APPENDIX S
REASONABLE DEVELOPMENT SCENARIO: OIL AND GAS IN THE GLENWOOD SPRINGS FIELD OFFICE ADMINISTRATIVE BOUNDARY

REASONABLE FORESEEABLE DEVELOPMENT:
OIL AND GAS IN THE GLENWOOD SPRINGS FIELD OFFICE (GSFO)
ADMINISTRATIVE BOUNDARY AREA

CLUSTERED GAS DEVELOPMENT IN THE GSFO

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REASONABLE FORESEEABLE DEVELOPMENT
OIL AND GAS DEVELOPMENT IN GLENWOOD SPRINGS FIELD OFFICE ADMINISTRATIVE BOUNDARY AREA

1. SUMMARY

This Reasonable Foreseeable Development (RFD) document was prepared to support the Resource Management Plan (RMP) Revision for the Glenwood Springs Field Office (GSFO). It provides the planning team with a forecast of the oil and gas development activities that are likely to occur on the BLM administered lands within the Field Office Area over the next 20 years.

The Bureau of Land Management (BLM) Energy Office staff at the GSFO interviewed operators, compiled data from various sources, and developed underlying assumptions regarding future development. Management and staff reviewed guidance from the BLM's Washington Office to ensure that the RFD was sufficiently rigorous for the purpose stated above.

Most of the area within the favorable geologic Piceance Basin (High Potential Area) within the GSFO is leased, and all but approximately 7,000 acres of the BLM Federal mineral estate, outside the top of the Roan Plateau is leased (Map 17). Most of the unleased Federal minerals underlie the Roan Plateau Area and National Forest Lands. Fourteen oil and gas fields are identified within the GSFO (Map 5), and all are located in the high potential area west of the Grand Hogback. Most of the existing gas production is from the Mesaverde Group formations, with lesser but significant production from the Wasatch Formation. Currently coalbed gas development is minor in the GSFO. The high potential area is underlain by the Cameo Coal zone, which is being produced on a limited basis in the Divide Creek field. Once water disposal problems are solved, the GSFO can expect greater interest in developing coalbed natural gas

The western portion of the GSFO (area west of and including the Grand Hogback) is in the southern part of the Piceance Basin (Map 2), which is part of the greater geologic basin known as the Uinta-Piceance Basin. The Roan Plateau Planning Area is included in this area. Most of the hydrocarbon production in the GSFO is natural gas with little associated oil, natural gas liquids, and water. This basin has a host of hydrocarbon plays identified by the United States Geological Survey (USGS), but the current gas production is from the Tertiary Wasatch and Cretaceous Mesaverde Group formations. The eastern three-fourths of the GSFO (area east of the Grand Hogback) comprise the Eagle Basin, the White River Uplift, and mountain ranges to the south and east.

The Eagle Basin is primarily a Pennsylvanian-age depositional basin located in a structurally complex area. This basin has relatively low potential for the discovery of significant gas based on available well data (subsurface data) and surface data. The basin has low potential for discovery of economic oil accumulations due to high thermal maturity of most Paleozoic shales and the presence of only small areas containing younger rocks with oil source beds. Therefore, the emphasis of this report is on the Piceance Basin portion of the GSFO.

The BLM Glenwood Springs Energy Office estimates that 55.7 TCF of technically recoverable gas resources are within the GSFO area mapped as high potential. These minerals include federal, fee and private. A recent U.S. Department of Energy article estimates that the southern Piceance Basin alone contains 300 TCF of gas. It is estimated that 5,768 wells will be drilled on

BLM mineral estate within the GSFO over the next 20 years involving 824 well pads[1]. This is approximately 40% of the wells needed to develop the estimated BLM gas resources. At this rate of projected development it will take approximately 50 years to develop the estimated technically recoverable gas resources. Technically recoverable oil resources are estimated to be significantly less than the gas resources, and much of the oil will be produced as condensate in association with future gas production. This discussion is detailed in section 6.2.4.

An oil and gas potential map (Map 25) was created for the GSFO defining areas as high, medium, low, or no known potential for the occurrence of oil and gas resources. Within the GSFO, 20% of the area is rated as high, 12% is rated as medium, 46% is rated as low, and 22% is rate as no known potential. Based on Industry input, leasing activity, former exploration and development activity, and the probability of resource occurrence, it is estimated that 99% of the future wells will be drilled within the area mapped as high potential, 1% will be drilled within the areas mapped as medium and low potential, and no wells will be drilled within the areas mapped as no known potential.

There have been approximately 875 BLM jurisdictional wells drilled within the GSFO boundary. The vast majority of the wells have been drilled since 1999 with the practice of multi-well drilling from single pads. Existing net disturbance[2] is 1,150 acres for BLM administered well pads, roads, and central facilities. Future long term disturbance has a direct correlation with the number of new wells projected to be drilled. Future long term disturbance is the amount of future gross disturbance minus interim reclamation and it is estimated at 5,331 acres which includes well pads, roads, and central facilities. This combined with the existing net disturbance is equal to 6,481 acres. This is 0.9% of the total BLM mineral estate and 0.2%[3] of the total land mass of the Glenwood Springs Field Office. Reclamation of well pads as a result of dry holes being drilled is virtually non-existent in the GSFO. It is assumed that interim reclamation will be the predominant form of reclamation since few wells are predicted to be plugged and abandoned and other wells co-located on the same pads will most likely be productive. This is due to the high success rate of drilled wells being paying wells and the fact that most of the producing wells are in their infancy and thus will not be depleted and plugged during the life of this plan.

Seismic activity will continue to play a role in finding the gas resources and in reducing the number of dry holes drilled. It is estimated that 40 seismic surveys will be performed over the next 20 years and that virtually will be 3D surveys. These surveys cover an average area of 8,300 acres per survey based on recent activity, but they only directly disturb about 1% of this area due to avoidance measures and the use of existing roads and trails. The total disturbance before reclamation is estimated at 3,320 acres (mostly fee land) over the life of the RMP Revision. Reclamation is estimated at 100% due to the temporary nature of the surveys and to BLM and State reclamation requirements.

2. BACKGROUND

The Glenwood Springs Field Office (GSFO) administrative boundary covers all of Eagle and Pitkin Counties, most of the eastern two-thirds of Garfield County, the northeastern tip of Mesa County, and the southeastern tip of Routt County in western Colorado and involves more than 2.9 million acres of land. The GSFO is bisected from west to east by Interstate 70. The GSFO has

[1] 5,768 wells ÷ 7 wells per pad average = 824 well pads

[2] Existing gross disturbance – interim reclamation – final reclamation= net disturbance

[3] Net surface disturbance over life of RMP (6,481 acres) ÷ total acres within the GSFO (2.9 million acres) = 0.0022 or 0.2% of total land mass: 6,481 acres ÷ 748,228 acres of BLM mineral estate = 0.0091or 0.9%

stunning scenic beauty with its high mesas and river valley in the western part and its high mountains and river valleys in the eastern part. The three major rivers within the GSFO are the Colorado, Eagle, and Roaring Fork Rivers.

This Reasonable Foreseeable Development (RFD) was prepared to support the preparation of the Resource Management Plan (RMP) Revision for the lands within Glenwood Springs Field Office (GSFO) administrative boundary. Recently the Roan Plateau Planning Area EIS was completed (Map 1). This area was discussed in great detail and also has its own RFD which included projected well numbers and surface disturbance. This document will be a separate RFD from the Roan RFD, but for geologic and resource discussion the Roan Plateau Planning Area will be included. This is necessary because this GSFO RFD geologic discussion is based heavily on the 2002 USGS Resource Assessment, which does not separate the Roan Plateau area from the rest of the Piceance Basin. The RFD is intended for input into the RMP by:

- Describing the level of fluid mineral exploration and production likely to occur over the next 20 years and estimating the surface disturbance associated with that activity. This information will provide the planning team the basis for assessing the impacts to other resources within the GSFO. The analysis of impacts and associated mitigation measures will be described in the RMP and other National Environmental Policy Act (NEPA) documents.

- Providing a description of past and present exploration and development activities to include conventional and unconventional reservoirs and plays located within the GSFO. Discussing the ancillary facilities and surface impacts from past and current activity is also discussed.

- Analyzing the geology, technologies, and methodologies that occur within the GSFO in order to support assumptions and projections for the RFD.

The RFD was prepared in accordance with Instruction Memorandum (IM) No. 2004-089; subject "Policy for Reasonable Foreseeable Development (RFD) Scenario for Oil and Gas," dated January 16, 2004.

3. DESCRIPTION OF GEOLOGY

3.1 General Description of Geology

The Piceance Basin, formed mainly in Tertiary time, is located in the western part of the GSFO and encompasses roughly 20% of the field office (FO) surface area (Map 2). This basin includes the Roan Plateau and is bounded on its eastern side by the Grand Hogback and White River Uplift. Outside of the FO boundary, the basin in bordered by the Gunnison Uplift to the south, the White River Uplift (Grand Hogback) to the east, the Axial Basin Arch to the north, and the Uncompahgre Uplift to the southwest (Map 28). The Douglas Arch separates the Piceance Basin from the Uinta Basin to the west. The Uinta-Piceance Basin is kidney-shaped, oriented northwest-southeast, and about 100 miles long and 40 to 50 miles wide. The general stratigraphy of the Piceance Basin ranges from Cambrian to Tertiary in age (Figure 1). The basin is asymmetrical and deepest along its east side near the White River Uplift, where more than 20,000 feet of sedimentary rocks are present.

The 2002 USGS Resource Assessment and the 2006 Energy Policy and Conservation Act (EPCA) phase II inventory discuss the Uinta and Piceance Basins as a single basin for the purposes of their respective inventories, but only the Piceance Basin exists in the GSFO. The EPCA inventory does have supporting data that include hydrocarbon resources and land access

