible items such as social and environmental impacts in a benefits/costs equation.
- *Regulation* was historically determined by the energy corporations themselves until the 1950s, when government became more involved with energy policy. Government policies are influenced by political and economic factors, and are therefore as dynamic as the governments they serve.
- Special interest groups advocating concern for the effects of energy development on society and the environment reflect the *values and perceptions* of a population. This is a relatively new phenomenon where previously technology, politics, and the economy, which are influenced by values and perceptions of a society, determined the direction of energy development.
- Energy *resources* are a result of past geologic forces and so it is therefore the physical environment that determines the extent of availability of the energy. In addition, any stage of energy development has some *residual* impact upon the

environment, which has in turn increased regulations, often resulting in increased energy costs.

- *Distance and density* of energy production and consumption directly affect the spatial structure of energy. The location of the energy source may impact regions of high density and also areas that may have a low population density but may have high ecological value. Supplying energy to high density areas will provide a quicker revenue return, whereas an area of low population density may not be able to afford the same energy benefits.

The study of energy structure and variables was typically in either the social or physical sciences. A shortcoming of these studies is that each discipline applies a narrow perspective to the energy studies spectrum. A holistic, inter-disciplinary approach is required for balanced inquiry. Geography's integrated approach to the relationship between people and their environment provides an excellent avenue for research about energy and the policy context (Chapman, 1989).

One set of studies in the sub-discipline of energy geography is presently looking at landscapes of power, which are created during energy development. Energy development is directly influenced by energy policy, as is indicated in the U.S. National Energy Policy which emphasizes the development of traditional energy sources (the National Energy Policy is introduced in Chapter Three and given a full examination in Chapter Five) (Bryner, 2002). What results from such policies are land use changes and visual intrusions on the landscape (Solomon, Pasqualetti, and Luchsinger, 2003). Within this context of change, the notion of landscape aesthetics and an individual's attachment

to place emerges. This visual landscape is apparent when discussing coal bed methane extraction and the network of roads, pumps and infiltration ponds associated with this industry.

Lastly, remote sensing is the method that will be applied to carry out much of the research and analysis. "Defining the spatial and temporal linkages between people and pixels and people and the environment through image characterizations of the landscape, image change detections…are part of the current and anticipated integration of remote sensing in studies involving human-environment interactions" (Messina and Walsh, 2003, p. 392). To approach this problem without remote sensing technology would be a daunting task, and would result in limited accuracy due to the evolving nature of coal bed methane development.

Energy Geography, a Multi-Scaled Approach

John Newcomb (2001), a geographer from the University of Victoria, addresses spatial dimensions of energy exploitation in British Columbia, the Northwest and the continent. He clearly states that energy geography is a neglected field, and the need for research in this area increases as energy resources narrow. He acknowledges that geo-political energy alliances can sharply impact societies locally and globally. In order to understand local changes, one must also have an understanding of the global organization of energy and resources. A pipeline accident, increased air pollution from natural gas generation, and wood mill layoffs are all local impacts from an increasingly global

interdependence. While Newcomb focuses on cross-continental energy alliances and hints at sovereignty issues, this study will look at national and state policy.

National Scale Analysis: A Power Landscape

The Powder River Basin, with coal bed methane infrastructure visually obvious, is quickly being transformed into an "industrial landscape" (Barlow, 2005). The notion of a technological transformation on the landscape is comparable to landscapes of power. Derek Spooner is one of the few geographers tackling the issue of energy geography and landscapes of power.

Spooner (2002) describes energy production patterns in the U.K. from that of coal dependent electricity generation to one of gas dependency. It is predicted that by 2020 fifty percent of electrical generation will be gas powered. He also discusses the "technological intrusion" and human perception of the landscape associated with energy resource development. He suggests that local impacts should be weighed against global environmental impacts when assessing a technological transformation. He describes wind power as one such energy source that does not leave lasting environmental impacts, though there can be local resistance to the visual appearance and aesthetics of wind energy.

Spooner (2002) states that any discussion on energy geography must include the political environment of energy development (discussed further in Section Three in Chapter Two). He further points out that it was the policy of the U.K. government in the 1980s to remove impediments to energy production and promote privatization and free market exchanges. Bureaucracy was to blame for energy inefficiencies and problems with national energy supply. This led to a shift from government owned energy

producers to a majority of privately owned producers, of which many are foreign owned and could be described as monopolies. This is important to note because the proposed National Energy Policy encourages removing obstacles to development and permitting, many of which are described as bureaucratic, in order to increase domestic energy production and supply.

Eventually, these monopolies, in addition to geo-politics, were blamed for the oil crisis and price hikes in the 1990s. This has led to a partial trend toward more sustainable energy production methods, such as natural gas fueled electric plants. Though cleaner than coal, it is still a distant example of sustainable development as there is a finite supply, and natural gas contributes to greenhouse gases.

Spooner notes a current trend toward energy diversification and avoidance of dependence on imported gas in the U.K. In this light, he notes that motives behind the coal to natural gas shift are more commercial than environmental and that its sustainability is questionable. He also says that attention should continue to be given to alternative sources such as wind, solar, and wave power. Further, the U.K. should look to other European countries for models to successful shifts to alternative methods, of which many have been successful with wind energy.

Both Spooner (2002) and Newcomb (2001) assert that local impacts related to energy production are directly tied to national politics, and in some cases, geo-politics. It is the goal of this study to examine local and regional impacts of coal bed methane development through the lens of policy. To do so will fill a void in current research related to energy geography and the Powder River Basin.

Local Scale Analysis: A Technological Landscape

One of the ways geographers have linked energy policy to on the ground or local impacts of people and landscape is by examining case studies of wind energy development. Martin Pasqualetti (2001) incorporated the concept of a power landscape at a local scale with wind energy near Palm Springs, CA. He notes that initially, residents were resistant to the new, alternative energy landscape. Residents were resistant to the wind turbines' appearance, noise, and potential threats to wildlife and aircraft.

Ultimately, the study investigated the human perception of energy extraction as it related to the visual landscape. People felt that the wind turbines had "transformed" the desert landscape to that of a technological landscape, thereby "ruining the desert." Regulation focused on turbine size, color, spacing, noise, and decommissioning, which produced support for the industry. Conclusively, the study found residents more accepting of wind power, and that wind energy development should be encouraged.

Wind power, a renewable energy source, does not have direct impacts on the land or impact quality of life processes, such as water and soil quality and water quantity. In addition, wind power does not create waste or leave behind irreversible landscape changes. Water placed on the surface of an arid environment and a network of dirt roads, such as with coal bed methane development, fragment the landscape, leaving long-term consequences that are largely unknown.

Remote Sensing and Energy Geography

Remote sensing is a technique commonly used by geographers to derive information through analysis of data acquired through means that do not have direct

contact with the data source (e.g., an electronic sensor on a satellite recording data that transmits a digital image to earth, which is then interpreted and analyzed (Lillesand and Keefer, 2000). Temporal analysis is one such remote sensing technique that measures change detection between different time periods. Quantification of landscape fragmentation is one form of temporal remote-sensing. The measure of fragmentation reflects how much of a landscape is patchy. No previous remote sensing studies that specifically address changes in landscape fragmentation in the Powder River Basin have been undertaken; however, a study funded by the Wilderness Society on oil and gas development in southwest Wyoming is pertinent to this thesis.

The Wilderness Society published a study entitled "Fragmenting Our Lands, the Ecological Footprint from Oil and Gas Development" (Weller et al. 2002). Landscape fragmentation, as applied to this study, is the decrease in size of land patches and interior habitat along with the increase in distance between patches. Basically, landscape fragmentation is taking a piece of land and breaking it into smaller pieces while at the same time increasing the distances between the pieces.

The study area was 166 acres in the Big Piney-LaBarge oil and gas field in the Upper Green River Basin in southwestern Wyoming. The work was not intended to be comprehensive, as development extends beyond the study area. Rather, the intent of the study was to illustrate a range of linear feature densities associated with oil and gas development in the Big Piney-LaBarge region. The study revealed 8.43 miles of roads per square mile, which, for comparative purposes, is three times greater than road densities found on national forests across the West.

Big Piney-LaBarge was the chosen study site for several reasons. The region has experienced much oil and gas development, the area is home to an abundance of wildlife, and remotely sensed data were available for the study area to allow for spatial analysis. Twelve digital orthophoto quarter quads with one meter resolution were used in the analysis and obtained from the Wyoming Geographical Information Advisory Council. Linear features such as roads and pipelines were digitized as lines. Drill pads, pumping stations, utility buildings and retention ponds were delineated with polygons.

The study used three metrics to measure fragmentation: linear feature density, acreage of habitat in the infrastructure effect zone, and the acreage of habitat in the core areas. The linear feature metric primarily focused on the density of roads and pipelines. The infrastructure effect zone refers to areas beyond the physical structures, such as a road or compression station. The study defined core areas as portions of the landscape far from human influence and infrastructure that were relatively unaffected by humans.

The study delineated 1,400 miles of roads and 3.8 square miles of polygon features in the one hundred sixty-six square mile study area. This equates to seven square miles, or four percent of the study area. Ninety seven percent of the study site fell within one quarter mile of infrastructure.

The study concluded with three recommendations for future research. First, that future studies employ a variety of scales to better understand fragmentation impacts. Second, research should focus on the effects above and below ground and the effects on shallow and deep aquifers. And lastly, that future studies distinguish the effects between the linear features and polygon features.

Section 3: The Relationship between Landscape Fragmentation and Energy Policy: Towards a Conceptual Model

As geographers aspire to inform energy policy-makers in the United States, one must bear in mind that energy policy has never been the result of any rational plan, but rather, a wrestling match between various interest groups (Katz, 1984). This thesis uses landscape fragmentation to evaluate energy policy. Road density, a primary contributor to landscape fragmentation, is increasing as a result of coal bed methane development in the Powder River Basin. This research theorizes that energy policy impacts landscape fragmentation in a region impacted by energy extraction. A power landscape, introduced in section 2, suggests that where there is energy development, whether sustainable or not, one can begin to see a technological transformation.

In *Congress and National Energy Policy*, James Katz (1984) provides a background on U.S. energy policy. He argues that of the three perspectives applied in energy policy - supply, conservation and energetics - the supply perspective has dominated. The primary goal of the supply perspective is to secure abundant, cheap energy. Given this, ironically, they argue that higher prices will encourage the search for additional sources of energy (conventional and non-conventional[4]) in order to increase the supply and to ultimately lower the price of energy. Lack of an abundant supply of energy is the destruction of our advanced, industrial society and proponents of this perspective are willing to risk environmental damage and public health and safety to attain their energy goals. Lastly, corporations have a central position in policymaking,

[4] Conventional refers to traditional sources of energy such as fossil fuels while non-conventional generally refers to more sustainable, often cleaner burning, renewable energy sources.

while government plays a secondary role in advancing the supply perspective (Katz, 1984).

The conservation perspective's goal is to reduce energy waste as we transition into a system of renewable energy sources. This perspective is dependent upon the government setting energy standards in order to force industries to become more energy efficient. In addition, energy waste would be minimized as more technologically advanced methods were developed as we move towards a more energy abundant, renewable energy sources future. The federal government has a key role in providing regulation over energy resources to provide equity to all parties as we transition to more advanced, renewable energy sources.

The energetics perspective contends that energy efficiency is key to our survival and growth. Energetics proponents welcome the demise of cheap, centralized energy systems. To them, this means that local, community centered systems will prevail. The energetics perspective encourages citizen participation in energy development, and that such public participation will eliminate destructive energy exploitation and lead to low-technology, soft energy paths which are more responsive to the finite nature of energy resources.

The supply perspective has prevailed throughout U.S. history while conservation perspectives surfaced in the 1970s during the energy shortages and peaked in the late 1970s. During the conservationists' presence, energetics' ideas emerged, but their influence was short-lived. The election of Ronald Reagan in 1980 re-established the supply perspective, opening public lands for oil and gas exploration and easing energy regulation (Katz, 1984). Our current energy policy reflects this position.

Katz (1984) acknowledges that the complex nature of energy problems substantiates conflict over the national energy policy. In addition, the goals of the national energy policy are inherently contradictory, and in some cases mutually exclusive. An example is increasing domestic energy supply while at the same time improving the environment. Current energy resources require degrading impacts on the environment. Effective energy policy will require a change in social values, perhaps at the cost of some individual freedoms, in favor of benefiting a larger audience, as Katz states (1984, p.188):

> "Those who are strip-mined, polluted, and poisoned are usually least able to participate in the benefits of energy expansion or to control their own destinies, and future generations are seldom considered in decisions that will determine the habitability of their environment."

Katz proposes (1984) that U.S. energy policy encourages energy production even though potential risks to the environment, including landscape fragmentation, are likely effects. Figure 9 illustrates a conceptual relationship between energy policy directed at increasing, among other traditional energy sources, coal bed methane extraction and supply. The methods described in Chapter Three are designed to see if this model holds true for coal bed methane development in the Powder River Basin.

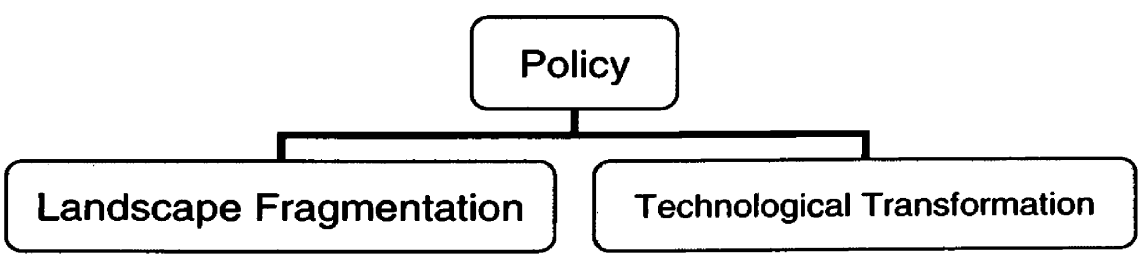


Figure 9 Model of Policy Impacts on the Landscape in the Powder River Basin, Kreilick, 2005.

