U.S. Department of the Interior
Bureau of Land Management
Kemmerer Field Office, Wyoming
January 2004

Kemmerer Field Office Planning Area

Mineral Assessment Report

It is the mission of the Bureau of Land Management to sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations.

MINERAL ASSESSMENT REPORT

Kemmerer Field Office Planning Area

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EXECUTIVE SUMMARY

The Bureau of Land Management (BLM) Kemmerer Field Office is revising the Resource Management Plan (RMP). As part of the RMP revision process, the BLM is required to prepare a Mineral Assessment Report providing specific information regarding mineral occurrences and development potential within the Kemmerer Planning Area. The information will be incorporated into the RMP and the Environmental Impact Statement (EIS) for the RMP revision.

In November 2000, Congress passed the Energy Policy and Conservation Act Amendments (EPCA) that directed the Secretary of the Interior to conduct an inventory of oil and natural gas resources beneath federal lands. The inventory was to identify: United States Geological Survey (USGS) reserve estimates of oil and gas resources underlying these lands; and 2) the extent and nature of restrictions or impediments to the development of those resources (Department of the Interior [DOI] et al. 2003). The report of the inventory reviewed federal oil and gas resources and constraints on their development in five basins in the Interior West, including the Southwestern Wyoming Province, a portion of which lies within the Kemmerer Planning Area. EPCA report results for the Southwestern Wyoming Province were used in preparation of this mineral assessment report.

The Kemmerer Planning Area is in the southwestern corner of Wyoming and includes most of Lincoln and Uinta counties, a small portion of Sublette County, and the western part of Sweetwater County. The BLM Field Office manages 1.4 million acres of public land and 1.6 million acres of federal mineral estate. Minerals within the Kemmerer Planning Area are classified into three major categories: leasable minerals (e.g., oil and gas, coalbed natural gas [CBNG]; coal, and trona); locatable minerals (e.g., uranium, bentonite, and precious metals and gems); and salable minerals (e.g., common varieties of sand and gravel, and clay).

Future mineral development in the Kemmerer Planning Area is influenced by the price of commodities, management, laws, and regulations. With all commodities, whether they are locatable, leasable, or salable, the level of resource potential can be difficult to predict, even with extensive geological studies. The potential demand and value of hydrocarbon resources is likely to stay above other leasable, locatable, or salable minerals. Other locatable and salable resources are likely to experience a steady growth rate, which could mirror the growth rate of Wyoming's economy.

The majority of the Kemmerer Planning Area is considered by the BLM to have very low potential for oil and gas resources. An area of moderate oil and gas potential is located in the eastern part of the planning area in Uinta, Lincoln, and Sweetwater counties. A smaller area of moderate potential occurs in Uinta and Lincoln counties in the southwestern part of the planning area. CBNG potential is also estimated to be limited. Areas with a low potential for CBNG resources are concentrated in the central portion of the planning area near the eastern edge of the Overthrust Belt. Two additional low-potential areas have been identified in the Southwestern Wyoming Province, which includes the Green River Basin portion of the planning area. The Kemmerer coal mines are expected to continue to serve the local market, mainly due to existing coal supply agreements. One or two coal exploration permits for on-lease exploration are anticipated during the life of the RMP. No off-lease exploration licenses are expected. There is one coal lease application for a new mine north of Evanston.

Existing conventional underground trona mining is expected to continue with a potential expansion involving underground solution mining around the year 2008. No new federal sodium leasing within the Known Sodium Leasing Area (KSLA), or prospecting permits outside the KSLA are expected during the life of the plan. No prospecting permits or lease applications for phosphate or geothermal are anticipated. Oil and gas fields in the vicinity of the planning area are expected to continue to produce carbon dioxide, which will be processed at a plant site in the planning area. Carbon dioxide flooding projects in oil fields in eastern Wyoming are expected to increase the demand for this product. Production of recovered sulfur from gas plants in the planning area is expected to continue its steady growth to meeting air quality requirements and to supply a steady North American sulfuric acid market.

Although bentonite is known to occur in the Kemmerer Planning Area, there has been no commercial production there. Coal withdrawals prevent bentonite mining claims in certain areas, and some of the bentonite is of minor economic significance. A fireclay exploration program was conducted on public land, but the deposit was determined to be unsuitable for commercial use. The planning area has had little development of gemstones, and little production is expected in the future. Although there are small deposits of metals in the planning area, there have been no economically significant discoveries and very little activity is anticipated during the life of the RMP.

Aggregate (sand and gravel) demand is expected to remain high. Current production and demand for building stone and moss rock is expected to continue. Substantial commercial limestone or sandstone production in the planning area is not expected.

No recommendations or stipulations for minerals management have been developed at this time. Appropriate recommendations relating to management of the future mineral resource development within the Kemmerer Planning Area will be developed during the RMP process.

1.0 INTRODUCTION

1.1 Purpose of Report

The Bureau of Land Management (BLM) Kemmerer Field Office is revising their Resource Management Plan (RMP). As part of the RMP revision process, the BLM is required to prepare a Mineral Assessment Report providing specific information regarding mineral occurrences and potential within the Kemmerer Planning Area. This report provides an intermediate level of detail for mineral assessment as prescribed in BLM Manual 3031. The information will be incorporated into the revised RMP and the Environmental Impact Statement (EIS) for the RMP revision.

In November 2000, Congress passed the Energy Policy and Conservation Act Amendments (EPCA) of 2000 that directed the Secretary of the Interior, in consultation with the Secretaries of Agriculture and Energy, to conduct an inventory of oil and natural gas resources beneath federal lands. The inventory was to identify: 1) United States Geological Survey (USGS) reserve estimates of oil and gas resources underlying these lands; and 2) the extent and nature of restrictions or impediments to the development of those resources (Department of the Interior [DOI] et al. 2003). In late 2001, Congress indicated that the study should be considered a top priority for the DOI.

The DOI report of the inventory reviewed federal oil and gas resources and constraints on their development in five basins in the Interior West including the Southwestern Wyoming Province, a portion of which lies within the Kemmerer Planning Area. The basins reviewed contain most of the onshore natural gas and much of the oil under federal ownership within the contiguous 48 states (DOI et al. 2003). Since EPCA requires that all onshore federal lands be inventoried, the inventory will be expanded in the future to include additional areas of federal energy resources.

For federal public land managing agencies such as the BLM, this inventory is intended to serve primarily as a planning tool that provides land managers with additional information to help them develop management plans for the lands under their jurisdiction (DOI et al. 2003). It allows them to identify areas of high oil or gas potential and to evaluate the effectiveness of available stipulations in balancing the responsible development of those resources with the protection of other valuable resources in the area. The federal lands inventory also allows resource managers to identify areas of low oil and gas potential but high potential for other resources or uses (e.g., wildlife or recreation). The report is a critical step in evaluating whether existing rules are appropriate, or need to be changed, either to provide greater protection to the environment or to promote appropriate resource development (DOI et al 2003). EPCA report results for the Southwestern Wyoming Province were used in preparation of this mineral assessment report.

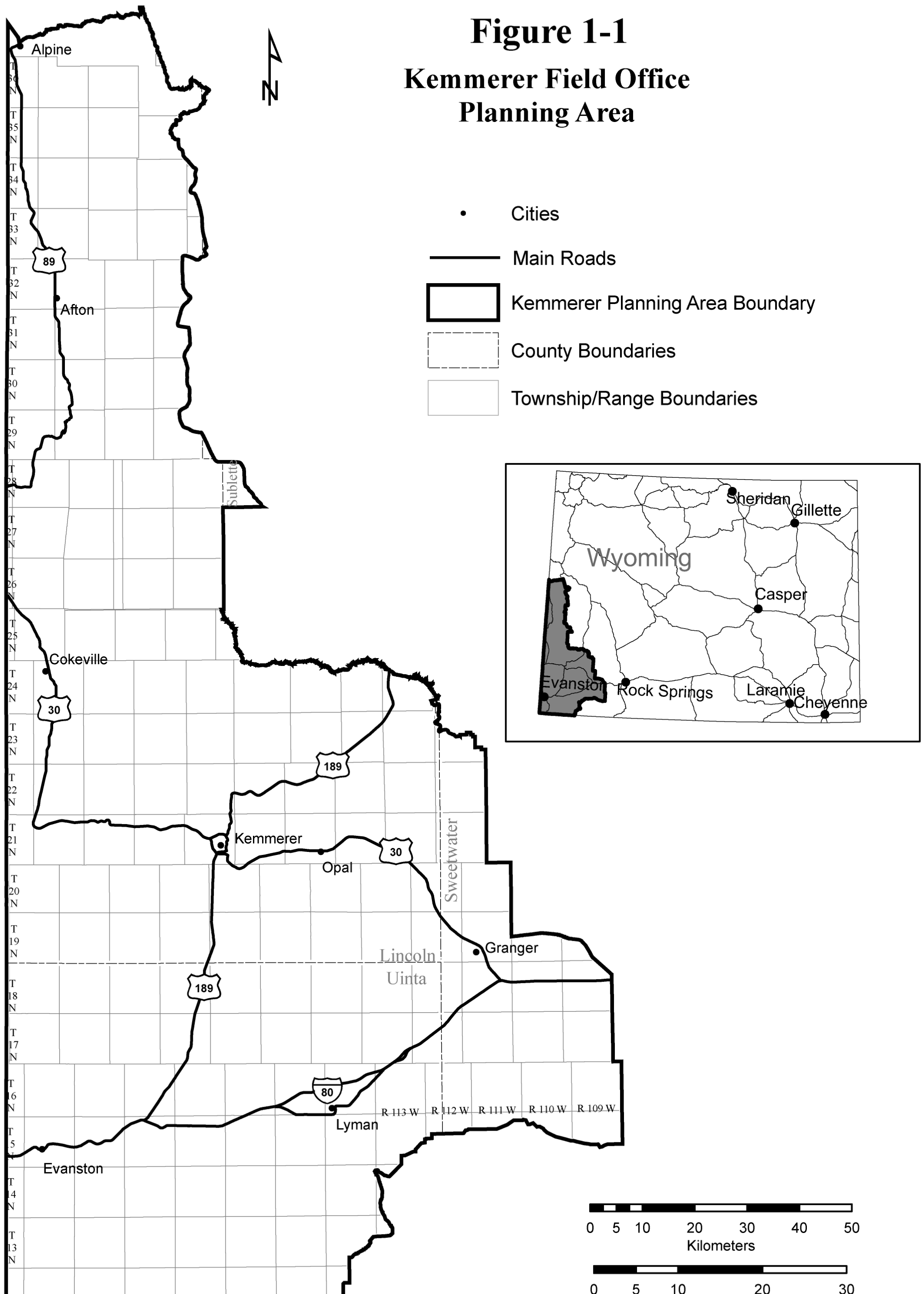
This Mineral Assessment Report is organized into six chapters and three appendices. Chapter 2.0 summarizes geological resources as they relate to the development and use of leasable, locatable, and salable minerals in the planning area. Subsections include physiography, stratigraphy, and structural geology and tectonics. Chapter 3.0 describes the leasable, locatable, and salable mineral resources of the planning area. Chapter 4.0 discusses the mineral resource potential of the Kemmerer Planning Area. Chapter 5.0 provides recommendations developed by BLM staff regarding future development of leasable, locatable, and salable minerals. Chapter 6.0 lists references used in development of the report. Appendix A provides a description of oil and gas operations procedures. Appendix B lists oil and gas lease stipulations for the planning area. Appendix C lists data sources used in the preparation of the report figures.

1.2 Lands Involved and Record Data

The Kemmerer Planning Area is in the southwestern corner of Wyoming and includes portions of Lincoln, Uinta, and Sublette counties, and the western part of Sweetwater County. The office manages 1.4 million acres of public land and 1.6 million acres of federal mineral estate. There are approximately 832,492 BLM-administered acres in Lincoln County; 184,143 acres in Sweetwater County; and 404,785 acres in Uinta County. Within the planning area border, land is also managed by the United States Forest Service (USFS), the National Park Service, the Bureau of Reclamation, the State of Wyoming, and by private landowners. Figure 1-1 is a map of the Kemmerer Planning Area.

Information sources for this mineral report were obtained from the BLM, the Wyoming State Geological Survey (WSGS), the Wyoming Oil and Gas Conservation Commission (WOGCC), the USGS, industry reports, personal communication with BLM resource specialists, and a variety of other sources listed in detail in the reference section. Reasonably Foreseeable Development (RFD) scenarios for oil and gas in the Kemmerer Planning Area are expected to be prepared later in 2004 and are therefore not included in this report.

Figure 1-1
Kemmerer Field Office Planning Area



2.0 GEOLOGY

2.1 Physiography

The Kemmerer Planning Area lies within the Northern Great Plains and Northern Rocky Mountain physiographic provinces (Figure 2-1) and includes portions of the Wyoming Overthrust Belt and the Green River Basin, both of which contain important mineral resources. The Overthrust Belt covers approximately the western half of the planning area and the Green River Basin occupies the central and eastern planning area. The rugged topography of the Overthrust Belt consists predominantly of north-south trending ridges. The Green River Basin is a complex of structural depressions separated by uplifts and ridges. It is bounded on the west by the Wyoming Overthrust Belt.

The primary mountains in the area include the Salt River Range, located in the northern section of Lincoln County, and the Uinta Mountains, which extend into the southern end of Uinta County. Steep slopes and north-south trending hogback ridges characterize the central part of the planning area, with elevations reaching around 2,500 to 3,000 feet above the surrounding landscape. The planning area covers portions of three watersheds including the Green River, the Bear River, and the Snake River watersheds. The majority of the area is sagebrush steppe and receives fewer than 6 to 10 inches of precipitation per year (1941 to 1990).

2.2 Stratigraphy, Structural Geology, and Tectonics

The Overthrust Belt is part of a zone of intense structural deformation extending from Canada to Mexico, including all of the western part of the Kemmerer Planning Area. Figure 2-2 depicts the location of the Overthrust Belt in the planning area. Deformation occurred during late Jurassic, Cretaceous, and Paleocene geologic time, when a series of north-south-trending thrust faults

developed that resulted in displacement and folding of a thick wedge of accumulated Paleozoic and Mesozoic sediments. During the late Cretaceous period, a structural basin began forming within the Overthrust Belt. The basin, now called Fossil Basin, received a wide variety of continental and lacustrine sediments. The Overthrust Belt contains many coal-bearing formations including three north-south trending belts: the Frontier formation (Late Cretaceous), the Adaville formation (Late Cretaceous), and the Evanston formation (Late Cretaceous-Paleocene). These are located immediately east and west of the town of Kemmerer, and north and south of Evanston, Wyoming. The rugged topography of the Overthrust area has complicated the extraction of mineral resources, particularly coal and oil and gas. Figure 2-2a is a geology map of the Kemmerer Planning Area. Figure 2-3 shows the stratigraphic nomenclature of the Overthrust Belt.

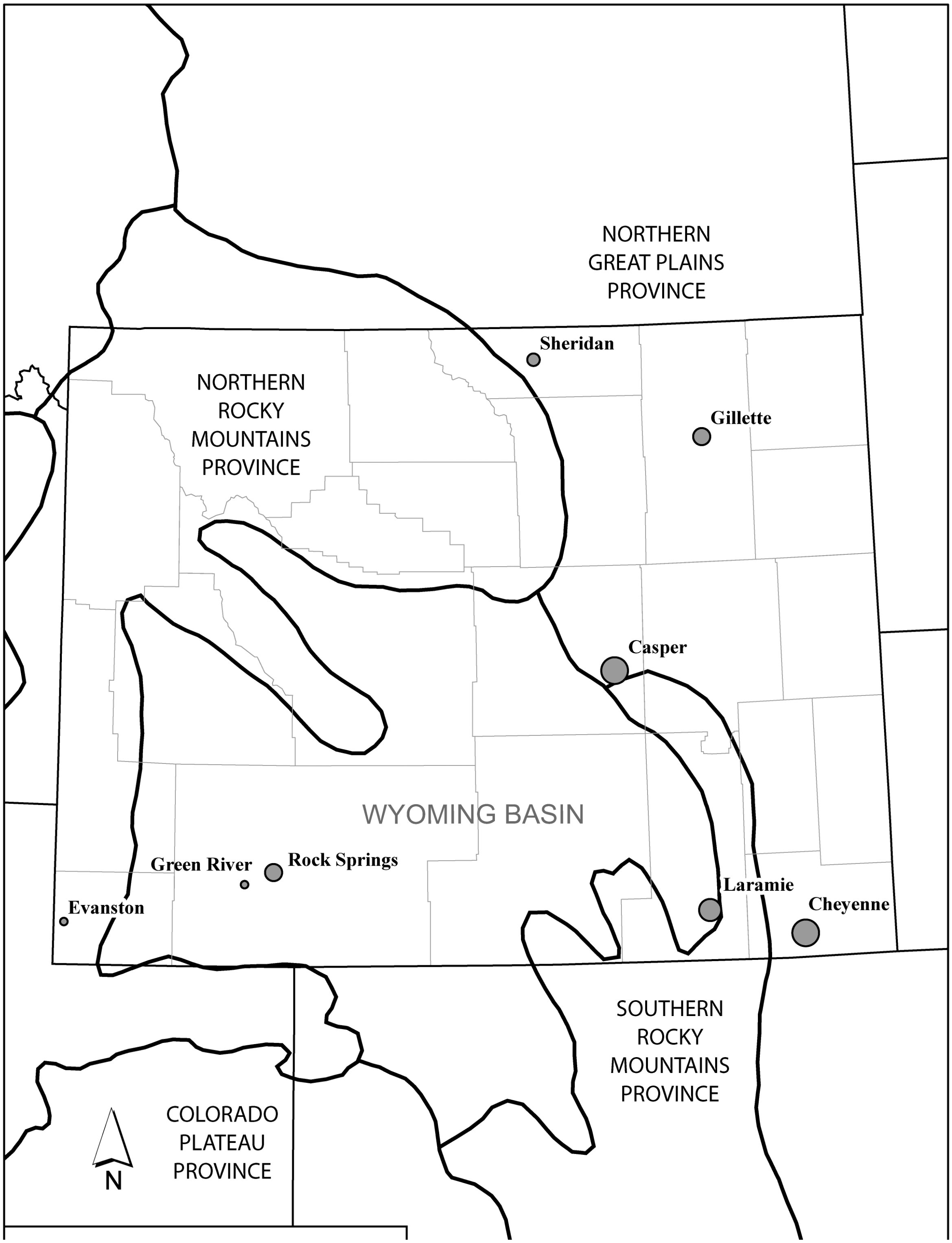
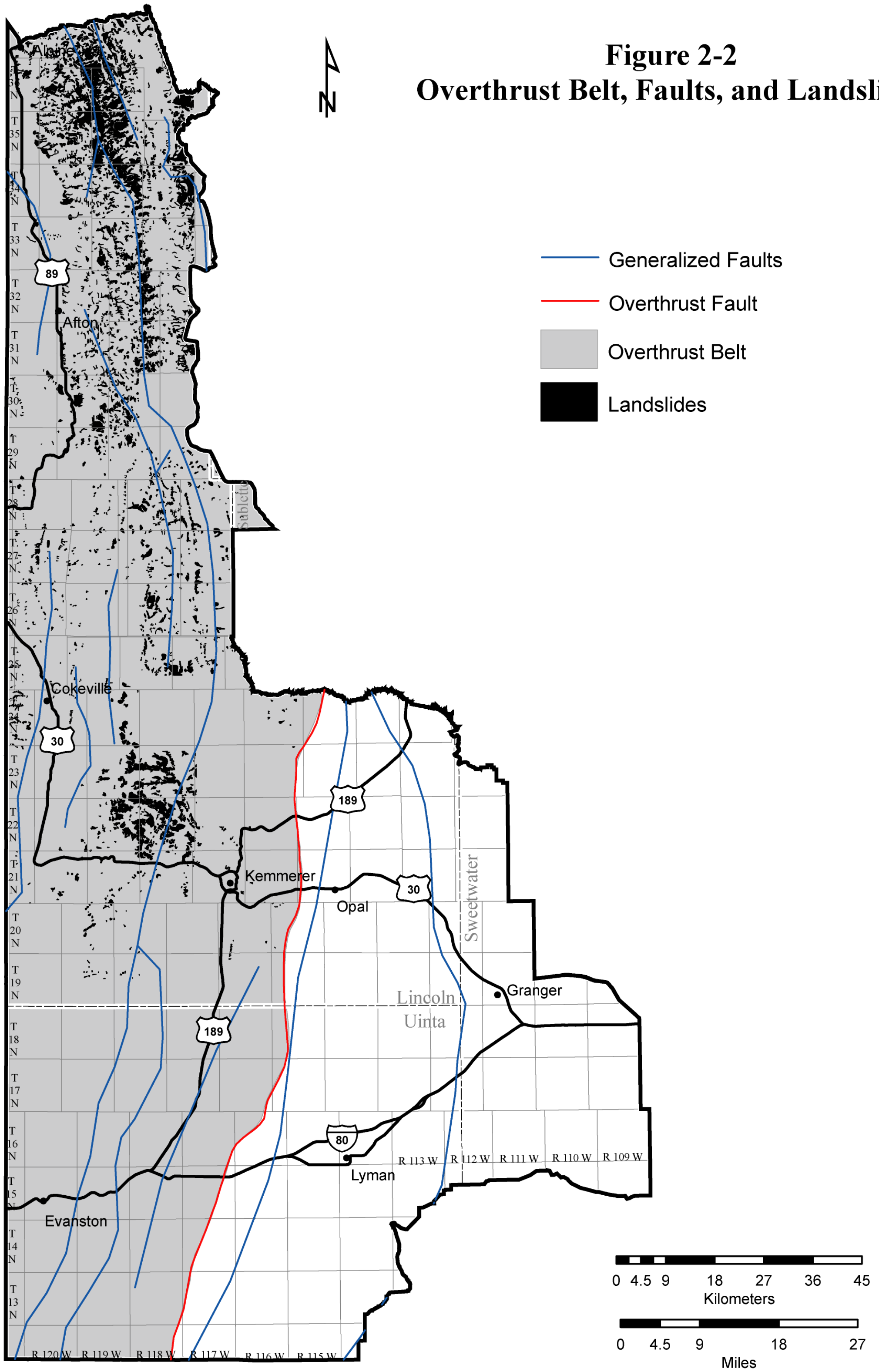


Figure 2-1. Wyoming Physiographic Provinces

Figure 2-2
Overthrust Belt, Faults, and Landslides

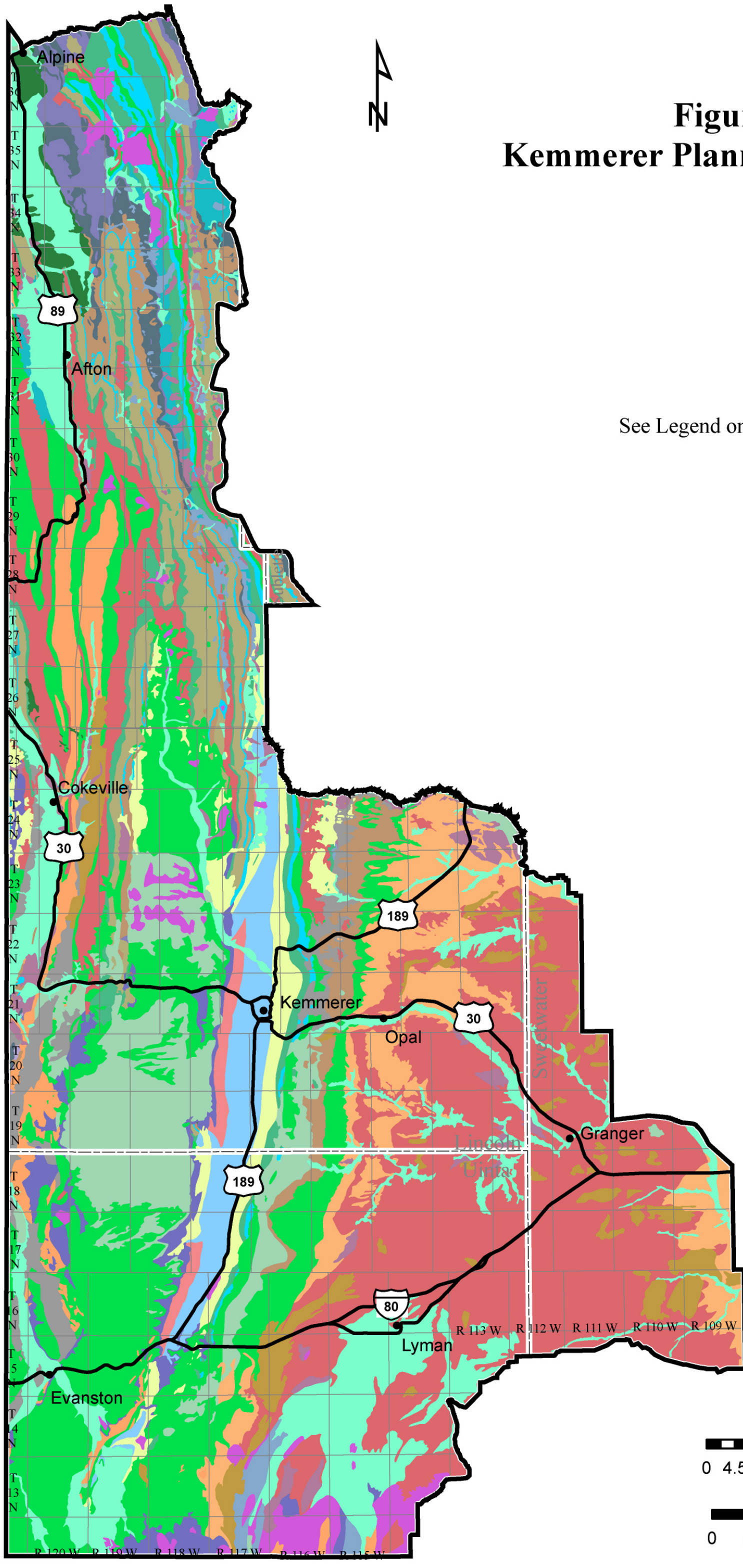


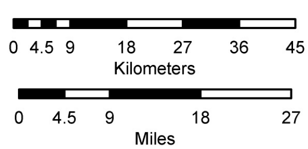
Bedrock Geology

- Adaville formation
- Alluvium and colluvium
- Ankareh formation, Thaynes limestone, Woodside shale, and Dinwoody formation
- Aspen shale
- Bear River formation
- Bighorn dolomite, Gallatin limestone, GrosVentre formation, and Flathead sandstone
- Bishop conglomerate
- Blind Bull formation
- Bridger formation
- Conglomerate of Sublette range
- Dune sand and loess
- Evanston formation
- Fowkes formation (Pliocene? and Eocene)
- Frontier formation
- Gannett group
- Glacial deposits
- Gravel, pediment, and fan deposits
- Green River and Wasatch formations
- Green River formation: Laney member
- Green River formation: Wilkins Peak member
- Hilliard shale
- Intrusive and extrusive igneous rocks
- Laketown Dolomite
- Landslide deposits
- Madison limestone and Darby formation
- Madison limestone or group
- Madison limestone, Darby formation, Bighorn dolomite, Gallitin Limestone, GrosVentre formation and Flathead sandstone
- Nuggest sandstone and Chugwater and Dinwoody Formations
- Nugget sandstone
- Phosphoria formation and related rocks
- Phosphoria, Wells, and Amsden formations
- Sage Junction, Quely, Cokeville, Thomas Fork, and Smiths formations
- Salt Lake Formation
- Stump formation, Preuss sandstone or redbeds, and Twin Creek limestone
- Teewinot formation, Central Jackson Hole
- Terrace gravel (Pleistocene and/or Pliocene)
- Undivided surficial deposits
- Wasatch and Green River formations: New Fork tongue of Wastach and Fontenelle tongue or member of Green River
- Wasatch formation, diamictite and sandstone
- Wasatch formation, main body
- Wasatch formation: La Barge and Chappo members
- Wastach Formation: Cathedral Bluffs tongue
- Water
- Wayan and Smiths formation
- Wells and Amsden formations

Figure 2-2a
Kemmerer Planning Area Geology

See Legend on Facing Page





AGE		FORMATION OR GROUP	
TERTIARY		Green River Formation	
TERTIARY		Wasatch Formation	
TERTIARY		Evanston Formation	
CRETACEOUS	Late	Adaville Formation	
CRETACEOUS	Late	Hilliard Formation	
CRETACEOUS	Late	Frontier Formation	
CRETACEOUS	?	Aspen Shale	
CRETACEOUS	Early	Bear River Formation	
CRETACEOUS	Early	Gannett Group	
JURASSIC		Stump Formation	
JURASSIC		Preuss Sandstone	Preuss Redbeds (salt)
JURASSIC		Twin Creek Limestone	
		Nugget Sandstone	
TRIASSIC		Ankareh Formation	
TRIASSIC		Thaynes Formation	
TRIASSIC		Woodside Formation	
TRIASSIC		Dinwoody Formation	
PERMIAN		Phosphoria and Park City Formations	
PENNSYLVANIAN		Wells Formation	Tensleep Sandstone
PENNSYLVANIAN		Amsden Formation	
MISSISSIPPIAN		Madison Group	Mission Canyon Limestone
MISSISSIPPIAN		Madison Group	Lodgepole Limestone
DEVONIAN		Darby Formation	Three Forks Formation
DEVONIAN		Darby Formation	Jefferson Formation
ORDOVICIAN		Bighorn Dolomite	
CAMBRIAN		Gallatin Formation	
CAMBRIAN		Gros Ventre Formation	
CAMBRIAN		Flathead Sandstone	
PRECAMBRIAN		Precambrian rocks	

Figure 2-3. Stratigraphic Nomenclature, Overthrust Belt

The Green River Basin was formed as a structural depression during the late Cretaceous period as a result of crustal downwarping. The basin filled with sediments from surrounding mountain ranges, including the Uinta, the Wind River, and the Overthrust Belt. During the continued downwarping of the Green River Basin in Eocene time, Lake Gosiute, a large inland lake formed. It lasted four to eight million years, fluctuating both in size and in salinity. Trona, an evaporite mineral, was deposited over broad areas during certain stages of the lake's history, along with oil shale and uranium. The Green River Basin also contains large deposits of oil and gas. In the Kemmerer Planning Area portion of the basin, concentrations of hydrocarbons are associated with a geologic structure called the Moxa Arch, a broad arch in the subsurface running from the Uinta Mountains northward to the Big Piney-La Barge gas fields. Figure 2-4 shows the stratigraphic nomenclature of the Green River Basin. Figure 2-5 presents a generalized cross-section of the basin.

One of the most hydrocarbon-rich formations in the Green River Basin is the Cenozoic Green River formation. The Green River formation contains an estimated 244 billion barrels of shale oil in the Tipton Shale Member (early Eocene), Wilkins Peak Member (early Eocene age), and Laney Member (middle Eocene). Oil shale also occurs in thin beds (fewer than 4 feet thick) in Fossil Basin. The Wilkins Peak Member of the Green River formation includes at least 42 trona beds, occurring from 400 to 3,500 feet below the surface. In the Green River Basin portion of the planning area, coal is found in the subsurface at various depths in the Fort Union formation (Cenozoic, Tertiary period, Paleocene age) and Mesaverde formation (Cretaceous).

The phosphate-bearing Phosphoria formation is present at the surface in the Overthrust Belt in north-south trending outcrops. These outcrops are located north and west of Kemmerer, primarily in the Tunp Range, Sublette Range, and Beckwith Hills. The Phosphoria formation also is host to source rocks for oil and gas.

In the planning area, the most prolific vertebrate-bearing formations are the Bridger, Green River, and Wasatch formations. The Bridger formation has produced at least 25 families of fossil Eocene mammals and is world-renowned among paleontologists. The lacustrine deposits of the Green River formation contain some of the best-preserved vertebrate fossils in the world.

The Overthrust portion of the planning area is in the Intermountain Seismic Belt (ISB), which extends from Montana to northern Arizona. Seismic hazards result from the presence of high-angle faults in the Overthrust Belt (e.g., the Rock Creek fault), an area characterized as a moderate risk zone. Recent movement has occurred on the fault, as indicated by offset of deposits of recent age. The Rock Creek Fault may be capable of magnitude 6.5 to 7.0 earthquakes. Other faults with Quaternary movement (less than 2 million years old) in the area include the Whitney Canyon fault north of Evanston; faults near the Crawford Mountains; and the Bear Lake Fault. The Bear Lake Fault, about 10 miles west of the western edge of the Kemmerer Planning Area, produced an earthquake of magnitude 6.3 in 1884. The extent of the hazard presented by various faults depends on many factors, including the time interval between movements, and the last date of movement. Generally, the eastern half of the area within the Green River Basin is considered to be at risk for minor damage, while the Overthrust Belt is part of a moderate damage area that extends into Utah. Refer to Figure 2-2 for the location of faults within the planning area.

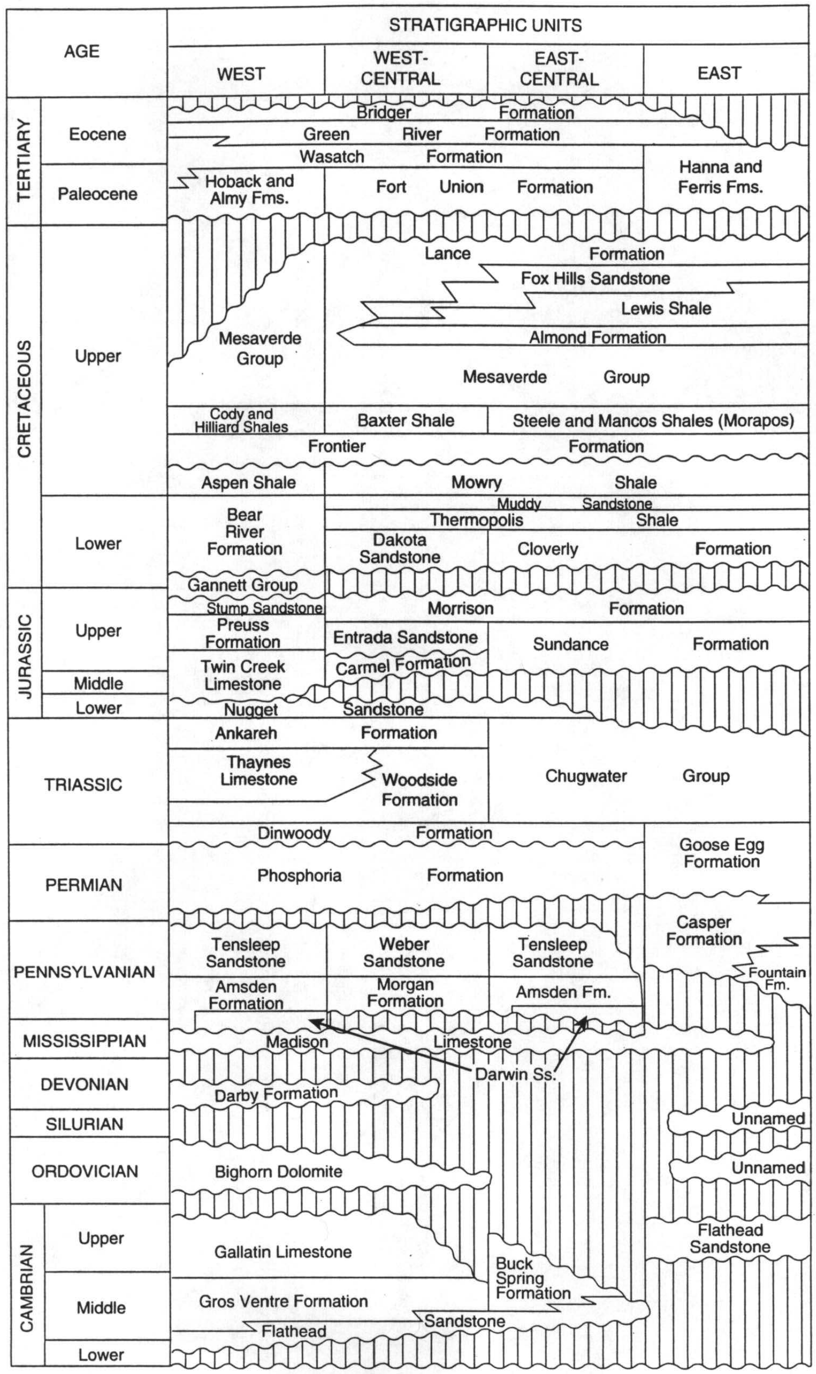


Figure 2-4. Stratigraphic Nomenclature, Green River Basin

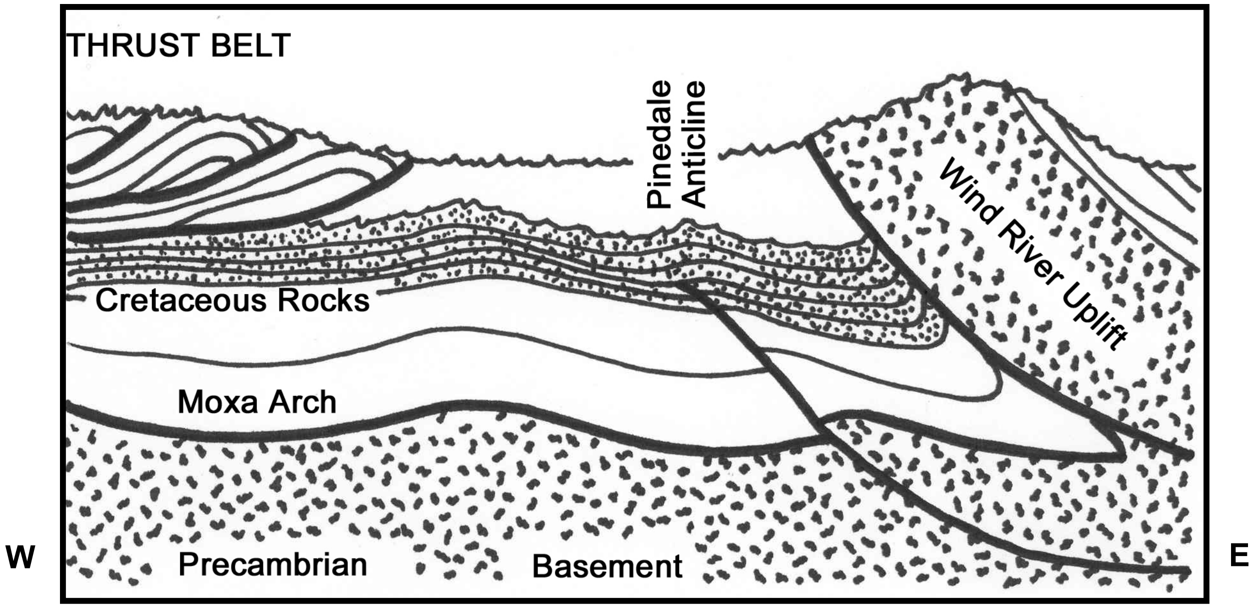


Figure 2-5. Green River Basin Cross-Section

Landslides and earth flows are common in the Overthrust Belt where steep slopes, relatively high moisture, and impermeable clay subsoils occur. The contact between the Green River and Wasatch formations is particularly susceptible to slumping. The Wasatch formation is prone to swelling and failure due to presence of bentonite clay. A massive earth flow of approximately 50 acres occurred in the Wasatch formation inside Fossil Butte National Monument west of Kemmerer. This movement caused major damage to a rail line, requiring extensive earthwork to restore service.

3.0 DESCRIPTION OF MINERAL RESOURCES

Minerals within the Kemmerer Planning Area are classified into three major categories: leasable minerals (e.g., oil and gas, coal, and trona); locatable minerals (e.g., uranium, bentonite, metals, and gems); and salable minerals (e.g., common varieties of sand and gravel and clay). This categorization is based on several laws, beginning with the *General Mining Law of 1872,* which allowed the location of placer and lode mining claims as well as patents. Specifically, the law declared "all valuable mineral deposits in lands belonging to the United States, both surveyed and unsurveyed, [are] to be free and open to exploration and purchase" (Legal Information Institute 2003).

In addition to the *General Mining Law of 1872*, a number of laws govern mineral activity in the Kemmerer Planning Area. Some of the major laws are summarized below.

- *Mineral Leasing Act of 1920* (as amended). Under this act, the BLM grants leases for development of deposits of coal, phosphate, potash, sodium, sulfur and other leasable minerals on public domain lands and on lands having federal reserved minerals (National Oceanic and Atmospheric Administration [NOAA] 2003).

- *Materials Act of 1947* (as amended). This act provides that certain mineral and vegetative materials may be disposed either through a contract of sale or a free-use permit. These types of minerals, commonly known as salable minerals, include common varieties of sand, stone, gravel, pumice, pumicite, cinders, clay, petrified wood and other mineral materials. The law also provides for free use of material by government agencies, municipalities or nonprofit organizations, if the material is not to be used for commercial purposes.

- *Mineral Leasing Act for Acquired Lands of 1947* (as amended). This law authorizes and governs mineral leasing on acquired lands. It provides that minerals subject to the *Mineral Leasing Act* that are located on acquired federal lands are subject to the federal mineral leasing system.

- *Mining and Minerals Policy Act of 1970.* This law states that it is the continuing policy of the federal government to foster and encourage private enterprise in the development of a stable domestic minerals industry and the orderly and economic development of domestic mineral resources.

- *Federal Coal Leasing Amendments Act of 1976* (FCLAA). This act amended Section 2 of the *Mineral Leasing Act of 1920* to require that all public lands available for coal leasing be offered competitively. Competitive leasing provides an opportunity for any interested party to competitively bid for a federal coal lease (BLM 2003a).

With the scattered land ownership pattern in the planning area, commercial industry has been unable to rely solely on use of public lands to meet their business needs. Mineral extraction interests have become accustomed to working with a mix of federal, state, and private lands in order to secure the rights needed to extract, transport, and process raw mineral resources. The following sections provide a description of the leasable, locatable, and salable minerals in the Kemmerer Planning Area.