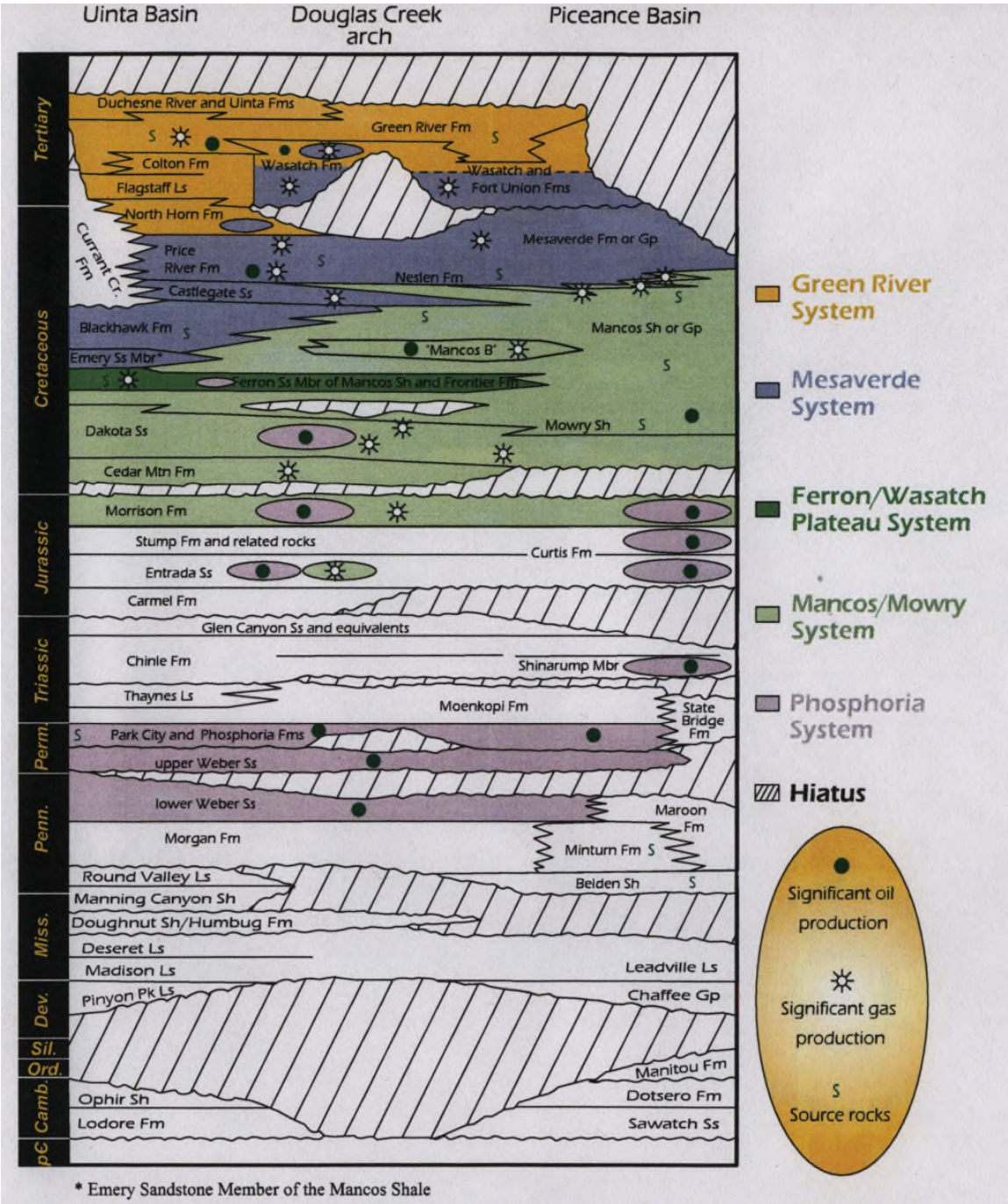

Figure 1. Generalized stratigraphic column showing the reservoir rocks that contain significant amounts of oil and gas derived from the five major TPSs contributing hydrocarbons to the Uinta-Piceance Province (modified from Sanborn 1977, Spencer and Wilson 1988). Source: USGS.

categorization by individual BLM and U.S. Forest Service (USFS) offices in spreadsheet format. The USGS and EPCA resource estimates are discussed in greater detail in the section of the RFD titled Oil and Gas Occurrence Potential. This section also has a discussion of the BLM Glenwood Springs Energy Office resource estimates, and these are the estimates used for the

basis of this RFD. All of the estimated resources are in within the Piceance Basin portion of the GSFO. Hydrocarbon resources were not considered for the remaining portion of the GSFO due to its unfavorable oil and gas potential. Most of the hydrocarbon production in GSFO is natural gas with very little associated oil, natural gas liquids and water. The gas production is from the Tertiary Wasatch and Cretaceous Mesaverde Group formations.

The Eagle Basin encompasses much of the eastern portion of the GSFO and encircles the White River Plateau. It is a structural feature and coincides in part with the Pennsylvanian-age Eagle Evaporite Basin, although the present-day Eagle Basin is much smaller than the paleodepositional basin (Mallory 1971). It is bordered on the west by the Grand Hogback structural feature and the Piceance Basin, on the east by the Park Range and Gore Range, and on the south by the Elk and Sawatch Mountain Ranges. The Grand Hogback is prominent monocline that doglegs its way through the GSFO in a north-south direction. It is the defining line between the area west, which is high potential for oil and gas and the rest of the field office area to the east, which has medium to no known potential for oil and gas. The basin has relatively low potential for the discovery of significant gas based on available well data (subsurface data) and surface data. The basin has very low potential for discovery of economic oil accumulations due to very high thermal maturity of most Paleozoic rocks and the presence of only small areas containing younger rocks with oil source beds (Nuccio and Schenk 1986). Therefore, the emphasis of this report is on the Piceance Basin portion of the GSFO.

3.2 U.S. Geological Survey Assessment of Undiscovered Oil and Gas Potential in the Uinta-Piceance Province (2002)

In 2002, the U.S. Geological Survey (USGS) completed an assessment of the undiscovered oil and gas potential of the Uinta-Piceance Province in which the Piceance Basin is included. The assessment is based on the geologic elements of each Total Petroleum System (TPS), which are mappable entities encompassing genetically related petroleum that occurs in seeps, shows, and accumulations. The largest likely extent of the TPS is mapped taking into consideration the areal distribution of known petroleum accumulations with potential migration paths for oil and gas. Identified within each TPS is at least one assessment unit (AU), defined as a mappable volume of rock that contains hydrocarbon accumulations with shared geologic traits (Figure 2). Using this geologic framework, the USGS defined and quantitatively estimated the undiscovered oil and gas resources of twenty AUs within five TPSs. In the Piceance Basin portion of the assessment, four TPSs are identified and nine AUs. The mapped TPS and AU boundaries are useful for determining the areas of greatest potential for oil and gas occurrence.

According to the USGS, approximately 99 percent of the undiscovered gas resource, within the Uinta-Piceance Province, is continuous and distributed in the Mesaverde TPS and Mancos/Mowry TPS (Maps 3 through 10). About 60% of this gas is contained in the Mesaverde Continuous Gas AU (the largest occurrence of gas), the Mesaverde Transitional Gas AU, and the Mesaverde Coalbed Gas AU (Maps 4 through 6). The remaining 40% occurs within the Mancos/Mowry Continuous Gas AU. The remainder of the undiscovered gas (≈1%) is associated/dissolved gas in oil accumulations within the Phosphoria TPS and the Green River TPS, or is in conventional nonassociated gas accumulations such as the Mesaverde Conventional Gas AU (Map 7), which is part of the Mesaverde TPS.

The Phosphoria TPS and Green River TPS are estimated to contain 100 percent of all the undiscovered oil in conventional reservoirs (Maps 11 through 15). About 60% of the oil occurs within the Green River Conventional Oil and Gas AU, and the remaining 40% occurs in the Hanging Wall and Paleozoic/Mesozoic AU (Maps 13 and 14).

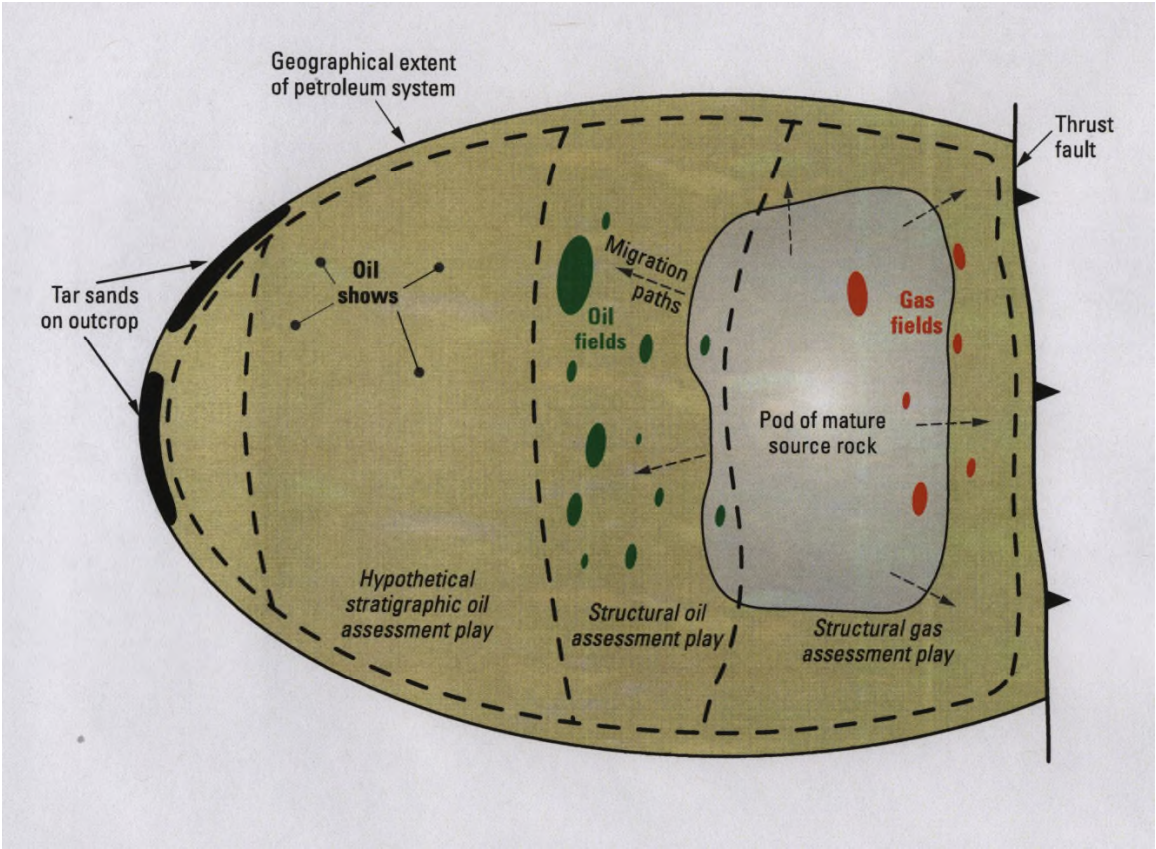

Figure 2. Schematic plan view of a TPS, showing a pod of mature source rock, distribution of known petroleum occurrences, and boundaries of the AUs. Source: USGS.

3.3 Summary of Piceance Basin Plays

A study by Spencer (2002) analyzed conventional plays and unconventional plays (for undiscovered resources) (Figure 3). A play is a set of known or postulated oil and gas accumulations sharing similar geologic, geographic, and temporal properties, such as source rock, migration pathway, timing, trapping mechanism, and hydrocarbon type. A play may or may not differ from an AU, and an AU can include one or more plays. Conventional plays are plays associated with structural or stratigraphic traps, commonly bounded by a down-dip water contact, and therefore affected by the buoyancy of petroleum in water. Unconventional plays (1) are generally very large accumulations occupying the more central, deeper parts of basins; (2) have an absence of down-dip water contacts; (3) are abnormally over- or under-pressured; (4) contain gas that is in the pressuring phase; (5) produce little or no water; (6) have a permeability of less than 0.1 md; (7) are overlain by a normally pressured transition zone containing gas and water; (8) contain thermogenic gas; (9) have a source of gas that is local—typically from either interbedded or adjacent lithologies; (10) have a 0.75 to 0.9 percent vitrinite reflectance at the top of accumulations; (11) consist only secondarily in structural and stratigraphic traps and; (12) are "sealed" by the presence of multiple fluid phases in low-permeability reservoirs.