Chapter Summary

This chapter provided a conceptual framework in which to study coal bed methane development in the Powder River Basin from a geographical perspective. A broad background on national coal bed methane use and extraction was presented. Specifically, impacts of coal bed methane development in the Powder River Basin were included under the following topics: water related problems, development on both private and public lands, and industry infrastructure as it relates to coal bed methane development.

Major concepts of energy development including structure and variables were presented, as well as an argument for the ways in which geography contributes to energy policy decision-making. Geography's inherently synthetic and holistic orientation makes it a highly effective disciplinary approach to a research topic.

The technological transformation of a landscape as a consequence of energy development was discussed. An evolving transformation influenced by policy is described according to Derek Spooner (2002) in the UK. An additional study by Pasqualetti (2001) further described California residents' response to the technological transformation caused by wind energy.

A remote-sensing project (Weller et al. 2002) that examined landscape fragmentation as a result of energy development was described in detail. Remote-sensing methods and concepts such as roads, road density and patches were highlighted because of their pertinence to this study.

Lastly, a framework in which to analyze energy policy in the United States was provided, as well as a conceptual model describing the relationship with energy policy, landscape fragmentation and technological transformation were presented. The results of the application of this model in the case of the Powder River Basin are discussed in the final chapter.

CHAPTER THREE: METHODOLOGY AND DATA SOURCES

Introduction

The methodological approach employed in this study entails three distinct components: 1) landscape analysis, 2) assessment/examination of historical and current energy policy, and 3) local scale analysis. First, two studies incorporating remote-sensing techniques to quantify landscape fragmentation are described. Next, data sources and methods used to analyze the problem in this study are detailed. Data and methods include remote-sensing data and techniques, historical acts, energy policy, and informal interviews. In addition, an aerial reconnaissance surrounding Gillette, Wyoming was undertaken in order to better understand the research setting and the spatial impacts of coal bed methane development.

Section 1: Landscape Analysis Methods

The methods described in this section address the first research question, *How much landscape fragmentation has occurred between 1994 and 2002 and can a repeatable method be employed to determine this basin-wide?* The two time periods were chosen for two reasons; one, the quality and availability of data, and two, 1994 represents pre development and 2002 represents a more current level of coal bed methane development. The methods for the landscape analysis draw on previous studies by Civco et al. (2001) and Apan et al. (2002) that are similar to this study. These studies analyze

landscape fragmentation using mean patch size and number and both incorporate two time periods.

Civco et al. (2001) researched forest fragmentation as it relates to urban sprawl in the Salmon River watershed in Connecticut. The study area was 140 acres and consisted of two parts: 1) creating accurate land-cover maps and classifications, and 2) generating a method to measure forest fragmentation resulting from urban sprawl.

The study compared two 1985 and 1995. Seven Landsat TM images were used in classification. Extensive digitizing was applied on the image because the linear features were difficult to extract with thirty meter Landsat data. Roads were digitized not only because of the low resolution but also because of mis-registration between the vector data and the TM imagery. Patch Analyst® (Rempel, 2005), an ArcView® (ESRI, 2005) extension, was then applied to determine the number of patches, mean-patch size, and the maximum-patch size for each class and for each year.

Conclusively, the study found that there was a considerable increase in urban and non-woody areas and the urbanization pattern revealed urban sprawl. The study was beneficial in that it developed a method to determine landscape fragmentation, and it provided information for local land-use decision-makers about the effects of development.

The relevant study by Apan et al. (2002) applied a very similar methodology. The study site was the 743,000-acre Lockyer Valley Catchment, Queensland, Australia. The study focus was structural change assessment and evaluation within the catchment using a Landsat MSS image from 1973 and a Landsat TM image from 1997. The focus was at a larger catchment scale, providing more of a perspective for landscape managers.

Citing Turner (1989), the researchers defined landscape structure as the relationship between the physical, biological, economic, political, and social forces which is often influenced by human land use. Patches within a particular landscape vary in size, shape, and arrangement. In addition to size and shape, landscape connectivity was also addressed.

Like the previous study, Patch Analyst® was used. Woody vegetation was the primary class of interest. A cross-tabulation layer was created showing all the possible combinations of landscape change. For example, woody vegetation changed to pasture or woody vegetation changed to urban.

The study revealed that the number of patches almost doubled (4,964 to 8,000) and that the mean-patch size was reduced by half (33.7 to 15.4 hectares). Separation increased from an inner-patch nearest neighbor distance of 89 meters to 99 meters, meaning that the patches are becoming more isolated. Conclusively, the study found that the catchment had undergone degradation due mainly to converting woody vegetation to pasture.

Both studies demonstrated that landscape fragmentation can be effectively measured in number of patches and mean patch size. In addition, both studies revealed landscape fragmentation due to human management. Though a classification approach was used for the two studies, data issues encountered using a land-use classification with this study made it an ineffective method. These data issues are discussed in the following section and are followed by a description of an alternative, feature extraction technique to determine landscape fragmentation.

Landscape Fragmentation Analysis, Classification Approach

This section describes the process used to extract remotely sensed information in order to determine the amount of landscape fragmentation due to coal bed methane development. Successes as well as failures are included to fully demonstrate the process and to provide a broad background for future study.

Initially, the classification process entailed using 30 meter Landsat imagery to quantify landscape fragmentation between pre-development (1989) and the most recent development (2004) (note that these are different years than what was used in the final analysis). The original study area covered the extent of wells in the Wyoming portion of the basin, and was intended to be a basin-wide analysis. The Landsat program began in 1972, and among other uses, is used for examining land-surface change and specifically human effects on land surface and the environment (NASA, 2004). This approach required two Landsat image scenes, path 35 row 29 and path 35 row 30, to cover the coal bed methane development area in the Powder River Basin.

Because the data came from two different sources, several challenges arose with the Landsat imagery. The projections for the two time periods used different vertical datums, the spatial resolution varied, and there was misregistration in multiple directions. The spatial reference system for the earlier data was projected in WGS84 UTM13N and the later data came in NAD83 UTM13N. The 1989 data had a 28.5 ×28.5 meter resolution and the 2004 data had 30 × 30 meter resolution. To address the datum issue, the 2004 data were reprojected from NAD83 to match the WGS84 datum found in the 1989 data. To resolve the resolution issue, the 1989 data was resampled to 30 meters because data is only as precise as the lowest precision level.

Misregistration in multiple directions was revealed after a simple classification with the 2004 images. As Figure 10 indicates, the shift was not systemic. Were the data systematically misaligned, a shift could have rectified the alignment. This left two choices, rubbersheet the 2004 layer, or find new data. Ultimately, the latter option would be employed, as the rubbersheeting could produce inconsistent results across the entire

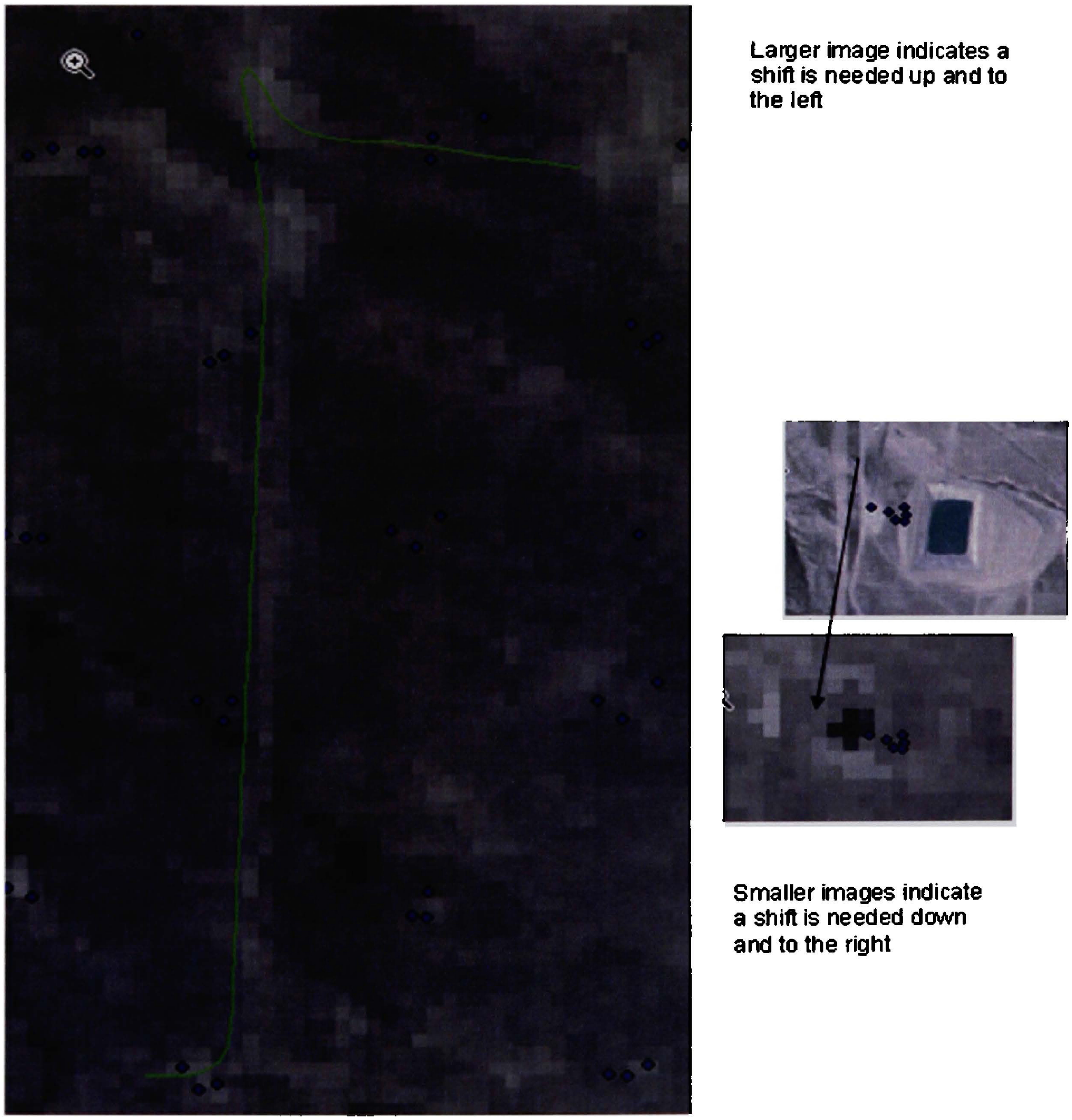


Figure 10 Misalignment across the Study Area is not Systemic, Kreilick, 2005.

study area. Misalignment with just one pixel would make classification of five meter wide roads (a typical coal bed methane road width) impossible using 30 × 30 meter data.

In addition to the data complications described above, an initial classification revealed that the 30 × 30 meter 1989 Landsat TM imagery would be inadequate for the purposes of this study for two reasons. First, central to coal bed methane development and quantifying landscape fragmentation are the linear features such as roads and pipelines that are created on the landscape. The typical road constructed for coal bed methane development is dirt road and less 15% of a 30 meter pixel width. Though it was possible to see the coal bed methane pattern of roads in a few instances on the 30 × 30 meter imagery, it was very rare.

Secondly, the spectral signatures between classes were not distinct enough to distinguish several classes (including linear features such as buried pipelines) arising from coal bed methane development. On the landscape, pipelines are hard to see when standing directly in front of them. From the air, they appear as 5 meter wide strips that extend in straight lines. They differ from the roads in that they are broader in width, they turn with sharp angles, and that for the most part, they are vegetated. On either side of a pipeline, sagebrush is typically present, while in the pipeline path itself, the sagebrush does not regenerate for some years, if ever. Vegetation differences are not extractable at 30 × 30 meter resolution.

Feature Extraction Approach

Because reflectance values of the linear features created by coal bed methane development are spectrally similar to the natural landscape, it was determined that a classification system would be abandoned for a *feature extraction* process. Feature

extraction utilizes pattern recognition in images to detect objects, such as roads or rooftops. By extracting this information it was not necessary to classify the entire landscape to determine the degree of patchiness caused by coal bed methane roads across the landscape. Rather, looking at the landscape as a whole instead of classified parts of sage, short grasses, and barren ground would give a better picture of how industry has segmented the landscape. The final outcome remained the same; determining mean patch size and number before and after coal bed methane development as a means of measuring landscape fragmentation.

The new approach required adopting new study years. The Wyoming Geographical Information Advisory Council (WGIAC) recently completed the Powder River Basin portion of their 1 × 1 meter resolution 2002 color infrared (CIR) archive. Most photos in the project were taken in 2001, with a few flown in 2002. The 2002 CIR photographs, which are 6 × 9 miles, were used to represent present development.

Black and white 1 × 1 meter resolution photos (also obtained from WYGIAC) from a 1994 archive were used to represent pre-development. Each black and white photo is a quarter of USGS topographic quadrangle map, (3 × 4.5 miles in this area) and therefore takes four black and white images to match one of the 2002 CIR (Figure 11).

Due to time constraints, available resources, and the large volume of data, one quadrangle, Three Mile Creek Reservoir, was used. Bounding coordinates for the quadrangle are: -105.630107W, -105.495171E, 44.003353N, and 43.871645S. Three Mile Creek Reservoir was one of four quadrangles originally chosen that were located in four quadrants of the Powder River Basin, and it was the first quadrangle that the images were prepared for analysis.

