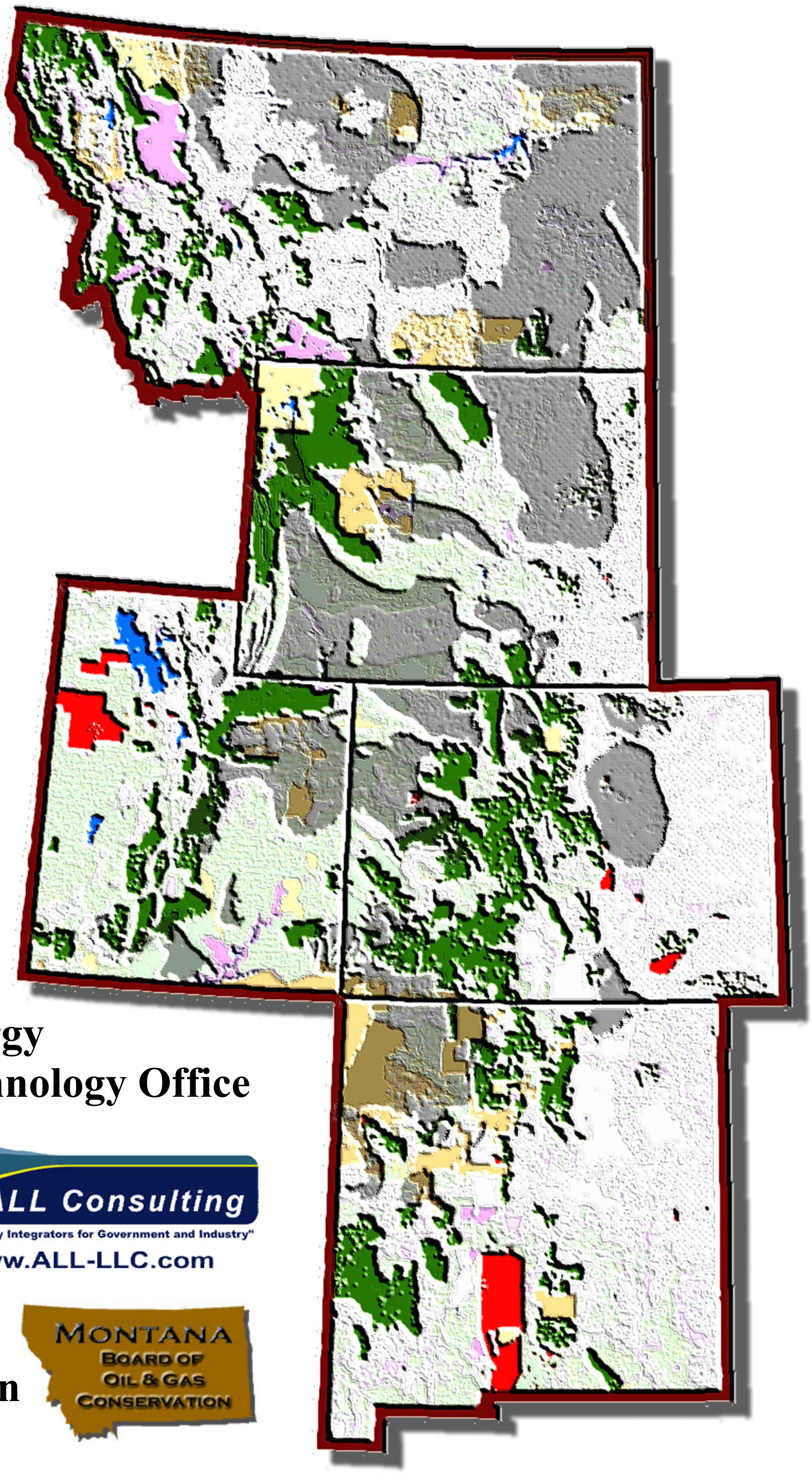
COAL BED METHANE PRIMER

New Source of Natural Gas–Environmental Implications

Background and Development in the Rocky Mountain West



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Prepared by:
ALL Consulting

"Technology Integrators for Government and Industry"
www.ALL-LLC.com

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TABLE OF CONTENTS

TABLE OF CONTENTS
(CONTINUED)

ACRONYMS AND ABBREVIATIONS

ACEC	Area of Critical Environmental Concern
APD	Application for Permit to Drill
ARM	Administrative Rules of Montana
BACT	Best Available Control Technology
BCF	billion cubic feet
bgs	below ground surface
BIA	Bureau of Indian Affairs
BLM	U.S. Bureau of Land Management
BMP	Best Management Practice
BTU	British thermal unit
CAA	Clean Air Act
CBM	coal bed methane
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CFS	cubic feet per second
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
COA	Condition of Approval
CWA	Clean Water Act
DEIS	Draft Environmental Impact Statement
DOE	U.S. Department of Energy
EA	Environmental Assessment
EIS	Environmental Impact Statement
EO	Executive Order
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FEIS	Final Environmental Impact Statement
FERC	Federal Energy Regulatory Commission
FLM	Federal land managers
FLPMA	Federal Land Policy and Management Act
FR	Federal Register
FWS	Fish and Wildlife Service (USDI)
gpm	gallons per minute
MBOGC	Montana Board of Oil & Gas Conservation
MCA	Montana Code Annotated
MCF	thousand cubic feet
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act

ACRONYMS AND ABBREVIATIONS
(CONTINUED)

NO_2	nitrogen dioxide
NO_X	oxides of nitrogen
NOA	Notice of Availability
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service (USDI)
NRHP	National Register of Historic Places
NSO	no surface occupancy
POD	Plan of Development
RCRA	Resource Conservation and Recovery Act of 1976
RFFA	Reasonably Foreseeable Future Actions
RFD	Reasonably Foreseeable Development
RMP	Resource Management Plan
ROD	Record of Decision
ROW	right-of-way
SAR	Sodium Adsorption Ratio
SHPO	State Historic Preservation Office
SN	Sundary Notice
SO_2	sulfer dioxide
T&E	Threatened and Endangered
TCF	trillion cubic feet
TDS	total dissolved solids
UIC	underground injection control
U.S.	United States
U.S.C.	United States Code
USDI	U.S. Department of the Interior
USFS	U.S. Forest Service (USDA)
VRM	visual resource management
WMP	Water Management Plan
WQS	water quality standards
WSA	Wilderness Study Area

ATTACHMENTS

COAL BED METHANE PRIMER

New Source of Natural Gas - Environmental Implications

INTRODUCTION

During the second half of the 1990s Coal Bed Methane (CBM) production increased dramatically to represent a significant new source of natural gas for many Western states. Matching these soaring production rates during this period was a heightened public awareness of environmental concerns. These concerns have created a significant growth in public involvement, which has generated thousands of comments resulting in the inconsistent prioritization of concerns and resources protection efforts. The accelerating interest in CBM development coupled with growth in public involvement has prompted the creation of this CBM Primer.

"America must have an energy policy that plans for the future, but meets the needs of today. I believe we can develop our natural resources and protect our environment."

-President George W. Bush

The Primer is designed to serve as a summary document, which introduces and encapsulates information pertinent to the development of CBM. The discussions focus on coal deposits, methane as a naturally formed gas, split mineral ownership, development techniques, operational issues, producing methods, applicable regulatory frameworks, land and resource management, mitigation measures, preparation of project plans, data availability, Indian Trust issues and relevant environmental technologies.

An important aspect of this CBM Primer involves the sharing of information with a broad array of stakeholders, including land and mineral owners, regulators, conservationists, tribal governments, special interest groups, and numerous others that could be affected by the development of CBM within their vicinity. Perhaps the most crucial aspect of successfully developing CBM resources and instituting appropriate environmental protection measures is public awareness, information sharing, and acceptance.

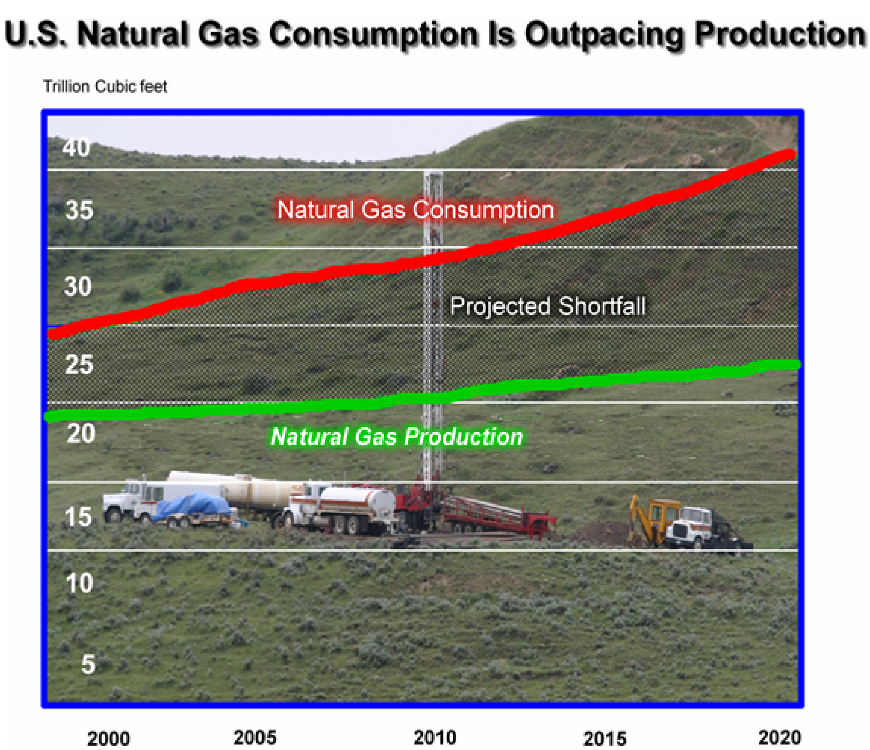
The current image of CBM that exists is dependent on the stakeholders' perspective of energy development versus environmental protection. There is significant diversity in the view points expressed by nearly all stakeholders, including industry, government, special interest groups, and land owners. The primer is designed to serve as an accessory to public discussions that will contribute to policy making decisions by examining the current CBM development practices throughout the Western U.S. and by discussing mitigation measures and more environmentally friendly development methods from various CBM areas.

The Primer sections focus on the following areas:

Section 1 – What is CBM? How is it formed? Where does it come from? How is it developed? This section provides the backdrop and circumstances for outlining the issues encompassing CBM formation and production, including coal seams and how they originate; the general location of CBM basins in the United States; the various development techniques, operational issues and production methods used based on regional conditions; and the position CBM serves in meeting our current and future national energy requirements.

Section 2 – Regulatory framework. This section addresses federal, state and local regulations governing the development of CBM across the west; analyzes existing regulations guiding CBM development, including regionally specific Plan of Development variances; identifies federal land and resource management practices, Indian Trust Issues, surface owner agreements and local land uses per region; and the state oil and gas programs including typical lease stipulations and field rules.

Section 3 – Best Management Practices and Mitigation. Section three identifies the typical environmental effects associated with CBM development in the west and the mitigation measures employed to address these effects. Focus is on the results of production and distribution affecting natural resources to local populations, and the tension between opposing land uses and land users. Vital to this discussion are the potential effects of CBM extraction on water quality and quantity, and the numerous mitigation measures employed to control and eliminate these effects.



Over the next 20 years, U.S. natural gas consumption will grow by 50 percent. At the same time, U.S. natural gas production will grow by only 14 percent, if it grows at the same rate of the last 10 years.

Coal bed methane is a clean-burning energy source well suited as a fuel for production of electricity, residential and commercial heating, and as a vehicle fuel. CBM currently supplies approximately eight percent of the nation's natural gas production, and is an important facet of the nation's energy mix. United States CBM production grew by 13 percent in 2001 to 1.562 Trillion cubic feet (Tcf). (EIA 2001). CBM will become more important as the demand for natural gas increases, and the focus on domestic production is heightened due to the deregulation of electricity and the tension over international energy supplies. As illustrated in the figure on the left, natural gas consumption is outpacing production. However, CBM production has the potential to significantly reduce this gap, if development can continue to increase at the rates observed between 1998 and 2001.

The extraordinarily dramatic growth of CBM development has created comprehensive challenges for communities

Agricultural irrigation in Wyoming

throughout the Rocky Mountain region. The development of CBM infrastructure including construction of utility right-of-ways, pipelines, new roads, compressor stations, water conveyance and storage systems, and other facilities have affected rural communities.

Another issue responsible for many disputes is split estates - land owners who hold only surface rights may have government agencies such as the BLM or State Trust Land departments leasing the subsurface mineral rights to one or many development companies. CBM development plans can be opposed by many farmers, ranchers, hunting and fishing outfitters, environmentalists, recreational users, homeowners, and others who use the land for their specific purposes. Increases in exhaust gases and noise levels have also created strife between residents and the CBM industry.

Beyond the land use disputes and affecting nearly all Rocky Mountain citizens are the concerns associated with produced water from CBM development. CBM produced water has the potential to affect groundwater quantity and quality. Coal seam aquifers may have competing water rights and be diminished as CBM production increases. Surface water quality could be altered by mineral-laden discharge, and agricultural productivity of soils could be reduced by irrigating with altered surface water. Riparian ecosystems may be negatively affected by the release of large quantities of produced water. Some produced water, on the other hand, has the potential to be a prized source of fresh water in many arid regions.

The development of CBM throughout the Rocky Mountain Region is a major issue facing citizens, special interest groups, federal land management agencies, state governments, Tribal governments, county commissions, and energy companies. The major challenge is obtaining a balance between the development of this important resource and environmental protection while maintaining the local culture. This can be done by sharing the responsibilities for governing the development by federal, state, Tribal and local governments. These governments have varying and often competing interests and responsibilities for regulating CBM production. The coordination between these agencies will be essential to the balance and will ultimately influence the pace of development.

It is envisioned the Primer will be used by a variety of stakeholders to present a consistent and complete synopsis of the key issues involved with CBM. This primer is intended to add focus to the public discussion and policy making for CBM development by offering a comprehensive, user-friendly overview that clarifies what CBM is and how it is produced, analyzes and evaluates the knowledge gained from various CBM developments throughout the Rocky Mountains, provides options for addressing conflicts, and improves policies that regulate CBM development. This primer also recognizes lessons-learned from different basins and various environmental groups and producers that could resolve similar challenges posed by development in other areas.

WHAT IS CBM?

How is it formed, where does it come from, and how is it developed?

CBM - THE BASICS

Coal Bed Methane (CBM) is an important facet of the nation's energy mix. While currently supplying approximately eight percent of the nation's natural gas, CBM is expected to increase in importance (EIA 2001). Natural gas is a clean-burning energy source well suited as a boiler fuel, vehicle fuel, and for heating residences as well as large structures. CBM is a non-conventional hydrocarbon resource that fundamentally differs in its accumulation processes and production technology when compared to conventional natural gas resources. The following paragraphs detail the formation of coal and CBM.

Coal Formation

Coal is a sedimentary rock that had its origin on the surface of the earth as an accumulation of inorganic and organic debris. Major coal basins across the United States are depicted in Figure 1 below. Coal is predominantly made up of organic plant material, in particular ancient wood, leaves, stems, twigs, seeds, spores, pollen, and other parts of aquatic and land plants. When the debris first begins to pile up it is termed peat; the earth's crust subsides, and more sediments are piled on top of the organic material, causing it to sink ever deeper into the sedimentary layer.

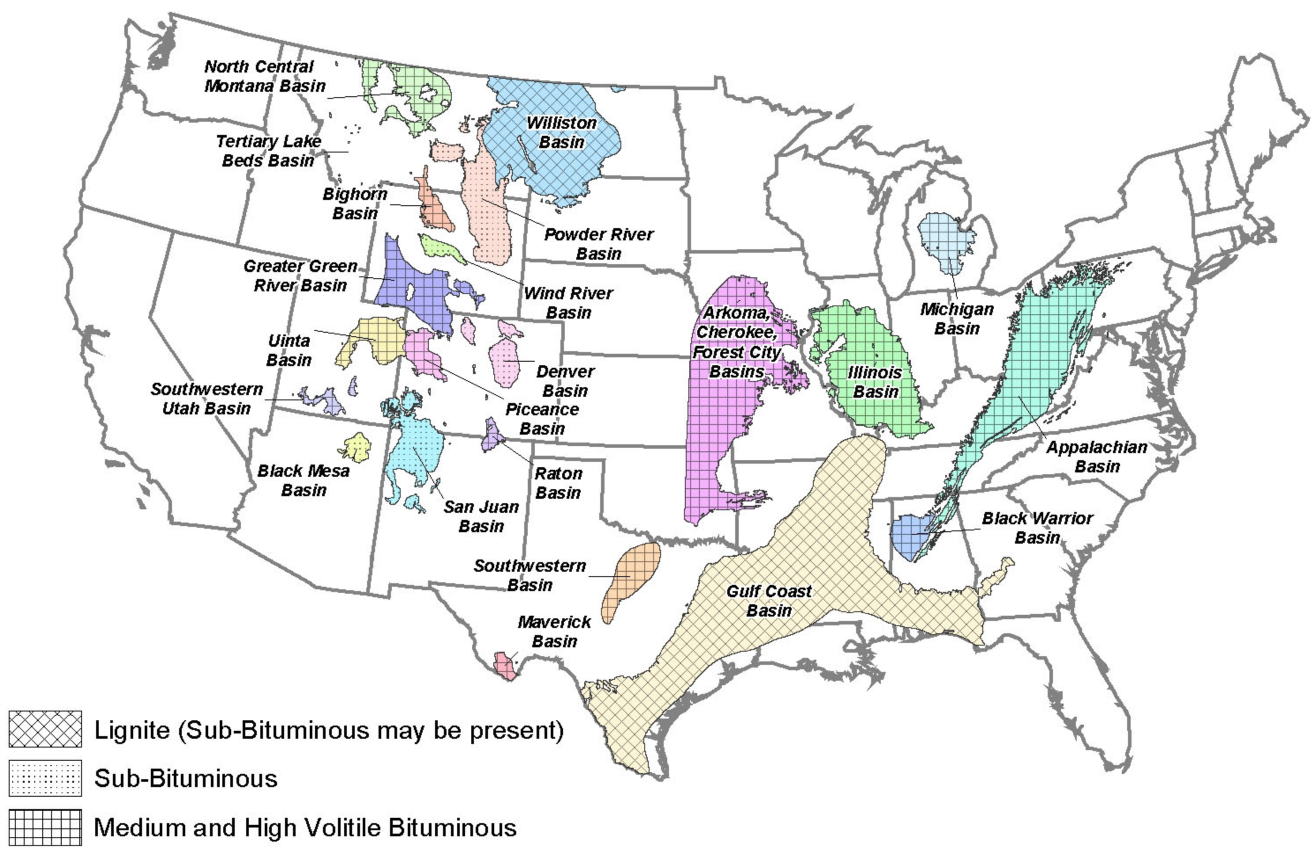


Figure 1
Major Coal Basins within the Contiguous United States by Coal Rank

Layers of peat may be separated by clay and sand deposited during times of flood or other breaks in the accumulation cycle. As the peat accumulates, organic processes begin to break the plant debris down, both physically and chemically.

Physically, small insects, worms, and fungi break the fragments into smaller pieces. As the peat solidifies, the small fragments formed are termed macerals, and can be identified microscopically as coming from plant products. At the same time, the peat is squeezed by overlying material, driving out its water content and compacting the plant debris into rock.

Chemically, the plant material is slowly converted into simpler organic compounds ever richer in carbon. These combined processes are called sedimentation, and are illustrated in Figure 2. After sedimentation, the peat is buried deeper while pressure and heat build up. It is the heat and pressure that slowly transforms the peat into coal through the process of maturation. To generate one foot of coal it took approximately five feet of raw organic material.

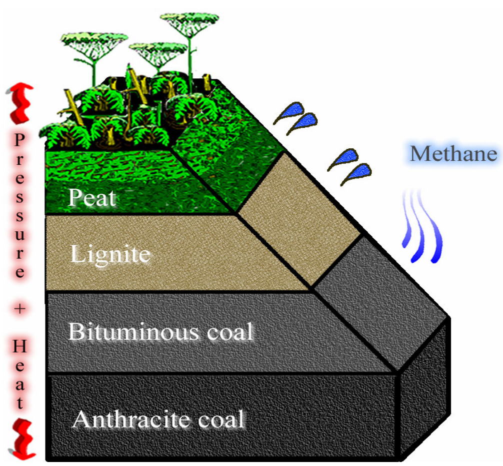


Figure 2
Sedimentation and the formation of coal

Coals are deposited over a narrow range of sedimentary environments, such as swamps or bogs. In all cases the fresh, organic plant material needs to be buried quickly and protected from oxidation. In order for the organic matter to be preserved, the plant debris must accumulate in a local area of restricted oxygen supply.

Coal Classification

There are two main recognized ways to classify coal – by rank or by grade. Coal rank is a measure of the degree of coalification or heat content and coal grade is a measure of the coal purity. For the purposes of the Primer, Rank will be used to describe coal and it's relationship to methane production.

Rank

The degree of coalification or metamorphosis undergone by a coal, as it matures from peat to anthracite, has a significant bearing on its physical and chemical characteristics, and is referred to as the 'rank' of the coal. The major ranks of coal from lowest to highest are lignite, sub-bituminous, bituminous, semi-anthracite and anthracite. The higher the coal rank the higher the temperature and pressure of coal formation. The higher coal ranks have a greater percent of carbon. As moisture and volatiles are driven off during coal maturation carbon is left behind. With an increase in carbon content there is also an increase in the heat content of the coal.

The earth's crust exhibits an average geothermal gradient of about 1.5° F for every 100 feet of burial depth. As coal seams are depressed ever-deeper into the earth under accumulating sediments, much of the water and volatile matter are driven away, leaving behind the fixed carbon as well as residual amounts of ash, sulfur, and tiny amounts of a few assorted trace elements. The extent of this *de-volatilization* varies according to the deepest depth of ultimate burial, resulting in a continuous series of coal grades according to the relative percentages of fixed carbon they contain.

Lignite is the lowest rank of coal and is characterized as browner and softer. Lignites have a high oxygen content (up to 30 percent), a relatively low fixed carbon content (20-35 percent), and a high moisture content (30-70 percent) (WCI). Lignite is found in great quantities in the United States in the Gulf Coast Basin and the Williston Basin. Lignite is not particularly efficient in producing energy per mass of fuel. These coals are also susceptible to spontaneous combustion.

Sub-bituminous coals usually appear dull black and waxy. Sub-bituminous coals have a fixed carbon content between 35 to 45 percent and a moisture content of up to 10 percent. These coals are frequently used for electrical generation and are found

throughout the west in the Black Mesa, Bighorn, Denver, Greater Green River, North Central Montana, Powder River, San Juan and Wind River basins (WCI).

Bituminous coals are dense black solids, frequently containing bands with brilliant colors. The carbon content of these coals ranges from 45 to 80 percent and the water content from 1.5 to 7 percent (WCI). Major deposits of bituminous coals are found in the central United States in the Appalachian, Arkoma, Black Warrior, Cherokee, Forest City, Illinois, Maverick, Michigan, Raton and Southwestern basins. The coals are well suited for the production of metallurgical coke, power generation, cement making, and to provide heat and steam in industry.

Because of their higher fixed carbon content and lower moisture content, bituminous coals contain more energy per pound than sub-bituminous coals, which in turn contain more energy than lignite coal. In the U.S., this heat energy is typically expressed as BTU's (British Thermal Units) per pound. A typical pound of bituminous coal will yield about 10,500 to 12,000 BTU's of energy. Figure 3 illustrates the composition changes associated with coal rank.

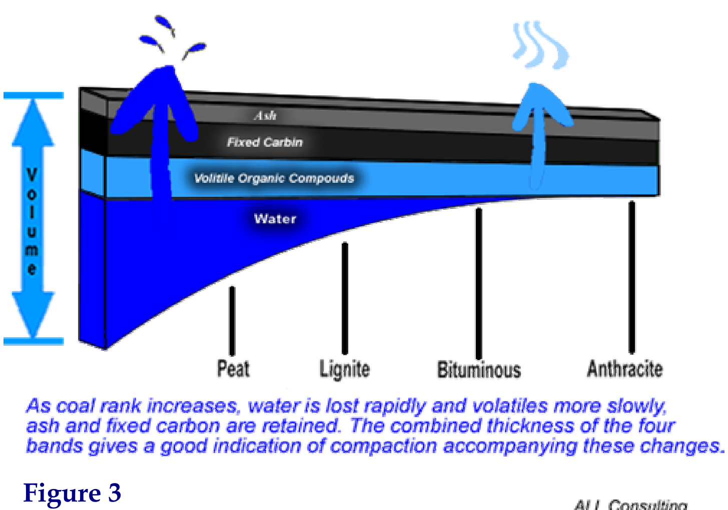


Figure 3
Composition Changes with Coal Rank

Anthracite is dense, hard and shiny and defined as having more than 86% fixed carbon and less than 14% volatile matter on a dry, mineral-matter-free basis. The rank is divided into semi-anthracite, anthracite, and meta-anthracite groups on the basis of increasing fixed carbon and decreasing volatile matter. Anthracite coals are relatively uncommon representing less than 1% of all world coal reserves. The high carbon and energy content coupled with being a relatively hard material and clean burning makes anthracite a desired product. The value-added anthracite products are used in carbon filtration water purification and space heating. Anthracite is also used as a reductant in metallurgical processing, pulverized coal injection for steel making, in cooking and heating briquettes, and as fuel used in the manufacture of cement and generation of electricity.

WHAT IS CBM?

Coal Bed Methane is naturally occurring methane (CH_4) with small amounts of other hydrocarbon and non-hydrocarbon gases contained in coal seams as a result of chemical and physical processes. It is often produced at shallow depths through a bore-hole that allows gas and large volumes of water with variable quality to be produced. Shallow aquifers, if present, need to be protected but in the Rocky Mountain Region, the producing coal bed is often a source of water for both livestock and human consumption. CBM resources represent valuable volumes of natural gas within and outside of areas of conventional oil & gas production. Many coal mining areas currently support CBM production; other areas containing coal resources are expected to produce significant volumes of natural gas in the near future.

CBM is intimately associated with coal seams that represent both the source and reservoir. Significant reserves of coal underlie approximately 13% of the U.S. landmass as shown in Figure 1. Coals have an immense amount of surface area and can hold enormous quantities of methane. Since coal seams have large internal surfaces, they can store on the order of six to seven times more gas than the equivalent volume of rock in a conventional gas reservoir (USGS 1997). CBM exists in the coal in three basic states: as free gas; as gas dissolved in the water in coal; and as gas "adsorped" on the solid surface of the coal.

Coal varies considerably in terms of its chemical composition, its permeability, and other characteristics. Some kinds of organic matter are more suited to produce CBM than are others. Permeability is a key characteristic, since the coal seam must allow the gas to move once the water pressure is reduced.

Gas molecules adhere to the surface of the coal. Most of the CBM is stored within the molecular structure of the coal; some is stored in the fractures or cleats of the coal or dissolved in the water trapped in the fractures. Methane attaches to the surface areas of coal and throughout fractures, and is held in place by water pressure as shown in Figure 4. When the water is released, the gas flows through the fractures into a well bore or migrates to the surface.

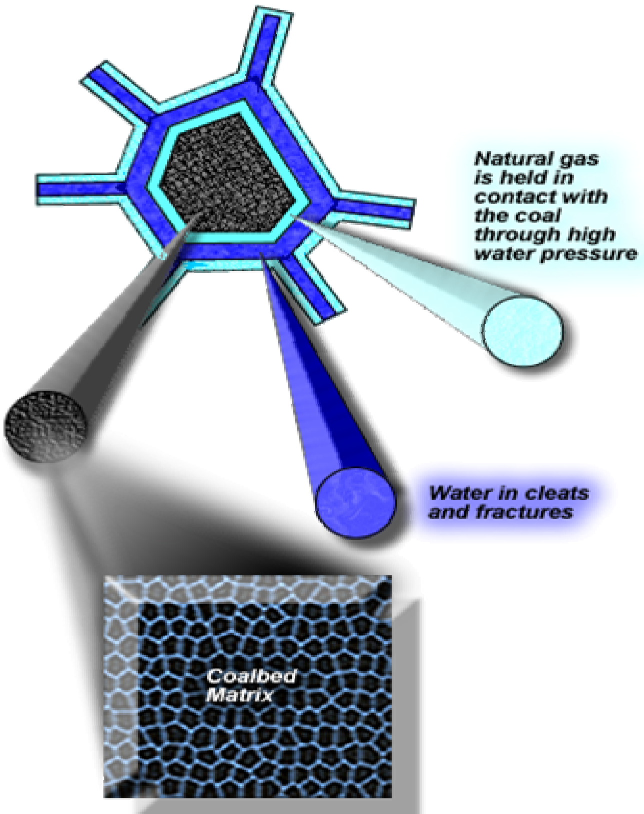


Figure 4
Coal Bed Matrix illustrating gas surrounding the coal bound by water and rock

Coals can generally generate more gas than they can absorb and store. Basins that contain between 500 to 600 standard cubic feet (SCF) of methane per ton are considered to be "very favorable for commercial production," as long as there is sufficient reservoir permeability and rate of desorption (Murry, 1993). Desorption is the process by which coals frees methane when the hydrostatic pressure is reduced. Some coals have generated more than 8,000 SCF of methane per ton of coal. The most productive coals are saturated with gas, fractured and highly permeable (Cook NRLC, 2002).