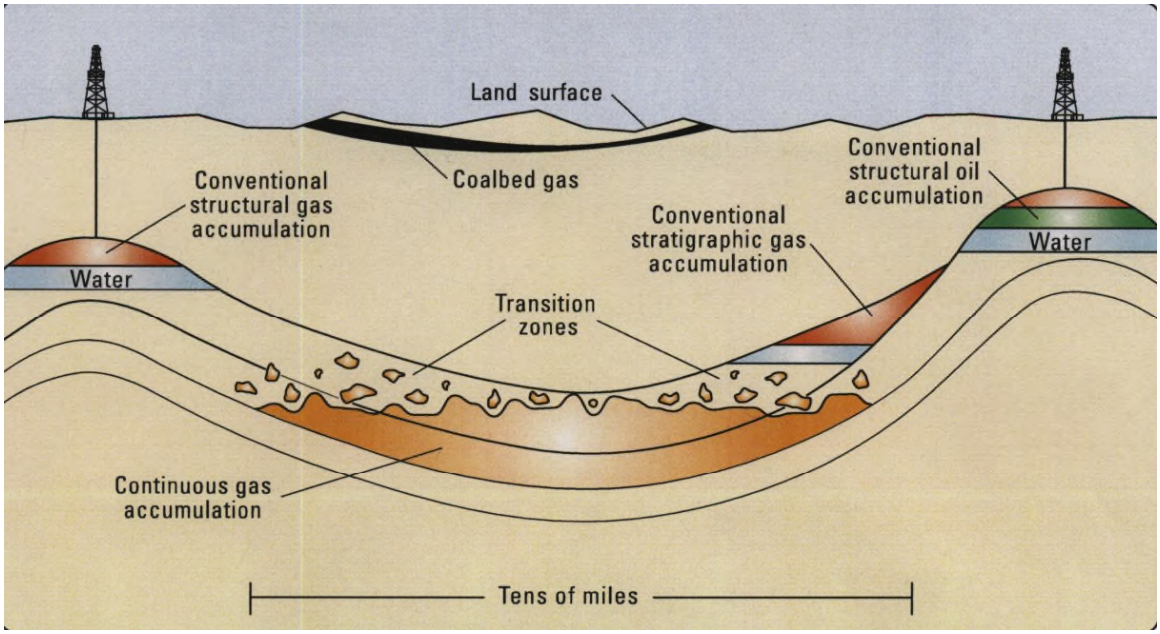

Figure 3. Schematic diagram of the types of oil and gas resources assessed. Source: USGS.

For the purposes of this RFD, a homogeneous distribution of resources within a play boundary is assumed because of the lack of more geologically specific information. However, gas resources are generally not distributed homogeneously within a play. This is particularly true for conventional accumulations but less so for continuous accumulations. Despite the assumption of homogeneity, various oil and gas densities can be mapped as a result of play stacking. Following is a discussion of the plays with AU and TPS that pertain to the Piceance Basin. For a more detailed discussion refer to the USGS 2002 Assessment.

3.3.1 USGS Conventional Oil and Gas Plays and Assessment Units

Piceance Tertiary Conventional Play

This play includes conventional sandstone reservoirs in the Tertiary Green River and Wasatch Formations. This play is included in the Piceance Green River Conventional Oil and Gas AU, which is located in the extreme western part of the GSFO (Map 14). Gas from the Green River Formation is considered to be sourced from the Green River TPS and gas produced from the Wasatch Formation is considered to be sourced from the Mesaverde TPS. Approximately 11% of the mapped AU is actually mapped within the GSFO boundary and most of that is within the Roan Plateau Planning Area (RPPA). In the Piceance Basin, the Green River Formation inter-fingers with and overlies the Wasatch Formation and was deposited in lacustrine environments of the Eocene Lake Uinta. The Green River Formation near the center of the basin is more than 5,000 feet thick. Most of the gas produced from this formation is from marginal lacustrine (lake-deposited) rocks or basal transgressive (marine) beds. Most of the gas produced has been in the central part of the basin. Source rocks appear to be from the underlying Mesaverde Group and from organic rocks within the Green River Formation itself. Traps are primarily stratigraphic and structural stratigraphic. Seals are enclosing shale, mudstone, and siltstone.

Gas produced from the Wasatch Formation is also sourced from the underlying Mesaverde Group strata. Some oil production also occurs from the Green River Formation, despite the low maturity of the lacustrine source rocks there. Although there are producing wells, the fields are very small. This play is only moderately explored even though it is has been penetrated by numerous wells drilled to Mesaverde objectives. The Tertiary gas reservoirs are underpressured, mostly fluvial sandstone, and many of these shallow gas reservoirs may have been bypassed. Due to the higher Mesaverde per-well gas recoveries, these wells will be completed first in the Mesaverde and after depletion, possibly recompleted in the Wasatch Formation. Green River Formation does not produce oil or gas within the GSFO. Gas production from the Wasatch Formation, mostly the G Sand, can be found in nearly 200 wells, most of which are located within or near the mapped AU boundary. The USGS expects that 12 more nonassociated gas accumulations will be found within this AU and that a maximum of 65 such accumulations may exist. Within the GSFO, it is expected that one more field will be discovered, and a maximum of seven fields may exist.

Upper Cretaceous Conventional Play

This play includes gas in sandstones of the Mesaverde Group and the Mancos "B" reservoirs. This play is included within the Mesaverde Conventional Gas AU (Map 7). This AU represents that area in the Uinta-Piceance Province in which migrated gas is produced, or has the potential to be produced, from Mesaverde TPS reservoirs in conventional-type structural and stratigraphic traps with discrete gas-water contacts at depths ranging from 1,000 to 6,000 feet. Most of the discovered fields are in the Piceance Basin portion of the unit. Approximately 6% of the mapped AU is actually mapped within the GSFO boundary, which encompasses the entire high potential area mapped in the western ¼ of the FO boundary. The Mancos "B" gas is most likely sourced from the Mancos/Mowry TPS.

The reservoir rocks are Cretaceous Mesaverde Group sandstones deposited in marginal-marine, deltaic, and fluvial (stream) environments. Some very fine-grained sandstone and siltstone reservoirs were deposited in a shallow-marine shelf environment seaward of, and in part beneath, the Mesaverde. These reservoirs include the Mancos "B" and equivalents, but much of the Mancos "B" fields are tight and mostly developed by drilling, but have some potential for field growth. Source rocks for the Mesaverde gas are organic shales and coals generated in the late Tertiary to present.

This play is well explored in the Piceance Basin. Within the GSFO boundary only a small portion of the numerous wells in the Mesaverde produce from conventional reservoirs, and only two wells produce from the Mancos. Because of the large volume of gas generated within the Mesaverde TPS, the USGS estimates that 10 conventional fields will be found and a maximum of 50 may be discovered. Within the GSFO it is expected that one more field will be discovered and a maximum of three fields may exist. These resources will most likely be found only with the aid of 3D seismic surveys.

Basin Margin Structural Play

This play is included within the Hanging Wall AU (Map 13). This AU includes all conventional hydrocarbon accumulations contained in structural and stratigraphic-structural traps associated with thrusted anticlines, subthrusts, and other faults. These structures were formed mainly during the Late Cretaceous through Paleocene Laramide orogeny. The thrust and their associated folds are basin vergent, meaning they display structural movement toward the basin. Accumulations could occur in Paleozoic and Mesozoic sediments immediately east and south of the Grand Hogback monoclinal axis. The main hydrocarbon source is the Phosphoria TPS and will

predominantly be oil with associated gas. More than 20 wells have been drilled within this play; all have been dry holes, with some wells displaying hydrocarbon shows. Virtually all of the wells have been drilled northwest of the town of New Castle in parallel strike with the monoclinal axis. This is a high-risk play due to the small size and complex nature of the structures present. The USGS predicts that only one new field will be discovered in the entire Hanging Wall AU. Since only 10% of the mapped AU is within the GSFO boundary, the probability of finding a new field in this limited narrow band is minimal. It is highly likely that some leases in T4S, R93W, and T4S, R94W, will experience some limited wildcat drilling during the life of the RMP Revision. Following is a discussion of some of the wells drilled in this play.

There is a show of oil in Weber SS in core data from the Clayton Oil #1 well in section 3, T5S, R92W, on the eastern side of the Grand Hogback monocline. Several wells drilled on the east side of the hogback in T5S, R91W, are dry holes with no shows reported. There is a small amount of oil reported in the Rifle Cr Hatchery #1 well in section 22, T4S, R92W. Oil is reported in the Pennsylvanian age Paradox Formation at a shallow depth of 250 feet. However, the Paradox Formation found farther southwest in Colorado and in southeastern Utah, is not known to exist in this area. The equivalent in this area and the likely formation to contain oil are the variegated clastic rocks and evaporites of the Minturn Formation, between the Belden and Maroon Formations. Although Bass and Northrop (1963) use the name Paradox Formation for the variegated clastics and evaporites between the Belden and Maroon Formations in the Glenwood Springs area of Garfield County, Colorado, there is no evidence that the Paradox Formation of the Paradox Basin is continuous with the Pennsylvanian sequence in the Eagle Basin. As a result, the name Paradox Formation should not be used in the Eagle Basin. *Source: GNU records (USGS DDS-6; Denver GNULEX).* Another well on the east side of the hogback, the Fish and Game #1 in section 22 T4S, R92W, has shows of oil stain in the Pennsylvanian age Maroon Formation.

Paleozoic/Mesozoic AU

This play is primarily a play for structural and stratigraphic traps and is included within the Paleozoic/Mesozoic AU (Map 12). This AU encompasses all of the GSFO south and west of the Hanging Wall AU and includes all conventional hydrocarbon accumulations thought to be sourced from the Phosphoria TPS and in one case from a combination of Paleozoic and Mesozoic rocks, south and west of the Hanging Wall AU. Hydrocarbons contained in this AU are mostly oil and associated gas. The principal hydrocarbon traps in this AU are anticlinal structures associated with two major structural elements; the Douglas Creek Arch and the Uncompahgre Uplift. Both of these structural features are located west of the study area. As a result this play although mapped within the GSFO boundary will mostly likely not contain any commercially viable reservoirs in the study area. There are no producing wells in this AU within the GSFO boundary.

3.3.2 USGS Continuous Oil and Gas Plays and Assessment Units

The Mesaverde Continuous Gas AU (Map 4), Mesaverde Transitional Gas AU (Map 6), the Mancos/Mowry Continuous Gas AU (Map 9), and the Mancos/Mowry Transitional and Migrated Gas AU (Map 10), all have tight gas plays within the Piceance Basin. Following is a discussion of each AU.

Mancos/Mowry Continuous Gas AU

This AU includes three groups of reservoirs: (1) a lower group consisting of units in the Morrison Formation (including Salt Wash and Brushy Basin Members), and Dakota Sandstone; (2) a middle group consisting of units in the Frontier Formation, Mancos Shale, and Mancos B; and (3) an upper group consisting of units in the Sego Sandstone, Morapos Sandstone Member, and sandstones of the Iles Formation or equivalents (Corcoran, Cozzette, and Rollins Sandstone Members), all within the Mancos/Mowry TPS. Reservoirs in this AU are usually tight and may be overpressured. Production is dependent on fracture permeability. Locally nonassociated gas is produced from the Cozzette, Corcoran, and Dakota Sandstones and in two Morrison Formation wells within the Shire Gulch field located just west of the GSFO boundary. Several wells with some Mancos production are also present in the Grand Valley and Rulison fields.