Coal bed methane well locations indicate areas of development, and therefore, areas that will have access roads. The Three Mile Creek Reservoir quadrangle has 639 wells established (1996-2005) on it; while the eight surrounding quadrangles have an average of 619.6 wells (including all wells 1990-2005). Development did not begin on the Three Mile Creek Reservoir quadrangle until 1996. The well point data came from the Wyoming Oil and Gas Conservation Commission.

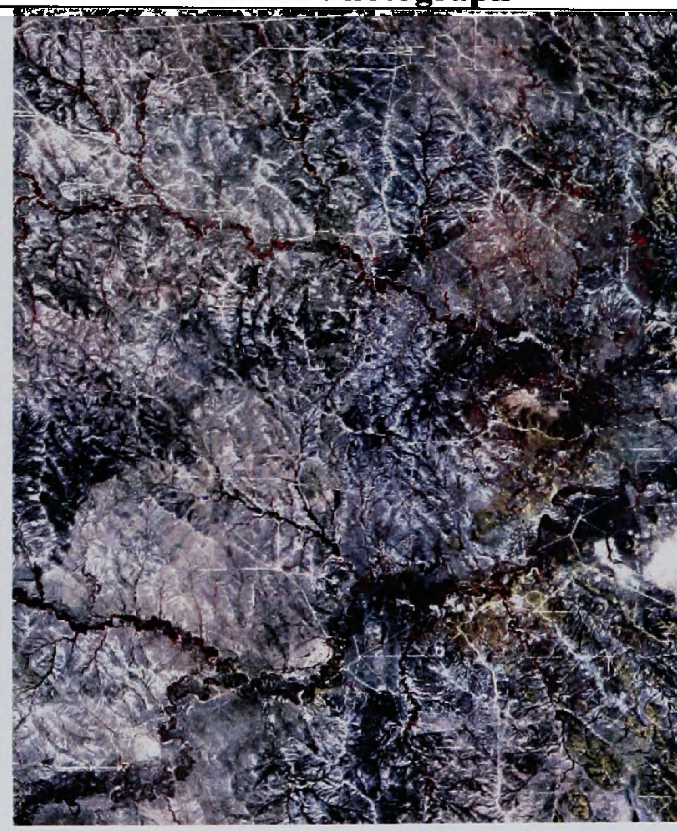
1994 Black and White Aerial Photograph	2002 CIR Aerial Photograph
	

Figure 11 Aerial Photographs for 1994 and 2002, WYGIAC, 2005.

All images from the WYGIAC site were downloaded as Mr. Sid files and converted to Arc grids in the MrSID (LizardTech, 2005) viewer. The imagery was then ready to begin extracting the linear features, roads, and pipelines. The well point data

came in x, y geographic coordinates and was converted to a shapefile in ArcCatalog® (ESRI, 2005).

Feature Extraction Using Feature Analyst

Feature Analyst®, an ArcGis® (ESRI, 2005) extension created by Visual Learning Systems (VLS, 2005), was used to extract linear coal bed methane features from the 2002 CIR aerial photograph.

White roads were the predominant linear feature on the 2002 image, consequently the training shapefile component of Feature Analyst® employed white roads. Any pipelines on the quadrangle were classed as roads, as it is difficult to distinguish between the two. If all linear features were used in the training file, the learner (a Feature Analyst® process) would produce too many undesired results.

The most efficient and accurate trainer shape was a polyline, which returned far better results than when the trainer shape was a polygon and much less clutter. Polygons were then aggregated progressively, beginning with 100 pixels. This means that any polygon with 100 pixels or less was deleted. The threshold that yielded the best results was 1200 pixels. The shapefile was then converted to a line with a jump gap of 50, which connected lines that fell within a 50 pixel radius and any unwanted lines were manually deleted. Figure 12 shows the final results using Feature Analys®t in yellow.

Because Feature Analyst® did not extract all of the roads (approximately 60% were extracted), and some of the roads were still incomplete, it was necessary to digitize the remaining linear features. The most efficient way to do this was to export the shapefile into a feature class within a geodatabase, set the snapping environment, and

begin digitizing. When all of the linear features were digitized, the "must not have dangles" topology rule was applied and the topology was cleaned (Figure 12).

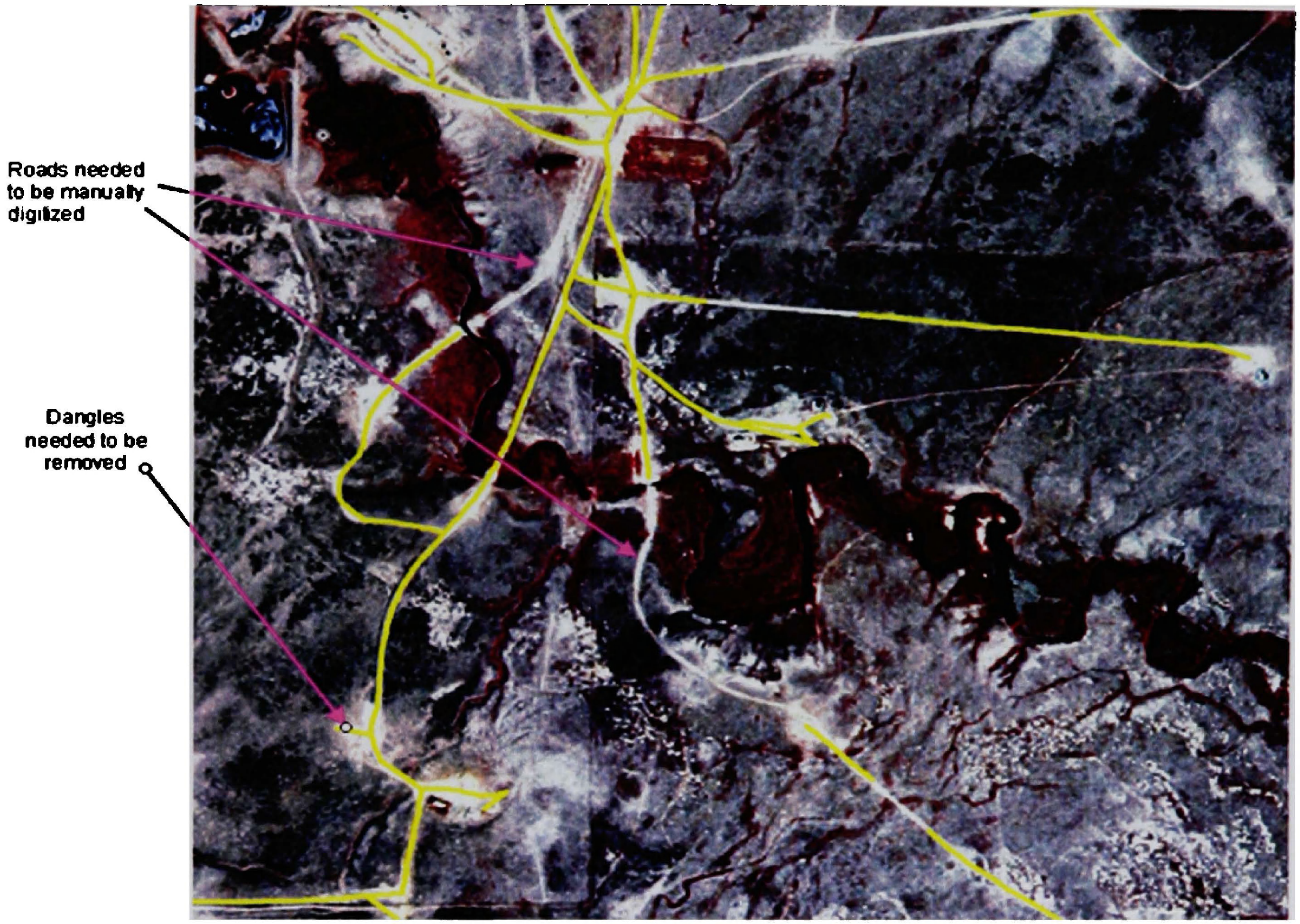


Figure 12 Feature Analyst® Results, Kreilick, 2005.

In order to attain patch statistics, the linear features and the area that was not classed as a linear feature needed to be in vector format. In other words, there needed to be two feature types; coal bed methane linear features (roads and pipelines) and non-coal bed methane features. The feature class was converted to a raster file, and all of the linear feature values were classed to 1 and the nodata was reclassed to 2. The raster file was then converted back to a vector file format, with a grid class field consisting of 1s and 2s as shown in Figure 13.

FID	Shape*	ID	GRIDCODE
0	Polygon	1	1
1	Polygon	2	2
2	Polygon	3	1
3	Polygon	4	2
4	Polygon	5	2
5	Polygon	6	2
6	Polygon	7	2

Figure 13 Grid Code Field with Values 1 and 2, Kreiiick, 2005.

Area and length fields were added to the vector file, a script was added to both of the fields to calculate statistics, and the fields were populated. Field summaries then provided the necessary data to determine patch statistics shown in Figure 14.

Attributes of 2002_finalpoly

FID	Shape*	ID	GRIDCODE	area	length
0	Polygon	1	2	434.918196	106.172756
1	Polygon	2	2	0.684675	3.772901
2	Polygon	3	2	220.620442	76.047019
3	Polygon	4	2	1.349660	5.673509
4	Polygon	5	2	2775.568457	346.917448
5	Polygon	6	1	0.684674	3.772900
6	Polygon	7	2	6658.476669	509.681175
7	Polygon	8	2	7681.838289	474.111000

Figure 14 Area and Length Fields Populated, Kreilick, 2005.

Feature Analyst® was not used with the black and white 1994 image because the pixels were merely shades of gray and thus were in only one band (2002 CIR Photograph has three spectral bands in the green, red, and near-infrared, respectively), and would be more difficult for the program to detect patterns. Fortunately, there were far fewer roads for the earlier images, and they were fairly easy to see. Roads from the 1994 image were simply digitized in ArcMap® (ESRI, 2005) (see Figure 15). Once the roads were digitized, statistical procedures were applied as described above.

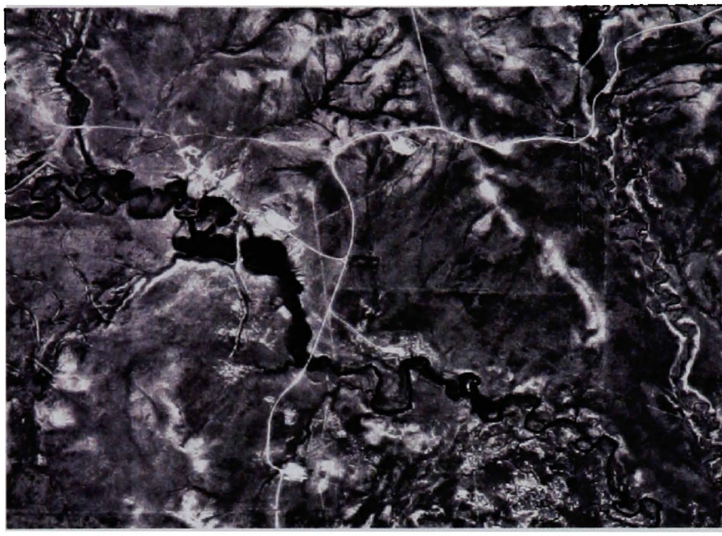
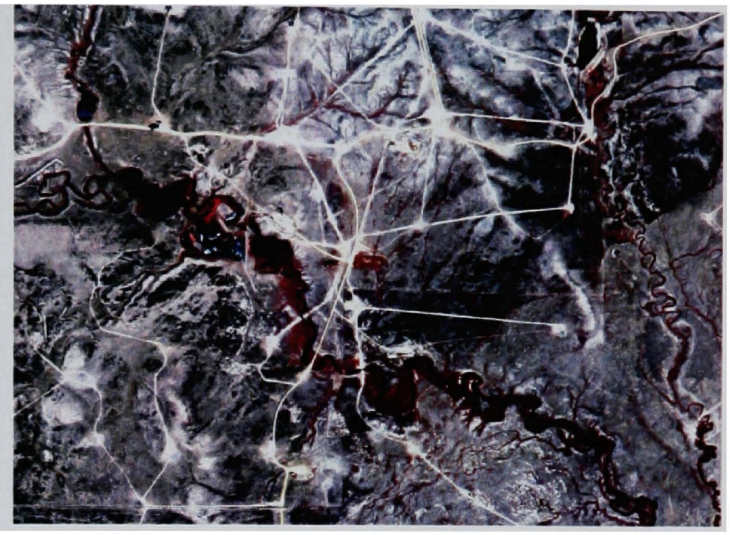
1994 Digitized Only	2002 Feature Analyst and Digitized
	

Figure 15 Visual Comparisons of Two Time Periods, Kreilick, 2005

Section 2: Historical and Current Energy Policy Analysis

Spooner (2002) states that energy geography cannot be fully examined without the consideration of the political environment that monitors and regulates the energy industry. Methods to address the second research question, *How has energy policy at the state and national levels impacted landscape fragmentation change as it relates to the coal bed methane industry?* focus on the review and evaluation of historical acts and energy policies.

Two historical acts are critical to building an understanding of current trends in coal bed methane development in the Powder River Basin. These acts include the Stock Raising Homestead Act and Mineral Leasing Act. Much contention in the research setting exists over the fact that mineral rights take precedence over surface rights. The mineral precedence dates back to the Stock Raising Homestead Act of 1916. The Stock

Raising Homestead Act was one of several subsequent acts to the original Homestead Act of 1862 which encouraged settlement in the West, while at the same time withholding mineral rights to the properties being settled. The creation of the Mineral Leasing Act of 1920 enabled the lease of federally controlled mineral estates through the Stock Raising Homestead Act. Essentially, these two historic acts created the split-estate concept that property can have separate surface and mineral rights.