3.1 Leasable Minerals

Under the *Mineral Leasing Act of 1920* (as amended), the BLM grants leases for the development of leasable minerals. Besides coal and oil and gas, leasable minerals include chlorides, sulfates, carbonates, borates, silicates or nitrates of potassium or sodium; sulfur in Louisiana and New Mexico; phosphate; asphalt; and gilsonite (43 Code of Federal Regulations [CFR] 3501.5). This law specifies royalty rates, rental rates, lease size, and terms required for each kind of leasable mineral. The law also provides for the issuance of prospecting permits prior to lease issuance and competitive bidding for certain deposits. Under the FCLAA, prospecting permits are for non-coal solid leasable minerals. Coal uses exploration licenses instead.

The BLM issues leases for solid leasable minerals other than coal in two different ways. Competitive leases are issued through a bidding process in areas where there is a known mineral deposit. Prospecting permits are issued in areas where there is not a known mineral deposit. If prospecting permittees discover a valuable mineral deposit, the permittee can obtain a preference right lease without having to bid. Before any lease is issued, the BLM considers the comprehensive land use plan and environmental concerns of the proposed activity. The BLM can lease solid minerals on public and federal lands and on certain private lands, provided that the federal government owns the mineral rights.

Leasable minerals in the Kemmerer Planning Area include: oil and gas, coalbed natural gas (CBNG), carbon dioxide, coal, phosphate, trona, oil shale, geothermal resources, and sodium chloride. The following section provides a detailed description of the leasable minerals in the Kemmerer Planning Area.

3.1.1 Oil and Gas

Wyoming has been explored for oil and gas for nearly 120 years. In 1884, the first oil well was drilled southeast of present-day Lander. During 2002, 2,734 wells were drilled and completed in the state (Petroleum Association of Wyoming [PAW] 2003). Sixty-six (2.4 percent) found oil; 2,585 (94.6 percent) found gas; and 83 (3 percent) were dry holes. Forty-four new field wildcat wells (wells drilled in unproven areas) were drilled in the state in 2002. Thirty-seven percent of these located oil or gas (PAW 2003). Wyoming ranked seventh nationally in crude oil production and second in natural gas production during 2001 (PAW 2003).

Oil and gas reserves in the Kemmerer Planning Area have been the focus of industry attention since commercial discoveries began around the year 1900. Of the 1.6 million acres of oil and gas mineral estate managed by the Kemmerer Field Office, approximately 1,071,449 acres are currently leased for oil and gas development. Figure 3-1 depicts oil and gas leases in the planning area.

Lands in the Kemmerer Planning Area are made available for oil and gas production through leasing. Based on the requirements of the *Federal Onshore Oil and Gas Leasing Reform Act of 1987*, all lands available for leasing are first offered in competitive lease sales, held at least quarterly by the BLM State Office. An Application for Permit to Drill (APD) must be filed before an operator or lessee can begin any surface-disturbing activities for an oil or gas well. If necessary, conditions of approval are developed for the application, and are used to minimize the impacts to other site-specific resource values.

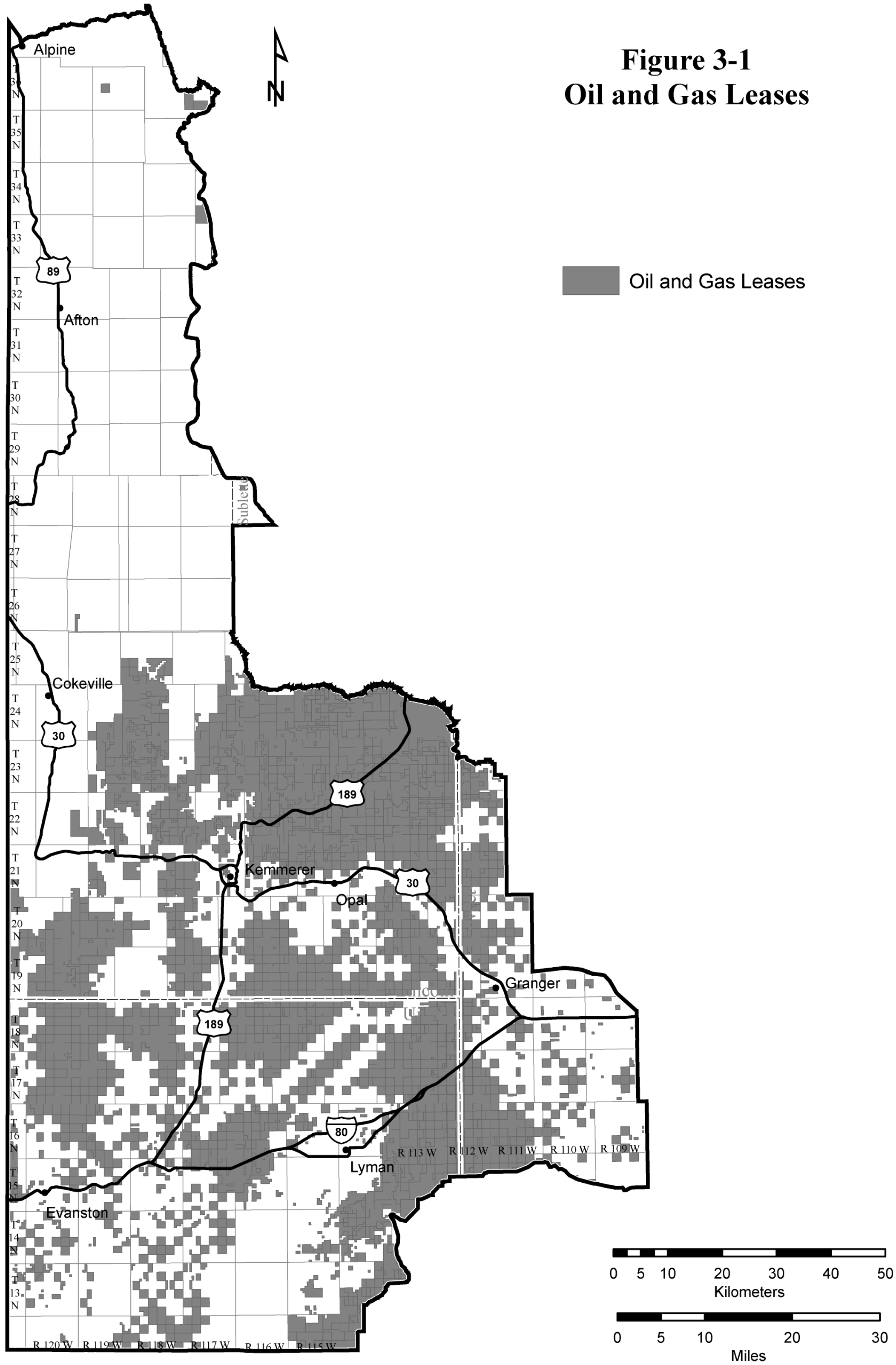


Figure 3-1
Oil and Gas Leases
Oil and Gas Leases
Alpine
Afton
Cokeville
Kemmerer
Opal
Granger
Lyman
Evanston
89
30
189
80
R 113 W
R 112 W
R 111 W
R 110 W
R 109 W
R 120 W
R 119 W
R 118 W
R 117 W
R 116 W
R 115 W
0 5 10 20 30 40 50
Kilometers
0 5 10 20 30
Miles

A combination of federal and state laws and agencies govern oil and gas operations in the Kemmerer Planning Area. Federal laws include the *Mineral Leasing Act*, *Mineral Leasing Act for Acquired Lands*, *Mining and Minerals Policy Act*, and the *Combined Hydrocarbon Leasing Act*. During the leasing and development stage of oil and gas development, the appropriate level of National Environmental Policy Act (NEPA) analysis is performed. WOGCC is the state agency responsible for oil and gas development. The Wyoming Department of Environmental Quality (DEQ) regulates surface water discharge and air emissions from oil and gas production and processing. Other water disposal methods may involve additional federal and state agencies.

3.1.1.1 Origin, Occurrence, and Trapping

Crude oil and gas consist primarily of hydrocarbon compounds found in sedimentary rocks. Petroleum hydrocarbons are thought to derive from organic matter. The largest petroleum accumulations occur in sedimentary basins with widespread organic debris. Petroleum hydrocarbons have been found closely associated with organic matter. Source rocks are generally derived from sediments rich in organic matter deposited in sedimentary basins. When the rocks are subjected to increasing temperature and pressure, they are thermally altered to form petroleum and natural gas. Hydrocarbons may mobilize and migrate away from the source rocks into more porous and permeable rocks called reservoir rocks where petroleum is held in traps (BLM 2003e).

There are three types of petroleum traps: structural, stratigraphic, and combination or unconventional (Figure 3-2). Structural traps occur as a result of folding of reservoir strata. Hydrocarbons migrate into the reservoir and are held there by less permeable rock on top of the reservoir. Structural traps also form when a reservoir is sealed by movement of a fault that places less permeable strata opposite the reservoir, or when the fault itself is the sealing agent (BLM 2003e).

Stratigraphic traps form as a result of a lateral change in the physical characteristics of the reservoir or a change in the continuity of the rocks resulting in a change in permeability. A change in permeability may also result from later alteration (diagenesis), which causes a reduction in pore sizes, decreasing the potential flow paths through the reservoir to form a barrier to petroleum migration. Combination and unconventional traps can have elements common to both structural and stratigraphic traps. Unconventional traps include fractured reservoirs, coal seams, and basin-centered gas accumulations. In the

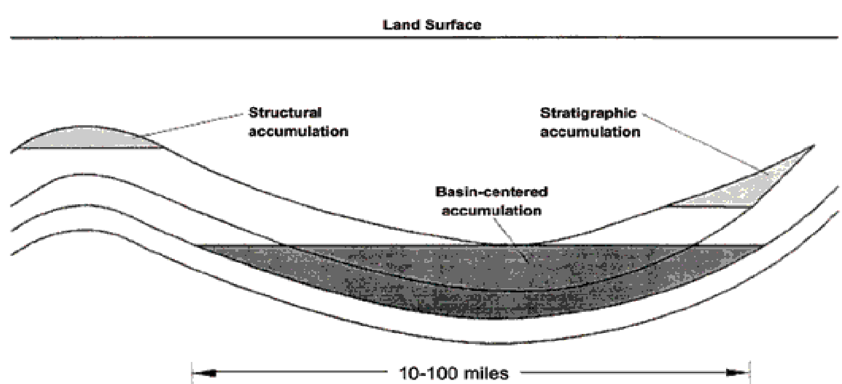


Figure 3-2. Petroleum Traps

basin-centered gas accumulation, there is no obvious seal or permeability barrier. Instead of a continuous seal, hydrocarbons are trapped in widespread low- permeability reservoirs (BLM 2003e).

Primary production is characterized by initial stages of reservoir production in which the hydrocarbons can be fairly easily moved to the well bore, either by the natural forces in the reservoir or through artificial lift (pumping). Primary recovery sometimes only recovers a fraction of the hydrocarbons originally in place in the reservoir. In order to more efficiently extract the oil as the reservoir energy is depleted, oil and gas operators conduct secondary recovery operations that involve the injection of water, gas, or steam to help push the oil to production wells. There are also tertiary recovery methods that involve the injection of miscible fluids to combine with the oil to try to move the oil to production wells (BLM 2003e).

Green River Basin. In the Kemmerer Planning Area portion of the Green River Basin, concentrations of hydrocarbons are associated with the Moxa Arch. Production in the planning area is mainly from fields located in, and adjacent to, the La Barge Platform-Moxa Arch trend (Law 1995) in eastern Lincoln and Uinta counties and western Sweetwater County. Productive reservoirs range from Cambrian through Tertiary in age and are predominantly sandstone.

Overthrust Belt. The faulted and folded strata of the Overthrust Belt contain many structural traps for hydrocarbons in the subsurface. Twenty-nine oil and gas fields have been identified in the Thrust Belt Province in traps found in three of the major thrust systems (Powers 1995). In the Kemmerer Planning Area, oil and gas production is centered in the area of Evanston and to the north, primarily in Uinta County.

3.1.1.2 Historical Development and Production

Oil and gas reserves in the Kemmerer Planning Area have been the focus of industry attention since commercial discoveries began around the year 1900 (BLM 2003a). Oil and gas production in the Green River Basin, as a whole, began with the 1916 discovery of the Lost Soldier Field (Law 1995). Oil and gas exploration of the Overthrust Belt dates to the 1890s. It has been the focus of intense exploration, including seismic and drilling programs, since the mid 1970s (BLM 2003a).

3.1.1.3 Current Development and Production

Following the discovery of Utah's Pineview field in 1975 and Ryckman Creek field in 1976, intense exploration, consisting of seismic and drilling programs, resulted in major discoveries of oil and gas in what is known as the fairway of the Overthrust Belt (BLM 2003a). An important factor in the success of oil and gas exploration in the Overthrust Belt has been the improvement in geophysical techniques and in the processing of data, enabling companies to decipher more clearly some of the very complex, deep structures in the subsurface which trap oil and gas (BLM 2003a). Oil production rose from 1.8 million barrels in 1978 to a high of 12.4 million barrels in 1985. However, since 1985, oil production has declined steadily each year, falling to 3.5 million barrels in 2002. Gas production in the Kemmerer Planning Area rose from 15 billion cubic feet in 1978, to a high of 343.5 billion cubic feet in 1995. Since 1995, gas production has declined steadily each year, falling to 251.4 billion cubic feet in 2002. Table 3-1 lists oil and gas production levels in the planning area for selected years since 1978.

Table 3-1. Oil and Gas Production, 1978 - 2002

Year	*Oil (MBBLS)*	*Gas (BCF)*
1978	1.8	15.2
1985	12.4	252.8
1995	6.5	343.5
1999	5.7	288.4
2001	4.4	269.4
2002	3.5	251.4

MBBLS – million barrels
BCF – billion cubic feet
Source: BLM 2003a

At the end of 2001, there were more than 40 active oil and gas fields in the Kemmerer Planning Area. Five of the 25 largest gas fields in Wyoming for 2001 were in the Kemmerer Field Office area (BLM 2003a). Some of the oil and gas fields in the Kemmerer Planning Area overlap with the Pinedale Field Office and/or with the Rock Springs Field Office. Figure 3-3 shows oil and gas fields in Kemmerer Planning Area. Figure 3-4 shows oil and gas wells; and Figure 3-5 shows oil and gas pipelines.

Table 3-2 lists the oil and gas industry's share of 2002 property taxes for each of the counties in the planning area. Table 3-3 presents oil and gas well status for 1970 through 2001, and for 2002 and 2003 within the Kemmerer Planning Area.

Table 3-2. Oil and Gas Industry Property Tax Share, 2002

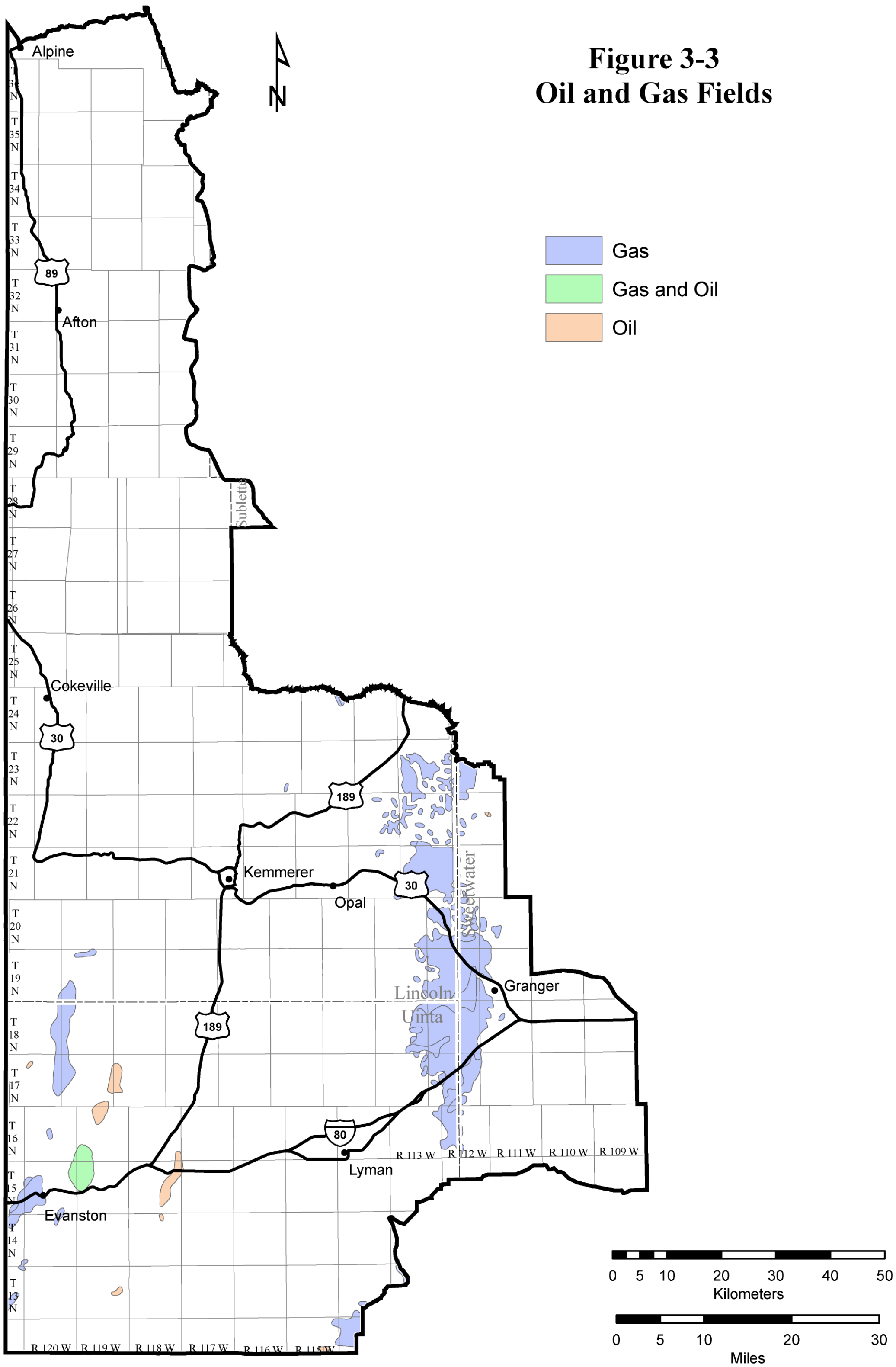
County	*Oil/Gas Share of County Property Tax*
Uinta	86.78%
Lincoln	67.88%
Sweetwater	53.26%

Source: PAW 2003

3.1.2 Coalbed Natural Gas

The presence of methane in coal seams was historically recognized as a potential hazard in coal mining (BLM 2003e). Methane was originally extracted from coal prior to mining in order to provide a margin of safety for underground coal mining. Concentrations of methane gas between 5 and 15 percent are an explosion hazard. Methane released by surface mining methods is not generally considered hazardous because, in the absence of an enclosed space, it can seldom build to an explosive concentration. Methane is a greenhouse gas and a valuable resource otherwise lost in the mining process. In the early 1980s, Congress considered CBNG to be an unconventional gas resource and enacted tax incentives for the production of the gas from coal seams. CBNG production in Wyoming now occurs for economic reasons.

Figure 3-3
Oil and Gas Fields



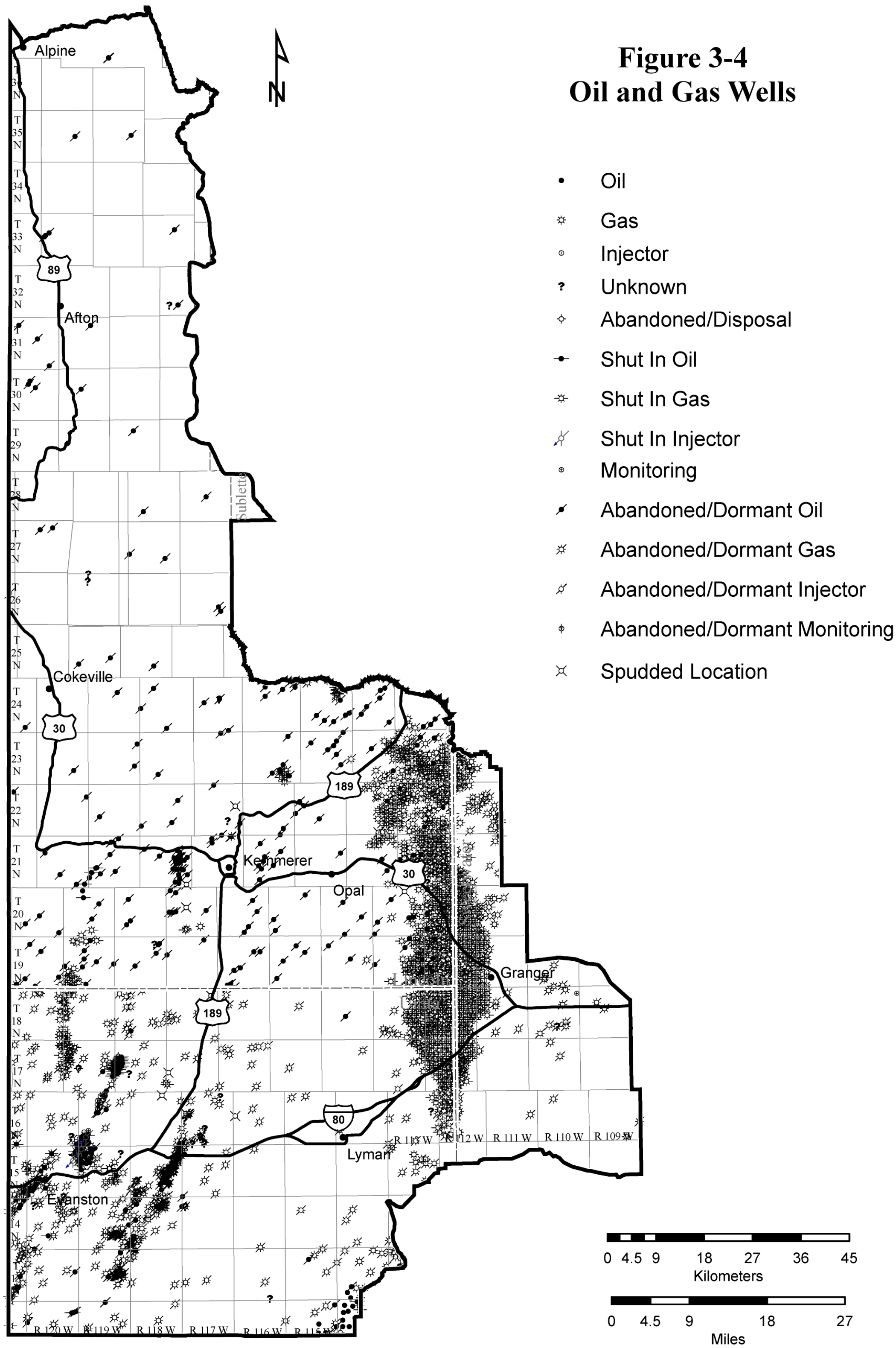


Figure 3-4
Oil and Gas Wells

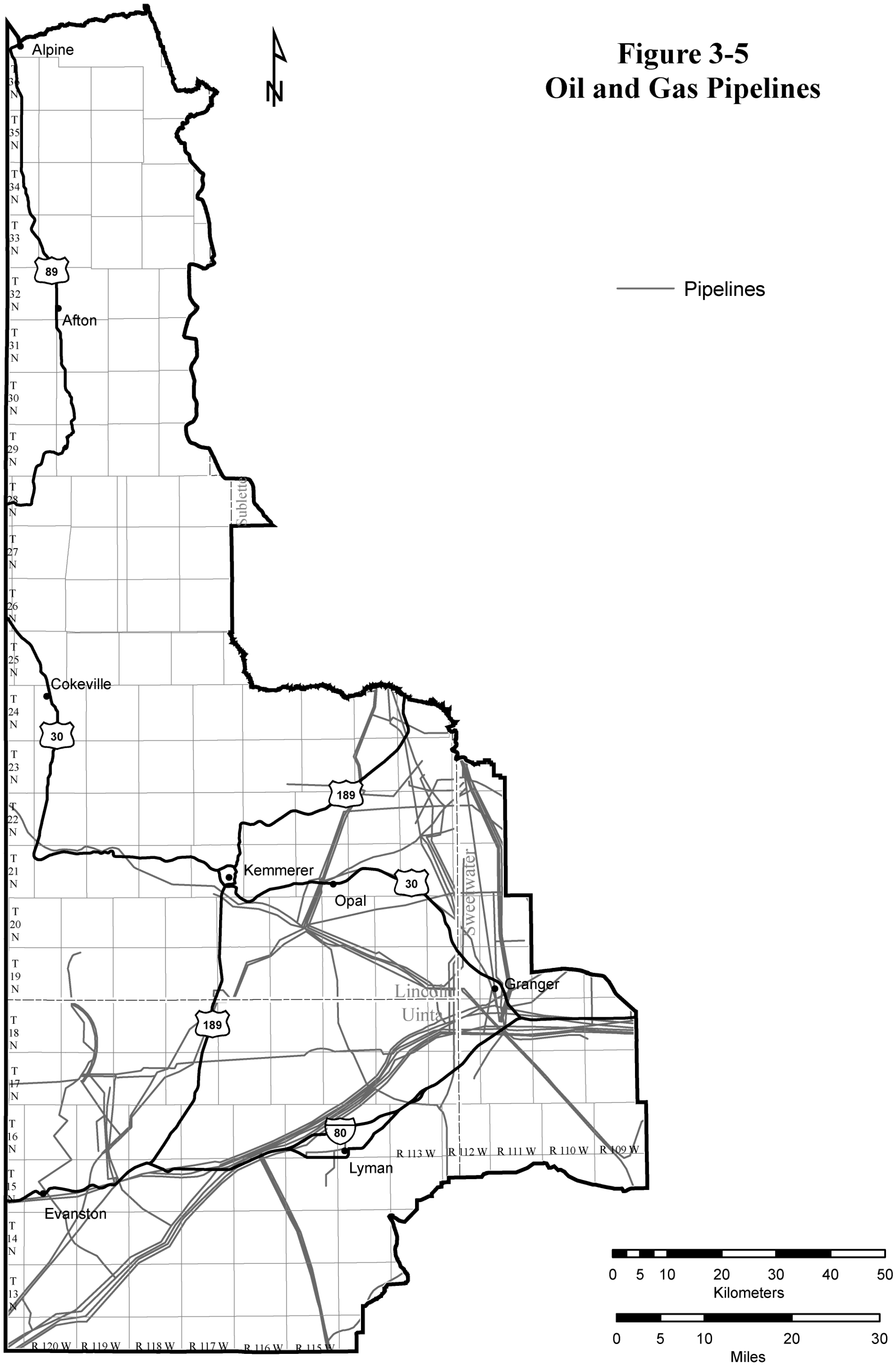


Figure 3-5
Oil and Gas Pipelines
Pipelines
Alpine
Afton
Cokeville
Kemmerer
Opal
Granger
Lyman
Evanston
Sublette
Sweetwater
Lincoln
Uinta
89
30
189
80
R 113 W
R 112 W
R 111 W
R 110 W
R 109 W
R 120 W
R 119 W
R 118 W
R 117 W
R 116 W
R 115 W
0 5 10 20 30 40 50
Kilometers
0 5 10 20 30
Miles

Table 3-3. Kemmerer Planning Area Oil and Gas Well Status, 1970 – 2003[1]

Status of Wells (1970 - 2001)				Status of Wells (2002)				Status of Wells (2003)			
	Federal	*Fee or State*	*Total*		*Federal*	*Fee or State*	*Total*		*Federal*	*Fee or State*	*Total*
Plugged and Abandoned Wells	313	349	662	Plugged and Abandoned Wells	1	0	1	Plugged and Abandoned Wells	1	0	1
Dormant Wells	13	15	28	Dormant Wells	0	0	0	Dormant Wells	0	0	0
Completed Wells	596	658	1254	Completed Wells	18	8	26	Completed Wells	8	3	11
Monitoring Wells	3	3	6	Monitoring Wells	0	0	0	Monitoring Wells	0	0	0
Notice of Intent to Abandon	17	18	35	Notice of Intent to Abandon	0	0	0	Notice of Intent to Abandon	0	0	0
Spuds	27	14	41	Spuds	8	5	13	Spuds	6	5	11
Expired Permits	293	235	528	Expired Permits	10	6	16	Expired Permits	0	0	0
Permits to Drill	46	23	69	Permits to Drill	38	21	59	Permits to Drill	25	18	43
Permits Issued	1,310	1,315	2,625	Permits Issued	75	40	115	Permits Issued	40	26	66
Waiting on Approval	0	0	0	Waiting on Approval	0	0	0	Waiting on Approval	0	0	0
Total	1,310	1,315	2,625	*Total*	75	40	115	*Total*	40	26	66

Note: 1. The sum of numbers in the top eight rows equals the sum of the numbers in rows nine and ten.

3.1.2.1 Origin and Occurrence

CBNG is a byproduct of the process that turns plant materials into coal. During coalification, methane is formed by chemical reactions in carbonaceous material. Methane formation is accelerated by high temperatures and is most plentiful in higher-rank coals. Although much of the methane generated by the coalification process escapes to the surface or migrates into adjacent rocks, some is trapped within the coal itself (DeBruin et al. 2001). The methane is stored as free gas in pores and fractures in the coal; as dissolved gas in water within the coal; or as adsorbed gas on the surface of the coal (DeBruin et al 2001). Because most coals have microfractures, or cleat, there is a great deal of surface area on which gas can be adsorbed, allowing for the storage of a much higher volume of gas than in conventional gas reservoirs (BLM 2003e).

Biogenic methane, related to bacterial activity, forms first. Generation of thermogenic methane begins at higher temperatures in the higher ranks of the high volatile bituminous coals. Maximum generation of methane from coal occurs at about 300 degrees Fahrenheit (°F). At higher temperatures and in higher ranking coals methane is still generated, but at lower volumes (DeBruin et al. 2001).

Methane gas is extracted when the hydrostatic pressure in the coal is lowered by pumping out the water. Gas extraction often involves pumping of large amounts of water in the initial stages of development. As much as 6,000 barrels of water per day have initially been produced from a single well. But once wells reach economic production, water production rates are typically substantially lower (BLM 2003e). Water quality can range from less than 200 milligrams per liter (mg/l) of total dissolved solids, to more than 90,000 mg/l. Figure 3-6 shows a CBNG well production profile.

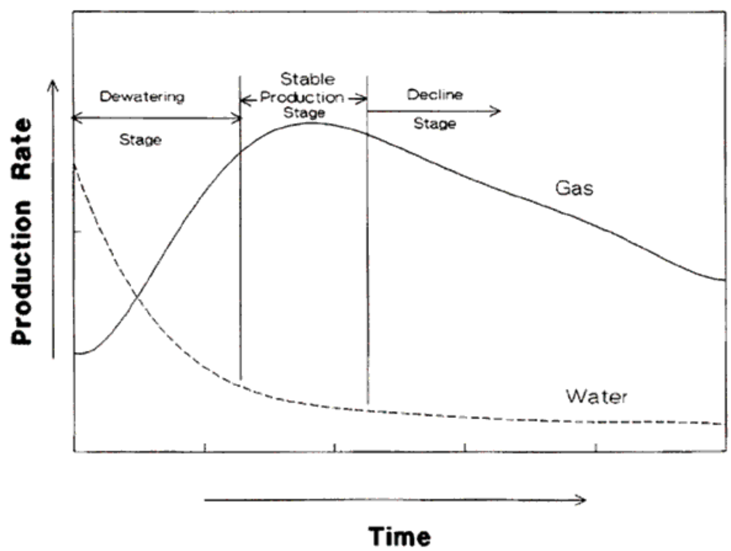


Figure 3-6. CBNG Well Production Profile

Gas storage in coalbeds is more complex than in most conventional reservoirs because coalbeds are both the source rocks and the reservoir rocks. Water flow, rock porosity, and fissures allow gas migration. Methane has been known to travel a considerable distance through roof and floor strata, but moves with difficulty through the coal seam itself (Hartman 2003). The process of CBNG extraction would be expected to draw some portion of the methane outside of the coal seam.

CBNG is stored in four ways (DeBruin et al. 2001):

1. As free gas within the micropores and cleats in the coal;

2. As dissolved gas in water within the coal;

3. As adsorbed gas held by molecular attraction on surfaces of macerals (organic constituents that comprise the coal mass), micropores, and cleats in the coal; and

4. As absorbed gas within the molecular structure of the coal.

Wyoming's coalbeds are Cretaceous and Tertiary in age. Although Cretaceous coals may attain a rank of high volatile type A bituminous coal, many are lower in rank and have not attained the thermal maturity to generate large amounts of thermogenic CBNG. However, they may contain biogenic CBNG (DeBruin et al. 2001). Tertiary coalbeds in Wyoming are generally lignite to sub-bituminous in rank. Some may be high volatile bituminous in rank when they have been deeply buried and have reached sufficient maturity for thermal generation of methane. See section 3.1.3 for information concerning coal ranking.

Exploration activity for CBNG in the Southwestern Wyoming Province as a whole has been low to moderate. Drilling activity has focused outside the planning area in the Rock Springs formation and at other locations (Law 1995). The high water content of the coal has been an obstacle to economic gas production. In addition, the gas content of the area's low rank coals is generally low (Law 1995).

3.1.2.2 Historical and Current Production

CBNG production in Wyoming has increased steadily since 1994. However, as of November 2002, WOGCC did not show CBNG production in the planning area (BLM 2003a). In 2002, several of the CBNG wells on fee or state land were inactive and new wells were awaiting completion or pipeline connections. WOGCC records in December of 2003 indicate a similar situation in the planning area. Lincoln County shows no activity on federal land. Uinta County shows six federal permits issued and six expired. Sweetwater County shows 102 permits issued and 15 spuds; however, one well is within the planning area. Table 3-4 lists the status of CBNG wells in Lincoln, Uinta, and Sweetwater as of December 12, 2003 (WOGCC 2003).

3.1.3 Coal

The BLM manages coal leasing and other administrative duties relating to coal production on federal coal lands throughout the United States (U.S.) (BLM 2003b). Wyoming has the largest federal coal program in the BLM and is the nation's largest producer of coal, with about 34 percent of the nation's coal production. Most Wyoming coal is used for steam generation in the electrical utility industry.

Coal operations within the Kemmerer and Rock Springs planning areas are managed by the BLM Mineral and Lands Group in the Rock Springs Field Office (Clawson 2003). The Minerals and Lands Group is responsible for managing all coal in the Green River Basin, the Overthrust Belt, and the Washakie Basin. If reserves were to exist there, the group would also manage coal in the Pinedale Planning Area. The group is composed of geologists, mining engineers, and environmental specialists. Its primary responsibilities include managing new leases and existing leases. A large component of the group's activity is to conduct inspections of active mines. At a minimum, all active mines are inspected on a quarterly basis and all leases inspected annually. In addition, the group carries out production verification inspections to confirm that the lessee's reported extraction values are correct. Through the preparation of environmental documents, the Kemmerer Field

Table 3-4. CBNG Well Status in Lincoln, Uinta, and Sweetwater Counties[1]

	Federal	*Fee or State*	*Total*
Lincoln County			
Plugged/Abandoned Wells	0	1	1
Dormant Wells	0	0	0
Completed Wells	0	0	0
Monitoring Wells	0	0	0
Notice of Intent to Abandon	0	1	1
Spuds	0	0	0
Expired Permits	0	1	1
Permits to Drill	0	0	0
Permits Issued	0	3	3
Awaiting Approval	0	0	0
Sweetwater County			
Plugged/Abandoned Wells	0	2	2
Dormant Wells	0	0	0
Completed Wells	16	16	32
Monitoring Wells	0	0	0
Notice of Intent to Abandon	0	0	0
Spuds	15	19	34
Expired Permits	31	33	64
Permits to Drill	40	25	65
Permits Issued	102	95	197
Awaiting Approval	3	7	10
Uinta County			
Plugged/Abandoned Wells	0	2	2
Dormant Wells	0	1	1
Completed Wells	0	1	1
Monitoring Wells	0	0	0
Notice of Intent to Abandon	0	2	2
Spuds	0	3	3
Expired Permits	6	1	7
Permits to Drill	0	4	4
Permits Issued	6	14	20
Awaiting Approval	0	0	0

Note: 1. For each county, the sum of numbers in the top eight rows equals the sum of the numbers in the bottom two rows.
Source: WOGCC 2003

Office provides input to the Rock Springs Field Office group regarding surface resources affected by coal development operations.

The Kemmerer Planning Area contains bituminous and sub-bituminous deposits. Coal begins as a buildup of carbonaceous plant matter associated with freshwater lowland swamps. The material experiences rapid burial to isolate it from oxygen. As burial becomes deeper and adjacent ground temperatures become elevated, it begins metamorphosing. As heat and pressure increase, the coal changes from peat, to lignite to sub-bituminous, to bituminous to anthracite coal; each with a higher carbon content and an increased British Thermal Unit (BTU) content up through bituminous. Generally, lignite is defined as having a heat output value of less than 8,300 BTU per pound (one BTU is the amount of heat required to heat one pound of water 1 °F. Sub-bituminous coal has a heat output value of greater than 8,300 and less than 11,500 BTU per pound. Bituminous coal has a heat output value of greater than 11,500 BTU per pound. Wyoming coal is generally all a low-sulfur coal.

Coal is classified by rank according to the Standards of the American Society for Testing Materials (ASTM). In southern Wyoming, coal quality is generally good with high BTU value and low to moderate sulfur content (MWH 2003). Detailed information regarding coal classification is provided in ASTM D-388. The classification system is summarized as follows:

I. Anthracitic
- Meta-anthracite
- Anthracite
- Semi-anthracite

II. Bituminous
- Low volatile bituminous
- Medium volatile bituminous
- High volatile "A" bituminous
- High volatile "B" bituminous
- High volatile "C" bituminous

III. Sub-bituminous
- Sub-bituminous "A"
- Sub-bituminous "B"
- Sub-bituminous "C"

Outcrops of coal-bearing formations in the planning area are confined to the Overthrust portion of the area, and occur mainly in three north-south-trending belts. Coal reserves in the Kemmerer Planning Area occur in two major regional coal fields: the Hams Fork Coal Field and the western portion of the Green River Coal Field. Coal production is currently occurring in the Hams Fork Coal Field (Pittsburgh and Midway Coal Company's [P&M] Kemmerer and Skull Point mines). Figure 3-7 depicts Wyoming coal-bearing formations. Figure 3-8 shows regional coal fields that overlap the Kemmerer Planning Area.

Primary coal reserves occur in the Adaville, Evanston, and Frontier formations. The reserves in the Adaville formation are estimated at one billion tons, based on 13 of the formation's coal seams. One seam in the Adaville exceeds 100 feet in thickness, and another 17 appear to be greater than six feet thick. The Upper Cretaceous Adaville formation consists of coal, gray sandstone, siltstone, and carbonaceous claystone. It is conglomeratic in the upper part and coal-bearing in the lower part.