The total area that has potential for additions to reserves in the next 30 years is most likely in areas of current production and mostly limited to the lower (Morrison and Dakota) and upper (Iles sandstones) reservoir groups. The best potential comes from (1) isolated sweet spots in the Rulison, Divide Creek, Baldy Creek, Grand Valley, and Mamm Creek fields; (2) areas where there are porous and permeable sandstones in the Morrison and Dakota; and (3) infill drilling and recompletions from the upper group of reservoirs of the Iles and its equivalents. New fields developing resources within this AU are likely.

Mancos/Mowry Transitional and Migrated Gas AU

This AU (Map 10) consists of continuous accumulations of gas within reservoirs of the Morrison, Dakota Sandstone, Frontier Formation, Mancos B, Castlegate Sandstone, Sego Sandstone, Morapos Sandstone, and Niobrara Formation. Most of these produce in fields west of the GSFO boundary but not within the GSFO boundary. Reservoirs may be tight and may be normally pressured or underpressured. Some conventional gas/water contacts or water-saturated reservoirs may exist.

The USGS predicts that the area within this AU that has potential for additions to reserves in the next 30 years is most likely in areas of current production. Since virtually no current production occurs within the GSFO, it is highly unlikely that new fields with this AU as the primary production will be discovered in the planning area.

Mesaverde Continuous Gas AU

This AU (Map 4) is defined as that area of the Piceance Basin where a basin-centered continuous gas accumulation developed from the generation and predominantly vertical migration of gas from thermally mature coal and carbonaceous shale source rocks in the lower part of the Mesaverde Group. The boundary of the assessment unit is defined solely by the isoreflectance line being Ro=1.10 percent (vitrinite reflectance in oil). Stratigraphically, the AU extends vertically from the base of the Cameo coal zone in the Mesaverde Group (Williams Fork Formation) to the base of the Green River Formation. Fluvial channel sandstones in the Mesaverde Group and Wasatch Formation are the primary gas reservoirs. Gas accumulations are sealed by relatively impermeable mudrock that surrounds many of the sandstone units and by the process of capillary seal within the basin-centered accumulation (Law and Dickinson 1985). Much of the established production is from fields within valleys cut by the Colorado River and its tributaries. Unloading of overburden because of this downcutting and erosion may have increased permeability by opening up pore throats and fractures (Law and Dickinson 1985, Johnson 1989).

Gas production from fields, in this AU, within the GSFO is primarily from the Williams Fork Formation at total depths ranging from 6,000 to 9,000 feet. Initial production in new wells using modern frac techniques ranges from 800 MCFGPD to 1.4 MCFGPD on as little as 10-acre spacing. Mesaverde wells usually produce a minor amount of condensate and the USGS determined that average amount to be about 4,324 barrels per well (over the life of the well). Only small amounts of water are produced with the gas. Gas is trapped in a 1,700- to 2,400-foot interval of stacked, very low permeability, highly discontinuous fluvial sandstones that are part of a large, basin-centered gas accumulation where the lower two-thirds of the Williams Fork is continuously gas-saturated down dip of water-bearing sandstones.

A widespread, thin shale interval in the upper part of the Williams Fork may have been important as a top seal for overpressuring of the basin-centered gas accumulation. This interval ties closely with a seismic reflector that can be correlated over much of the Piceance Basin. Outcrop and subsurface studies indicate that the typical size of the Williams Fork sandstone reservoirs is small, with typical lateral extents of 500 to 800 feet. In general, the small size of these sandstones is the result of deposition as point bars by meandering streams. Seismic data and well control indicate early movement of Laramide structures. This movement has effected deposition of the Iles and Williams Fork strata.

Many attempts to produce this vast basin-centered resource were unsuccessful until modern hydraulic-fracturing technology made it possible to produce wells at economic rates. Natural fracturing is the primary control of well productivity, and 3D seismic can be used to identify structurally favorable areas (Figures 4 and 5). A combination of natural fractures and manmade factures is what makes this play economic. Areas within the Mesaverde Continuous Gas AU that contain gas resources but have little natural fracturing may not be economic to produce even with current hydraulic fracturing techniques. The low permeability and highly lenticular nature of the fluvial sandstones require 20-acre or denser well spacing to adequately drain the Williams Fork reservoir (Cumella and Ostby 2003).

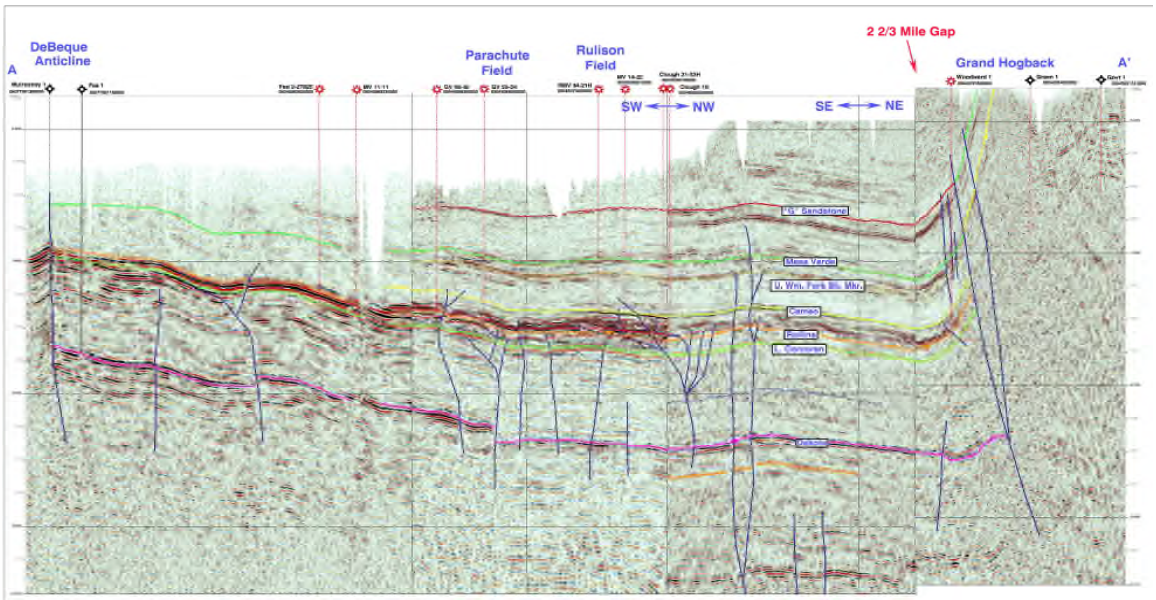

Figure 4. Seismic section across High Potential Area and Grand Hogback. Taken from Cumella and Ostby (2003).

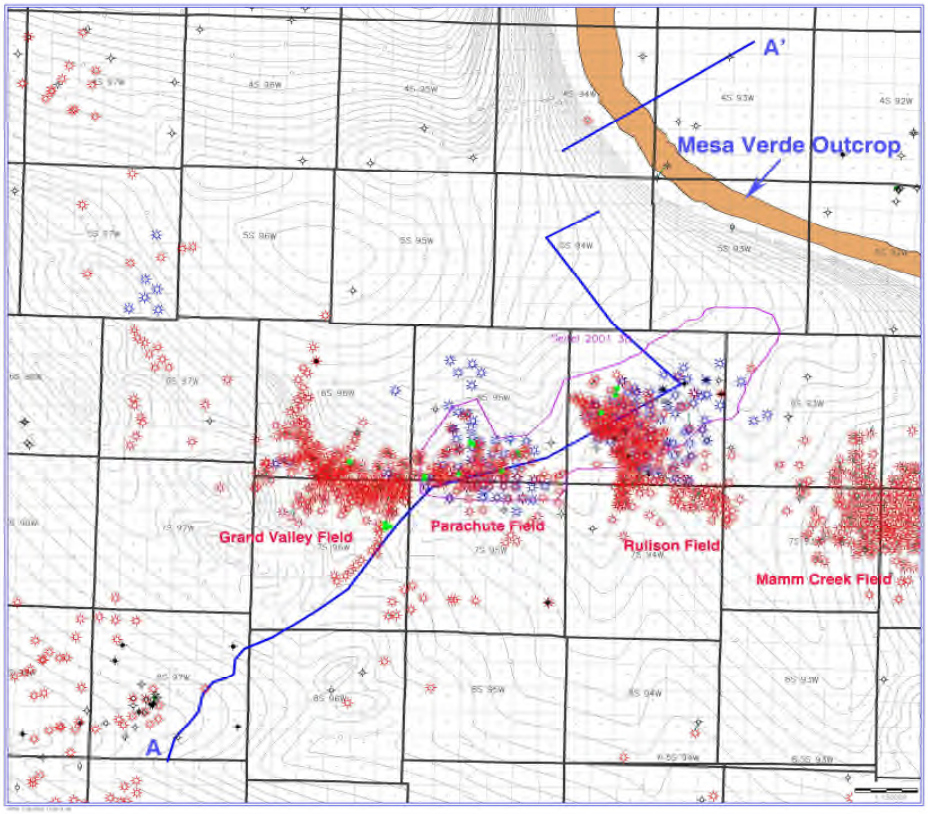

Figure 5. Map view of seismic section across High Potential Area and Grand Hogback Taken from Cumella and Ostby (2003).

Wasatch reserves are second in size only to the Mesaverde reserves. The Wasatch Formation consists of multiple, lenticular, sandstone lenses interbedded with bentonitic varicolored shales and siltstones. The sands of the Wasatch were deposited as channels cut into the shales and siltstones. The sands, which usually contain high clay content, are considered tight with low permeability. Most of the Wasatch production is expected to be derived from stratigraphic traps in the G Sand of the Molina Member. Production has been established in the G Sand in several fields within the GSFO. Much like the Williams Fork, the best production from the Wasatch is dependent on natural fractures as well as induced fracturing. In this area, the Wasatch has been developed at depths between 2,000 and 3,000 feet, with initial well productions of 200 to 300 MCFGPD on 160-acre spacing (Roan EIS). The Wasatch wells do not produce condensate.

It is likely that reserves growth will be experienced within most of the fields, in this AU, within the GSFO from both improved drilling and completion techniques and from additional infill drilling. Expansion of existing fields will also occur with drilling in untested areas that have geologic characteristics similar to those in the existing fields. New fields may be discovered as a result of new drilling and completion techniques in untested areas. These areas may or may not have the significant natural fracturing that is critical to economic production today. Future fracturing techniques may be able to unlock gas even in areas without significant natural fractures.

Mesaverde Transitional Gas AU

This AU (Map 6) surrounds the Mesaverde Continuous Gas AU and is defined as the area in the Piceance Basin where strata in the Mesaverde TPS include and overlie source rocks in the lower part of the Mesaverde Group with Ro values between 0.75 percent and 1.10 percent. The AU extends stratigraphically from the base of the Cameo coal to the base of the first significant lacustrine shale in the Green River Formation. Gas accumulations are thought to result primarily from vertical migration of gas from underlying thermally mature coal and carbonaceous shale. Gas saturation is probably less complete than in the Mesaverde Continuous Gas AU because some of the source rocks, high up in the Mesaverde formations, are less mature; thus, a higher percentage of water-saturated sandstone reservoirs are anticipated in this AU. Reservoir pressures vary from being moderately overpressured in the lower part of the AU to being normally pressured or underpressured in the upper part. Some of the gas-charged reservoirs may have conventional permeability (>0.1 md) as well as gas-water contacts, particularly in upper stratigraphic intervals of the Mesaverde TPS.