Since the late 1970s, state and national energy policy have continued to affect this region. The specific policies include the split estate, beneficial uses of water, and the Surface Mining Control and Reclamation Act (SMCRA). In an attempt to give the surface owner more leverage, the state of Wyoming recently passed the New Split Estate Law (2005). In addition, state law concerning beneficial uses of water is another arena for conflict regarding the split-estate. Implications of the new split-estate law and the concept of beneficial uses of water in the state of Wyoming are discussed in depth in Chapter Five.

Congress passed the SMCRA in 1977 to give more control to states when granting permits to mine. The intent of the law was also to allow more stringent reclamation standards. The SMCRA and its influence over coal bed methane development in the Powder River Basin are examined further in Chapter Five.

The current U.S. energy policy, which utilizes a supply perspective, encourages building domestic supplies of natural gas and reducing dependence on foreign energy sources. Included in the policies are opening new lands and minimizing regulations throughout the U.S. (ALL Consulting and MBOGC, 2004, Bryner, 2002).

The national energy policy, written in 2001, required several attempts to pass through Congress. President Bush was finally successful at making the policy a bill when Congress passed the National Energy Bill and the President signed the bill in August 2005. Details and implications of the new energy policy are discussed fully in Chapter Five.

Section 3: Qualitative Basin Scale Analysis

A field site visit was conducted March 2005 in order to acquire a priori knowledge about the study site and to see coal bed methane development firsthand in the Powder River Basin. In addition to six informal in-person interviews, an aerial reconnaissance surrounding Gillette, Wyoming, was taken in order to gain a landscape perspective of the region and to gain a better understanding of the visual impacts of coal bed methane extraction.

Informal Interviews

Informal interviews were conducted while visiting the Powder River Basin. The persons interviewed represent a range of perspectives related to coal bed methane development in the Powder River Basin. Interviews were conducted in a variety settings including: three BLM offices, a home and ranch tour, a plane ride, and two driving tours. The impetus behind each interview was for the interviewee to share his/her experiences, opinions, and concerns regarding coal bed methane development. In addition, because policy evaluation was a key component to this thesis, individuals who were impacted by

policy were targeted for interviews. This qualitative approach was adopted to gain a better understanding of the issues and concerns associated with development.

The list of interviewees was generated from an email requesting an interview that was sent out prior to the visit. The original list of approximately twenty individuals came from the Buffalo Field Office Powder River Basin Interagency Working Group (2004) that is available in the Environmental Impact Statement for the Wyoming portion of the Powder River Basin. All individuals listed on the Interagency Working Group were government representatives (with the exception of one), who represented a coalition based on government, industry and landowners. From this list, two private landowners and one industry representative were referred. Of the three referrals, one landowner was interviewed. Due to current litigation, the industry representative was not able to give a tour of the company's development site and an interview was not conducted.

Though six people were interviewed, five were referenced throughout the paper. To protect confidentiality, interviewees were referred to in the following manner: the Rancher, Coordinator A, Coordinator B, the Permitting Official, and the Hydrologist.

Field Observations

Landscape scale impacts due to coal bed methane development are difficult to see while driving. It is also impossible to discern a pattern from the ground. And invariably, much of the property was inaccessible, no trespassing signs were posted, and many gates were locked.

The single-engine, four-person plane ride began in the Gillette Airport. Well houses could be seen from the runway, as well as from the main street downtown Gillette. In addition, the massive pits of the coal mines on either end of Gillette were

equally visible. The aerial reconnaissance was made in two loops, one north along Wild Horse Creek and one south along the Bel Fourche River.

The topography south of Gillette is very flat and the vegetation varies little; short prairie grasses dominate. This area is where coal bed methane development began in the late 1980s. Naturally occurring depressions, or playas, could be seen from the plane due to the salts they leave behind after evaporation. Coal bed methane impoundment ponds were scattered and a grid-like pattern of roads could be seen resulting from the original 40-acre spacing of the wells. Technological improvements allowed the wells to become more spread out to accommodate the current 80-acre spacing. Traditional oil derricks were interspersed with the coal bed methane wells. The pipelines ran for miles at right angles, and could be discerned mostly by texture and pattern (Figure 16).

Figure 16 Texture and Pattern make Pipelines Easy to See, Kreilick, 2005.

The northern aerial loop complimented the drive taken the previous day from Sheridan to Gillette. What appeared to be isolated well houses and compressor stations from the ground were obviously part of a much larger network of roads and pipelines. The topography consisted of drainages and ravines, valleys, hills and ridge tops. Vegetation varied, with deciduous trees in the riparian zones and sagebrush and prairie grasses covering the hills.

The aerial view revealed the fragmenting nature of the linear features created for coal bed methane development (Figure 17). Linear features refer primarily to the

Figure 17 Fragmenting Nature of Coal Bed Methane Roads, Kreilick, 2005.

network of roads and pipelines built in order to access and distribute. The well pads appear circular from the air and on imagery. Often, the roads are linked to each other, creating what appears to be a fishnet pattern upon the landscape. The pipelines distribute the gas underground to the compression stations and beyond for commercial distribution. The pipeline paths stand out from the roads because they are much straighter and wider and turn at sharp angles. On the other hand, they are usually somewhat vegetated, and are discerned visually by texture and pattern.

Chapter Summary

The purpose of this chapter was to present the methodology. The first section of this chapter described the process to analyze landscape fragmentation. Two previous studies were described that utilized patch size and number as well as a classification system. An initial attempt to classify the Powder River Basin was made with 30 meter data, but was determined to be unsuccessful due to data quality and image resolution. A second and successful method was employed using a feature extraction approach using Feature Analyst.

An introduction to historical acts and current energy policy was presented and methods of assessment were described. Highlights of certain acts and policy focused on aspects that have particular relevance to coal bed methane development.

The field-based component of the research was discussed in the last section. In-person qualitative methods were discussed in the last section, which included a field site visit in March, personal interviews, and aerial field observations. A primary

understanding from the reconnaissance flight as well as the site visit was that the impacts of coal bed methane development are happening at a landscape scale. The linear features and patterns seen from the air have a localized dimension consisting of roads, well houses, compression stations, noise and dust.

CHAPTER FOUR: RESULTS OF LANDSCAPE ANALYSIS

Introduction

This chapter describes in detail the findings from the landscape analysis outlined in Chapter Three. Studies by Civco et al. (2001) and Apan et al. (2002) demonstrated that landscape fragmentation can be measured by number of patches mean patch size. The following paragraphs summarize the findings that pertain to the degree of landscape fragmentation due to coal bed methane development for one quadrangle in the Powder River Basin. In addition, road density statistics are included for each year.

Patch Analysis

The patch analysis examined 59 square miles located in the Powder River Basin. As indicated in Figure 18, all statistics of the patch analysis increased the latter year, except for mean patch size which decreased by 93%. The analysis found a 939% increase in the number of patches, 147 % increase in miles of roads, and 157% increase in road density.

Figure 19 shows roads, pipelines, and patch polygons for both years; the fragmenting nature of coal bed methane development is obvious between 1994 and 2002. The data for 1984 was included to show how dramatic the change between 1994 and 2002 is. The substantial increase in patches and roads relative to the number of wells

	1984	1994	2002	Percent Increase 1994 to 2002
Total Area Analyzed	*59 square miles*	59 square miles	59 square miles	na
Number of Patches	*25*	41	426	939% increase
Miles of Roads	*84 miles*	117 miles	290 miles	147% increase
Road Density	*1.4 miles per square mile*	1.9 miles per square mile	4.9 miles per square mile	157% increase
Mean Patch Area	*2.3 square miles*	1.43 square miles	.1 square miles	93% decrease
Number CBM Wells	*0*	0	481	na

Figure 18 Patch Analysis Statistics, Kreilick, 2005.

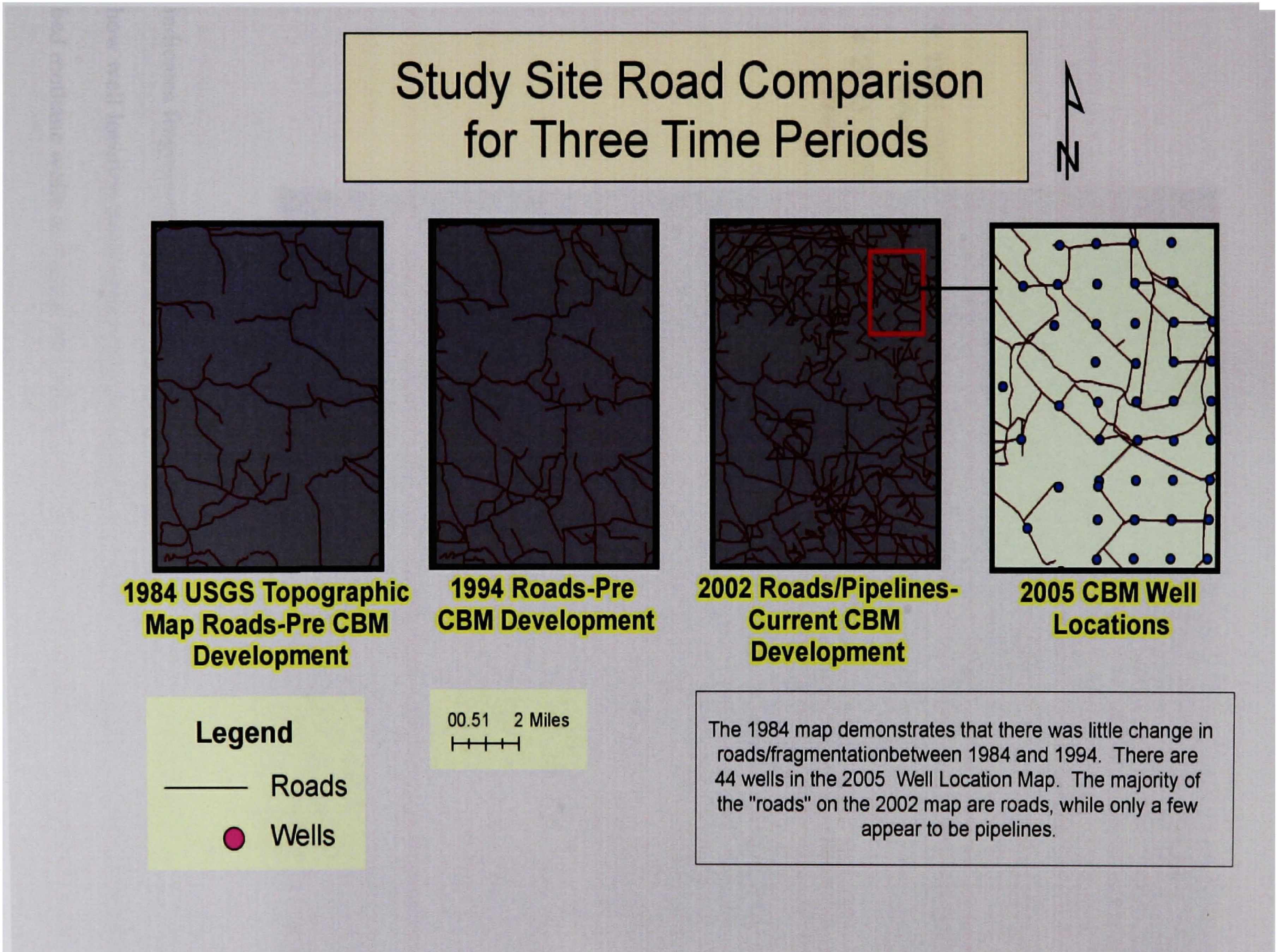


Figure 19 Study Site Road Comparison for Three Time Periods, Kreilick, 2006.

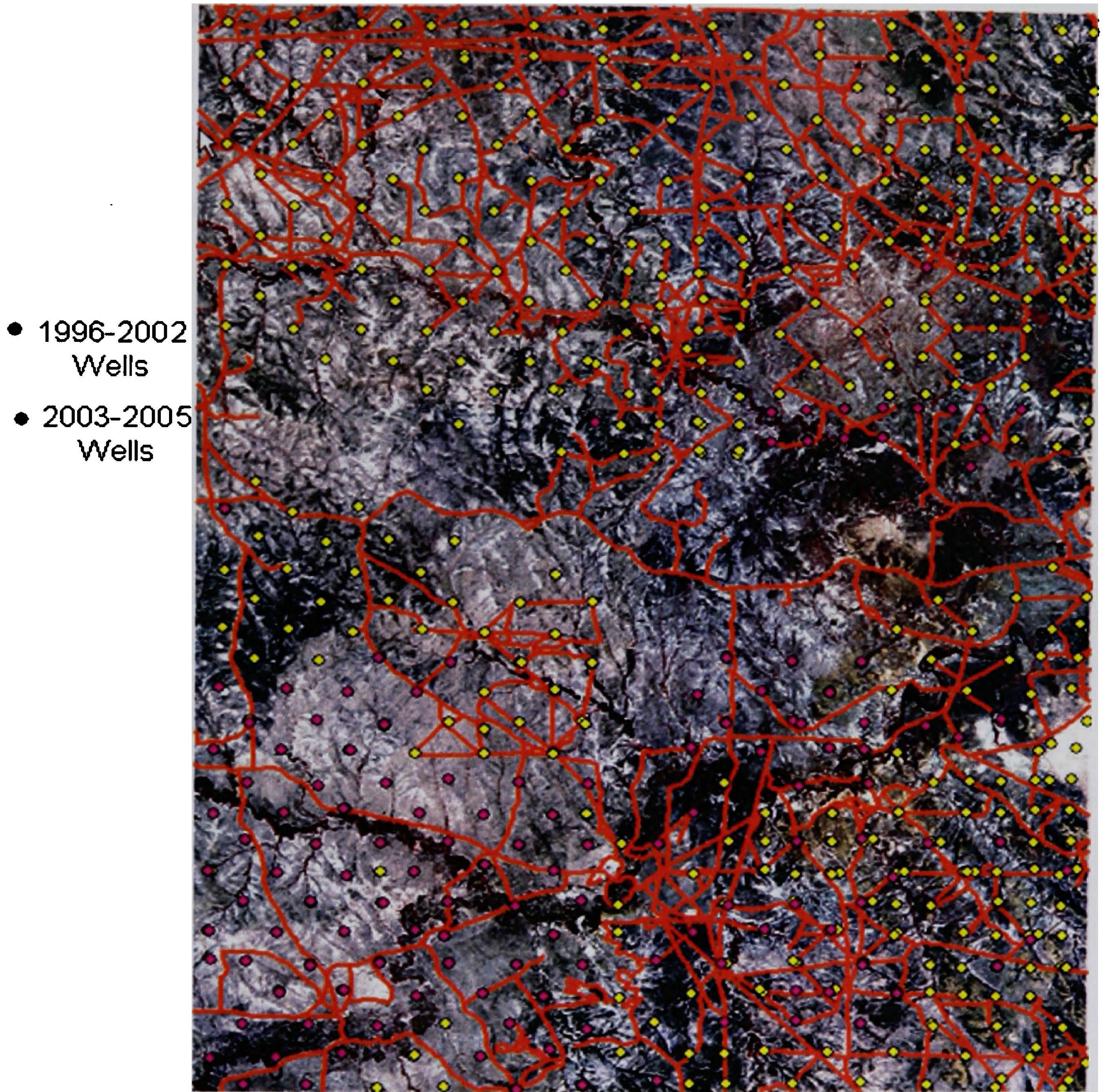


Figure 20 2004 Coal Bed Methane Well Locations, Kreilick, 2005.