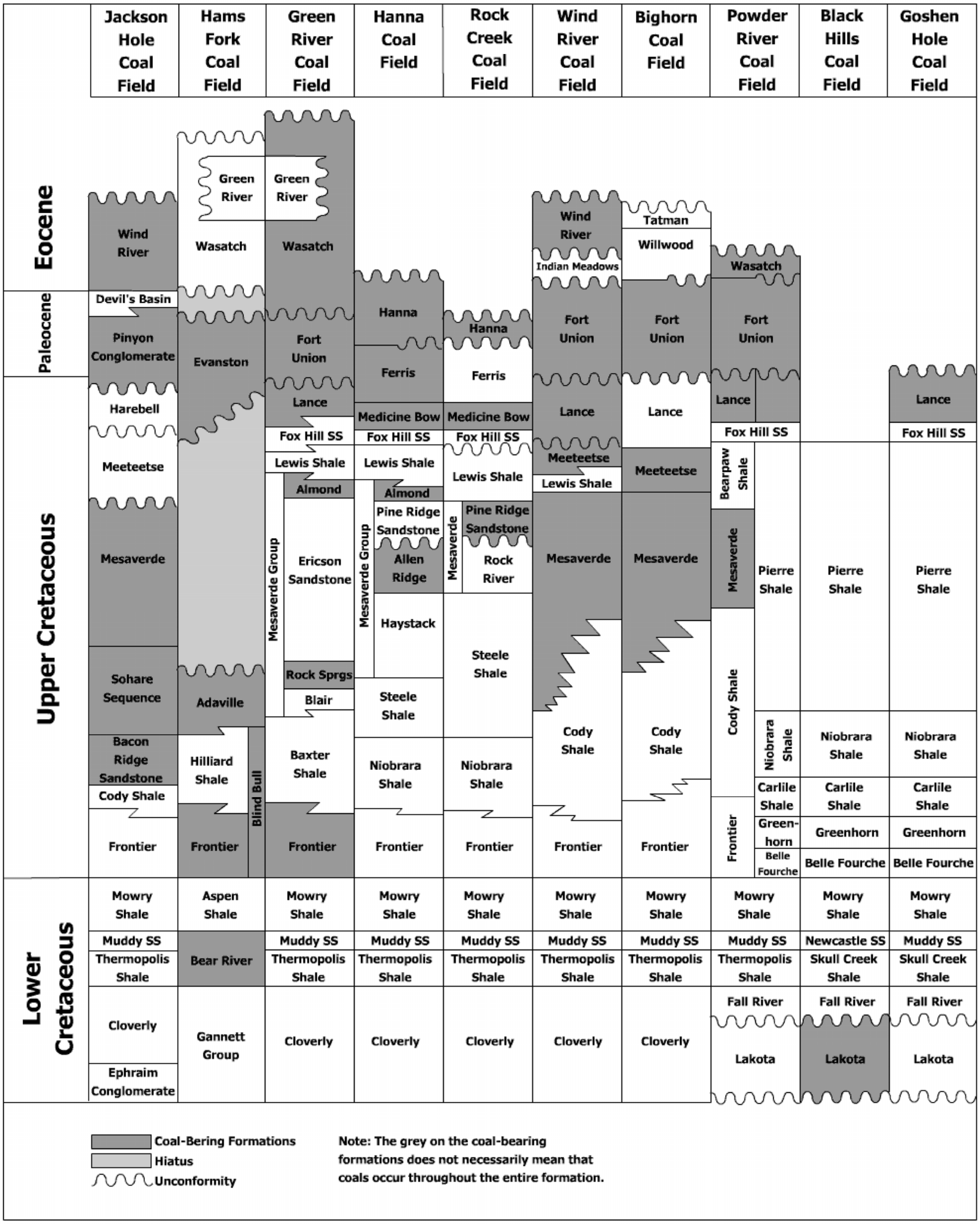


Figure 3-7. Wyoming Coal-Bearing Formations

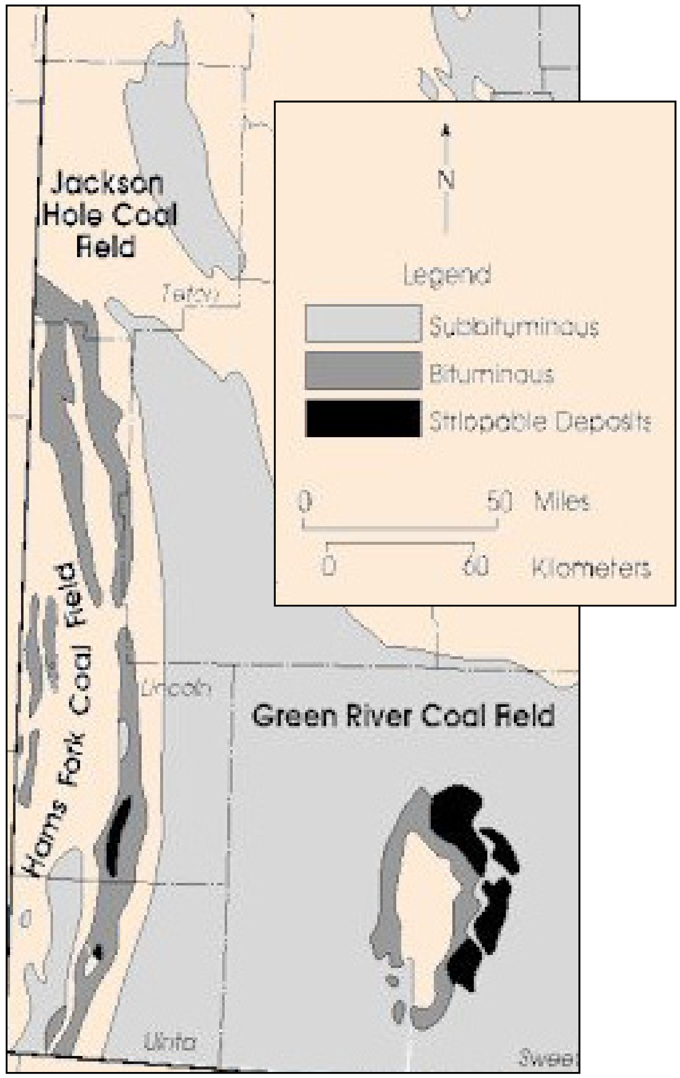


Figure 3-8. Kemmerer Planning Area Regional Coal Fields

The Adaville outcrop is in the footwall of the Absaroka Thrust sheet and on the hanging wall of the Darby Thrust sheet about 3 to 4 miles from the leading edge of the Absaroka Thrust. Generally, the thickest coals lie near the base of the coastal plain section just above the progradational marine sands of the Lazeart Sandstone. Frontier formation coals have a higher BTU value than the Adaville coals, and contain beds up to 20 feet thick.

Hams Fork Coal Field

The Hams Fork Coal Field is Wyoming's fifth largest coal region. The field extends from southwestern Teton County into Lincoln County, western Sublette County, and the western half of Uinta County (refer to Figure 3-5). It is a narrow elongate field within the Overthrust Belt of western Wyoming (Salt River and Wyoming Ranges) (University of Wyoming 2003). The Hams Fork Coal Field contains sub-bituminous and bituminous coals suitable for mining using both surface and underground methods. The Hams Fork coal region includes the Salt River Range, Greys River Coal Field, Wyoming Range, the McDougal Coal Field, and the Kemmerer Coal Field. The coal-bearing formations exposed in the Hams Fork region are the Bear River, Frontier, Adaville, and Evanston formations (BLM 2003e). Coal-bearing rocks are exposed in long, narrow parallel belts. The major coal-bearing formation in the Hams Fork Coal Field is the Adaville formation, which contains eight to 12 seams of coal that are mined on a regular basis.

The McDougal Coal Field is east of the Wyoming Range in Lincoln and Teton counties. It includes coalbeds believed to be part of the Frontier formation. The coal in this formation has not been correlated with coal zones to the south. A few widely-spaced sections, located south of the Snake River, include coalbeds that range in thickness from 1.2 to 20.0 feet; but the majority of the coalbeds are under 5 feet thick. Specific information has not been identified for the complex structure west of the Snake River where the Frontier formation occurs and is likely to be coal bearing (BLM 2003e).

The Kemmerer Coal Field is in the southern part of the Hams Fork coal region. The Kemmerer Coal Field is underlain by the Lazeart Syncline, which extends north from near the southern border of Wyoming into the Oyster Ridge and Commissary Ridge area. Coal has been mined underground from the Adaville, Frontier, and Evanston formations, although underground mining in the area ceased by 1964. Currently, surface mining is occurring in the Adaville formation, just west of the town of Kemmerer. Most past underground mining in the Kemmerer area has been in the Kemmerer Coal Zone, in the Frontier formation. The other coal zones are the Willow Creek (near the middle of the formation) and the Spring Valley (near the base of the formation). Within the Frontier formation, the Kemmerer Coal Zone is situated above the Oyster Ridge Sandstone Member. Underground Mmines near the town of Kemmerer exploited the main Kemmerer coalbed, which ranges from 5 to 20 feet thick, dipping approximately 15 to 25 degrees to the west. Most coalbeds in the Frontier formation are greater than 3 feet in thickness, with a few being more than 10 feet thick(BLM 2003e).

Green River Coal

The Green River Coal Field is the largest in Wyoming, with 16,800 square miles containing more than 1.46 trillion tons of coal. The far western edge of this coal region overlaps the eastern portion of the Kemmerer Planning Area. However, coal deposits in the Green River coal region portion of the planning area are buried by younger formations, and no surface or underground mining of those coalbeds has occurred in the planning area. The only named coal field in the western portion of the Green River Basin is the La Barge Ridge field in portions of Lincoln and Sublette Counties, outside the planning area .

3.1.3.1 Historical Production

The presence of coal in the Green River region was the primary factor for Union Pacific Railroad's (UPRR's) decision to build a rail line through southern Wyoming in the 1860s (State of Wyoming 2001). The railway created a demand for coal, as well as the means for conveying it to other regions. By the end of 1868, the railroad had reached as far west as Evanston (State of Wyoming 2001). Coal was discovered on Hams Fork, near Kemmerer, in 1868 (State of Wyoming 2001). High quality coal was known to be in the area based on federal surveys in 1874. Hams Fork Coal Company (later the Diamond Coal and Coke Company, a subsidiary of Anaconda Copper Company) was established during this time (Wyoming Tails and Trails 2003). Coal mining began near Kemmerer when UPRR opened a mine at Twin Creek in 1881, and completed a spur track to Kemmerer in 1885 (Kemmerer 2003). However, mining did not begin in earnest until 1897 when the Kemmerer Coal Company was founded. After trains switched to diesel engines in the 1950s, most coal mines shut down. Open pit mining began in 1963 (University of Wyoming 2003).

3.1.3.2 Current Production

Current federal coal production in the Kemmerer Planning Area is centered in Lincoln County west of Kemmerer. Figure 3-9 shows the location of current coal leases and Wyoming DEQ coal mining permit boundaries. The only production from the Hams Fork Coal Region is within the Kemmerer Planning Area. The fields are characterized by coal reserves ranging from 9,000 to 11,000 BTU/pound and 0.4 percent to 0.9 percent sulfur. The reserves are characterized by steeply dipping seams that have been mined by underground methods in the past, but are currently only mined using surface methods. The relatively thin and divided nature of the seams and the steep dip results in higher mining costs for these seams. The major surface mining company is the P&M, which operates a mine west of Kemmerer. P&M has a total of 8,679 acres of federal coal leases, produced 4.5 million tons of coal in 2001 and has a planned production of 4.5 to 5 million tons per year in the near future. This coal is produced from multiple seams in the Adaville formation. The coalbeds dip about 20 degrees and the coal is extracted using truck and shovel surface-mining methods. The Kemmerer Mine is the largest and deepest open-pit coal mine in the nation.

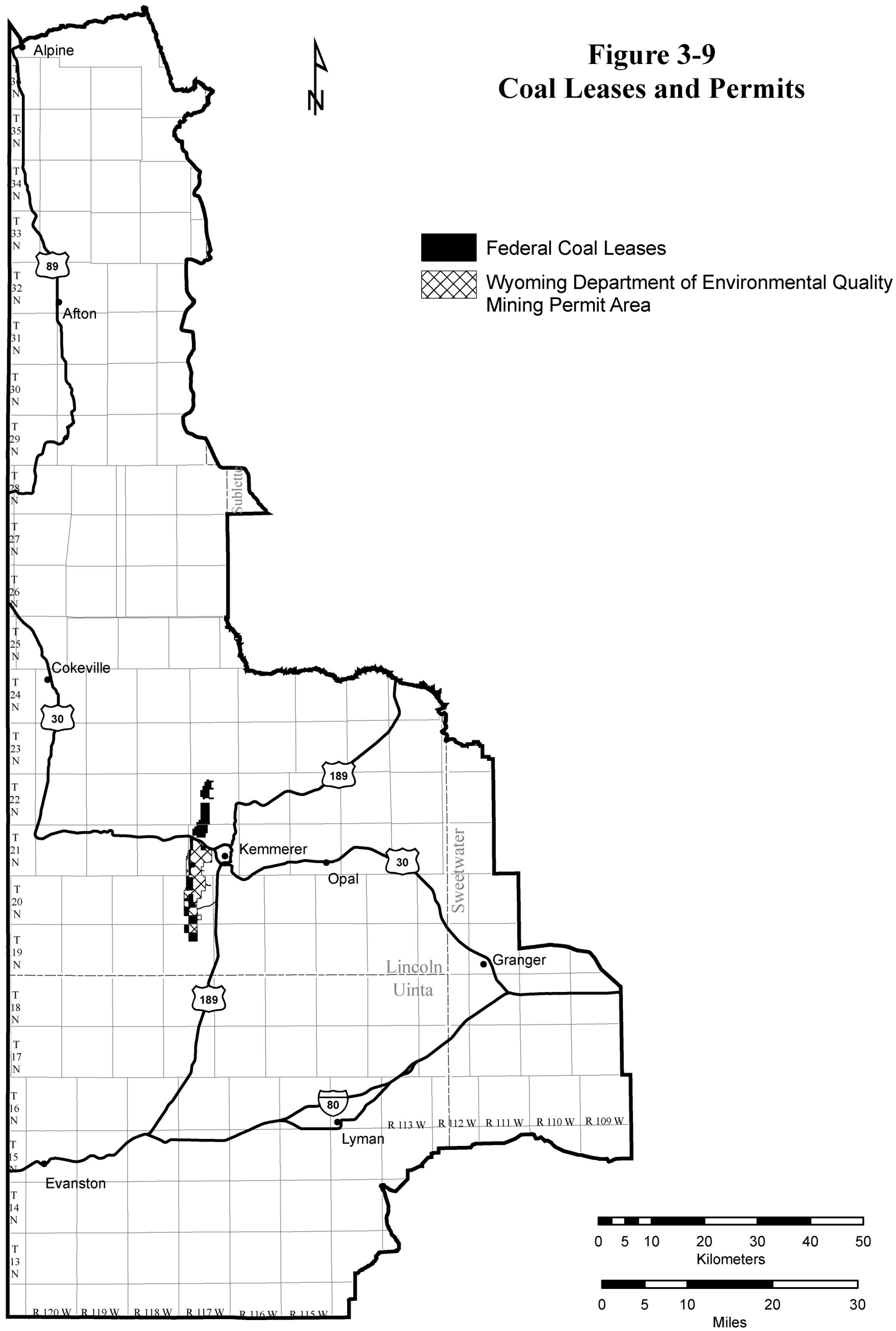
In 1997, FMC Corporation's Skull Point Mine was located next to the Kemmerer Mine. The Skull Point Mine was later acquired by P&M (UPRR 2003). P&M was acquired by Chevron Texaco in 2003 (Kemmerer 2003). The coal at this mine has a heat content of BTU of 9,889 per pound, a sulfur content of 0.95 percent, a moisture content of 22 percent, a volatile material content of 34 percent, and a fixed carbon content of 39.5 percent. Table 3-5 lists coal production at the Kemmerer Mine from 1998 through 2002.

Table 3-5. Kemmerer Mine Coal Production, 1998 – 2002

Year	*1998*	*1999*	*2000*	*2001*	*2002*
Coal Produced (million tons)	4.7	4.3	3.7	4.5	4.2

Source: Wyoming Mining Association (WMA) 2003

Figure 3-9
Coal Leases and Permits



3.1.4 Trona

All public lands within the Known Sodium Leasing Area (KSLA) that are not currently leased are available for leasing consideration. Sodium leases are subject to renewal every 10 years after the initial 20-year term. Prospecting permits outside of the KSLA are considered and possibly modified to ensure consistency with the objectives of the RMP. Prospecting permits may be denied if it is determined that exploration or development impacts are inconsistent with the objectives of the RMP. In addition to prospecting permits for sodium, exploration licenses may be issued in areas of known sodium resources that are not leased. Known sodium resources are those that are in the KSLA boundaries. Figure 3-9a depicts the KSLA and the location of trona leases in the planning area.

The Kemmerer Field Office is involved in developing mitigating measures for exploration licenses. The Minerals and Lands Rock Springs Field Office group is responsible for managing all trona in Wyoming's share of the KSLA, including operations within the Kemmerer Planning Area (Clawson 2003). The group is composed of geologists, mining engineers, and environmental specialists. Its primary responsibilities include managing new leases and existing leases. A large component of the group's activity is to conduct inspections of active mines. At a minimum, all active mines are inspected on a quarterly basis and all leases inspected annually. In addition, the group carries out production verification inspections to confirm that the lessee's reported extraction values are correct. Through the preparation of environmental documents, the Kemmerer Field Office provides input to the Rock Springs Field Office group regarding surface resources affected by trona development.

A study is currently being conducted regarding safety issues associated with oil and gas drilling within or near active trona mining areas. As a result, existing oil and gas leases in the KSLA have been suspended since 1993, and no new oil and gas leases are being issued pending completion of the study.

3.1.4.1 Origin and Occurrence

The world's largest known trona deposit is located in southwestern Wyoming and extends into the eastern portion of the Kemmerer Planning Area. Trona is a hydrous sodium carbonate mineral that is refined into soda ash, sodium bicarbonate, sodium sulfite, sodium tripolyphosphate, and chemical caustic soda (WSGS 2002). Soda ash is the trade name for sodium carbonate, which is a chemical obtained from trona and sodium-carbonate-bearing brines (USGS 2003d). Approximately 1.8 tons of trona are required to produce a ton of soda ash. Soda ash is used in a wide variety of applications: glass production accounts for 48 percent of the domestic use; the chemical industry accounts for 26 percent; soap and detergents, 14 percent; and other users such as the pulp and paper and water treatment industries make up the remaining 12 percent (WSGS 2002). Soda ash can be synthetically manufactured from salt and limestone, both of which are practically inexhaustible. However, synthetic soda ash is more costly to produce and it generates environmentally harmful wastes (USGS 2003d).

The Wilkins Peak Member of the Green River formation includes at least 42 trona beds, occurring from 400 to 3,500 feet below the surface. Identified trona reserves in the planning area total 114 billion tons, with more than 30 billion tons of halite-free trona in 13 beds that are six or more feet

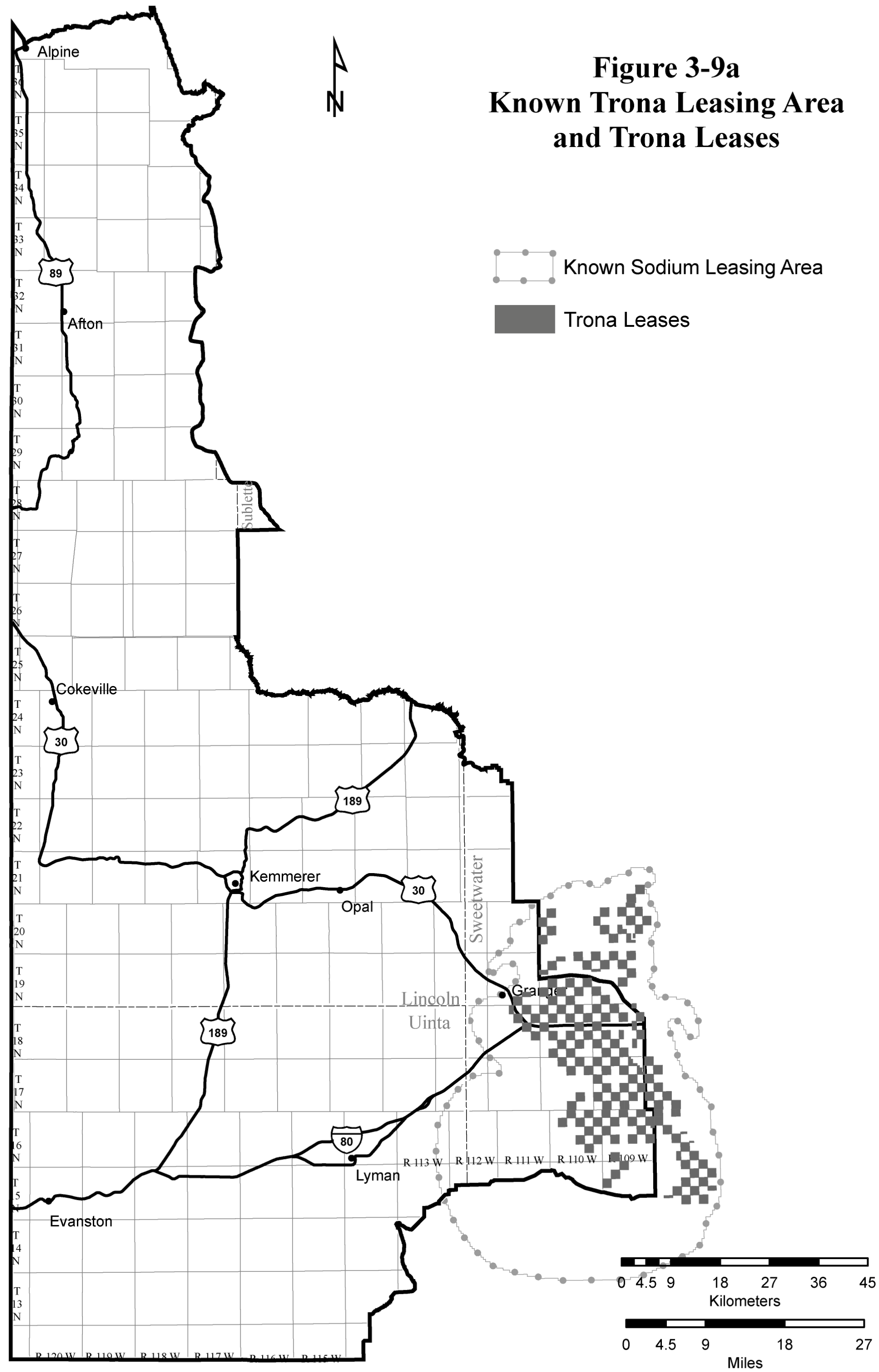


Figure 3-9a
Known Trona Leasing Area
and Trona Leases
Known Sodium Leasing Area
Trona Leases
Alpine
Afton
Cokeville
Kemmerer
Opal
Granger
Lyman
Evanston
89
30
189
80
Sublette
Sweetwater
Lincoln
Uinta
R 113 W
R 112 W
R 111 W
R 110 W
0 4.5 9 18 27 36 45
Kilometers
0 4.5 9 18 27
Miles

thick. The KSLA includes the area where trona is known to exceed 4 feet in thickness. Half of the 1,100 square-mile KSLA is within the Kemmerer Planning Area. Figure 3-10 shows 2002 mining permit areas for trona and other mineral resources.

3.1.4.2 Current and Historical Production

Ninety percent of the nation's trona production, and 30 percent of the world's soda ash production, comes from Wyoming. All of Wyoming's trona production is from southwestern Wyoming, with four of the five mines in the planning area. Trona mining began in southwestern Wyoming in 1947. Wyoming production of trona in 1996 was more than 18.3 million short tons. In 1999, about 17 million short tons of trona were mined, and about 9.5 million tons of soda ash were sold by Wyoming producers (BLM 2003d). In 2001, production stood at 17.7 million short tons. Approximately 35 percent of total Wyoming soda ash production is exported. According to the American Natural Soda Ash Corporation (ANSAC), about 4.41 million short tons of soda ash were exported from Wyoming in 2000 (WSGS 2002).

Within the Kemmerer Planning Area, FMC Wyoming Corporation, General Chemical Corporation, and Solvay Minerals, Inc. produce trona from four underground mines. The FMC Granger operation (one of the two FMC mines and processing plants) is currently closed due to market conditions. Together, FMC Wyoming Corporation, General Chemical Corporation, and Solvay Minerals produced a total of more than 12.3 million short tons of trona in 2002 from underground mines in the planning area (State Inspector of Mines 2002). Table 3-6 displays trona production statistics by mine in 2002. Three trona lessors (federal, state, and private) have issued leases within the KSLA in the Granger/Little American area.

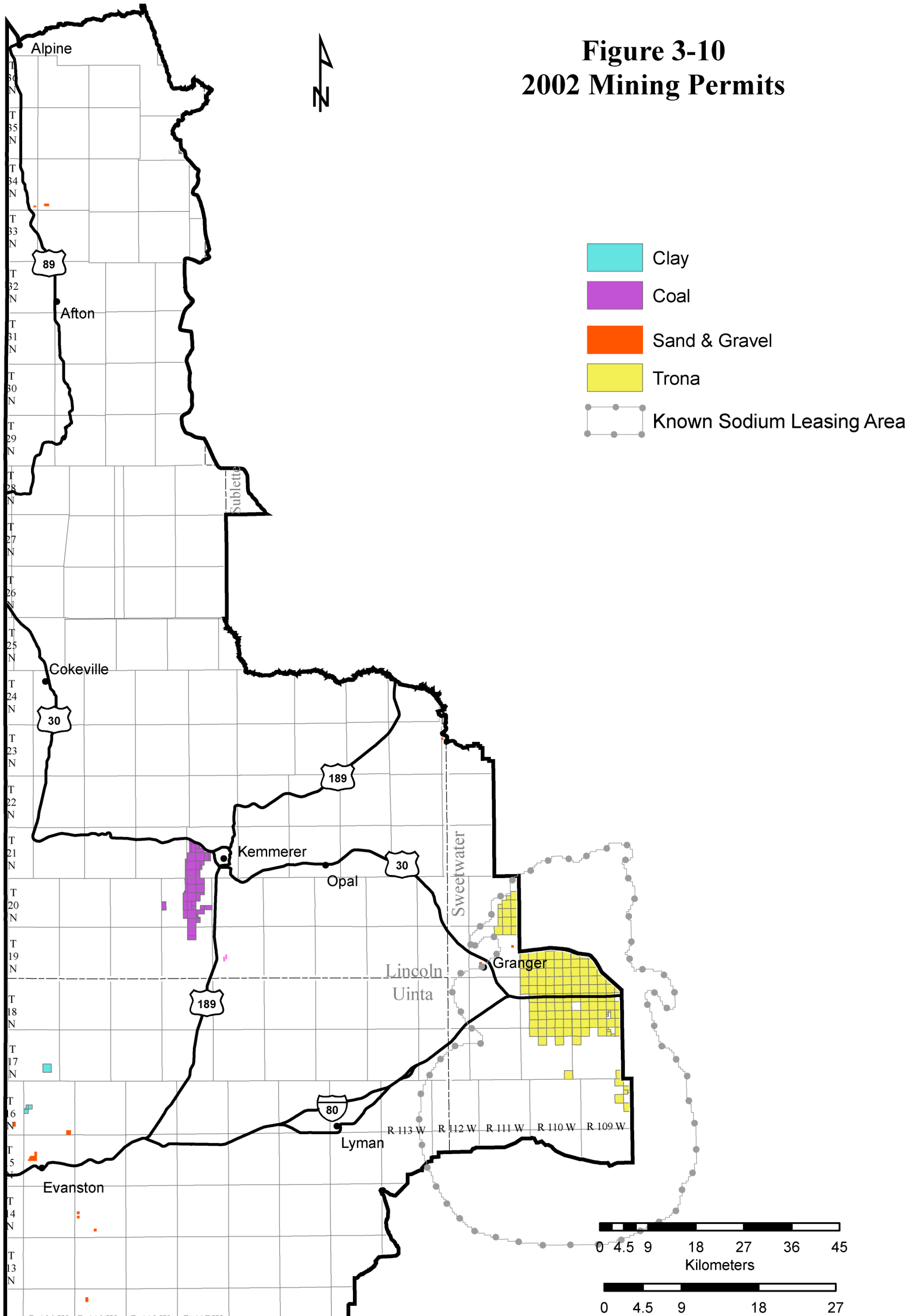
In addition to numerous sodium leases for trona, there is a sodium lease for halite (sodium chloride) in the planning area. It is located about 50 miles northwest of Kemmerer in the Bridger-Teton National Forest on a small salt spring. There has been no production under the current lease. Although plans for removing salt brine from the spring have been proposed, there is no certainty of when, or if, production will occur.

Table 3-6. Trona Production by Mine, 2002

Mine Name	*County*	*Facilities Operated*	*Production (tons)*
Granger Mine/FMC Wyoming Corporation	Sweetwater	Underground Mine Processing Plant	Idle Idle
Westvaco Mine/FMC Wyoming Corporation	Sweetwater	Underground Mine Processing Plant	4,247,000 Not reported
Alchem Mine/General Chemical Corporation	Sweetwater	Underground Mine Processing Plant	4,493,096 Not reported
Solvay Trona Mine/Solvay Chemicals, Inc.	Sweetwater	Underground Mine Processing Plant Other Products	3,598,023 2,151,573 93,617
Totals: Underground Mines 12,338,119 Processing Plants 2,151,573 Other Products 2,151,573			

Source: State Inspector of Mines (SIM) 2002

Figure 3-10
2002 Mining Permits



3.1.5 Phosphate

Phosphorus is an essential nutrient for plants and animals, and the majority of phosphorus is consumed by the fertilizer industry (USGS 2003b). More than 95 percent of U.S. phosphate rock ore mined is used to manufacture phosphate-based fertilizers and animal feed supplements (USGS 2003b). The U.S. is the largest producer and consumer of phosphate rock in the world, as well as the leading producer and supplier of phosphate fertilizers (USGS 2003b).

In the Kemmerer Planning Area, phosphate rock occurs at the surface in north-south trending outcrops of the Phosphoria formation (Permian age). These outcrops are located north and west of Kemmerer, primarily in the Tunp Range, Sublette Range, and Beckwith Hills. Phosphate mining began at an underground mine near Cokeville in 1906. This mine had the first production in Wyoming. Leefe mine near Sage Junction (25 miles west of Kemmerer) was the last and largest phosphate operation in Wyoming. Surface mining ended in 1977, and the plant was closed in 1985 and removed. The State Abandoned Mine Land (AML) Division and its contractors are currently reclaiming pits and spoil piles at the Leefe Mine. The last federal phosphate leases in the Kemmerer Planning Area (in the Sublette Range north of Cokeville, Wyoming) were relinquished in 1995. Currently, most phosphate rock production in the U.S. is from outside Wyoming (USGS 2003b). Refer to Figure 3-10 for the location of phosphate mining permit areas.

3.1.6 Oil Shale

The most significant oil shale reserves within the Kemmerer Planning Area are just northwest of Flaming Gorge Reservoir in the Green River Basin. The Green River Basin contains an estimated 244 billion barrels of oil shale in its Tipton Shale Member, Wilkins Peak Member, and Laney Member of the Green River formation. This estimate is based on oil shale that yields at least 15 gallons of oil per ton of rock. Oil shale occurs throughout most of the Green River Basin and in thin beds (under 4 feet thick) in the Fossil Basin. The upper part of the Tipton Shale Member contains beds up to 75 feet thick and yields up to 24 gallons of oil per ton. The Overburden is 2,000 to 3,000 feet thick. Other significant oil shale beds in the Wilkins Peak Member and the Laney Member are near the edge and just to the east of the southeast border of the planning area. Only the western part of the Green River Basin is in the Kemmerer Planning Area.

Areas that contain known deposits of oil shale are available for leasing consideration. Currently, there is no regulatory provision for oil shale leasing, though oil shale leasing occurred in the 1970s under a prototype leasing program to encourage its development (BLM 2003a).

3.1.7 Geothermal

High temperature geothermal resources are generally used for electric power generation. Low temperature resources are used directly and for ground-source heat pumps (Geothermal Resources Council [GRC] 2003). Geothermal energy has the third highest production rates among renewable energy sources, behind hydroelectricity and biomass, and ahead of solar and wind energy (GRC 2003). Technology is still being developed to capture the geothermal resources available.

Overall, there has been minimal geothermal activity in the Kemmerer Planning Area. Currently, there are no geothermal leases, and there are no pending applications for exploration or leasing. Geothermal resources occur at Auburn in the Star Valley portion of the Kemmerer Planning Area.

Auburn Hot Springs contains numerous vents producing saline water ranging from about 68 to 140 °F, and carbon dioxide and hydrogen sulfide gas. Several pools contain native sulfur, which was mined from 1947 to 1949 (Ruby 1958). No other locations in the planning area are known to have high-temperature geothermal resources.

3.1.8 Carbon Dioxide

The primary market for carbon dioxide is for use in oil production operations to enhance oil recovery. Oil and gas fields in the Big Piney-La Barge vicinity, outside the planning area, had produced 3.17 trillion cubic feet of carbon dioxide by the end of 2001 (BLM 2003e). A 28-inch gas pipeline operated by Exxon/Mobil moves carbon dioxide-rich gas from the Lake Ridge and Fogarty fields for treatment at Exxon/Mobil's Shute Creek Gas Plant, 25 miles south of LaBarge (within the planning area). The gas stream is processed to remove hydrogen sulfide and methane. In 2001, the plant processed about 435 million cubic feet of gas per day (BLM 2003e). Following processing, the carbon dioxide is piped to Baroil, Wyoming and to northwestern Colorado where it is used for enhanced oil recovery in area oil fields (BLM 2003e).

In 2003, Howell Petroleum (a wholly-owned subsidiary of Anadarko) completed a 125-mile pipeline extension to move by-product carbon dioxide gas from the Shute Creek Gas Plant to the ageing Salt Creek Oil Field in eastern Wyoming. The company plans to inject about 7,200 tons of carbon dioxide a day into the field in order to boost production from about 5,300 barrels a day to 35,000 barrels a day (Department of Energy [DOE] 2003).

3.1.9 Sulfur

Sulfur occurs as native sulfur or as a component in rock-forming minerals such as gypsum, iron, and other common industrial minerals. It occurs as a contaminant in coal, crude oil, and natural gas. Sulfur is an important industrial raw material as sulfuric acid. Recovered sulfur is a byproduct of petroleum refining, natural gas processing, and coking plants (Ober 1997). During the 1950s, the Claus process came into use to recover sulfur from oil and gas. This process was added to oil refinery infrastructure to recover sulfur from hydrogen sulfide during the refining process (Wilburn et al. 2001). Sulfur recovered during oil refining increased steadily during the second half of the 20th century. After enactment of the *Clean Air Act of 1970*, producers began stripping sulfur from fuel before combustion in order to comply with clean air requirements (Wilburn et al. 2001). Wyoming ranks second in the nation in the production of recovered sulfur. Sulfur is currently produced in the planning area at three plants: Chevron Carter Creek, BP Whitney Canyon, and Exxon Mobil Shute Creek.

Sulfur is subject to federal lease, but only on public lands in the States of Louisiana and New Mexico, and on all acquired lands. It is listed with leasable minerals in this document because sulfur is produced in Wyoming from hydrogen sulfide gas, the sulfur content of which is one of the factors entering into the valuation of the gas by the Minerals Management Service (MMS). In other words, the gas price to which federal royalties are applied is adjusted by the MMS based on the quality of the gas, of which the presence of sulfur is a contributing factor.

3.2 Locatable Minerals

The Kemmerer Planning Area contains 1.6 million acres of public land and approximately 250,000 acres of federal mineral estate. The primary locatable minerals that have had production activity, or have the potential to occur, include bentonite, fire clay, metals, and gemstones. This section provides a general background on locatable minerals in the planning area. Active mining claims in the planning area are summarized in Table 3-7.

The *Mining Law of 1872* is the principal law through which metallic and nonmetallic locatable minerals on public lands are made available. The law encourages mining companies to initiate exploration and development. The *Mining and Minerals Policy Act of 1970* also governs locatable minerals and other mineral activity in the Kemmerer Planning Area. The BLM must approve any Plan of Operations for mining, or Notice to explore on all public land under the Mining Law.

Locatable mineral occurrences in the Kemmerer Planning Area have been delineated, but generally there has been limited exploration and analysis of individual deposits, with some exceptions such as fire clay. Some locatable commodities are known to occur in the area (e.g., bentonite) but no detailed work has been done. For others, such as diamonds, exploration is in the very early stages.

Although numerous claims have been staked over the years, there has been a very limited mining history in the Kemmerer Planning Area. Interstate Brick Company has mined clay for about 35 years on mining claims located north of Evanston, Wyoming. Some of the claims received a patent from the BLM in 1991 and others were abandoned. Another area of patented claims is located on phosphate outcrops north of Cokeville, Wyoming, which were located prior to the *Mineral Leasing Act of 192*0. Those claims were prospected and mined for a brief period. There are some commodities, such as limestone or building stone, which can be classified as either locatable (uncommon variety) or salable (common variety) depending on the characteristics of the deposit. Currently, there is a mining claimant who has been quarrying building stone from an 80-acre placer claim since approximately 1986 under the authority of the *Building Stone Placer Act*.

The 1969 9th Circuit case, *McClarty v. Secretary of the Interior*, 408 F2d 907, 908, set the following standards to distinguish locatable minerals from salable minerals:

1. "there must be a comparison of the mineral deposit in question with other deposits of such minerals generally;
2. the mineral deposit in question must have unique property;
3. the unique property must give the deposit a distinct and special value;
4. if the special value is for uses to which ordinary varieties of the mineral are put, the deposit must have some distinct and special value for such use; and
5. the distinct and special value must be reflected by the higher price which the material commands in the market place (or by reduced cost or overhead so that the profit to the claimant would be substantially more)" (Maley 1990).

The primary locatable minerals that occur in the Kemmerer Planning Area are bentonite, fire clay, metals, and gemstones.

Table 3-7. Active Mining Claims in the Kemmerer Planning Area

Serial Number	*Case Type*	*Claim Number*	*Location*	*County*
WMC231199	Placer Claim	Cumberland Gap	06 01910N 1160W 020 NE SW SE	Lincoln
WMC231199	Placer Claim	Cumberland Gap	06 01910N 1160W 020 NE SW SE	Lincoln
WMC257610	Placer Claim	Cumberland Gap #1	06 0190N 1160W 032 NW	Lincoln
WMC257611	Placer Claim	Cumberland Gap #2	06 0190N 1160W 032 NW	Lincoln
WMC257612	Placer Claim	Cumberland Gap #3	06 0190N 1160W 032 NW	Lincoln
WMC257613	Placer Claim	Cumberland Gap #4	06 0190N 1160W 032 NW	Lincoln
WMC257614	Placer Claim	Cumberland Gap #5	06 0190N 1160W 032 NW	Lincoln
WMC257615	Placer Claim	Cumberland Gap #6	06 0190N 1160W 032 NW	Lincoln
WMC257616	Placer Claim	Cumberland Gap #7	06 0190N 1160W 032 NW	Lincoln
WMC257617	Placer Claim	Cumberland Gap #8	06 0190N 1160W 032 NW	Lincoln
WMC257618	Placer Claim	Cumberland Gap #9	06 0190N 1160W 032 SW	Lincoln
WMC257619	Placer Claim	Cumberland Gap #10	06 0190N 1160W 032 SW	Lincoln
WMC257747	Placer Claim	Cumberland Gap #11	06 0190N 1160W 020 NE	Lincoln
WMC257748	Placer Claim	Cumberland Gap #12	06 0190N 1160W 020 SE	Lincoln
WMC259371	Placer Claim	Cumberland Gap #13	06 0190N 1160W 032 NE	Lincoln
WMC259372	Placer Claim	Cumberland Gap #14	06 0190N 1160W 032 NE	Lincoln
WMC259374	Placer Claim	Cumberland Gap EXP 15	06 0190N 1160W 004 SW	Lincoln
WMC259374	Placer Claim	Cumberland Gap EXP 15	06 0190N 1160W 004 SW	Lincoln
WMC259375	Placer Claim	Cumberland Gap EXP 16	06 0190N 1160W 004 SW	Lincoln
WMC259375	Placer Claim	Cumberland Gap EXP 16	06 0190N 1160W 004 SW	Lincoln
WMC259376	Placer Claim	Cumberland Gap EXP 17	06 0190N 1160W 004 SW	Lincoln
WMC259376	Placer Claim	Cumberland Gap EXP 17	06 0190N 1160W 004 SW	Lincoln
WMC259377	Placer Claim	Cumberland Gap EXP 18	06 0190N 1160W 004 SW	Lincoln
WMC259377	Placer Claim	Cumberland Gap EXP 18	06 0190N 1160W 004 SW	Lincoln
WMC259486	Lode Claim	Grandiose No. 1	06 0180N 1170W 014 SE	Uinta
WMC259486	Lode Claim	Grandiose No. 1	06 0180N 1170W 014 SE	Uinta

Source: BLM 2003a

3.2.1 Bentonite

Bentonite is sodium montmorillonite clay used as a binder in foundry molds, pet litter, drilling mud, and iron ore pelletizing (WSGS 2003c). It is increasingly used to form impermeable liners for waste disposal ponds. During the Cretaceous period, ash from volcanic eruptions dropped into the seas that covered much of Wyoming, forming sediments as much as 50 feet deep. These sediments formed the clay, bentonite. There are several linear deposits of bentonite in Uinta and Lincoln Counties (Geo/Resource Consultants 1984). They are within the Evanston-Wasatch sequence (Knight formation), Frontier formation, and Hilliard Shale, and occur in thin beds up to 5 feet thick (Geo/Resource Consultants, Inc. 1984). Bentonite in the Green River Basin primarily occurs within shales and sandstones. It consists of volcanic ash beds that have been altered, and typically has the characteristic of swelling to many times its original size (Geo/Resource Consultants, Inc. 1984).

Bentonite was first mined on a small scale in Wyoming during the 1880s. More substantial deposits were discovered during the 1920s (Black Hills Bentonite 2002). Today, Wyoming is the leading producer of bentonite in the U.S. (WSGS 2003c). However, although bentonite is known to occur in the Kemmerer Planning Area, there has been no commercial production. In 2002, a company filed a Notice to explore for bentonite under the *Mining Law of 1872*, but the application was never completed and no exploration occurred on public land. The lack of interest in Kemmerer bentonite is in part due to coal withdrawals that prevent bentonite mining claims in certain areas. Also, some of the bentonite within the planning area tends to be deformed and is of only minor economic significance (Geo/Resource Consultants, Inc. 1984). There are non-deformed bentonite reserves that are more profitable elsewhere in the state and in other regions.

3.2.2 Fire Clay

Fire clay (also known as refractory clay) is one of six types of clay mined in the U.S. Other types of clay include ball clay, bentonite, common clay, fuller's earth, and kaolin (USGS 2003c). Fire clay and refractory clay are detrital materials that are either plastic or rock-like (Harris and King 1986). Fire clay is able to withstand temperatures of 1500 degrees Celsius (°C) without deforming or melting (Harris and King 1986).

Fire clay occurs in scattered areas within the Overthrust Belt portion of the Kemmerer Planning Area. Specifically, it is known to occur in outcrops within the Evanston formation (north of the town of Evanston in Uinta County) and in outcrops within the Frontier formation. There are also occurrences within the Adaville formation in Lincoln County near the town of Elkol (south of Kemmerer). A large proportion of the total clay produced in Wyoming occurs in Uinta County. Refer to Figure 3-10 for the locations of 2002 mining permits for clay.

Currently, there are two companies producing fire clay in the planning area. Interpace Industries, Inc. produces refractory clay on private land from one of the Evanston formation locations (Harris and King 1986). Interstate Brick Company produces clay from the Evanston formation in a pit northeast of the Interpace Industries pit. In 1985, Interstate Brick Company filed for a clay patent maintaining that its clay deposit was locatable under the *Mining Law of 1872*. The patent examination concluded that some portions of the application area did, in fact, contain a marketable and valuable clay deposit, thus making it a locatable deposit. In 2000, Interpace Industries, Inc. conducted an exploration for fire clay on public land. However, the deposit was determined to be unsuitable for commercial use.

3.2.3 Gemstones

The Kemmerer Planning Area has seen little development of gemstones, and minimal production is expected in the future. In 1997, mining claims were staked and there was drilling exploration for possible diamond-bearing deposits in the southern and southeastern portions of the planning area. More recent exploration has occurred in portions of the adjacent Rock Springs Planning Area. However, none of the exploration activity is known to have produced a significant discovery. To date, the Kemmerer Field Office has no evidence of an economically viable diamond discovery. However, the WSGS considers diamond potential to be high for the entire state, except for the Yellowstone area (Hausel 2003).

Pyrope garnet and chromium diopside, which have some potential for faceted stones, have been found in the Anthills in the Green River Basin (Hausel 1993). To date, there are no other known significant gemstone deposits in the Kemmerer Field Office area, and there is no demand other than for hobby collection.