Worldwide, coal is present in most sedimentary basins that are Devonian to Tertiary in age. Coal deposits in the Eastern and Central U.S. are Paleozoic in age (Mississippian and Pennsylvanian) and in the Western U.S. and Gulf Coast the coals are younger (Cretaceous and Tertiary) in age. This diversity of age has given rise to two different types of CBM basins. The eastern hard coals are higher rank and thinner. They contain less water within the coal seam and require fracture enhancement to increase the productivity. The water contained within the coals is typically low quality, which does not lend itself to many beneficial uses. The western soft coals are lower in rank but very thick. These coals contain vast amounts of water that requires removal to initiate production. The produced water is typically high to medium quality water that lends itself to many beneficial uses. Table 1 provides a summary of the coal reserves across the U.S.

Table 1
Coal Reserves by State

State	Tons (billions)	Percent of U.S.
Montana	120	25.4
Illinois	78	16.5
Wyoming	68	14.4
West Virginia	37	8.0
Kentucky	30	6.3
Pennsylvania	29	6.1
Ohio	19	4.0
Colorado	17	3.6
Texas	13	2.7
Indiana	10	2.1
Other States	51	10.9
Total Coal Reserves	472	100.0

Source: *COAL: Ancient Gift Serving Modern Man*; American Coal Foundation, 2002

WHERE DOES CBM COME FROM?

CBM is generated either through chemical reactions or bacterial action. Chemical action occurs over time as heat and pressure are applied to coal in a sedimentary basin. This is referred to as thermogenic production. Bacteria that obtain nutrition from coal produce methane as a by-product in a method referred to as biogenic. The gas in higher rank coals is a result of thermogenic production as heat and pressure transform organic material in the coal. Gas in lower rank coals results from the decomposition of organic matter by bacteria.

Typically, the deeper the coal bed, the less the volume of water in the fractures, but the more saline the water becomes. The volume of gas typically increases; with coal rank, how far underground the coal bed is located, and the reservoir pressure (USGS 2000). Natural desorption occurs when the fracture system releases water, the adsorptive capacity of the coal is exceeded, pressure falls, and the gas trapped in the coal matrix begins to desorb and move to the empty spaces in the fracture system. The gas remains stored in the fracture system or in nearby non-coal reservoirs until it is extracted.

As coals mature from peat to anthracite, the associated fluids transform as well. Low rank peat and lignite have high porosities, high water content, and produce low temperature biogenic methane and few other fluids. As coals mature into bituminous types, water is expelled, porosity decreases, and biogenic methane formation decreases, because temperatures rise above the most favorable range for bacteria. At the same time, heat breaks down complex organic compounds to release methane and heavier hydrocarbons (ethane and higher). Inorganic gases may also be generated by the thermal breakdown of coals.

As the coal matures to anthracite, less methane is generated and little porosity or water remains in the matrix. The chart below (Figure 5) lists the steps in the maturation of coal from peat to anthracite and the fluid generated and expelled during the maturation process. Peat, largely unaltered plant debris, and lignite ("brown coal") can give rise to biogenic methane, produced by methanogenic bacteria. Minor production of CBM has been reported from lignite in North Dakota and Louisiana. CBM production in most of the Western U.S. comes from sub-bituminous and bituminous coals. CBM in the Eastern U.S. originates in higher rank coals.

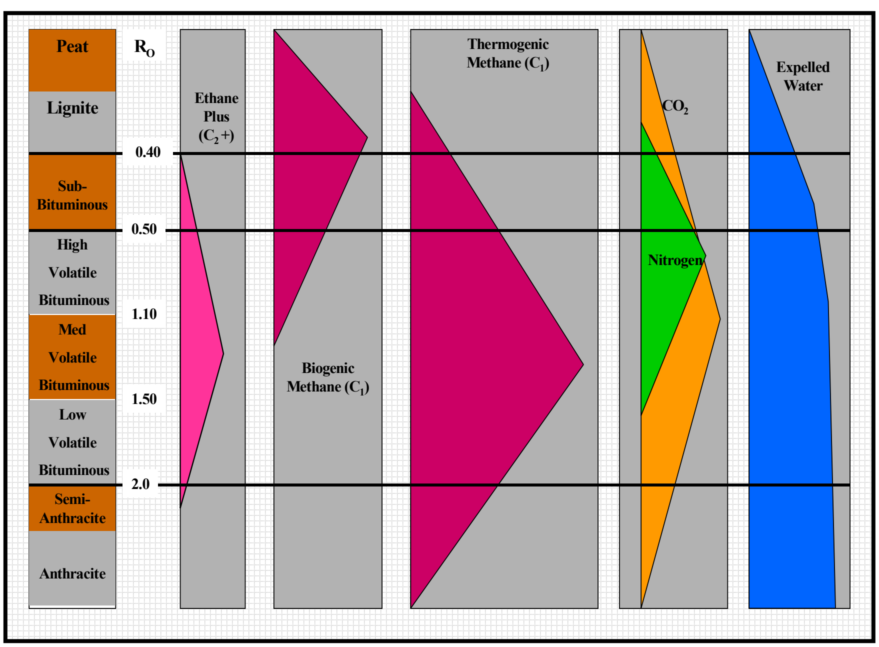


Figure 5
Coal Maturation Chart

What Controls CBM Production?

CBM production potential is a product of several factors that vary from basin to basin – fracture permeability, development, gas migration, coal maturation, coal distribution, geologic structure, CBM completion options, hydrostatic pressure and produced water management. In most areas, naturally developed fracture networks are the most sought after areas for CBM development. Areas where geologic structures and localized faulting have occurred tend to induce natural fracturing, which increases the production pathways within the coal seam. This natural fracturing reduces the cost of bringing the producing wells on line.

Most coals contain methane, but it cannot be economically produced without open fractures present to provide the pathways for the desorbed gas to migrate to the well. As long as the pressure exerted by the water table is greater than that of the coal the methane remains trapped in the coal bed matrix. Coal cleats and fractures are usually saturated with water, and therefore the hydrostatic pressure in the coal seam must be lowered before the gas will migrate.

Lowering the hydrostatic pressure in the coal seam accelerates the desorption process. CBM wells initially produce water primarily; gas production eventually increases, and as it does water production declines. Some wells do not produce any water and begin producing gas immediately, depending on the nature of the fracture system. Once the gas is released, it is usually free of any impurities; is of sufficient quality and can be easily prepared for pipeline delivery.

Some coals may never produce methane if the hydrostatic pressure cannot be efficiently lowered. Some coal seams may produce gas, but are too deep to economically drill. CBM wells are typically no more than 5000' in depth, although some deeper wells have been drilled. Figure 6 illustrates the relationship between hydrostatic pressure, coal seam depth and well location.

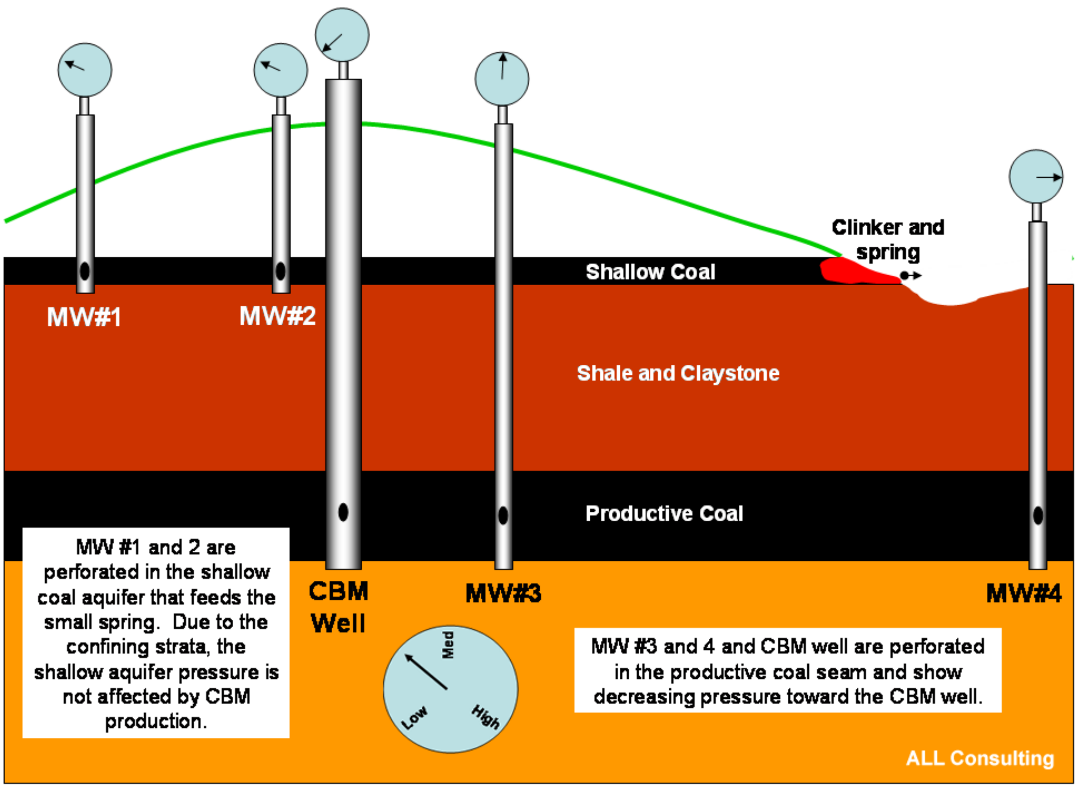


Figure 6
CBM Production Relationship to Hydrostatic Pressure

Cleat (Fracture) Development

Coal contains porosity but very little matrix permeability. In order for fluids to be produced out of coal seams into a well-bore, the coal must possess a system of secondary permeability such as fractures. Fractures allow water, and natural gas to migrate from matrix porosity toward the producing well. Cleat is the term used for the network of natural fractures that form in coal seams as part of the maturation of coal. Cleats form as the result of coal dehydration, local and regional stresses, and unloading of overburden. Cleats largely control the directional permeability of coals and therefore are highly important for CBM exploitation through well placement and spacing.

Two orthogonal sets of cleats develop in coals perpendicular to bedding. The face cleats are the dominant set that are more continuous and more laterally extensive; face cleats form parallel to maximum compressive stress and perpendicular to fold axes of the coal bed. The butt cleats are secondary and can be seen to terminate against face cleats. Butt cleats are strain-release fractures that form parallel to fold axes. Figure 7 shows the cleat orientation.

Cleat spacing is related to rank, bed thickness, maceral composition, and ash content. Coals with well-developed cleat sets are brittle reflecting fracture density. In general, cleats are more tightly spaced with increasing coal rank. Average cleat spacing values for three coal grades include: sub-bituminous (2-15 cm), high-volatile bituminous (0.3-2 cm), and medium-to low-volatile bituminous (<1 cm) (Cardott, 2001). Cleat spacing is tighter in thin coals, in vitrinite-rich coals, and in low-ash coals.

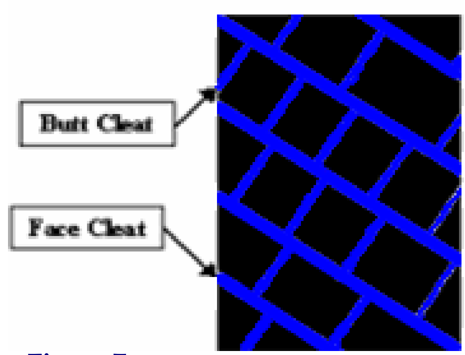


Figure 7
Coal Cleat Orientation

Natural Gas Migration

In coal seams, most gas is absorbed by the microscopic laminations and micropores within coal macerals. As hydrostatic pressure is decreased by water production, gas desorbs and moves into the cleat system where it begins to flow towards the producing well, as diagrammed in Figure 8.

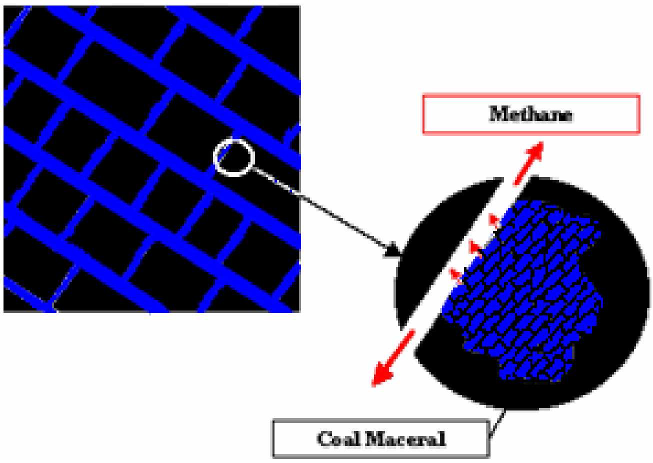


Figure 8
Methane Migration Pathways

Natural gas can also migrate through more wide-spread fracture sets related to faults and tectonic jointing. Faults can persist over several miles and are related to geologic movement and structure, and can enhance the migration pathways for the methane in the subsurface.

Coals can be analyzed for adsorbed gas content using standardized techniques that mechanically pulverize the core samples. The gas content figures range from several hundred standard cubic feet (scf) per ton to less than 50 scf per ton of coal. The test results cannot be directly equated with ultimate recoverable CBM reserves since not all the gas can be desorbed and produced from the coal. Methane content values in producing basins range from around 800 scf per ton in Oklahoma, to 450 scf per ton in the San Juan Basin, and to an average of 40 scf per ton in the Powder River Basin.

CBM Background

CBM development has its roots in the coal mining industry. Attempts to develop marketable CBM began in the United States in the 1970s, as a result of the U.S. Bureau of Mines' efforts to improve mine safety by extracting methane in advance of mining operations. As recently as 1982, CBM production in the United States was practically non-existent. In 1983, the Gas Research Institute commenced field investigations that motivated the expansion of CBM recovery. At the end of 1983, annual CBM production was nearly 6 Bcf (billion cubic feet) from about 165 wells. By 1994, it had grown to 85.1 Bcf from more than 6,000 wells, and by 1999, there were 14,000 wells producing roughly 1,252 Bcf.

In 1980, Congress enacted a tax credit to promote domestic production from alternative sources, including CBM. Known as the Section 29 tax credit (section 29 of the 1980 Crude Oil Windfall Profit Tax Act), the requirement has two limits: the gas needs to be sold to an unconnected group, and the tax credit can only be applied to wells brought on line before Dec 31, 1992. The credit, valued at $3 barrel of oil or Btu equivalent, ended on December 31, 2000, however the tax credit was modified and extended in both the House and Senate energy bills that the two chambers passed in 2001 and 2002, respectively. The greatest increase in development, however, didn't begin until approximately 1988. This was due to the 1980 tax incentives being put in place by the Congress coupled with improved production techniques.

Currently, there are thousands of CBM wells in the United States, and active exploration, development, and/or production is being carried out in Alabama, Alaska, Arkansas, Arizona, Colorado, Illinois, Indiana, Kansas, Kentucky, Louisiana, Montana, Nebraska, New York, North Dakota, Oklahoma, Pennsylvania, Texas, Utah, Virginia, Washington, West Virginia and Wyoming. To date almost 88 percent of the United States total CBM production is from the Rocky Mountain region encompassing Colorado, Montana, New Mexico, Utah and Wyoming (EIA 2001)

The San Juan Basin in Northern New Mexico and Southern Colorado has contributed the most to CBM production and is the most extensively developed basin in the region. Exploration and development began in the late 1980s and quickly grew throughout the 1990s. Production is nearing its peak in the basin, but companies are trying to maintain recovery with new production enhancement methods and reduced well spacing.

The Powder River Basin in eastern Wyoming and southeastern Montana is currently the fastest growing basin for CBM development. In 1997 there were 360 wells producing 54 million cubic feet (MMcf) of gas/day, by the end of 2002, 935 MMcf/day was being produced from 10,991 wells. During the past 12 months an additional 5400 Applications for Permit to Drill (APDs) have been submitted (http://wdogcc.state.wy.us April 2003). Significant CBM resources in the Rocky Mountains have also been identified in the Raton Basin in central Colorado, the Piceance Basin in northwestern Colorado, the Unita Basin in Eastern Utah, Kaiparowits Plateau Basin in Southern Utah, Hanna-Carbon Basin in south-central Wyoming and the Greater Green River Basin in southwestern Wyoming.

It has been estimated that the Rocky Mountain basins contain as much as 595 Trillion cubic feet (Tcf) of CBM, (GTI 2000). The technically recoverable amount may currently be less than one quarter of that volume, but with improved methods and enhanced recovery techniques CBM in the Rocky Mountains will remain an important source of natural gas.

CBM production continues to advance across North America as operators develop new techniques for drilling and producing coal seams of different rank and quality. It is anticipated that production will only increase as the demand for natural gas continues to increase.

How is CBM Produced?

CBM wells are completed in several ways, depending upon the type of coal in the basin and fluid content. Each type of coal (sub-bituminous to bituminous) offers production options that are different due to the inherent natural fracturing and competency of the coal seams. The sub-bituminous coals are softer and less competent than the higher rank low-volatile bituminous coals, and therefore are typically completed and produced using more conventional vertical well bores. The more competent higher rank coals lend themselves to completions using horizontal as well as vertical well bores.

Western Soft Coals

The coals found mostly in the Western U.S. are frequently sub-bituminous in rank and although competent enough to be completed and produced open-hole, they are often too soft to allow the use of horizontal wellbores with any major success to date. Figure 9 provides a typical well completion for CBM production wells in the Western U.S. The well is drilled to the top of the target coal seam and production casing is set and cemented back to surface. The coal seam is then drilled-out and under-reamed to open up more coal face to production. The borehole and coal face are then cleaned with a slug of formation water pumped at a high rate (water-flush). In areas where the cleat or natural fracture system is not fully developed, the coal may be artificially fractured using a low-pressure water fracture treatment.

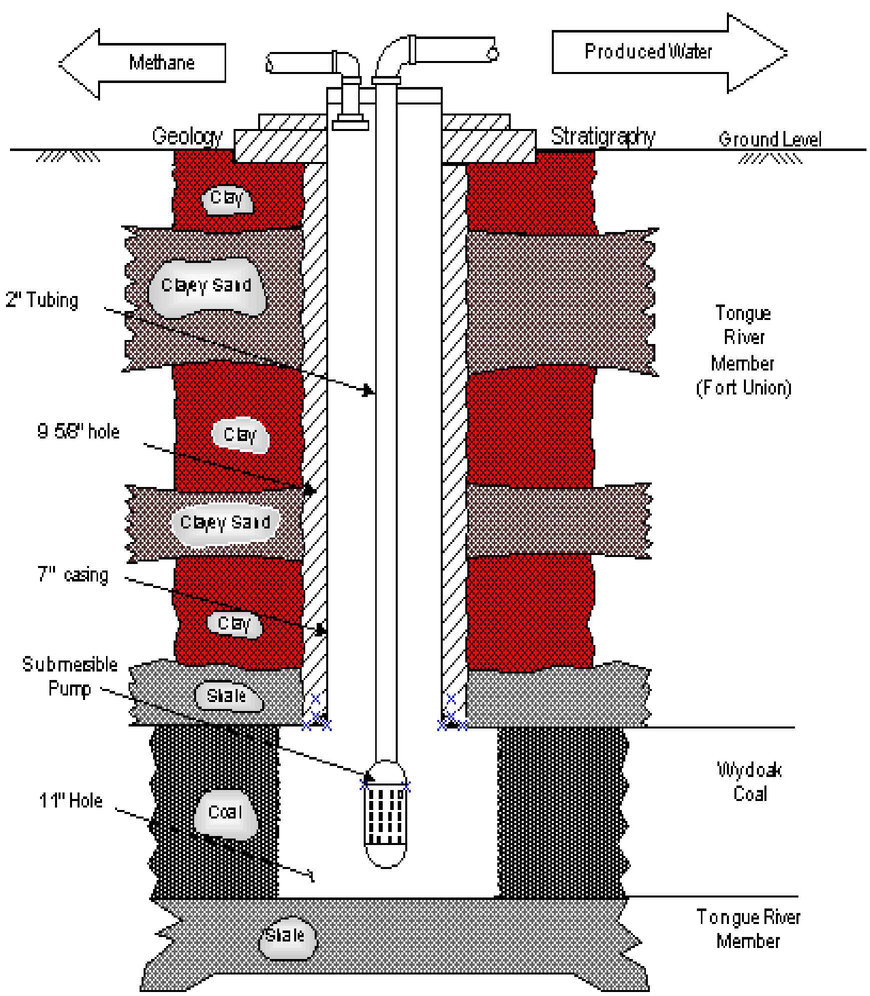


Figure 9
CBM Wellbore Diagram--Open-hole Completion
Example from Powder River Basin

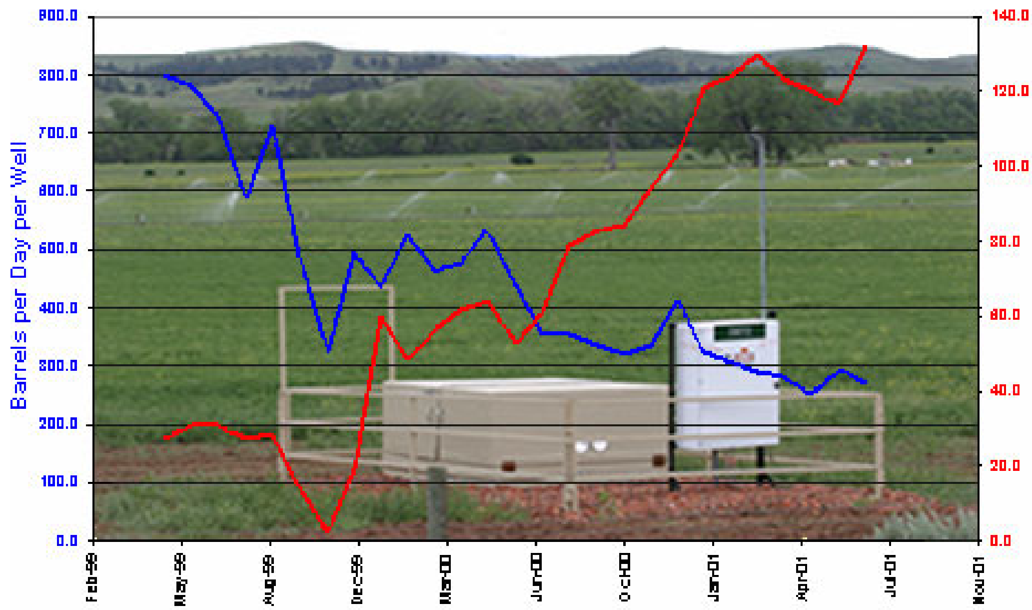


Figure 10
Production Plot, Powder River Basin - Production History

ALL Consulting

These shallow wells are typically drilled with a small mobile rig mounted on a truck. For example, most wells in the Powder River basin are drilled in under a week and have a residual foot print of approximately ¼ acre. Spacing between wells is currently 80 acres in the Powder River Basin but can be as much as 320 acres (San Juan Basin) depending on the coal bed characteristics.

Once the well is completed, a submersible pump is run into the well on production tubing to pump the water from the coal seam. By removing the water from the coal seam the formation water pressure is reduced and the methane is desorbed (released) from the coal, thus initiating production. The methane flows up both the casing and tubing of the well and is sent via pipe to a gas/water separator at the compression station. The methane is then compressed for shipment to the sales pipeline. In most western soft coal areas only one coal seam is produced in each well.

Three CBM wells finished with surface enclosures in the Powder River Basin

Attempts at producing more than one coal seam per well have been mostly unsuccessful due to the inherent problem of lowering the water level in each coal seam independent of each other. Size constraints of the production equipment and use of submersible pumps make the use of dual completion complicated and expensive. With CBM production wells typically being so shallow, it is less expensive and less complicated to drill wells into each coal seam independently than to use dual or triple completion well systems.

As water is pumped off the coal aquifer, increasing amounts of methane are produced from the CBM wells. This relationship is shown in the production plot (Figure 10). The plot uses data obtained from the CX ranch in the Montana portion of the Powder River Basin. The plot details the field-wide average water and gas production over time from the date of first production. As can be seen, the water production is very high during the initial stages of production, but declines as more wells are installed and the hydrostatic pressure is lowered in the coal seam. As the hydrostatic pressure is lowered, the gas production increases as new fractures are desorbed and more methane is released.

Eastern Hard Coals

The coals found in the eastern portions of the U.S. are often higher rank medium to low volatile bituminous coals. While these coals are very competent and can be completed open hole, these coals are often drilled and cased to total depth. Wells are then perforated and stimulated to remove damage caused by drilling and to enhance fracturing near the wellbore. However, many of the eastern coals do not have significant water to be removed from the coal to initiate methane production. As such, several coal seams are often perforated in a single bore-hole. Figure 11 provides an example of vertical well bore completed in multiple coal seams.

Eastern hard coals are often exploited by way of horizontal drain-holes from a single bore-hole. Each individual well may have up to 3,500-feet of lateral extent within a single coal seam. Several laterals can be drilled from a single wellbore to exploit several seams or to take advantage of several cleat (fracture) trends. Each leg would not necessarily be horizontal but would closely follow the dip of the individual seam. Many of the coal seams are often less than five-feet thick, requiring the drilling contractor to exercise great care in steering the drill bit. Figure 12 illustrates an example of this method. Operators in Alabama, Arkansas, and Oklahoma have made use of horizontal laterals to enhance CBM production.

The production of CBM from eastern coals is similar to the western coals except for the use of horizontal well bores and the extensive use of fracturing to enhance production. With the coals being of higher rank, the methane content per ton of coal is typically higher, but requires in many areas additional enhancement to the natural fracture content to maximize production. Production rates of CBM depend upon local gas content of the coal, local permeability of the coals, hydrostatic pressure in the coal seam aquifer, completion techniques, and production techniques.

HOW DOES CBM COMPARE TO CONVENTIONAL NATURAL GAS?

Methane is the chief component of natural gas, and CBM can be used in very much the same way as conventional gas. Conventional gas is formed in limestone and shale formations; pressure and temperature unite to transform organic matter into hydrocarbons over time, similar to thermogenic production in deeper coals. Natural gas migrates upward until trapped by a geologic barrier or fault and remains in this reservoir until it is discovered and drilled, or released by some natural means. Conventional gas wells are typically 4,000 to 12,000

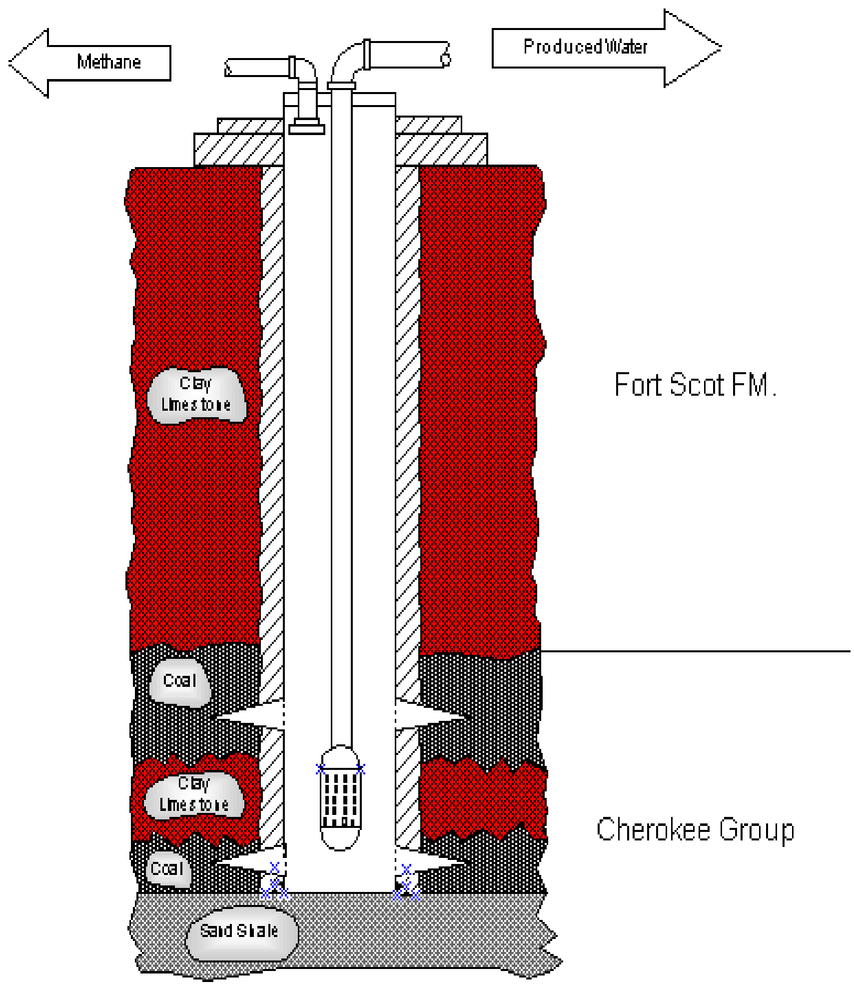


Figure 11
CBM Drilling Example
Vertical Wellbore Example from Cherokee Basin, Kansas

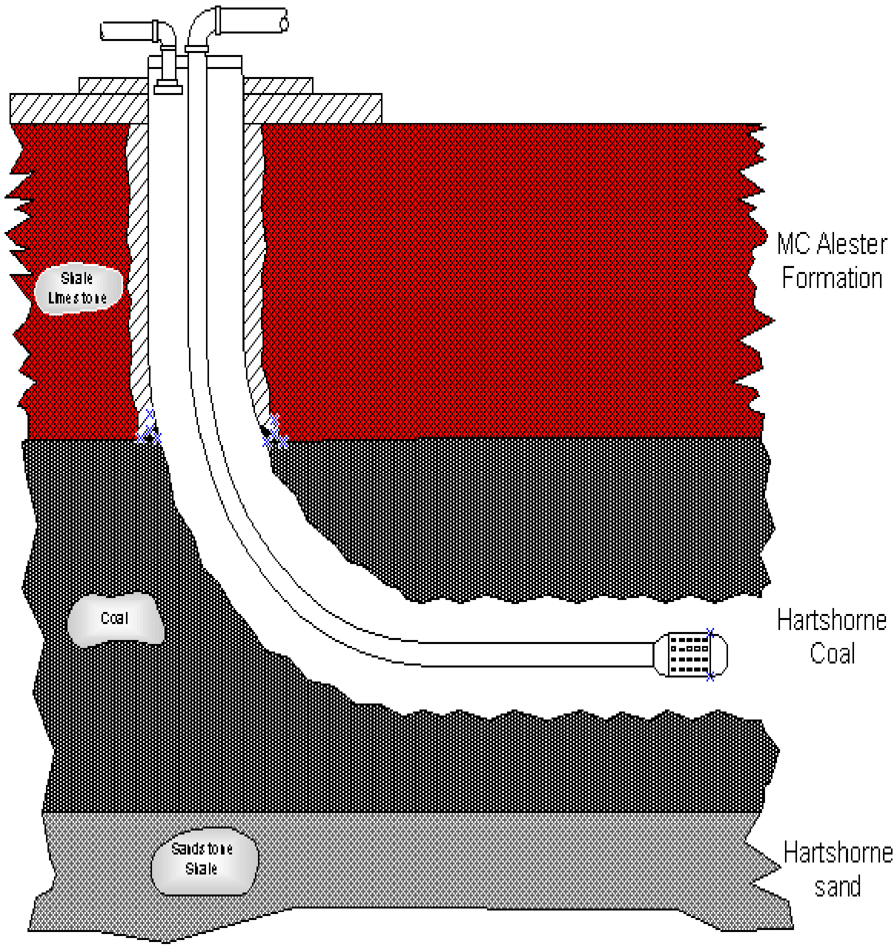


Figure 12
CBM Drilling Example
Horizontal Wellbore Example from Arkoma Basin

feet deep and extract gas from sandstone and shale formations (PRCBMIC, 2002). The location and extent of conventional gas typically requires exploratory drilling since the location of reservoirs is not apparent from the surface (Cullicott et al., 2002). Coal bed wells are generally considered shallow and range from 400 to 1,500 feet in the Powder River basin but can be as deep as 5,000 feet in some basins.