indicates fragmentation due to coal bed methane development. In addition, one can see how well location determines road placement in Figure 20. There are a total of 648 coal bed methane wells in Figure 20 with multiple wells in one location. The pink colored

wells were drilled after the image was taken and it is possible that there may be more roads now to access the wells drilled after the image date.

There are several implications related to landscape fragmentation. Landscape fragmentation due to road development diminishes the quality of life for the residents as well as ecological and wildlife health (Weller et al. 2002, Bryner 2002). A loss of privacy due to increased traffic along with dust and noise alters what could previously be described as a secluded lifestyle for the residents of the basin. Air pollution caused by dust and exhaust from compressor stations increase and or exacerbate instances of asthma and respiratory disease (Weller et al. 2002).

The roads allow for increased human damage to fragile ecosystems, resulting in soil compaction and soil erosion due to surface water runoff. Vegetation removal and weed invasion threaten wildlife resources. In addition, high volumes of traffic increase road kill numbers (Weller et al. 2002).

Weller et al. (2002) state that the access for people to previously remote areas is the most significant impact of roads related to coal bed methane development. In addition, Weller et al. (2002) add that roads built for oil and gas development are often permanent features on the landscape, which bring with it permanent impacts and alterations to the people and wildlife that live there.

The total area of the patch analysis was much smaller than in the original design of this study. The original study area encompassed all of the wells in Wyoming. Because of data issues, time, and resources, the study area became the Three Mile Creek Reservoir Quadrangle. One of the goals of this thesis was that the methods used in the patch analysis be repeatable basin-wide. The methods described and employed in

Chapter Three are indeed repeatable basin-wide, yet wholly dependent on the availability of time and resources. In addition, future upgrades to Feature Analyst or similar programs that utilize pattern recognition will shorten the time needed for projects such as this one, making basin-wide analysis increasingly more attainable.

Chapter Summary

Chapter Four outlined patch analysis findings using orthorectified images from 1994 and 2002. Most significantly, the analysis revealed a 939% increase in number of patches and a 93% decrease in mean patch size. In addition, a road density increase from 1.9 miles per square mile to 4.9 miles per square mile represented a 157% increase. These results have implications for wildlife, soils, hydrology, rural residents' quality of life, and overall ecosystem health. The next chapter provides insight into the policy context that has influenced these quantifiable changes on the landscape.

CHAPTER FIVE: A BASIN FRAGMENTED: POLICIES AND PERCEPTIONS

Introduction

The Powder River Basin is representative of western culture, but it is that of a changing culture. Driving through the heart of the basin is proof that what Michelle Barlow (2005) refers to as an "industrial landscape" is emerging. Several national and state polices have contributed to this landscape scale transition. This chapter addresses the second research question, *How has energy policy at the state and national levels impacted landscape fragmentation change as it relates to the coal bed methane industry?* Findings from the analysis of historical and current energy policy shaping landscape fragmentation as well as from first person interviews in the Powder River Basin are presented here.

First, historical acts and their power over today's legislation and land use are discussed. These acts include the Stock Raising Act of 1916, the Mineral Leasing Act of 1920, the Surface Mining Control and Reclamation Act, and Wyoming's interpretation of beneficial use of water. A complete discussion on the split estate is included. A response to the aforementioned laws' impacts on coal bed methane development in the Powder River Basin from a local perspective follows. Second, an analysis of the proposed National Energy Policy (NEP) is included to provide an inventory of recommendations pertinent to coal bed methane in the Powder River Basin. This is followed by a review of the "National Energy Policy: Inventory of Major Federal Energy Programs and Status of Policy Recommendations" report given by the Government Accountability Office.

Finally, the effects of the NEP on the Powder River Basin, which includes the hidden costs of energy development on public lands and subsidy incentives provided to energy companies, are discussed.

1: Western Settlement and the Evolution of the Split Estate

It is important to examine energy policy in the Powder River Basin because historical and current mineral development trends and landscape changes have been impacted by it. A historical homestead act, split estates between surface and mineral owners, state law, and current energy policy are all factors shaping current development in the Powder River Basin. Skov and Myers (2004, p. 6) note that coal bed methane development "is a matter of land use, water and habitat impacts, property rights, and energy policy." Such viewpoints demonstrate the political nature of coal bed methane development. As previously stated, land cover change is tied to politics, economics and policies (Gaile and Wilmont, 2003). The following section will illustrate these connections.

Stock Raising Homestead Act of 1916

One of the first laws that impacted landscape fragmentation and the nature of property rights in the Powder River Basin today is the Stock Raising Act of 1916. The Stock Raising Homestead Act was enacted to encourage further settlement on lands in the West suitable for stock raising and ranching. Congress wanted to stimulate the livestock industry while ensuring control over mineral assets. The creation of the Stock Raising Homestead Act was the conception of the split estate, whereby ownership belongs to two

separate entities. The Act allowed for the patenting of stock lands and reserved the mineral estate for the United States government (One Hundred First Congress, 1990). All coal and other minerals fell under this governmental proprietary reservation (Supreme Court of the United States, 2004).

Subsequently, amendments to the Stock Raising Homestead Act have provided a framework for allowing mineral estates to enter split estate properties. The mineral owner must notify the surface owner with a development plan sixty days prior to proposed development. In addition, the development plan must be presented to the Secretary of the Interior, which is administered by the BLM.

Approximately seventy million acres were patented in the West under the Act. Western states most impacted by Stock Raising lands were Wyoming, New Mexico, Montana, Colorado, Idaho, California and Arizona. Wyoming has the largest amount of Stock Raising Homestead Act lands with approximately sixteen million acres, along with roughly 3,000 mining claims (One Hundred First Congress, 1990).

The Stock Raising Homestead Act of 1916 allows for a complex relationship between surface landowners and mineral owners, called a split estate or severed minerals. Here, the landowner and the mineral owner are not the same entity, and the mineral owner retains the right to extract resources from a given property and can claim mineral rights over the objection of the landowner (EWG, 2004 and Stanford and Hauer, 2002).

Mineral Leasing Act of 1920

The second significant act affecting landscape fragmentation change from coal bed methane development on the Powder River Basin is the Mineral Leasing Act of 1920. Historically, the U.S. government withheld mineral rights on homestead land,

creating a large number of split estates in the West including such areas as the Powder River Basin. The enactment of the Mineral Leasing Act of 1920 (MLA) allowed the lease of government held mineral rights, which includes oil and gas leases. In 1981, the Department of the Interior (DOI) determined that coal bed methane falls under federal oil and gas regulation (All Consulting, 2004). It is through the MLA that the Bureau of Land Management (BLM) as well as the Forest Service (FS) regulates federal oil and gas leases. The public land in the Powder River Basin is primarily managed by the BLM, and, therefore, is under BLM rather than FS jurisdiction. The BLM relies on several acts to regulate federal leases, including the Federal Land Policy and Management Act, the National Environmental Policy Act, which requires Environmental Assessments (EA) or Environmental Impact Statements (EIS), and the Federal Onshore Oil and Gas Leasing Reform Act of 1987.

Surface Mining Control and Reclamation Act (SMCRA)

The third act is directed at restoration of lands impacted by mining, and was due in part to the grassroots efforts of the Northern Plains Resource Council in Montana. In 1977 Congress passed the Surface Mining Control and Reclamation Act (SMCRA) in order to provide more stringent guidelines and power to states when granting mining permits. The new law raised reclamation standards and required the Decker Coal Mine, which is just north of Sheridan, to implement a different approach to reclamation in the 1970s. Rather than reclaiming with rolling hills and wheat, the Decker Coal Mine implemented a plan that reclaimed the pits by mimicking the natural topography. The plan incorporated native grasses and plant species, in addition to providing for wildlife needs.

Wyoming's Beneficial Use of Water

Lastly, Wyoming's definition of beneficial use of water encourages coal bed methane development, which eventually results in landscape fragmentation. Irrigation, agricultural, recreation, and stock watering are generally considered beneficial uses of water (ALL Consulting, 2003). Wyoming water law takes a preferred use approach when permitting for coal bed methane water. Industrial use is the fourth in the list of preferred uses for the state, and coal bed methane water falls under this category. The State Engineer for Wyoming is the entity responsible for groundwater appropriation permits and for determining the applicability of preferred use (Bryner, 2002; Jacobs, Fasset, and Brosz, 1995).

Ramifications of a Split Estate for the Landowner

The previously discussed acts have led to the split estate, which have ramifications for landowners. Fifty-eight million acres of privately owned land have a split estate status with the federal government. Conversely, the federal government owns mineral rights on 744 million acres of land across the US (ALL Consulting and MBOGC, 2004). The mineral rights held by the federal government are auctioned off by the BLM for coal bed methane development. In addition, more than half of the land slated for coal bed methane production is on split estate properties (Skov and Myers, 2004).

If the mineral owner is unable to gain access to the property from the surface owner, the BLM can grant access with the addition of a federal bond, which is acquired by the mineral owner. The bond is held by the federal government to ensure proper reclamation of the land and payment to the surface owner.

Payments to the surface owner include surface use and surface damage fees. Service use is similar in concept to paying a rental fee for the use of the land. This could include service use for the pipeline under the ground, space for the well pad, and road access to the wells. Surface damage is payment for effects that are more long term or permanent. Grazing or pasture land converted to roads or holding ponds also warrant surface damage fees.

If the mineral owner accesses the land through a bond (an agreement between surface and mineral owner could not be reached), surface use and damage fees are paid at fair market value. This is not as common, and in many cases is not as lucrative as agreeing to a payment plan between both surface owner and mineral owner, according to the Permitting Official. If the land is accessed through an agreement between the two owners, then the surface fees are paid under those terms.

Consequently, the landowner does not have complete control over a split estate property. According to Skov and Myers (2004), the split estate institution gives the oil and gas companies power over a region in which they have temporary interest. As outsiders, the oil and gas companies do not have the same vested interest in the health of region's economies, the people or the environment as that of a permanent resident. Decisions are made with the market, competition, efficiency and profitability in mind and are not necessarily in the best interest of the permanent residents and or in the best interest of the region (Skov and Myers, 2004).

Split estate precedence can ellicit various responses from surface owners. Two landowners on neighboring properties can have entirely different responses to the same oil and gas operator developing on their land. One landowner could be cautious and

unwilling to sign use agreements with mineral owners on his/her property even though the development may proceed without landowner approval. Meanwhile, an adjacent owner could be completely supportive of the development, and sign use agreements at the first attempt to negotiate. This landowner will receive use compensation and will potentially have the roads on his/her property upgraded.

Whichever the case, the compensation may or may not be satisfactory to the landowner. If compensation is found to be grossly unsatisfactory, there is little or no recourse for the landowner. According to the Permitting Official, legal battles are costly, and oil and gas companies have more financial resources and experience than do private landowners.

There is only a single instance in the Powder River Basin where a private landowner just miles north of Sheridan was able to take the coal bed methane developers to court and win the case. The Brannamans sued a Michigan (not in reference to the state, but rather the name of the company) owned company for land degradation and destruction of their horse training clinic business, and won (case number 03-143 WY). At this point the production on this family's land has stopped. Even though development stopped, Michigan still holds mineral rights on the property (Bernofsky, 2005, Lam, 2003).

Wyoming's New Split Estate Law 2005

In an attempt to standardize and provide more information and protection to the private landowner regarding development on their property, an act was passed by the Wyoming Legislature in the spring of 2005. The Split Estate-Procedures for Oil and Gas Operations Law came into effect July 1, 2005 (State of Wyoming, 2005).

The law outlines four major guidelines (Barlow, 2005, p. 12). First, the operator must notify the landowner thirty days before any development can begin on the property. If operations fail to begin one hundred eighty days after the initial notice, a second thirty day notification is required. Next, the surface owner and developer must collaborate on a surface use plan that includes surface resources, reclamation, and payment of damages. In addition, the surface owner must be compensated for loss of production and income, loss of land value, and loss of value of improvements. Lastly, under the new law, if the landowner and the oil and gas developer are unable to agree upon a development plan, the oil and gas developer is required to post a $2,000 bond with the state. The purpose of the bond is to compensate the landowner for damages to the surface.