3.2.4 Metals

Although there are small deposits of various metals in the planning area, there are not any economically significant discoveries. Titanium occurs in a black sandstone layer within the Frontier formation in the vicinity of Cumberland Gap (in the northern part of Uinta County). The deposits average 5 feet in thickness (Hausel 1990). Copper deposits, as well as silver and zinc, occur in some sedimentary formations in Lincoln County, including the Wells formation, Nugget Sandstone, and the Beckwith formations. Uranium is associated with phosphate rock in the Phosphoria formation (Geo/Resource Consultants, Inc. 1984). Uranium also occurs in numerous other formations in the Kemmerer Planning Area (Geo/Resource Consultants, Inc. 1984). Chromium, gold, and silver also have been reported in the Phosphoria formation (Hausel 1987). The limited exploration for these resources over the years has not led to any production, and very little activity is anticipated during the life of the RMP.

3.3 Salable Minerals

According to the *Materials Act of July 31, 1947* (as amended) certain mineral and vegetative materials may be disposed either through a contract of sale or a free-use permit (Legal Information Institute 2003). These types of minerals, also known as salable or mineral materials, include common varieties of sand, stone, gravel, pumice, pumicite, cinders, clay, petrified wood, and other mineral materials. Salable minerals are generally bulky, have a low unit price, and their weight makes transportation costs high. It is BLM policy to make these materials available to the public and local governmental agencies whenever possible and wherever it is environmentally acceptable. Salable minerals are sold to the public at fair market value, but are given free to states, counties, or other government entities for public projects. Also, a limited amount may be provided free to nonprofit organizations. Materials obtained free of charge cannot be bartered or sold.

There are some salable minerals such as building stone and limestone, which can be either locatable (uncommon variety) or salable (common variety) depending on the characteristics of the deposit. The DOI has defined common varieties as the following:

> "'Common varieties' includes deposits which, although they may have value for use in trade, manufacture, the sciences, or in the mechanical or ornamental arts, do not

> possess a distinct, special economic value for such use over and above the normal uses of the general run of such deposits. Mineral materials which occur commonly shall not be deemed to be 'common varieties' if a particular deposit has distinct and special properties making it commercially valuable for use in a manufacturing, industrial, or processing operation" (Maley 1985).

The Kemmerer Field Office administers the permits and purchases of salable minerals. The office maintains Community Pits and Common Use Areas, which are open to the public to obtain materials at a reasonable price. Generally, these are for sand and gravel, shale, moss rock, and boulders. The Kemmerer Field Office also issues exclusive use permits when a party makes a request to obtain material from a specific location as an exclusive permittee. This can be done as a "Free Use Permit" (usually for government entities such as city, county or state) or as a private party sale. Depending on the size and nature of a sale or Free Use Permit, a mining/reclamation bond may be required. The Wyoming Department of Transportation (DOT) uses Material Sites Rights-of-Way to obtain salable minerals from the BLM for federal aid road construction.

In the State of Wyoming in 2002, 60 materials sales generated $299,229 from 475,283 tons. Local governments and nonprofit groups utilized 33 free use permits to obtain 44,370 tons valued at $34,979, and 85 community pits and common use areas provided 18,526 yards of material and generated $16,306 (BLM 2003c). Salable minerals in the Kemmerer Planning Area consist of sand and gravel (aggregate), decorative stone including moss rock, and limestone and sandstone. Refer to Figure 3-10 for the locations of 2002 mining permits for sand and gravel and decorative stone/rock. Table 3-8 displays the production statistics by sale type of salable minerals in the Kemmerer Planning Area for 2003. Tables 3-9 and 3-10 list salable minerals production for fiscal years (FY) 2002 and 2003 respectively.

The following sections describe the primary salable minerals of the planning area including sand and gravel, decorative stone, and limestone and sandstone.

3.3.1 Sand and Gravel

Aggregate (sand and gravel) is one of the most widely used salable resources in Wyoming and in the Kemmerer Planning Area (USGS 2003a). The sand and gravel produced from the planning area is largely used for construction purposes, including roads, bridges, houses, and buildings. Construction aggregate is the fourth most important mineral product in value produced in Wyoming after oil and gas, coal, and trona. On a state-wide scale, the value of construction aggregate is higher than the value of other important minerals such as bentonite, uranium, and gypsum (WSGS 2003a). The four types of sand and gravel deposits in the planning area include: alluvial sand and gravel from recent stream deposits; glacial sand and gravel in the southern portion of the planning area; quaternary terrace gravels; and older sand and gravel deposits of Late Cretaceous to Pleistocene age (Harris 1996).

The primary sand and gravel deposits in the Kemmerer Planning Area are in the Star Valley (Salt River drainage) and along other major drainages including the Bear River, Black's Fork, Smith's Fork, Hams Fork, and Green River. Currently, there are permits for gravel pits in Lincoln and Uinta counties. In addition, there are three free-use permit areas for county government sand and gravel pits, and numerous material site rights-of-way issued to the Wyoming DOT. Material sites are required for federal aid highway projects. The Kemmerer Field Office has averaged 14 salable

Table 3-8. Sale Types and Commodities, FY 2003

Sale Type	*Number of Sites*	*Total Amount Authorized*	*Commodity*	*Comments*
Negotiated Sales (active cases)	1	98,000 cubic yards	Borrow	
Competitive Sales (active cases)	0	0	N/A	
BLM Common Use Area	1	996 tons since 1998	Mostly moss rock, some boulders	
Material Sites Rights-of-Way	19	Unknown	Sand and gravel and limestone	Issued to Wyoming DOT
BLM Giraffe Creek Community Pit	1	1,160 cubic yards since 1998	Limestone	Talus
BLM Cokeville Community Pit	1	300 cubic yards since 1998	Shale and limestone	Talus
BLM Willow Springs Community Pit	1	20 cubic yards since 1998	Sand and gravel	Pit to be closed
Free Use Permits (active cases)	3	38,000 cubic yards since 1998	Sand and gravel	2 permits to Lincoln County, 1 permit to Uinta County

Source: McNaughton 2003

Table 3-9. Salable Mineral Production, FY 2002

Sale Type	*Number of Sales*	*Quantity Produced*	*Value ($)*
Community pit sales	5	420 cubic yards	105
Common use area sales	9	246 tons	3,835
Negotiated sales	0	0	0
Competitive sales	0	0	0
Free use permits	1	8,000 tons	4,800

Source: Heffern 2003

Table 3-10. Salable Mineral Production, FY 2003

Sale Type	*Number of Sales*	*Quantity Produced*	*Value($)*
Community pit sales	4	520 cubic yards	130
Common use area sales	10	291 tons	2,910
Negotiated sales	0	0	0
Competitive sales	0	0	0
Free use permits	1	10,000 cubic yards	7,500

Source: Heffern 2003

mineral authorizations per year over the last 4 years, including negotiated sales (including those in community pits and common use area), free use permits, and authorizations for exploration. Numerous older gravel pits occur throughout the area, many of which were originally issued to the Wyoming DOT.

3.3.2 Decorative Stone

Decorative stone is defined as "any type of rock product exclusive of aggregate that is used for its color or appearance" (Harris 1993). In the planning area, decorative stone is found in many of the more resistant ridges, especially in the Overthrust Belt. Currently there is production of building stone and moss rock, though other varieties of decorative stone have been produced in the past. An active market has developed for moss rock, or lichen-covered sandstone, which is mainly found on hogback ridges in the Overthrust Belt portion of the planning area. Refer to Figure 3-10 for the location of one of the larger decorative stone areas under a state permit. Many other smaller areas have been used on public land, on which the State does not issue mining permits.

About 1,000 tons of moss rock have been sold from public land in the Kemmerer Planning Area since 1998, and demand continues, especially from the Jackson Hole area. In 2003, 520 tons were sold from scattered locations in the Overthrust Belt portion of the planning area.

3.3.3 Limestone and Sandstone

Limestone of variable quality and thickness occurs throughout the Green River Basin portion of the planning area in the Bridger formation and Green River formation. Also, outcrops of Thaynes Limestone, Twin Creek Limestone, and a small area of Madison Limestone are possible sources of limestone in the Overthrust Belt area. Some of the aggregate produced in the planning area is limestone. Not only is the crushed limestone a valuable resource, but the fines (small particles produced in the crushing process) are used for various construction projects. The utility of this resource results in minimal wastes in the production process (Durst 2003).

Salable limestone (common variety) differs from locatable limestone (uncommon variety). The only type of limestone in the planning area is of the common variety and considered a salable mineral. Unlike locatable limestone, salable limestone is not of chemical grade and is not used as an ingredient in cement manufacturing. According to *U.S. v. Chas. Pfizer & Co, Inc.,* (1969), limestone must contain 95 percent or more calcium and magnesium carbonates for it to be locatable (Maley 1990).

Salable limestone is an inexpensive and abundant resource within the Kemmerer Planning Area; however, there is currently minimal production. Other than relatively small amounts of limestone produced from the Giraffe Creek Community Pit, there are no commercial sales of limestone in the planning area. The Wyoming DOT does, however, have a limestone quarry on public land under a Material Site Right-of-Way.

In addition to the decorative stone uses of sandstone mentioned in section 3.3.2 above, there have been some sales of sandstone talus. For example, there are some sandstone talus deposits in the northwest portion of the planning area, such as Nugget Sandstone deposits in Pine Creek, which have been utilized for roadwork. In the past, the Wyoming DOT had two sandstone quarries on BLM land for highway reconstruction, but those sites are now closed. Historically, sandstone in the planning area has been used for many of the older structures in various towns. For example, local sandstone from the Frontier formation was used for some of the original buildings in the town of Kemmerer.

3.4 Abandoned Mines

More than a century of mining in Wyoming has left mining hazards in the Kemmerer Planning Area. This section discusses the hazards associated with abandoned mines and management practices aimed at reclaiming sites and mitigating dangers. Figure 3-11 is a map of abandoned mines in the planning area.

Common hazards include: open shafts; unstable rock and decayed support structures; deadly gases and lack of oxygen; explosives and toxic chemicals; disorientation; and high walls, open pits, and open drill holes. For hikers, cave explorers, and other recreationists, the hazards are not always apparent and serious injury or death can occur at these sites. In 1999, 17 people died at abandoned mines sites in the U.S. (Wyoming DEQ 2002).

In addition to physical hazards, abandoned mines can also cause environmental effects. AML often contain unmined mineral deposits, mine dumps, and tailings that can contaminate the surrounding watershed and ecosystem (USGS 1999). Streams that flow near or through AML sites can pick up heavy metals and other contaminants.

The BLM and Wyoming DEQ are undertaking several AML reclamation projects on public lands within the Kemmerer Planning Area. The Kemmerer Field Office has identified key abandoned mine sites in need of reclamation. Concentrations of abandoned coal mines are found along Oyster Ridge, lying along a north/south axis through the central part of the Kemmerer Planning Area, and also north of Evanston, in the historic Almy mining area. Surface subsidence from underground coal mining along Oyster Ridge is confined to areas near the abandoned mines, primarily due to the rapid increase in depth of steeply dipping coal seams away from the mine openings. There are other abandoned coal mines on public land scattered throughout the overthrust portion of the Kemmerer Planning Area. Phosphate mines that are being reclaimed, or that have recently been reclaimed, include Leefe and Top of the World.

Underground coal mine fires, which can lead to surface fires and subsidence, also present a hazard in the planning area. For example, a fire exists south of Kemmerer at the abandoned Brilliant Coal Mine.

In addition to abandoned coal mines, there are also abandoned mine hazards at former phosphate mining and prospecting areas. These sites are primarily in the more mountainous areas northwest of Kemmerer. Several abandoned phosphate mining sites are currently in the process of reclamation. Table 3-11 lists the locations of abandoned mines in the Kemmerer Planning Area.

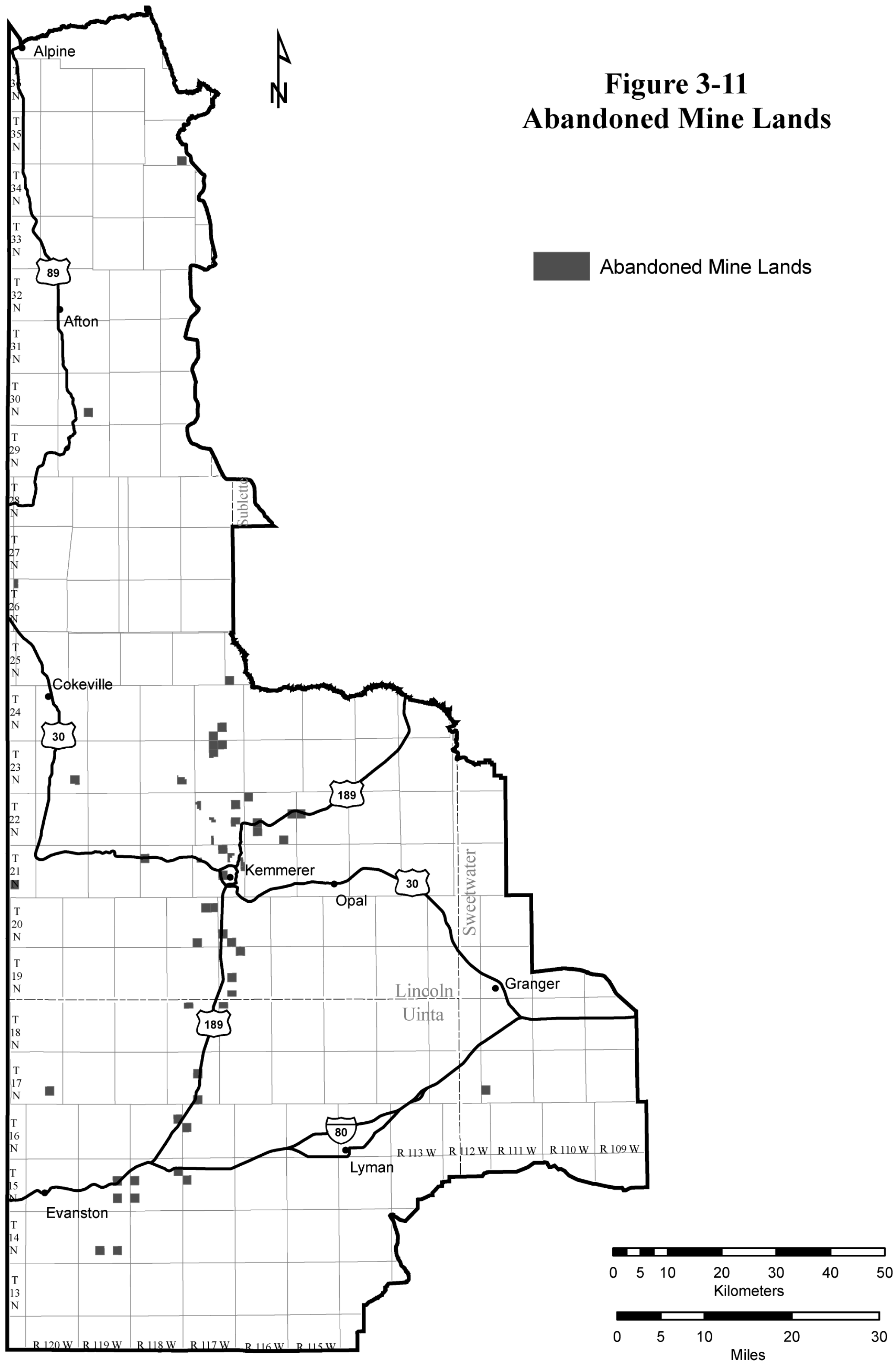


Figure 3-11
Abandoned Mine Lands

Table 3-11. Abandoned Mine Locations, Kemmerer Planning Area

Township, Range	*Section*	*Township, Range*	*Section*
T35R116	35	T21R116	13
T30R118	27	T21R116	22
T26R119	6	T21R120	27
T25R115	31	T20R117	12
T24R116	27	T20R117	11
T24R116	33	T20R116	30
T23R116	3	T20R116	32
T23R116	4	T20R117	34
T23R116	9	T19R116	4
T23R117	26	T19R116	20
T23R119	26	T19R116	32
T22R115	6	T18R116	6
T22R116	TR 62	T18R117	4
T22R116	7	T17R117	15
T22R114	18	T17R111	30
T22R115	13	T17R120	26
T22R116	TR 42	T17R117	34
T22R116	TR 55	T16R118	12
T22R115	20	T16R117	18
T22R115	29	T15R118	12
T22R115	35	T15R117	18
T22R116	33	T15R118	18
T21R116	3	T15R119	14
T21R116	TR 68	T15R118	30
T21R117	7	T15R119	26
T21R116	TR 61	T14R119	28
T21R116	TR 102	T14R119	26

Source: BLM Kemmerer Field Office 2003

4.0 MINERAL RESOURCE POTENTIAL

Future mineral development in the Kemmerer Planning Area is influenced by the price of commodities, management, laws, and regulations. With all commodities whether they are locatable, leasable, or salable, the level of resource potential can be difficult to predict, even with extensive geological studies. The potential demand and value of hydrocarbon resources is likely to stay above other leasable, locatable, or salable minerals. Other locatable and salable resources are likely to experience steady growth rates, which could mirror the growth rate of Wyoming's economy. Sand and gravel, an indispensable material for roads and building project, is likely to remain a significant salable material.

This section describes the resource developmental potential for leasable, locatable, and salable minerals in the Kemmerer Planning Area.

4.1 Leasable Minerals

4.1.1 Non Coalbed Hydrocarbons

4.1.1.1 Non Coalbed Hydrocarbon Plays

An oil or gas play is an area, geologic formation, or geologic trend that has good potential for oil or gas development, or is generating interest for leasing and drilling (BLM 2001). A play is defined by the geological properties (such as trapping style, type of reservoir, nature of the seal) that are responsible for the accumulations or prospects (BLM 2003e). Geologic heterogeneity, uneven distribution of resources, and reservoir size variations keep hydrocarbons from being evenly distributed across a play area (BLM 2001). A conventional play contains oil and gas accumulations that have hydrocarbon-water contacts (due to the hydrocarbons being a separate phase and the buoyancy of hydrocarbons in water) and seals that hold or trap the hydrocarbons. Hydrocarbons in conventional plays can be recovered using traditional development and production practices (BLM 2003e). Unconventional continuous plays are pervasive throughout a large area, and are not a result of the buoyancy of hydrocarbons as conventional accumulations are. The reservoir rock of a continuous accumulation is oil- or gas-charged everywhere. Other characteristics include low reservoir permeability, abnormal pressures, and close association of the reservoir with the source rocks from which hydrocarbons were generated (BLM 2003e).

THRUST BELT PROVINCE

Play 3601. Moxa Arch Extension Play. This play is a north-south trending regional basement uplift in the western Green River Basin that extends north from the Utah boundary for about 100 miles before turning northwest at LaBarge, where it passes under the Hogsback thrust (Powers 1995). The play has probable carbon dioxide-rich gas accumulations in Paleozoic carbonate reservoirs in "footwall anticlinal traps on the extensional axis of the Moxa Arch" (Powers 1995). The axial portion of the arch is part of a large, thrust-faulted structural feature known locally as the LaBarge Anticline. The axis of the arch trends to the north for about 100 miles from the southeast part of the LaBarge area, to south of Jackson (Powers 1995). The presence of gas was established in the play in 1961 on LaBarge Anticline (Powers 1995). More than 50 wells were drilled from 1961 to 1995. Exploration was expected to be limited by extremely rugged topography and possible restrictions to access on public lands (Powers 1995). Figure 4-1 is a map of the play in the planning area.

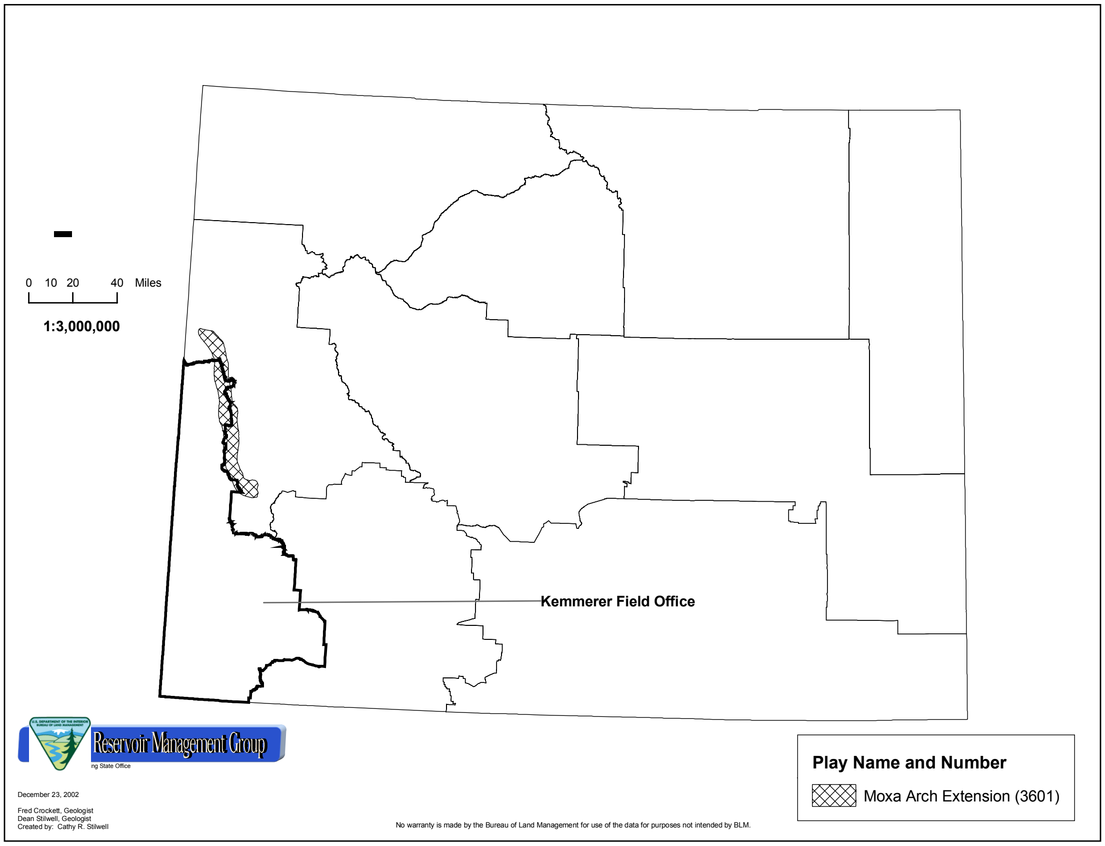


Figure 4-1. Moxa Arch Extension Play

Play 3602. Crawford-Meade Thrusts Play (Hypothetical). This play lies mainly in Utah and Idaho, extending slightly into Wyoming. It is bounded on the west by the Willard-Paris Thrust and on the east by the Crawford-Meade Thrusts. The play is characterized by "(1) probable hydrocarbon accumulations in footwall structural or truncation traps in reservoir rocks interbedded with source rocks, both of Cretaceous age, and (2) gas from Paleozoic shale sources accumulating in Paleozoic and Mesozoic reservoirs in tightly folded anticlines in hanging wall traps in the Crawford Thrust Plate" (Powers 1995). The play is approximately 180 miles long and from 8 to 30 miles wide. It is considered to be hypothetical and in a young stage of exploration. As of 1995, the majority of shows reported were limited to dry gas, except for the few wells that had oil staining in Triassic rocks. The only production found in the play was from the one-well Hogback Ridge field, between the edges of the Crawford and Willard-Paris Thrusts (Powers 1995). Any significant potential in the play, particularly for gas, was expected to remain in the footwall Cretaceous section of the Crawford Thrust Plate in the southern half of the play (Powers 1995). Figure 4-2 is a map of the play in the planning area.

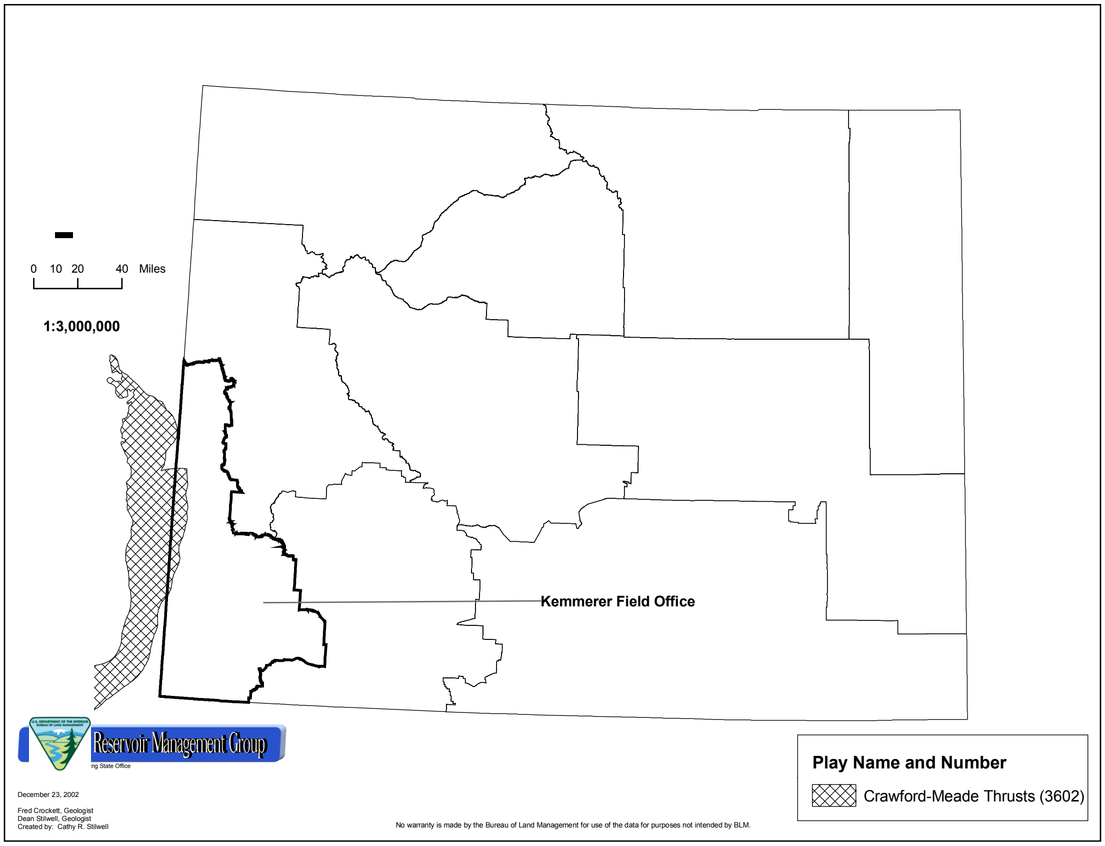


Figure 4-2. Crawford-Meade Thrusts Play

Play 3603. Northern Thrusts Play (Hypothetical). This play lies mainly northwest-southeast for a distance of about 105 miles. It ranges in width from 35 to 55 miles, and is bounded on the east by the Prospect Thrust. The play includes the northern extensions of three of the major thrust systems: Crawford-Meade, Absaroka, and Prospect-Darby (Powers 1995). It involves mainly "Paleozoic reservoir rocks in hanging wall anticlines juxtaposed against Cretaceous source rocks in the footwall of the thrust systems" (Powers 1995). The play was considered hypothetical in 1995 because of the extremely low density of drilling within it. No fields had been discovered and no hydrocarbons were produced. Future potential for undiscovered oil was considered fair to good, and for gas, excellent (Powers 1995). Additional exploration in the play could be hampered by limited access to some public lands and by extremes of topography. Figure 4-3 is a map of the play in the planning area.

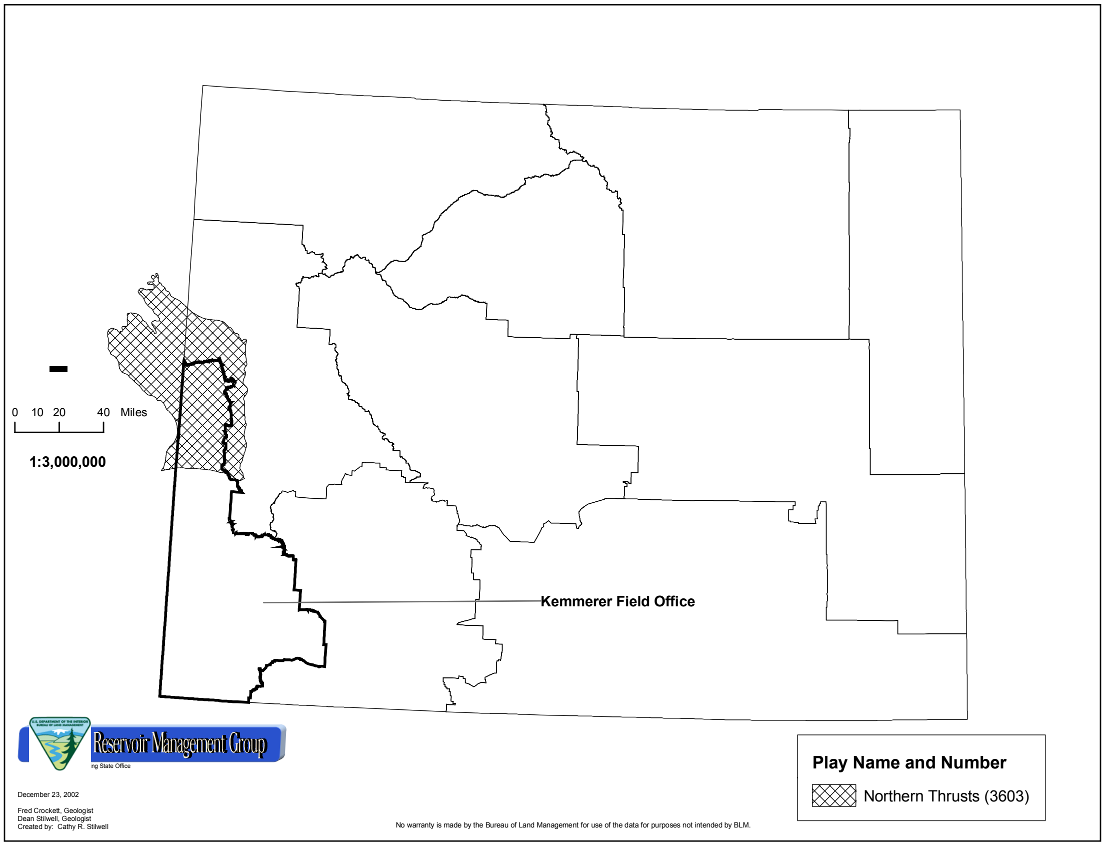


Figure 4-3. Northern Thrusts Play

Play 3604. Absaroka Thrust Play. This play contains nearly all the discovered fields in the Overthrust Belt Province. It trends north-south for approximately 140 miles, and ranges from 18 to 35 miles wide in northern Utah and southwestern Wyoming. The play is characterized by gas and oil accumulations in "dolomite and sandstone reservoirs in hanging-wall anticlines along three subparallel lines of folding within the Absaroka Thrust Plate" (Powers 1995). Fields on the eastern line of folds produce mainly oil and gas from Mesozoic rocks. Fields on the central line of folds produce primarily sour, wet gas and condensate from Paleozoic rocks. The western line of low-relief anticlinal folds produces minor wet gas and condensate, also from Paleozoic rocks (Powers 1995). Between 1975 and 1992, a total of 24 new fields (actively producing) were found. In the northern part of the play, production was established in the late 1980s on the central fold trend at the Bridger Fork and Collett Creek fields. In the early 1990s, substantial new oil production was found by horizontal drilling in the Elkhorn Ridge field in fractured Jurassic Twin Creek Limestone; the first horizontally drilled production in the province. As of 1995, Anschutz Ranch East, Painter Reservoir, Painter Reservoir East, and Pineview had produced most of the oil and gas in the play. In 1995, future potential of the play was considered to be good to excellent (Powers 1995). Figure 4-4 is a map of the play in the planning area.

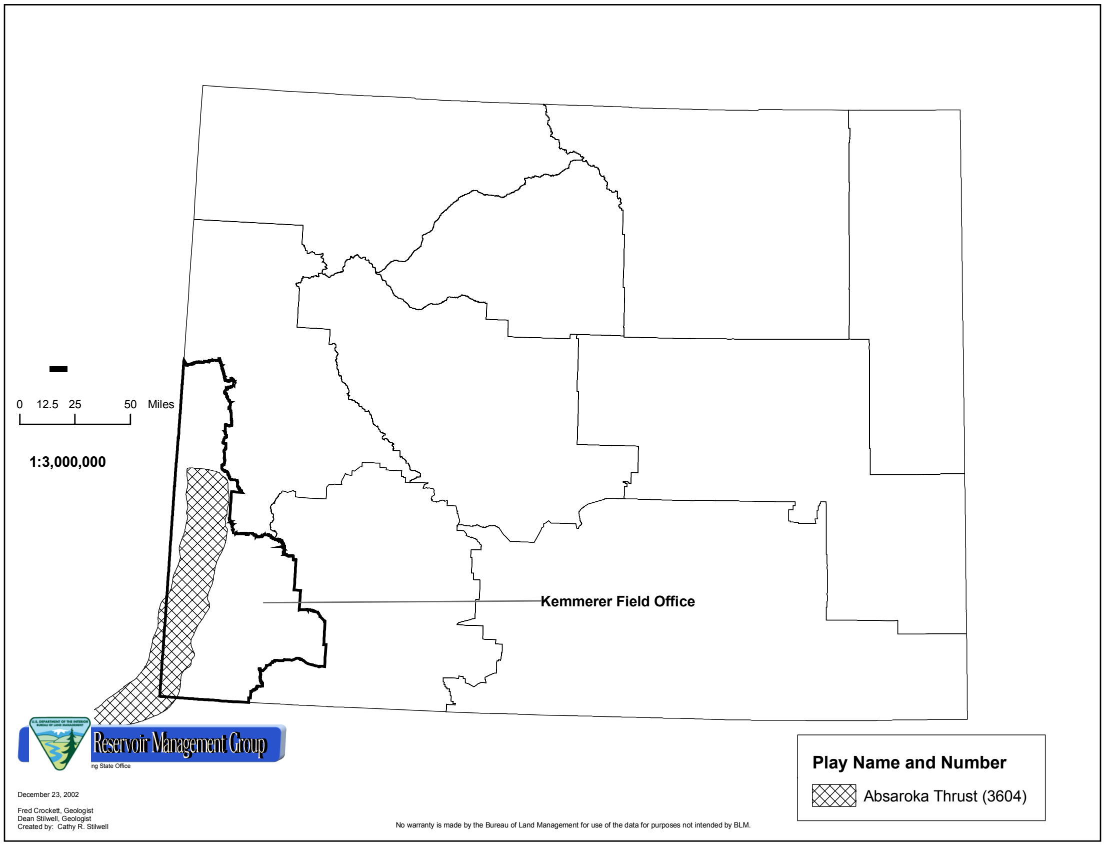


Figure 4-4. Absaroka Thrust Play

Play 3607. Cretaceous Stratigraphic Play. This play extends north from the Wyoming-Utah border for 115 miles to a point west of the LaBarge complex. The play is characterized by "probable oil accumulations resulting from pinchout of reservoir sandstone facies updip and eastward into shale source-rock facies of Cretaceous age on the west-dipping trailing edge of the Hogsback Thrust" (Powers 1995). The play extends, on the east, to the western part of the hanging wall of the Hogsback Thrust. Within this trend is the narrow, sharply folded Lazeart Syncline, whose eastern limb forms the trailing edge of the Hogsback Thrust (Powers 1995). The earliest exploration and drilling in the play were concentrated near oil seeps in the vicinity of the present-day Aspen field in 1884. Wells were first completed in the Spring Valley field in 1900. The Sulphur Creek field was discovered in 1942. In 1995, future potential for oil and associated gas was considered low to moderate. Field sizes were anticipated to be in the small to medium category (Powers 1995). Although the amount of oil in Cretaceous rocks in the play was considered to be significant, improvement in extraction practices was considered necessary for the success of commercial recovery of oil in undiscovered accumulations (Powers 1995). Improved techniques could include the use of inclined or horizontal drilling and different completion methods (Powers 1995). Figure 4-5 is a map of the play in the planning area.

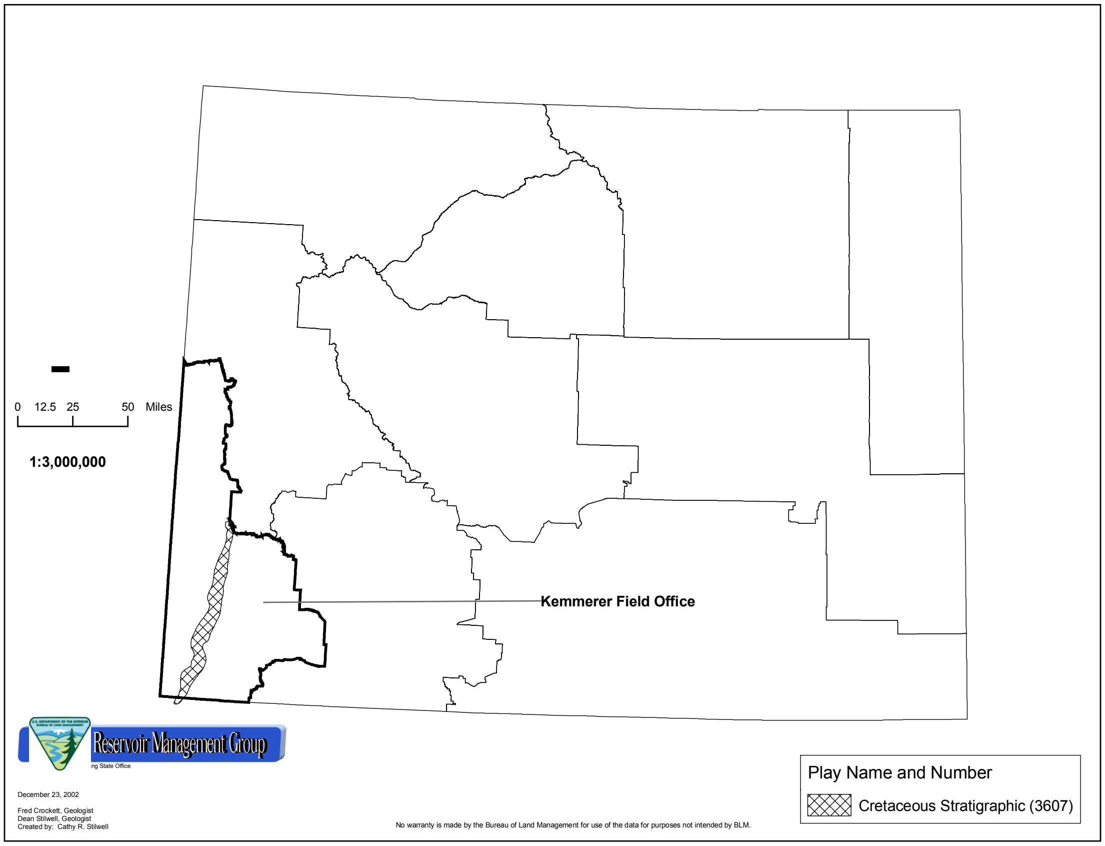


Figure 4-5. Cretaceous Stratigraphic Play

SOUTHWESTERN WYOMING PROVINCE

The 2003 geology report developed as part of the national assessment of oil and gas for the Southwestern Wyoming Province is not yet available. Several gas plays identified as part of the assessment are expected to be described in that report. Figures 4-6 through 4-12 are location maps of the plays within the planning area.