Within the GSFO, much of the gas production is from the Divide Creek and Parachute fields. Most production is from fluvial channel sandstones in the Mesaverde Group formations, with lesser production from fluvial channel reservoirs in the Wasatch Formation. Because this AU overlies thermally mature source rocks, gas can be found throughout the entire extent of the AU. However, the number of fields to be discovered could be limited in number and size because of incomplete gas saturation and the increased chance of penetrating water-wet reservoirs. Future fields may be best found in areas where structures can enhance gas migration and accumulation. The USGS predicts that additional reserves in the next 20 years will be found primarily in existing fields. Favorable structural conditions may be found within the GSFO boundary as evidenced in the 3D seismic reflections (Figure 4) near the Grand Hogback.

3.3.3 USGS Coalbed Natural Gas Plays and Assessment Units

Mesaverde Group Coalbed Natural Gas AU

This AU represents areas where the Williams Fork Formation in the Piceance Basin contains significant coalbeds at depths estimated to be 7,000 feet or less. The depth cutoff was extended to 7,000 feet in the Piceance Basin in order to include all coalbed natural gas production (CBNG) in the Grand Valley and Parachute fields. The top of the Rollins Sandstone Member of the Iles Formation, which marks the base of the Cameo coal group in the lower part of the Mesaverde Group, was used to define the location of the 7,000-foot depth cutoff. More than 5,000 feet of erosion and downcutting in the Colorado River drainage in the Piceance Basin has decreased the drilling depths to higher rank (more thermally mature) coalbeds. Thermally mature coal in the Williams Fork Formation is present in a belt as much as 10 miles wide along the southwestern margin of the Piceance Basin and in an area as much as 7 miles wide on the northeastern flank of the Divide Creek Anticline. Unfortunately, much of the coal has low permeability.

Total net coal thickness in the Cameo coal group varies from near zero in the extreme southeastern part of the Piceance Basin to greater than 180 feet in the northeastern corner. Throughout most of the basin, however, the zone contains from 20 to 80 feet of total net coal; in the southwestern part of the basin, total net coal thickness near the Utah-Colorado border decreases to less than 20 feet (Hettinger and Kirschbaum 2002). Coalbed gas content is about

600 standard cubic feet per ton (scf/t) at depths of 7,000 feet and may be as high as 765 scf/t at a depth of about 7,100 feet (Johnson and others 1996).

Coalbed natural gas wells have been drilled within the GSFO. Wells completed in the Cameo coals within the Great Divide field have high water production. Individual wells have reported as much as 3 million barrels of water produced within a 6 year period while producing 1.2 MCF gas. Water within the Great Divide field averages around 9,000 milligrams per liter (mg/L) of total dissolved solids (TDS). This does not meet State surface discharge standards and, as a result, injection of the water into the deeper Cozzette Sandstone is being considered. Analysis of the Cameo coals, in areas where coalbed natural gas is considered viable, show excellent gas saturation.

Many wells today have production from the Cameo coal zone commingled with production from adjacent sandstones. This is evident in the Parachute and Grand Valley fields. According to PI Dwights Production Data the Parachute field has more than 700 wells of which 29 are classified as CBNG wells. The same database show the Grand Valley field with more than 1000 producing wells and 40 of these wells being classified as CBNG wells. The perforation zones range from 200 to more than 500 feet, which is much thicker than the coals zones and encompasses a lot of gas sands as well.

Because of the lack of progress in solving the problems in producing commercial quantities of coalbed gas in the Mesaverde Coalbed Gas AU during the past, it is difficult to estimate how much of the included area has potential for additions to reserves over the next 20 years. This AU is largely untested but has the potential for new discoveries of coalbed gas. In the future, coalbed gas production may result largely from recompleting existing gas wells after depletion of the gas resource in associated sandstone reservoirs. Recompletion in existing wells is far cheaper than drilling new wells and may make coalbed gas economically viable. Additional sweet spots may be found in untested areas that will augment coalbed gas production from recompleted wells in established fields, and new advanced recovery techniques could increase the productivity, especially in areas of thick coal accumulation. If disposal of produced water becomes successful and economical, increased interest in future coalbed gas exploration and drilling will occur as well. Currently, operators in the area have been experimenting with water quality improvement processes. If successful in the future, these may lead to acceptable surface discharge scenarios that may be more economical than underground injection.

Piceance Basin-Grand Hogback Play (Hypothetical)

This is a hypothetical play that extends along most of the eastern margin of the Piceance basin, in the Grand Hogback area, where beds dip from 45° to overturned. Because of the steep dips, the coalbeds reach a depth of 6,000 feet in a short distance from the outcrop. Only a few wells have been drilled in this play and although some gas shows were reported, no commercial production has been established. Potential for reserves in this play is rated as fair to poor based on the structural complexity and limited extent of the play area.

Piceance Basin-Divide Creek Anticline Play

This play includes the Divide Creek and Wolf Creek Anticlines in the southeastern part of the GSFO. Thermally mature coal in the Williams Fork Formation is present in a belt as much as 7 miles wide on the northeastern flank of the Divide Creek Anticline. In the Divide Creek Anticline, overpressuring exists as the result of artesian conditions where permeabilities are higher and relatively fresh water is produced. The Divide Creek Anticline field has coalbed

natural gas wells producing from the Cameo coal zone. PI Dwight's shows only five wells actively producing coalbed natural gas at this time. The Divide Creek #21 well produced 1,679 MCF gas and 41,645 barrels of water in 2005. This is the kind of production that limits the high potential for reserves of coalbed natural gas. New advanced completion techniques, coupled with solutions to the problem of copious quantities of produced water, could lead to significant increased drilling and production.

Plays Identified by Industry

It is the BLM's policy to encourage input on planning documents from all sources of public land users and interested parties. Fourteen energy companies, being aware of the GSFO undertaking a major plan revision, expressed an interest in identifying plays that they are currently assessing for current and future exploration and production activities. These companies also supplied information needed to complete **section V, Past and Present Oil and Gas Development Activity**, of the RFD. All of the companies have existing leases and/or production with the GSFO and all are currently major players. The GSFO contacted the interested companies and met with them on several occasions in order to assess their interest and to receive input and data on specific plays, predicted activity, production costs, gas transmission capacities, production equipment, and field operation practices. To facilitate confidentiality in a very competitive business, companies did not want development scenarios and associated costs specific to their company to be disclosed in this RFD. Therefore, generalities and ranges are used in this report.

The plays discussed below are the Industry submissions and do not represent all potential plays within the GSFO. Many of the operators/lessees with interests in the GSFO were not part of this process. Some declined invitations to participate. As a result, not all current and future plays are discussed here. Some of the USGS plays discussed above are also discussed here because they are the plays most likely to be explored and developed.

Mesaverde Gas Play

Most of the major oil and gas operators in the GSFO area are interested in this play. This play includes all production from the Mesaverde Group, including the Corcoran, Cozzette, and Rollins Sandstone Members of the Iles Formation and the Williams Fork Formation. The latter includes the Cameo coal zone. The large majority of the oil and gas reserves within the GSFO are in this play, which extends across all of the high potential area of the GSFO. It is assumed that this play will continue to be developed on 10-acre spacing using multi-well pads. Industry input has predicted approximately 16,230 wells to be drilled in this play over the life of the Plan Revision.

Wasatch Gas Play

This play is second in reserves only to the Mesaverde play. Most of the production is expected to be from the G Sand of the Molina Member. Infill drilling will continue in the sweet spots such as the Rulison, Parachute, and Grand Valley fields. Much of the future production will be from existing wellbores through recompletions when the Mesaverde gas is depleted. New drilling will also occur outside the established production areas and spacing is assumed to be at 160 acres. The number of wells to be drilled specifically to exploit the Wasatch has not been identified by Industry, but some of the projected wells for the Mesaverde Gas Play will have multiple completions in the Mesaverde and Wasatch.

Niobrara Gas Play

There is no Niobrara production within the GSFO at this time. Interest in this play is located south of I-70 on the Divide Creek Anticline. This play is mostly for gas. It is hoped that the Niobrara has significant natural fracturing within the indurated shales that will act as secondary, not primary, porosity. Ultimate spacing has not been determined at this time, but 46 wells are currently projected to be drilled in this play, mostly on USFS lands south of Interstate 70. Other areas within the GSFO that have Niobrara with significant fractures will be also be explored.

Coalbed Natural Gas Play

Other new fields being developed today involve coalbed natural gas from the Williams Fork Formation coal zones such as the Cameo coal and the Paonia coal that are present in the Divide Creek field. Gas content within the Cameo coals has been classified as world class and exceeds 750 scf/t. These coals produce a lot of water. If the produced water can be disposed or processed for beneficial use in an economical way, new fields in areas of known Cameo coal gas reserves will also be developed. Currently, five wells produce coalbed natural gas from the Divide Creek Anticline and a small percentage of wells in other fields have been reporting CBNG production. The CBNG producing wells outside the Divide Creek field are thought to be commingled CBNG production with natural gas from interbedded sandstone reservoirs.

Gas Plays East of the Grand Hogback

There are no identified USGS oil and gas plays east of the Grand Hogback area outside the boundary of the Piceance Basin as mapped by the USGS. The Grand Hogback is a prominent monocline that doglegs its way through the GSFO in a north-south direction. It is the defining line between the area of high potential for oil and gas to the west, with more than 99% of the past and present drilling activity, and the rest of the field office area to the east. The area to the east of the hogback which includes the Eagle Basin has medium to no-known potential for oil and gas and accounts for less than 1% of past drilling activity, and no present oil and gas drilling or production. The basin has relatively low potential for the discovery of significant gas based on available surface data and well (subsurface) data. The basin has very low potential for discovery of economic oil accumulations due to very high thermal maturity of most Paleozoic rocks and the presence of only small areas containing younger rocks with oil source beds (Nuccio and Schenk 1986).

The exploratory wells drilled in the Eagle Basin have been dry holes, although a few wells have had shows of hydrocarbons. For the most, part these wells are clustered in the northeastern part of the GSFO north of the town of Eagle and another smaller cluster northwest of the town of Aspen. Some non-competitive leases are located north of the towns of Eagle and Gypsum. These are located in the low potential area for the oil and gas resources and have no drilling or production activity. It is unlikely that any wells will be drilled in the future and even more unlikely that these leases will be held by production beyond their 10-year issuance lives. It is predicted that a few wildcat wells will be drilled in the Eagle Basin.

In the northeastern part of the GSFO, in the general area of T1N to T2S and R84W and R85W, at least seven wells have been drilled. This area currently has no Federal leases. The wells have a relatively shallow total depth (TD) within Precambrian and Paleozoic formations, and there have been no reported shows of hydrocarbons. The Benton Land #1 well in section 14, T3S, R85W, was cored and had a show of gas in the core taken from the Pennsylvanian Minturn Formation at a depth of 8,042 feet. The core sequence shows the Belden Shale above and below the Minturn,

with a fault identified at a depth of 7,700 feet. This well TDs at 8,100 feet in the Belden Shale. The Benton Frank #13-31, located in section 13, T3S, R85W, has a TD of 11,260 feet in what the drilling report calls the Peerless Dolomite below the Belden Shale. The Peerless is late Cambrian (Franconian) in age. A drill stem test (DST) was run and a salt horizon had shows of hydrocarbons at a depth of 7,040 feet. This salt horizon most likely occurs in the Eagle Valley Evaporite. Two wells drilled nearer the center of the basin within the GSFO, in T5S, R84W, and T6S, R85W, had no shows of hydrocarbons.