According to the Permitting Official, the surface owner and mineral owner rarely come to bonding scenarios. And when they do, the landowner rarely benefits. The fair market value granted to the landowner for access value is usually less than it would have been had the two parties come to an agreement.

Under debate is whether a developer is responsible for the state bond in addition to the already mandated $1,000 federal bond required on all federally held mineral estates (Associated Press, 2005). Like the new state split estate law, the federal bond is applicable where the landowner and oil and gas operator are unable to agree upon a surface use agreement. While some operators are agreeable to the state law, others would prefer one bond that would compensate both entities rather than posting two separate bonds.

Kathleen Clarke, Director of the Bureau of Land Management, contends that operators on the 11 million acres of federal mineral rights under private land in Wyoming

should be exempt from the new state law. Clarke stated that the new law would burden the federally owned mineral estate. The Governor of Wyoming, Dave Freudenthal, and Attorney General Pat Crank contend that the oil and gas operators are subject to the new split estate law and both believe the state would win if sued by the BLM (Associated Press, 2005).

A Wyoming Rancher's Response to Beneficial Use of Water

When the coal bed methane company proposed in 2004 twenty-three reservoirs of coal bed methane water on the Rancher's property located between Gillette and Buffalo in Wyoming, it did not have to include beneficial use beyond gas production. The reservoirs would consume twenty acres of the ranch, not considering the infiltration and horizontal travel of the water once brought to the surface. It would not be possible for the Rancher to put the water to any generally understood beneficial use without permanently damaging the quality of the soil or contributing to invasive plant species dominance. According to the Rancher, the sheer quantity of water would be impossible to put to beneficial use in a naturally arid climate.

In 2003, seven coal bed methane wells were installed on the ranch, and they pumped water for a short period of time. The wells produced 88 gallons of water per minute and the SAR value was 15-18[5]. The water was allowed to run down the draws to the main drainage that runs through the property. The water killed grass along its path, filled potholes, raised the surface water, created salt flats, and lush weeds flourished.

The ranch property lies on three coal seams with the potential to develop three wells per eighty acres with current technology. A company owning the mineral rights on

[5] Salts that have sodium are dangerous to soil and prevent water infiltration. The sodium absorption rate (SAR), the ratio of sodium to calcium plus magnesium, is the measurement used to determine salt concentrations. A SAR of 15 or higher is considered detrimental to soil.

the property wanted to build twenty-three water reservoirs on the ranch. The Rancher disagreed to the proposed development and all coal bed methane extraction on the ranch was on hold at the time of the interview.

Under the proposed development plan, the amount of water on the surface will create a drop in water pressure and be difficult, if not impossible, for the Rancher to put this water to a beneficial use. If development proceeds, the eight artesian wells on the ranch will require pumps, creating an additional cost for ranch operations.

Local Response to the Coal Bed Methane Industry's Standards and Accountability

Reclamation standards that are required by the coal industry are the type of standards that both Coordinators A and B say the coal bed methane industry is lacking. Both Coordinator A and B agree that the coal bed methane industry is not being held to the same stringent standards as the coal industry.

The lack of standards is evident in the viewscape that results from development. An altered viewscape is tied directly to the transition from ranch lands to industry. The presence of power lines on a once isolated ridgeline, or the lights of a compressor station at night create a visual change. Attachment to place is related to how one perceives his/her surroundings, and how appealing one finds the view (Tuan, 1993). Today, the viewscape is a constant reminder of increased traffic, background noise, trash and micro-litter.

Coordinator B would like to see the industry make infrastructure less obtrusive. Landscaping around the compression stations would provide a visual transition on the landscape. Other areas of improvements could include burying the power lines and keeping the lines off ridges. Telemetrizing the wells, monitoring the wells by computer,

would reduce the traffic on dirt roads. Further improvements could include burying compressor stations and placing motion detectors on night lights.

The Rancher has dealt directly with the gas and oil industry's lack of standards. The ranch has a long history with the oil industry with maximum production occurring on their land in the 1950s to 1980s. The oil has 160 acre per well spacing. The Rancher recently had an abandoned oil well plugged after many years of requesting that it be reclaimed. The delay meant three times the expected volume of cement was needed to plug the well.

Inadequate standards and communication have allowed multiple electric and pipeline ditches to be dug side by side just off the road to the Rancher's house. The six pipelines laying adjacent to each other have all been dug in the last eighteen months, the result of seven coal bed methane companies developing within a half mile of each other. Redundancy with compression stations is also a problem. Better standards would eliminate such redundancy and create a framework for sharing infrastructure.

Closely related to standards is accountability. The Rancher believes that accountability, engagement, and education are necessary components for successful mineral extraction on split estate properties. The process the Rancher followed to reclaim the well illustrates what he would like to avoid with coal bed methane companies. A lack of industrial accountability leads to landowner mistrust and future conflict. Problems the Rancher faced with the reclamation on his property demonstrate potential problems landowners can encounter with industry due to a lack of standards.

Wyoming is a wealthy state, with a rich wildlife trust fund and healthcare system. Both programs are beneficiaries of coal bed methane development. The state worries that

requiring stricter standards from the coal bed methane industry will prompt companies to leave and Wyoming will lose valuable coal bed methane dollars. According to Coordinator A, this concern leads to indecision among state agencies, and a lack of industrial monitoring.

2: Current Energy Policy

The Powder River Basin clearly shows that landscape fragmentation and energy development are indeed impacted by federal policy. The rationale behind much of the 2001 National Energy Policy's (NEP) 106 recommendations was to increase the national energy supply while at the same time protecting and improving our environment (NEPD, 2001). The NEP emphasizes increasing the supply of fossil fuels by opening new lands for exploration, streamlining the permitting process, easing regulatory requirements, and expanding the energy infrastructure (Bryner, 2002). Many of the recommendations have been enacted and put into legislation directly impacting the energy development in the Powder River Basin.

When President George W. Bush began his first presidential term, he appointed a National Energy Policy Development Group (NEPD Group). The NEPD Group, including Vice President Dick Cheney, Colin Powell, and Gale Norton, was directed to generate a national energy policy. The list of persons who met with this group has been kept confidential under executive privilege claimed by the Vice President (Hamburger, Cart, and Miller, 2004). The report the NEPD Group produced provides the President with a series of recommendations for implementing the NEP.

The report describes the current status of energy in the United States, projected energy needs and demands, and recommendations for the President to further increase our domestic energy supply. The report states that there is an energy supply imbalance, and that there is an energy crisis in the United States. Americans are paying higher fuel prices and millions are experiencing blackouts or brownouts (NEPD, 2001). According to the report, if the imbalance persists, our economy, standard of living, and national security are in jeopardy. Energy conservation, the energy infrastructure, and increasing our supply by protecting and improving our environment are areas of concern in addressing the energy crisis.

A contributing factor to a deteriorating energy infrastructure, according to the report, is the regulatory process administered by the government. "Regulatory hurdles, delays in issuing permits, and economic uncertainty are limiting investment in new facilities making our energy market more vulnerable to transmission bottlenecks, price spikes and supply disruptions" (NEP, 2001, p. 11). To expedite the process, the NEPD Group recommended that the President issue an Executive Order to require all agencies that decline or impair permits to provide a "detailed statement" describing reasons for a decline. That statement must address the following: energy impacts of the action, adverse energy impacts were the project implemented, and alternatives to the proposal.

Put in the context of coal bed methane development, were the BLM to decline a development plan, a written document stating the energy impact of the decision, impacts of the project if allowed to proceed, and alternatives to the original development plan would be required. The declined proposal documentation would be submitted to the Office of Management and Budget as well as with the Federal Register. According to the

BLM officials in Buffalo, WY, and Miles City, MT, no proposed coal bed methane permits have been declined.

The national energy policy recognizes that energy development is potentially damaging to the environment and natural resources. To mitigate possible environmental degradation, the NEPD report recommends a Royalties Conservation Fund, whereby potential funds of billions of dollars from the development of the Arctic National Wildlife Refuge (ANWR) be allocated to land conservation efforts elsewhere.

Further mitigation is derived at the state and federal level with environmental regulation. The national energy policy states that traditional regulatory programs may not be the most effective way to protect the environment. The policy suggests market-based incentives to promote environmentally sound energy development. Finally, the report recommends the President issue an Executive Order requiring permitting agencies to rationalize the permitting process and expedite the issuance of permits. It is also recommended that permitting agencies coordinate their activity.

The Government Accountability Office Reports on the National Energy Policy

In January 2005, the Department of Energy (DOE) provided a status of the NEPD Group recommendations and directives and the Government Accountability Office (GOA) reported to Congress in June 2005 on the status of the recommendation and inventory of federal energy related programs.

The GOA (2005) report, "National Energy Policy: Inventory of Major Federal Energy Programs and Status of Policy Recommendations" initially states that many of the NEPD Group's recommendations are open-ended and not presented in a measurable format. Given the ambiguity, the GOA still provided a status report on the 106

recommendations based on their observations. In some cases, the recommendations were given a not measurable or unclear rating.

The DOE reports that in 2001 the President directed public agencies responsible for permitting to expedite projects related to the production, transportation, or conservation of energy and within the means of the law with Executive Order 13212. In addition, a task force was created to monitor and ensure efficiency throughout federal agencies whose purpose is to grant permits for energy development. Executive Order 13337 gives authority to the Secretary of State to grant pipeline permits in trans-boundary regions. The GOA reported that it was unclear if the task force had met its goals and that it was unsure of the task force's future as the charter ended in January 2005.

Another related recommendation from the NEPD Group is that the President directs the Secretaries of Energy and the Interior to increase oil and gas production with new technology. A subsequent recommendation is aimed at oil and gas production improvements with public and private organizations. The DOE reports that new technology will allow for more drilling precision and certain programs have been known to improve energy production, reduce costs and find areas with oil previously overlooked. Also, improvements in technology allow for energy extraction structures to be raised above ground, resulting in lower impacts in the Arctic and other sensitive areas. The GAO notes the status report does not address DOI programs aimed at energy production efficiency.

A final recommendation that has a bearing on the Powder River Basin addresses federal land status and lease stipulations. It is recommended that these be scrutinized to ensure that all unnecessary stipulations are removed and modifications be made to leases

where possible. The DOE reports several studies, one of which was in the Powder River Basin as it relates to coal bed methane development. BLM officials have been directed to reconsider restrictions imposed on leases and ensure that they are reasonable. The GAO reports no observations related to this recommendation (U.S. GAO, 2005).

National Energy Policy Impacts on a Local BLM Field Office

The NEP has direct impacts on coal bed methane permits at the BLM field office level. The directive to expedite permits within the Powder River Basin is clearly evident in the permitting process at the Buffalo, Wyoming BLM Field Office, where ten times more permits have been granted than any other BLM office. According to the Permitting Official, the Secretary of the Interior Gale Norton has requested officials involved in the permitting process to grant all permits to drill for coal bed methane. Officials in the Buffalo and Miles City field offices stated that no coal bed methane permits had ever been denied.

Partly due to the rate of development and partly due to the length of time it takes to receive a permit, companies submit incomplete applications in order to get put on the list for consideration. Rather than decline incomplete applications, the Buffalo Field Office sends out letters of deficiency, which allows the applying company ten days to complete their application. According to the Permitting Official, companies fail to invest the time to determine the best well-site location within the allowed 80-acre per well spacing. Often, a company surveyor just determines the center of the 80-acre division in order to place the wells, disregarding the topography and surrounding resources. Consequently, the BLM finds itself planning for companies that have simply not taken

the necessary time to submit complete plans. They do this because the BLM cannot deny an application because it is incomplete.

According to the Permitting Official, the federal government has a monetary incentive to grant well permits. The federal government is compensated for the lease of the mineral right and 12.5% of the royalties from production. Currently, the federal government is losing millions of dollars for two reasons. First, the federal leases go through a slower and lengthier process than state permits. A federal permit requires an onsite visit and an environmental assessment because it is on public land. The BLM leased land is often on rougher terrain, making the environmental assessment more difficult. Second, development adjacent to federal land is taking gas that may lie under federal land, but is being produced through private leases. Due to the nature of coal bed methane mining, gas lying under nearby lands can escape through wells on adjacent properties.

Hidden Costs of Development on Public Lands

Energy development on public lands can be more timely and costly to produce for a variety of reasons. A recent study by the Energy Policy and Conservation Act (EPCA) (2003) researched the effects of opening lands currently under partial or complete restrictions and lands that have limited access. Leasing restrictions can include environmentally sensitive areas, such as nesting sites. There can also be timing restrictions where companies need to vacate a development site during wildlife migration seasons. Often, the land has environmental amenities that can be difficult to quantify with a monetary figure.

According to the EPCA report, 138 TCF of undiscovered natural gas lies under federal land consisting of five basins, which includes the Powder River Basin. Of the 138 TCF of gas, 63% is completely unrestricted, 12% cannot be leased at all due to access and or restrictions, while 25% lies on public land with varying degrees of leasing restrictions.

The removal of restrictions on sensitive public land for natural gas production is controversial. The EPCA looked specifically at costs related to gas development of land with restrictions and how removal of restrictions would increase the nation's natural gas supply. Costs related to drilling on public land is often higher than that of private land because the land is remote, terrain can be more challenging, and colder temperatures can inhibit speedy development. And, due to lower population densities in the West, the labor market can be more expensive.

The study found that recovery of gas on public land would not increase the nation's energy supply in the short term; removal of all federal restrictions to natural gas development on public land would increase gas production from 27.9 TCF to 28.1 TCF, an increase of less than 1%. In this scenario, the increase in gas supply would also decrease gas prices by $.06 in 2020, which makes development economically less viable.