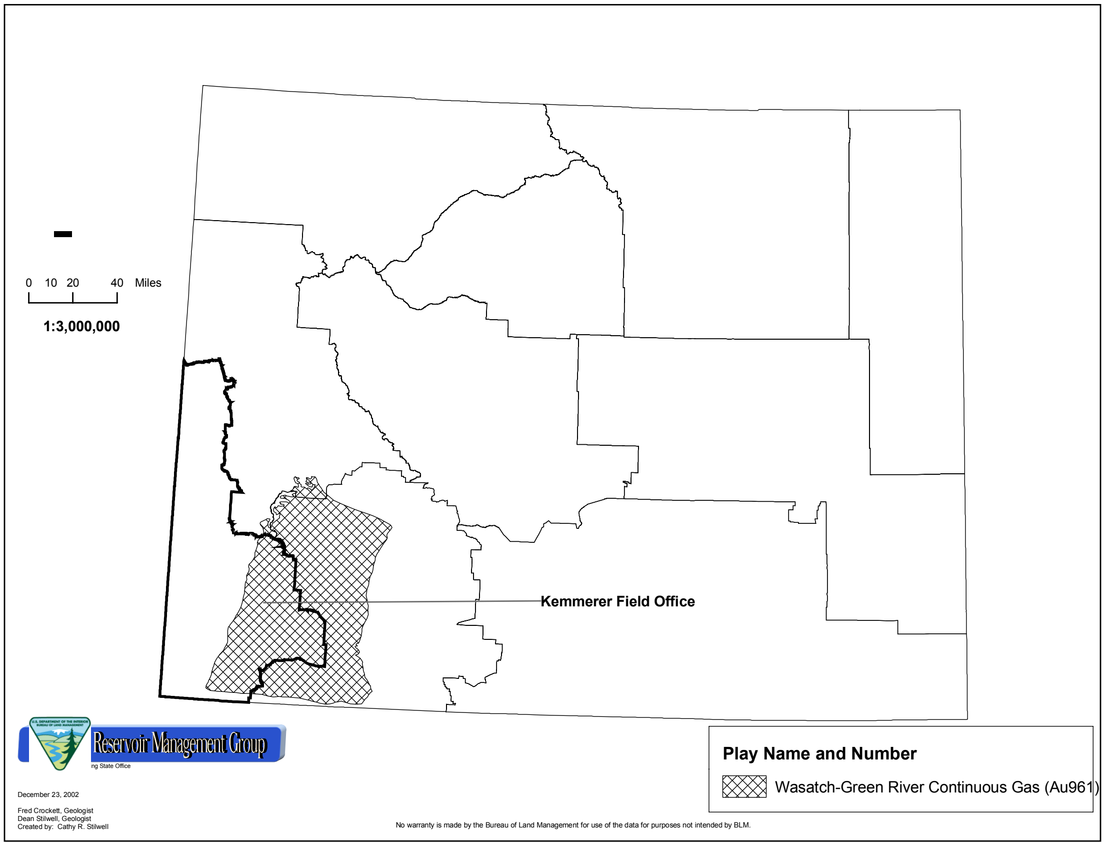


Figure 4-6. Wasatch-Green River Continuous Gas Play

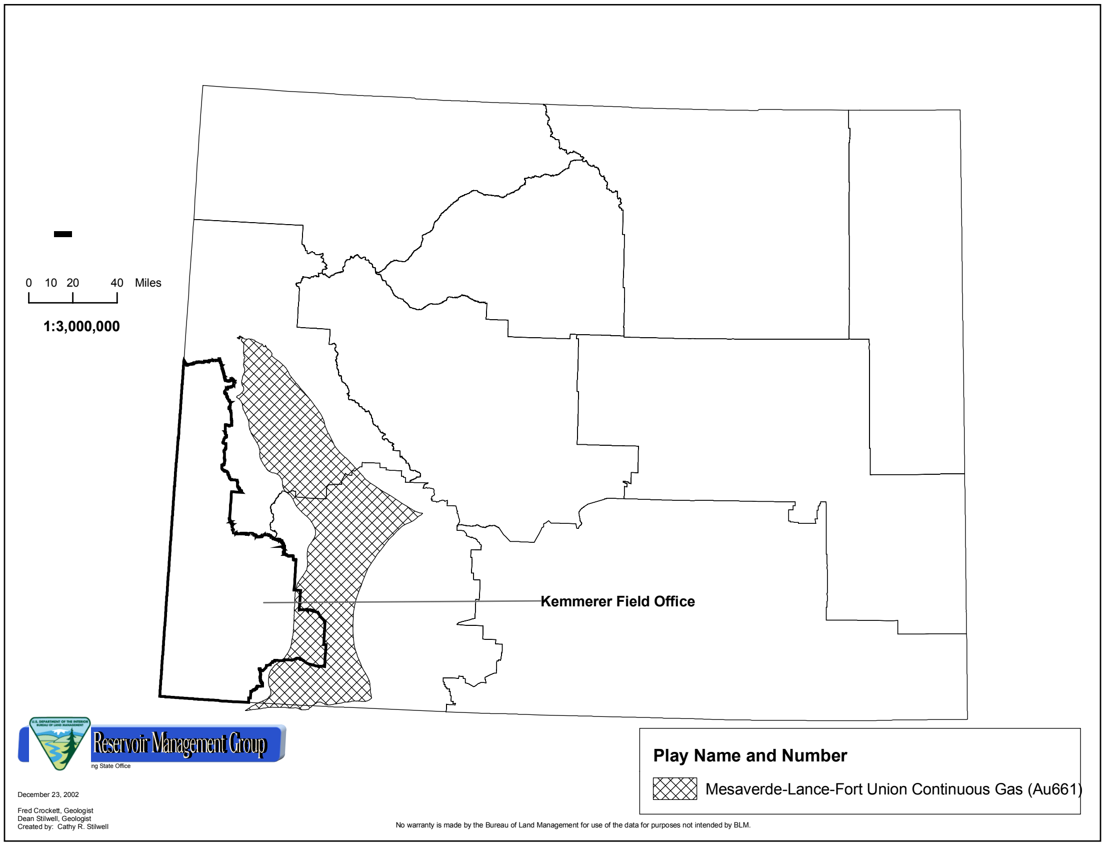


Figure 4-7. Mesaverde-Lance-Fort Union Continuous Gas Play

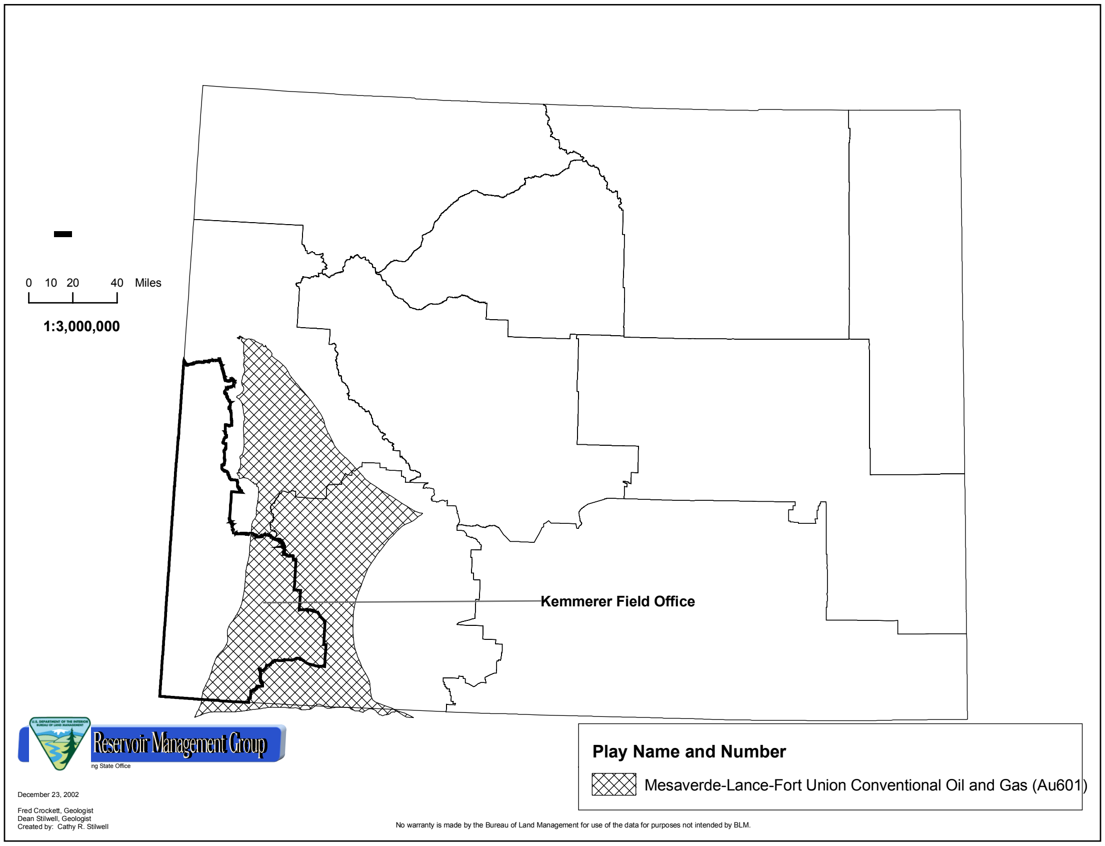


Figure 4-8. Mesaverde-Lance-Fort Union Conventional Oil and Gas Play

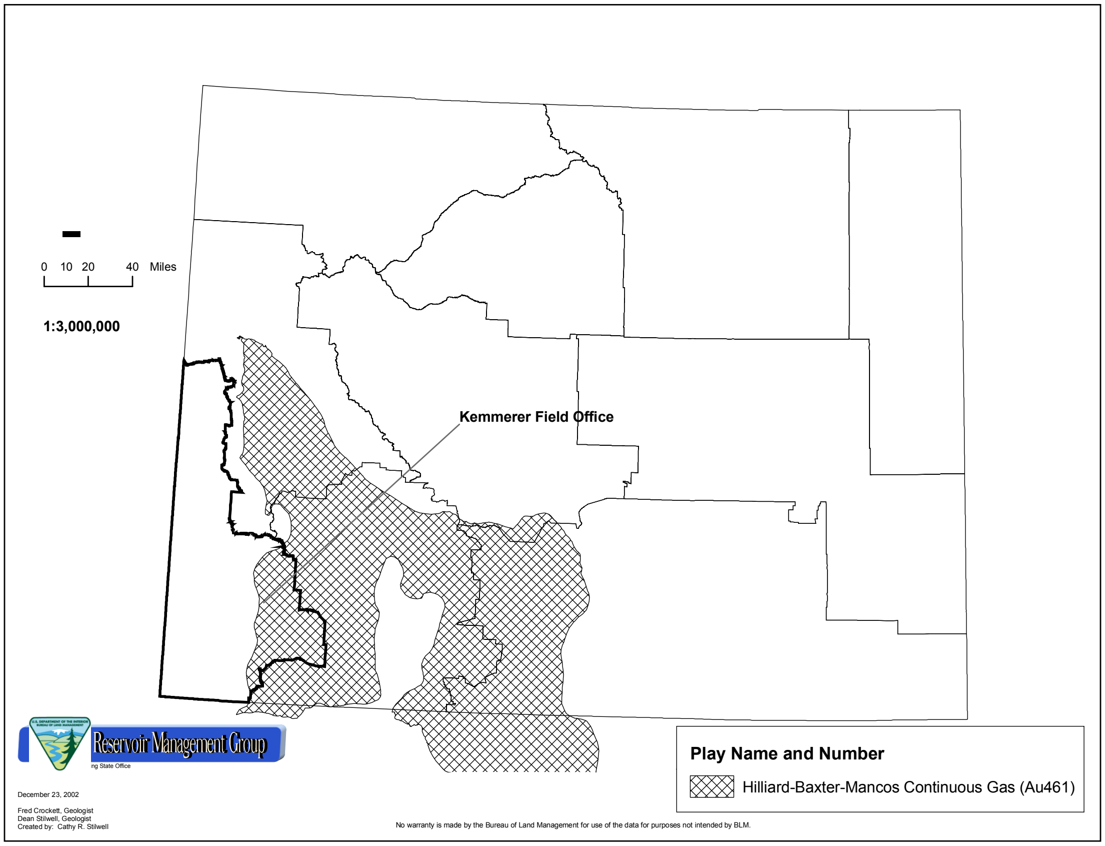


Figure 4-9. Hilliard-Baxter-Mancos Continuous Gas Play

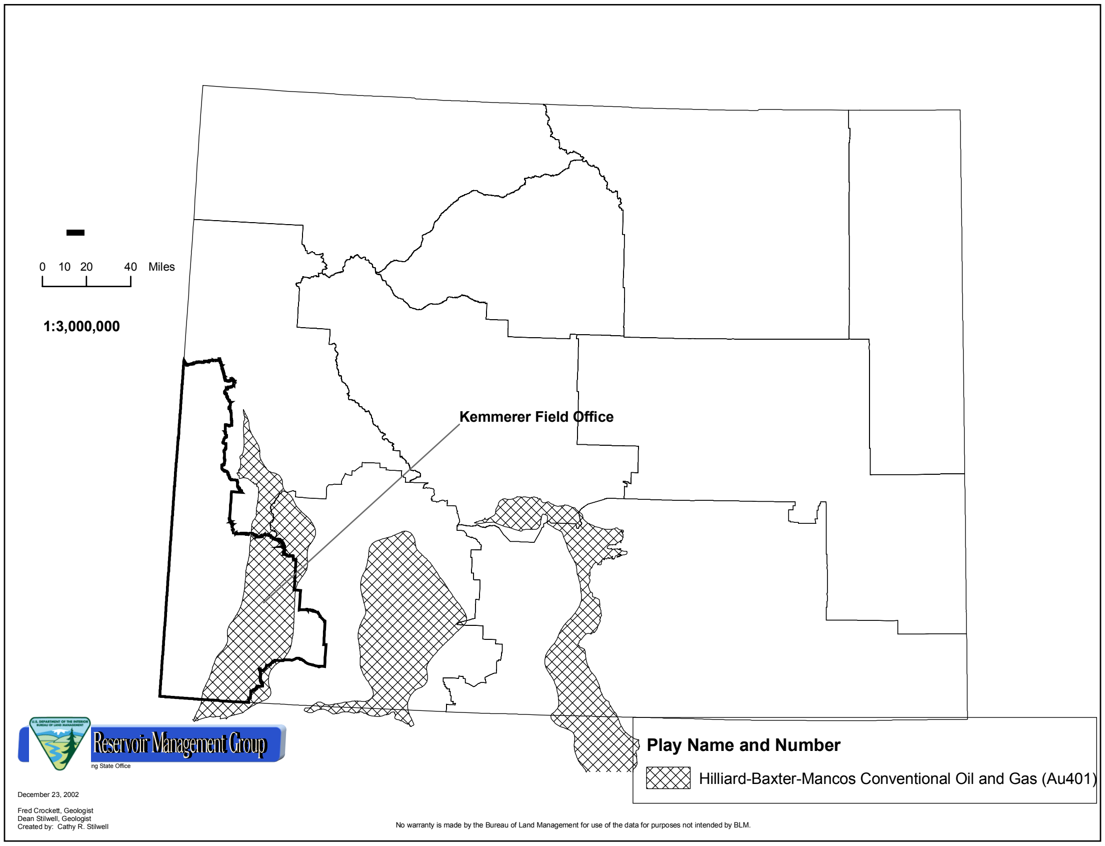


Figure 4-10. Hilliard-Baxter-Mancos Conventional Oil and Gas Play

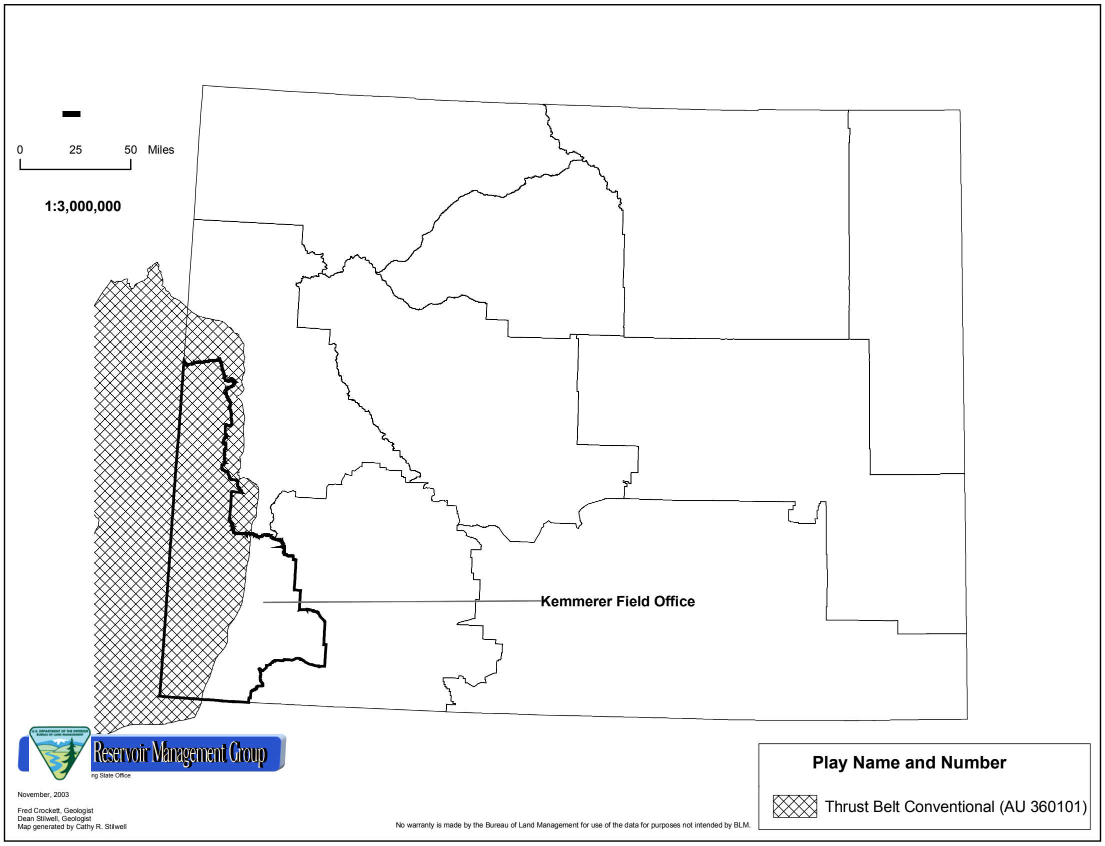


Figure 4-11. Thrust Belt Conventional Play

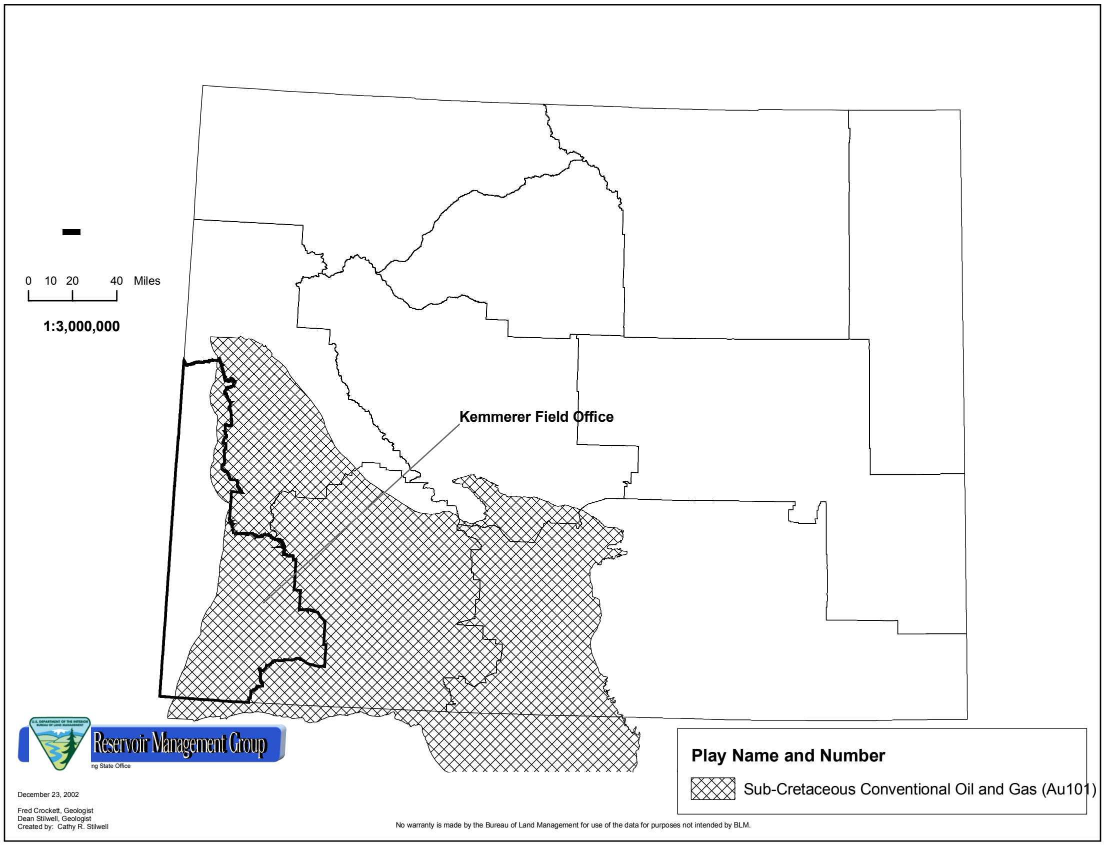


Figure 4-12. Sub-Cretaceous Conventional Oil and Gas Play

4.1.1.2 Non Coalbed Hydrocarbon Resources

To meet the requirements of the EPCA, the USGS conducted an assessment of undiscovered oil and gas resources in five Rocky Mountain provinces. One of these, the Southwestern Wyoming Province, includes the eastern part of the Kemmerer Planning Area (USGS 2002). The USGS assessments were based on the geologic elements of each Total Petroleum System (TPS) defined in the province, including hydrocarbon source rocks (source-rock maturation, hydrocarbon generation and migration), reservoir rocks (sequence stratigraphy and petro-physical properties), and hydrocarbon traps (trap formation and timing) (USGS 2002).

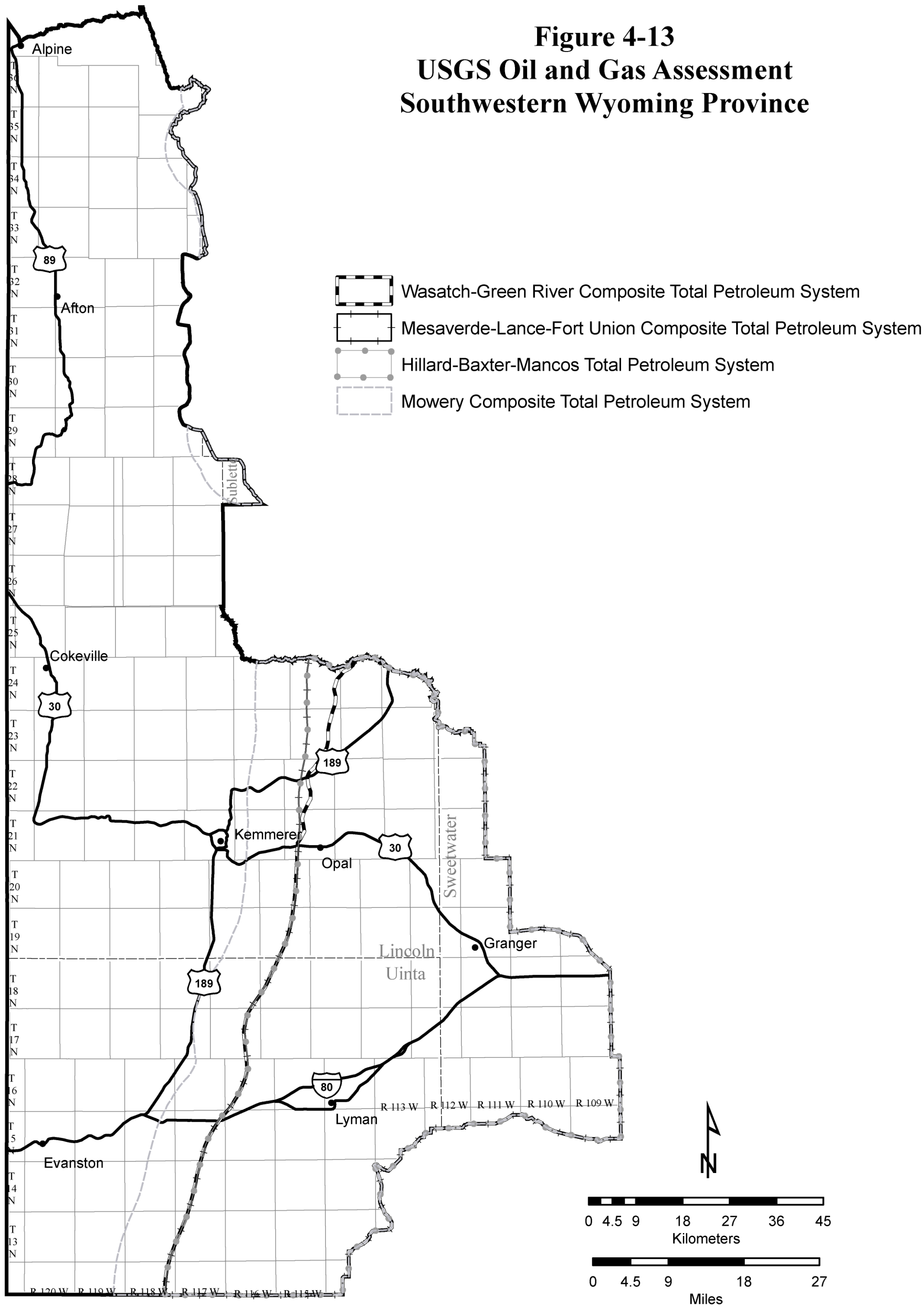
Nearly all (97 percent) of the undiscovered gas resource in the province is continuous and distributed in six primary TPSs. Three of the six primary TPSs fall partially within the Kemmerer Planning Area: the Mowry Composite TPS (8.5 trillion cubic feet of gas); the Mesaverde-Lance-Ft. Union Composite TPS (13.7 trillion cubic feet of gas); and the Lance-Ft. Union Composite TPS (8.7 trillion cubic feet of gas) (USGS 2002). The remaining undiscovered gas is associated/dissolved gas in oil accumulations, or is in conventional non-associated gas accumulations. The majority of the undiscovered oil is outside the planning area in the Niobrara TPS and the Phosphoria TPS. Smaller quantities of undiscovered oil were identified in the Mowry TPS and the Mesaverde-Lance-Ft. Union Composite TPS (USGS 2002). The Wasatch-Green River Continuous Gas Assessment Unit (AU) was not quantitatively assessed as part of this study (USGS 2002). Figure 4-13 depicts TPS locations within the southwestern Wyoming province.

4.1.1.3 Non-Coalbed Hydrocarbon Occurrence Potential

The DOE's Office of Fossil Energy, along with the BLM and USFS commissioned a series of detailed studies in response to a National Petroleum Council (NPC) study that found that 40 percent (137 trillion cubic feet) of the potential natural gas supply from the Rocky Mountain area on federal lands is currently unavailable or restricted because of competing uses or environmental considerations (Advanced Resources International, Inc. [ARI] 2001). The DOE report focused on southern Wyoming and northwestern Colorado, particularly the Greater Green River Basin and adjacent areas. The Green River Basin was chosen because it contains the largest quantity of potential natural gas resource in the Rockies (ARI 2001). All federal lands within the BLM offices of Little Snake, Rock Springs, Kemmerer, Pinedale and Rawlins, and Forest Services lands of the Bridger-Teton and Medicine Bow-Routt National Forests were analyzed for the impact of stipulations on natural gas resources availability. Undiscovered, technically recoverable natural gas resource data from 29 resource plays were obtained for the DOE study, primarily from the USGS's 1995 national oil and gas assessment (ARI 2001).

The DOE study identified lands within the Kemmerer Planning Area as having little in the way of technically recoverable natural gas resources (ARI 2001). A little more than two-thirds of the technically recoverable federal natural gas resources in the study area were found either to be closed to development or available with restrictions. About 30 percent of the potential federal resources were found to be off limits, with about 1 percent of underlying resources closed by statute (e.g., national parks and wilderness areas). The remaining inaccessible areas (about 29 percent of the potential federal resources) were administratively closed (not available for lease under a Forest Plan or in a wilderness re-inventory area) (ARI 2001). Leasing stipulations restrict an additional 38 percent of the federal natural gas resource. More than 90 percent of the restrictions are due to timing limitations of between three and nine months for critical winter habitat for big game, or

Figure 4-13
USGS Oil and Gas Assessment
Southwestern Wyoming Province



nesting periods for sage grouse or raptors. Table 4-1 identifies wildlife timing limitations in the Kemmerer Planning Area. The remaining 32 percent of the federal resource is subject to standard lease terms that dictate that the lessee comply with environmentally protective requirements (ARI 2001). Appendix B lists oil and gas lease stipulations for the planning area.

Table 4-1. Wildlife Timing Limitations

Affected Areas	*Restriction*	*Restricted Area*
Big Game Crucial Winter Ranges	Nov 15 – April 30	Antelope, elk, moose, and mule deer crucial winter ranges
Parturition Areas	May 1 – June 30	
Designated parturition areas		
Sage Grouse Leks [Stip Code K-7]	Feb 1 – May 15	Within ¼ radius of lek
Sage Grouse Nesting Area [Stip code K-7]	Apr 1 – July 1	Up to 2 mile radius of lek
Golden Eagle Nest [Stip code K-5]	Feb 1 – July 31	Within one-half mile radius
Osprey Nest	Feb 1 – July 31	Within one-half mile radius
Swainson's Hawk Nest	Feb 1 – July 31	Within one-half mile radius
Ferruginous Hawk Nest [Stip code K-6]	Feb 1 – July 31	Within one mile radius
Coopers Hawk Nest	Feb 1 – July 31	Within one-half mile radius
Burrowing Owl Nest	Feb 1 – July 31	Within one-half mile radius
Merlin Nest [Stip code K-1]	Feb 1 – July 31	Within one-half mile radius
Other raptors [Stip code K-4]	Feb 1 – July 31	Within one-half mile radius
Game Fish Spawning Areas	Determined on case-by-case basis.	

Source: ARI 2001

The majority of the Kemmerer Planning Area is considered by the BLM to have very low potential for oil and gas resources. An area of moderate oil and gas potential is located in the eastern part of the planning area in Uinta, Lincoln, and Sweetwater Counties. A smaller area of moderate potential is in Uinta and Lincoln counties in the southwestern part of the planning area. The areas of moderate potential are bordered by locations considered to have low potential. Restricted resource locations are primarily in the northern and central portions of the planning area (ARI 2001). Figure 4-14 depicts areas of oil and gas potential in the Kemmerer Planning Area.

4.1.1.4 Non Coalbed Hydrocarbon Future Activity

This section summarizes reports from a variety of sources that describe potential future oil and non-CBNG gas activity. The numbers used by these sources are assumed to be correct, but have not been independently verified. RFD scenarios for oil and gas development in the Kemmerer Planning Area are expected to be released by the BLM in 2004.

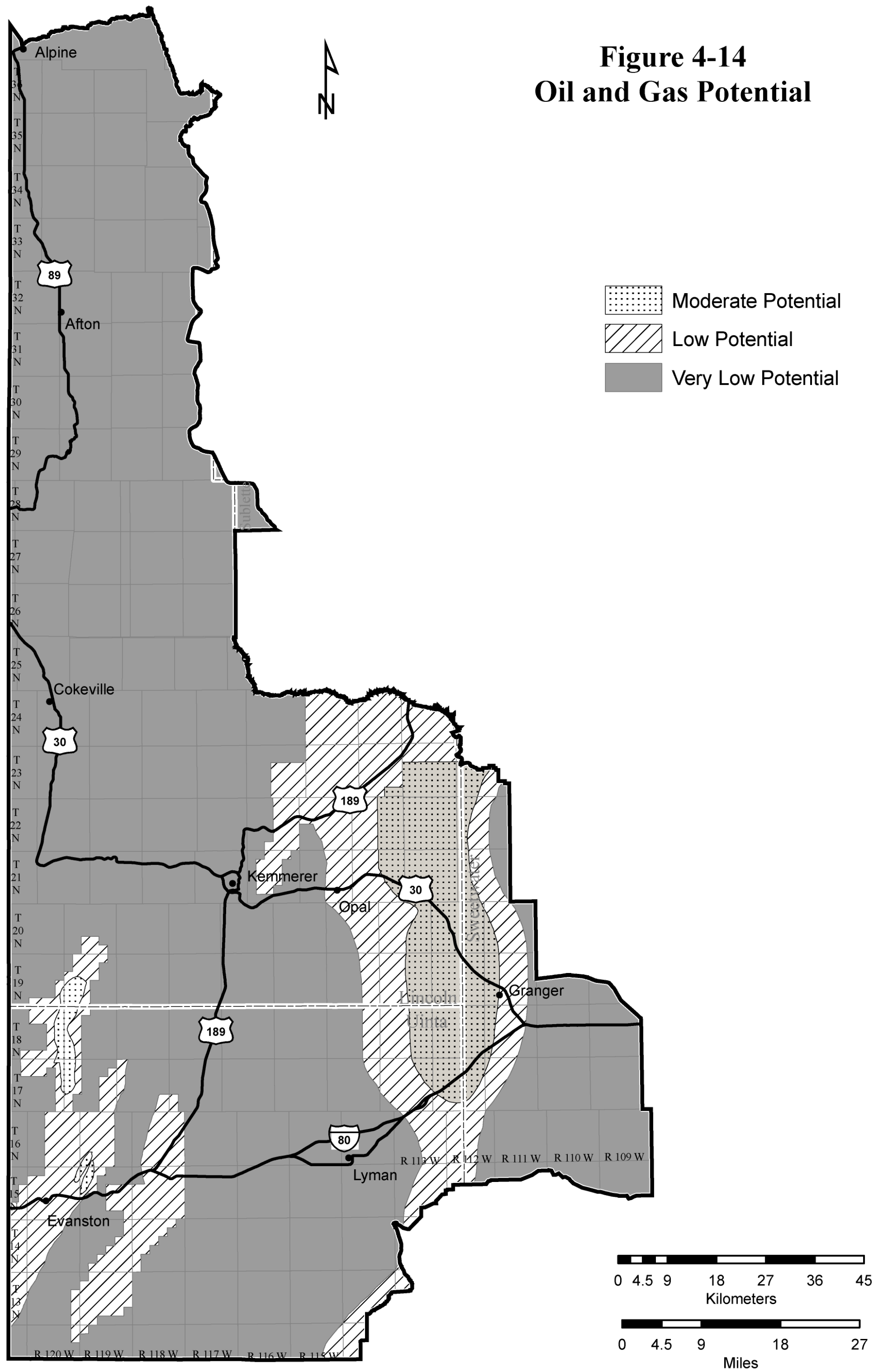


Figure 4-14
Oil and Gas Potential
Moderate Potential
Low Potential
Very Low Potential
Alpine
Afton
Cokeville
Kemmerer
Opal
Granger
Lyman
Evanston
89
30
189
80
R 112 W
R 111 W
R 110 W
R 109 W
R 120 W
R 119 W
R 118 W
R 117 W
R 116 W
0 4.5 9 18 27 36 45
Kilometers
0 4.5 9 18 27
Miles

OIL AND NATURAL GAS PRICE ESTIMATES

The Energy Information Administration (EIA) Annual Energy Outlook (AEO) has projected average world oil prices to increase from $22.01 per barrel (2001 dollars) in 2001 to $25.83 per barrel in 2003, then to decline to $23.27 per barrel in 2005. Rising prices are projected for the longer term, to roughly $25.50 in 2020 and roughly $26.50 in 2025 (EIA 2003).

After 2002, natural gas prices are projected to move higher as technology improvements become inadequate to offset the impacts of resource depletion and increased demand (EIA 2003). Natural gas prices are projected to increase in an uneven fashion as higher prices allow the introduction of major new, large-volume natural gas projects that temporarily depress prices when initially brought on line. The EIA projects prices to reach about $3.70 per thousand cubic feet by 2020 and $3.90 per thousand cubic feet by 2025 (EIA 2003). At $3.70 per thousand cubic feet, the 2020 wellhead natural gas price in AEO 2003 is more than 35 cents higher than the AEO 2002 projection. This is due to a reduction in estimates of the potential for inferred natural gas reserve appreciation, and a reduced expectation for technology improvement over time. As demand for natural gas increases, expected technology improvements are not expected to completely offset the effects of resource depletion (EIA 2003).

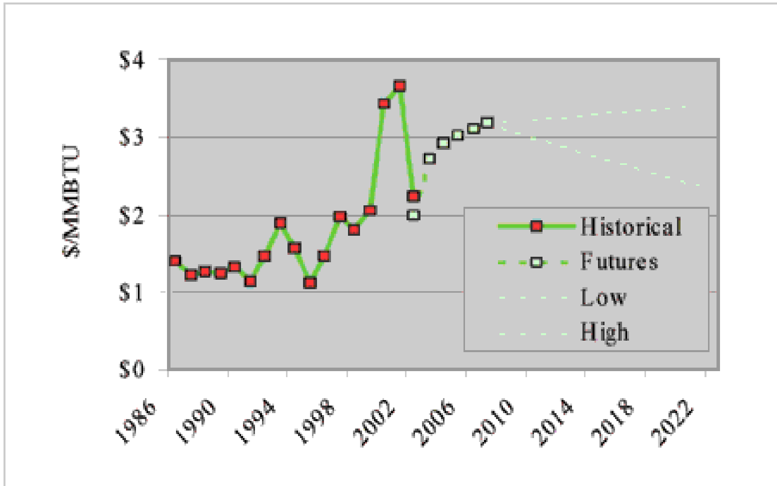
Oil and gas prices are volatile. Figures 4-15 and 4-16 show price fluctuations since the 1980s, as well as providing an estimate of potential future highs and lows. These projections were prepared for the BLM's Pinedale Field Office (BLM 2003e).

LEASING

Leases on lands where the U.S. owns the oil and gas rights are offered at auction at least quarterly. The maximum lease size is 2,560 acres and the minimum bid is $2.00 per acre. An administrative fee of $75.00 per parcel is charged and each successful bidder must meet citizenship and legal requirements. Leases are issued for a ten-year term, and a 12.5 percent royalty rate on production is required. Leases that become productive do not terminate until all wells on the lease have ceased production. Many private oil and gas leases contain a Pugh clause, which allows only the developed portion of the lease to be held by production. However, federal leases have no such clause, allowing one well to hold an entire lease. Since 1996, only lands requested for lease have been offered. Before that, virtually all federal lands available for lease were offered at each sale (BLM 2003e). Appendix A describes oil and gas operation.

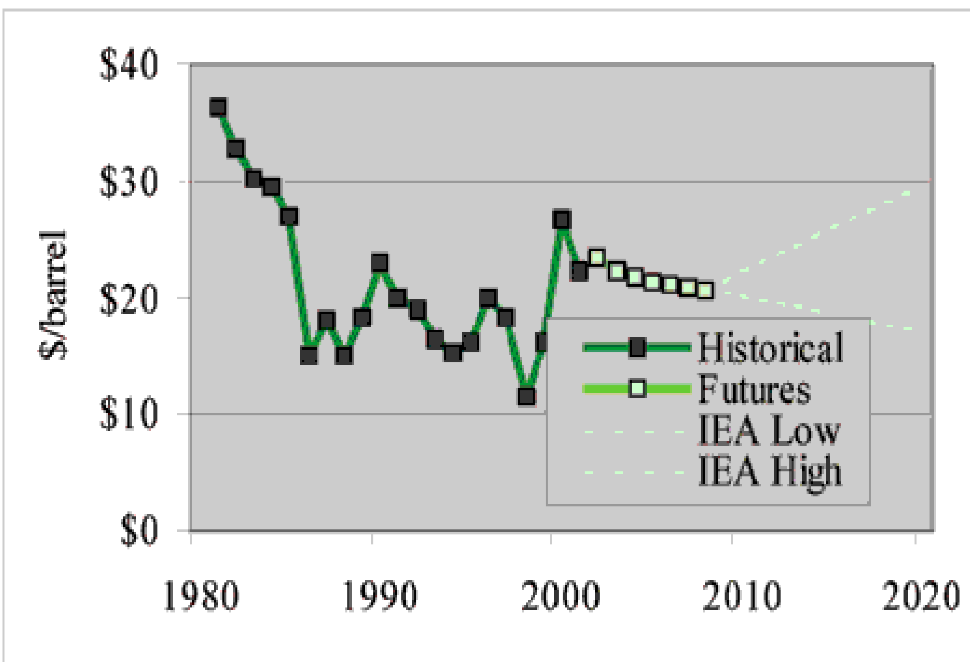
SEISMIC SURVEYS

Reflection seismic prospecting is the most common indirect method for locating subsurface structures that may contain hydrocarbons. Seismic energy is induced into the earth using one of several methods at a location called a source point or shot point. As the waves travel downward and outward, they encounter rock strata that transmit seismic energy at different velocities. The end product of the seismic processing is a seismic section that presents the strata or structures below the surface. Seismic surveys are authorized on BLM managed surface by approval of Notice of Intents (NOIs) to conduct geophysical operations. Table 4-2 lists seismic projects in Kemmerer Planning Area counties that were permitted by WOGCC from 2000 through 2003.



Note: The 2002 price is based on an average of January and February prices. Projected prices are based on gas futures at Henry Hub and the Energy Information Administration (2001) low and high price projections for 2020.

Figure 4-15. Gas Prices and Projections



Note: Projected prices are based on oil futures of West Texas Intermediate and the Energy Information Administration (2001) low and high price projections for 2020.

Figure 4-16. Oil Prices and Projections

Table 4-2. Seismic Projects Permitted by WOGCC

	2000			2001			2002			2003		
County	*Permits*	*Miles*	*3-D Sq. Mi.*	*Permits*	*Miles*	*3-D Sq. Mi.*	*Permits*	*Miles*	*3-D Sq. Mi.*	*Permits*	*Miles*	*3-D Sq. Mi.*
Lincoln	0	0	0	1	0	25	0	0	0	0	0	0
Sweetwater	13	54	1,004	11	129	802	7	348	485	2	1	8
Uinta	0	0	0	1	259	0	2	196	0	1	0	47
Totals	**13**	**54**	**1,004**	**13**	**388**	**827**	**9**	**544**	**485**	**3**	**1**	**55**

Source: WOGCC 2003

FUTURE ACTIVITY

U.S. crude oil production in the contiguous 48 states is projected to increase from 4.8 million barrels day in 2001 to 5.3 million barrels per day in 2007, and then to decline to 4.2 million barrels per day in 2025 (EIA 2003). U.S. natural gas production is expected to increase by 7.3 trillion cubic feet through 2005 (EIA 2003). The largest increase in domestic natural gas production, from 2001 through 2025, is projected to come from the Rocky Mountain region, predominantly from unconventional sources.

In response to recommendations by the National Petroleum Council in their 1999 report *"Meeting the Challenges of the Nation's Growing Natural Gas Demand",* the National Energy Technology Laboratory (NETL) began a program combining resource assessment, industry tracking, and technology modeling focused primarily on resources that were considered subeconomic and unrecoverable. The program used a log-based, gas-in-place approach with a high level of geographic and stratigraphic detail. The first phase of the program focused on the Greater Green River and Wind River basins, which contain the majority of the total low-permeability sandstone resource for the Rocky Mountain region (Boswell et al. 2002). This estimate was based on past gas-in-place resource assessments conducted for the DOE by the USGS.

Results of the NETL program confirmed past accounts of large quantities of natural gas existing in the two basins. In the Greater Green River Basin, more than 3,600 trillion cubic feet of gas was determined to be remaining in place (Boswell et al. 2002). Accessing these resources would require the development and application of advanced exploration, drilling, completion, stimulation, and production technologies.

Gas Systems Analysis Model (GSAM) analyses were conducted to estimate the amount of gas in place that is technically and economically recoverable with current technologies. About 10 percent of gas in place in the Greater Green River Basin (360 trillion cubic feet) was determined to be recoverable. GSAM's estimates significantly exceeded USGS 2002 estimates. USGS estimates were based on extrapolations of current conditions to predict the productivity expected from selected resource elements. In contrast, GSAM estimated what could happen if an entire resource was fully developed using the most current technology as a baseline for identifying the most promising research and development approaches (Boswell et al. 2002).