Three wells were drilled in section 29, T9S, R85W, just northwest of the town of Aspen. One well core showed tight porosity and pyrite and calcite filled fractures in the Cretaceous Dakota Sandstone at 3,530 to 3,750 feet, with no shows of hydrocarbons. Another well the Cook #1 had shows of gas at shallow depths (710 feet) in the Cretaceous Dakota Sandstone. This well TDs in the Upper Triassic Chinle at approximately 3,500 feet but no shows occur in the formations below the Dakota or the deeper part of the Dakota itself. Another two wells were drilled just east of the town of Carbondale. In section 12, T7S, R89W, the JV Rose #1 has no hydrocarbon shows and TDs at 3,070 feet. The formation at TD is reported as unknown. The Patterson #1 well located in section 36, T7S, R88W, has no hydrocarbon shows and TDs in the Permian at 875 feet.

There are a few more wells just east of the Grand Hogback that are north and west of the Carbondale wells. These wells have various shows of hydrocarbons, and some even have production, but all are within the eastern boundary of the Piceance Basin and not considered as Eagle Basin wells. They are discussed in the plays mentioned previously.

4. PAST AND PRESENT OIL AND GAS EXPLORATION ACTIVITY

4.1 Geophysical and Geochemical Surveys

There have been moderate amounts of geophysical exploration surveys involving Federal surface in the GSFO within the last 20 plus years (Table 1). The following information is based on the limited records available at the recently established Glenwood Springs Energy Office and on information taken from the Colorado Oil and Gas Conservation Commission (COGCC) website. There was a small flurry of activity in the late 1980s and early 1990s. These 2D surveys were distributed across the entire area rated as high potential for the occurrence of oil and gas resources within the GSFO. For the middle and late 1990s, the GSFO only has one geophysical permit on file, and it took place in 1996. This may be because of the depressed market prices for oil and gas during this timeframe. In the past, the geophysical companies were New Frontier Exploration, Oryx Energy, Grant Norpac, Phoenix Geoscience, and Northern Geophysical. The COGCC website shows six pending geophysical permits (Map 16), all located west of R92W in the area classified as high potential. These permits involve approximately 49,759 acres and were submitted by Western Geophysical, Dawson Geophysical, and Trace Energy Services.

There have been several seismic surveys in the Grand Hogback Monocline area, one survey between the town of New Castle and the community of Canyon Creek, and one survey south of Carbondale and Sunlight ski area. These surveys were probably looking for hanging wall/basin margin structural traps, which may harbor oil and gas in older sediments. The remaining surveys are also looking for favorable structure and fracture areas within the GSFO high potential area. These may be sweet spots for basin centered continuous gas plays in the Mesaverde Group and for Niobrara and coalbed natural gas plays.

Table 1. Geophysical permits involving BLM lands.

Year	No. of Geophysical NOI Applications
2006	6 (pending)
2003	6
2001	1
1996	1
1991	1
1990	6
1989	3
1988	3
1987	2

No geochemical surveys were on file with the GSFO. But this does not mean that surveys have not occurred within the GSFO boundary. Surface geochemical exploration for petroleum is the search for chemically identifiable surface or near-surface occurrences of hydrocarbons or hydrocarbon-induced changes as clues to the location of oil and gas accumulations. Surface geochemical methods have been used since the 1930s, but the past decade has seen a renewed interest in geochemical exploration. Together with developments in analytical and interpretive methods, this has produced a new body of data and insights about geochemical exploration.

4.2 Exploration Drilling and Success Rates

Most of the drilling activity within the GSFO has occurred in recent years. Of the approximately 3,500 producing wells within the GSFO (PI Dwights, April 2006), about 2,400 have been spud since January 2000. About 2,000 of the spudded wells have been completed. These numbers indicate a greater than 83% success rate. More than 90% of the wells are producing from the Williams Fork Formation. Only a small percentage is producing from the Wasatch or Iles Formations. The Iles Formation has production from all three members: the Rollins, Cozzette, and Corcoran. Two wells are producing gas from the Mancos Shale.

All of the recent drilling is within the area mapped as high potential. Wildcat drilling in the eastern part of the GSFO has taken place on a limited scale. Wildcat areas are areas not yet proven to be productive. These areas are typically under explored or not explored. They can include large areas far from producing fields or step-out areas just off known geologic structures in producing fields. Wildcat wells can also be drilled within known geologic structures to zones that have never produced or are not known to be productive. Portions of the Piceance Basin within the GSFO are considered wildcat areas. Outside the Wasatch and Williams Fork Formations, the best wildcat plays are the Hanging Wall, Mesaverde Transitional Gas, and Mesaverde Coalbed Gas AUs.

The eastern portion of the GSFO is mapped mostly as low or no-known potential, with some minor areas of medium potential. Approximately 40 wells have been drilled in this area, many in the 1950s and 1960s. There has been no production, and only a few have shows of hydrocarbons.

4.3 New Field and Reservoir Discoveries

Although it has been known for decades that the Williams Fork Formation contains significant gas resources, very low permeability of the sandstones made it difficult to complete wells that would produce at economic rates. With the advent of advanced completion techniques, true dry holes are now rare. For the most part, the lower two thirds of the Williams Fork is gas saturated.

Production from the Williams Fork was established in the Rulison field in the 1960s and repeatable commercial production from the Williams Fork first occurred in the mid 1980s. The Grand Valley field was discovered in 1984. In 1981 the Department of Energy (DOE) performed a multi-well experiment in the Rulison field. This experiment involved three wells being drilled on a tight pattern of 100 to 200 feet of each other. A horizontal DOE well was also drilled in the same section in the Cozzette Member of the Iles Formation. These experiments have greatly expanded the knowledge about the tight gas sand reservoirs within the southern Piceance Basin. Better completions as a result of this knowledge have increased estimated ultimate recoveries (EUR) of previously drilled wells in this area from as little as 0.15 BCF to wells drilled in 1994 that have maximum EURs of 1.9 BCF.

Further experimentation by operators drilling and producing from the Williams Fork Formation has shown field growth reserves can be expanded considerably by drilling on 10-acre spacing. This spacing has been proven effective in draining a vast majority of the reservoir which was not occurring at greater spacing intervals. This tight spacing coupled with improved completion techniques has led to the expansion of existing fields and the development of new fields producing from the Williams Fork Formation.

Other new fields being developed today involve coalbed natural gas from the Cameo coal zone such as is present in the Divide Creek field. Gas content within the Cameo coals has been classified as world class and exceeds 750 standard cubic feet per ton (scf/t). These coals produce a lot of marginally fresh water. If the produced water can be disposed in an economical way, new fields in areas of known Cameo coal gas reserves will also be developed.

Presently the Niobrara Formation is being drilled with hopes of producing natural-fracture gas reservoirs. These fractures are a result of the indurated shales being stretched and folded over the point of greatest flexure on anticlinal fold axis. The fractures act as the primary porosity for the gas, and the reservoir is sealed by a more fissile shale layer above.

5. PAST AND PRESENT OIL AND GAS DEVELOPMENT ACTIVITY

5.1 Leasing Activity, Unit Descriptions, Communitization Agreements, and Spacing Requirements

The BLM issues two types of leases for oil and gas exploration and development on lands owned or controlled by the Federal Government: competitive and noncompetitive. The Congress passed the Federal Onshore Oil and Gas Leasing Reform Act of 1987 to require that all public lands that are available for oil and gas leasing be offered first by competitive leasing. Noncompetitive oil and gas leases may be issued only after the lands have been offered competitively at an oral auction and not received a bid. The maximum competitive lease size is 2,560 acres in the lower 48 States and 5,760 acres in Alaska. The maximum noncompetitive lease size in all States is 10,240 acres. Since passage of the Energy Policy Act of 1992, both competitive and noncompetitive leases are issued for a 10-year period. Both types of leases continue for as long thereafter as oil or gas is produced in paying quantities.

Much of the GSFO that is classified as high occurrence for oil and gas is leased (Map 17). Currently almost all of the BLM Federal mineral estate outside the Roan Plateau planning area (Roan PA) and in the area classified as high potential is leased. The total acres of BLM mineral estate in the high potential area (including the Roan PA and split estate) is 200,937 acres (99 RMPA). The remaining acres available to be leased are approximately 7,000 acres outside the Roan PA and 54,932 acres within the Roan PA (BLM GIS and Roan Plan). Most of the unleased land in the high potential area outside the Roan PA is located along the Grand Hogback, with the remainder in small, scattered parcels.

The total USFS mineral estate available for leasing within the Energy Office boundary is 231,729 acres (USFS GIS). Currently 117,191 acres are leased (all within the high potential area); the remaining 113,988 acres available for lease include 59,040 acres within the high potential area (USFS GIS). Of the 59,040 acres, a total of 8,117 acres are authorized and awaiting bids. The remaining acreage is available for leasing but most of the area is classified as Roadless areas. The total State mineral estate in the high potential area is 3,512 acres (99 RMP), and the total private mineral estate is 205,144 acres. See tables 2a, b, and c.

Table 2a. Leased and remaining available acres within high potential area of GSFO, including Roan PA.

Mineral Ownership	Total mineral estate (acres)	Leased lands (acres)	Unleased lands available for lease (acres)
BLM (split estate)	50,500	47,757	2,743
BLM (surface +mineral)	150,437	88,505*	7,000
BLM (total)	**200,937**	**139,005**	**61,932****
USFS	176,231	117,191	59,040
DOE	205	Unknown	Unknown
State	3,512	Unknown	Unknown
Fee	205,144	Unknown	Unknown

* 150,437 acres – 7,000 acres – 54,932 acres = 88,505 acres
** 54,932 acres + 7,000 acres = 61,932 acres

Table 2b. Leased and available unleased BLM lands within Roan PA (127,007 acres).

Mineral ownership	Total mineral estate (acres)	Leased Lands (acres)	Unleased lands-available for lease (acres)
BLM (split estate)	6,668	3,925	2,743
BLM (surface + mineral)	66,934	14,745	52,189
Total BLM	**73,602**	**18,670**	**54,932**
Total Non-Federal	53,398	Unknown	Unknown

Table 2c. Leased and available unleased BLM lands in high potential area of GSFO, outside Roan PA.

Mineral ownership	Total mineral estate (acres)	Leased lands (acres)	Unleased lands available for lease (acres)
BLM (split estate)	43,832	43,832	0
BLM (surface + mineral)	83,503	76,503	7,000
Total BLM	**127,335**	**120,335**	**7,000**

Much of the fee land within this area has also been leased. The number of leases will increase when the Roan PA is nominated for leasing in the future. Additional leasing may occur in the area of the Hanging Wall AU, which is sparsely leased in the northern part of the play. Most of the areas mapped as medium, low, and no-known potential for occurrence of oil and gas are currently unleased. This is approximately 78% of the area within the GSFO boundary and involves most of the lands east of the Grand Hogback. Some non-competitive leases are located north of Gypsum, which is classified as a low potential area.