CBM is occasionally compared to another unconventional gas—"tight" gas—which is found at deeper depths and in low permeability sandstones. Companies often use hydraulic fracturing, injecting fluid into the rock formation to cause cracking in anticipation of releasing gas from tight sands (Kelly, 2001). Fracturing is also used in some CBM seams to increase production, as previously explained. CBM differs from conventional natural gas in other important ways. CBM is held in an adsorbed form on the surface of the coal; reservoir pressure must be reduced before CBM can be produced in significant quantities; and water is typically present in the reservoir and is usually co-produced with the CBM (Fidelity, 2002).

The economic feasibility of CBM compared to conventional natural gas is typically affected by four primary variables: the production cost, the rate of gas production, hub price, and economies of scale (Boyer, 1999).

Most CBM wells are shallow (less than 5,000 feet) and can be constructed in a short amount of time resulting in low to moderate well costs in comparison to conventional natural gas.

The volume and rate of gas production from CBM wells may fluctuate significantly unlike conventional gas, which is often more consistent once tapped. Minimum or low gas CBM producers yield about 50 thousand cubic feet (mcf) per day; high yield wells produce as much as 5 MMcf per day (Williams, 2001).

The location of the CBM production field with respect to the regional or interstate transmission pipelines also affects the economics of CBM development. The gas hub price, minus production and transportation costs, equal the wellhead net back price. In some areas, the transportation costs may be as much as the wellhead net back price.

The economy of scale refers to the number of wells or field size that has to be reached in order for the company to make a profit. Costs affecting the economic viability of CBM developments include compression, gas treatment, geologic and engineering services, transmission of gas and field operations. The minimum number of wells or volume of gas produced for a feasible project therefore depends on a diversity of issues.

Conventional natural gas wells produce large volumes of gas initially and then taper off over time as water production steadily increases; the exact opposite is true for CBM production. As previously mentioned CBM wells produce large volumes of water during the initial lowering of the hydrostatic pressure, and as the quantities of produced water decline the gas production increases. This is a result of lowering the hydrostatic pressure of the coal seam and allowing more gas to escape along the fractures and open cleats. Furthermore, conventional gas wells do not need to normally utilize artificial lift until the end of the well life, when pumps are sometimes installed to remove water if a well is incapable of lifting the water to the surface on its own. CBM wells on the other hand have submersible pumps installed initially and remove water for a number of years before peak production is reached, see Figure 13 which depicts a typical Powder River CBM well construction. In most cases towards the end of the CBM life cycle the submersible pumps can be turned off and gas will flow freely from the well even though most of the water remains in the coal seam (PRCBMIC, 2002).

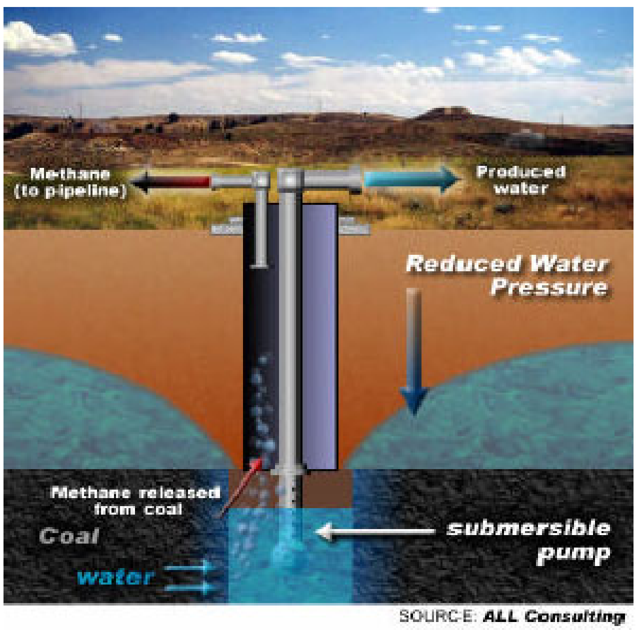


Figure 13
Typical CBM Well Construction Diagram
Powder River Basin, Montana

The production curve will depend on several factors including the field geology, well spacing, permeability of the reservoir, initial reservoir hydrostatic pressure, production techniques, and water saturation. In some basins, such as the San Juan Basin peak gas production can be reached in as little as two or more years (AAPG, BP Seminar, 2001). The relationship between peak gas production and production time is a function of the reservoir's permeability and well density. The lower the reservoir permeability the longer time it takes to reach peak gas production, or the more wells are needed to reach peak production sooner.

Typically, CBM wells produce less gas than conventional wells, therefore the cost to dispose of the production water is a significant expense compared to that of conventional development. Also, unlike conventional gas wells CBM wells are not shut off in reaction to falling gas prices; since the coal seam may refill with water, operators don't alter production rates in response to price fluctuations. Figure 14 compares CBM development to conventional natural gas development with regards to the quantities of water produced over the life of the wells.

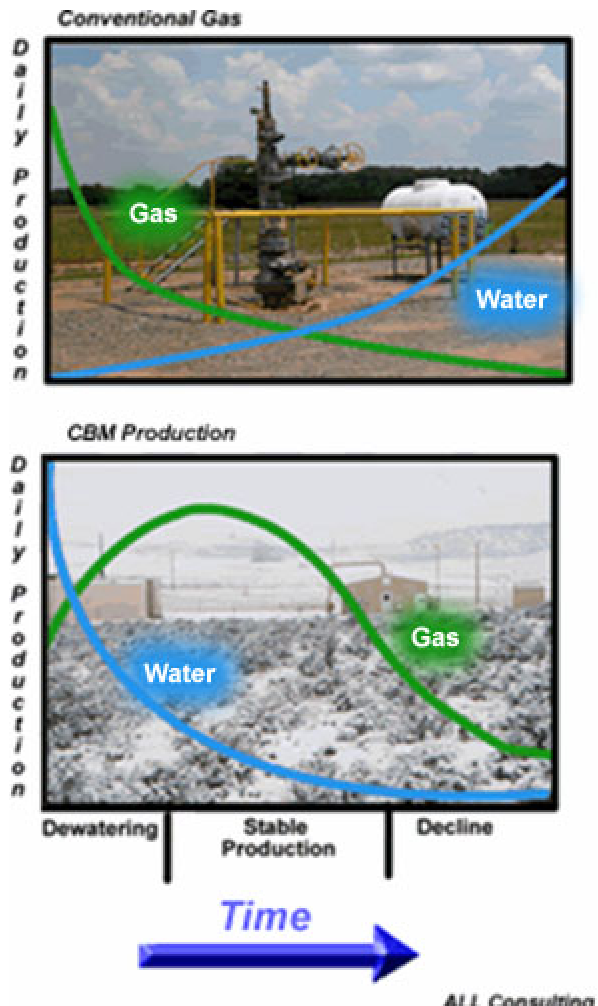


Figure 14
Production of Gas – Coal bed vs Conventional Reservoir

Another important characteristic affecting the economics of CBM development is the comparatively brief production time wells actually produce gas. Wells vary in production duration depending on a variety of factors. Conventional gas wells can produce from a few years to over 50 years. Well duration is affected by technology and as advances are made, reserves are recovered more quickly, which reduces the expected well life. Current estimates for the life of a CBM well vary from 5 to 15 years. CBM wells in the Wyoming portion of the Powder River Basin are estimated at only 7–10 years (BLM, 2003a), while the Montana portion of the same basin was estimated at 10–20 years (BLM, 2003b). Other basins have shown some longer production times, however it is generally feared by the public that basins may be relatively quickly pumped and then abandoned.

Enhanced Production

The CBM industry is exploring new methods of enhancing gas production from older fields that have produced for more than 10 years. Several companies are experimenting with the injection of nitrogen (N) and carbon dioxide (CO_2) into the coal bed to displace methane along the coal face cleats. Generally, the N and/or CO_2 molecules replace the methane molecules within the cleats at a ratio of approximately 4 to 1 (Schoeling, 2002). This forced gas exchange has resulted in elevated methane production rates as compared to just lowering the hydrostatic pressure. Injection of nitrogen, usually generated by manufactured gas plants, reduces the partial pressure and therefore the concentration of methane in the coals in the fracture system. Even though the partial pressure is reduced, the total pressure is generally constant (depending on whether or not the seams hydrostatic pressure is being lowered) and the fluids maintain head that drives liquids to the production wells. It is theorized that nitrogen injection affects methane production from the coal seam via inert gas stripping and sorption displacement. Coals can replace 25% to 50% of their methane storage capacity with nitrogen.

This enhanced production method has a beneficial side effect—the sequestering of CO_2. Carbon dioxide is a common by-product of many industrial processes and is considered a green house gas. The sequestering of CO_2 lowers the amount available to be exhausted to the atmosphere and helps the United States meet its goal for reduced CO_2 emissions. Laboratory studies indicate that coal adsorbs nearly twice as much volume of CO2 as methane. There are some concerns, however, that injection of CO_2 into mineable coals presents a safety hazard, as the mines are required to have a limit of 3% CO_2 by volume in the mine air. One potential method for reducing CO_2 levels in the mine air is to use a mixture of CO_2 and other gases, such as nitrogen. Studies indicate that for each volume of nitrogen that is injected, two volumes of methane are produced (Schoeling 2002). There is growing interest in mixed nitrogen/CO_2 injection for two reasons: there may be a synergy of production mechanisms, and its use would result in the lowering of CO_2 levels in the mine air (EPA 2002a). More research is needed in this arena, but preliminary results are promising for both CBM production and CO_2 sequestering.

Compression

Gas produced from CBM wells requires dehydration to remove the water vapor in the gas, and is usually compressed 2 to 3 times before it reaches the sales line. CBM leaves the wellhead at relatively low pressures that range from 2 to 5 pounds per square inch/gauge (psig) (Fidelity 2003). The CBM first passes through a field compressor unit, typically a rotary screw compressor that will increase the gas to 70-80 psig. At this pressure the gas flows through a gathering system on its way to the sales compressor. The sales compressor boosts the pressure to approximately 1200 psig. Following this stage the CBM in the sales line is transported locally or regionally to end-user sites, which are metered. It is important to note that as a CBM field matures, the CBM may contain increased levels of CO_2 that needs to be removed prior to being transported to market (Fidelity, 2003). Gas processing plants installed on the pipelines typically in conjunction with sales compressors treat the natural gas and remove the CO_2 and water vapor.

Typical sales compressor facility in the Powder River Basin, Wyoming

WHERE ARE CBM RESOURCES LOCATED?

The majority of CBM development has been conducted in the West, South, and, to a smaller degree, the Midwest. Figure 15 identifies the major CBM basins in the Rocky Mountain region.

To date approximately 56 percent of CBM production in the United States has come from the Rocky Mountain region. The four principal basins responsible for this include the Powder River, Raton, San Juan, and Uinta. Potential development is being considered for the Piceance and Denver basins in Colorado and for the Greater Green River basin in Wyoming. These basins may contain as much as 200 Tcf of recoverable CBM, representing approximately 50 to 80 percent of the estimated recoverable CBM in the United States. In addition to those basins another 1,000 Tcf of methane may also be located in Alaska (Lang 2000). It's important to recognize that estimates differ greatly, based on conflicting hypothesis's and differences between proven reserves and those that are economically or technically recoverable.

How do the Western CBM Basins Compare?

The major producing CBM basins in the Rocky Mountain region include the San Juan, Raton, Uinta, and the Powder River Basin. Potential or initial development is being considered for the Piceance, Green River, and Denver basins.

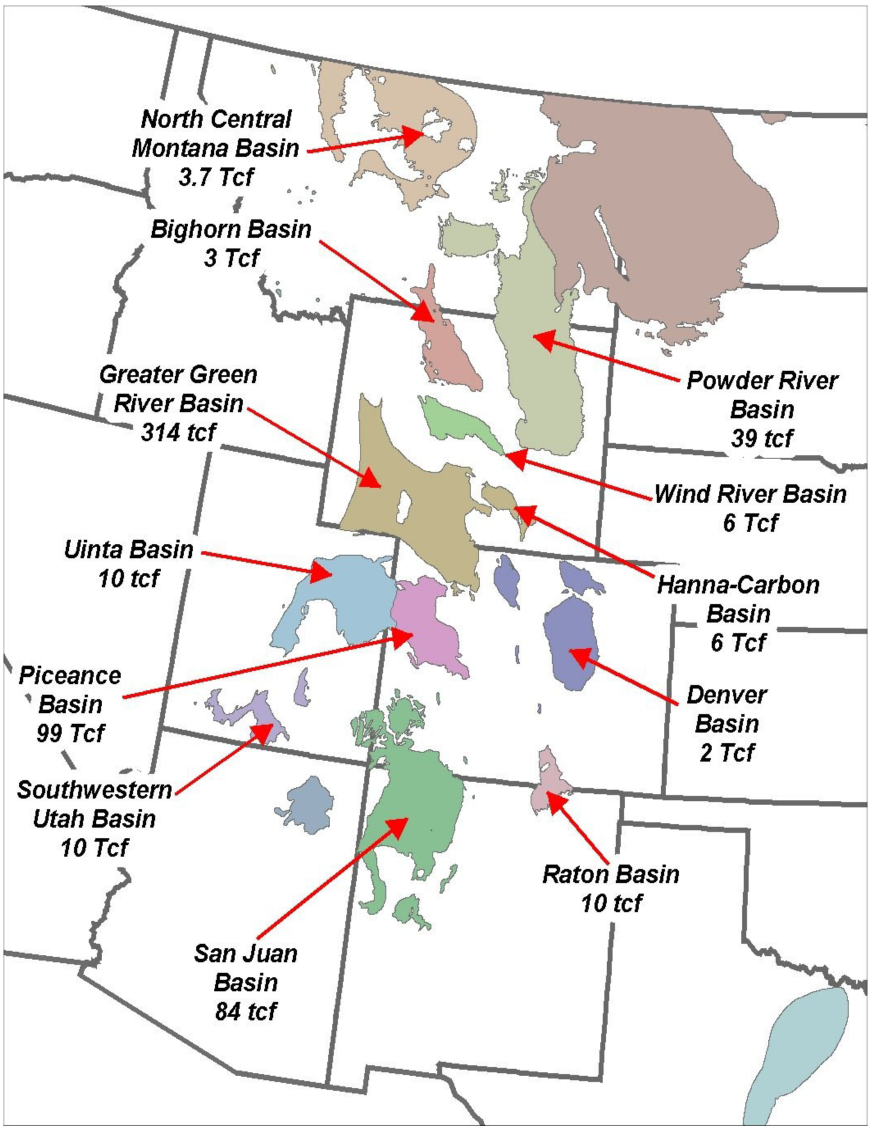


Figure 15
Rocky Mountain Region Coal Basins and Estimated CBM Reserves
Source: Nelson 2000

Each coal basin is different and poses its own unique set of development criteria and exploration challenges. Due to these differences, developments in various basins cause distinct changes to the surrounding communities and ecosystems. Some basins have been produced for many years and are nearing their peak while others are in the initial stages of development and some have still yet to be considered. Some basins produce good quality water that can be used for a variety of beneficial uses including irrigation, dust control, livestock watering, wetlands construction, wildlife source ponds, and even human consumption (ALL 2003), while other basins have poor quality water that must be managed for proper disposal. The common factor among CBM basins in the Rocky Mountains is that they each have unique characteristics. Operators take a long hard look at the various basins regional geology, coal types and characteristics, existing infrastructure, surrounding ecosystems and production potential before any investments are contemplated. New technologies are being advanced each year, which make some seemingly non-profitable basins more economic as differences are evaluated time and again. Table 2 summarizes the key characteristics of producing CBM basins in the Rocky Mountain Region of the United States.

Table 2				
Comparison of Producing CBM Basins in the Rocky Mountain Region				
Basin	**San Juan**	**Raton**	**Uinta**	**Powder River**
State Location	NM, CO	NM, CO	UT	WY, MT
Drilling Method	Air Percussion	Air Percussion	Air Percussion	Air-Water
Completion Methods	Cased Hole Perforate/Multistage	Cased Hole Perforate/Multistage N_2 Foam/Sand	Cased Hole Perforate/Multistage X-Link/Sand	Open-hole Under-ream
Producing Wells	2,550	694	558	10,358
Primary Water Disposal Methods	Injection	Deep Injection	Deep Injection	Surface Discharge, Beneficial Use
Water Lift Method	Rod Pump	Progressive Cavity and Rod Pump	Rod Pump	Electric Pump
Average water Production per well	25 Bbl/day	266 Bbl/day	215 Bbl/Day	400 Bbl/day
Coal Rank	Sub-bituminous	high-volatile bituminous	high-volatile bituminous	Sub-bituminous
Well Depth (feet)	550-4000 bsl	400-4000 bsl	2000-7000 bsl	200-2500 bsl
Net Coal Thickness	20-80 feet	10-40 feet	10-40 feet	75 feet
Gas Content	350-450 scf/ton	50-400 scf/ton	250-400 scf/ton	30 scf/ton
Well Spacing	320-160 acres	160 acres	160 acres	80 acres
Average Well Cost	$275,000	$330,000	$375,000	$75,000
Average Well Reserves	10 Bcf	1.8 Bcf	1.5 Bcf	0.4 Bcf
Average Well Gas Production Rate	800 Mscf/day	300 Mscf/day	625 Mscf/day	180 Mscf/day
Bbl, Barrel (42 gallons), bsl – below surface level				

Sources: PTTC Rockies 2000, GTI 2000, EPA 2002, USGS 2000, CO, NM, WY, MT Oil and Gas Commissions, Williams 2001,

The San Juan Basin

The San Juan Basin covers an area of about 7,500 square miles located near the Four Corners region of Colorado, New Mexico, Arizona and Utah (Figure 16). The basin measures roughly 100 miles in length in the north-south direction and 90 miles in width.

The foremost coal-bearing unit in the basin is known as the Fruitland formation. CBM production occurs predominantly in coals of the Fruitland Formation, however, some CBM is held in the underlying and adjacent Pictured Cliffs sandstone, and numerous wells are completed in both zones. Individual coalbeds of the Fruitland Formation average from 20 to over 40 feet thick. The total net thickness of the coal beds ranges from 20 to over 80 feet across the basin.

The waters in parts of the Fruitland Formation usually contains less than 10,000 mg/L TDS. In the northern half of the formation, most water contains less than 3,000 mg/L, and wells near the outcrop produce water that contains less than 500 mg/L.

Typical CBM wells in the San Juan Basin range from 550 to 4,000 feet in depth, and about 2,550 such wells are currently operating (COGCC and NM OCD, 2001). The San Juan Basin is the most productive CBM basin in North America. CBM production in the basin averages about 800 Mscf per day per well (Stevens et al., 1996).

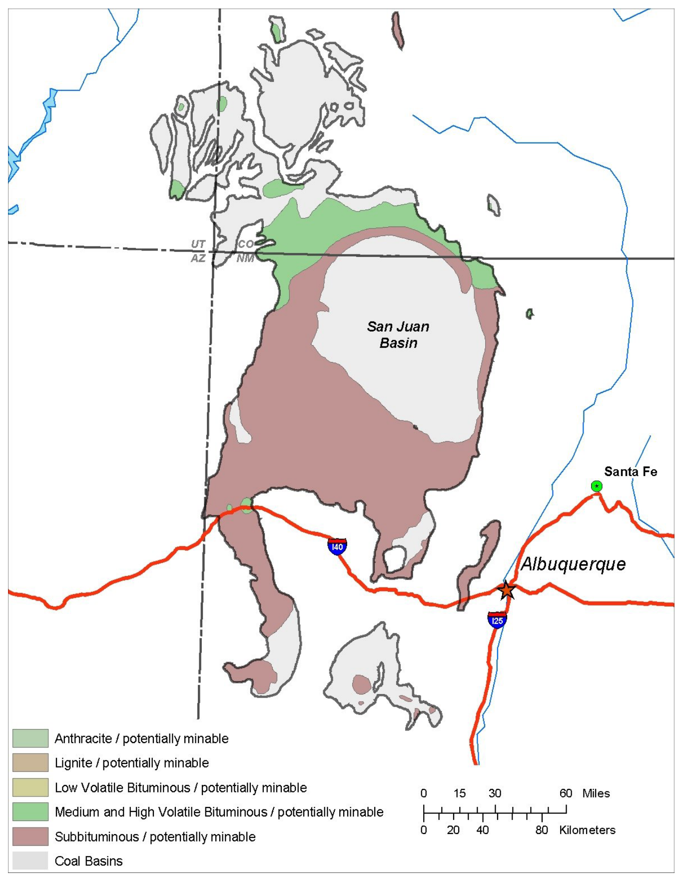


Figure 16
General location map and coal rank map of the San Juan Basin

Production began in the late 1980s and rapidly expanded through the 1990s but is no longer increasing. Companies are attempting to maintain production by focusing on enlarging gathering facilities, upgrading production equipment, installing pumping units and wellhead compression, recavitating producing wells, experimenting with secondary recovery efforts, and downspacing from 320-acre units to 160 acre spacing.

In 2000, the San Juan Basin produced 0.78 Tcf of gas, representing 4% of total U.S. natural gas production and 80% of the nation's CBM production. The BLM's recently completed EIS predicts that 12,500 new oil, gas, and CBM wells will be drilled in the San Juan Basin over the next 20 years. Infill drilling—drilling wells on reduced spacing requirements, at every 160 acres rather than 320 acres—has already begun.

The Powder River Basin

The Powder River Basin is located in northeastern Wyoming and southeastern Montana (Figure 17). The basin covers an area of approximately 25,800 square miles, of which approximately 75% is in Wyoming. Fifty percent of the Powder River basin is believed to have the potential for CBM production.

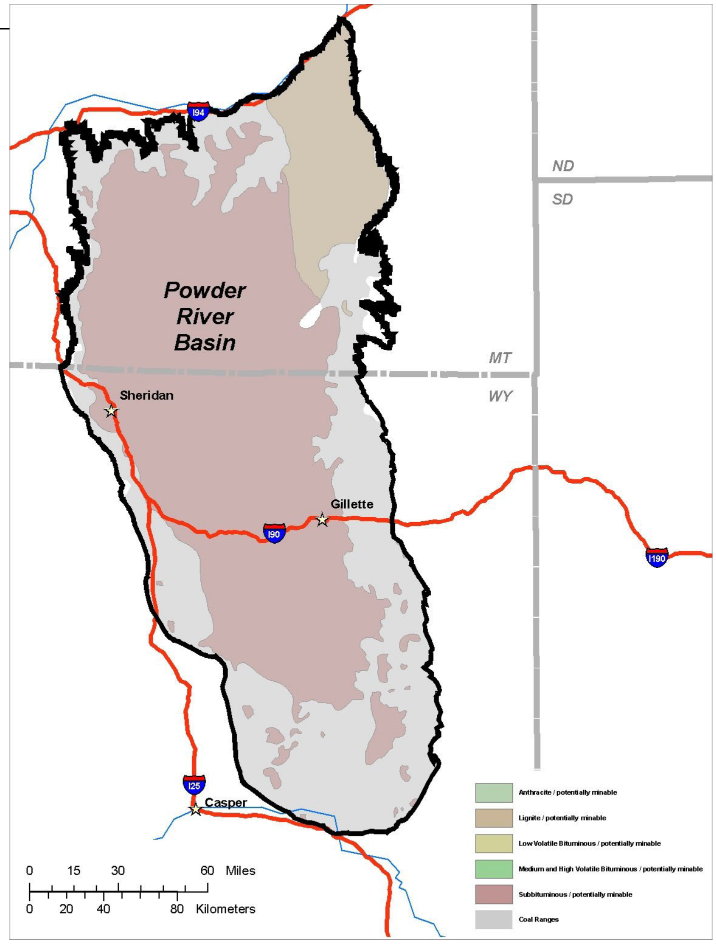


Figure 17
General location map and coal rank map of the Powder River Basin

Coal beds in this region intermingle at varying depths with sandstones and shale. The majority of the productive coal zones range from 150 feet to 1,850 feet below ground (Randall, 1991). The uppermost formation is the Wasatch Formation, extending from land surface to 1,000 feet deep. Most of the coal seams in the Wasatch Formation are continuous, but thin (six feet or less). The Fort Union Formation lies directly below the Wasatch Formation and can be as thick as 3,000 feet. The coal beds in Fort Union formation are usually more plentiful in the upper portion, named the Tongue River member. This member is normally 1,500 to 1,800 feet thick, of which a net total of 350 feet of coal can be found in various seams. The thickest of the individual coal seams is over 150 feet thick. CBM production is primarily from the Fort Union rather than the overlying Wasatch.

The Fort Union Formation supplies municipal water to the city of Gillette, WY and is the same formation that contains the coals that are developed for CBM. The coal beds contain and transmit more water than the sandstones. The sandstones and coal beds are both used for the production of water and the production of CBM. Total Dissolved Solids (TDS) levels in the water produced from these coal beds meet the water quality criteria for drinking water.

The Powder River Basin is the fastest growing CBM area in the United States. The huge coal deposits contain enormous amounts of methane gas due to their unusual thickness as evident in the amount of coal produced from this region. The low gas content per ton and low pressure were initially seen as barriers to development. The first wells drilled and completed produced massive volumes of water but little gas. As companies altered their drilling to more shallow wells, production increased. The low drilling costs, the short completion time and the relatively good quality of water coupled with inexpensive water management i.e. surface discharge encouraged development.

The BLM in Montana and Wyoming issued their Final EISs for the Powder River Basin in January 2003, and they anticipate combined activity of upwards of

60,000 new wells and accompanying roads, pipelines, and electrical utilities, and compressors in the basin. Currently, there are approximately 14,000 producing wells in the Powder River Basin, mainly in the Wyoming portion.

The Raton Basin

The Raton Basin is the southern most Laramide basin in the Rockies and covers about 2,200 square miles along the Colorado-New Mexico border (Figure 18). The basin extends 80 miles north to south and as much as 50 miles east to west (Stevens et al., 1992). It is an elongate asymmetric syncline, 20,000 to 25,000 feet thick in the deepest part.

Coal beds occur in the Upper Cretaceous Vermejo and Paleocene Raton formations at depths from outcrop to more than 4,000 ft. Vermejo coal beds are lenticular and fairly continuous, with net coal thickness of 10 to 40 ft. Raton coals generally are thinner and less continuous. Most of the coal in the basin is high-volatile bituminous in rank. Measured gas contents range from less than 50 scf/ton to more than 400 scf/ton.