The EPCA report emphasizes that restrictions do not unnecessarily increase costs without returning any benefits, rather access restriction exists because our society values the natural resources and ecosystems on which the restrictions are applied. Restrictions demonstrate a social value though the benefits may be difficult to quantify economically. Protected land benefits a broader segment of society than does the beneficiaries of energy development (Cleveland, 2003).

Subsidy Incentives: Federal Tax, State Tax and Research Funding

In addition to a national energy policy that encourages the removal of obstacles to energy development, several subsidies promote coal bed methane development and therefore have direct impacts on landscape fragmentation. Skov and Myers (2004) outline several federal subsidies that benefit energy companies of which the non-conventional fuels tax credit is the largest. The non-conventional fuels tax credit, known as section 29, came into effect in 1980 and provided tax credits to energy companies that produced alternative sources of energy, such as coal bed methane. The tax credit was originally applied to wells drilled prior to 1993. Most of the development in the Powder River Basin happened after 1993, and few companies have benefited from this particular tax credit within the basin.

However, recent passage of the new energy bill will ease development restrictions. Section 29 is incorporated into the general business credit, allowing for credit one year back and twenty years forward for unused credits beginning after 2005. Under the new law, non-conventional source energy sold to unrelated parties can benefit for an income tax credit of $3.00 per barrel (CCH, 2005). If half of the proposed wells in the Powder River Basin received this federal subsidy, energy companies would gain over $300 million in tax credits a year (Skov and Myers, 2004).

A second federal tax break provided to all oil and gas companies is called percentage depletion, where oil and gas companies can deduct 15% of their gross income from their taxable income. The cost to the federal government for percentage depletion from 1999-2004 was between $200 to $700 million a year (Skov and Myers, 2004).

Another way oil and gas companies benefit financially is through state policies. States not only collect severance taxes on the coal bed methane produced in their state, but at the same time contribute to coal bed methane subsidies. In fact, severance tax in Wyoming has dropped from six percent to two percent on new wells for the first two years. In addition, Wyoming state energy policy encourages the development of pipelines and has provided low interest loans for this purpose (Skov and Myers, 2004).

Research indirectly supports coal bed methane development. Skov and Myers (2004) argue that energy research funded by the federal government favors coal bed methane development. According to Katz (1984), a select "technocracy" holds a disproportionate amount of control over energy research resources because of the technical nature of many energy problems. This technocracy emphasizes complex technologies while at the same time ignoring or minimizing the environmental and social costs.

Much of the research conducted at state funded universities in Wyoming and Montana strive to solve environmental problems associated with the industry, including how to remove salt from coal bed methane water and finding plants that are more tolerant to high salt levels. The research is valid, say Skov and Myers (2004), but the public has assumed the responsibility as well the expenses, alleviating the expense and responsibility from the industry. Findings from such research could actually contribute directly to coal bed methane development expansion, which in turn could be "the most profitable subsidy of all." (Skov and Myers, 2004, p. 25)

Chapter Summary

Chapter Five discussed the results of policy analysis, observation, and interviews. The first half of the chapter provided a description of historic acts and state legislation that impact coal bed methane development and have direct impacts on landscape fragmentation in the Powder River Basin. Historic acts included the Stock Raising Homestead Act of 1916, the Mineral Leasing Act of 1920, and the Surface Mining Control and Reclamation Act. The long-term effects of these acts are that many properties in the West were and are currently held in a split estate. This can lead to much controversy when the interests of "mineral estates" conflict with those of the "surface owner".

In order to mitigate these conflicts and to provide more leverage to the surface owner, Wyoming passed the Split Estate Law 2005 this summer. According to the new law, if the surface and mineral owners are unable to come to development agreement, the mineral owner must place a $2000 bond with the state of Wyoming for reclamation costs. This was then followed by a brief description of beneficial uses of water where in Wyoming coal bed methane production is considered a beneficial use.

This chapter then discussed the apparent lack of standards and accountability within the coal bed methane industry, which also contributes to landscape fragmentation in the region. The sheer rate of growth and a fear that the coal bed methane industry will take its business elsewhere are in part responsible for standards and accountability deficiencies.

The next section analyzed the federal energy policy and how it impacts coal bed methane production, which in turn contributes to landscape fragmentation in such places as the Powder River Basin. The policy strongly urges speedy permitting and opening restricted access lands for development in order to increase energy production. Additional sources argue that opening restricted lands would provide a minimal increase, if not insignificant, in energy supply. Restrictions are applied to areas of ecological and aesthetic value, and these areas have inherent value. Removing such restrictions could permanently destroy these areas for debatable gains. Where many are currently able to enjoy the benefits of protecting such areas, only a few would reap the benefits from developing energy in restricted areas, namely shareholders in energy companies.

CHAPTER SIX: STUDY IMPLICATIONS, RECOMMENDATIOS, AND CONCLUDING REMARKS

Introduction

Will our society look back in twenty years and question what happened to the landscape in the Powder River Basin? Will one wonder what became of its cultural past and invaluable water; or will we be content with the change and glad for the energy benefits while we had them? *Based on past and current trends, what can we expect to see on the landscape at a basin-wide scale?* This chapter aims to specifically address this last critical question.

Landscape fragmentation is one way to measure the impacts of coal bed methane development in the Powder River Basin. The implications of the analysis of landscape fragmentation (Chapter 4) are discussed in this chapter as well as the effects of the current national energy policy that promotes increasing existing development and opening new land for further resource extraction (Chapter 5). The first section is divided into three sections that address the empirical, theoretical, and methodological implications of this study. This is followed by recommendations to entities involved in various aspects of coal bed methane development. The chapter concludes with final remarks.

Empirical Implications

This thesis examined energy geography by studying coal bed methane development in the Powder River Basin. In addition, this is the first study undertaken that attempts to quantify landscape fragmentation as a result of coal bed methane development within the research setting. Individuals involved with different aspects of the development were interviewed to gain a more thorough understanding of the geographical implications of coal bed methane development. A major theme that evolved from these discussions was a changing landscape. By quantifying landscape fragmentation from a temporal context using remotely sensed methods, this study was able to directly address one aspect of a changed landscape.

Based on the patch analysis in the Figure 18, the fragmenting results of coal bed methane development with its current development practices is evident. Road density increased from 1.9 to 4.9 miles per square mile. Average road density on national forests in several western states is approximately 3 miles per square mile (Weller et al, 2002). A 939% increase in patch number, 41 to 426 patches per 59 square miles, indicates extreme fragmentation. One can expect landscape fragmentation to continue across the Powder River Basin based on current coal bed methane development practices and policies.

While all the impacts of fragmented landscape are still unknown, it is clear that increased traffic, miles of roads, and night lights from the numerous compression stations are evidence that the Wyoming portion of the Powder River Basin is swiftly transforming the landscape from an agricultural environment to that of an industrial one. Michele Barlow (2005, p. 12), in a article in the Wyoming Outdoor Council's spring newsletter,

writes about a recent drive across the Basin, "as the miles slipped away, my mind increasingly focused on the latest add-ons to this prairie: twisting roads, giant trucks, drilling rigs, wastewater pits, metal buildings and great clouds of dust." Pipelines, compressor stations, roads and electric lines make this transformation apparent. With the expectation of 51,000 new coal bed methane wells under the current and expected future energy policy, this transformation to a power landscape is unlikely to turn around (BLM Record of Decision, 2003).

Clearly, as the literature, local residents, and my observations suggest, there is a need for more baseline data. Topics of future study should include: socio-economic impacts and change, impacts on ephemeral streams, reclamation concerns on public and private land, methane migration, and underground and surface water quality.

Conceptual Implications

The theoretical implications of this study pertain to the link between landscape fragmentation and energy policy. This section begins with a discussion on continuing concerns related to private and public lands related to current energy policy. The conceptual model depicting the relationship between policy, landscape fragmentation and technological transformation on the landscape is then addressed.

Development of Private and Public Lands and Energy Policy

Conflict exists over coal bed methane development on both public and private lands. Outdated policy is tied to keeping the status quo with property rights and decisions are made with outdated data concerning values of the present residents in the West

(Baden, 1997). With any split estate, the mineral estate holds precedence over the surface owner which stems from the historical Stock Raising Act of 1916. A law that was applicable ninety years ago may not be in the best interest for all involved parties. This concept can be compared to irrigation laws surrounding the prior appropriations doctrine western water law (Getches, 1990). Irrigation rights allow a senior rights holder to continue irrigating even though there is an extreme shortage of water and the practice itself can be ecologically damaging (Baden, 1977).

Debate over development on public land is a matter of resources and values. The conflict lies with protecting the inherent value of the land and its inhabitants or extracting the valuable resources found on the land for human consumption (Bryner, 2002). Ultimately, the choice is one of social values; whether the American public wants to extract a relatively inexpensive, non-renewable energy source from their public lands or maintaining a pristine, untouched backyard. Coal bed methane development in the Powder River Basin illustrates these conflicting cultural and environmental values found in the West. The rate of development is directly related to national energy policy, and in turn, the effects of development, such as landscape fragmentation, are therefore tied directly to energy policy.

Policy Impacts on Landscape Fragmentation

At a basic level, beginning with the Stock Raising Act of 1916 and the creation of the split estate, policy has affected the landscape in the Powder River Basin. As long as the mineral estate takes precedence over the surface owner, the landscape will be at the mercy of market demands, industry, and administrative policies. Subsequently, national

energy policies will be influenced by markets, industry and administration, which in turn dictate policies of federal administrative bodies of mineral estates such as the BLM.

In the Powder River Basin, as long as policy encourages development of coal bed methane with present methods, the landscape will continue to be fragmented which will lead to an increased technological and ecological transformation at a landscape level. As long as the national energy policy continues to promote development of traditional energy sources, the trans-boundary effects of water removal in the Powder River Basin will continue. The theory presented in Chapter Two with the model (Figure 9) remains unchanged in terms of its explanatory power in this particular case.

Possible alterations in the above model would include enhanced technology advancements, a shift in energy perspectives to that of conservation or energetics, and a national dependence on alternative, renewable sources of energy. While natural gas (including coal bed methane gas) produces 28% less carbon dioxide than oil and 48% less than coal, alternative sources of energy such as wind and solar produce no emissions. Coal bed methane supplies will be nearly depleted in the Powder River Basin by 2020 and should not be considered a long term energy supply solution. In addition, this short term solution leaves long term problems for the Powder River Basin, leaving potential costs over several generations (Skov and Myers, 2004).

The West has been, in our current history, a region rich in natural resources which has allowed for an abundant extraction of natural resources. But as the demographics and values found in the West have changed, so has the pattern of extraction. Access restrictions and conservation resistance has increased even as the demand for such resources has risen.

Consequently, national policies should reflect the values of its constituents, as well as take into consideration the impacts these policies have on precious resources such as cultures, public land, biodiversity, water, and wildlife. By being mindful of all the resources, we will minimize the damage and impacts on the landscape, according to the Rancher.

Methodological Implications

This study applied a mixed method approach to answer the three questions presented in Chapter One concerning coal bed methane development in the Powder River Basin.

The remote sensing techniques that were eventually used in the analysis differed greatly from the original approach. The first method attempted to classify 30 × 30 meter Landsat data in order to determine landscape fragmentation. But that method was abandoned for one of feature extraction using 1 × 1 meter data. The higher resolution was necessary to extract, or correctly classify, coal bed methane infrastructure such as roads and pipelines. Determining landscape fragmentation due to the infrastructure (roads and pipelines) associated with coal bed methane development would not have been possible with coarser data. Future studies involving linear features created by coal bed methane development would require a similar resolution.

Policy analysis related to coal bed methane development required research of historical acts and current energy policy. Energy policy is dynamic, and future studies involving energy policy would require re-examining policy

Informal interviews were primarily with government officials and private landowners. Unfortunately, no interviews were conducted with industry representatives due to a lack of time and resources. An attempt was made to visit Fidelity's development near Decker, Montana, and to meet with a Fidelity representative. The Fidelity representative that was contacted said that a meeting would be difficult and would require much paperwork due to the current litigation in which Fidelity is involved. The interviews proved to be invaluable, especially in understanding the problem from a local perspective. Observations made during this research suggest that those residing in the basin stand to be the most affected by policy and landscape impacts.

Recommendations

A common thread throughout the interviews that were conducted in spring 2005 is that coal bed methane extraction could be done better. The following recommendations are based on landscape fragmentation analysis on the Three Mile Creek Reservoir Quadrangle, personal interviews, and the analysis of policy impacting landscape fragmentation in the Powder River Basin:

- State of Montana: Wyoming provides a clear example of what to expect with coal bed methane development and an opportunity to decide how to do it differently. Montana should demand clearly defined, high reclamation standards and require companies to use the best technology available. Using the latest technology means that well spacing is greater than the current 80-acre well spacing and impacts on the land is less.

- Coal bed methane mining companies: Coal bed methane companies have an opportunity to improve public relations by applying the best practices available both with well placement and water mitigation. The most current technology should be used which could include telemetrized wells that would lessen traffic and greater well spacing that would minimize landscape fragmentation. Whenever possible, companies should reinject the water.
- Future Research: There are a number of directions future research could take to better understand coal bed methane and energy development, of which this thesis touched the surface. The following list is not intended to be exhaustive, merely suggestive. Quantifying social and cultural impacts and the costs from coal bed methane development to residents in the Powder River Basin would provide information to local politicians and policy makers. A quantitative analysis of water left in impoundment ponds in the basin would help to further understand physical impacts of development. And lastly, aggressive research on alternative and sustainable energy sources such as wind and solar would provide long term solutions to an impending problem associated with fossil fuels.