The objective of unitization is to proceed with a program that will adequately and timely explore and develop all committed lands within the unit area without regard to internal ownership boundaries. Exploratory units normally embrace a prospective area that has been delineated on the basis of geological and/or geophysical inference. Exploratory unit agreements normally encompass all oil and gas interests in all formations within the unit area and provide for the allocation of unitized production to the committed lands reasonably proven to be productive of unitized substances in paying quantities on the basis of the surface acreage included within the controlling participating area. By effectively eliminating internal property boundaries within the unit area, unitization permits the most efficient and cost-effective means of developing the underlying oil and gas resources.

The BLM approves a unit agreement when appropriate in the interest of conserving the natural resources and when it is determined to be necessary or advisable in the public interest. When such a determination is made and lands are committed to the unit, the BLM has a responsibility to ensure that unit development proceeds in a way that continues to serve the public interest, regardless of whether the Federal lands comprise only a small fraction or a major part of the unit area.

The GSFO boundary contains 28 units and participating areas (Map 18), all of which are located in the area classified as high potential for the occurrence of oil and gas. The units are all located south of Interstate 70 and involve 259,600 acres of land regardless of mineral estate and surface ownership. In fact much of the unitized area is on the White River National Forest. When and if the Roan PA is leased, it has been recommended that this area be unitized as well. Unitization of the area on top of the Roan Plateau is required to be leased as a Federal unit under the Record of Decision for the RPPA.

When a lease or a portion thereof cannot be independently developed and operated in conformity with an established well spacing or well development program, the BLM may approve drilling agreements or communitization of such lands with other lands, upon a determination that it is in the public interest. Operations or production under such an agreement is deemed to be operations or production as to each lease committed in the agreement.

Communitization is used extensively within the GSFO, which currently has 128 communitization agreements (CAs) involving more than 44,746 acres (Map 19). These mainly communitize gas production from the Mesaverde/Williams Fork, but some CAs communitize gas production from other formations such as the Wasatch Formation and Cozzette Member of the Iles Formation. All of the CAs are located within the area classified as high potential for occurrence of oil and gas.

The current State of Colorado spacing requirement is 40 acres (600-foot setbacks from the lease line) for wells greater than 2,500 feet in depth, but this spacing can be increased or decreased depending on geology and reservoir characteristics and has been greatly modified in the Piceance Basin. The Colorado Oil and Gas Conservation Commission (COGCC) uses the term "default spacing" with modification occurring through Cause Orders. These adjustments are meant to maximize production of the resource while minimizing surface disturbance and expense. In the case involving production from the Williams Fork Formation, 10-acre spacing has been justified and approved. Currently, the Wasatch Formation is be drained on 160-acre spacing in selected areas. New spacing regulations may be necessary to accommodate new drilling and production techniques. Future production from previously undeveloped plays such as the Niobrara may also require spacing changes. Tight sands, compartmental geology, and reservoir characteristics may increase the demand for tighter spacing in the future in reservoirs other than the Williams Fork Formation.

5.2 Drilling and Completion Statistics, Fields, and Development Plans

The current drilling and production within the GSFO boundary exists in the western 20% of the area. Map 20 shows all current wells and permits locations. Following is a list of the well status and abbreviations shown on the map legend:

AC = ACTIVE

AL = ABANDONED LOCATION

DA = DRY AND ABANDONED

DB = DRILLING

DM = DOMESTIC WELL

IJ = INJECTING

PA = PLUGGED AND ABANDONED

PR = PRODUCING

SI = SHUT IN

TA = TEMPORARY ABANDONED

UN = UNITIZED

WO = WAITING ON COMPLETION

XX = LOCATION

Drilling and production have increased significantly over the last 6 years compared to the decades prior to the year 2000. As of September 2006, there are approximately 3,500 wells within the GSFO boundary. A search of the Automated Fluid Minerals Support System (AFMSS) software shows that of the 3,500 wells, a approximately 2,300 are Federal or private mineral estate wells associated with Federal units or CAs, and 760 are strictly Federal mineral estate wells with an additional 61 wells still categorized in active drilling status. There are a total of 875[4] Federal wells. Ninety three (93) wells, Fee and Federal, have been plugged and abandoned (PI Dwights Well Data). The AFMSS database shows that of these 93 wells, 21 are Federal plugged and abandoned wells, and 13 are Federal final abandonment wells. Final abandonment means that not only is the well plugged, but the location has been fully reclaimed and cleared by the BLM as finally abandoned.

Of the 3,500 wells, approximately 2,400 have been spud since January 2000. Of the spudded wells, about 2,000 have been completed. They are classified as gas wells, and some have associated natural gas liquids (NGLs). Of the wells completed within the GSFO, more than 3,000 are reported producing from the Williams Fork Formation and the Cameo coal zone. Some wells are reported merely as Mesaverde producers and do not delineate the exact production horizon. Approximately 111 wells are reported producing from the Wasatch Formation, 2 from the Mancos, and the remainder from the Corcoran, Cozzette, and Rollins Members of the Iles Formation. The number of wells completed in the different zones does not sum to the total well count because many wells are reported as producing from multiple zones. Most of the wells are being drilled within existing fields due to decreased spacing. Multiple wells, as many as 22 per pad, are being drilled from new and existing locations. Few wildcat wells are being drilled.

The GSFO contains 14 oil and gas fields (Table 3, Map 21), all of which occur within the area mapped as high potential for occurrence of oil and gas resources. The high potential area encompasses approximately 586,000 acres, and the existing gas fields as mapped by the Colorado Geological Survey (CGS) encompass almost 130,000 acres, or about 22% of the total area. A significant amount of successful drilling is occurring between these fields, which is having the effect of enlarging them and in some cases the fields appear to be merging. Future drilling in the Roan PA may add new fields as well as expand existing fields just south of the Roan cliffs.

The BLM is currently working on or recently completed eight Geographical Area Plans (GAP). Seven existing GAPs were previously approved, and permitting is now taking place within their boundaries (Map 22). According to the 1999 Record of Decision for the GSFO Oil and Gas Leasing and Development EIS, in areas being actively developed, the operator is encouraged to submit a GAP that describes a minimum of 2 to 3 years of activity for operator-controlled Federal leases within a reasonable geographic area (to be determined jointly with the BLM). The GAP is used to plan development of Federal leases within the area; to account for well locations, roads, and pipelines; and to identify cumulative environmental effects and appropriate mitigation.

5.3 Directional and New Technology Drilling Practices

Directional drilling in the GSFO occurs in the large majority of new wells, where it usually is used to access reservoirs from locations that are not directly over the reservoir. Such cases may involve locating wells on mesa tops instead of steep slopes or canyon (riparian) bottom areas.

[4] 738 gas wells + 22 gas SI wells + 8 TA wells + 21 P&A wells + 13 ABD wells + 12 service wells + 61 active drilling wells (as classified in AFMSS) = 875 total Federal wells

Table 3. Oil and gas fields within the GSFO jurisdiction.

Field	Age	County	Commodity	Pay Zone(s)	Primary Pay
Wolf Creek	Upper Cretaceous	Pitkin	Gas	Kicz, Kico	Kicz
Hells Gulch	Upper Cretaceous	Mesa	Gas	Kmv	Kmv
Horsethief Creek	Tertiary	Mesa	Gas	Tw	Tw
De Beque	Upper Cretaceous	Mesa	Gas	Kmv, Kwf	Kmv
Divide Creek	Upper Cretaceous	Garfield	Gas	Kwfc, Kicz, Kico, Kr	Kwfc
Baldy Creek	Upper Cretaceous	Garfield	Gas	Kr, Kicz, Kico, Km	Kr
Grand Slam	Upper Cretaceous	Garfield	Gas	Kmv	Kmv
Mamm Creek	Upper Cretaceous	Garfield	Gas	Kmv, Kwf, Kwfc	Kmv
Kokopelli	Upper Cretaceous	Garfield	Gas	Kmv	Kmv
Timberline	Upper Cretaceous	Garfield	Gas	Kmv	Kmv
Rulison	Upper Cretaceous	Garfield	Gas	Kwf, Kwfc, Tw, Kmv	Kwf
Parachute	Tertiary	Garfield	Gas	Tw, Kwf, Kwfc, Krc	Tw
Grand Valley	Upper Cretaceous	Garfield	Gas	Kwfc, Kmv, Kwf, Tw	Kwfc
Trail Ridge	Tertiary	Garfield	Gas	Tw, Kmv	Tw

Tw = Tertiary Wasatch
Kmv = Cretaceous Mesaverde Group
Kwf = Cretaceous Williams Fork
Kwfc = Cretaceous Williams Fork-Cameo
Kr = Cretaceous Rollins Sandstone
Kicz = Cretaceous Iles-Cozzette Member
Kico = Cretaceous Iles-Corcoran Member

Lease line locations and spacing can also force a directional drilling situation. Directional drilling is used extensively in the entire area mapped as high potential.

While new well pads are still being constructed, extensive use of directional drilling to multiple downhole locations from existing pads is also occurring. Operators in this GSFO have drilled as many as 22 wells from one pad. Many wells before the year 2000 were drilled vertically, but with the advent of more advanced completion techniques and with bottomhole densities to 10 acres for the Williams Fork, the future will involve mostly multi-well directional drilling from a single pad. In the north Parachute field area, horizontal reaches of the bottomhole location from the surface hole location can approach 4,000 feet. This kind of offset is dependent on the geology and reservoir characteristics, and most of the directional drilling within the GSFO has a horizontal reach of less than 2,500 feet. Economics is also a major consideration—since directional drilling is more costly, gas reserves need to be significant enough to recover costs in a reasonable amount of time and a reasonable rate of return.

Slim-hole (diameter < 6”) drilling and completion, coiled tubing applications, high-energy gas fracturing, and new methods of well stimulation are currently being used within the GSFO and may play a part in an increased number of wells being drilled. These technologies will make it

more practical to explore in moderate- to high-risk wildcat areas. Since cost may be reduced and production increased using these technologies, marginal plays not economic with today's commonly used technologies may become economic. Some of the undeveloped plays in the GSFO considered marginal or uneconomic today may become attractive and economic in the future. Slim holes cost less than large-diameter wells because the smaller rigs require less transportation and site preparation. In addition, the smaller wellbores record faster drilling times and have less expensive drilling tools, casing, and cement jobs.

Coiled tubing is packed in giant reels and can hold different sizes of tubing. The tubing is unreeled and lowered into the hole. Instead of rotating the tubing to spin the bit, high pressure drilling mud is sent through the tubing. At the other end is a hydraulic motor that rotates in response to mud pressure. Coiled tubing also lends itself to scavenger operations -- tapping pockets of petroleum that seismic techniques show are near to existing wells. Coiled tubing drilling, combined with steerable drill bits, may be used when a new pocket of hydrocarbons is discovered, for example 1,000 feet from a deep well.

5.4 Oil, Gas, and Water Production by Formation

Production within the GSFO is profiled by two producing gas horizons: the Mesaverde Group and the Wasatch Formation. As of September 30, 2006, the Mesaverde Group was the more prolific, with cumulative gas production totaling 1.37 TCF (95.4% of the total), while the Wasatch formation had totaled 66.06 BCF (4.6% of the total). Rate verses time for production of gas, oil, and water for each producing formation is illustrated in Figures 6 through 11. The slight dip toward the end of each production curve reflects a partial year's production. The production data used to generate the production curves were retrieved from IHS Petroleum Information (PI)/Dwights Plus® Rocky Mountain Release November 27, 2006.