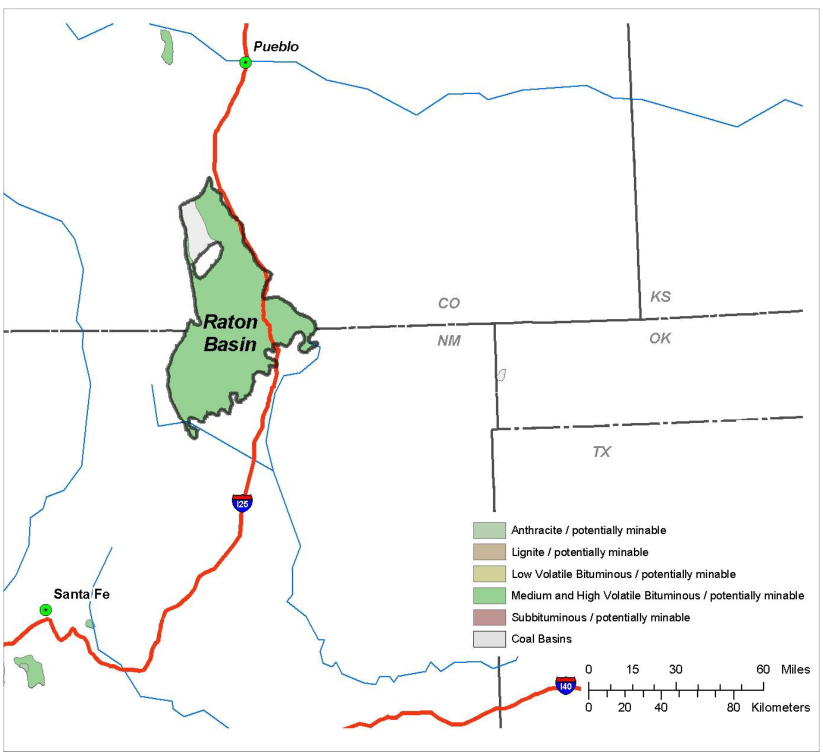


Figure 18
General location map and coal rank map of the Raton Basin

The coal seams of the Vermejo and Raton formations developed for methane production also contain water that meets the federal water quality criteria for drinking water. The underlying Trinidad Sandstone and other sandstone beds within the Vermejo and Raton formations, as well as intrusive dikes and sills, also contain water of sufficient quality to meet the drinking water quality criteria.

Methane resources for the basin have been estimated at approximately 10.2 Tcf contained in the Vermejo and Raton formations (Stevens et al., 1992). It was reported recently that the average CBM production rate of wells in the Raton Basin was close to 300 Mcf per day, and annual production in 2000 was 30.8 Bcf (GTI, 2002).

The Unita Basin

The majority of the Uinta Basin is contained within Utah, with a small segment of the basin lying in northwestern Colorado (Figure 19). The basin covers approximately 14,450 square miles (Quarterly Review, August 1993). Stratigraphically the Uinta Basin is adjacent to the Piceance Basin of Colorado, but is structurally separated from it by the Douglas Creek Arch, an uplift near the state line. It is bordered on the West by the San Rafael Swell and Uncompahgre Uplift and on the north by the Uinta Mountains.

Significant down-warping of the basin occurred during the Late Creatceous and Eocene (Laramide) timeframe. Coal beds in the Uinta Basin occur in the Mesaverde Group, however the majority of development activity targets the high-volatile bituminous coals in the Ferron Sandstone member of the Mancos Shale. A 80-mile-long, 12-mile-wide, "Corridor" paralleling the thickest development (10 to 40 ft) of Ferron coal seams has been identified by the Utah Geological Survey. (UGS 1997)

Sandstone is interbedded with the Ferron coals and forms a segment of clastic sediment 150 to 750 feet thick. The Ferron Sandstone coals range in depth from 1,000 to over 7,000 feet below surface level (Garrison et al., 1997). The Blackhawk Formation comprises coal seams interbedded with sandstone in combination with shale and siltstone. Wells drilled in the Blackhawk

Formation coals are finished at 4,200 to 4,400 feet below the surface (Gloyn and Sommer, 1993).

The Blackhawk Formation and the Ferron coals of the Uinta Basin have water that meets the National Primary Drinking Water (NPDW) criteria. Groundwater from the Blackhawk Formation taken at the Castlegate Field contains a TDS level below the federal drinking water standard of 10,000 mg/L. Castlegate Field coal beds have published TDS levels of 5,000 mg/L in production waters indicating that the methane gas wells in this portion of the basin are located in an aquifer that meets the NPDW standard (EPA 2002b).

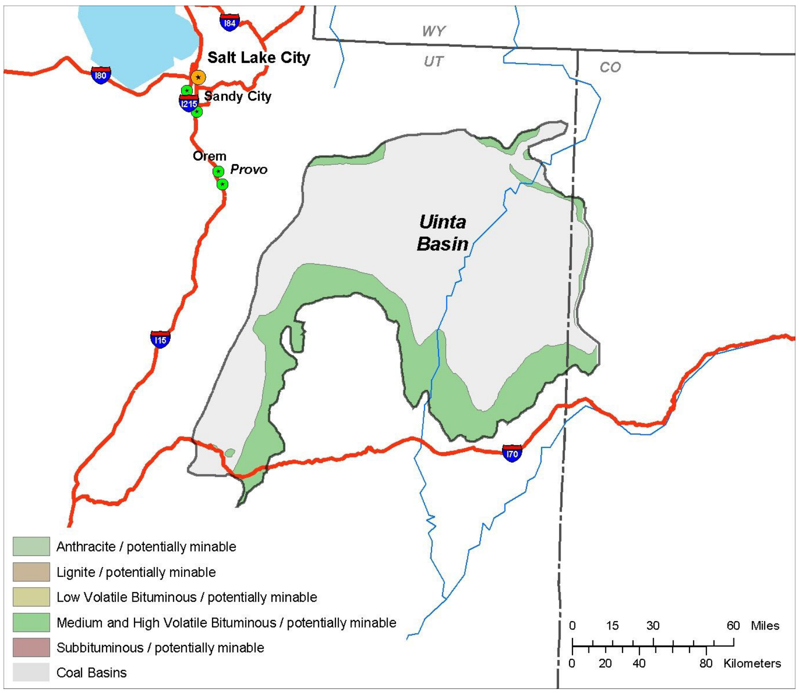


Figure 19
General location map and coal rank map of the Uinta Basin

Full scale exploration within the Uinta Basin began in the 1990s (Quarterly Review, 1993). The CBM potential of the Uinta Basin was estimated by the Utah Geological Survey in the early 1990s to be between 8 Tcf and 10 Tcf (Gloyn and Sommer, 1993). Total production was 75.7 Bcf in 2000 (GTI, 2002). The Ferron coals at the north end of the corridor, primarily in River Gas Utah's Drunkards Wash Unit, have produced more than 200 Bcf of methane with daily production of 260 MMcfd from 470 wells (EPA 2002b).

OTHER BASINS

The other major basins in the Rocky Mountain region which have tremendous potential to produce vast amounts of CBM are the Denver, Greater Green River, and Piceance basins. These basins are currently being investigated by numerous development companies and it is anticipated that several federal EISs will be conducted in the next few years (DOI 2003).

The majority of the Denver Basin lies in the east central region of Colorado and contains an estimated 2 Tcf of CBM (Figure 15). Development has been delayed by a deficiency in the data regarding the extent of the CBM resource and the disposition of the gas reservoirs. The two main coal formations are enclosed by four Denver basin aquifers, presenting concerns about the degree to which the aquifers and coals are linked hydraulically and to what extent CBM development would have on the groundwater resources (Wray & Koening, 2001).

CBM resources in the Greater Green River Basin of Colorado and Wyoming have been estimated at upwards of 314 Tcf (GTI 2001). A sizable portion of CBM resource is located at depths less than 6,000 feet. (Kaiser et al., 1995). Some exploration and limited development of CBM occurred in the late 1980s and early 1990s. Colorado Oil and Gas Commission records indicate that approximately 31 Bcf of CBM was produced in Moffat County during 1995 (COGCC web site, 2001). There appears to be no commercial production at present. Development of CBM in the basin has lagged due to the current limited economic viability. The degree to which the lowering of the hydrostatic pressure is required in most wells has been the chief restraining factor, compounded by the depth of the coal zone and the relatively low CBM recovery potential. Recently, permits for new gas wells have been issued indicating that there may be some continued interest in this area (COGCC, web site 2001).

The Piceance Basin is located within the state of Colorado in the northwest corner of the state (Figure 15). The depth to the CBM bearing coal zone (Cameo-Wheeler-Fairfield) is about 6,000 feet. Two-thirds of the CBM occurs in coals deeper than 5,000 feet making the Piceance Basin one of the deepest CBM areas in the U.S. (Quarterly Review, August 1993). Due to the depth of the coals the permeability is reduced, thereby increasing the difficulty of extraction. This has hindered CBM development in the basin. However, the Cameo-Wheeler-Fairfield coal zone in the basin is estimated to contain between 80 and 136 Tcf of CBM (Tyler et al., 1998). Total CBM production was 1.2 Bcf in 2000 (GTI, 2002).

Basins of interest outside the Rockies (Figure 20) include Black Warrior Basin in Alabama; the Central Appalachian Coal Basin located across parts of Kentucky, Tennessee, Virginia, and West Virginia; the Northern Appalachian Coal Basin in Pennsylvania, West Virginia, Ohio, Kentucky, and Maryland; the Western Interior Coal Region which encompasses the areas of six states Arkansas, Oklahoma, Kansas, Missouri, Nebraska, and Iowa; and coal basins in Alaska.

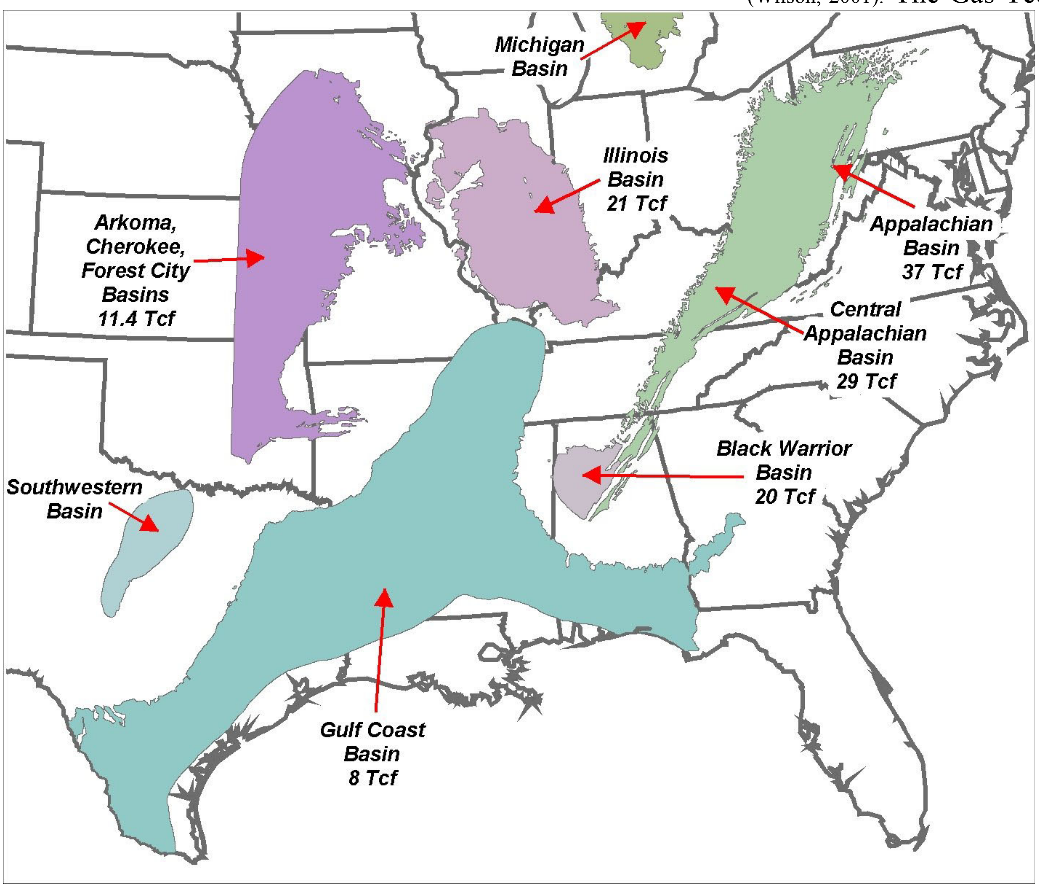


Figure 20
General location map of eastern coal basins
Source: Nelson 2000

Of these the Black Warrior Basin has been the most productive. To date there has been nearly 4,000 wells permitted in Alabama (GTI, 2002). These wells produce an average of about 300 Mcf per day per well (Hewitt, 1984; McFall et al., 1986; Schraufnagel, 1993). It has been estimated that the Black Warrior Basin produces roughly 100 Bcf of gas annually, which is about 20 percent of Alabama's gas production from all methods (Pashin and Hinkle 1997).

The Central Appalachian basin has seen recent development in the Nora Field in southwestern Virginia. The Nora Field had over 250 CBM wells drilled in 2000. Approximately 2,500 new CBM wells were drilled last year within Buchanan County, southwestern Virginia (Wilson, 2001). The State of Virginia reportedly produced 72 Bcf of CBM in 2000 (Wilson, 2001). The Gas Technology Institute reports that basin-wide CBM production stood at 52.9 Bcf in 2000 (GTI, 2002).

CBM has been produced in commercial quantities from the Pittsburgh coal bed of the Northern Appalachian Coal Basin since 1932 (Lyons, 1997). As of 1993 at least 20 wells have been in continuous production in southern Indiana County, Pennsylvania (Quarterly Review, 1993). CBM production development in the Northern Appalachian Basin has lagged, however, due to insufficient reservoir knowledge, inadequate well completion techniques, and CBM ownership issues revolving around whether the gas is owned by the mineral owner or the oil and gas owner (Zebrowitz et al., 1991). This issue is discussed in detail in the Regulatory Framework section. Discharge of produced waters has also proven to be problematic (Lyons, 1997) for current and would-be CBM field operators in the Northern Appalachian Coal Basin. Total CBM production stood at 1.41 Bcf in 2000 (GTI, 2002).

The Western Interior Coal Region comprises three coal basins that include the Arkoma, the Cherokee, and the Forest City basins. As of March 2000, there were 377 CBM wells in the Arkoma Basin of Eastern Oklahoma, ranging in depth from 589 to 3,726 feet (Oklahoma Geological Survey website, 2002). The Arkoma basin contains an estimated 1.58 to 3.55 Tcf of gas reserves contained primarily in the Hartshorne coals (Quarterly Review, 1993). In the Cherokee Basin, unknown amounts of CBM gas have been produced as conventional natural gas for over 50 years (Quarterly Review, 1993). Targeted CBM production increased in the late 1980s, and at least 232 CBM wells had been completed as of January 1993 (Quarterly Review, 1993). The Cherokee Basin contains an estimated 1.38 MMcf of gas per square mile basin-wide (Stoeckinger and Brady, 1989) in the targeted Mulky, Weir-Pittsburg, and Riverton coal seams of the Cherokee Group (Quarterly Review, 1993). Nearly 10 Tcf of gas is located in eastern Kansas alone (PTTC, 1999). The Forest City Basin was relatively unexplored in 1993, with about ten coal bed wells concentrated in Atchison, Jefferson, Miami, Leavenworth, and Franklin Counties, Kansas (Quarterly Review, 1993). The Forest City Basin contains an estimated 1.0 TCF of in-place gas (Nelson, 1999). For the entire region, CBM production was 6.5 Bcf in 2000 (GTI, 2002).

Additionally, Alaska has nearly as much coal as the entire continental U.S. Investigations have indicated that coals in Northern Alaska's Bristol Bay Basin, the Colville Basin, and the Yukon Basin of the Alaskan Peninsula have the highest CBM production potential (PTTC 2000).

The Future Role of CBM in the U.S. Energy Policy

Natural gas currently provides 24 percent of the energy needs of the U.S. and CBM comprises 8 percent of the natural gas domestically extracted (EIA 2001). The United States produces the majority (85%) of the gas it consumes and imports the remainder from Canada. The average U.S. family uses about 45,000 cubic feet of natural gas per year consuming 4.4 Tcf of natural gas to meet the nation's residential needs annually (NEP 2001).

By the year 2020, the Energy Information Administration projects the United States will need nearly 50 percent more natural gas to meet demand. While the resource base that supplies today's natural gas is immense, conventional production in the U.S. is expected to reach a peak in 2015, see Figure 21. The demand for natural gas will almost certainly continue to increase, widening the gap with domestic production. Consequently, the U.S. will progressively rely on imports of natural gas from Canada, and imports of liquified natural gas from producers across the globe (NEP 2001). Additionally, the nation will look for natural gas from unconventional resources, such as CBM.

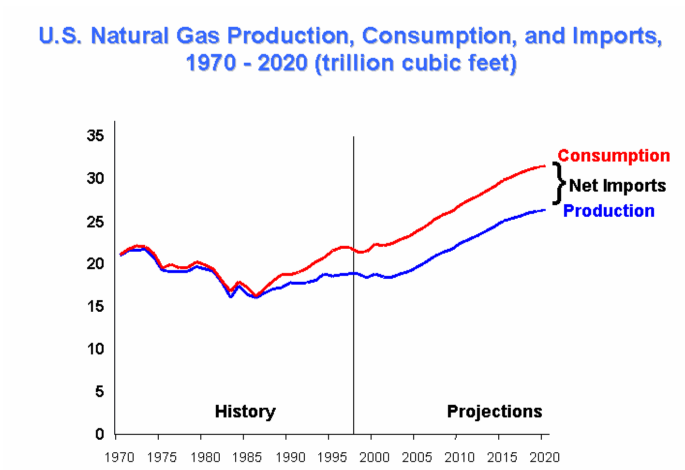


Figure 21
Natural Gas Production, Consumption, and Imports
Source: Mariner-Volpe, 2000

Many CBM basins are found in environmentally sensitive areas that increasingly require the use of less intrusive technologies. New technologies are being engineered to decrease both the environmental effects and the economic costs of CBM exploration and development. These new technologies like horizontal drilling and enhanced recovery through CO_2 or N_2 injection technology permit greater exactness and significantly reduce surface disturbing activities.

Natural gas, including CBM has been assigned a major role in the current administration's energy policy. The Bush administration's National Energy Policy emphasizes escalating domestic sources of fossil fuels, in fact 35 specific recommendations were made that address increasing supplies of fossil fuels. The recommendations include opening new lands or redefining federal lands for increased exploration, streamlining the permitting process, reducing the regulatory burden, and expanding the nation's energy related infrastructure. The energy challenge presented can be summarized as follows: Even if the U.S. can improve energy efficiency there will still be a need for more energy supplies. The future projected shortfall between supply and demand can be made up in only a few ways: improve energy efficiency, import more energy; increase domestic energy supply or utilize a combination of these methods (PTTC 2000).

Economically, the most important long-term challenge relating to natural gas is the ability to maintain the price in the face of ever increasing demand tied to limited supplies (DOE 2002). If supplies cannot be maintained, elevated natural gas prices such as experienced in 2000 could become a common problem. Elevated natural gas prices could have an impact on electricity prices, home heating bills, and the cost of industrial production. To meet this long-term challenge, the U.S. natural gas industry needs to increase production and invest in the natural gas pipeline network and infrastructure (NEP 2001).

It is evident in the National Energy Plan that the Bush administration recognizes that short-term increases in natural gas production will come from non-traditional sources in the Rocky Mountain Region such as CBM. The increased reliance on Rocky Mountain CBM production coupled with the national energy policy recommendations to open more federal land to exploration, expedite permitting and reduce regulatory hurdles can only mean that the Rocky Mountain States will be at the center of the national energy policy debates. These changes and their associated implications could result in energy development clashes with other closely held western values such as, preservation of wild lands, protection of ecoystems and wildlife habitat, recreational and aesthetic interests, and traditional lifestyles. Conflicts will be unavoidable as people across the Rocky Mountains have intensely opposed opinions about what should be done on public lands.

Weathered landscape with exposed Fort Union Formation, Powder River Basin, Montana

REGULATORY FRAMEWORK

Federal, State and Local Regulations Governing CBM Development across the West

Numerous regulations designed to control conventional natural gas development can and do apply to CBM exploration and production. However, due to the differences in produced water volumes and quality, well spacing, and utility infrastructure, specific CBM regulations have been drafted by federal, state and local agencies to meet various concerns. This section provides an overview of the current regulations and discusses some case histories regarding CBM development.

FEDERAL REGULATIONS

CBM ownership has been a point of contention since the early 1900s; questions regarding its status as part of the coal estate or as part of the natural gas resource is still under debate in some Eastern states. However, CBM originating in federally held coal deposits may be explored for and extracted under either a fee or Federal oil and gas lease, depending on the non-coal minerals ownership. This determination was made by the Department of the Interior's (DOI) solicitor, after examining the relevant Federal statutes. The determination states that U.S. reservations of coal do not include the CBM. However, Federal reservations of gas do include the CBM found in coal deposits. The CBM is therefore disposable as a gas under Section 17 of the Mineral Leasing Act (DOI 1981). As a result where the coal and oil and gas are federally owned, Federal oil and gas lease regulations cover the CBM. CBM operations and production under a Federal lease are subject to the regulations governing conventional oil and gas drilling and production operations (Cohen et. al. 1984).

The Mineral Leasing Act (MLA) of 1920 was determined in 1981 by the DOI solicitor to refer only to gas or natural gas, without excluding CBM (DOI 1981). Additionally, the standard Federal oil and gas lease allows the lessee to drill for, extract, and dispose of any oil and gas, except helium. Therefore, since 1981 CBM gas has been developed under the oil and gas leasing provisions of the Mineral Leasing Act.

The DOI Solicitor also concluded that the coal leasing requirements of the MLA do not grant the coal lessee the right to extract minerals associated with coal (Kemp and Peterson 1988). The Solicitor clarified that the requirements do not authorize a coal lessee to extract CBM, other than the venting of gas required to maintain a safe working atmosphere. It was also pointed out in the determination that the oil and gas lease holder does not have the right to extract the CBM utilizing a method that would harm the coal deposit or generate hazardous conditions for later coal mining operations. In conclusion, the Solicitor affirmed that the rights of an oil and gas lessee would be restricted to the rights not previously granted to the coal lessee (Kemp and Peterson 1988).

Since this determination was made the MLA has provided the framework for authorization and management of CBM operations on federal lands. The MLA serves as the umbrella regulation for all Federal agency policies regarding fluid minerals development. BLM and U.S. Forest Service managed lands and other lands owned by the U.S. are available for CBM production under the MLA. BLM manages the majority of the federal mineral estate and is the primary agency responsible for developing and implementing land management plans. BLM's management of federal lands is also governed by the Federal Land Policy and Management Act (FLPMA). The National Environmental Policy Act (NEPA) addresses the procedures required to evaluate impacts on federal lands. Activity in national forests follows the National Forest Management Act (NFMA), which guides development operations. However, before drilling can take place on fee or federal lands numerous documents must be drafted and decisions made, including revisions to land use plans, leasing determinations, Environmental Assessments or Impact Statements, Surface Owner Agreements, Plans of Development (POD), and Applications for Permit to Drill (APD). Several of these steps require public involvement and have provisions for public feedback.

Land Use Plans

The BLM and Forest Service maintain Land Use Management plans for all property under their jurisdiction. These plans known as Resource Management Plans (RMPs) or Land and Resource Management Plans (LRMPs), respectively, are the principal documents used to govern the development of mineral extraction on federal lands including CBM. BLM RMPs are developed following the requirements of section 202 of FLPMA. Forest Service LRMPs are drafted in accordance with NFMA. Land Use Plans typically include discussions of expected land uses, such as livestock grazing, wilderness study areas, and mineral extraction. Opening areas to activities addressed in the plans usually requires conducting an Environmental Assessment (EA) or Environmental Impact Statement (EIS) following the requirements of the National Environmental Policy Act (NEPA). Figure 22 shows the BLM RMP areas for the Rocky Mountain States, each area has a land use plan which addresses the specific development actions within their boundaries. The figure also shows shadows of the coal basins.

In a formal EIS process, the lead agency must state the "reasonably foreseeable development" (RFD) scenario that is anticipated from allowing lands to be developed. The EIS addresses impacts to the land based on the agency's prediction as to where and how development will occur.

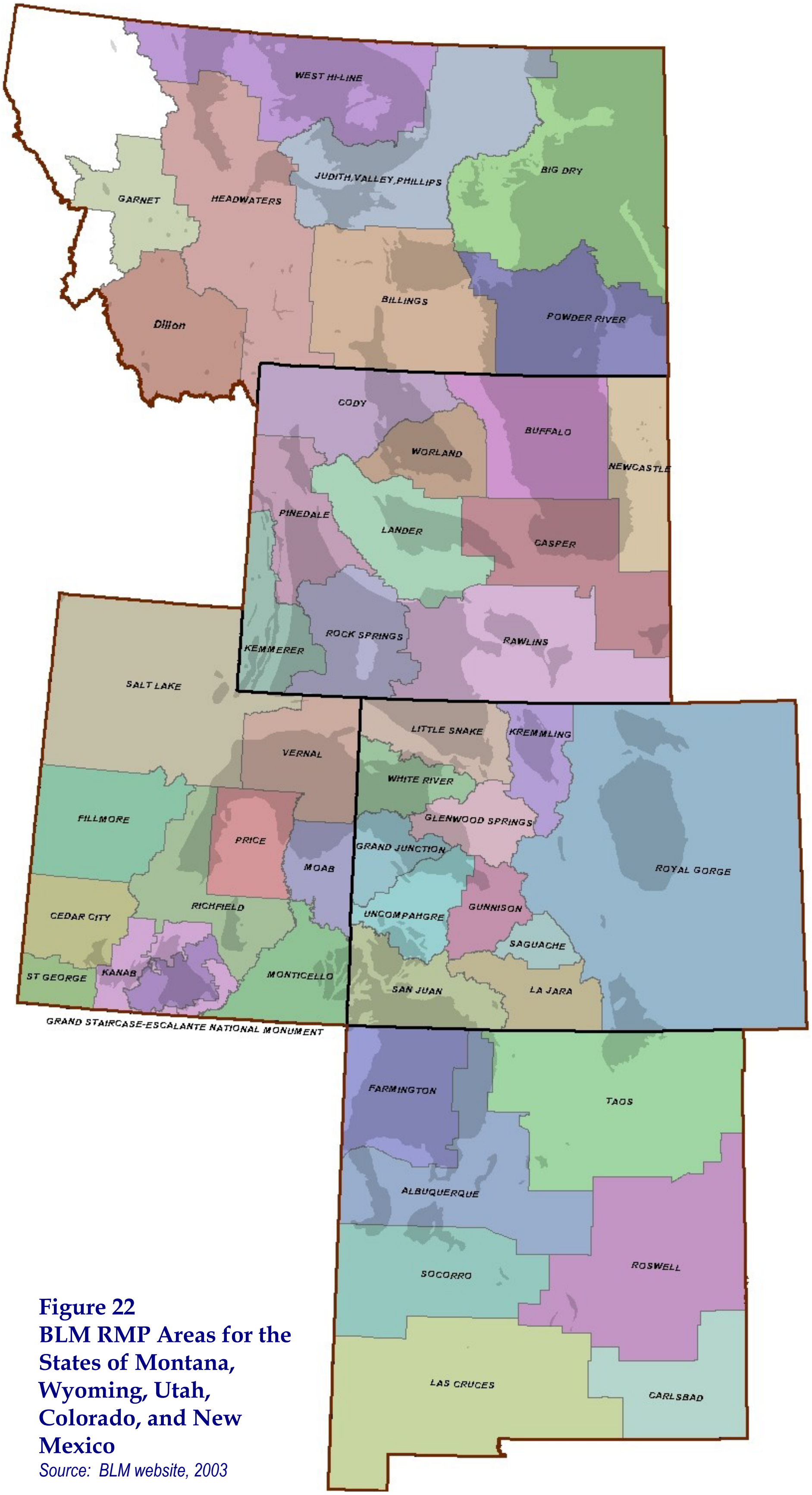


Figure 22
BLM RMP Areas for the States of Montana, Wyoming, Utah, Colorado, and New Mexico
Source: BLM website, 2003

Typically, agencies provide alternatives, which can be compared with one another to assess the impact potential of various approaches. CBM development has been very rapid in the Rocky Mountain region and most existing RMPs/LRMPs did not foresee or address the impacts from this level of CBM development. Recent EISs have been completed for the Southern Ute Tribe in the San Juan Basin and for the States of Montana and Wyoming. Additionally, several CBM related EISs and/or RMP/LRMP updates are planned for USFS and BLM areas throughout the Rockies in the coming year.

NEPA and the EIS Process

The National Environmental Policy Act of 1969 requires all federal agencies to conduct an EA or EIS when proposed actions may have an impact on man's environment. EIS' have recently been conducted for actions such as CBM development throughout a RMP area or when lands are opened to previously unconsidered oil and gas leasing activities. EAs are conducted for new development scenarios proposed within areas covered by an EIS, unless the proposed action was not adequately addressed in the original EIS or land use plan. NEPA affects leasing decisions, although it is often contested whether an EIS or an environmental assessment is appropriate. Federal courts have issued contradictory rulings on the issue.