Final Remarks

The Powder River Basin lies in the heart of the West, both physically and conceptually. The basin fits the myth of the West - that of cowboy hats and ranching, wide open spaces and rolling hills, pick-up trucks, and rugged mountaintops in the distance. This region fulfills nature longings for many individuals with its visual

amenities and outdoor lifestyle (Baden, 1997). But this region, though no stranger to extractive activities, is experiencing rapid and complex processes of transformation.

Yi-fu Tuan (1993, p. 2), a world renown geographer specializing in human-environment interactions states "Every road followed implies other roads not taken, every new creation implies a prior stage of destruction, and every new perception dims, if it does not wipe out altogether, the old, which has its own -- perhaps irreplaceable – value." Without perceived value, there is no impetus to protect the land (Steward, 2005). If the inherent value of the Powder River Basin is recognized, perhaps more time will be taken to better understand the unknown effects and impacts associated with coal bed methane extraction and the long term effects of landscape fragmentation.

BIBLIOGRAPHY

Works Cited:

ALL Consulting and Montana Board of Oil and Gas Conservation (MBOGC). 2004. *Coal Bed Methane Primer, New Source of Natural Gas-Environmental Implications, Background and Development in the Rocky Mountain West.* United States Department of Energy, National Petroleum Technology Office.

Apan, A. A., Raine, S. R., and Paterson, M.S. 2002. Mapping and Analysis of Changes in the Riparian Landscape Structure of the Lockyer Valley Catchment, Queensland, Australia. *Landscape and Urban Planning Journal*, 59: 43-57.

Associated Press. 2005. Split-Estate Law Worries Industry. *Casper Star Tribune*, July 13.

Baden, John A. and Snow, Donald, eds. 1997. *The Next West: Public Lands, Community, and Economy in the American West.* Washington, D.C.: Island Press.

Barlow, Michele. 2005. New Law Protects Wyoming's Landowners Surface Owner Protections Signed into Law after Three Years of Work. *Wyoming Outdoor Council Newletter*, Spring 2005, 12.

Bernofsky, Gene Director/Producer. 2005. *Gassing the Big Sky.* DVD Recording. Missoula, MT: A Real Documentary.

Bryner, Gary. 2002. *Coalbed Methane Development in the Intermountain West: Primer.* University of Colorado Natural Resource Law Center. Retrieved 2005 from World Wide Web: http://www.colorado.edu/law/centers/nric/publications/CBM_Primer.pdf

___________. 2003. "Coalbed Methane Development: The Cost and Benefits of an Emerging Energy." *Natural Resources Journal*, 43(2), 519-560.

CCH. 2005. "CCH Tax Briefing: Energy Tax Incentives Act of 2005, Special Report." Retrieved October 2005 from the World Wide Web: http://tax.cchgroup.com/tax-briefings/2005-2007-Highway-Energy.pdf

Chapman, J.D. 1989. *Geography and Energy: Commercial Energy Systems and National Policies.* New York: John Wiley & Sons, Inc.

Civco, Daniel D., Hurd, James D., Lammey, Steven G., Wilson, and Emily Hoffine. 2001. "Characterization of Forest Fragmentation and Urban Sprawl Using Time

Sequential Landsat Imagery." *ASPRS 2001 Annual Convention*, St. Louis, MO.April 23-27, 2001.

Cleveland, Cutler. 2003. "A Preliminary Economic Assessment of Scientific Inventory of Onshore Federal Lands' Oil and Gas Resources and Reserves and the Extent and Nature of Restrictions or Impediments to Their Development." U.S. Departments of the Interior, Agriculture and Energy. March, BLM/WO/GI-03/002+3100.

Clifford, Hal. 2001. "Wyoming's Powder Keg." *High County News*, 5 November, 33(21).

Department of Energy (DOE). 2003. "Multi Seam Well Completion Technolgoy: Implications for Powder River Basin Coalbed Methane Production." Office of Fossil Energy National Energy Technology Laboratory Strategic Center for Natural Gas. September.

ESRI (Environmental Systems Research Institute). 2005. *ArcCatalog GIS*. Redlands, California. Environmental Systems Research Institute.

ESRI (Environmental Systems Research Institute). 2005. *ArcMap GIS*. Redlands, California. Environmental Systems Research Institute.

ESRI (Environmental Systems Research Institute). 2005. *ArcView GIS*. Redlands, California. Environmental Systems Research Institute.

Environmental Working Group, (EWG). 2004. "Who Owns the West? Oil and Gas Leases." Retrieved Spring 2005 from the World Wide Web: http://www.ewg.org/oil_and_gas/.

Energy Information Administration (EIA) U.S. 2003. International Energy Outlook 2003. Retrieved Spring 2005 from the World Wide Web: http://www.eldis.org/static/DOC1840.htm

Gaile, Gary and Wilmont, Cort, eds. 2003. *Geography in America at the Dawn of the 21st Century*. Oxford, U.K.: Oxford University Press.

Getches, David H. 1990. *Water Law in a Nut Shell*. St. Paul, MN: West Publishing Company.

Government Accountability Office (GAO). 2005. "National Energy Policy: Inventory of Major Federal Energy Programs and Status of Policy Recommendations." Report GAO-05-379, 14 June. Retrieved Spring 2005 from the World Wide Web: http://www.gao.gov/htext/d05379.html.

Hamburger, Tom, Cart, Julie, and Miller, Alan. 2004. "White House Puts the West on Fast Track for Oil, Gas Drilling." *Los Angeles Times*, 25 August.

High Plains Regional Climate Center. 2004. Historical Data Summaries. University of Nebraska, Lincoln. Retrieved February 2005 from the World Wide Web: http://hprcc.unl.edu/products/normals.html.

Ivins, Molly, Dubose, Lou. 2004. *Bushwhacked.* First Vintage Books, New York: Random House. Chapter 9.

Jacobs, J., Fassett, G., and Bosz, D. 1995. "Wyoming Water Law: A Summary." Wyoming Water Research Center, University of Wyoming. June.

Katz, James Everett. 1984. *Congress and National Energy Policy.* New Brunswick, New Jersey: Transaction, Inc.

Keith, Kristen, Bauder, Jim, and Wheaton, John. 2003. "Frequently Asked Questions: Coal Bed Methane." The Department of Land Resources and Environmental Sciences, Montana State University.

Lam, Tina. 2003. "Michigan Digs up Wyoming Anger." *Detroit Free Press*, 11 January.

Lillesand, T. and R. Keefer. 2000. *Remote Sensing and Image Interpretation*, 4th ed. New York: John Wiley and Sons.

LizardTech. 2005. *MrSID.* A Celartum Company. http://www.lizardtech.com/.

Long, J. 2002. "When Life Gives you Coal Bed Methane, Make Lemonade." Retrieved June 2005 from the World Wide Web: http://www.westernwaterlaw.com/coalbedmethane.htm

Messina, and Walsh. 2003. In *Geography in America at the Dawn of the 21st Century.* Gaile, Gary and Wilmont, Cort, eds. Chapter 25. Oxford, U.K.: Oxford University Press.

Montana Department of Natural Resources. 1999. "Final Order: In the Matter of the Designation of the Powder River Basin Controlled Groundwater Area." Retrieved Spring 2005 from the World Wide Web: http://www.dnrc.mt.gov/wrd/final%20order.htm

NASA. 2004. "Remote Sensing Tutorial, RST, Technical and Historical Perspectives of Remote Sensing." Retrieved Spring 2005 from the World Wide Web: http://rst.gsfc.nasa.gov/Intro/Part2_1.html.

National Energy Policy Development Group (NEPD). 2001. National Energy Policy, Department of Energy. Retrieved May 2005 from the World Wide Web: http://www.whitehouse.gov/energy/

Naugle, D. et al. 2004. "From the Field: Outbreak of West Nile virus in greater sage-grouse and guidelines for monitoring, handling, and submitting dead birds." *Wildlife Society Bulletin,* 32 (3): 1.

Newcomb, John. 2001. "Energy Geography of the Pacific North West – Changing Landscapes of Power." Notes for Presentation to the Pacific Northwest Regional Economics Conference. 17 May, 2001. University of Victoria.

One Hundred First Congress. 1990. Hearing before the Subcommittee on Mineral Resources Development and Production of the Committee on Energy and Natural Resources United States Senate, S. 1805, H.R. 3727, S. 1908, H.R. 737.

Pasqualetti, M.J. 2001. "Wind Energy Landscapes: Society and Technology in the California Desert," *Society and Natural Resources,* 14: 689-99.

Pinsker, Lisa M. 2002. "Coal Bed Methane: The Future of US Natural Gas?" *Geotimes,* November. Retrieved August 2005 from the World Wide Web: http://www.agiweb.org/geotimes/nov02/resources.html

Rempel, Rob. (2005). Patch Analyst. Centre for Northern Forest Ecosystem Research, Lakehead University Campus, Thunder Bay, Ontario.

Rice, C.A., Ellis, M.S., and Bullock, J.H., Jr. 2000. "Water co-produced with coalbed methane in the Powder River Basin, Wyoming: preliminary composition data." USGS, Open-File Report 00-372.

Skov, Joshua and Myers, Nancy. 2004. "Easy Money, Hidden Costs: Applying Precautionary Economic Analysis to Coalbed Methane in the Powder River Basin." A Report of the Science and Environmental Health Network, 30 June. Retrieved August 2005 from the World Wide Web: http://www.powderriverbasin.org/cbm/easymoney.shtml

Solomon, Pasqualetti, M.J., and Luchsinger. 2003. "Energy Geography." In *Geography in America at the Dawn of the 21st Century.* Gaile, Gary and Wilmont, Cort, eds. Oxford, U.K.: Oxford University Press.

Spooner, Derek. 2002. Landscapes of Power: Shaping of the UK's New Energy Geography", *Geography,* 84(1): 66-79.

Stanford, Jack and Hauer, F. Richard. 2003. "Coalbed Methane (CBM) in Montana: Problems and Solutions." Division of Biological Sciences, University of Montana, 4 February.

________________ 2002. "Coalbed Methane Update", *Flathead Lake Journal,* 16 (2): 2-9.

Stark, Mike. 2004. "Dry wells blamed on CBM." *Billings Gazette*, 30 January.

__________ 2004. "Following a busy year, Wyoming ties to cope with coalbed growing pain." *Billings Gazette*, 7 January.

State of Wyoming. 2005. "Split Estate-Procedures for Oil and Gas Operations." Senate File No. 0060, 2005.

Steward, Mickey. 2005. In *Powder River County.* Zugel, Marianne, director. DVD Recording. Missoula, MT: High Plains Films.

Supreme Court of the United States. 2004. Syllabus of Bedroc Limited, LLC, et al. v. United States et al., Certiorari to the United States Court of Appeals for the Ninth Circuit.

Tuan, Yi-fu. 1993. *Passing Strange and Wonderful.* New York, NY: Island Press.

__________ 1990; 1974. *Topohpilia: A Study of Environmental Perception, Attitudes and Values.* New York, NY: Columbian University Press.

Turner, M.G. and Ruscher, C.L. 1988. "Changes in landscape patterns in Georgia, USA." *Landscape Ecology*, 1: 241-251.

VLS, Visual Learning Systems, Inc. (2002). Feature Analyst®. Missoula, Montana, Visual Learning Systems, Inc. http://www.featureanalyst.com/index.htm.

Water Pollution Control Advisory Council (WPCAC) Meeting. 2005. 12:30 p.m. – 3:00 p.m., Director's Conference Room 111 Metcalf Building, Helena, MT. Retrieved October 2005 from the World Wide Web: http://www.deq.state.mt.us/adv_councils/wpcac/WPCAC_07_06_05.pdf.

Weller, C. et al. 2002. "Fragmenting Our Lands: The Ecological Footprint from Oil and Gas Development." The Wilderness Society, Seattle, WA and Denver, CO. Retrieved October 2005 from the World Wide Web: http://www.wilderness.org/Library/Documents/FragmentingOurLands.cfm

Wilbanks, Thomas. 1984. Geography and Energy: The Quest for Roles and Missions. In *Geographical Dimensions in Energy*, ed. Calzonetti, Frank and Solomon, Barry. Hingham, MA: Kluwer Academic Publishers.

Wright Area Chamber of Commerce. 2004. "Powder River Basin History." Retrieved June 2005 from the World Wide Web: http://www.wrightareachamber.com/powder_river_basin_history.htm

Wyoming Geographical Information Advisory Council (WYGIAC). 2005. Retrieved March 2005 from the World Wide Web: http://wgiac2.state.wy.us.

Wyoming Oil and Gas Conservation Commission (WOGCC). 2005. Retrieved May 2005 from the World Wide Web: http://wogcc.state.wy.us/coalbedchart.cfm.

US Departments of Interior, Agriculture, Energy (Energy Inventory 2003). 2003. "Scientific Inventory of Onshore Federal Lands' Oil and Gas Resources and Reserves and the Extent and Nature of Restrictions or Impediments to Their Development." U.S. Departments of the Interior, Agriculture and Energy. BLM/WO/GI-03/002+3100.

US Department of the Interior Bureau of Land Management Wyoming State Office (BLM). 2003. "Record of Decision and Resource Management Plan Amendments for the Powder River Oil and Gas Project." Buffalo Field Office, BLM/Wy/pl-03/016+1310.

US Geological Survey (USGS). 2000. "Coal Bed Methane: Potential and Concerns Fact Sheet." USGS Fact Sheet FS-123-00.

U.S. Government Accountability Office (GAO). 2005. "National Energy Policy, Inventory of Major Federal Energy Programs and Status of Policy Recommendations." GAO-05-379.

Zugel, Marianne. 2005. *Powder River County.* DVD Recording. Missoula, MT: High Plains Films.