Within the Kemmerer Planning Area, the BLM estimates that approximately 1,000 oil and gas wells (excluding CBNG wells) could be drilled in the planning area within the next 20 years (BLM 2003a).

4.1.2 Coalbed Natural Gas

Coalbed gases in the Southwestern Wyoming Province coalbeds have been estimated at 314 trillion cubic feet (Law 1995). Despite problems associated with high water content, Law (1995) suggested that there is a good potential for gas production in the Southwestern Wyoming Province as a whole, especially where coalbed water can be drawn down to levels at which economic rates of gas can be produced. He identified potential prospective areas as "the crests of folds where gas has accumulated by buoyancy, sites where the flow of water through coalbeds is impeded by the presence of faults, or near mining operations that have lowered the water table in coal" (Law 1995).

As a result of technological improvements and rising natural gas prices, natural gas production from unconventional sources (tight sands, shale, and CBNG) is projected to increase more rapidly than conventional production (EIA 2003). The Wyoming CBNG industry has grown extensively in recent years. CBNG wells in the state increased from 52 in 1992 to 4,800 in 2000. In 2000, the monthly production in the state was 14 billion cubic feet and climbing (University of Wyoming 2003). A 2001 report indicated that although drilling on federal land had slowed because of a moratorium on permitting in the Powder River Basin, it was expected to increase following the completion of the EIS allowing development to proceed (DeBruin et al. 2001).

In the Kemmerer Planning Area, CBNG potential is estimated to be limited. Areas with a low potential for CBNG resources are concentrated in the central portion of the planning area along the eastern edge of the Overthrust Belt. Two additional low-potential areas have been identified in the Southwestern Wyoming Province portion of the planning area. The remainder of the area is considered to have no potential for CBNG. Figure 4-17 shows areas of CBNG potential in the planning area. Figure 4-18 shows the Frontier-Adaville-Evanston coalbed gas play location in the planning area. Figure 4-19 shows the Fort Union coalbed gas play.

Some CBNG development is considered likely to take place in the future following successful pilot-scale testing (BLM 2003a). The BLM estimates that approximately 200 CBNG wells could be drilled in the Kemmerer Planning Area within the next 20 years (BLM 2003a).

4.1.3 Coal

4.1.3.1 Coal Resources

Current coal production in the Kemmerer Planning Area is centered in the Overthrust Belt Province in Lincoln County west of Kemmerer. Figure 4-20 shows the coal Logical Mining Units (LMUs) and the surface coal mined areas in the planning area.

For federal coal areas with surface mining potential within the Kemmerer Planning Area, about 5,800 acres containing approximately 25 million tons of coal are areas acceptable for further consideration for coal leasing (BLM 2003a). About 1,340 acres with approximately 5.7 million tons of coal are acceptable for coal development with certain stipulations and mitigation requirements. About 390 acres with approximately 1.7 million tons of coal are acceptable for further consideration for coal leasing, but are pending additional studies. Forty acres of privately owned land containing 0.2 million tons of federally-owned coal are unavailable for coal leasing (BLM 2003a). The planning

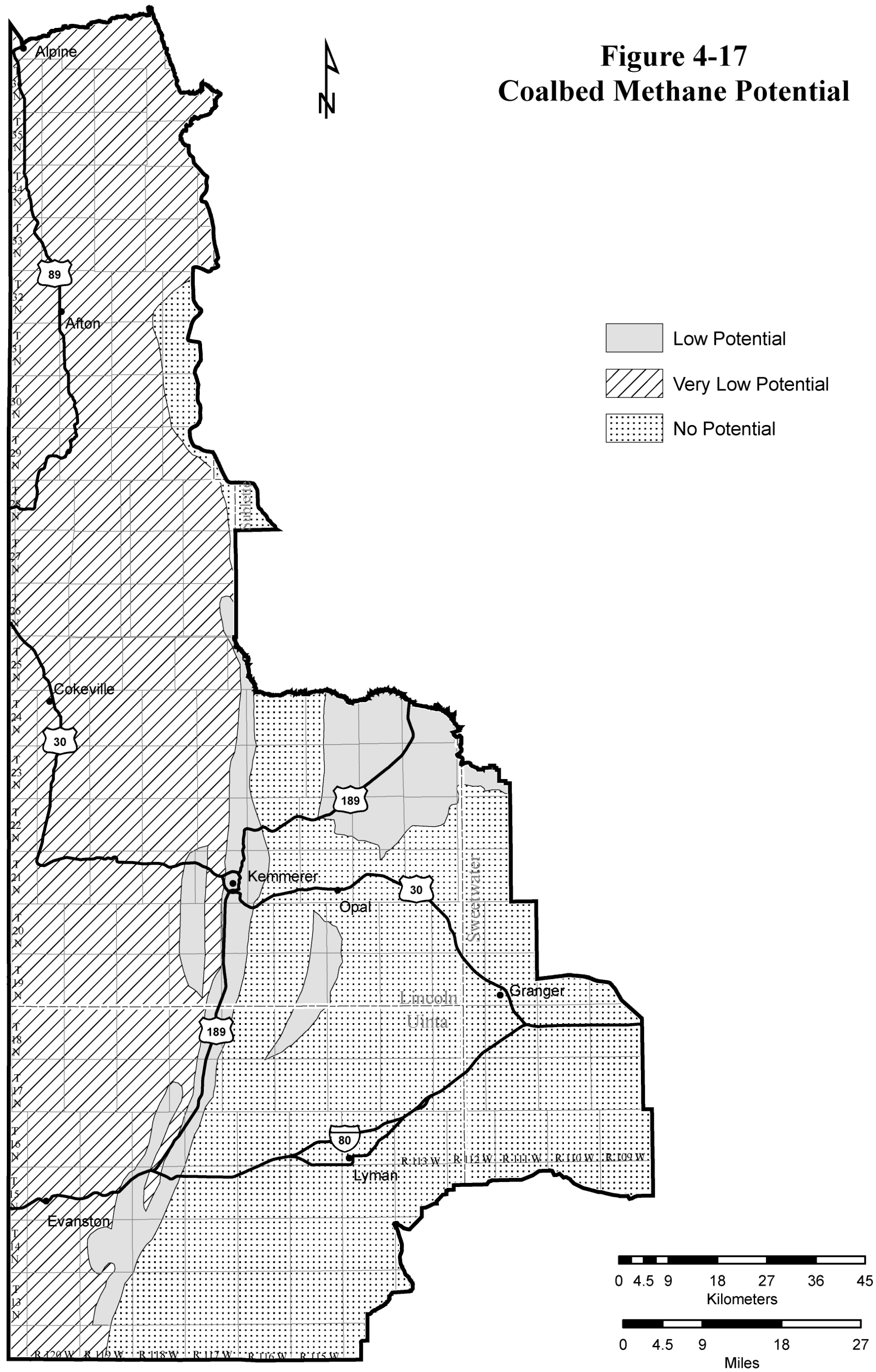


Figure 4-17
Coalbed Methane Potential
Low Potential
Very Low Potential
No Potential
N
Alpine
Afton
Cokeville
Kemmerer
Opal
Granger
Lyman
Evanston
89
30
189
80
Sweetwater
Lincoln
Uinta
0 4.5 9 18 27 36 45
Kilometers
0 4.5 9 18 27
Miles

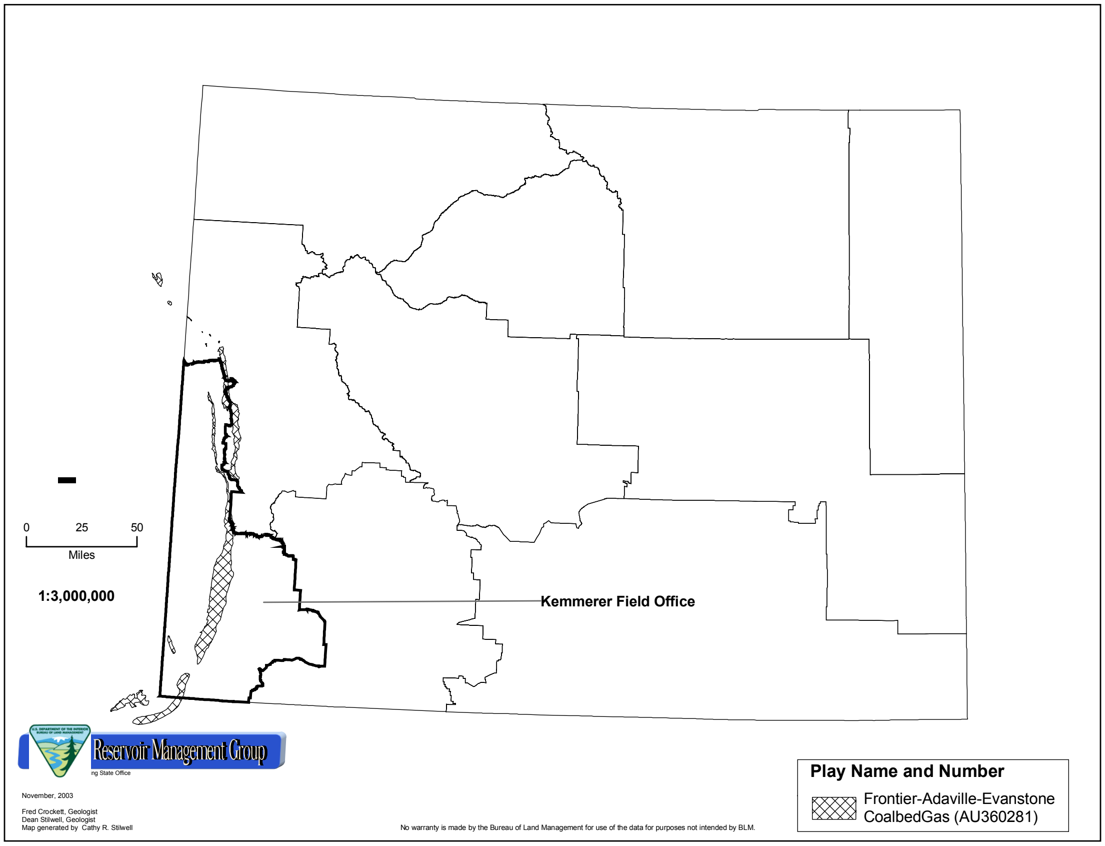


Figure 4-18. Frontier-Adaville-Evanston Coalbed Gas Play

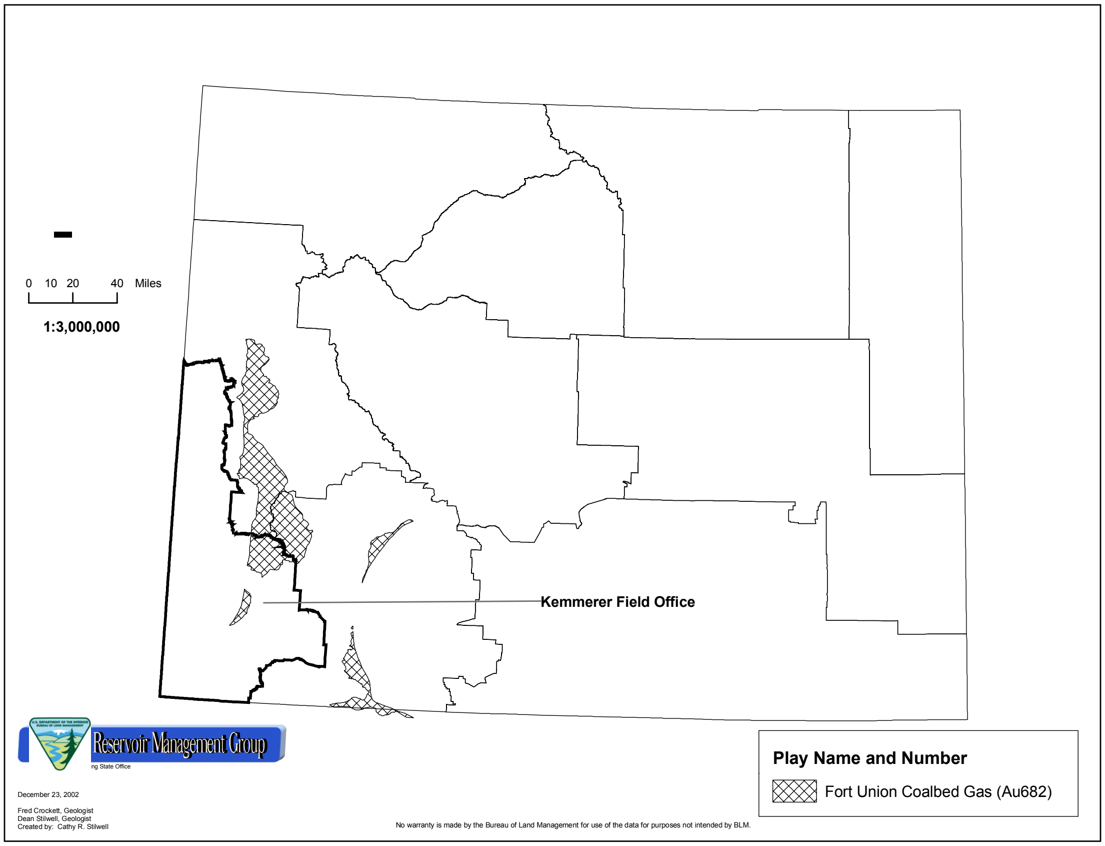


Figure 4-19. Fort Union Coalbed Gas Play

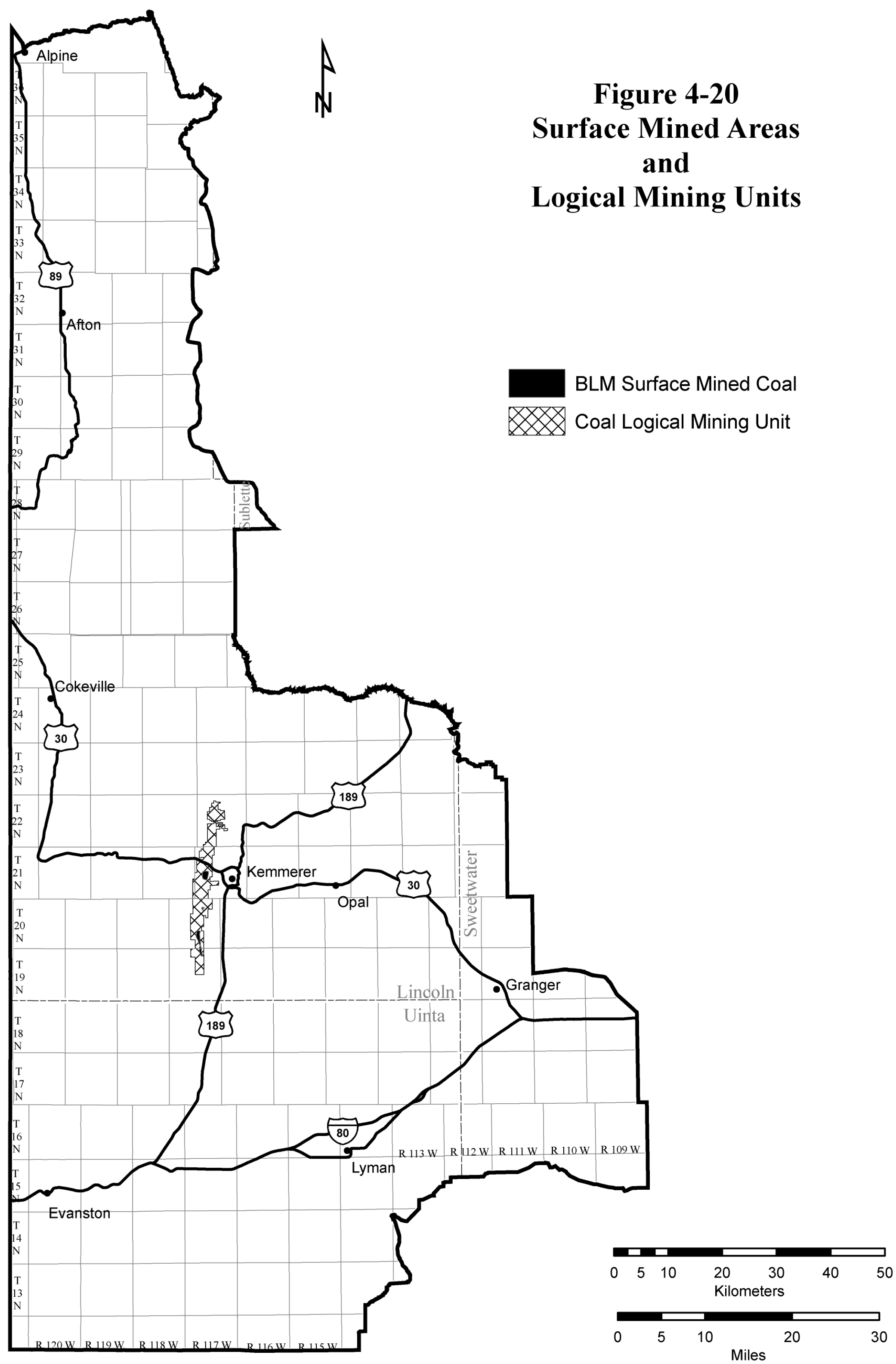


Figure 4-20
Surface Mined Areas
and
Logical Mining Units
BLM Surface Mined Coal
Coal Logical Mining Unit
Alpine
Afton
Cokeville
Kemmerer
Opal
Granger
Lyman
Evanston
Lincoln
Uinta
Sweetwater
89
30
189
80
R 113 W
R 112 W
R 111 W
R 110 W
R 109 W
R 120 W
R 119 W
R 118 W
R 117 W
R 116 W
R 115 W
0 5 10 20 30 40 50
Kilometers
0 5 10 20 30
Miles

area has one coal Lease by Application (LBA) area. The BLM's Coal Screening Process will be applied to the LBA. The steps in the process are: 1) identification of areas with federal coal development potential; 2) application of coal unsuitability criteria; 3) evaluations of other multiple use conflicts; and 4) surface owner consultations, if applicable.

For federal coal areas with subsurface mining potential in the Kemmerer Planning Area, about 4,800 acres with approximately 33 million tons of coal are acceptable for development, about 1,891 acres are acceptable for limited surface operations (i.e., subject to restrictive types and placement of facilities, seasonal restrictions, etc.). About 53 acres with approximately 0.4 million tons of coal are acceptable for further consideration for coal development. About 940 acres are acceptable for surface operations and impacts associated with subsurface mining, with certain stipulations and mitigation requirements (BLM 2003a). Table 4-3 summarizes coal development potential within the Kemmerer Planning Area.

Table 4-3. Coal Development Potential, Kemmerer Planning Area

Action	*Acres*	*Coal (million tons)*
Surface Mining, Federal Land		
Acceptable for coal development.	5,800	25
Acceptable for coal development with stipulations/mitigation requirements.	1,340	5.7
Acceptable for consideration for coal development.	390	1.7
Surface Mining, Private Land		
Unavailable for coal development.	40	0.2
Subsurface Mining, Federal Land		
Acceptable for coal development.	4,800	33
Acceptable for acceptable for limited surface operations.	1,891	N/A
Acceptable for consideration for coal development.	53	0.4
Acceptable for surface operations associated with subsurface mining, with stipulations and mitigation requirements.	940	N/A

Source: BLM 2003a

In 1999, the USGS assessed coal resources in five regions of the U.S., including the Southwestern Wyoming Province, to determine the quantity, quality, and minability of coal likely to be used within the next 20 to 30 years. The Southwestern Wyoming Province contains major coal resources in Cretaceous and Tertiary rocks that have been estimated at 1,276 billion tons (Law 1995).

4.1.3.2 Future Development

This section summarizes reports from a variety of sources that describe potential future coal activity. The projections used by these sources are assumed to be correct, but have not been independently verified.

Coal Price Estimates

The sale price of federal coal in Wyoming has fluctuated since 1985 from about $14.00/ton to about $3.00/ton. Royalties received from the mining of federal coal in Wyoming have increased since 1983 due to adjustments in royalty rates paid on the coal mined, and to increased production. Prior to 1977, royalty rates were 17.5 cents per ton. All leases issued after 1977 have a royalty rate of 12.5 percent on surface-mined coal and 8 percent on underground-mined coal.

Coal market prices are expected to remain stable for the long term, and coal pricing variations are likely to have little impact on coal production levels in southern Wyoming because these mines operate in semi-captive markets (MWH 2003). All of the leases in the Kemmerer Planning Area pay a 12.5 percent royalty.

Future Activity

The EIA, an official U.S. government information agency, provided coal predictions in a 2003 draft report (Gaskill 2002). These predictions are summarized as follows:

- As domestic coal demand grows, U.S. coal production is projected to increase from 1,138 million short tons in 2001 to 1,359 million short tons by 2020, an average rate of 0.9 percent per year. By 2025, U.S. coal production is projected to reach 1,440 million short tons.

- Net coal exports are expected to fall, reflecting declining coal demand in some countries and intense competition from other international producers.

- Generation from natural gas, coal, nuclear, and renewable fuels is generally projected to increase through 2025 to meet growing demand for electricity and to offset the projected retirement of existing generating capacity which would primarily be due to fossil steam capacity being displaced by more efficient natural gas-fired combined-cycle capacity. The share from coal is projected to decline from 52 percent in 2001 to 48 percent in 2025.

- Industry is expected to invest in less capital-intensive technologies and in technologies which generate a natural gas that burns more cleanly. However, coal is expected to remain the primary fuel for electricity generation through 2025.

- The average mine mouth price of coal (nationally) is projected to decline from $17.59 in 2001 to about $14.40 per short ton (2001 dollars) in 2020, remaining at about that level through 2025. Prices are expected to decline because of increased mine productivity, a shift to western production, and competitive pressures on labor costs.

- Several major factors that will affect demand on coal are: Clean Air Act Amendment (CAAA) requirements on sulfur dioxide expected to take effect in 2008; National Ambient Air Quality Standard (NAAQS) for pollutants of particulate matter with a diameter greater than 2.5 microns ($PM_{2.5}$), expected to affect the market by 2004; and limitations on mercury discharges from power plants.

Over the next 20 years, overall U.S. coal demand is expected to grow at a rate of approximately 1.8 percent annually (MWH 2003). The primary reasons for this slow rate of growth are the increasing use of natural gas for power generation, and the anticipated effects of more stringent air emission limitations for coal-fired power plants. Between 2010 and 2020, power plants may be required to install more sophisticated scrubber units on power plants that currently rely on low-sulfur western coal, eliminating one of the primary advantages of western coal over other coal sources (MWH 2003).

Demand for southern Wyoming coal should remain consistent with a slow, but stable growth curve (MWH 2003). The coal production growth rate for southern Wyoming is anticipated to be 0.9 percent in 2005, and 0.8 percent in 2010 and 2015 (MWH 2003). Production levels for southern Wyoming for 2000 were 14.6 million tons per year. This is expected to decline slightly to 14.2 million tons per year in 2005, and rise again to 14.9 million tons per year in 2010, with greater increases estimated for 2015 and 2020. Table 4-4 lists southern Wyoming predictions for coal production and leasing growth (MWH 2003). Projected leasing requirements are based on operator projections through 2005, pending lease applications (2000 through 2010), and projected production rates.

Table 4-4. Coal Production and Leasing Growth, Southern Wyoming

	2000 - 2005	*2005 - 2010*	*2010 - 2015*	*2015 - 2020*
Annual growth rate	0.9% (2005)	0.8% (2010)	0.8% (2015)	-- (2020)
Coal production level (mmtpy)	14.2 (2005)	14.9 (2010)	15.6 (2015)	16.4 (2020)
Supplemental leasing (mmt)	110	--	--	10
New leasing (mmt)	--	--	--	--

mmtpy: million tons per year
mmt: million tons
Source: MWH 2003

Hill & Associates, Inc. (2002) provides projections for Southern Wyoming coal demand from 2002 to 2012 (Table 4-5). In 2012, new air pollution regulations are expected to take effect. Hill & Associates state:

> The Bridger mine is expected to continue producing at the 6.4 mmtpy level, and the Bridger plant will continue to take 2.5-3.0 mmtpy from the Black Butte/Leucite Hills mine. Naughton is expected to continue taking 2.5-2.7 mmtpy from the Kemmerer mine. The model output suggests that PRB [Powder River Basin] coals are competitive at Bridger and Naughton and could potentially displace Southern Wyoming coals by 2012.

The existing coal supply agreements with these power plants will expire by 2012. With the introduction of new air pollution control regulations, the competitive advantage would shift to the Powder River Basin coals, and they would be expected to pick up market share.

Table 4-5. Projected Southern Wyoming Coal Demand

Year	*Demand (million tons)*
2002	15.2
2003	14.8
2004	15.3
2005	15.7
2006	17.0
2007	21.5
2008	21.9
2010	22.8
2011	21.8
2012	15.1

Source: Hill & Associates 2002

Southern Wyoming coal operations occupy a niche market, supplying coal to nearby power plants or short-hauling coal to industrial users such as trona operations. Production costs are relatively high and operations in this area cannot generally compete with coal from other areas if transportation costs are added (MWH 2003). The primary markets are mine-mouth power plants, such as the Bridger and Naughton plants. Combined, these plants consume 11 to 12 million tons per year. The trona operations along the UPRR main line west of Green River, Wyoming consume .5 to .7 million tons per year. Other users include sugar plants in Idaho, the Valmy plant in Nevada, and local markets around Cheyenne and Laramie. Many of these industrial boilers or cement kilns need the higher BTU coal produced in southern Wyoming to achieve maximum output (Hill & Associates 2002).

Kemmerer mines are expected to continue to serve the local market mainly due to existing coal supply agreements. All mines in this region will be under pressure from Powder River Basin suppliers to keep their costs low. The existing price structure in the region is $ 3.00 to $6.00 dollars above costs of coal from other sources. This is expected to change when the mines' coal supply agreements begin to expire, allowing competitive bidding for coal supplies in the currently captive markets (Hill & Associates 2002).

Kiewit Mining Company recently revisited its late 1970s development plans to prepare a mine permit application for the Haystack property located near Evanston. In the earlier work, Kiewit had identified 52 million tons of surface recoverable coal at a 6:1 strippable ratio. Expected quality of the coal was 9,650 BTU/pound with 0.33 percent sulfur (Mining Engineering Online 2003). The BLM Wyoming State Office has received a coal lease application from Kiewit for a portion of one section in T17 N, R117W near the proposed Haystack surface coal mine. No other coal lease applications are anticipated during the life of the RMP due to the large quantity of acreage already under lease (McNaughton 2003). One or two coal exploration permits for on-lease exploration are anticipated. No off-lease exploration licenses on public land are expected at this time (McNaughton 2003). Mining is expected to continue at the existing Pittsburg and Midway Kemmerer Mine, with possible expansion to a new area, the North Block.

The coal screening process established that the BLM would defer to coal leasing in the event that oil and gas fields are established in competitive coal areas (including subsurface and surface); would conduct the coal unsuitability review and multiple use conflict evaluation on a case-by-case basis for some areas not considered in the review; would keep the entire Kemmerer Resource Area open to coal resource inventory and exploration; and would pursue determination of eligibility of the Bear River City Historic Site for listing in the National Register of Historic Places (BLM 2003a). The BLM may alter or modify any oil and gas lease that interferes with the orderly development of coal resources, coal mine worker safety, coal production rates, or recovery of the coal resource (refer to Appendix B).

EFFECTS OF ENVIRONMENTAL REGULATIONS

Currently applicable air quality regulations affecting coal-fired power plant emissions are those promulgated and implemented under the Phase I program of Title IV of the 1990 *Clean Air Act*. Under existing court decisions more restrictive limits for nitrogen oxide would be in force by 2004. New regulations for the control of mercury emissions are proposed for development and implementation in the 2004 to 2010 timeframe. The proposed mercury emission regulations are the most likely regulations to have an impact on Wyoming coal production. More stringent controls would eliminate much of the current advantage of the low sulfur western coal. The current cost advantage of those coals is that they do not require the installation and use of scrubber units in the power plants using this coal. The more stringent emission controls would require the installation of more sophisticated scrubber units on most, if not all, power plants. Once this capital cost is required, the incremental cost of using the scrubbers is not as great as the transportation costs of Wyoming coal. In addition the Wyoming coals are thought to contain mercury in a form that is not as easily removed as it is in some other coals. The Naughton power plant currently has scrubbers for sulfur. Mercury must be removed by some other method. It is not clear at this time which technology will be adopted to remove mercury, however some sort of upgrade would need to occur to the scrubbing equipment.

Implementation of these regulations could result in a shift from Wyoming coals to coal from the Illinois and Appalachian areas for utilities in the Midwest and Great Lakes area. As coal from the Kemmerer Planning Area is not currently being shipped to these markets, this would not affect existing production directly, but could inhibit future growth.

4.1.4 Other Leasable Minerals

Other leasable minerals in the Kemmerer Planning Area include trona, phosphate, oil shale, geothermal resources, carbon dioxide, and sulfur (as a component of hydrogen sulfide gas).

Conventional underground trona mining is expected to continue at the existing FMC, Solvay, and General Chemical mines. Around 2006, a new subsurface solution mine and processing plant may open near the eastern edge of the planning area. Solution mining may also be used by some of the current operators. Ongoing development at the current operations could include new shafts and new construction or expansion of other surface facilities. It appears that current permit boundaries, which can include federal, private, and state lands, will accommodate the new development. Exploration drilling and drilling of tailings injection wells on existing federal leases is expected to continue.

No new federal sodium leasing, prospecting permits, or off-lease drilling are expected during the life of the plan. Changing market conditions could cause these assumptions to change.

Other than reclamation of abandoned phosphate mining operations, no activity relating to phosphate, including exploration, has occurred in the Kemmerer Planning Area since the Leefe operation closed. No prospecting permits or lease applications for phosphate are anticipated, given the reserves nearby in Idaho and Utah.

Overall, there has been minimal geothermal activity in the Kemmerer Planning Area. Currently, there are no geothermal leases or pending applications for exploration or leasing. Geothermal resources occur at Auburn. No other locations in the planning area are known to have geothermal potential.

Oil and gas fields in the La Barge area are expected to continue to produce carbon dioxide for treatment at the Shute Creek Gas Plant. Carbon dioxide flooding projects in aging oil fields in eastern Wyoming are expected to increase the demand for this product.

Wyoming ranks second in the nation in the production of recovered sulfur. The USGS has indicated that recovered sulfur from petroleum refineries in the U.S. is expected to continue its steady growth. The February 3, 2003 edition of *Chemical Market Reporter* reported that the North American sulfuric acid market continues to benefit from steady demand resulting from supply shortages from Canadian smelter capacity, increased fertilizer operating rates, and the scarcity of sulfur (Van Savage 2003). Sulfuric acid pricing increased from approximately $5.00 per ton to $25.00 per ton in late 2002 and early 2003 (Van Savage 2003).

In the world market, estimates of future sulfur demand are not as optimistic. The Sulphur Institute, an organization that focuses on world sulfur markets, noted that although world sulfur consumption recently reached 60 million tons, world-wide demand is still short of production by 2 million tons (Petroleum Retailers 2003). According to a June 2003 report, sulfur has been trading at historical lows in recent years, and unless new markets are developed, supplies could exceed demand by more than 5 million tons by 2010 (Petroleum Retailers 2003). Sulfur is currently produced in the planning area at three plants: Chevron Carter Creek; BP Whitney Canyon; and Exxon Mobil Shute Creek.

4.2 Locatable Minerals

Locatable minerals in the Kemmerer Planning Area include bentonite, fire clay, gemstones, and metals. The WSGS (2003c) anticipates that Wyoming's bentonite production will remain stable in the near future. Although bentonite is known to occur in the Kemmerer Planning Area, there has been no commercial production there. Coal withdrawals prevent bentonite mining claims in certain areas, and some of the bentonite is of minor economic significance. There are more profitable bentonite reserves elsewhere in the state. Two companies produce fire clay in the planning area. One of them conducted an exploration for fire clay on public land, but the deposit was determined to be unsuitable for commercial use.

The planning area has had little development of gemstones, and minimal production is expected in the future. To date there has been no evidence of economically viable diamond or other significant gemstone deposits in the planning area. There is currently no demand except for hobby collection.

Although there are small deposits of metals in the planning area, there have not been any economically significant discoveries. The limited exploration for these resources over the years has not led to production, and very little activity is anticipated during the life of the RMP.

4.3 Salable Minerals

Salable minerals in the Kemmerer Planning Area include sand and gravel, decorative stone, limestone, and sandstone. Aggregate (sand and gravel) is one of the most widely used salable resources in the Kemmerer Planning Area. Construction aggregate is the fourth most important mineral product produced in Wyoming and demand is expected to remain high. Current production and demand for building stone and moss rock is expected to continue, especially in the Jackson Hole area. Substantial commercial limestone or sandstone production in the planning area is not expected.

4.4 Mineral Potential Summary

Leasable mineral occurrence and development potential in the Kemmerer Planning Area is associated with oil and gas, CBNG, coal, and trona. Potential occurrence and development of locatable minerals is associated with building stone, fire clay, bentonite, metals, and gems. Potential occurrence and development for salable minerals is associated with sand and gravel, decorative stone, limestone, and sandstone. Levels of potential and certainty for these minerals, as specified in BLM Manual 3031, have not been identified for the presence or occurrence of minerals in the Kemmerer Planning Area.

The majority of the Kemmerer Planning Area is considered by the BLM to have very low potential for oil and gas resources. Additionally, a DOE study identified lands within the planning area as having little in the way of technically recoverable natural gas resources. The majority of technically recoverable federal natural gas resources were found either to be closed to development or available with restrictions. About 1/3 of the potential federal resources are off limits, with about 1 percent closed by statute. BLM estimates suggest that approximately 1,000 oil and gas wells (excluding CBNG wells) could be drilled in the planning area within the next 20 years.

CBNG potential is also estimated to be limited in the planning area. Several areas with a low potential for CBNG resources have been identified, but the majority of the planning area is considered to have no potential for CBNG. BLM estimates suggest that there could be approximately 200 CBNG wells in the Kemmerer Planning Area within the next 20 years.

Demand for southern Wyoming coal should remain consistent with a slow, but stable growth curve. Kemmerer mines are expected to continue to serve the local market mainly due to existing coal supply agreements. This is expected to change when the mines' coal supply agreements begin to expire, allowing competitive bidding for coal supplies in the currently captive markets. One coal lease application has been submitted in the planning area. No other coal lease applications are anticipated during the life of the RMP, due to the large quantity of acreage already under lease. Mining is expected to continue at the existing P&M Kemmerer Mine, with possible expansion to a new area, the North Block.

Conventional underground trona mining is expected to continue at the existing FMC, Solvay, and General Chemical mines with possible expansion around 2006. No new federal sodium leasing or prospecting permits outside the KSLA or drilling off-lease inside the KSLA are expected during the life of the plan. Geothermal activity has been minimal and there are no geothermal leases or pending applications for exploration of leasing. Oil and gas fields in the La Barge area are expected to continue to produce carbon dioxide for treatment. Carbon dioxide flooding projects in ageing oil fields in eastern Wyoming is expected to increase the demand for this product. Production of recovered sulfur from petroleum refineries is expected to continue its steady growth to meeting air quality requirements and to supply a steady North American sulfuric acid market.

Although bentonite is known to occur in the Kemmerer Planning Area, there has been no commercial production there. Coal withdrawals prevent bentonite mining claims in certain areas, and some of the bentonite is of minor economic significance. A fireclay exploration was conducted on public land, but the deposit was determined to be unsuitable for commercial use. The planning area has had little development of gemstones, and little production is expected in the future. Although there are small deposits of metals in the planning area, there have been no economically significant discoveries and very little activity is anticipated during the life of the RMP.

Aggregate is one of the most widely used salable resources in the Kemmerer Planning Area. Construction aggregate is the fourth most important mineral product in Wyoming and demand is expected to remain high. Current production and demand for building stone and moss rock is expected to continue. Substantial commercial limestone or sandstone production in the planning area is not expected.

5.0 RECOMMENDATIONS

No minerals management recommendations or stipulations have been developed at this time. Appropriate recommendations relating to management of the future development of mineral resources within the Kemmerer Planning Area will be developed during the RMP revision process.

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APPENDIX A

OIL AND GAS OPERATIONS

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FIGURES

APPENDIX A OIL AND GAS OPERATIONS

The operations information in this appendix was prepared for the Bureau of Land Management (BLM) as part of the *Mineral Occurrence and Development Potential Report* for the Rawlins, Wyoming Planning Area (ENSR 2003). It has been shortened and edited for use in this report.

1.0 GEOPHYSICAL EXPLORATION

Oil and gas reservoirs are discovered by either direct or indirect exploration methods. Direct methods include mapping of surface geology, observing seeps, and gathering information on hydrocarbon shows observed in drilling wells. Indirect methods, such as seismic, gravity, and magnetic surveys, are used to delineate subsurface features that are not directly observable, but that may contain oil and gas.

1.1 Gravity Surveys

Gravity surveying uses micro-variations in the earth's gravitational field, caused by the differences in rock densities, to map subsurface geologic structures. These surveys are generally of low resolution due to the many data corrections required (e.g., terrain, elevation, latitude, etc.), and to the complexity of subsurface geologic structures. The instrument used for gravity surveys is a small portable device called a gravimeter. Generally measurements are taken at many points along a linear transect and the gravimeter is transported either by backpack, helicopter, or off-road vehicle. Surface disturbance associated with gravity prospecting is minimal.

1.2 Geomagnetic Surveys

Magnetic prospecting is commonly used for locating metallic ore bodies, but may also be used in oil and gas exploration. Magnetic surveys use a magnetometer to detect small variations in the earth's magnetic field caused by mineralization or lithologic variations in the earth's crust. These surveys can detect large trends in basement rock and the approximate depth to those basement rocks. However, they generally provide little specific data to aid in petroleum exploration. Many data corrections are required to obtain reliable information and maps generated often lack resolution and are considered preliminary. Magnetometers vary in size and complexity. Most magnetic surveys are conducted from the air by suspending a magnetometer under an airplane. Magnetic surveys conducted on the ground are nearly identical to gravity surveys in that surface disturbance is minimal.

1.3 Reflection Seismic Surveys

Reflection seismic prospecting is the most popular indirect method currently used for locating subsurface structures that may contain hydrocarbons. Seismic energy (shock waves) is induced into the earth using one of several methods at a location called a source point or shot point. As the waves travel downward and outward, they encounter rock strata that transmit seismic energy at different velocities. As the wave energy encounters the interfaces between rock layers that transmit seismic energy at different velocities, some of the seismic energy is reflected upward and some of the energy continues down into the earth. Sensing devices, called geophones, are placed on the surface to detect these reflections of energy. The geophones are wired in groups and are connected to a data recording truck that stores the data. The time required for the shock waves to travel from the source point down to a given reflector and back to the geophone can be related to depth. After the data are acquired, the digital information is processed with a computer. The end product of the seismic processing is a seismic section that presents the strata or structures below the surface. Figure 1 depicts the seismic survey process.

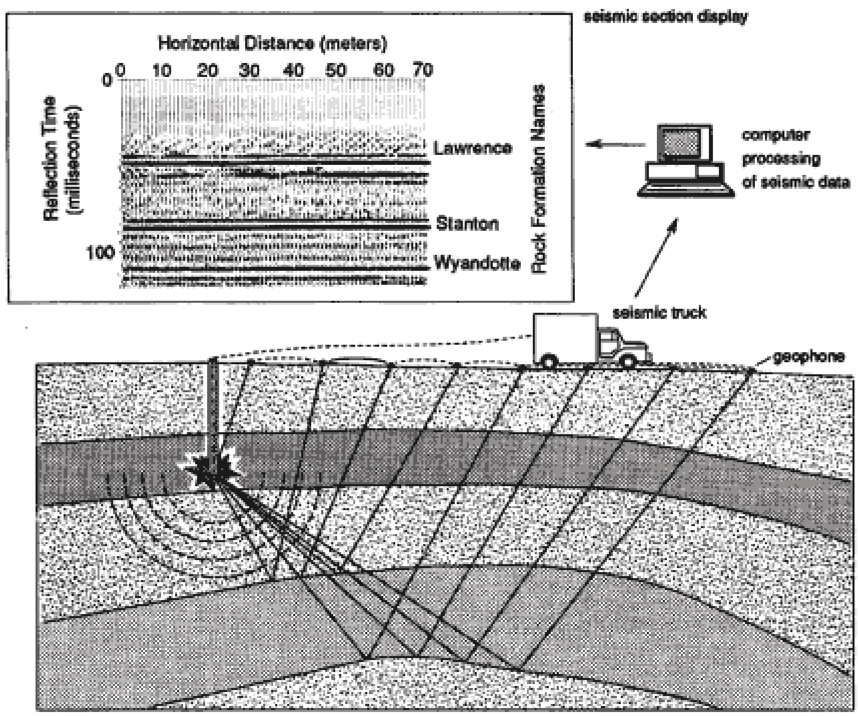

Figure 1. Seismic Survey Process

The seismic section is an image of the reflected seismic energy and is not the same as a geologic cross-section that is constructed from data derived directly from wells or outcrops. For onshore oil and gas exploration, there are two methods used to create the seismic energy: vibroseis and shot point. Vibroseis uses hydraulic actuated devices called vibrator pads mounted on trucks to thump on the surface of the ground to create shock wave energy. Usually four to five "thumper" trucks are used, each equipped with 4-foot-square vibrator pads. At a location called the source point, the trucks are spaced at specified intervals and the vibrator pads are simultaneously triggered to vibrate or thump on the ground. The thumping will last for 10 to 30 seconds. The information is recorded and then the trucks move to the next source point and the process is repeated. As the trucks move to the next source point, groups of geophones are picked up and moved to the end of the line. Less than 50 square feet of surface area is required to operate the equipment at each source point. The geophone groups are transported by vehicle when moved, but have to be laid out and picked up by hand.

The shot-point method of creating shock wave energy uses truck-mounted drills that drill small-diameter holes to depths of up to 200 feet. Four to 12 holes are drilled per mile of line. Usually, a

50-pound explosive charge is placed in the hole, covered, and detonated. In rugged topography, a portable drill is sometimes carried in by helicopter. Charges are placed in the hole as in a truck-mounted operation. Another portable technique is to carry the charges in a helicopter and place the charges on wooden sticks, or lath, approximately 3 feet aboveground. The charges weigh 2.5 to 5 pounds. Usually 10 charges in a line on the ground are detonated at once.