Photograph of typical CBM well head in Wyoming with pronghorn antilope (*Antilocapra Americana)*

The EIS process considers the proposed action whether it is leasing or development, and attempts to quantify the impacts under various alternatives for several natural resources. A typical EIS may address impacts to the following: air quality, cultural resources, environmental justice issues, geology and minerals, hydrology (surface- and ground-water), Indian Trust assets, lands and realty, livestock grazing, noise, paleontological resources, recreational opportunities, social and economic values, soils, vegetation, visual quality, wilderness study areas, and wildlife. Mitigation is then applied via standard lease stipulations or other measures such as agency guidelines or by imposing new mitigation measures to the alternative approaches. It is important to note that the EIS process is not designed to eliminate all impacts from the proposed action but to quantify the residual impacts so a balanced decision can be made with regards to the proposed action.

Following the impact analysis a comparison of the alternatives is conducted using residual impacts (impacts after mitigation). By comparing residual impacts from various different alternatives, decision makers can assess the various components of each alternative and either choose one or develop a different approach based on portions of the analyzed alternatives. When a decision is made it is drafted in a document referred to as the Record of Decision (ROD), which is used to update the RMP/LRMP with the addressed changes (CEQ 2002).

During the EIS process the public is provided several opportunities to state their concerns and help design the scope of the impact analysis. Usually, the lead federal agency will hold public scoping meetings throughout the area that will be affected by the proposed action. The public scoping meetings are the first opportunity for citizens to express their concerns with the proposed action and to request impact analysis for various resources. This is also the appropriate time for citizens and special interest groups to provide the lead federal agency with data and special reports to be included in the impact analysis. The purpose of these meetings is to gather information regarding issues the public is particularly concerned with, and to exchange information with the public for project clarification. After all the scoping meetings are held the public scoping comments are entered into a database where they can be grouped by topic and analyzed. A scoping report detailing the public concerns is typically issued and the impact analysis is designed to encompass all the applicable concerns.

It is possible for some concerns to be outside the scope of the intended EIS and therefore not considered in the analysis. For example, if the proposed action addresses a resource development scenario i.e. gas, and the public comment requests that a particular area be excluded from leasing, this may not be possible to analyze under the current development EIS. Typically, a leasing EIS is conducted prior to determining which lands will be developed for which resources or multiple resources. If a leasing EIS has been conducted and a particular area was designed for gas development it would not be appropriate to revisit that determination when a gas development action is proposed.

The next opportunity the public has to comment is typically at the Draft EIS stage, unless supporting technical reports have been conducted. Supporting technical reports are issued in draft form and the public is provided an opportunity to review the findings and submit comments. Regarding the Draft EIS, there is a 90-day public review period built in for EIS' which will result in a management plan amendment. Anyone who requests a copy of the Draft EIS is provided one, and has until the deadline to submit comments. These comments are grouped by topic, and similar comments are paraphrased into a public concern statement (PCS). A PCS can cause various actions to be taken, the most common of which is a reanalysis of a portion of the EIS; a clarification added to a specific section; an explanation regarding where information can be found or why the PCS is not relevant to the analysis. In either case, all PCSs are specifically addressed in the Final EIS and all citizens who submitted comments are typically listed.

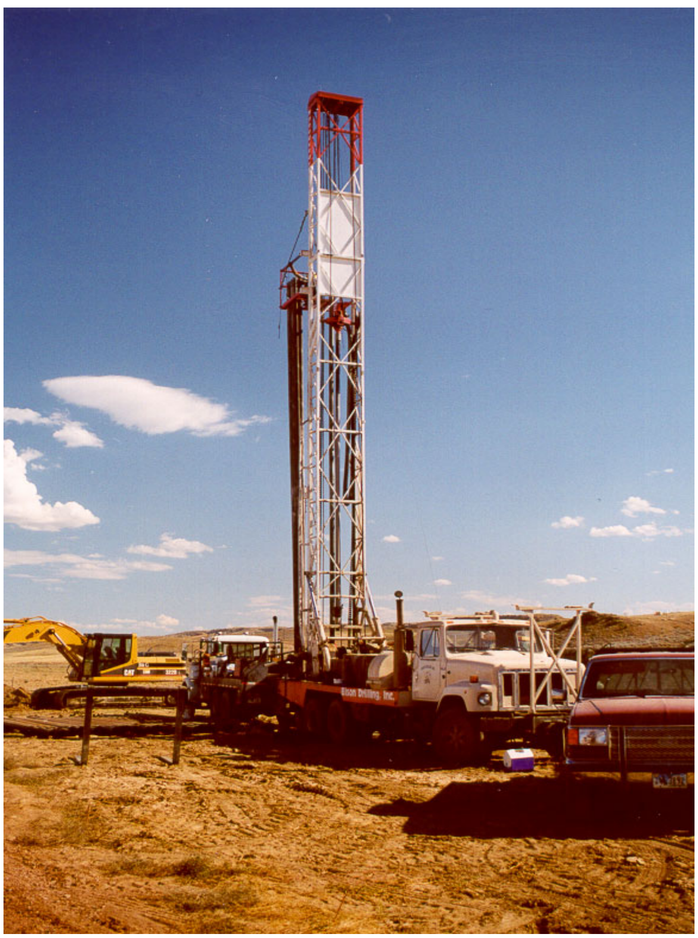
Once the Draft EIS has been modified based on public feedback a Final EIS is issued. A 30-day protest period is generally incorporated into this process to allow the public a final opportunity to express their concerns with the proposed action. Following the protest period a ROD is issued, effectively changing the land use plan and adopting the preferred alternative or a combination of actions derived from the various alternatives.

Photograph of CBM well cluster CX Ranch Montana

Leasing

Leases issued on federal land are competitively bid in accordance with the Federal Onshore Oil and Gas Leasing Reform Act (FOOGLRA) of 1987. Federal environmental laws are generally incorporated into standard lease terms. However, lease terms may be augmented with additional mitigation measures to minimize specific foreseen impacts (FOOGLRA 1987). These added mitigation measures can include special or supplemental stipulations suggested by State or local governments. Standard lease terms provide the lessee the right to access the leased land to explore, drill, and extract oil and gas resources beneath the surface.

Leasing decisions can be disputed in court and are often challenged by special interest groups. If the lead federal agency fails to conduct adequate environmental analysis before issuing leases a court decision could bring a halt to the proposed development. In fact, this very scenario was recently played out in the spring of 2002 in Wyoming. The Wyoming Outdoor and Powder River Basin Resource Councils challenged three BLM issued CBM leases as being based on inadequate environmental data (IBLA 2002). The Interior Board of Land Appeals (IBLA) found that the two BLM reports that the agency based their leasing decisions on were not sufficient to provide the necessary pre-leasing NEPA analysis (IBLA 2002). The decision effectively stopped existing leasing,



Typical truck mounted drill rig used for shallow CBM wells

and questioned whether the analysis process the BLM follows is adequate for the thousands of anticipated new leases. Consequently, the Wyoming BLM could not depend on those documents to fulfill its commitments under NEPA. The Wyoming BLM issued a new CBM Final EIS in February 2003 to clarify the issues.

Development

Before a gas developer can drill an exploration well or develop a field an Application for Permit to Drill (APD) must be submitted along with a Plan of Development (POD). Exploration and development of CBM resources on BLM minerals are allowed subject to agency decisions, lease stipulations, permit requirements, and surface owner agreements. In the newly issued Montana and Wyoming RODs operators are required to submit a POD outlining the proposed development of an area (BLM 2003a./b.). PODs are required when the development spacing proposed is tighter than 1 well per 640 acres. The PODs are to be developed in consultation with affected Tribes, affected surface owner(s), and other involved permitting agencies.

A step-by-step guideline for preparation of the POD was recently issued by the Buffalo, WY and Miles City, MT BLM offices, respectively (Breisch 2003). PODs are required to be submitted in draft form so that they can be reviewed and any changes made prior to allowing surface disturbing activities. Key components to a PODs include:

- An APD (form 3160-3) for each federal well in the project area
- An application for permit form for all state and private wells
- A list of all other permitting agencies involved in the project and the point-of-contact for each office
- A list of all existing wells in the project area, including monitoring wells
- Maps showing proposed roads, compressor stations, pipelines, powerlines, CBM well locations, all existing wells, current and proposed monitoring wells, surface ownership, mineral ownership, surface features, and existing structures
- Master drilling and surface use information as required by Onshore Order No. 1 (for BLM lands)

- A Reclamation Plan for surface disturbance
- A wildlife monitoring plan demonstrating how the project will meet the needs of the BLM Wildlife Monitoring and Protection Plan (WMPP) for BLM lands
- A Water Management Plan for the project area
- Surface owner agreements, including water well agreements (or notice that the Surface Owner Damage and Disruption Compensation Act applies and surface owner agreements are pending settlement or court action)
- A list of all potentially affected surface owners within the project area
- A cultural resource plan addressing identification of strategies commensurate with the level of the proposed development
- BLM also requires compliance with Onshore Oil and Gas Order Number 7 (Disposal of produced water)

Draft PODs are used by the lead federal agency to analyze the local cumulative effects of a proposed development project, and to evaluate ways to further reduce these effects such as requiring companies to consider alternative beneficial uses of production water in the case of CBM development (Laakso 2003). A team of interdisciplinary professionals comprised of land planners, environmental scientists, geologists, biologists, archaeologists, hydrologists, wildlife specialists, cultural specialists, engineers and others evaluate the PODs, perform on-site inspections, and conduct field monitoring (Bloom 2003). Onsite inspections conducted by the lead agencies personnel may activate alterations of the APD or conditions of approval. Prior to approving the APD, the lead agency will also verify that the required performance bond is in place.

Laws Governing Water

The Clean Water Act (CWA) of 1987, as amended, establishes objectives to restore and maintain the chemical, physical, and biological integrity of the Nation's Water. In accordance with the CWA, CBM extraction is controlled by water quality standards so that designated uses of water are protected. Standards include both numerical and narrative descriptions. Numerical standards are directed at controlling the daily pollutant discharges from point sources to ensure that total pollution levels are not exceeded. Numerical standards usually take the form of pollution limits or total maximum daily loads (TMDLs). Currently most Rocky Mountain States are still in the process of developing their TMDLs as per EPA Region VIII requirements (EPA 2001). Narrative standards are typically written to prevent the degradation of current water quality and protect established uses of the surface water (MDEQ 2002).

CBM developers must determine what they are going to do with their excess production water and at that point various other water laws apply. For example, if they decide to discharge produced water into the surface waters of the state they will have to obtain a National Pollution Discharge Elimination System (NPDES) permit from EPA. State Water Quality Standards and effluent volume limits will be applied to the NPDES permit, however at present there are no scientifically established effluent standards for CBM discharges. To ensure that State Water Quality Standards are not violated the permits will have effluent limitations attached.

Photograph of typical CBM wells co-located with injection well, Wyoming

In the Powder River Basin the BLM chose to draft two EISs because of the differences between Montana and Wyoming state law and various other reasons (BLM 2003 a./b.). In Wyoming, for example CBM produced water is not regulated by numeric standards, WDEQ simply requires that CBM produced water does not degrade designated uses of surface water. Montana, on the other hand, has numeric standards for some constituents in produced water and therefore Wyoming operators are required to comply with Montana regulations since they are downstream. The two states have negotiated an 18-month interim memorandum of cooperation (expires in early 2004) intended to protect the quality of the downstream watersheds (BLM 2001). Often irrigated agriculture is the most sensitive beneficial use for surface waters and therefore downstream water quality standards are based on vegetation changes.

The Clean Water Act requires applicants to obtain a certification stating that their activities will comply with the Clean Water Act. The certificate is issued from the state where the discharge originates. Requirements initiated by the state become part of the federal permit and are enforced by either the BLM or Forest Service. Additionally, operators must receive a 404 permit the Corps of Engineers anytime they dispose of or deposit fill into the waters of the U.S.

The Federal Water Pollution Control Act requires federal land managers to comply with all Federal, State, and Local requirements, administrative authorities, process, and sanctions regarding the control and abatement of water pollution in the same manner and to the same extent as any nongovernmental entity. The BLM requires all operators to obtain appropriate water handling, discharge and injection permits prior to submitting their Application for Permit to Drill (APD).

The Safe Drinking Water Act (SDWA) is designed to make the nation's waters "drinkable" as well as "swimmable". Amendments in 1996 established a direct connection between safe drinking water and watershed protection and management. The SDWA regulates the re-injection of produced water from CBM production. Underground injection is permitted under various well classes depending on the quality of the injectate and the zone where the fluid is injected: Part C of the SDWA attempts to protect underground sources of drinking water by requiring permits for all underground injection of liquids. There are five classes of injection wells under these regulations, the majority of CBM produced water is injected via Class II wells. Class II wells handle liquids that are produced as a by-product of oil and gas operations or are used in enhanced recovery.

The EPA conducted a study of the environmental risks to underground sources of drinking water (USDWs) when hydraulic fracturing is used to enhance CBM recovery. The study was prompted by complaints that CBM development has altered water quality in some drinking wells. The goal of EPA's nationwide hydraulic fracturing study was to determine if a threat exists to public health, as a result of aquifer contamination from the narrow practice of hydraulic fracturing, as it relates to CBM wells, and if so, is high enough to warrant further study (EPA 2002b). The process of hydraulic fracturing involves forcing fluids under pressure into subsurface cracks utilizing the wellbore tubulars, treated fluids and surface pumps to form pathways for the natural gas and water to reach the well.

EPA's final report published in October 2002 states that they reviewed claimed incidents of drinking water well contamination and found no confirmed cases, despite the thousands of fracturing events that have been conducted on CBM wells during the past decade. EPA also assessed the theoretical potential for hydraulic fracturing to contaminate drinking water wells. Two potential scenarios by which hydraulic fracturing may effect aquifer water quality were evaluated: (1) the injection of fracturing fluids directly into a aquifer, and (2) the creation of a hydraulic communication through a confining layer between the target coal bed formation and adjacent aquifer. EPA's determination is that the threat of contaminating drinking water supplies by CBM hydraulic fracturing activities is low. Studies have found no observed breach of confining layers from hydraulically-created fractures, consistent with theoretical understanding of fracturing behavior (EPA 2002b).

Laws Governing Air

The Clean Air Act (CAA) of 1990, as amended, requires Federal agencies to comply with all Federal, state, and local requirements regarding the control and abatement of air pollution. This includes abiding by requirements of the State Implementation Plans. Potential changes in ambient air quality from CBM activities, such as reduced visibility, air quality emissions, dust emissions, harmful gases, and changes in climate are evaluated in the BLM EISs.

Photograph of typical CBM field compressor station

Air pollution emissions are limited by local, state, tribal and federal air quality regulations, standards, and implementation plans established under the CAA. These rules are administered by the State via Environmental Quality Departments and the EPA. Air quality regulations require certain proposed new, or modified existing, air pollutant emission sources (including CBM compression facilities) to undergo a permitting review before their construction can begin. Therefore, the applicable air quality regulatory agencies have the primary authority and responsibility to review permit applications and to require emission permits, fees and control devices, prior to construction and/or operation.

In addition, the U.S. Congress (through the CAA Section 116) authorizes local, state, and tribal air quality regulatory agencies to establish air pollution control requirements more (but not less) stringent than federal requirements. Site-specific air quality analysis would be performed, and additional emission control measures, including a best available control technology (BACT) analysis and determination, may be required by the applicable air quality regulatory agencies to ensure protection of air quality resources. Also, under the Federal Land Policy and Management Act (FLPMA) and the CAA, BLM cannot authorize any activity that does not conform to all applicable local, state, tribal, and federal air quality laws, regulations, standards, and implementation plans.

The significance criteria for potential air quality changes include local, state, tribal, and federally enforced legal requirements to ensure that air pollutant concentrations remain within specific allowable levels. These requirements include the National and State Ambient Air Quality Standards, which set maximum limits for several air pollutants, and PSD increments, which limit the incremental increase of NO_2, SO_2, and PM_{10} concentrations above legally defined baseline levels. Where legal limits have not been established, the BLM uses the best available scientific information to identify thresholds of significant adverse impacts.

Endangered Species Act

As required by Section 7 of the Endangered Species Act (ESA) of 1973, the BLM and Forest Service must prepare and submit a Biological Assessment to the U.S. Fish and Wildlife Service (FWS). The biological assessment defines the potential impacts to threatened and endangered species as a result of management actions proposed in the RMP/EIS. Perceived impacts to threatened and endangered species are required to be mitigated or management actions altered to reduce impacts.

In addition to complying with the ESA and consulting with the FWS, lead agencies often develop Wildlife Monitoring and Protect Plans (WMPP) which outline the steps they will take to ensure threatened and endangered species as well as candidate species are protected (BLM 2003b). WMPP may also require operators to conduct periodic surveys for various plant and animal species and alter their operations if observations indicate increased impacts (BLM 2003b).

Photograph of endangered Ute ladies-tresses orchid, Spiranthes diluvialis (Photograph provided by BLM)

Antiquities Act

The Antiquities Act of 1906 protects cultural resources on Federal lands and authorizes the President to designate National Monuments on Federal Lands. The BLM EISs completed for CBM development in Montana and Wyoming have requirements for the POD to include provision for a cultural resource plan addressing identification strategies commensurate with the level of the proposed development (for BLM lands) (BLM 2003a./b.). Developers are required to use a qualified archeologist to conduct a study of their proposed CBM field and identify any cultural resources present. The survey finds are incorporated in the APD and reviewed prior to issuing permission to drill. The identification and protection of these important sites meets the requirements of the Antiquities Act.

National Historic Preservation Act

Lead federal agencies must complete the process for considering the effects of the development action on historic properties as required by Section 106 of the National Historic Preservation Act (NHPA). The area of potential effect has to be reviewed and all existing inventory data scrutinized, historic properties identified also need to be reviewed, and interested parties consulted. Consultation under Section 106 of the NHPA for CBM development is usually required with the State Historic Preservation Office (SHPO), the Advisory Council on Historic Preservation (ACHP), affected Tribes and other interested parties (Federal Register, 1983).

BLM has a National Programmatic Agreement in place with most Western state SHPOs and the ACHP. The agreement states that there would be no new disturbance of historic properties not previously considered, and outlines survey procedures to be followed for all new oil and gas developments.

Tribal Resources

The Indian Mineral Leasing Act of 1938 and the Indian Mineral Development Act of 1982 govern the development of CBM on tribal lands. A dual legal system of federal and tribal laws control energy development on tribal lands. The Bureau of Indian Affairs (BIA) is required under these acts to authorize energy leases. NEPA regulations also apply to any energy development decisions made for Tribe lands. Under certain federal laws such as the CWA and CAA, qualifying tribes can obtain states status and draft more stringent environmental laws. The Tribes are also responsible for enforcement and may regulate their lands in areas not covered by federal laws or programs (BOR 1994).

Rock art near Blackleaf Canyon, Montana

Indian lands can also be owned by individual Indians pursuant to Federal statute or treaty providing for the distribution of tribal property in severalty or pursuant to the General Allotment Act of 1887. An allotted parcel of land may be owned by the United States in trust for an individual Indian (trust allotment) or owned by the individual subject to certain restrictions. Allotted Indian lands may be leased for the development of oil and gas (25 CFR 214.2 – 212.6) and other minerals pursuant to the Indian Leasing Act of 1909 or the Indian Mineral Development Act of 1982.

American Indian Religious Freedom Act

The American Indian Religious Freedom Act (AIRFA) was passed as a joint resolution of Congress. The resolution states that it shall be the policy of the United States to protect and preserve for the American Indian the inherent right of freedom to believe, express and exercise their traditional religions, to use sacred objects and to worship through ceremonies and ritual. Federal agencies comply with this Act by consulting with and considering the views of American Indians when proposed land uses might conflict with traditional American Indian religious beliefs or practices. The Act does not require that land uses be denied, if it conflicts with such religious beliefs or practices.

Split Estates

Many federally administered minerals, including oil and gas rights, underlie privately owned surface. In addition, in many Western states, federally administered surface lands greatly exceed private and state lands. Furthermore, Western states, recognize separate ownership of surface and subsurface (or mineral) estates and the unique private property rights connected with each. Often, different parties own the surface and the subsurface. This is commonly referred to as “split estate” or "severed minerals". The ownership differences are commonly the result of the U.S. government reserving minerals when the lands were originally patented, or may be the outcome of a decision by a previous landowner to separately sell or lease the subsurface mineral interest. In the area of emphasis in the Western U.S., the federal government frequently withheld mineral interests on homestead land, which resulted in large areas of CBM plays in split estate.

A mineral estate provides property rights to selected natural resources lying on or below the earth's surface. A transfer of the mineral estate may be accomplished without transfer of the surface estate. For example, a landowner may sell or lease the rights to natural gas or oil found under the surface to an oil company. Later, the same landowner can sell the surface to a purchaser and reserve the rights to all coal that may be found under the land. After these transactions, three parties have ownership interests in this piece of real estate: (1) the oil company owns the oil and gas; (2) the seller owns the coal; and (3) the purchaser owns the surface.

An easement is a property interest that one party has in land owned by another, entitling the holder of the easement to use the other's land. Easements are typically in writing, usually in the form of a separate document or by a reservation in a deed. Thus, an easement is an interest in land rather than a mere contractual agreement. When easements are properly created and recorded they are transferred with a land sale and remain in effect.

A right-of-way is a type of easement conveying the right or privilege, acquired through accepted usage or by contract, to pass over, through or under a designated portion of the property of another. A right-of-way may be either private, as in an access easement given a neighbor, or public, as in the right of the public to use the highways. For example, a gas company might send its agents to meet with landowners and negotiate the purchase of rights-of-ways or easements for a pipeline. Under Federal law, the mineral estate is dominant (Straube and Holland, 2003), therefore surface owners cannot deny access to developers, but may demand compensation for that access. In many states the oil and gas or CBM operator is required to obtain a Surface Use and Damage Agreement with the land owner or owners. Due to the senior estate, the holder of CBM interests can obtain access to the property by way of court action if the CBM operator has shown good faith in attempting to make an agreement with the land owner and been denied. Surface access may include drilling site, pits, roads, and pipelines.

Split ownership is a common phenomenon. Fifty-eight million acres of privately owned property are split estates where the federal government owns some or all of the mineral estate. That is 6 million more acres than are contained in the State of Kansas and represents 1/8 of all privately owned land in the U.S. The federal government owns mineral rights to 744 million acres, equivalent to 29 percent of all the land of the U.S. Most of the split estates are located in the Western U.S. and many overlap prime CBM locations, see table 3.

Tables 3

SPLIT ESTATES -The BLM manages (controls) subsurface acreage of privately owned land as follows:

State	Acreage
Arkansas	1 in 9 acres
California	1 in 19 acres
Colorado	1 in 6 acres
Idaho	1 in 4 acres
Montana	1 in 5 acres
New Mexico	1 in 4 acres
North Dakota	1 in 8 acres
Oregon	1 in 14 acres
South Dakota	1 in 24 acres
Utah	1 in 11 acres
Wyoming	1 in 2 ¼ acres

AK, NE, NV, OK, WA and Eastern states AL, FL, IL, IN, IO, KS, LA, MI, MN, MS, MO, OH, WI. Split estates total 920,000 acres, representing small to very small fractions of privately owned land.

Source: http://www.blm.gov/natacq/pls02/pls1-3_02.pdf

State Regulations

State oil and gas commissions and boards were created out of conservation statutes and were intended to oversee oil and gas operations by establishing drilling units and providing well permit regulations. Oil and Gas commissions/boards were commonly established to maintain a level playing field for all owners to pursue oil and gas production, to prevent the waste of oil and gas resources, and to prevent the drilling of unnecessary wells. The responsibilities of the boards have changed as production has matured to include the regulation of drilling, casing, plugging and abandonment of wells and in some States the administration of the Underground Injection Control Program. Additionally, some boards may be tasked with protecting the rights of surface owners. The different Rocky Mountain state boards involved in overseeing CBM development are charged with varying statutory provisions:

Colorado: the role of the Colorado Oil and Gas Conservation Commission (COGCC) is to promote production and prevent and/or encourage the mitigation of adverse environmental impacts. The COGCC was originally created to foster, encourage, and promote the development, production, and utilization of oil and gas, however, in 1994 its mandate was expanded to include the prevention and mitigation of significant adverse environmental impacts on any air, water, soil, or biological resource resulting from oil and gas operations. The 1994 mandate also called for the COGCC to investigate, prevent, monitor, or mitigate conditions that threaten to cause, or that actually cause, a significant adverse environmental impact (Colo. Rev. Stat.)

Montana: Montana passed the Montana Oil and Gas Conservation Act in 1953 establishing the Board of Oil and Gas Conservation (MBOGC). The act authorizes the MBOGC to require a drilling permit before any oil or gas exploration, development, production, or disposal well may be drilled. MBOGC's mandate includes the prevention of oil and gas resource waste, encouragement of the efficient recovery of oil and gas, and the protection of owner's rights to recover their share of the resource. The MBOGC oversees the Underground Injection Control Class II program for oil and gas production water. The MBOGC also issues field rules and guidelines to prevent contamination of or damage to the environment caused by drilling operations. The State of Montana also has a State environmental policy act similar to NEPA which requires its state agencies to complete environmental analyses prior to approving management actions (Mt. Admin. Code Annotated).

New Mexico: The Energy, Minerals and Natural Resources Department of New Mexico contains the Oil Conservation Division and the Oil Conservation Commission. The Commission and Division regulate the conservation of oil and gas and handling and disposal of wastes generated by oil and gas operations. They also establish guidelines and field rules for the protection of public health and the environment (N.M. Stat. Ann.).

Utah: There are two agencies in Utah which govern the testing, spacing, drilling, completing, locating, operating, producing, and plugging of wells as well as the disposal of salt water and field wastes. These agencies are the Board of Oil, Gas and Mining and the Division of Oil, Gas and Mining. The Board has set rules requiring operators to "take all reasonable precautions to avoid polluting lands, streams, reservoirs, natural drainage ways, and underground water". The Board also attempts to encourage the development of surface use agreements with landowners but has not adopted statewide standards for reclamation (Utah Admin Code). The division serves in a technical and administrative capacity with regards to well development.

Wyoming: The Wyoming Oil and Gas Conservation Commission (WOGCC) regulates the drilling, casing, spacing and plugging of wells, it also requires operators to furnish a reasonable bond for plugging each dry or abandoned well. The WOGCC also monitors well performance throughout the state and regulates the production, as well as the perforating and chemical treatment of wells, disposal of production water and drilling fluids, and the protection and conservation of underground water. The WOGCC has a responsibility to encourage the development of natural gas and to prevent the waste of this resource. According to WOGCC rules the operator cannot pollute streams, ground-water, or unreasonably damage or occupy the surface. The WOGCC is also tasked with keeping natural gas from polluting or damaging crops, vegetation, livestock, or wildlife. (WOGCC Rules)

CBM Well produced water discharge point, Powder River Basin, Wyoming

State Water Laws

Of particular concern regarding CBM produced water is its affects on water rights. Water rights are governed under the prior appropriation approach to water law in all the Rocky Mountain States. The prior appropriation approach refers to the creation of water rights by usage or diversion, for a beneficial purpose, thus, ownership of land does not guarantee ownership of water. Prior appropriation primarily refers to surface waters; groundwater that is produced generally is not subject to appropriation, but belongs to those who produce it, unless otherwise specified. The key stipulations of prior appropriation fall under the general categories as follows:

- Purpose
- Date
- Quantity
- Beneficial Use
- Acquisition
- Transfer

Purpose – The purpose for appropriating waters does not need to be for riparian lands; waters may be diverted to any location and do not need to be used in the watershed from which they are drawn. A practical means of diverting the water which is both direct and efficient is generally required.

CBM produced water being aerated in the Powder River Basin, Wyoming

Date - The water right priority date is established based on the date of the original appropriation. Right-holders are either senior or junior to other right holders depending on the date of their appropriation. The oldest or senior water right is guaranteed conveyance of the full right; junior right-holders are permitted to obtain water from the remaining available source only after senior rights-holders have withdrawn their water. Upstream junior right-holders are required to allow adequate amounts of water to flow past their capture points to meet downstream senior rights.

Seniors are not permitted to reduce the volume of water available for juniors. This may restrict the senior's ability to transfer their rights, change diversion, purpose, or place of use. A large portion of water in the west is diverted for agriculture and typically about half is returned to the hydrologic cycle. The return flow may have been "called" by other right-holders, and therefore senior right-holders are not permitted to adversely affect the return flow; junior right-holders should receive their full appropriation based on the stream conditions that existed when they established their right.

Quantity - A water right is the volume put to a recognized beneficial use; there are no restrictions to the quantity of water used as long as it is reasonable for the intended use. Most state statutes, however, stipulate that right-holders must show via records that the water appropriated is put to a beneficial use and not misspent.

Use/Non-use - Beneficial use is generally defined as agricultural, irrigation, commercial, domestic, industrial, municipal, mining, hydropower production, recreation, stockwatering and fisheries, wildlife and wetlands maintenance. Conservation of environmental and visual resources have also recently been included as beneficial use. Beneficial uses are not ranked and one does not outweigh another, therefore, junior claims can not displace a senior right by stating their use is more beneficial. However, right-holders can lose their appropriation if their diversion method or purpose is determined wasteful. Restrictions are also placed on the use of water for environmental protection and recreational uses by the public trust doctrine.

Acquisition – Recognition of a water right is generally accepted when an appropriator obtains a permit or ruling from the appropriate state engineering office or is acknowledged by a court that the water is being used for a beneficial purpose. The majority of Western states require rights-holders to apply for a permit.

Generally the appropriator must notify all affected parties, construct a diversion facility within a specified time period, and put the water to beneficial use. If these requirements are met a hearing is held to review the criteria and establish the right.

Colorado uses a water court system to decide rights, instead of issuing permits. Seniority is recognized when the appropriator puts the water to beneficial use, and makes a physical demonstration of the intent to divert the water.

Colorado also allows water to be reserved for future use under a "conditional decree". The right is established on the date of the decree, however, appropriators need to prove that there is a significant likelihood that the project will be finished within a evenhanded timeframe. The court must also, decide if there is enough water available for the proposed diversion.

Water rights obtained through use, may be forfeited by non-use. Forfeiture can occur when there is non-use for a specific time-period or if the diversion is not constructed in time, but in either case does not require the appropriator to intentionally abandon the water right. Abandonment, on the other hand, can be initiated by the right-holder if they intend to surrender the water right.

Transfer - Water rights can be transferred to new land owners when land is sold, but does not have to be if the right-holder specifically reserves those rights. Furthermore, water rights may be transferred separately from the land if allowed by state law.

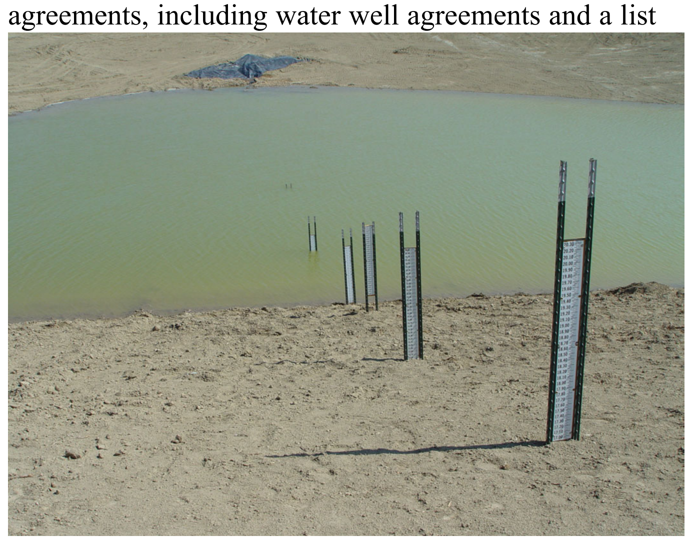
Colorado Water Law

Colorado water law does not require operators to obtain a permit from the state engineer's office when producing or withdrawing non-tributary water except when that water is intended for beneficial use. If produced water is going to be used for a beneficial purpose, the state engineer needs to ascertain whether the use will cause a "material injury to the vested water rights of others" (Co. Rev. Stat.). If material injury is anticipated, the permit needs to include mitigation measures to protect the other right holders. It is important to note that a lowering of the hydrostatic pressure in an aquifer or reduction in groundwater level is not deemed a material injury. (Colo. Rev. Stat.)

Produced water falls under the Colorado Oil and Gas Conservation Commission's (COGCC) definition of "exploration and production waste." The COGCC jurisdiction over produced water is covered in Rule 907 which addresses the management and disposal of "E&P" waste. The rule includes various disposal options such as evaporation, infiltration, reinjection, commercial disposal, reuse and discharge into state waters. Evaporation and infiltration must take place in a permitted pit either lined or unlined and the produced water needs to be treated prior to reaching the pit to eliminate crude oil and condensate. Reinjection needs to be accomplished via a permitted Class II well. Commercial disposal may include dust control through road-spreading. Reuse generally refers to enhanced recovery or drilling but in both cases it must meet the water quality standards. Permits are required for all of these options. Additionally, the rule includes a provision which allows the surface owner to use the water as an alternative domestic water supply that cannot be traded or sold.

Montana Water Law

The Montana statutes directly address CBM wells and specifically protects groundwater from being wasted. However, under certain scenarios, including management, discharge, or reinjection of CBM water, the production and use of groundwater is not considered a waste. Currently CBM operators are given three choices for produced water management; (1) beneficial use, such as irrigation, stock water, dust control, wetlands protection, etc., (2) reinject via a permitted Class II injection well, or (3) discharge into surface waters of the state provided a NPDES permit is obtained. CBM operators are required to have a Water Management Plan for their project area, surface owner agreements, including water well agreements and a list



Unlined water retention/infiltration pond being filled, Powder River Basin, Wyoming of all potentially affected surface owners within the project area. Under the water well agreements the operators must replace any affected wells or offer other mitigation measures to avoid impacts to existing groundwater users (Mt. Admin. Code Annotated).

Montana law also recognizes the designation of controlled groundwater areas; areas where groundwater withdrawals exceed or are likely to exceed the recharge rate of the aquifers. Operators in these areas must obtain a permit in order to withdraw and appropriate water. The permit application needs to demonstrate that the water withdrawn is available, that existing uses will not be impacted, and that all produced water will be beneficially used.

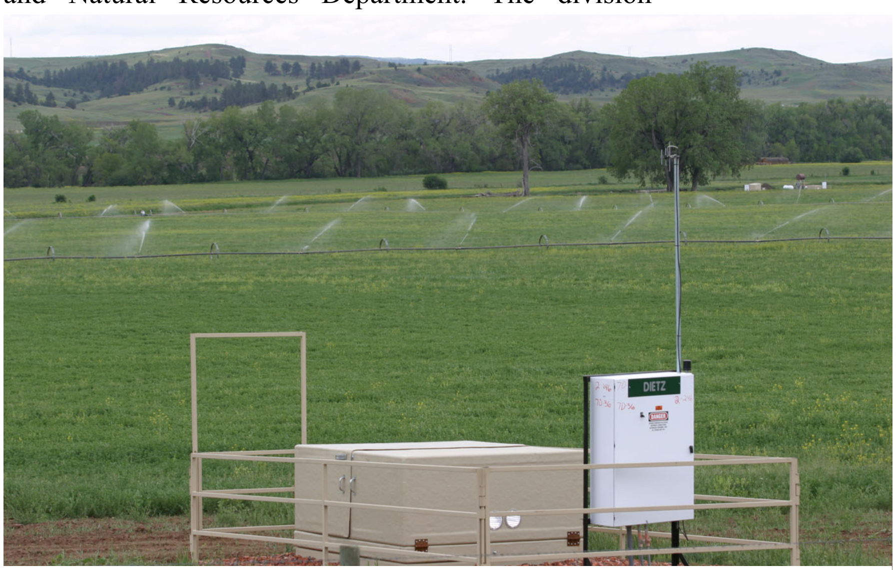
New Mexico Water Law

Waters used for drilling, mining, or prospecting operations intended to discover or develop natural resources in the state are classified as beneficial. Under certain circumstances mine operators need to obtain permits to withdraw these waters. Aquifers at 2,500 feet below ground surface that contain non-potable water are outside the jurisdiction of the state engineer and do not require a permit to be produced. Most CBM wells in New Mexico are completed below 2,500 feet in non-potable aquifers, and therefore are not required to be permitted by the state engineer. Water produced or used in connection with drilling for or production of oil and gas falls under the authority of the Oil Conservation Division of the Energy, Minerals and Natural Resources Department. The division regulates the subsurface and surface discharge of producted water with the intention of protecting fresh water sources. All groundwater with a background concentration of 10,000 mg/l or less of Total Dissolved Solids (TDS) is protected and reserved for beneficial use. The injection of produced water into subsurface reservoirs is also regulated by the Division.

New Mexico law also has requirements fashioned to safeguard existing water rights during mineral development throughout the state. Under New Mexico's Mine Dewatering Act, any operator who desires to acquire water for a beneficial use or to dewater a mine has the opportunity to replace the waters of existing users which may be impacted (N.M. ST. ANN a. The cost to restore the water is solely the operators' liability, who must submit an application with the state engineer to replace water. Although, an operator may make an appropriation of water under this act, merely dewatering a mine does not create water rights for the applicant. The state engineer may only approve an application under this statute if he is satisfied that the water restoration plan will provide sufficient waters to the affected parties. Before the water restoration plan is approved the state engineer considers the following issues; characteristics of the aquifer, present withdrawals on the aquifer and their collective effects on water levels and water quality, the impact of the mine dewatering on the aquifer, and the present and future withdrawal from, recharge to and storage of water in the aquifer (N.M. ST. ANN b).

Utah Water Law

The Utah Board and Division of Oil, Gas and Mining has jurisdiction over byproduct water even though there is a groundwater appropriations system in place the state. The state engineer may under certain circumstances issue a temporary water right to put byproduct water resulting from mining development to a beneficial use. However, this can only happen after the water has been diverted from its original underground source. An assortment of rules has been developed by the Division to control the disposal of "salt water and oil field wastes," (Utah Admin. Code a) this includes CBM water. Produced water can be placed in lined pits, or unlined pits provided it does not



CBM well head equipped with radio monitoring system and field irrigation in background, Wyoming have a TDS content higher than the groundwater, that could be affected or contain other unacceptable components such as oil, grease, heavy metals, chlorides, sulfates, aromatic hydrocarbons or pH outside of an acceptable range (Utah Admin. Code b). If all, or a considerable part of the produced water is being used for beneficial purposes unlined pits may be used provided an analysis of the water has been preformed and indicates that it can be used for those purposes. Finally, unlined pits may also be used when the quantity of produced water is less than five barrels per day. Operators may also choose to inject the produced water into Class II injection wells under the state UIC program (Utah Admin. Code c).

Wyoming Water Law

Wyoming water regulations address byproduct water appropriations; however they do not apply to CBM produced water. The state engineer has jurisdiction over CBM produced water, and operators therefore are required to obtain a permit for groundwater appropriation. The Wyoming water law states that applications to acquire groundwater "shall be granted as a matter of purpose, if the proposed use is beneficial and, if the state engineer finds that the proposed means of diversion and construction are adequate" (WY. Stat. a). If the state engineer finds that the application would not be in the public's best water interest he may deny it (WY. Stat. b). Wyoming water law outlines beneficial uses by preference.

The importance assigned to putting appropriated groundwater to a beneficial use and preventing waste created problems for the initial CBM applicants. On the early versions of "Application for Permit to Appropriate Ground Water" (WY. Stat. c) forms, applicants were required to identify which beneficial use would be used. CBM operators routinely checked the "miscellaneous" box and explained that the water was used to produce CBM. Revised forms now have a box for CBM produced water. The Wyoming State Engineer has determined that a beneficial use is the production of water in conjunction with the production of the CBM.

Local Regulations

CBM development has been subject to county regulation in some areas while it has been contested in others. Some counties have placed regulations on operations which require special use, building, and road permits; establish visual requirements and address noxious weeds. La Plata and Las Animas Counties in Colorado have ratified regulations that restrict noise levels, establish air and water quality standards, address vibration and odor levels, institute access requirements, define visual impacts, require fire protection, and attempt to mitigate impacts to wildlife and public safety. Disagreements have transpired between the county and state officials and between the county and developers.

La Plata County was the first to adopt regulations regarding CBM development in 1991. These regulations were contested by several gas companies claiming that they were superceded by state and/or federal laws. The county was sued by the industry and the court upheld the county's authority. The county then issued new regulations in 1995, stating that surface owners must be given an opportunity to determine the specific sites where drilling and road construction could take place. The county was again sued, and this time the court found in favor of industry and struck down the regulations (Bryner, 2002). County officials explained that their objective is to tackle the impacts of CBM development on local communities and not to inhibit production.

Counties in other states may have broad regulations that effect CBM development, but have not developed specific regulations for CBM development. In Montana, local regulations are permitted if they guarantee actual use of resources. In New Mexico, counties can adopt regulations provided they address traditional issues currently within the jurisdiction of county government. In Utah, counties are prohibited from drafting regulations relating to state law, especially where the oil and gas board has exclusive authority. However it is foreseeable that Utah counties can regulate noise, appearance, traffic, and compatibility with surrounding activity.

In Wyoming, counties can not prevent the use of land for the extraction or production of mineral resources. Five Wyoming counties along with the State and two conservation districts have signed a Memorandum of Understanding (MOU) designed to coordinate the flow of information and provide consistency between agencies. These counties have hired a CBM coordinator to help resolve any problems. The coordinator has attempted to maintain regulatory consistency across the Powder River Basin.

BEST MANAGEMENT PRACTICES/MITIGATION

Typical Environmental Impacts vs Mitigation Measures

This section addresses the typical environmental effects associated with CBM development in the west and the mitigation measures employed to address these effects. Focus is on the influences from production and distribution affecting natural resources and local populations and the tension between opposing land uses and users. Vital to this discussion are the potential affects of CBM extraction on water quality and quantity, and the numerous mitigation measures employed to control and eliminate these concerns.

INTRODUCTION

Environmental resources altered from present-day conditions by CBM production practices have caused concern for federal, state, and local regulatory agencies; land and resource managers; industry; landowners; and the general public. Along with rising public awareness and more stringent regulations, increased pressure has been placed on those involved in the CBM industry to develop methodologies to accurately define specific areas of environmental risk as well as develop Best Management Practices (BMPs) and mitigation strategies to aid in minimizing and alleviating these risks. As a result, development of fundamentally sound BMP's and mitigation strategies that facilitate resource development in an effective, timely, and environmentally sensitive manner, have become increasingly important.

BMPs are defined as techniques, procedures, and sustainable strategic plans which are generally site specific, economically feasible, and are used to guide, or may be applied to, management actions to aid in achieving desired outcomes. Implementation of BMPs can be used to reduce adverse environmental effects or enhance beneficial effects resulting from CBM operations. Typically, available management options for BMPs are dictated by site-specific characteristics such as, land and mineral ownership, geologic and hydrologic conditions (including depth of coal seams), soil types, local and regional wildlife issues, etc., and project objectives and applicable regulations. In any case, effective use of BMPs can assure at a minimum, a basic level of maintainable environmental protection in a cost efficient manner. Although BMPs are often derived from Federal, State, or local standards, BMPs by definition do not constitute regulations and therefore, should only be considered as a guidance tool for protecting foreseeable affects to resources.

Mitigation measures are closely associated with BMPs and are best described as techniques, procedures, and sustainable strategic *practices* which are implemented upon formulation of environmentally sound BMPs. Mitigation measures, in all cases, are site specific and will vary depending on the type of disturbance, the degree of the disturbance, and the requirements of landowners or other involved parties. These practices are often implemented in phases or in a practical chronological order to ensure that the disturbances of a specific phase of a project is linked with the appropriate measures so as to maximize the efficiency and effectiveness of the mitigation (EPA, 2002c). As with BMPs, the objective(s) of mitigation measures are to aid or alleviate the consequence to various resources resulting from CBM project operations.

Effective use of BMPs necessitates careful planning and coordination with federal and state agencies, as well as between operators and landowners. From a functional perspective, successful mitigation are development of preventative or beneficial plans, that when implemented, maximize the number and magnitude of protected resources. As an example, immediately reseeding bare soils during construction activities or after a project's completion can help minimize erosion events that may occur during seasonal flooding. This practice can also aid in the reclamation of native vegetation, help prevent infestation of noxious weeds, reduce dust control issues, provide additional lands for livestock grazing, provide suitable habitat and food resources for certain wildlife species, and control sediment run-off to nearby water systems. With this cost effective and flexible approach, the quantity and quality of protected resources can be enhanced to meet or exceed expectations of affected landowners, resource managers, or public agencies.

To further augment the effectiveness of BMPs, many employers are now providing mitigation specific training to employees. The training opportunities assure that employees are proficient in contemporary, as well as traditional techniques, which include; dust and noise control, hazardous waste reduction, seeding, and construction "footprint" minimization. With this approach and minimal investment employers can help protect vulnerable resources while at the same time, maintain a high level of project efficiency.

There are many aspects of CBM exploration and development that present unique challenges to resource managers, landowners, and State and Federal agencies. BMPs and mitigation measures specific to the CBM industry have been developed, as an example, by the Bureau of Land Management (BLM), the Montana Board of Oil & Gas Conservation (MBOGC), and others to identify resource issues, provide guidance for potential mitigation strategies, and to further enhance related beneficial uses. Within these documents implementations of measures to mitigate effects are generally presented as a procedure that is based on industry or activity related issues specific to the CBM industry that may negatively affect or potentially enhance individual resources.

The discussion below redirects this approach by focusing on resource specific issues, as well as resource-specific mitigation strategies that can or are required to be implemented to minimize disturbances to these resources. It is hoped this approach will help better define and clarify CBM related resource issues in a manner that will benefit landowners, operators, and federal or state agencies. This concise discussion should not be considered exhaustive since additional measures may also be identified during CBM development or in the NEPA process.

Beneficial Use

During the production of CBM, groundwater is extracted from coal seam aquifers to facilitate the release of methane gas trapped under hydrostatic pressure. Development of new CBM fields typically generate large volumes of water that may represent an opportunity for operators to provide themselves, the landowner, and nearby industry with water that does not result in the waste of this resource. The ability of a CBM operator to provide CBM produced water for uses by industry, landowners, or other parties, can provide unique and substantial benefits.

The water produced from CBM wells varies from very high quality (meeting state and federal drinking water standards) to low quality, essentially unusable (with Total Dissolved Solids [TDS] concentration up to 180,000 parts per million). Currently, the management of CBM produced water is conducted using various water management practices depending on the quality of the produced water. In areas where the produced water is relatively fresh, the produced water is handled by a wide range of activities including direct discharge, storage in impoundments, livestock watering, irrigation, and dust control. In areas where the water quality is not suitable for direct use, operators use various treatments prior to discharge, and/or injection wells to dispose of the fluids.

The use of CBM produced water for beneficial use represents a flexible and valuable approach to utilizing an important resource by providing benefits to operators, land owners, and in some cases the general public. The quality of the produced water, the surrounding environmental setting, operator and landowner needs, and pertinent regulations, will often dictate the water's designated use. In most cases certain aspects of development can benefit either by practical resolution or by satisfying public requests or needs. Beneficial uses for CBM produced water have been integrated into the resource discussion, when applicable, to provide the reader with a practical understanding of this mitigation approach. For more information on beneficial uses for CBM produced water refer to: CBM Produced Water: Management and Beneficial Use Alternatives, GWPRF, 2003, in cooperation with BLM and the Department of Energy (http://www.all-llc.com/CBM/BU/index.htm).

Resources of Concern

Air Quality

The 1990 Clean Air Act is a federal law that establishes nationwide limits on how much of a pollutant can be in the air. This ensures that all Americans have the same basic health and environmental protection with respect to the air they breathe. Under this Act, states are responsible for implementing the law; since pollution control problems often require special understanding of local industries, geography, housing patterns, etc. The law allows individual states to require more stringent pollution controls, but does not allow for weaker pollution regulations. Figure 23 shows the Class I areas in the Rocky Mountain region as designated by the Clean Air Act. Class I areas are generally major parks and wilderness areas over 6,000 acres, where pristine air quality and scenic vistas are integral features.

Excessive air emissions resulting from CBM development will vary for any region since pollutant transport is affected by the magnitude and distribution of pollutant emissions, as well as local topography and meteorology. Although air quality changes from the CBM industry can be localized and short-term in duration, appropriate mitigation could eliminate potential long-term air quality affects and conciliate concerns raised by involved parties. Fugitive dust and exhaust from construction activities, along with air pollutants emitted during operation, (compression) may be expected to cause some air quality changes.

Dust from construction activities and standard travel of personnel and equipment over unpaved roads has the potential to alter air quality and create a nuisance to those traveling or living in these areas. The use of high quality CBM produced water (low SAR) for dust control offers multiple benefits from an environmental viewpoint, including the prevention of air quality concerns and the loss of surface soils. Possible applications of produced water for dust control include use on lease roads, other unpaved roads in the development area, and various construction sites where surface disturbances due to CBM development exist.

Applying seed or re-vegetating bare soil areas is

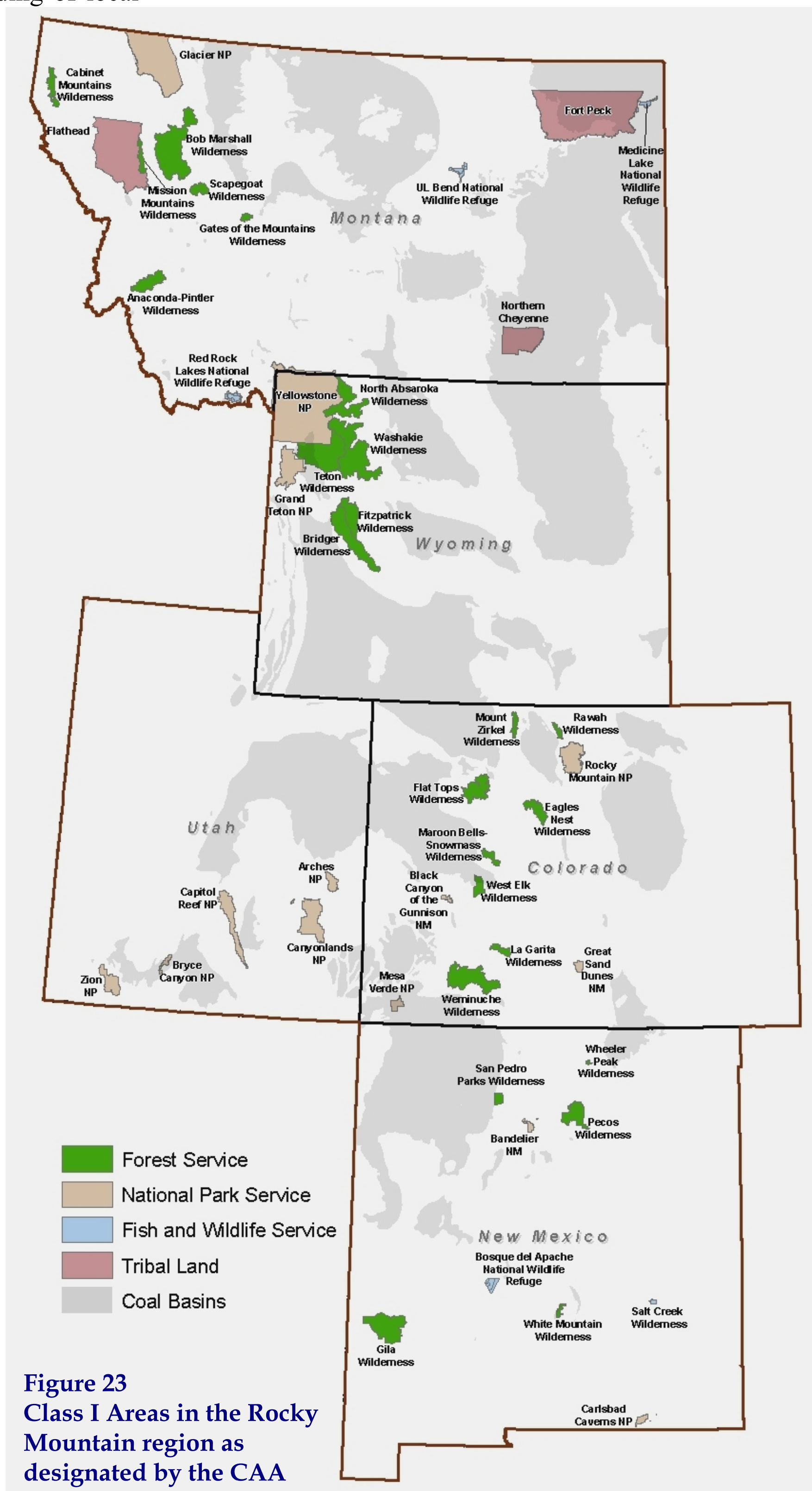


Figure 23
Class I Areas in the Rocky Mountain region as designated by the CAA

another successful measure that is used to minimize dust emissions, as well as to protect soils, and reduce erosion. The benefit of re-seeding bare areas far out ways management and monitoring costs and should be looked on as a necessity, rather than an option. This measure not only aids in the reduction of fugitive dust emissions, but facilitates the health and abundance of native vegetation, helps prevent the infestation of noxious weeds, may provide additional lands for livestock grazing and wildlife habitat and, can control sediment run-off to nearby water systems resulting from erosion.

Compressor engine emissions are another source of air pollution commonly associate with CBM development. Emissions from compressor engines would have an appropriate level of control determined by the applicable air quality regulatory agencies during a mandatory preconstruction permit process. Some of the measure employed to control emissions may include, limiting the number of field compressors, requiring the use of electric-powered compressors or the use of Best Available Control Technology to reduce the NO_x emission rate.

As with any BMP, site specific conditions will dictate which BMP strategy is best suited to address and mitigate potential air quality changes. Common practices that could be applied to a BMP program to control air quality issues are listed below.

- Avoidance of surface construction on soils susceptible to wind erosion
- Use of dust inhibitors as necessary on unpaved collector, local, and resource roads to minimize fugitive dust emissions
- Install pollution control equipment on field and sales compressors
- Install catalytic converters on heavy machinery to minimize air pollutants
- Avoid specific geographic locations susceptible to excessive winds
- Use soil erosion control techniques when bare ground is temporarily or permanently exposed
- Enclose painting operations, consistent with local air quality operations
- Properly store materials that are normally used in repair such as paints and solvents.

Cultural Resources and Paleontological Resources

Cultural resources are best described as material remains of, or the locations of past human activities, including sites of traditional cultural importance to both past and contemporary Native American communities. The existence of cultural resources within a specific location is determined through examination of existing records, field surveys, and subsurface testing of areas that are proposed for disturbance on federal and state lands. Section 106 of the National Historic Preservation Act (NHPA) requires an inventory of cultural resources if federal involvement is present either in terms of surface or mineral estate, federal funds, federal grant, or federal license. The BLM has also identified survey standards that must include approved plans for avoidance when resources are discovered. In addition, State Historical Preservation Offices (SHPO) maintain a register of all identified sites, as well as all sites that are listed or eligible for listing on the National Register of Historic Places (NRHP).

Native American Petroglyphs, Utah

Unidentified cultural resources could potentially be affected by surface and subsurface activities that involve the use of heavy equipment (road construction, well drilling, pad construction, pipeline and utility placement, etc.) that ultimately change the natural landscape of an area. As such, the most sensible and preventative measure to protect this resource is to properly identify historic or pre-historic locations and more importantly, to avoid or relocate project facilities in these areas when feasible a point which is enforced by Federal mandate. Federal and state laws require the performance of surveys prior to the commencement of construction or other surface disturbing activities as well as prohibit land usage when an area is designated for conservation use, public use, or sociocultural use.

In the rare event when exploratory or development procedures unearth previously undiscovered resources, enforceable mitigation would require that work be stopped in the area of discovery until an evaluation can be preformed. If appropriate, consultations would be conducted with the SHPO, tribal historic preservation officer and/or Advisory Council on Historic Preservation. Appropriate and responsible action would be determined by these agencies and coordinated with operators and/or landowners.

In most cases, instruction on procedures to follow in case previously unknown archeological resources are uncovered during construction would constitute an important element of the BMP. This may include; informing operators of the penalties for illegally collecting artifacts or intentionally damaging archeological sites or historic properties, instruction on rehabilitation of buildings or structures, minimizing equipment traffic, and restricting placement of equipment and material staging areas near known archeological resources (National Park Service, 2002).

Paleontologic resources consist of fossil-bearing rock formations containing information that can be interpreted to provide a further understanding about any given location's past.

Aquatic fossils
Photograph provided by The Fossil Conservancy

Surface occupancy is prohibited within paleontological sites on BLM project lands unless it can be demonstrated that the paleontological resource values can be protected, or undesirable disturbances can be mitigated. BLM provides guidelines for notifying and mitigating damage to paleontological resources discovered during oil and gas construction activities. Limitations include restricted use of explosives for geophysical exploration, monitoring requirements, and work stoppages for discovered damaged resources. As with Cultural Resources, investigative surveys to identify this resources and/or avoidance are typically considered the most effective mitigation to prevent damage.

Geology and Minerals

As stated earlier in this document, it is important to recognize that geology and mineral resources are directly associated with coal deposits. CBM gas is generated within the coal deposits under both thermogenic (heat-driven) and biogenic (microbe-driven) conditions. The magnitude of the CBM resource is determined by coal type and volume; and the location of coal seams, which coincide with the location of CBM resources. Existing BLM regulations allow for the production of CBM, but dictate that development be conducted in a manner that conserves these other resources present so they are not wasted.

The selection of an appropriate BMP to minimize alterations to these resources will depend greatly on local site conditions, but will usually consist of a collection of practices. Well spacing and field rules are established to maintain the integrity of surface formations while at the same time aiding in the efficient production of hydrocarbons. Drilling and completion practices, such as steel casing and cementing, stabilize the well bore dramatically and reduce the opportunity for hydrocarbon migration. In addition, certain operator practices can reduce surface disturbances as well. Sharing access roads, flowline routes, and utility line routes minimize surface disturbances and in certain circumstances, constructing multiple well pads and production facilities on the same pad can be implemented to consolidate work disturbing operations.