In remote areas where there is little known subsurface data, a series of short seismic lines may be required to determine the attitude of subsurface formations. Seismic lines are aligned relative to the regional structure to make seismic interpretation more accurate. In seismic surveys, several seismic lines are shot and the distances of the lines and the spacing between the lines are predetermined based on the purpose of the survey. The seismic lines are often separated on a 1 to 2-mile grid spacing. Spacing of the lines can often be changed 0.25 mile on a 1-mile grid before the results will significantly affect the investigation. At predetermined source points, short cross-spreads can be laid out perpendicular to the main line to obtain higher accuracy in the survey.

A variation of this technique is the three-dimensional (3D) seismic profile survey. The methods of generating the seismic waves are the same as those used in conventional seismic surveys. This type of survey differs from the more common two-dimensional (2D) survey in the greater number of datapoints and the closer spacing of the lines. Three-dimensional seismic surveys are more computer intensive for the processing of the data, but they result in a more detailed and informative subsurface image (with an accompanying higher cost). The orientation and arrangement for the components in 3D seismic surveys are less tolerant of adjustments to the physical locations of the lines and geophones, but they can be more compact in aereal extent. Three-dimensionsal surveys are commonly used in established field areas to help better define structure, stratigraphy, and movement of fluids between wells or used to focus on a promising exploration target in order to lessen risk in locating a exploratory drill location. A typical seismic operation conducting a shot-point survey may utilize a 10 to 15-person crew operating five to seven trucks.

Under normal conditions, 3 to 5 miles of line can be surveyed each day using the shot-point method. The vehicles used for a drilling program include several heavy truck-mounted drill rigs, water trucks, a computer recording truck, several light pickups or stake-bed trucks for the surveyors, shot hole crew, geophone crew, permit man, and party chief. Public roads and existing private roads and trails are used when available. Off-road cross-country travel may be necessary to conduct the survey. Road graders or bulldozers may be required to provide access to remote areas. Concern about unnecessary surface disturbance has caused government and industry to use care when planning surveys. As a result, earth-moving equipment is now only rarely used in seismic exploration work. Several trips a day are made along a seismic line; this usually establishes a well-defined two-track trail. The repeated movement back and forth along a line (particularly the light pickups) creates a new trail. In some areas, in order to reduce impacts, crews are instructed to deviate from straight routes and not to retrace the same route. This practice has, in some cases, prevented the establishment of new trails and has reduced impacts. Drilling water, when needed, is usually obtained from the nearest source.

Each of these methods has inherent strengths and weaknesses and the exploration team must decide which method is the most practical with regard to surface constraints (such as topography), but will still produce information that can be useful for the particular study. Extensive computer processing of the raw data is required to produce a useable seismic section from which geophysicists interpret structural relationships to depths of 30,000 feet or more. The effective depth of investigation and resolution are determined to some degree by which method is used. In the last 20 years, the technology has progressed so that better resolution has been obtained from greater depths and to be able to discern structures hidden beneath salt layers or overthrust blocks.

1.4 Permitting Geophysical Surveys

Geophysical operations on and off an oil and gas lease are reviewed by the federal surface management agency (SMA), which can include the BLM, Bureau of Reclamation, or U.S. Forest Service (USFS), as appropriate. Good administration and surface protection during geophysical operations is accomplished through close cooperation of the operator and the managing agency. In the process of permitting geophysical surveys, the responsibilities of the geophysical Operator and the Field Office (FO) Manager during geophysical operations are as follows:

Geophysical Operator. An operator is required to file with the FO Manager a "Notice of Intent to Conduct Oil and Gas Exploration Operations" or (NOI). The NOI shall include a map showing the location of the line, all access routes, and ancillary facilities. The party filing the NOI shall be bonded. A copy of the bond or other evidence of satisfactory bonding shall accompany the NOI. For geophysical operational methods involving surface disturbance, NEPA documentation, including surveys for cultural resources and wildlife also may be required. A pre-work field conference may be conducted. Earth-moving equipment shall not be used without prior approval. Upon completion of operations, including any required rehabilitation, the operator is required to file a Notice of Completion.

FO Manager. The FO Manager contacts the operator after the NOI is filed to apprise the operator of the practices and procedures to be followed prior to commencing operations on BLM-administered lands. Then FO Manager completes a final inspection and notifies the operator if the terms and conditions of the NOI have been met or that additional action is required. Consent to release the bond or termination of liability will not be granted until the terms and conditions have been met.

1.5 State Standards for Seismic Surveys

In Wyoming, seismic survey operators must comply with Wyoming Oil and Gas Conservation Commission (WOGCC) rules. The standards for seismic operations are found in WOGCC Rules, Chapter 4, Section 6, Geophysical/Seismic Operations. The rules cover permitting, bonding, shot-hole drilling, and shot-hole plugging.

1.6 Mitigation of Conflicts with other Resources or Activities

Seasonal restrictions may be imposed to reduce conflicts with wildlife, watershed damage, and hunting activity. The most critical management practice is compliance monitoring during and after seismic activity. Compliance inspections during the operation ensure that stipulations are followed. Compliance inspections upon completion of work ensure that the lines are clean and the drill holes are properly plugged.

2.0 FLUID MINERALS LEASING

The *Mineral Leasing Act* provides that all public lands are open to oil and gas leasing unless a specific order has been issued to close an area. Leasing procedures for oil, non-coalbed methane (non-CBM) gas, and CBM are the same. Based on the *Federal Onshore Oil and Gas Leasing Reform Act of 1987*, all leases must be exposed to competitive interest. Lands that do not receive competitive interest are available for noncompetitive leasing for a period not to exceed two years. Competitive sales are held at least quarterly and by oral auction. Competitive leases are issued for a term of five years and noncompetitive leases are issued for a term of 10 years. If the lessee establishes hydrocarbon production, the competitive and noncompetitive leases can be held for as long as oil or gas are produced. The federal government receives yearly rental fees on non-producing leases. Royalty on production is received on producing leases, one-half of which is returned to the State of Wyoming.

3.0 DRILLING PERMIT PROCESS

3.1 Permitting

A federal lessee or operator is governed by procedures set forth by the Onshore Oil and Gas Order No. 1, "Approval of Operations on Onshore Federal and Indian Oil I and Gas Leases," issued under 43 Code of Federal Regulations (CFR) 3164. Operating Order No. 1 lists the following as pertinent points to be followed by the lessee or operator: notice of staking (NOS); application for permit to drill (APD), which includes a multi-point surface use and operations plan; approval of subsequent operations; well abandonment; conversion to water well; responsibilities on privately-owned surface; and reports and activities required after well completion. The permitting process for drilling is the same for oil, non-CBM gas, and CBM.

The lessee or operating company selects the location of a proposed drill site. The selection of the site is based on well location and spacing requirements, the subsurface geology as interpreted by the operator's geoscientists, and the topography. Well location and spacing requirements are established by the WOGCC. Each well is to be drilled within a given distance from the center of a legal subdivision (such as a quarter/quarter of a section or quarter section, depending on the spacing assigned to the particular area). A proposed location may be moved within the tolerance established by rule or outside the designated tolerance with a location exception granted by the WOGCC.

There are two procedural options for obtaining approval to drill a well. After an operator decides to drill a well, it must decide whether to submit a NOS or an APD. The NOS process, if properly planned and coordinated, can expedite permit approval. The APD process is more familiar to industry in general and does not require as much up-front coordination as the NOS. In either case, no surface activity can be conducted until the well is approved by the BLM. Figure 2 depicts the NOS and APD processes.

The NOS process is as follows:

- The operator submits an outline of the plan to the BLM, which includes a location map and sketched site plan. The NOS is then used as a document to review any conflicts with known critical resource values.

- The BLM and operator conduct an on-site inspection. The NOS provides preliminary site-specific information, which will be reviewed during the on-site inspection. As a result of this inspection and review, additional information required for the APD process is identified.

	NOS OPTION	APD OPTION
Step I	Staking Notice Submitted	Application for Permit to Drill
Step II	Onsite Inspection	Onsite Inspection
Step III	APD Submission and Processing	APD Review and Processing

	APPROVED DRILLING PLAN
Step IV	Operations Conducted Under an Approved Plan
Step V	Production/Dry Hole-Subsequent Actions
Step VI	Abandonment

Figure 2. Federal Permitting Process

An APD is submitted based on the findings of the inspection and review of potential conflicts. The APD procedure is as follows:

- The operator may submit a completed APD in lieu of the NOS.

- A field inspection is held with the operator and any other interested party. The purpose of the field inspection is to evaluate the operator's plan, assess the situation for possible impacts, and to formulate resource protection stipulations.

- The APD is reviewed with respect to the field inspection.

To lessen environmental impacts, a site may be moved, reoriented, or reconfigured, within certain limits, at the site inspection. The proposed access road also may be rerouted. Normally, site-specific mitigations are added to the APD for protection of surface and subsurface resource values in the vicinity of the proposed activity. The BLM is responsible for preparing environmental documentation necessary to satisfy the National Environmental Policy Act (NEPA) requirements and provide any mitigation measures needed to protect the affected resource values.

Consideration also is given to the protection of groundwater resources. When processing an APD, the BLM geologist is required to identify the maximum depth of usable water as defined in Onshore Oil and Gas Order No. 2 (BLM, 1988). Usable water is defined as that water containing 10,000 parts per million (ppm) or less of total dissolved solids (TDS). Water quality is protected by running surface casing to a depth prescribed by the geologist. Determining the depth to fresh water requires specific water quality data in the vicinity of the proposed well or geophysical log determination of water quality. Information on water quality is obtained from analytical data from nearby water wells or from geophysical well logs. If water quality data or well logs from nearby wells are not available, the depth to the deepest fresh water zone in wells within a 2-mile radius of the proposed well is determined. Surface casing for the proposed well is required to be set below the deepest fresh water zone found in nearby water wells or to reach a depth below the reasonably estimated level of usable water that will be protective of usable water.

The Wyoming DEQ has determined that several types of short-term activities associated with coalbed methane production require coverage under a National Pollutant Discharge Elimination System (NPDES) permit (DEQ 2004). The Coal-Bed-Methane General Permit for Temporary Discharge authorizes the discharge of wastewaters to surface waters of the state associated with coalbed methane facilities in which groundwater is pumped from coal-bearing formations resulting in the release of methane from the coal bed. This general permit covers two categories of coal-bed-methane discharges. The first category involves characterizing groundwater prior to issuance of an individual or general NPDES permit for a coalbed methane facility. This category authorizes, on a case by case basis, discharges that occur in order to characterize groundwater quality in areas proposed for coal bed methane production.

When final approval is given by the BLM, the operator may begin construction and drilling operations. Approval of an APD is valid for one year. If construction does not begin within one year, the stipulations must be reviewed prior to approving another APD.

3.2 Surface Disturbance Associated With Drilling

Upon receiving approval to drill the proposed well, the operator moves construction equipment over existing roads to the point where the access road will begin. Surface disturbing activities for oil, non-CBM gas, and CBM are similar, except the typical CBM drilling location generally requires less surface area than for oil and gas wells. Road and drill-pad construction must conform to the standards set forth by the BLM. The information provided on construction in this section is taken from the construction standards manual published jointly by the BLM and USFS (1989).

Generally, the types of construction equipment used include bulldozers (track-mounted and rubber-tired), scrapers, and road graders. Equipment is transported to the construction area by semi-trailer trucks over public and private roads. Existing roads and trails may be improved in places and occasionally culverts and cattleguards are installed, if required. The lengths of the access roads vary. Generally, the shortest feasible route should be selected to reduce the haul distance and construction costs. Environmental factors or the surface landowner's wishes may dictate a longer route.

Road construction in rough terrain may require sidecasting (using the material taken from the cut portion of the road to construct the fill portion). Slightly less than one half of the road bed is placed on a cut area and the remainder is placed on a fill area. Roads are usually constructed with a 14-foot (single lane) or 24-foot (double lane) running surface in relatively level terrain. Soil texture, steepness of the topography, and moisture conditions may dictate surfacing the access road with gravel in some places, but generally not for the entire length of the road. The total acreage disturbed for each mile of access road constructed varies significantly with the steepness of the slope.

During construction of well locations, all soil material suitable for plant growth is first removed from areas to be disturbed and stockpiled in a designated area. Sites on flat terrain typically require minimal earthwork including the removal of topsoil and vegetation. Drilling sites on ridge tops and hillsides are constructed by cutting and filling portions of the location. The majority of the excess cut material is stockpiled in an area that will allow easy recovery for rehabilitation. It is important to confine extra cut material in a stockpile rather than cast it down hillsides and drainages where it cannot be recovered for rehabilitation.

The amount of level surface required for safely assembling and operating a drilling rig varies with the type of rig, but averages 300 feet by 400 feet. The dimensions of a typical CBM location are smaller than oil or non-CBM gas locations because of the shallower drilling depths and smaller drilling rigs that are required. The well pad should be constructed such that the drilling rig will sit on solid ground and not on fill. This ensures that the foundation of the drilling derrick is on solid ground and prevents it from leaning or toppling due to settling of uncompacted soil. Figure 3 illustrates a typical oil and gas well location. Figure 4 depicts a typical layout of a CBM drilling location.

In addition to the drilling platform, a reserve pit is constructed, usually square or rectangular but sometimes in other shapes, to accommodate topography. Reserve pits are used to store water, drilling fluid, and drill cuttings. Generally, the reserve pit is 8 to 12 feet deep, but may be deeper to compensate for smaller length and width or deeper drilling depths. Generally, the deeper the well,

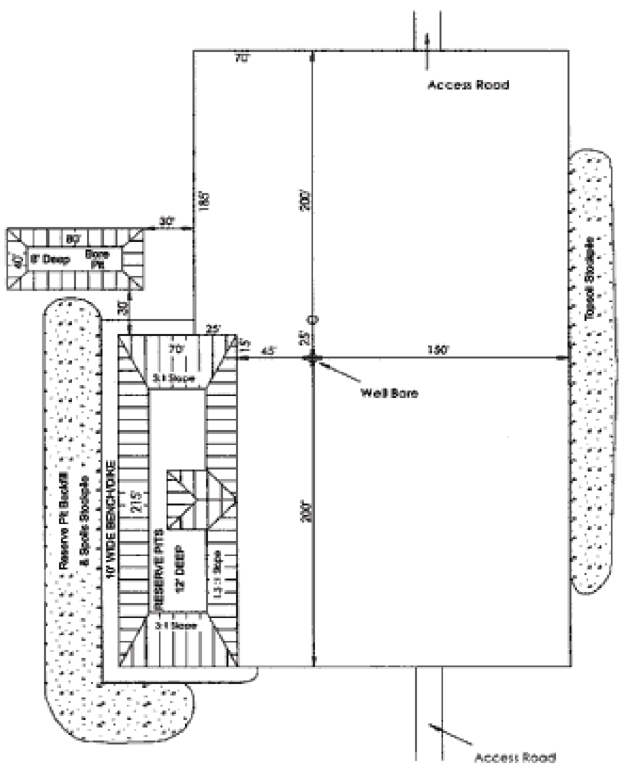

Figure 3. Typical Single Wellpad Layout

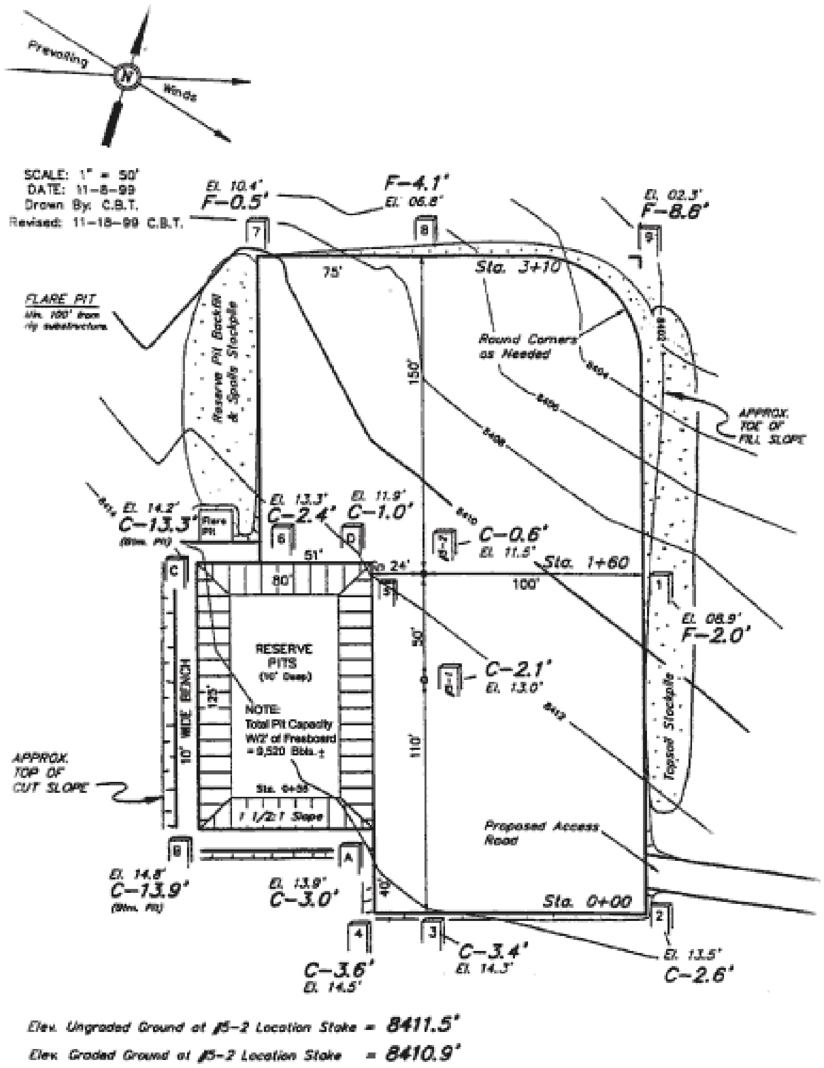

Figure 4. Typical CBM Drilling Location

the larger the reserve pit. If possible, pits should be constructed on cut material and not fill. If constructed on fill, there is a high potential for leakage. Depending on specific site conditions, the WOGCC or BLM may require that pits be lined with suitable plastic material to prevent leakage of pit fluids into shallow aquifers. Pits may be divided into compartments separated by berms for the proper management of derived waste (e.g., drill cuttings, mud, water flows).

Depending on how the drilling location is situated with respect to natural drainages, it may be necessary to construct water bars or diversions. The area disturbed for construction and the potential for successful revegetation depends largely on the steepness of the slope. Water for drilling is hauled to the rig storage tanks or transported by surface pipeline. Water sources are usually rivers, wells, or reservoirs. Occasionally, water supply wells are drilled on or close to the site. The operator must obtain a permit from the Wyoming State Engineer for the use of surface or subsurface water for drilling. When the BLM holds the water permits for surface water (stock ponds or wells), it also must approve such use. During drilling operations, water is continually transported to the rig location. Approximately 40,000 barrels or 1,680,000 gallons of water are required to drill an oil or gas well to the depth of 9,000 feet. Water demand may vary depending on the specific subsurface conditions that are encountered during the drilling of the well.

Drilling activities begin as soon as practicable after the location and access road have been constructed. The drilling rig and associated equipment are moved to the location and erected. Moving a drilling rig requires moving 10 to 25 truck loads (some over legal weight, height, and width) of equipment over public highways and private roads. The derrick, when erected, can be as much as 160 feet high, but derrick heights vary depending on the depth and weight capacity of the rig.

3.3 Rights-of-Way

Rights-of-way are required for all facilities, tank batteries, pipelines, truck depots, powerlines, and access roads that occupy federally owned land outside the lease or unit boundary. When a third-party contractor (someone other than the lease operator or the federal government) constructs a facility or installation on or off the lease, a right-of-way also is required. Rights-of-way on federal lands are issued by the BLM.

3.4 Drilling Operations

3.4.1 Oil and Non-CBM Gas

3.4.1.1 Drilling Operations

Starting to drill is called "spudding in" the well. Initially, drilling usually proceeds rapidly mainly because of the unconsolidated shallow formations. Drilling is accomplished by rotating special bits under pressure. While drilling, the rig derrick and associated hoisting equipment bear most of the drill string weight. The weight on the bit is generally a small fraction of the total drill string weight. The combination of rotary motion and weight on the bit causes rock to be chipped away at the bottom of the hole. T he rotary motion is created by a square or hexagonal rod, called a kelly, which is attached to the top of the drill pipe. The kelly fits through a square or hexagonal hole in a turntable, called a rotary table. The rotary table is turned by diesel or diesel-electric combination motors on the drill rig. The rotary table sits on the drilling rig floor and, as the hole advances, the kelly slides down through it. When the full length of the kelly has moved through the rotary table, drilling is stopped and the kelly is raised and an additional piece of drill pipe (or joint) about 30 feet in length is placed on top of the drill string. The top of the drill pipe is then lowered to the rotary table and held in place by devices called slips and the kelly is attached to the top of it. The slips are removed by pulling up on the pipe and drilling recommences.

Drilling fluid or mud is circulated through the drill pipe to the bottom of the hole, through the bit, up the bore of the well, and finally to the surface. When the mud emerges from the hole, it goes through a series of equipment used to screen and remove rock chips and sand-size solids. When the solids have been removed, the mud is placed into holding tanks and from the tanks it is pumped back into the well. The mud is maintained at a specific weight and viscosity to cool the bit, seal off any porous zones (protect aquifers or prevent damage to producing zone productivity), subsurface pressure control, lubrication of the drill string, clean the bottom of the hole, and bring the rock chips to the surface.

There are three common types of drilling fluids: water-based, oil-based, and synthetic. Water-based muds are the most common and are largely made up of water and bentonite, a clay that has special properties used to maintain proper viscosity and other properties over a wide range of drilling conditions. Fresh water is usually used, but brine is used if salt layers are to be drilled (to prevent solution of the salt). Oil-based mud is used for subsurface conditions where water may react with shale and cause caving and sloughing of the sides of the wellbore. Synthetic drilling fluids are used for special conditions and have become more common in recent years. They are composed of organic polymers or other chemicals and are often designed to be environmentally benign. Additives are used to maintain the drilling mud properties for specific conditions that may be encountered during drilling. Some of the additives may be potentially hazardous in large quantities, but these additives are used in relatively small amounts during drilling operations. Other additives are composed of organic materials, such as cottonseed hulls, and are not hazardous.

Another common drilling system uses the pump pressure that is used to circulate the drilling fluid to turn the bit. This type of system is called a mud-motor and consists of a turbine that is part of the bottom-hole-assembly (BHA) at the bottom of the drill string. The pump pressure turns the turbine that rotates the bit. There is no rotating movement in the drill string above the mud-motor. Mud–motors are used under special conditions such as directional or horizontal drilling, but also are commonly used in normal drilling operations in conjunction with special bits to drill long sections of hole at fast rates and without the need to trip the drill string to change out the bit.

Eventually, the bit becomes worn and must be replaced. To change bits, the entire string of drill pipe must be pulled from the hole, in 60-foot or 90-foot sections (stands), until the bit is brought out of the hole. The stands of drill pipe are stacked vertically in the rig derrick. The bit is replaced and then the drill string is reassembled and lowered into the hole, stand by stand, and drilling is started again. The process of removing and reinserting the drilling string is called a trip and may take up to 24 hours or more on a deep well to make a “round trip” to retrieve a worn bit.

Drilling operations are continuous, 24 hours a day, 7 days a week. There are three 8-hour or two 12-hour shifts or tours (pronounced towers) a day. Pickups or cars are used for workers' transportation to and from the location. Upon completion of the drilling, the equipment is removed to another location.

If hydrocarbons are not discovered in commercial quantities, the well is called a "dry hole." The operator is then required to follow state and BLM policy procedures for plugging a dry hole. The drill site and access roads are rehabilitated according to stipulations attached to the approval of the well site.

3.4.1.2 Casing and Cementing

Casing consists of steel pipe that is placed into the hole to prevent the collapse of the hole, to protect aquifers, and to isolate producing zones from other formations. Several strings of casing may be placed into the well that have different purposes. In the initial stages, the first casing set into the hole is called a conductor pipe. The conductor pipe is a large diameter pipe (greater than 12 inches) that is set at a fairly shallow depth (50 feet or less). The conductor pipe provides support for unconsolidated surface material. The conductor pipe is usually drilled and set in by a small auger rig prior to the set up of the drilling rig.

The next casing to be placed into the well is called surface casing. The well is drilled to a predetermined depth and the surface casing is run into the hole and cemented in place. The cementing operation involves pumping cement down through the bottom of the casing and up around the annulus (the space between the pipe and the sides of the hole). The cement holds the casing in place and protects potential shallow aquifers. Surface casing can be set from a couple hundred feet to over one thousand feet, depending on local requirements. Surface casing should be set to a depth greater than the deepest freshwater aquifer that could reasonably be developed. Surface casing must be large enough to accommodate one or more sets of casing strings that may be set as the well is drilled deeper.

In many cases, the next string of casing to be set in the hole is called the production string. Once the target zone is reached, the well is deepened slightly below the zone and the production string is run and cemented in place. Generally, only the bottom few hundred feet of the production string are cemented in place, enough to cover the producing zone plus enough cement above the producing zone to provide adequate protection against leakage of the reservoir into the annulus. Operators are required to cement off hydrocarbon bearing zones to prevent contamination of aquifers. Operators also are required to protect other hydrocarbon productive and water-containing strata as directed by the WOGCC or the BLM.

For some drilling conditions, one or more intermediate casing strings may be required before the well reaches total depth. Intermediate strings are used to prevent loss of the hole while drilling deep wells, to control over-pressured zones, to protect hydrocarbon zones, to provide a point from which to drill a deviated hole, and to isolate lost circulation zones. Lost circulation occurs when the hydrostatic pressure of the mud breaks down a formation and large volumes of mud are lost into that zone . Intermediate casing is often the only way to prevent lost circulation from occurring and potential loss of the hole when drilling deep wells.

3.4.1.3 Blowout Prevention

In the early days of drilling, no blowout prevention equipment was used. However, because of concerns for environment, safety, and conservation of oil and gas resources (prevention of waste), blowout prevention is a primary concern during well drilling. Blowout prevention begins with an understanding of the subsurface pressure regime. In normally pressured rocks, the pressure increases with depth in a relationship expressed as 0.433 pound per square inch per foot. Blowout prevention is a concern in areas of abnormally high-pressure gradients. When a drill bit penetrates an abnormally high-pressured zone, there is a risk that a blowout, or uncontrolled flow of fluids to the surface, will occur. Abnormally high pressures have several causes. The main cause of over pressures are hydrocarbon generation and a sealing overburden.

In the Greater Green River Basin, one cause of abnormally high pressures is the presence of basin-centered gas trapping in Tertiary and Cretaceous rocks.

The drilling fluid is the first line of defense against a blowout. But if abnormally high pressures are encountered, the weight of the mud itself may not be enough to hold back formation fluids. Therefore, by rule, drilling rigs must be equipped with a device called a blowout preventer (BOP). During drilling of a well, the BOP is placed on top of the surface casing string. Blowout prevention equipment is tested and inspected regularly by both the rig personnel and the inspection and enforcement branch of the BLM. Minimum standards and enforcement provisions are currently in effect as part of Onshore Order No. 2. Well-trained rig site personnel also are a necessity for proper blowout prevention. Through a system of hydraulically activated valves and manifolds, the BOP is designed to shut the well in and prevent the uncontrolled flow of fluids. In addition, BOPs also are designed to allow fluid to be pumped into the hole (to "kill" the well) and allow drill pipe to move in and out of the hole.

3.4.1.4 Formation Evaluation

One of the primary activities that occurs during the drilling of the well is the acquisition of downhole information. Formation evaluation covers a variety of data gathering and retrieving methods that include mud logging, wireline logging, formation testing, coring, and measurement while drilling (MWD) surveys. In wildcat wells (wells drilled outside of areas of established production or into deeper untested zones in established fields), it is important that quality data be obtained in order to justify the costly decision to run (or not run) production casing and complete the well. In producing areas, adequate formation evaluation also is important so that reservoir properties are understood in order to make informed decisions about the development of a field.

MUD LOGGING

While the well is being drilled, the drilling mud is evaluated for the presence of hydrocarbons. This is commonly done through a technique called mud logging. Drilling liberates even small amounts of hydrocarbons from sedimentary rock. As the mud comes up out of the hole, instruments are used to monitor the presence of gas or oil that may be present as the bit penetrates the subsurface. Evidence for the presence of hydrocarbons is called a show, which must be evaluated to determine whether a show is indicative of commercial hydrocarbon reservoirs. Mud logging evidence of hydrocarbons often is not definitive of a commercial show, but mud logs, in combination with other formation evaluation tools, are an important part of the overall evaluation of the hydrocarbon potential.

Mud logging equipment also monitors for the presence of hydrogen sulfide (H2S), a deadly gas. The mud log, in addition to recording the presence of hydrocarbons and other gases, also is used to record and describe the rocks that are encountered in the well. The equipment used to remove rock cuttings from the mud also is used to obtain chips for sample description. Samples of rock cuttings from downhole are taken at prescribed intervals. The depths from which the samples came is determined by knowing the lag time it takes for the cuttings to reach the surface. The mud log can summarize all the formation evaluation activities for the well and the mud log format is a strip-chart display of the intervals logged depicting shows, formation tops, lithologic descriptions, wireline log data, gas readings, drilling data, and core and test intervals and descriptions.

WIRELINE WELL LOGS

Wireline well logs (or geophysical well logs) are basic to formation evaluation. Open-hole (hole without casing) wireline well logs can be run before intermediate casing strings are set and when the well reaches total depth. Wireline well logs also may be run in cased-holes. Wireline logs use a variety of techniques to provide indirect measurements of rock properties and are used to precisely determine the elevation and thickness of individual rock units or potential producing zones. In general, wireline logs require the application of electrical, sonic, mechanical, or radioactive energy to the rocks in order to obtain measurements that can be related to rock properties such as porosity, permeability, and fluid ratios. Only a few types of wireline logs do not require the application of energy to the rocks to make measurements. For example, the gamma ray log measures the natural gamma ray radiation from the rocks and is used to determine lithology (shale versus non-shale).

Wireline logs are created by lowering instruments (the logging tool) into the well. The instruments are suspended by a cable that not only supports the logging tools, but relays measurement data by electrical signals to the surface. The general procedure is to lower the logging tool to the bottom of the hole and take measurements while hoisting the tools back to the surface. Several types of logs can be run in combination. The data from the tools are digitally processed at the surface and the information is summarized on what are generally described as well logs.

FORMATION TESTING

Zones with porosity can be determined while drilling when the rate of penetration begins to increase. When combined with evidence of the presence of hydrocarbons in the increased penetration interval, the well can be temporarily completed. The temporary completion of the well is called a drill stem test (DST), and can be useful in determining if hydrocarbons are present in commercial quantities. In a DST, a tool is placed on the end of the drill string and run back into the hole opposite the prospective interval. A device called a packer is placed above the tool in the BHA and is inflated against the walls of the hole to seal the zone from the mud column above. The tool is opened and fluids from the formation are allowed to enter the drill stem.

A typical DST includes several periods of flow and shut-in. Pressure recorders are present in the test tool as well as sample chambers. When the test is over, the packer is released and the tool is brought to the surface. The pressure recorder charts are analyzed and the potential productivity of the zone can be estimated. Sample chambers placed near the formation are opened after a test and may contain oil, water, or gas. In addition, fluids produced into the drill stem may include varying amounts of oil, gas, and water. A good test can recover hundreds or thousands of feet of oil in the drill pipe or enough gas to the surface to flare.

A variation of the DST is the repeat formation test tool that is run into the hole by use of a wireline. The tool is pressed up against the sides of the borehole in the interval of interest. One of the major advantages of the wireline tester is the ability to obtain real-time pressure readings and the ability to test multiple zones. The wireline formation tester also has sample chambers for the recovery of formation fluids.

CORING

Coring is a method of formation evaluation whereby a whole sample of the subsurface rock is brought to the surface. Cores are obtained by placing a special bit and core barrel at the end of the drill string. Instead of drilling the rock into small pieces, a cylindrical core is cut. Core barrels are commonly 30 to 60 feet in length. When the core is brought to the surface, it is described by a geologist and then packaged and sent to a laboratory where it can be analyzed for certain properties such as porosity (space in the rock that is filled by fluids), permeability (the ability of the rock to transmit fluids), and the ratio of fluids present in the pores of the rock (oil, gas, and water).

Another method used to obtain whole rock samples is the side-wall core sampler. Side-wall cores are obtained using a wireline tool that shoots small core barrels into the side of the well bore. The barrels are secured to the wireline tool by cables and the core is retrieved by pulling on the tool.

MEASUREMENT WHILE DRILLING

Measurement While Drilling (MWD) is a well logging technique developed in the last two decades that allows some of the same measurements that are done by wireline logs to be accomplished in real time while the well is being drilled. This technique allows certain types of information to be gained in case the hole is lost before the wireline logs are run, to monitor rock properties that can indicate the presence of abnormal pressure conditions before drilling into them. Data from the measurement sensors near the bit are transmitted as fluid pulses through the drilling mud. MWD also is critical to directional and horizontal drilling providing real-time measurements so that immediate adjustments can be made in hole attitude and direction.

3.4.2 Coalbed Methane

3.4.2.1 Drilling Procedures

Drilling for CBM is very similar to drilling for conventional oil and gas except that generally much smaller drilling rigs are used since, at present, CBM resources are generally at much shallower depths on average than oil and gas.

3.4.2.2 Casing and Cementing

Surface casing also is required to be set in CBM wells to protect potential aquifers. The depth of surface casing is determined by the regulatory agency and depends on the depth of water zones that need to be protected. Production casing can be set in either of two ways: 1) the casing can be set below the coal zone and cemented in and completed like typical oil and gas wells; or 2) the casing can be set above the coal zone, which is called an open hole completion. Generally in this case, the open hole under the casing is under-reamed by a bit that expands to a large diameter and drills a larger hole.

3.4.2.3 Blowout Prevention

BOPs also are required for drilling CBM wells as required by Onshore Rule No. 2.

3.4.2.4 Formation Evaluation

Wireline well logs are common formation evaluation tools for CBM wells. The well logs provide information on depth, thickness, and total number of coal seams. In addition, other properties can be determined such as porosity, fractures, and the amount of ash (mineral material) in the coal. An important aspect of formation evaluation of coals for methane production is to estimate the amount of gas that is potentially available to produce from the coal. The gas in coal is present through a process called sorption, whereby the gas is attached to the surface of the coal in a molecular state. In order to produce the gas, it must be desorped from the coal. Desorption is accomplished by lowering the hydrostatic pressure on the coal by producing the water in the coal.

In CBM formation evaluation, the amount of gas that can be desorped is critical in determining whether a well or number of wells will be economic. The amount of gas that can be produced can be estimated using direct or indirect methods. One direct method is to conduct tests on whole core or drill cuttings whereby the coal samples are put into a gas-tight chamber and the gas is allowed to evolve and is measured. Corrections are made for the potential lost gas that occurs when the cores are brought to surface and before they can be placed into the gas-tight containers. A variation on this technique is to obtain pressure cores, a method that seals the core under formation pressure. In the pressure core method, gas losses are minimized and a more accurate estimate of potential gas can be made. Indirect methods of desorption potential do not measure gas directly but rather measure the sorption capacity of the coal.

4.0 FIELD DEVELOPMENT AND PRODUCTION

4.1 Oil and Natural Gas

4.1.1 Field Development

New field developments are analyzed under NEPA by means of an environmental assessment (EA) or environmental impact statement (EIS) after the second or third confirmation well is drilled. The operator should then have an idea of the extent of drilling and disturbance required to extract and produce the oil and gas. When an oil or gas discovery is made, a well spacing pattern must be established before development drilling begins. Well spacing is regulated by the WOGCC.

Factors considered in the establishment of a spacing pattern include reservoir data from the discovery well including porosity, permeability, pressure, composition, and depth. Other information pertinent to determining spacing includes well production rate, relative amounts of gas and oil in the production stream, type, and the economic effect of the proposed spacing on recovery. Spacing for oil wells usually varies from 40 to 320 acres per well, but can be as dense as 10 to 20 acres per well. Spacing for gas wells is generally from 160 to 640 acres per well, but spacings of 20 to 40 acres are possible.

Spacing requirements can pose problems in selecting an environmentally sound location. Reservoir characteristics and the drive mechanism determine the most efficient spacing to achieve maximum production. If an operator determines that a different spacing is necessary to achieve maximum recovery, the state and federal agencies may grant exceptions to the spacing requirements. Exceptions also may be obtained if the terrain is unsuitable, provided no geologic or legal problems are encountered.

The procedures for obtaining approval to drill, and for the drilling of development wells are generally the same as those for wildcat (exploration) wells. Many fields go through several development stages. A field may be considered fully developed and produce for several years and then new producing zones may be found. If commercial hydrocarbons are discovered in a new producing zone in an existing field, it is called a new pool discovery, as distinguished from a new field discovery. New pools can either be deeper or shallower that the existing producing zone. A new pool discovery may lead to the drilling of additional wells. Shallower pay might be exploited from existing wells or deeper zones may be accessed by deepening existing wells. Often it is found that an established spacing rule is not effectively draining the producing zone in the field because of factors, such as reservoir heterogeneity or non-continuity of the reservoir, that were not detected when the field was initially developed . If an operator can substantiate (through pressure testing, 3D seismic surveys, or other evidence) that the initial spacing is not effectively draining the reservoir, the operator can petition the WOGCC for a new spacing.

As more wells are placed in production, roads are improved by regular maintenance, surfacing with gravel or scoria, and installing culverts. Mineral materials are usually purchased from local contractors and obtained from federal sources. Materials that are obtained from areas of federally owned minerals require a sales contract and are processed through the field office where the materials occur. A new stage of field development can lead to changes in locations of roads and facilities. All new construction, reconstruction, or alterations of existing facilities-including roads, dams, pits, flowlines, pipelines, tank batteries, or other production facilities must be approved by the BLM.

Production from multiple wells on one lease may be carried by flowlines to a central processing facility. Central processing and storage facilities can be used for multiple wells on the same contiguous lease or multiple wells in an established unit. During the productive life of a field, problems may arise such as erosion, barren to sparsely vegetated areas, washouts of drainage crossings, plugging of culverts, deterioration of cattleguards, accumulation of derelict equipment, construction of unnecessary roads, unauthorized off-road cross-country travel, and improperly placed or out of service pipelines.

Rehabilitation plans are prepared by either BLM or industry to correct these problems and to return the field surface area to its original productivity. Corrective action is taken as problems arise. This ongoing restoration allows total rehabilitation to be more quickly accomplished at the end of a field's productive life.

4.1.2 Unitization

In areas of federally owned minerals, an exploratory unit can be formed before a wildcat exploratory well is drilled. Federal units were authorized by *The Mineral Leasing Act of 1920*. Title 43 CFR Subpart 3186 (2002) sets forth a model onshore unit agreement for unproven areas. The boundary of the unit is based on geologic data. A unit operator is determined by agreement of the leaseholders (often the leaseholder with the largest leasehold position is designated operator of the unit).

As oil and gas are discovered, unit development can proceed in a deliberate and efficient manner to minimize waste of hydrocarbon resources. For instance, pressure maintenance wells can be installed prior to full-scale production, which, in some types of reservoirs, may significantly increase recovery factors. Spacing in a unit is not regulated except for offset distances to the unit boundary. This allows location of wells to take advantage or reservoir heterogeneity and thereby increasing recovery. Another advantage of unitization is that surface use is minimized because all wells are operated as though on a single lease. Duplication of field processing facilities is minimized because development and operations are planned and conducted by a single operator. Often powerlines can be distributed throughout the unit and well pumps can be powered by electric motors. Unitization may enable the field to be developed with fewer wells minimizing surface disturbance through fewer locations and less road mileage.

It is the general intent of unitization to pool or unitize the interests in an entire structure or area in order to provide for adequate control of operations so that development and production can proceed in the most efficient and economical manner and with minimized environmental impact. Each proposal to unitize federally-supervised leases is evaluated on its specific merits. The unit agreement provides for the exploration, development, and production by a single operator. In effect, the unit functions as one large lease. The purpose of a unit is to conserve the natural resources of the pool, field, or area involved. The early consolidation of separate exploration and development efforts through unitization of separate leasehold interests eliminates the need (with respect to drainage) to drill protective wells along common boundaries between leases and serves to maximize benefits through a consistent exploration and development program.

4.1.3 Production Practices

4.1.3.1 Well Completion

After the production string is cemented into place, the drilling rig is moved off and a smaller rig (called a workover rig or pulling unit) is set in place over the hole. After time is given for the cement to cure, an interval coinciding with the producing zone is perforated. Perforating is accomplished through the use of bullet-like projectiles or, more commonly, with shaped-charges. Perforating cuts holes through the casing and to several feet into the formation. After the zone is perforated, the holes may be cleaned out using a fluid flush treatment, commonly acid. The acid helps remove invaded drilling mud and pulverized rock particles created by perforating.

Generally, most hydrocarbon wells require stimulation beyond cleanup of the perforations. Additional stimulation is accomplished through hydraulic fracturing of the producing zone. Hydraulic fracturing is accomplished by pumping large volumes of liquid, usually water and proppant material under pressure into the formation. The fluids from the fracturing are recovered, and the proppant is left in the fractures. The proppant may be composed of silica sand obtained from natural sandstone formations or may be derived from artificial materials such as ceramic. The proppant is used to keep the fractures open once the pumping pressure is stopped in the fracturing process. After stimulation is complete, production tubing is run into the well and may be anchored to the inside of the production string by the use of a production packer. The packer not only anchors the tubing but also prevents fluid from entering the annular space between the casing and tubing. At the surface, equipment is installed on the tubing to control pressure and the flow of the production stream to processing equipment.

4.1.3.2 Well Production

The following describes typical production practices at gas and oil wells.