BMPs with a hydrologic component (e.g., storage ponds or impoundments) can directly affect geologic resources and require planning. When designed properly, however, they can be utilized to help control soil erosion and sedimentation ocurring from rainfall events, as well as provide benificial use. State engineering offices or related agencies often provide specific construction guidelines for impoundments. These guidelines can dictate preventative elements in their design that may include topographic restrictions (slope), water rights permitting requirements, and specific benificial use limitations. As an example of benefical use, the Montana Department of Environmental Quality considers CBM produced water to be unaltered State water and therefore; does not require permitting if the water meets certain water quality standards. Under a current proposal, this high quality water could be used specifically for livestock or wildlife watering and would have minimum impact to geological or mineral resources.

Reclamation practices to re-establish local landscapes are considered an integral (and BLM required) BMP component during the production and abandonment phases of CBM development. In most cases operators, along with landowners should discuss development and reclamation plans to reach a common agreement. This process ensures that acceptable guidelines and objectives are met to satisfy regulatory stipulations, as well as provide suitable guarantees for the landowner. From a functional and aesthetic perspective, re-seeding disturbed areas, such as well pad locations or road systems, restores the visual appearance of any disturbed location, and resolves or prevents local erosion and climatic, i.e., dust control issues. "No Surface Occupancy" stipulations could also be utilized on new oil and gas leases, which are issued for lands that have existing coal leases to prevent additional disturbance.

Hydrological Resources

CBM production can produce large volumes of water that can affect both ground and surface water when the quality of the water is low. Generally, water quality in a certain watershed will vary, but in many cases is dependent on the volume and season. During times of high flow, streams receive large volumes of runoff water; while during times of base-flow, streams receive little runoff and are supplied primarily by groundwater. High-flow periods correspond to the seasonal influx of relatively high-quality, low-Sodium Absorption Ratio (SAR) surface water typically associated with spring snow-melt and early summer rains. Base-flow periods correspond to periods of scarce surface water during the winter when streams are fed only by the influx of lower quality, high-SAR groundwater from shallow aquifers.

When groundcover is broken it exposes soil to wind and water erosion, leading to suspended sediment being deposited in bodies of surface water. Artificial impoundments can cause water infiltration into the soil and migration into surface water, and accidental releases of wastes can migrate into water bodies. These issues are of particular importance to residents. As a result, implementation of water management alternatives is in the forefront of CBM development.

CBM Supplied Impoundment, Powder River Basin, Montana

Current protection of hydrological resources primarily focus on maintaining beneficial uses for the produced water; although water well, and spring mitigation agreements are often used to facilitate the replacement of groundwater lost to drawdown.

New technologies or strategies for CBM produced water are continually being developed and are responsible for reshaping the way landowners and operators think about beneficial use and resource protection. Current water management strategies include using the water for certain job specific needs, such as dust control, or to supplement other water related activities, including irrigation, impoundments, livestock watering, industrial use, and in some cases, potable water use.

In areas where there are distinct wet and dry seasons, during the wet seasons water is abundant in both surface streams and groundwater supplies. However, water supplies are often depleted during the dry season leaving a demand upon water supplies at this time. In these areas, water is captured from surface streams and other sources, then stored in permeable aquifers for use during the dry season to ensure that this resource is not wasted. The storage of produced water for future use could be accomplished through the use of a proven technology, Aquifer Storage and Recovery (ASR). In the case of CBM, large quantities of produced water could be stored in depleted aquifers or coal seams where gas has been depleted. ASR provides water storage at lower cost than traditional surface storage methods while functioning in a manner similar to a traditional surface reservoir.

Another management option for produced water is impoundment use. The impoundment of CBM water is the placement of water produced during operations at the surface in a pit or pond. There are a variety of ways in which operators can impound produced water at the surface. Impoundments can be constructed on or off channel, and the regulatory authority in some states varies based on whether the impoundments are off or on channel. See Figure 24 for a schematic diagram of an off-channel impoundment. The impoundment of

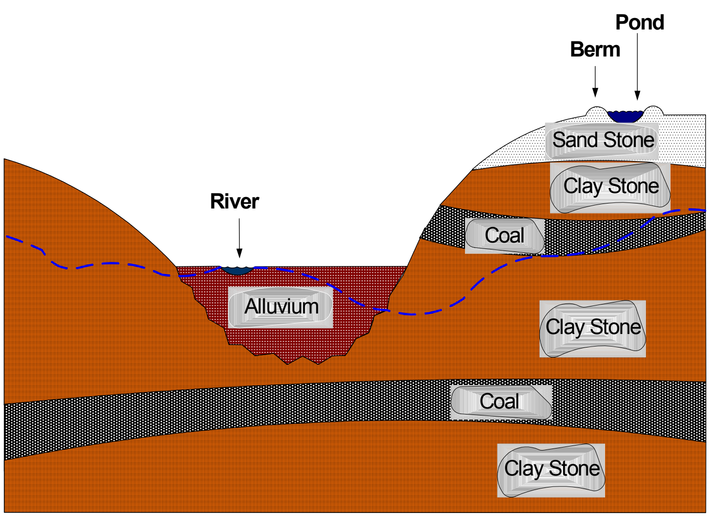


Figure 24
Off-Channel Impoundment
Schematic Diagram of Off-Channel Pond

produced water can be used as part of a water management plan to provide a variety of disposal options and benefits to both the lease operator and landowners. The options depend on site-specific conditions such as, the quality of produced water, soil type, current and future land use, and certain terrain factors. Under the right set of regulatory conditions, including water right and NPDES requirements, CBM supplied water could be used to sustain fish ponds, wildlife watering facilities, small recreational ponds, and utilized in retention ponds to restore depleted aquifers.

The impoundment of water can be performed in any area where there is sufficient construction space. In areas with limited rainfall or drought conditions, impoundments could be used to recharge groundwater in shallow alluvial and coal seam aquifers to provide livestock and wildlife water or for the storage of water prior to irrigation. Impoundments can be constructed to provide a single management option or a combination of management options including: livestock and wildlife watering from wetlands, fisheries and recreational ponds, recharge and evaporation ponds or other combinations.

Lands and Realty

Potential land use issues resulting from CBM development primarily consist of conflicts between conventional oil and gas activities and other uses of property, such as agriculture, residences, State lands, and coal mines. New realty authorizations for major gathering lines, major transportation lines, and power lines, for example, affect rights-of-way (ROWs) and land segmenting. The development of oil and gas resources affects agricultural production by taking land out of production, and by potential soil contamination from drilling and production. Soil contamination could result in loss of vegetation, reduced crop yields, or reduced acreage available for livestock grazing.

Proper surface selection and facility arrangement minimizes and mitigates surface conflicts and avoids unnecessary surface uses that would require additional reclamation, special operating procedures, or other restrictions that could be avoided. Geo-referenced spatial data depicting proposed facility locations, well locations, roads, pipelines, power lines, impoundments etc., is currently being utilized to mitigate potential surface conflicts. Locations in areas with a potential for high surface run-off, with increased erosion potential or in the flood plain of surface drainages could dramatically alter lands and thus, mitigation efforts. Avoidance of steep slopes, unstable soils, and locations that block or restrict natural drainages are successful tactics being implemented by operators to reduce surface alterations.

Another surface related issue involves removal of native vegetation, particularly in those areas where vegetation will be difficult to re-establish. Bare soils are susceptible to erosion and as a consequence, can lead to sediment build-up in local water systems, or result in negative alteration to the pre-existing topography. In situations where vegetative removal is necessary, reseeding should be performed immediately after development or when possible, during operations, to aid in the reclamation process and halt future surface disturbances. BLM provides seeding guidance when disturbances of this nature occur on federal lands (see Wildlife and Vegetation).

Livestock Grazing

CBM development only requires a small area for equipment, i.e., well pads and compressor stations, and therefore is relatively compatible with the foraging characteristics of livestock. Some changes to rangeland are expected however, and can be compensated for by appropriate mitigation. Loss of vegetation for livestock grazing, the disruption to livestock management practices, and loss of grazing capacity from construction of well pads and roads are some of the expected disruptions. Mitigation strategies that affect livestock grazing are often the result of coordination between the landowner and operator and serve to provide basic, sustainable practices which can help protect cattle, sheep, horses, and associated structures, such as watering ponds or fences.

Recycled Tire Stock Tank, Designed for Livestock Use

The availability of produced water from CBM activities would allow for, especially in arid regions, additional lands that could be utilized for grazing. There are estimates that, on average, cattle consume 11.5 gallons of water per day. Governmental standards for livestock water are less restrictive than potable water and would allow for the use of lesser quality CBM water for this purpose. Early coordination and cooperation between area CBM operators, landowners, and local ranchers on the potential uses of produced water could prove beneficial for involved parties. This practice is currently being implemented in portions of Montana through the use of stock tanks made from old heavy equipment tires such as the one depicted in the photo here. In some cases, ranchers would be responsible for obtaining water rights for such use of produced water.

The following list provides additional BMPs that can help protect livestock and their rangeland:

- Repair or replace damaged or displaced facilities such as fences or gates according to landowner requirements.
- Minimize project-related construction equipment and vehicle movement except on specific access roads to avoid disturbance of grazing land.
- Clearly define stipulations and responsibility for fence, gate, and cattle guard maintenance and for noxious weed control and incorporate into the planning process.
- Develop a reclamation plan for all areas that have been disturbed during production, and specify techniques for reclamation of well pads, pipeline rights-of-way, and roads.
- Locate facilities to avoid or minimize changes to livestock waters.

Recreation

Recreational areas are a vital component for communities nationwide and require close management to assure their protection. CBM related surface disturbances involving the use of heavy equipment for road construction or well drilling constitute a potential risk to this resource by changing the natural landscape. These types of construction activities could affect hiking, fishing, hunting, etc, as well as infringe on the solitude and rural characteristics of the area. Other activities such as increased travel, and vandalism resulting from access improvements, wildlife displacement, and increased erosion could also potentially affect recreational areas.

To prevent these potential disturbances to the extent possible, BLM has established stipulations that protect recreation areas. Specifically BLM has established such stipulations in areas receiving concentrated public use and in areas with reservoirs containing fish. Many states have also established stipulations for protection of recreation areas including prohibiting activity near streams, ponds, lakes, or other water facilities. Other possible mitigation strategies include coordinating the timing of exploration activities to minimize conflicts during peak periods of use.

The availability and volume of CBM produced water could be managed in a way to supplement, or in arid regions, create recreational opportunities for nearby communities. According to the second national water assessment by the U.S. Water Research Council, less than one-fourth of the surface waters in the Continental U.S. are accessible and useable for recreation because of pollution or other restrictions (Harney, undated). The construction of artificial lakes supplied by produced water could potentially have widespread use depending primarily on available lands, water volume and quality. Many areas of the country are overwhelmed with overcrowded or limited recreational facilities as a result of overpopulation and urban encroachment. The development of artificial lakes could provide additional recreational opportunities within these areas, while at the same time promoting community involvement and habitat improvement. In colder climates artificial lakes could also provide ice fishing or ice skating opportunities.

The addition of a large water body to an ecological community could provide additional habitat for resident and migratory birds, including waterfowl, and possibly provide resting and nesting sites for raptors (Bryan et al, 1996). An increase of waterfowl populations in the area could help support the local hunting community and potentially deter illegal hunting due to limited population sizes. The lake would effectively function as a watering pond or wetland system, potentially increasing wildlife ranges and populations resulting in an increase to the overall dynamics of the local ecosystem.

Social and Economic Values

The effects of CBM development on the socio-economics of any community is a dynamic issue which will differ at the community and individual level. Influences to social conditions would include changes in employment and population, changes in the services provided by governments, the effects of drilling and related activities on rural lifestyles in the project area, changes in levels of traffic, noise, visual resource alterations, and psychological stress levels; and the effects of population change on local housing, schools, and services.

Options to mitigate economic concerns will typically be performed as a case-by-case procedure, since varying aspects of this resource are often difficult to predict or are intrinsically linked with other resources or primary community industry(s). The most pragmatic solution would be to resolve issues by evoking public participation to determine appropriate minimization strategies or more importantly, approaches to maximize community benefits. Meetings to instruct and inform the public of proposed actions are one way to accomplish this task.

Soils

Changes to soils and the ensuing consequences have been well documented with regards to the oil and gas industry and as a result, many preventative and economically feasible measures have been developed to deal with these chnages. Changes to soils from CBM activities could occur from various facets of exploration, construction, operation, and abandonment processes. These changes include soil compaction under disturbed areas, such as well sites and lease access roads, soil erosion in disturbed areas, and chemical influences from spills of liquids. Some changes are unavoidable, such as those resulting from the construction of well sites. Short-term disturbances occur typically during construction phases, including

Revegetation of brine site using salt resistant prairie grasses reclamation of construction sites.

A healthy soil can absorb storm water, filter sediment, and reduce irrigation and fertilizer needs (Field and Engel, 2003). Changes to soils resulting from CBM related practices can affect multiple resources and as such, justifies serious consideration when devising appropriate management practices. In general, soil erosion is a gradual process that occurs when the actions of water, wind, and other factors deteriorate the land into an unproductive and in some cases, hazardous state. Application of BMPs to control such problems is dependent on proper evaluation and planning, and may include considerations such as, organic matter content and nutrient levels, mulching, topography, soil testing, and native plantings.

An example of an effective BMP to control erosion is to keep water from accumulating on road surfaces. Fast-moving water can easily erode soil from road surfaces and ditches, but can be controlled by dispersing runoff into vegetation and ground litter (Iowa Department of Natural Resources, undated). Roads can be designed to keep the surface dry, while at the same time maintaining a certain level of structural integrity. In-sloped roads should contain adequate drainage, whereas out-sloped roads, which are less expensive to construct and maintain, should be designed for moderate gradients and stable soils (Iowa Department of Natural Resources, undated).

Soil changes have been well documented allowing for development of many preventative measures. The list below provides some of these measures.

- Vegetation will be removed only when necessary
- Drill seeds into the ground
- Reduce timber cutting
- Control increases in turbidity and suspended sediments to the maximum extent practical by using berms, dykes or impoundments
- Areas with steep topography will be developed in accordance with the BLM Gold Book (USDI and USDA 1989) requirements
- Federal leases with slopes in excess of 30 percent will be required to obtain approval for occupancy from the BLM based on mitigation of erosion, surface productivity after remediation, and mitigation to surface water quality
- Riparian zones will be protected by federal lease stipulations and permit mitigation measures
- In areas of construction, topsoil will be stockpiled separately from other material, and be reused in reclamation of the disturbed areas
- Surface owners or surface lessee will be consulted regarding the location of new roads and facilities related to oil and gas lease operations
- Unused portions of the drill location will have topsoil spread over it and reseeded
- Construction activities will be restricted during wet or muddy conditions
- If groundwater is encountered in shallow or near shallow surface materials during drilling, all onsite fluid pits will be lined
- During road and utility construction, surface soils will be stockpiled adjacent to the sides of the cuts and fills
- Stream crossings will be designed to minimize soil disturbances and impede stream flow
- Erosion control measures will be maintained and continued until adequate vegetation cover is re-established.

Mulching as a Best Management Practice to Reduce Soil Erosion and Infestation of Noxious Weeds
Photograph provided by Libby Y. Field and Bernard A. Engel

Solid and Hazardous Wastes

In general, hazardous waste is a material or combination of hazardous materials that are no longer useable and are regulated by the Resource Conservation and Recovery Act of 1976 (RCRA). RCRA hazardous materials programs are designed to protect public health and environmental resources from improper disposal or releases of regulated materials. These programs assure future hazardous substance risks, costs, and liabilities on public lands are minimized. On Federal lands BLM is responsible for all releases of hazardous materials and requires notification of all hazardous materials to be used or transported on public land. Typical solid waste generated by drilling related procedures are considered RCRA-exempt waste and can be disposed of in local landfills. The largest volume of exempt waste generated from drilling activities are drilling mud and cuttings. Classified RCRA waste, such as paints would be disposed of in accordance with applicable regulations.

Waste minimization on CBM development sites is limited because waste volumes are primarily a function of activity, age, and state of depletion of a producing site (American Petroleum Industry, 1989). Nevertheless, mitigation planning will include proven practices to reduce waste to the extent practical. The mitigation of solid and hazardous waste consists primarily of disposing of all wastes according to federal and state regulations. Other mitigation activities include leak detection or monitoring system for hydraulic and lubricating systems, construction of secondary containments, and drilling mud retention ponds. The mitigation of accidental spills and releases involves the clean up and reporting of all spills in accordance with an approved Spill Prevention Control and Countermeasures Plan and any applicable state regulations. In addition site clearance surveys should be conducted prior to surface disturbance commencement.

Visual Resource Management

Visual resources are visual features that include landform, water, vegetation, color, adjacent scenery, uniqueness or rarity, structures, and other man-made features. Alterations resulting from oil and gas exploration and production activities occur locally on a case-by-case basis as native vegetation is disturbed and small structures are erected. Exploration may involve minor visual changes from clearing operations for access to exploratory sites. The majority of these changes result from access road construction, site construction, drill rig operations, and on-site generator use. Short-term visual changes occur where construction and drilling equipment are visually evident to observers. Long-term alterations may occur from construction of roads and pads, installation of facilities and equipment, vegetation removal, and change in vegetation communities. These could produce changes in landscape line, form, color, and texture.

Visual Resource Management Class I area near Bozeman, Montana

The USDA Forest Service recognizes special management zones surrounding riparian resources. For example, the Superior National Forest in Minnesota designates a 200- to 300-foot forest buffer, which is managed to optimize riparian resource values (Jaakko Pöyry Consulting, Inc., 1993). This management option can easily be applied to visual resources and in specific situations, coupled together with riparian or recreational resources to consolidate management efforts. Retaining a visual timber buffer could help isolate CBM-specific visual impairments such as, compressor stations or well pads, from local communities, highway travelers, and nearby recreational areas. Proper identification of timberlands play an important role in implementing this strategy. Due to the associated low costs and the flexibility of this strategy, successful implementation is often feasible.

Federally authorized projects undergo a visual assessment to comply with aesthetic requirements. Typically, sensitive areas include residential areas, recreation sites, historical sites, significant landmarks or topographic features, or any areas where existing visual quality is valued. Measures to minimize disturbance include designing compressor stations to blend into the background, landscaping options, and painting to camouflage the above ground equipment. Power lines and pipelines can be placed underground and wellheads camouflaged with landscaping or vegetation. Facilities on BLM lands require ample screening from highways or camouflage to retain basic elements of form, line, color and texture of the landscape.

Wilderness Study Areas

To the extent practical, BLM leasing restrictions are designed to protect Wilderness Study Areas (WSA). As such, the most reasonable practices to minimize disturbance is avoidance. BLM has implemented this type of strategy by identifying WSA policies that prohibit leasing of these lands for resource extraction. Such policies can be supplemented by collaborative partnerships among federal and state government agencies, local governments, business communities, volunteers, user groups, educational institutions, and individuals in the private sector to achieve management objectives and implement these guidelines (BLM, 2000).

Wildlife and Vegetation

Stipulations to perform wildlife surveys to assure responsible actions are taken to protect listed species associated with lands owned by the federal government and/or with projects which involve federal participation is an important element of any wildlife BMP. These stipulations are mandatory for federally owned (split-estates) or federally funded projects. (It should be noted that management practices, as well as identification of stipulations, for split-estates are the responsibility of the BLM.) If development practices occur on private lands, landowners, along with operators, are not bound by these same stipulations from a legal perspective even though they are still considered accountable for actions affecting state or federally listed species. Wildlife regulations are complex and will vary depending on geographic location, state and federal involvement, land-usage, and species distribution. In any case, wildlife surveys are a critical component of any mitigation strategy as they help identify listed species and alert operators and landowners of areas or habitats which should be avoided.

Black-footed Ferret
Mustela nigripes (Photograph provided by BLM)

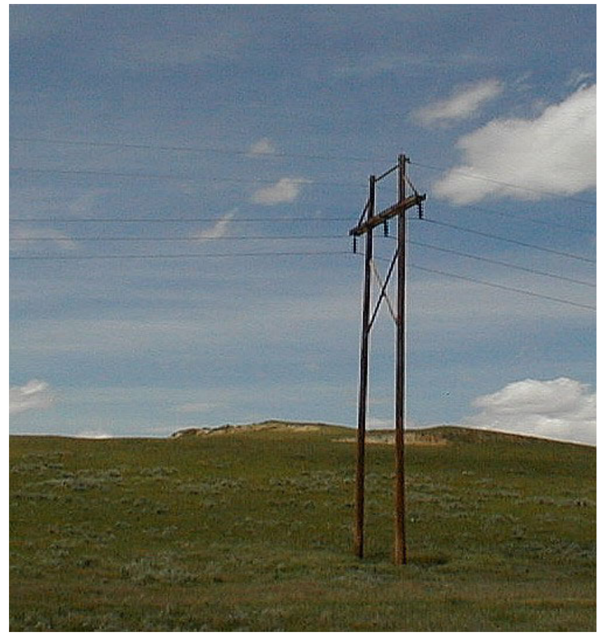
Wildlife surveys and inventories are used to identify fish and/or wildlife populations, their habitats, and other associated parameters such as home ranges, biodiversity values, and habitat usage. The inventory and monitoring of the abundance and distribution of wildlife species are essential in addressing development disturbances that pose threats to the effective and sustained management for protected, as well as common species. Monitoring programs provide the basis for formulation of adaptive wildlife management plans that document mitigation objectives and outline how each is to be implemented. Management issues relating to degree of human disturbance, conservation, management constraints, local communities' interests, and development are influenced by the resource availability and abundance over time.

A comprehensive biota database ensures that the full ranges of species utilizing the project area are identified as well as the time of year in which they are most likely present. This information can then be extrapolated and used as a strategy tool by wildlife biologists or resource managers to predict the degree of change(s) for specific species. With this inventory strategy, proper identification of fish, wildlife, and botanical species in the area will help those involved identity species-specific critical resources and plan for appropriate mitigation.

CBM development triggers Section 7 and/or Section 9 of the Endangered Species Act if environmental alterations are planned and if those alterations will pose as a potential threat to endangered species and their habitat. Section 7 of the Act directs federal agencies to mange projects in a manner that will not jeopardize the continued existence of listed species or modify their critical habitat during any federally authorized project. Section 9 identifies prohibited actions and outlines litigation authority for the FWS. Prohibited actions defined in this Section are extensive and require review to insure planning strategies are consistent with the law. In addition, identified sensitive species on federal lands are protected under the BLM Sensitive Species Policy (BLM Manual 6849).

Section 7 of the Endangered Species Act is not applicable to project related actions taking place solely on private lands. However, under Section 9 of the Act, operators or land owners still need to assure prohibited violations defined in this section are avoided, that is, in general, negative or deleterious disturbances to listed species. From a regulatory perspective, actions on private lands do not require performance of wildlife inventories, but as stated above, disturbances to threatened or endangered species could trigger Section 9 of the act, and subsequent law enforcement penalties from the FWS. To avoid such situations, the FWS service recommends incorporating wildlife inventory requirements into mitigations plans or at a minimum, assuming listed species inhabit the area.

In some cases, exemptions to Section 7 of the Endangered Species Act may apply if the FWS establishes "reasonable mitigation and enhancement measures, including, but not limited to, live propagation, transplantation, and habitat acquisition and improvement, as are necessary and appropriate to minimize the adverse effects of the agency action upon the endangered species, threatened species, or critical habitat concerned." This point alone establishes the importance of developing efficient and sustainable BMPs.



Raptor Safe Utility Pole
Photograph provided by the Wyoming Game and Fish Department

Practices to minimize alterations to habitat or natural activities can be very challenging and in some cases overwhelming, since the dynamics of any environment will vary from region to region, and as is often the case, will change over time. In any case however, wildlife management options are directly related to project-specific procedures and the findings of wildlife surveys. It is therefore, the responsibility of operators (and landowners) to submit work plans prior to the initiation of project activities to assure proper planning and if applicable, subsequent mitigation. Provided below is a listing of potential mitigation measures that could be used in a project plan to minimize disturbances to wildlife and their habitats. This list should not be considered all inclusive as wildlife mitigation measures are generally species specific and are continually being revised as more information is collected.

- No surface occupancy or use within 0.5 miles of known nests or riparian nesting habitat to minimize disturbances to nesting bald eagles.
- Surveys should be made for all prairie dog towns within the roadway corridor and pad sites. If prairie dog colonies or several of the other indicators are found, FWS survey protocol for mountain plover should be followed. Construction activities should be avoided during

breeding periods to allow nesting mountain plovers to establish territories.

- Surface occupancy and use is prohibited within 1/4 mile of wetlands used by nesting interior least tern during exploration. This stipulation would minimize disturbances to interior least tern.
- Construction of facilities or roadways that will disturb migration routes of terrestrial wildlife species should be avoided, unless construction activities can be scheduled in a manner to minimize disturbance.
- Overhead electric lines can threaten birds such as raptors or waterfowl and may impair visual resources. Buried electric lines can prevent such incidents and be as cost effective as pole-mounted lines when utility corridors are utilized. In situations where pole-mounted lines are the only feasible or best option, the use of raptor safe poles should be incorporated into the mitigation strategy.
- Remote monitoring of field data can help reduce traffic volume and the possibility of wildlife collisions. This type of monitoring will also decrease habitat defragmentation and sediment load to nearby water systems resulting from erosion.
- Use existing water structures including, reservoirs, impoundments, or stock ponds to dispose of water. This action will help avoid unnecessary disturbances to other areas, while possibly benefiting landowners or wildlife. Impoundments could be used as wildlife watering ponds or used for recreational or fish ponds by the local landowner.
- Construction of roadways in natural settings can affect multiple resources including wildlife. Reclamation of roads to pre-existing conditions upon completion of the project should be clearly defined within the project plan.

As a beneficial use, non-treated CBM produced water is currently being used to sustain privately owned fishponds in some states, including Wyoming. Water quality levels have been sufficient to support healthy populations of rainbow trout, blue gill, small-mouth bass, etc. The State of Wyoming discontinued fish stocking programs in certain ponds due to a general lack of available water needed to sustain the system. CBM produced waters are now being beneficially used to supplement these ponds, allowing for continuation of the State's stocking program.

Wetland system initial planting, June 2000, Marathon Oil Company, Powder River Basin, Wyoming

Same planting area as above, August 2001, Marathon Oil Company, Powder River Basin, Wyoming

Disturbances to native vegetation resulting from CBM activities will require a case by case evaluation to determine strategies to minimize the effected area. In general, pockets of vegetation will be lost to roads and drill sites, as well as other construction related procedures. Proper mitigation strategies will be based on area vegetative inventories to determine the presence of threatened, endangered, and regional sensitive species.

As directed by BLM or survey findings, operator plans should be adjusted as appropriate to avoid disturbances to federally listed species or state species of concern.

Sensitive habitats including wetlands and some riparian areas are also protected from direct disturbance under current stipulations on BLM land that restrict surface occupancy. In such cases riparian vegetation or other sensitive habitats should be avoided. When drilling sites are located in or at the head of drainages, drill sites and access roads may add sediment to streams and wetlands. Channel degradation may also occur. Heavy sediment loads or severe degradation would affect riparian vegetation. Roads and facilities are supposed to avoid sensitive areas "to the extent practicable."

When CBM development and operation practices result in the disturbance of existing non-protected vegetation and plant communities the potential exists for the loss of overall grazing/wildlife forage productivity, erosion, and introduction of noxious weeds. To help minimize disturbances to native vegetation operators are required to reduce the size of the drilling pads and to immediately restore the area once operations are complete or out-of-use. In situations that include unavoidable disturbances to common vegetation, proper mitigation can be applied to identify and re-introduce native species where necessary, to re-establish a local distribution, and to plant selected species that are determined to be valuable and successful in the area being restored. Other measures identified by BLM for specific protection of vegetation include:

- Where riparian areas and special habitat types have the potential to be inundated with water on a continuous basis. Measures will be taken to prevent continual inundation.
- Where water crossings cannot be avoided, crossings will be constructed perpendicular to wetland/riparian areas, where practical.For power lines, the minimum number of poles necessary to cross the area will be used.
- Wetland areas will be disturbed only during dry conditions or when the ground is frozen during the winter.
- No waste material will be deposited below high water lines in riparian areas, flood plains, or in natural drainage ways.
- Drilling mud pits will be located outside of riparian areas, wetlands, and floodplains, where practical.
- Reclamation of disturbed wetland/riparian areas will begin immediately after project activities are complete.

Noxious Weeds

Infestations of noxious weeds can occur in CBM development areas and require careful consideration on a site by site basis. Weeds can be transported and spread from vehicles, persons, and by other construction and reclamation materials. In some case native vegetation is unable to compete with exotic species and could lead to their elimination in a given local area. Mitigation, when properly applied, can help eliminate this problem, as well as sustain healthy native populations. To help assure the success of mitigation to control noxious weeds, BLM has identified certain protocols and practices that are required on federally involved projects in their Integrated Pest Management Plan (IPMP). Identified measures include: Prompt reseeding, cleaning of equipment prior to on-site delivery, minimization of soil disturbances, use of weed free mulch and hay, use of livestock to control outbreaks of certain weeds, use of BLM approved herbicides, and weed control instruction.

Dalmatian Toadflax (*Linaria genistifolia ssp. dalmatica*)is scattered throughout northern and western U.S. *Photograph provide by BLM*

the revitalized area resembles, in both appearance and functionality, its original state. As directed by BLM, re-establishment of vegetation is considered complete when the disturbed area is stabilized, soil erosion is controlled, and at least 60 percent of the disturbed surface is covered with the prescribed vegetation. On private lands, restoration efforts will be directed by landowner stipulations resulting from operator and landowner coordination.

Aquatic Resources

CBM exploration, production, and abandonment activities could disturb aquatic resources in a number of ways. The likelihood of these disturbances occurring depends on the exact nature, location, and timing of CBM activities; the proximity of CBM activities to water bodies and the presence of sensitive species and/or sensitive life stages in these water bodies; and the nature of stipulations and mitigation measures that should be implemented to minimize, avoid, or mitigate the potential disturbances. These include direct removal of habitat, habitat degradation from sedimentation, altered spawning and seasonal migration because of stream obstructions, direct loss of fish from accidental spills or pipeline ruptures releasing toxic substances, increased legal harvests of fish because of increased human access, and reduced stream flow because of removing water for drilling activities.

Tongue River, *Powder River Basin, Montana*

BLM has stipulations for federally involved projects that avoid or minimize disturbances to biological resources and hydrological features resulting from CBM exploration, production, and abandonment activities (BLM, 1992). Stipulations related to aquatic resources include a prohibition on the surface occupancy or use of water bodies and streams, within the 100-year floodplains for major rivers, and riparian areas. In addition, surface occupancy and use is prohibited within 1/4 mile of designated reservoirs with fisheries to protect the fisheries and recreational values of reservoirs. Surface occupancy is also prohibited on slopes exceeding 30 degrees to prevent excessive soil erosion, slope failure, and mass wasting, all of which would contribute increased sediment to drainages that may affect aquatic resources (BLM, 1992).

Stream channel monitoring for erosion, degradation, and riparian health is required by BLM on an annual basis, which includes surveying stream reach's above all CBM discharges and several stream reaches below CBM discharges. When avoidance of stream channel alteration is not feasible, BLM also requires re-contouring and stabilization of the channels.

Additional mitigation measures associated with aquatic resources, some of which are directed at special status species, include considerations of the location and timing of stream crossings as they relate to spawning periods and habitat, minimization or avoidance of in-channel activities to reduce the potential for habitat loss, the development of Spill Prevention Control and Countermeasures Plans to deal with accidental spills, control of storm water pollutant run-off, and various measures to prevent eroded materials from entering drainages.

Project Planning

As stated above, there are many aspects of the CBM industry that are unique and different from the conventional oil and gas industry. Also, given the fact that each project will present distinctive circumstances and challenges for resource managers or operators, it becomes imperative to systematically evaluate the situation prior to proposing or implementing BMPs in a project plan. A successful project plan will include BMPs and mitigation strategies aimed at minimizing environmental disturbances, while at the same time maintaining overall site productivity. Achieving effective use of BMPs requires consideration of lease stipulations, pre-planning, NEPA requirements, identification of permitting issues, monitoring, and implementation.

Lease stipulations consist of specific measures that are incorporated into a mineral lease and are intended to avoid potential effects on resources and land uses from oil and gas operations, including CBM. Lease stipulations can include provisions for, and constraints on, such things as site clearances, occupancy, and timing restrictions. Lease stipulations should be identified and agreed upon at the time of the lease signing before conducting exploration, production, and abandonment activities.

Depending on the situation, pre-planning for BMPs may occur before, during, or after CBM exploration activities. The success (or lack there of) of exploratory “findings” in many cases would contribute to the scheduling or initiation of a pre-planning program. In either case however, good planning is the best tool for effective implementation of BMPs. The pre-planning process should consider BMPs or mitigation strategies that are flexible, enforceable, have a preventative ability, and as stated earlier, can be implemented in phases.

Phase implementation for a particular aspect of the project should assure specific operations are paired up with the appropriate mitigation measures so as to maximize the effectiveness of any specific mitigation (EPA, 2002). This type of planning strategy should also ensure smooth implementation of the subsequent phases of work. Considering that the primary purpose of a BMP or mitigation measure is not only to resolve problems which may arise upon project initiation, but to prevent environmental problems before they occur, successful BMPs should be readily adapted to changes resulting from unforeseeable changes to a particular project (EPA, 2002). A flexible strategy can also prevent unnecessary delay due to further changes in the work environment. Lastly, a successful BMP should be easily enforceable. Operators should ask such questions as; What type of measure will be used? Where will the measure be implemented? and Why is the measure necessary? Sound and practical answers to these questions will aid operators in reducing concerns from the regulatory community, landowners, and citizens groups.

Planning efforts should begin with a thorough evaluation of the surface proposed for CBM development. Selection of the proper surface may help minimize and mitigate surface conflicts and avoid unnecessary surface uses that could require additional reclamation, special operating procedures, or other restrictions that could be avoided. At this time consideration also needs to be given to the proximity to schools, residences and other public areas, visual alterations, erosion potential, wildlife habit, and the improvements and structures of the landowner/surface lessee.

In addition operators should consider avoiding surfaces with steep slopes, unstable soils, and locations that block or restrict natural drainages during the pre-planning phase. Care should also be taken to disturb the minimum amount of native vegetation as possible, particularly in those areas where vegetation will be difficult to re-establish. Locations in areas with a potential for high surface run-off, with increased erosion potential or in the flood plain of surface drainages could dramatically increase maintenance costs and mitigation efforts, as well as create additional safety concerns. An exploration site that has a low slope, soils with low erosion potential, and a site that can be readily re-vegetated benefits the operator by reducing the costs of compliance with storm water discharge permits and associated well and road site remediation.

Section 102 of the National Environmental Policy Act requires Federal agencies to incorporate environmental considerations in their planning and decision-making process through a systematic interdisciplinary approach. Specifically, Federal agencies are to assess the environmental effects of, and alternatives to major federal actions significantly affecting the environment. Actions are classified into one of three categories and include: Categorically Excluded, Finding of No Significant Impact (as identified by an Environmental Assessment), and Finding of Significant Impact (as identified in an Environmental Impact Statement and Record of Decision).

Under this Act, Environmental Impact Statements (EIS) are developed to identify and evaluate the severity of project specific environmental disturbances that may result from CBM development practices. Identification of existing environmental conditions and potential disturbances will help those involved identify appropriate mitigation for site-specific impacts. Typically, resources evaluated in the EIS include:

- Environmental quality, including air, water, soils
- Social and socioeconomic conditions
- Natural resources, including fish, wildlife, and plants
- Endangered and threatened species
- Historical and cultural resources, including archeological materials

- Initial assessment for any hazardous, toxic, or radiological wastes

The number and complexity of applicable permit requirements and water right issues that can apply to CBM operations can be overwhelming, but are critical to the successful implementation of BMPs and mitigation strategies. Permit requirements can and will vary for any given state or region. Coupled with the discretionary practices agencies can exercise when applying their programs, it becomes essential for operators and landowners to have a thorough understanding of these requirements to allow for informed decisions as they relate to identifying and implementing site specific BMPs. Operators, landowners, or other entities involved in the CBM industry should contact their appropriate state authority for additional information. It should also be noted that permitting requirements within the CBM industry are continually being modified or new requirements are being drafted.

Conclusion

Not all BMPs or mitigation measures will be appropriate for any given resource and proper implementation will vary by the region, topography, climate, reclamation objectives, landowner stipulations, applicable regulations, and development characteristics. Established mitigation plans will require amendment when there are significant changes in design, construction, and operation or maintenance practices. Since operational and development conditions will likely change over time, developing monitoring plans for these changes will help faciltitae necessary adjustments to BMP programs.

The focus of many monitoring plans is to conduct an overall evaluation of the potential effects of CBM development and to track the changes that occur as CBM fields mature, and gas production declines and eventually ends. The end result of monitoring will allow those involved to determine if measures are achieving their intended environmental objectives, as well as to identify any further disturbances caused by the mitigation measures themselves (EPA, 2002). Effective monitoring can also provide a means for developing improved analytical procedures for future analysis and improving mitigation measures. Standards for monitoring resources such as air quality, water, wildlife, and surface disturbances historically have been well documented, and serve as a baseline for monitoring.

BMPs should not be thought of as a rigid set of guidelines that are mandatory for reduction of disturbances, but as an adaptive and concise management tool which can facilitate enhancement, as well as protection, for multiple resource use. Unfortunately, there is no one measure with a “fix all” quality. Rather, BMPs represent an intricate web of methodologies and practices resulting from careful planning and coordination that are used to accomplish pre-determined objectives. BMPs must be incorporated into the final design plan for any CBM construction project to help assure the success of the project, as well as the protection of the environment.

DEFINITIONS

AIR QUALITY. Air quality is based on the amount of pollutants emitted into the atmosphere and the dispersion potential of an area to dilute those pollutants.

ALKALINITY. The quantity and kinds of compounds present in water that collectively shift the pH to the alkaline side of neutrality. See **salinity**.

ALLUVIUM. General term for debris deposited by streams on river beds, floodplains, and alluvial fans, especially deposits brought down during a flood. Applies to stream deposits of recent time. Does not include below water sediments of seas and lakes.

ANNULUS OR ANNULAR SPACE. The space around a pipe in a wellbore, the outer wall of which may be the wall of either the borehole or the casing.

AQUIFER. A body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.

APPLICATION FOR PERMIT TO DRILL, DEEPEN OR PLUG BACK (APD). The Department of Interior application permit form to authorize oil and gas drilling activities on federal land or the state application form for similar purposes.

AREA OF CRITICAL ENVIRONMENTAL CONCERN. An area that needs special management attention to preserve historic, cultural, or scenic values; to protect fish and wildlife resources or other natural systems or processes; or to protect life and provide safety from natural hazards.

ARTESIAN. Groundwater with sufficient pressure to flow without pumping.

BASIN. A closed geologic structure in which the beds dip toward the center; the youngest rocks are at the center of a basin and are partly or completely ringed by progressively older rocks.

BEDROCK. The solid, unweathered rock underlying soils.

BEST AVAILABLE CONTROL TECHNOLOGY (BACT). The best available air pollution control technology for a given emission source, considering environmental benefits, economic and energy costs, as defined by the applicable air quality regulatory authority.

BIOGENIC. Produced by living organisms or biological processes.

BITUMINOUS. The most abundant rank of coal (synonymous with soft coal). It is dark brown to black and burns with a smoky flame.

BRACKISH WATER. Water that contains relatively moderate concentrations of any soluble salts. Brackish water is saltier than fresh water but not as salty as salt water or brine water.

BRINE. Water containing relatively large concentrations of dissolved salts, particularly sodium chloride. Brine has higher salt concentrations than ordinary ocean water.

BUFFER ZONE.

1. An area between two different land uses that is intended to resist, absorb or otherwise preclude developments or intrusions between the two use areas.

2. A strip of undisturbed vegetation that retards the flow of runoff water, causing deposition of transported sediment and reducing sedimentation in the receiving stream.

CASING. Steel pipe placed in a well and cemented in place to prevent the earth from collapsing and to isolate water, gas and oil from the original formations.

CAVITATION. The formation of an undercut in a mineral formation by means of mechanical forces, such as those resulting from rotation of a special drill bit at the base of a well.

CHANNEL INTEGRITY (STABILITY). A relative term describing erosion or movement of the channel walls or bottom because of water flow.

CLAYEY. A soil containing more than 35 percent clay. The textural classes are sandy clay, silty clay, clay, clay loam, and silty clay loam.

CLEAN AIR ACT. Public Law 84-159, established July 14, 1955, and amended numerous times since. The Clean Air Act: establishes federal standards for air pollutants emitted from stationary and mobile sources; authorizes states, tribes and local agencies to regulate polluting emissions; requires those agencies to improve air quality in areas of the country which do not meet federal standards; and to prevent significant deterioration in areas where air quality is cleaner than those standards. The Act also requires that all federal activities (either direct or authorized) comply with applicable local, state, tribal and federal air quality laws, statutes, regulations, standards and implementation plans. In addition, before these activities can take place in non-attainment or maintenance areas, the federal agencies must conduct a Conformity Analysis (and possible Determination) demonstrating the proposed activity will comply with all applicable air quality requirements.

CLOSED MUD SYSTEM. A drill mud system that reuses or reclaims all the drilling fluid used. Oil-based mud systems are often closed mud systems.

COAL BED METHANE. A clean-burning natural gas found deep inside and around coal seams. The gas has an affinity to coal and is held in place by pressure from groundwater. Coalbed methane is produced by drilling a wellbore into the coal seam(s), pumping out large volumes of groundwater to reduce the hydrostatic pressure and allow the gas to flow.

COALIFICATION. Compression and hardening over long periods of time, the processes by which coal is formed from plant materials.

COLLUVIAL. Loose, incoherent geological deposits at the bottom of a slope or cliff, having fallen from above.

COMMUNITIZATION. The pooling of mineral acreages based on the spacing for a well or wells set by the state or BLM.

COMPACTION. The process of packing firmly and closely together; the state of being so packed; for example, mechanical compaction of soil by livestock or vehicular activity. Soil compaction results from particles being pressed together so that the volume of the soil is reduced. It is influenced by the physical properties of the soil, moisture content, and the type and amount of compactive effort.

COMPLETION. The activities and methods to prepare a well for production. Includes installation of equipment for production from a gas well.

CONDITION OF APPROVAL (COA). Conditions or provisions (requirements) under which an Application for a Permit to Drill or a Sundry Notice is approved.

CONTROLLED SURFACE USE (CSU). Use or occupancy is allowed (unless restricted by another stipulation), but identified resource values require special operational constraints that may modify the lease rights. CSU is used for operating guidance, not as a substitute for the NSO or Timing stipulations.

CONVEYANCE LOSS. The percentage reduction in water volume between the time it is discharged to the surface and the time it reaches a perennial stream. This reduction in volume is due to the processes of infiltration and evaporation.

CORRIDOR. A strip of land through which one or more existing or potential facilities may be located.

CRUCIAL WINTER RANGE. That portion of the winter range on which a wildlife species is dependent for survival during periods of heaviest snow cover.

CULTURAL RESOURCE. A term that includes items of historical, archaeological, or architectural items; a remnant of human activity.

CUMULATIVE IMPACT. The impact on the environment that results from the positive or negative impacts of an action when added to other past, present, and reasonable foreseeable future actions, regardless of what agency or person performed such action(s).

DEEPER COAL SEAM. Designates a coal seam that is deep enough that it can be drilled to at a directional angle from a well pad in one spacing unit to another spacing unit. This avoids the need for constructing additional roads and well pads. The exact depth that the term "deeper" applies to is relative and will vary according to field spacing requirements and local geology.

DEVELOPMENT WELL. A well drilled in proven territory (usually within 1 mile of an existing production well).

DESORBED. To remove (an absorbed or adsorbed substance) from.

DISPOSAL WELL. A well into which produced water from other wells is injected into an underground formation for disposal.

DRAINAGE (GEOMORPHIC). A collective term for all the water bodies by which a region is drained; or, all the water features shown on a map.

DRAINAGE (OIL AND GAS). The uncompensated loss of hydrocarbons from Federal, Indian tribal or Indian-allotted mineral lands from wells on adjacent non-jurisdictional lands or jurisdictional lands with lower participation, allocation, royalty rate, or distribution of funds, resulting in revenue losses to the Federal or Indian lessors.

DRILL DIRECTIONALLY. The technique of drilling at an angle from a location at the surface to a different subsurface location at a specific target depth.

DRILL RIG. The mast, drawworks, and attendant surface equipment of a drilling or workover unit.

DRY HOLE. Any well incapable of producing oil or gas in commercial quantities. A dry hole may produce water, gas or even oil, but not enough to justify production.

ECOSYSTEM. A biological community, together with its nonliving environment, forming an interacting system inhabiting an identifiable space.

ELECTRICAL CONDUCTIVITY. A measure of the ability of a formation and the fluids present in it to conduct an electrical current. For shallow formations and coals, the conductivity is generally related to the soluble salts present in the formation fluid.

EMISSION. Air pollution discharge into the atmosphere, usually specified by mass per unit time.

ENDANGERED SPECIES. Those species of plants or animals classified by the Secretary of the Interior or the Secretary of Commerce as endangered pursuant to Section 4 of the Endangered Species Act of 1973, as amended. See also Threatened and Endangered Species.

ENHANCED RECOVERY. The use of artificial means to increase the amount of hydrocarbons that can be recovered from a reservoir. A reservoir depleted by normal extraction practices usually can be restored to production by secondary or tertiary methods of enhanced recovery.

EXPLORATION. The process of identifying a potential subsurface geologic target and the active drilling of a borehole designed to assess the coalbed methane potential. See also **development**.

EXPLORATION WELL. A well drilled in an area where there is no oil or gas production. Same as a “wildcat” well.

FAULT. A fracture surface in rocks along which movement of rock on one side has occurred relative to rock on the other side.

FLOODPLAIN. The relatively flat area or lowlands adjoining a body of standing or flowing water that has been or might be covered by floodwater.

FLOW LINE. A small diameter pipeline that generally connects a well to the initial processing facility.

FORMATION (GEOLOGIC). A rock body distinguishable from other rock bodies and useful for mapping or description. Formations may be combined into groups or subdivided into members.

FUGITIVE DUST. Airborne particles emitted from any source other than through a controllable stack or vent.

GEOMORPHIC. Pertaining to the form of the earth or its surface features.

GROUND COVER. Vegetation, mulch, litter, or rocks.

GROUNDWATER. Subsurface water that is in the zone of saturation. The top surface of the groundwater is the “water table.” Source of water for wells, seepage, and springs.

HABITAT. In wildlife management, the major elements of habitat are considered to be food, water, cover, and living space.

HAZARDOUS WASTE. (A) Any substance designated pursuant to section 311(b)(2)(A) of the Federal Water Pollution Control Act. (B) Any element, compound, mixture, solution, or substance designated pursuant to section 102 of this Act. (C) Any hazardous waste having the characteristics identified under or listed pursuant to section 3001 of the Solid Waste Disposal Act (but not including any waste the regulation of which under the Solid Waste Disposal Act has been suspended by Act of Congress.) (D) Any toxic pollutant listed under section 307(a) of the Federal Water Pollution Control Act. (E) Any hazardous air pollutant listed under section 112 of the Clean Air Act. (F) Any imminently hazardous chemical substance or mixture with respect to which the Administrator has taken action pursuant to section 7 of the Toxic Substances Control Act. The term does not include petroleum, including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance under subparagraphs (A) through (F) of this paragraph, and the term does not include natural gas, natural gas liquids, liquefied natural gas, or synthetic gas usable for fuel (or mixtures of natural gas and such synthetic gas).

HYDROSTATIC PRESSURE. relating to fluids at rest or to the pressures they exert or transmit; "hydrostatic pressure"

INFILTRATION. The flow of a fluid into a solid substance through pores or small openings; specifically, the movement of water into soil or porous rock.

INJECTION WELL. A well used to inject fluids into an underground formation either for enhanced recovery or disposal.

INTERMITTENT STREAM. A stream that flows most of the time but occasionally is dry or reduced to pool stage when losses from evaporation or seepage exceed the available streamflow.

LAND AND WATER CONSERVATION FUNDS. Federal revenues generated by a tax on federal off-shore oil and gas development through the Land and Water Conservation Fund Act; used to acquire highly desirable lands for the United States by the various governmental agencies.

LEASABLE MINERALS. Federal minerals subject to lease under the Mineral Leasing Act of 1920, as amended, and supplemented. Includes minerals, such as oil, gas, coal, geothermal, tar sands, oil shale, potassium, phosphate, sodium, asphaltic materials.

LEASE.

1. A legal document that conveys to an operator the right to drill for oil and gas.

2. The tract of land, on which a lease has been obtained, where producing wells and production equipment are located.

LEASE NOTICE. Provides more detailed information concerning limitations that already exist in law, lease terms, regulations, or operational orders. A lease notice also addresses special items the lessee should consider when planning operations, but does not impose new or additional restrictions. Lease notices attached to leases should not be confused with NTLs (Notices to Lessees).

LEK. A traditional breeding area for grouse species where territorial males display and establish dominance.

LIGNITE. A brownish-black coal that is intermediate between peat and subbituminous coal.

LOAMY. Soil that is intermediate in texture and properties between sandy and clayey soils. Textural classes are sandy loam, fine sandy loam, very fine sandy loam, loam, silt loam, sandy clay loam, and clay loam with clay content between 18 and 35 percent.

LOCALITY. The area where paleontologic material is discovered.

LOCATABLE MINERALS. Minerals or materials subject to disposal and development through the Mining Law of 1872 (as amended). Generally includes metallic minerals such as gold and silver and other materials not subject to lease or sale.

MACERALS. the small fragments formed in peat and coal, and can be identified microscopically as coming from plant products.

MINERAL MATERIALS. Widespread deposits of common clay, sand, gravel, or stone that are not subject to disposal under the 1872 Mining Law, as amended.

MITIGATION MEASURES. Methods or procedures developed for the purpose of reducing or lessening the impacts of an action.

MONITORING. Specific studies that evaluate the effectiveness of actions taken toward achieving management objectives.

NATIONAL AMBIENT AIR QUALITY STANDARDS OR NAAQS. The allowable concentrations of air pollutants in the air specified by the federal government. The air quality standards are divided into primary standards (based on air quality criteria and allowing an adequate margin of safety requisite to protect the public health) and secondary standards (based on air quality criteria and allowing an adequate margin of safety to protect the public welfare from any unknown or expected adverse effects of air pollutants).

NO SURFACE OCCUPANCY. Use or occupancy of the land surface for fluid mineral exploration or development is prohibited to protect identified resource values.

NOTICE TO LESSEES (NTL). The NTL is a written notice issued by the Authorized Officer. NTLs implement regulations and operating orders, and serve as instructions on specific item(s) of importance within a State, District, or Area.

PARTICULATE MATTER. A particle of soil or liquid matter (e.g., soot, dust, aerosols, fumes and mist).

PERENNIAL STREAM. A permanent stream that flows 9 months or more out of the year.

PERMEABILITY. The ease with which gases, liquids or plant roots pass through a layer of soil. Accepted as a measure of this property is the rate at which soil transmits water while saturated, and may imply how well water passes through the least permeable soil layer.

PERFORATING. Penetrating the well casing to open the reservoir to the surface.

pH. A measure of acidity or alkalinity. A solution with a pH of 7 is neutral, pH greater than 7 (to 14) is alkaline, and a pH less than 7 (to 0) is acidic.

PARTS PER MILLION (PPM). A measurement to identify the amount of particulates in air or water.

POD. Describes the general location of a series of wells that tap individual coal seams within a single spacing unit. For example, within the Powder River Basin, three coal seams are layered beneath the surface. On the surface, an operator may drill three separate wells to different depths to tap these individual seams. The wells may be located within 20 feet of each other, representing a pod of wells.

POROSITY. The ratio of the volume of all the pores in a material to the volume of the whole.

PREVENTION OF SIGNIFICANT DETERIORATION OR PSD. A regulatory program under the Clean Air Act (Public Law 84-159, as amended) to limit air quality degradation in areas currently achieving the National Ambient Air Quality Standards. The PSD program established air quality classes in which differing amounts of additional air pollution is allowed above a legally defined baseline level. Almost any additional air pollution would be considered significant in PSD Class I areas (certain large national parks and wilderness areas in existence on August 7, 1977, and specific Tribal lands redesignated since then). PSD Class II areas allow that deterioration associated with moderate, well-controlled growth (most of the country).

Class I. An area that allows only minimal degradation above "baseline." The Clean Air Act designated existing national parks over 6,000 acres and national wilderness areas over 5,000 acres in existence on August 7, 1977, as mandatory Federal Class I Areas. These areas also have special visibility protection. In addition, four tribal governments have redesignated their lands as Class I Areas.

Class II. An area that allows moderate degradation above "baseline." Most of the United States (outside nonattainment areas) is Class II.

Class III. Any area that allows the maximum amount of degradation above "baseline." Although the U.S. Congress allows air quality regulatory agencies to redesignate Class II lands to Class III, none have been designated.

PRODUCED WATER. Water produced from oil and gas wells.

RAPTOR. Bird of prey with sharp talons and strongly curved beaks (hawks, falcons, owls, and eagles).

RECLAMATION. Rehabilitation of a disturbed area to make it acceptable for designated uses. This normally involves regrading, replacement of topsoil, revegetation, and other work necessary to restore it for use.

RESERVE PIT.

1. Usually an excavated pit that may be lined with plastic, that holds drill cuttings and waste mud.

2. Term for the pit that holds the drilling mud.

RIGHT-OF-WAY GRANT. A document authorizing a nonpossessory, nonexclusive right to use federal lands for the limited purpose of construction, operation, maintenance, and termination of a pipeline, road, or powerline.

RILL. Small, conspicuous water channel or rivulet that concentrates runoff; usually less than 6 inches deep.

RIPARIAN/WETLAND AREA. An area of land directly influenced by permanent water. It has visible vegetation or physical characteristics reflective of permanent water influence. Lakeshores, streams and permanent springs are typical riparian areas. Excluded are such sites as ephemeral streams or washes that do not exhibit the presence of vegetation dependent upon free water in the soil.

ROAD. A vehicle route that has either been improved and maintained by mechanical means to ensure relatively regular and continuous use, or been established where vehicle travel has created two parallel tracks lacking vegetation.

SALINITY. A measure of the salts dissolved in water. See **alkalinity**.

SEDIMENT. Soil, rock particles and organic or other debris carried from one place to another by wind, water, gravity, ice, or other geologic agent.

SEDIMENTARY ROCK. A layered rock resulting from the consolidation of sediment, such as shale, sandstone, and limestone.

SEISMIC OPERATIONS. Use of explosive or mechanical thumpers to generate shock waves that can be read by special equipment to give clues to subsurface conditions.

SHALLOW COAL SEAM. Those coal seams that are too shallow to drill to directionally given the area geology and spacing limitations.

SHUT IN. To close the valves on a well so it ceases production.

SODIUM ABSORPTION RATIO. An expression of relative activity of sodium ions in exchange reactions with soil, indicating the sodium or alkali hazard to soil. It is a particularly important measure in waters used for irrigation purposes.

SODIUM-AFFECTED SOIL. A nontechnical term for sodic soil (also called alkali soil) that contains sufficient sodium to interfere with the growth of most crop plants and in which the exchangeable sodium percentage is 15 or higher. It is also a generic way of describing nonsaline-alkali soil or saline-alkali soil.

SOLID WASTE. Any solid, semi-solid, liquid, or contained gaseous material that is intended for disposal.

SPACING UNIT. The number of acres that one oil or gas well will efficiently drain. The state oil and gas commissions typically establish the size of spacing units for each oil and gas field.

SPECIES OF SPECIAL INTEREST OR CONCERN. Animals not yet listed as endangered or threatened but that are undergoing status review by a federal or state agency. This may include animals whose populations could become extinct by any major habitat change. A species that is particularly sensitive to some external disturbance factors.

SPLIT ESTATE. Surface and minerals of a given area in different ownerships. Frequently, the surface is privately-owned while the minerals are federally or state-owned.

STIPULATION. A condition or requirement attached to a lease or contract, usually dealing with protection of the environment, or recovery of a mineral.

SUBBITUMINOUS. A black coal, intermediate in rank between lignite and bituminous coal. Distinguished from lignite by higher carbon and lower moisture content.

SULFUR DIOXIDE OR SO_2. A colorless gas formed when sulfur oxidizes, often as a result of burning trace amounts of sulfur in fossil fuels.

THERMOGENIC. Generation or production of heat, especially by physiological processes.

TOTAL DISSOLVED SOLIDS (TDS). The dry weight of dissolved material, organic and inorganic, contained in water and usually expressed as parts per million (ppm).

TRANSMISSION LINE. A large diameter pipeline through which oil or gas moves off lease after being sold.

TURBIDITY. An interference to the passage of light through water due to insoluble particles of soil, organic material, micro-organisms, and other materials.

UNDERGROUND INJECTION CONTROL PROGRAM. A program administered by the Environmental Protection Agency, primacy State, or Indian Tribe under the Safe Drinking Act to ensure that subsurface emplacement of fluids does not endanger underground sources of drinking water.

UNITIZATION. Pooling of mineral acreages proposed by a company to facilitate the efficient development of a reservoir based on geology and reservoir characteristics of a producing formation or formations.

VIEWSHED. Landscape that can be directly seen under favorable atmospheric conditions, from a viewpoint or along a transportation corridor.

VITRINITE. A kind of naturally occurring glass which is very hard.

WATER QUALITY. The chemical, physical, and biological characteristics of water with respect to its suitability for a particular use.

WATERSHED. All lands which are enclosed by a continuous hydrologic drainage divide and lie upslope from a specified point on a stream.

WELL COMPLETION. See **completion**.

WELL LIFE. For the purposes of this plan the well life is defined as from the time the well is drilled until the final abandonment of the well is approved.

WETLANDS. Permanently wet or intermittently flooded areas where the water table (fresh, saline, or brackish) is at, near, or above the soil surface for extended intervals; where hydric wet soil conditions are normally exhibited, and where water depths generally do not exceed two meters.

WILDERNESS STUDY AREA (WSA). An area determined to have wilderness characteristics. WSAs are submitted to the President and Congress for wilderness designation. These areas are an interim designation, valid until either designated as wilderness or released to multiple-use management.

WORKOVER. To perform one or more remedial operations on a producing or injection well to increase production. Deepening, plugging back, pulling, and resetting the liner are examples of workover operations.

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