GAS WELLS

Production and processing equipment at a typical gas well location might consist of a wellhead (called christmas tree), a production separator, a dehydrator, and tanks. Figure 5 depicts a typical gas well production facility. The christmas tree has valves used to control the flow of gas and liquids from the well. As gas comes to the surface, it is diverted to processing equipment on the location. The gas must be separated from liquids in the production stream that may consist of water, gas condensates, or light crude oil. The production stream is placed into a production separator where the majority of the water and liquid hydrocarbons are removed from the gas. The gas is then fed into a device called a dehydrator to remove water that may remain in the gas. There are several processes used for dehydration, one of the most common being the use of

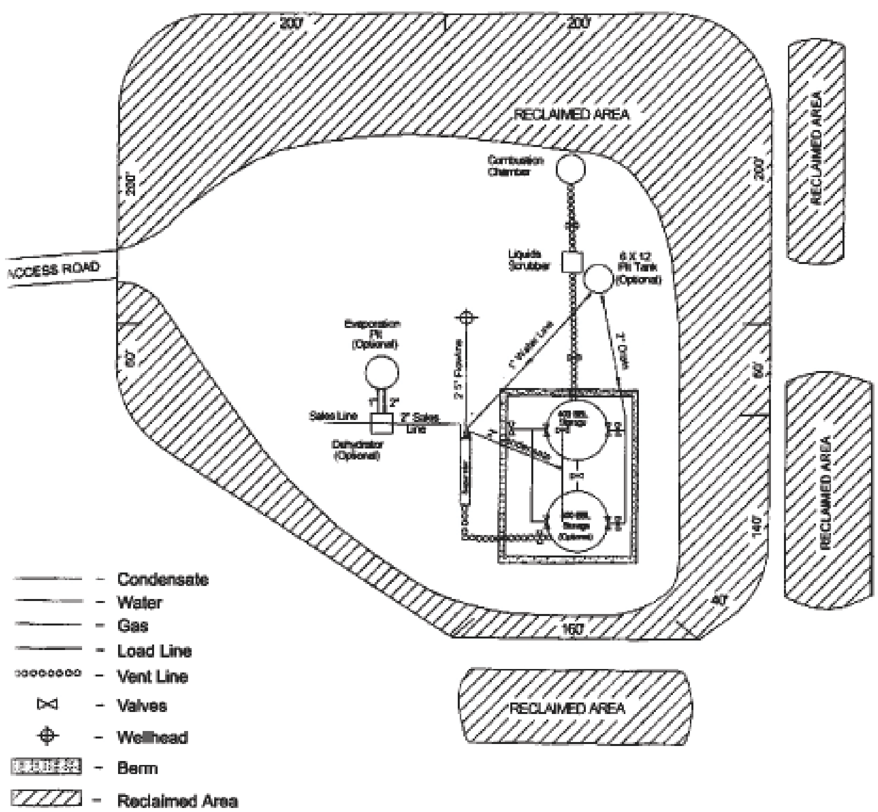

Figure 5. Typical Gas Well Production Facility

glycol. The gas then goes through a metering facility and then into a sales or gathering pipeline. The hydrocarbon liquids are recovered and placed into tanks. Often 400-barrel tanks (1 barrel equals 42 gallons) are used, but commonly gas wells make so little hydrocarbon condensate (drip) that it can be placed in smaller tanks. Condensate or crude oil is trucked from the well for sale or placed into a pipeline.

Produced water is either placed into a tank (often a below-grade steel tank called a tinhorn) or, if permitted, into a shallow evaporation pit. Unlined evaporation pits can be used if water production is less than 5 barrels of water per day and if there are no potential impacts to shallow groundwater. Water also may be disposed into the natural drainages if the required permit is obtained from the Wyoming Department of Environmental Quality (DEQ).

Methanol is commonly used to keep production and surface lines from freezing because of pressure drops that occur when gas comes to the surface and result in line freeze ups, even in summer. Methanol is injected into the wellhead. Sometimes a device called an intermitter is used to either shut-in the well to build up pressure or to open up the well (blow down) if it is being loaded with fluid. If too much fluid is coming into the well bore, gas may cease to flow, a condition called loading up. Loading up may cause loss of productivity or permanent damage to the well, which may result in the loss of flow.

After dehydration, the gas is moved into field pipeline gathering systems. In order to move the gas through the pipelines, compression equipment is used. Field compression units are small and mobile and are often skid-mounted for portability. Field units are sized for the amount of gas that needs to be moved and are often temporary because of the changing compression needs in a field, especially as it undergoes initial development. From the field gathering lines, the gas is fed into larger transportation lines, often at compressor stations along the transportation line. Before the gas is put into the transportation lines, it may undergo further processing to remove hydrocarbon condensates and water to ensure the gas meets stringent transportation pipeline specifications.

Commonly, natural gas needs more than simple wellsite processing. Large scale gas processing is conducted at facilities called gas plants. Gas plants typically handle large volumes of gas from multiple wells and can be designed to handle a variety of product and impurity separation processes. Sometimes the gas contains heavier hydrocarbon compounds known as natural gas liquids (NGLs). These NGLs, in addition to being valuable products, also need to be processed out of the methane stream to meet the transportation pipeline specifications. In addition to NGLs, natural gas also may contain impurities or large amounts of non-flammable gases that need to be removed from the methane. A major impurity is H2S that, for safety and environmental concerns, needs to be removed from the gas. Carbon dioxide (CO2) is an important non-flammable gas that, if found in large enough quantities, may be commercially viable as a byproduct.

OIL WELLS

Typical oil well locations consist of a wellhead, pumping equipment, phase separation equipment, and storage tanks. Multiple wells on the same lease or unit may produce into central processing facilities, whereas more remote wells or a single well on a lease will have all the necessary processing and storage equipment. Oil wells can be completed as flowing wells or pumping wells. Flowing wells have sufficient formation pressure to raise the oil to the surface. If formation energy is insufficient to raise the fluids to the surface, the oil is pumped.

The most common types of pumps are called rod pumps. These pumps are placed next to the perforations and are actuated by surface beam pumping units at the surface (or pump jacks). The downhole pumps are connected to the pump jacks by a string of steel rods called sucker rods. In both types of pumps, movement of the sucker rods moves traveling valves that either open or close and cause the fluid to move into the well casing and up the tubing. Pump jacks come in a variety of sizes depending on the depth and the total amount of fluid anticipated to be pumped, the larger ones reaching a height of 30 to 40 feet. Pump jacks are powered by internal combustion engines or electric motors. Fuel for the internal combustion engines may be casinghead gas (gas produced with the oil) or propane.

Another pumping method involves the use of electrically powered submersible pumps that are suspended below the fluid level in the well. The fluids are pulled into the tubing and pumped to the surface. Submersible pumps are used when large volumes of fluid have to be produced such as wells where there are large amounts of water produced with the oil. Submersible pumps can pump higher volumes of fluid and enable wells with high water cuts to remain economically viable. Artificial lift, called gas lift, is method whereby natural gas is pumped into a well to provide the energy to lift the fluids to the surface. Hydraulic pumps, where crude oil is pumped down one tubing string, activating a hydraulic piston and well fluids plus the hydraulic fluids are returned to the surface in a second string or the casing annulus are also used.

Fluids produced from an oil well are generally composed of three phases: oil, water, and gas. When the fluids reach the surface, they must be separated. This is accomplished through the use of separation equipment that is appropriate for the proportions of fluid that are being produced. If there are large amounts of water, the water is separated by a vessel called a free water knockout (FWKO). Free water is water that is easily gravity-separated from the oil. The remaining fluid is fed into heater-treaters, which separate not only the gas and the oil, but also break apart water-in-oil emulsions that may occur during the production process. Dilute brines can form emulsions that are difficult to separate into distinct oil-water phases. Produced water that is separated from the oil is routed into tanks for disposal.

FWKOs and heater-treaters burn gas to facilitate separation of the fluids. The gas may be used to heat the fluids and is either provided from commercial propane or casinghead gas. Emulsions are usually treated with chemicals for severe or difficult emulsion problems. The casinghead gas, depending on the quantities produced, can be used on the lease, recovered and placed into pipelines for sale, or vented. The WOGCC prohibits the flaring or venting of natural gas except during testing of a new well or when the amount of gas produced with the oil is so small that pipeline construction is not practical. An operator who intends to vent gas must submit an air quality permit application to the DEQ. Normally gas produced in such circumstances is granted a waiver of permit because the amounts are small. Flaring of gas also requires submission of an air quality permit application. Air quality permits are required for all production equipment for both conventional and coal bed operations. If an oil well produces sufficient quantities of gas, provisions for recovering the gas must be made before oil production can commence. If casinghead gas is placed in gathering or sales pipelines, it must be dehydrated and metered as at a gas well.

After the separation process, oil and water are stored in tanks either at the location or at central processing facilities. The capacities of the tanks are generally from 400 to 500 barrels and any given tank battery will have varying numbers of tanks depending upon the productive capacity of the well. Tanks and separation vessels are placed in earthen berms or other containment structures in order to contain spilled fluids in case of an upset condition or rupture of a tank or vessel. Production equipment are required to be painted in colors that will blend into the surrounding environment. Popular colors are brown and green. Some or all of the facility must be fenced. If production pits are present, the pits must be fenced and netted to protect livestock and wildlife.

Two main methods of oil measurement are used: the lease automatic custody transfer method which meters for pipeline transport; and tank gauging by company personnel. Measurement is required by 43 CFR 3162.7-2 (2002) and Onshore Order No. 4 (BLM, 1989) to ensure proper and full payment of federal royalty.

PRODUCTION WASTE

Water is produced in large quantities and is the largest volume of waste generated in oil and gas production. Disposal of water produced on leases managed by the BLM is regulated by the Onshore Oil and Gas Order No. 7 (BLM, 1993) and the State of Wyoming. Produced water with less than 5,000 ppm TDS can be disposed of in natural drainages for livestock and irrigation if the required permits are obtained from the DEQ. If the water has greater than 5,000 ppm TDS, it cannot be used for beneficial purposes and must be disposed in a manner protective of the environment.

The water can be handled in several ways. One of the most common methods is to re-inject the water into the producing formation to maintain pressure in the reservoir as part of a secondary recovery waterflood. Another method involves the injection of the fluid into brine disposal wells, either owned by the operator or by third parties. A new method has been developed that injects water into another zone in the same well and much of the water never reaches the surface. Subsurface water disposal methods are permitted by the WOGCC under the underground injection control program. Downhole injection in the same well is still a relatively new and experimental method for disposing of water and still being evaluated by the U.S. Environmental Protection Agency (USEPA).

Water can be placed into evaporation pits if water volumes are small. Pits may be lined or unlined depending upon the discretion of the permitting authority. Water also can be hauled from the location by third-party commercial contractors and disposed of in large lined evaporation pits. Such commercial facilities are licensed and regulated by the Wyoming DEQ.

Much of the waste generated by production operations is exempt from regulation as hazardous waste. However, the waste must be disposed of in a manner acceptable by law. Waste that is exempted is waste intrinsic to the production process. Examples of exempt waste are formation water, hydrocarbon impacted soil, drilling mud, and drill cuttings. These wastes can be dealt with in a variety of ways under existing regulations, but must be handled in a manner protective of public health and the environment. Other wastes, not classified as exempt, must be disposed of properly according to regulation.

PRODUCTION PROBLEMS AND WORKOVERS

Weather extremes pose problems for operators by causing roads to become impassable, equipment to malfunction, and freeze-up of flowlines, separators, and tanks. Other problems that operators face are H2S, CO2, paraffin, corrosion, electrolysis, and broken flowlines. During the life of a producing well, it may be necessary to take the well off-line and service the well or conduct a workover. Often workovers are done for routine maintenance (replace pumps, clean out perforations) or may be conducted because of severe operating malfunctions (e.g., rod separation, casing leaks, cement breakdowns). Workovers are conducted with small rigs called workover rigs or pulling units. Pulling units are typically self-propelled rigs that have a mast that is erected over the hole. Rods and tubing are pulled out of hole and stacked vertically within the mast.

4.1.4 Secondary and Enhanced Recovery

The initial stages of production, whether by natural flow or by pumping, is referred to as primary recovery. As the reservoir is produced over time, the energy needed to move fluid from the formation to the wellbore is depleted. Depending on economics, additional recovery methods may be used. These methods are referred to as secondary recovery. There are two basic secondary recovery methods in use, water flooding and displacement by gas. The most important secondary recovery method in use is water flooding. Water flooding is the process of injecting large volumes of water into oil reservoirs where primary reserves are being depleted to enhance and accelerate recovery. The process of injecting gas into the producing zone is another, but less common, secondary recovery technique.

Historically, produced gas was often flared (burned) at the point of production because of poor market conditions or absence of pipelines to transport the gas. Later, it was recognized that the energy could be conserved and the recovery of oil increased if the produced gas was re-injected into the producing zone. This increased production was achieved by: 1) maintaining reservoir pressure by injecting the gas into the existing gas cap; and 2) by injecting the gas directly into the oil saturated zone, creating an immiscible or miscible gas drive, which displaced the oil.

Beyond secondary recovery, enhanced recovery is used to describe recovery processes other than the more traditional secondary recovery procedures. These enhanced recovery methods include thermal, chemical, and miscible (mixable) CO2 drives. When enhanced recovery methods are used after secondary recovery methods have reached viable limits, they are often referred to as tertiary recovery.

Some reservoirs contain large quantities of heavy oil that cannot be produced using primary or secondary methods. In thermal drive processes, heat is introduced from the surface or developed in place in the subsurface reservoir. In the thermal drive process, hot water or steam is injected. In the in-situ process, spontaneous or induced ignition of in-place hydrocarbons are created in the presence of injected air to develop an in-situ fire front. Raising the temperature of heavy oil causes it to become less viscous and more mobile so that it may be produced through gravity forces or preferably by displacement.

There are several chemical drive techniques currently in use, including: 1) polymer flooding, 2) caustic flooding, and 3) surfactant-polymer injection. These methods attempt to change reservoir conditions to allow additional oil to be recovered. Another form of gas injection is accomplished with CO2, which is miscible with both crude oil and water. CO2 can also be used in a secondary recovery process with CBM reservoirs. This process reduces the partial pressure of methane and strips the methane off the coal to be replaced by the CO2. This process would probably require relatively thick coals with high methane contents to be economically feasible. Most enhanced or tertiary recovery processes are very costly and highly dependent upon large recoverable reserves in reservoirs of adequate flow characteristics.

4.2 Coalbed Methane

4.2.1 Field Development

Because a CBM reservoir has some inherent differences from oil and non-coalbed gas development, field development occurs in a different way. The economic viability of any particular project may not be known until several wells have been drilled and completed and the coal has been depressured enough to determine if gas can be produced in commercial quantities. When federal managed lands are involved, new CBM developments are analyzed under the NEPA by means of an EA but an EIS may be needed.

In initial CBM development, the operator may drill two or three wells from which to obtain core samples to determine methane desorption potential, total aggregate thickness of coal seams, and other data from which to get an estimate of future production. If it is determined that there is commercial potential for CBM, the typical route to development is to begin to produce the wells in order to draw off the water to see if the coal seams are able to produce at preliminary estimated rates. Often a pilot project will be proposed in which a few wells are drilled at an adequate spacing to test the efficacy of dewatering the reservoir to cause gas to desorb from the coal. Usually 8 to 10 wells are drilled and pumped to the point until significant gas is produced. If the production proves to be economical, then the operator will propose to drill a number of wells that will most efficiently drain the gas from the coal.

Spacing in CBM projects can vary from one well per 320 acres to one well per 20 or 10 acres and is under the jurisdiction of the WOGCC. The spacing depends on the amount of gas that could be recovered, depth, permeability, porosity, and net coal thickness. When a CBM project is deemed economical to warrant full-scale production, often many wells are proposed to be drilled. The number of wells is dependent upon several variables. As in oil and natural gas developments, a CBM development requires drilling pads, roads, pipelines, compressors, and other infrastructure. On federally managed lands, the construction and installation of the production infrastructure must be approved by the BLM.

4.2.2 Unitization

The establishment of an exploration unit is advantageous for CBM production so that the development can be conducted in an orderly manner by one operator. Unitization also should optimize the surface planning so that roads, pipeline corridors, and other infrastructure can be located to minimize the footprint of activities.

4.2.3 Production Practices

4.2.3.1 Well Completion

CBM wells can either be open hole completions or cased hole completions. In open hole completions, the production casing is set above the target coal zones. In cased hole completions, production casing is placed through the coal zones and cemented in. Often there are several coal zones that are produced in one well, rather a single coal zone. One common method of openhole completion involves creating a cavity in the coal. The cavity that is created can be 4 to 5 feet across (nominal borehole size: 7 7/8 inches) by repeated injection of compressed air into the coal zones. The cavitation process can enhance permeability without the use of hydraulic fracturing. In the traditional cased hole method, the coals may be hydraulically fractured to enhance permeability. Certain types of hydraulic fracturing can damage coal zones so that, over the years, treatments have been designed especially for CBM wells.

4.2.3.2 Production Practices

A CBM production unit consists of wells, gas and water gathering lines, compressors, gas dehydrators, measurement systems, water treatment facilities, roads, and utilities. In the production process, typically large amounts of water have to initially be drawn out of the coal seam in order to desorb the gas. Several methods of artificial lift can be used to move the water to the surface. Pumping methods include rod pumps, submersible pumps, gas lift, and progressing cavity pumps.

All that is on a CBM location is a covered wellhead, allowing for reclamation of the location to a minimal area and for less intrusion resulting from monitoring and maintenance of the separator. A separator also would be a visual intrusion, an increasing factor in environmental analysis. At this stage the gas may still be saturated with water and is put through a two-phase separator.

After separation of the water, gas is routed through a metering system and placed into a gathering pipeline system. The gas may have to go through another dehydration step prior to putting it into a sales or transportation line. The produced water also is routed into a gathering pipeline system for disposal. There are two major disposal options for the water: surface discharge and subsurface injection.

All water disposal methods must be approved by appropriate regulatory authorities. Surface disposal is allowed only if the water meets certain permit-required limitations on quality and constituents. Often the water is usable for livestock watering and irrigation. In those cases, it can be discharged to surface drainages or, more commonly, into ponds. If the water, as pumped from the subsurface, does not meet discharge limits, it can be treated and then discharged to the surface. However, pretreatment options such as reverse osmosis are relatively expensive compared to other disposal options, may not be effective for large volumes of water, and must be properly designed to ensure that the system operates effectively. Evaporation ponds can be used for disposal but are not effective for handling large amounts of water over long periods of time, especially in Wyoming. Although Wyoming has a semi-arid climate, ideal conditions for evaporation occur only within a period of a few months of high temperatures. For most of the year, conditions are not conducive to effective evaporation of large amounts of water. Subsurface disposal can be accomplished through deep well injection. The water also can be re-injected into an aquifer only if the water meets water quality requirements. To accomplish injection, the water may have to undergo limited pretreatment, such as solids settling and filtration.

As in oil and non-CBM gas wells, workover operations are conducted for routine maintenance, failure of downhole equipment (rods or pumps), or re-stimulation.

5.0 ABANDONMENT AND RECLAMATION

5.1 Plugging and Abandonment of Wells

The purpose of plugging and abandoning a well is to prevent fluid migration between formations, to protect minerals from damage, and to restore the surface area. Each well has to be handled individually due to a combination of factors including geology, well design limitations, and specific rehabilitation concerns. Therefore, only minimum requirements can be established then modified for the individual well. Oil, non-CBM gas, and CBM wells must be plugged according to the same protection requirements.

The first step in the plugging process is the filing of the Notice of Intent to Abandon to the BLM if the lease is federal or WOGCC if the lease is state or fee. This notice will be reviewed and approved by the controlling agency prior to plugging whether the well is former producing well or if the well was an exploratory well. If the well is an exploratory well, verbal plugging instructions can be given for plugging current drilling operations, but a Sundry Notice of Abandonment must be filed after the work is completed. If usable fresh water was encountered while the well was being drilled, the controlling agency will be allowed, if interested, to assume ownership and plugging liability of the well and convert it to a water well. Under this arrangement, the operator may be reimbursed for the costs involved. The Wyoming State Engineer must approve a water well appropriation before the well can be produced.

The operator's plan for plugging the hole is reviewed by the controlling agency. Minimum requirements are stated in Onshore Order No. 2. There are different requirements for open holes (wells without production casing) than for cased holes. In open holes, cement plugs must extend at least 50 feet above and below zones with fluid that has the potential to migrate, zones of lost circulation (this type of zone may require an alternate method to isolate), and zones of potentially valuable minerals. Thick zones may be isolated using plugs across the top and bottom of the zone. In the absence of productive zones and minerals, long sections of open hole may be plugged with plugs placed every 3,000 feet.

In cased holes, cement plugs must be placed opposite perforations and extending 50 feet above and below except where limited by the plug back total depth of the well. The cement plugs could be replaced with a bridge plug if the bridge plug is set within 50 to 100 feet above the open perforations, and only if the perforations are isolated from any open hole below. The bridge plug must be capped with 50 feet of cement. If the cement cap is placed using a dump bailer, a minimum of 35 feet of cement is sufficient. A device called a dump bailer is a wireline apparatus useful for cement placement because tubing does not have to be run and cement contamination is minimized. This method employs the use of a container of cement, which is lowered into the hole and dumped. In the event that the casing has been cut and recovered, a plug is to be placed 50 feet above and below the cut off point. No annular space can be open to the surface from the drilled hole below. At a minimum, the top 50 feet of the well must be plugged with cement.

Normally, at least 100 feet of cement is required to be spotted across the surface casing shoe. If the integrity of a plug is questionable or the position extremely vital to protect certain zones, it can be tested with pressure or by tagging the plug with the drill string. Tagging the plug means running pipe into the hole until the plug is encountered and placing a certain amount of weight on the plug to verify its placement and competency. The top surface plug must be a minimum of 100 feet and no less than 25 sacks of cement. The interval between plugs must be filled with drilling mud of a minimum weight of 9 pounds per gallon. After the casing has been cut off below the ground level, any void in the top of the casing must be filled. If a metal plate is welded over the top of the casing, weep holes should be drilled in the plate to vent the annular space.

A permanent abandonment marker is required on all wells unless otherwise requested by the SMA. This marker pipe is usually at least 4 inches in diameter, 10 feet long, 4 feet aboveground, and embedded in cement. The well identity and location must be permanently inscribed on the side of the pipe or on a cap placed on top of the pipe. The SMA is responsible for establishing and approving methods for surface rehabilitation and determining when the rehabilitation has been satisfactorily accomplished. At this point, a Subsequent Report of Abandonment can be approved.

5.2 Reclamation

An exploratory drilling location or an abandoned producing well location must be reclaimed according to requirements set forth by the BLM, the WOGCC, and stipulations in the original lease agreement. Once the drilling or production equipment is removed, the location and access road must be graded to original contours, pits properly closed and backfilled, and then the disturbed areas are revegetated with appropriate seed mixtures to enhance the reclamation of the area.

6.0 NEW TECHNOLOGIES

Drilling and production methods are constantly being improved to reduce costs and to more effectively produce oil and gas. Often new technologies create benefits for the environment. The following is a discussion of a number of new technologies that are being used or could be used in the planning area to improve production practices or help limit the impact to the environment. Innovative drilling and completion techniques have enabled the industry to drill deeper (with fewer dry holes) and to recover more reserves per well. Smaller accumulations once thought to be uneconomic can now be produced. Nationally, increased drilling success rates have cut the number of both wells drilled and dry holes. Advances in technology have boosted exploration efficiency and new advances will continue this trend. Significant progress that has and will continue to occur is expected in the following:

- computer power, speed, and accuracy;
- remote sensing and image-processing technology;
- developments in global positioning systems;
- advances in geographical information systems;
- 3D and four-dimensional (4D) time-lapse imaging technology that permit better interpretation of subsurface traps and characterization of reservoir fluid,
- improved borehole logging tools that enhance our understanding of specific basins, plays, and reservoirs; and

- advances in drilling that allow more cost-efficient tests of undepleted zones in mature fields, testing deeper zones in existing fields, and exploring new regions.

These new technologies allow companies to target higher-quality prospects and improve well placement and success rates. As a result, fewer drilled wells are needed to find a new trap and production per well is increased. With fewer wells drilled, surface disturbance and volumes of waste, such as drill cuttings and drilling fluids, is reduced. An added benefit of improved remote sensing technology is the ability to identify hydrocarbon seeps.

Technology improvements have cut the average cost of finding oil and gas reserves in the U.S. The US Department of Energy (DOE) estimated finding costs at approximately $12 to $16 per barrel of oil equivalent in the 1970s. Currently, estimated finding costs are $4 to $8 per barrel.

6.1 Drilling and Completion

Advanced Resources International (ARI) used industry guidance to determine an average time required to drill and complete a well for certain depth ranges. They predicted an average time of 40 days to drill and complete a well of less than 10,000 feet, 65 days for wells between 10,000 and 14,000 feet, and 190 days for wells greater than 14,000 feet.

Drilling improvements have occurred in new rotary rig types, coiled tubing, drilling fluids, and wellbore condition monitoring during the drilling operation. Technology is allowing directional and horizontal drilling use in many applications. New bit types have boosted drilling productivity and efficiency. New casing designs have reduced the number of casing strings required.

The environmental benefits of drilling and completion technology advances include:

- smaller footprints (less surface disturbance);
- reduced noise and visual impact;
- less frequent maintenance and workovers with less associated waste;
- reduced fuel use and associated emissions;
- enhanced well control for greater worker safety and protection of groundwater;
- less time on site with fewer associated environmental impacts;
- lower toxicity of discharges; and
- better protection of sensitive environments and habitat.

6.1.1 Horizontal and Directional Drilling

Oil and gas wells traditionally have been drilled vertically. Depending on subsurface geology, technology advances now allow wells to deviate by anywhere from a few degrees to completely horizontal. Directional and horizontal drilling enable producers to reach reservoirs that are not located directly beneath the drilling rig. The capability to directionally drill has been useful in avoiding sensitive surface features. Drilling and completion costs for directional wells are higher than for conventional vertical wells. Because of this, the need for directional wells must be evaluated in regard to the increased costs. It would not be economical in all cases to a drill a directional well in lieu of a conventional vertical well.

Operators have used directional wells to avoid causing extensive surface disturbance and to try to reduce drilling and operating costs. Indications are that operators were only successful in reducing overall costs in some instances (when they could drill four or more wells from one surface location). Horizontal drilling can enhance production by increasing the amount of reservoir exposed to the well bore or in the case of production from natural fractures, allow the well bore to intercept more vertical fractures. The benefits from increased production can, in some cases, outweigh the added cost of drilling these wells. Recent advances in directional drilling have encouraged multilateral drilling and completion, enabling multiple offshoots from a single wellbore to radiate in different directions or contact resources at different depths. Multilateral drilling can increase well productivity and enlarge recoverable reserves, even in aging fields.

Environmental benefits of horizontal and directional drilling include the following:

- fewer wells and surface disturbance;
- lower waste volume; and
- protection of sensitive environments.

6.1.2 Slimhole Drilling and Coiled Tubing

Slimhole drilling is a technique used to tap into reserves in mature fields. It has the potential to improve efficiency and reduce costs of both exploration and production drilling. Coiled tubing, used effectively for drilling in reentry, underbalanced, and highly deviated wells, is often used in slimhole drilling. In 1999, the DOE reported that a conventional 10,000-foot well in southwestern Wyoming costing $700,000 could be drilled for $200,000 by using slimhole and coiled tubing. It is expected that slimhole drilling and coil tubing technologies will be used more often in the future.

The DOE has identified several environmental benefits of using these techniques:

- lower waste volumes;
- smaller surface disturbance areas;
- reduced noise and visual impacts;
- reduced fuel use and emissions; and
- protection of sensitive environments.

6.1.3 Light Modular Drilling Rigs

New light modular drilling rigs currently in production can be more easily used in remote areas and are quickly disassembled and removed. Components are made with lighter and stronger materials. The modular nature reduces surface disturbance impacts. Also, these rigs reduce fuel use and emissions.

6.1.4 Pneumatic Drilling

Pneumatic drilling is a technique in which boreholes are drilled using air or other gases rather than water or other drilling liquids. This type of drilling can be used in mature fields and formations with low downhole pressures and in fluid-sensitive formations. It is an important tool in drilling horizontal wells. This type of drilling significantly reduces waste, shortens drilling time, reduces surface disturbance, and decreases power consumption and emissions.

6.1.5 Improved Drill Bits

Advances in materials technology and bit hydraulics have yielded tremendous improvement in drilling performance. Latest-generation polycrystalline diamond compact bits drill 150 to 200 percent faster than similar bits several years ago. Environmental benefits include:

- lower waste volumes;
- reduced maintenance and workovers;
- reduced fuel use and emissions;
- enhanced well control;
- less time on site; and
- less noise.

Reducing the time a drilling rig spends on location reduces potential impacts on soils, groundwater, wildlife, and air quality.

6.1.6 Improved Completion and Stimulation Technology

Hydraulic fracturing of reservoirs enhances well performance, can minimize the number of wells drilled, and allows the recovery of otherwise inaccessible resources. However, traditional fracturing techniques have caused damage to the formations and subsequent loss in expected productivity. The flow of hydrocarbons is restricted in some low-permeability and in unconventional resources (such as CBM), but can be stimulated by hydraulic fracturing to produce economic quantities of hydrocarbons. Fluids are initially pumped into the formation at high pressures that fracture the rock and followed by pumping a sand slurry into the fractures which props open the fractures, allowing hydrocarbons to enter the wellbore. Improvements such as CO2-sand fracturing, new types of additives, and fracture mapping, promise more effective fractures and greater ultimate hydrocarbon recovery.

6.2 Production

Once production commences, reservoir management is needed to ensure that as much hydrocarbon as possible is produced at the lowest possible cost, with minimal waste and environmental impact. In earlier days, recovery was only about 10 percent of the oil in a given field and sometimes the associated natural gas was vented or flared. Newer recovery techniques have allowed the production of up to 50 percent of the oil. Also, 75 percent or more of the natural gas in a typical reservoir is now recovered.

Operators have taken significant steps in reducing production costs. The DOE estimated that costs of production had decreased from a range of $9 to $15 per barrel of oil equivalent in the 1980s to an average of about $5 to $9 per barrel of oil equivalent in 1999. Since 1990, most reserve additions in the U.S., 89 percent of oil reserve additions and 92 percent of gas reserve additions, have come from finding new reserves in old fields. As of 1999, the DOE also reported that about half of new reserve additions are from more intensive development within the limits of known reservoirs. They reported that the other half of reserve additions were from finding new reservoirs in old fields and extending field limits. This section summarizes technologies and efficiencies that have helped reduce production costs and reduce impact on the environment.

6.2.1 Acid Gas Removal and Recovery

Before natural gas can be transported safely, any H2S or CO2 must be removed. Special plants are needed to recover the unwanted gases and sweeten gas for sale. Improvements in the process have made it possible to produce sour natural gas resources, almost eliminate noxious emissions, and recover almost all of the elemental sulfur and CO2 for later sale or disposal.

6.2.2 Artificial Lift Optimization

Improvements have enhanced production, lowered costs, and lowered power consumption, which reduce air emissions.

6.2.3 Glycol Dehydration

Dehydration systems use glycol to remove water from wet natural gas before it enters a pipeline. During operation, these systems may vent methane and other volatile organic compounds (VOCs) which may include hazardous air pollutants (HAPs). Improvements to these systems have allowed increased gas recovery and have reduced emissions of methane, VOCs, and HAPs.

6.2.4 Freeze-Thaw/Evaporation

A new freeze-thaw/evaporation process has been shown to be useful in separating out dissolved solids, metals, and chemicals that are contained in water produced from oil and gas wells. In 1998, this type of produced water facility was constructed for McMurray Oil Company (now Shell Oil) at Jonah Field in southwestern Wyoming. Over the first winter, 17,000 barrels of water with a TDS content of 22,800 milligrams per liter (mg/l) was treated. It yielded 9,500 barrels of treated water and 5,900 barrels of brine solution (1,900 barrels were lost to evaporation and sublimation). The treated water (1,200 mg/l dissolved solids) was suitable for reuse in near-surface wellbore applications. The brine (66,900 mg/l dissolved solids) was suitable for reuse in deep drilling operations. In each of the following years (2000 and 2001), progressively greater amounts of treated water have been produced at this facility.

6.2.5 Leak Detection and Low-bleed Equipment

New technology is facilitating hydrocarbon leak detection and the replacement of equipment that bleeds significant gas, thus allowing increased worker safety, reduced methane emissions, and increased recovery and usage of valuable natural gas.

6.2.6 Downhole Oil/Water Separation

Emerging technology to separate oil and water could cut produced water volumes by as much as 97 percent in applicable wells. By separating the oil and water in the wellbore and injecting the water directly into a subsurface zone, only the oil needs to be brought to the surface. The new technology can minimize environmental risks associated with produced water handling, treatment, and disposal, and would reduce costs of lifting and disposing of produced water. In addition, surface disturbance could be reduced, oil production could be enhanced, and marginal or otherwise uneconomic wells could become producible.

6.2.7 Vapor Recovery Units

Vapor recovery can reduce a lot of the fugitive hydrocarbon emissions that vaporize from crude oil storage tanks, mainly from tanks associated with high-pressure reservoirs, high vapor releases, and large operations. The emissions usually consist of 40 to 60 percent methane, along with other VOCs and HAPs. Where useable, this technology can capture over 95 percent of these emissions.

6.2.8 Site Restoration

Regulatory agencies are allowing flexible risk-based corrective action (RBCA) as a process to ensure quicker and more efficient clean up of sites impacted by oil or other regulated substances. RBCA allows cleanup standards for soil, groundwater, and surface water to be customized to the environmental setting of a particular site. Sites where drinking water or other sensitive receptors may be at risk may have more stringent cleanup standards than sites where there is a low probability of impact. This allows for a case-by-case approach to site remediation rather than one cleanup standard for all sites, regardless of threat..

APPENDIX B

OIL AND GAS LEASE STIPULATIONS

APPENDIX B OIL AND GAS LEASE STIPULATIONS, KEMMERER FIELD OFFICE

The information in this appendix was prepared as part of the *Federal Lands Analysis Natural Gas Assessment Southern Wyoming and Northwestern Colorado* (ARI 2001). It is reproduced *verbatim* here.

(TLS) (1) Feb 1 to Jul 31; (2) as mapped on the Kemmerer RMP stipulations overlay; (3) protecting sage grouse nesting habitat. (Stip code K-7)

TLS (1) Nov 15 to Apr 30; (2) as mapped on the Kemmerer RMP stipulations overlay; (3) protecting big game crucial winter range. (Stip codes Wy-1, Wy-2, Wy-3, Wy-4, Wy 5)

TLS (1) May 1 to Jun 30; (2) as mapped on the Kemmerer RMP stipulations overlay; (3) protecting big game parturition areas.

TLS (1) Feb 1 to Jul 31; (2) as mapped on the Kemmerer RMP stipulations overlay; (3) protecting raptor nesting habitat. (Stip code K-4)

TLS (1) Nov 1 to Apr 1; (2) T. 18 N., R. 120 W., Sec. 18: lot 8,SESW, S2SE; (3) protecting bald eagle roosting areas.

(CSU) (1) Surface occupancy or use will be restricted or prohibited unless the operator and surface managing agency arrive at an acceptable plan for mitigation of anticipated impacts; (2) as mapped on the Kemmerer RMP Visual Resource Management overlay; (3) protecting Class I and II Visual Resource Management Areas. (Stip code K-7)

CSU (1) Surface occupancy or use within a quarter-mile of a sage/sharp-tailed grouse strutting/dancing ground will be restricted or prohibited unless the operator and surface managing agency arrive at an acceptable plan for mitigation of anticipated impacts; (2) as mapped on the Kemmerer RMP stipulations overlay; (3) protecting sage/sharp-tailed grouse breeding habitat.

CSU (1) Surface occupancy or use within crucial big game winter range will be restricted or prohibited unless the operator and surface managing agency arrive at an acceptable plan for mitigation of anticipated impacts. This plan may include development, operations, as well as the number, location, and maintenance of facilities; (2) as mapped on the Kemmerer RMP stipulations overlay; (3) limiting winter access, protecting habitat quality, and preventing the loss of crucial big game winter range. (Stip codes Wy-1, Wy-2, Wy-3,Wy-4, Wy-5)

CSU (1) Surface occupancy or use within quarter-mile of the Hams Fork Cutoff of the Oregon Trail will be restricted or prohibited unless the operator and surface managing agency arrive at an acceptable plan for mitigation of anticipated impacts. This may include development, operations and maintenance of facilities; (2) as mapped on the Oregon/Mormon Pioneer National Historic Trails Management Plan; (3) protecting historic trails; (4) TEC or Other Species/Habitat: cushion plant communities.

Special Lease Notice

Neither the oil and gas lessee(s), operating rights holder(s), and/or oil and gas operator(s) of this Federal oil and gas lease may conduct any oil and gas operation, including drilling for, removing, or disposing of oil and/or gas in the following lands contained in federal coal lease WYW-055246 unless a plan for mitigation of anticipated impacts is developed between the oil and gas and the coal lessees, and the plan is approved by the Authorized Officer (AO).

Example:

T. 20 N., R. 117 W., 6th PM, WY
Section 4: lot 8, E1/2SE;
Section 9: E1/2 E1/2.

If the AO allows oil and gas operations on this lease, the AO may alter or modify any oil and gas operations on the lands described in this lease that may interfere with: 1) the orderly development of the coal resource by surface and/or underground mining methods; 2) coal mine worker safety; and/or 3) coal production rates or recovery of the coal resource. The oil and gas lessee(s), operating rights holder(s), and/or oil and gas operator(s) cannot hold the United States (as lessor), coal lessee(s), sub-lessee(s), and/or coal operator(s) liable for any damage or loss of the oil and gas resource, including the venting of coal bed methane gas, caused by coal exploration or mining operations conducted on federal coal lease WYW-055246.

APPENDIX C

DATA SOURCES

APPENDIX C DATA SOURCES

GIS Layer	*Source*	*Metadata Available*	*Figures*
Kemmerer Field Office Planning Area Boundary	BLM	Yes	1-1, 2-2, 2-5, 3-1, 3-3, 3-4, 3-5, 3-9, 3-10, 3-11, 4-13, 4-14, 4-17, 4-20
Wyoming County Boundaries	BLM	Yes	1-1, 2-2, 2-5, 3-1, 3-3, 3-4, 3-5, 3-9, 3-10, 3-11, 4-13, 4-14, 4-17, 4-20
Point Locations of Wyoming Cities	Tiger Data	Yes	1-1, 2-2, 2-5, 3-1, 3-3, 3-4, 3-5, 3-9, 3-10, 3-11, 4-13, 4-14, 4-17, 4-20
Statewide Township/Range	GCDB	Yes	1-1, 2-2, 2-5, 3-1, 3-3, 3-4, 3-5, 3-9, 3-10, 3-11, 4-13, 4-14, 4-17, 4-20
Tiger Mainroads	Tiger Data	Yes	11-1, 2-2, 2-5, 3-1, 3-3, 3-4, 3-5, 3-9, 3-10, 3-11, 4-13, 4-14, 4-17, 4-20
Overthrust Fault	BLM	No	2-2
Generalized Faults	BLM	No	2-2
Landslides	WY State Geological Survey	Yes	2-2
Overthrust Belt	BLM	No	2-2
Oil and Gas Lease Locations	BLM	Yes	3-1
Oil and Gas Field Locations	WY State Geological Survey	Yes	3-3
Oil and Gas Well Locations	WY Oil and Gas Conservation Commission	Yes	3-4
Oil and Gas Pipeline Locations	WY State Geological Survey	Yes	3-5
Coal Lease and Permit Locations	BLM	Yes	3-9
2002 Mining Permit Locations	BLM	No	3-10

GIS Layer	*Source*	*Metadata Available*	*Figures*
Abandoned Mine Locations	BLM	No	3-11
USGS Oil and Gas Assessment - Southwestern Wyoming	USGS	Yes	4-13
Oil and Gas Potential	BLM	Yes	4-14
Coal Bed Methane Potential	BLM	Yes	4-17
Surface Mined Areas	BLM	Yes	4-20
Logical Mining Units	BLM	Yes	4-20

ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
°F	degrees Fahrenheit
AEO	Annual Energy Outlook
AML	Abandoned Mine Lands
ANSAC	American Natural Soda Ash Corporation
APD	Application for Permit to Drill
ARI	Advanced Resources International, Inc.
ASTM	American Society for Testing Materials
AU	Assessment Unit
BCF	billion cubic feet
BLM	Bureau of Land Management
BTU	British Thermal Unit
CAAA	Clean Air Act Amendment
CBNG	Coalbed Natural Gas
CFR	Code of Federal Regulations
DEQ	Department of Environmental Quality
DOE	Department of Energy
DOI	Department of the Interior
DOT	Department of Transportation
EIA	Energy Information Administration
EIS	Environmental Impact Statement
EPCA	Energy Policy and Conservation Act
FCLAA	Federal Coal Leasing Amendments Act
FY	Fiscal Year
GRC	Geothermal Resources Council
GSAM	Gas Systems Analysis Model
ISB	Intermountain Seismic Belt
KSLA	Known Sodium Lease Area
LBA	Lease by Application
LMU	Logical Mining Units
MBBLS	million barrels
mg/l	milligrams per liter
MMS	Minerals Management Service
mmt	million tons
mmtpy	million tons per year
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NETL	National Energy Technology Laboratory
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPC	National Petroleum Council
P&M	Pittsburgh and Midway Coal Company
PAW	Petroleum Association of Wyoming
$PM_{2.5}$	particulate matter with a diameter greater than 2.5 microns
RFD	Reasonably Foreseeable Development
RMP	Resource Management Plan
SIM	State Inspector of Mines
TPS	Total Petroleum System
U.S.	United States
UPRR	Union Pacific Railroad
USFS	United States Forest Service
USGS	United States Geological Survey
WMA	Wyoming Mining Association
WOGCC	Wyoming Oil and Gas Conservation Commission
WSGS	Wyoming State Geological Survey