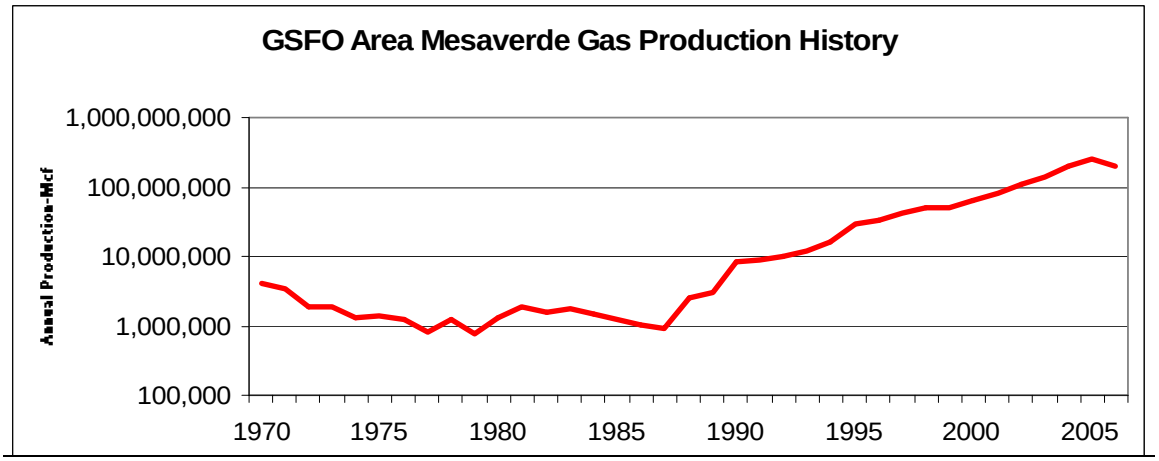

Figure 6. GSFO Area Mesaverde gas production history.

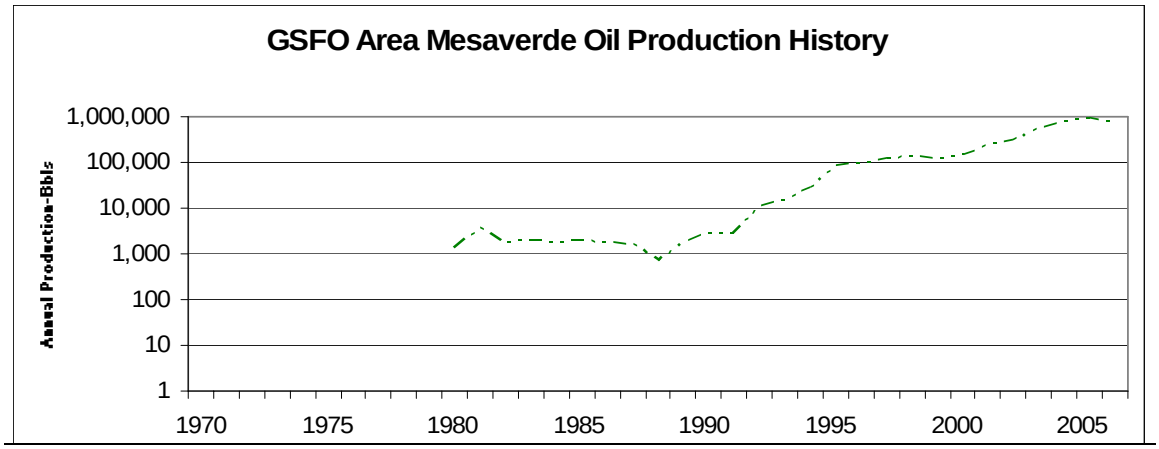

Figure 7. GSFO Area Mesaverde oil production history.

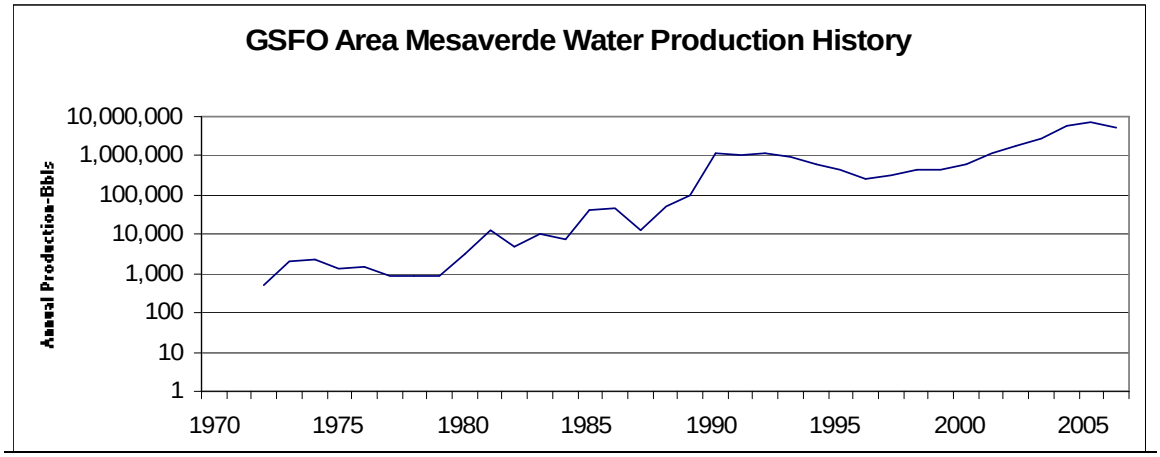

Figure 8. GSFO Area Mesaverde water production history.

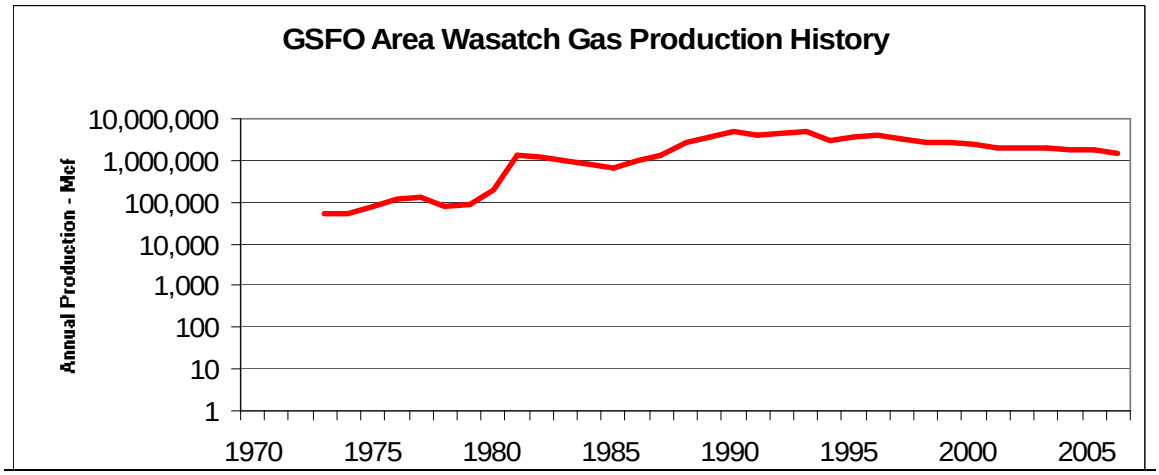

Figure 9. GSFO Area Wasatch gas production history.

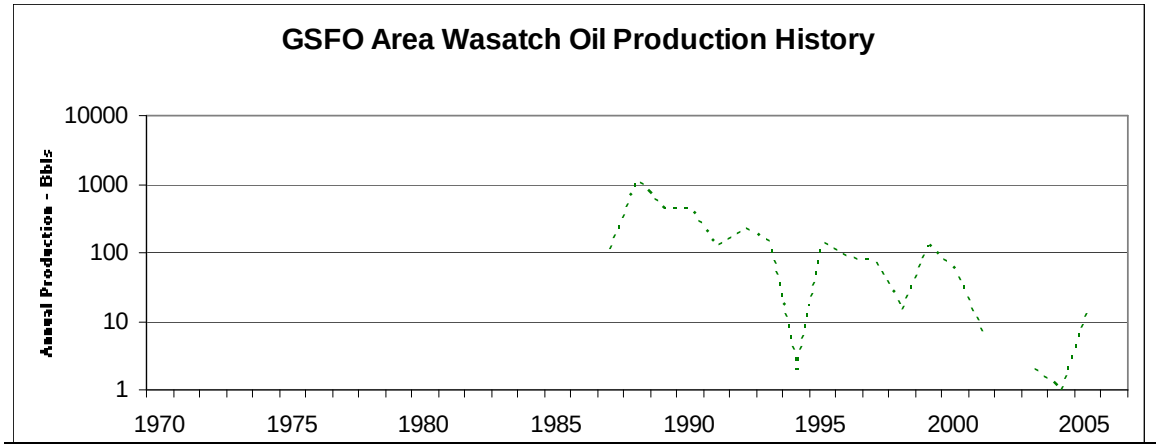

Figure 10. GSFO Area Wasatch oil production history.

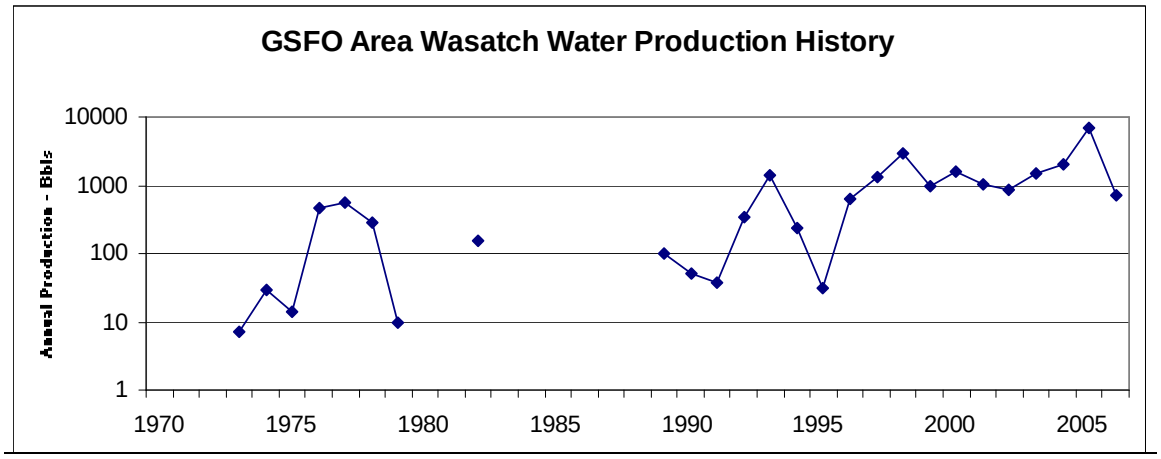

Figure 11. GSFO Area Wasatch water production history**.**

5.5 Oil and Gas Prices, Finding, and Development Costs

The price of oil and gas is dependent on the market. The industry standard is the New York Mercantile Exchange, Inc (NYMEX), the world's largest physical commodity futures exchange and the preeminent trading forum for energy and precious metals. The NYMEX natural gas commodities contract is widely used as a national benchmark price. The price for natural gas is volatile and fluctuates with supply and demand and economic and political news. Currently posted prices ranges from $7.25 to $7.50 per MMBtu. Figure 12 shows the historical daily price trend from 2002 to 2007.

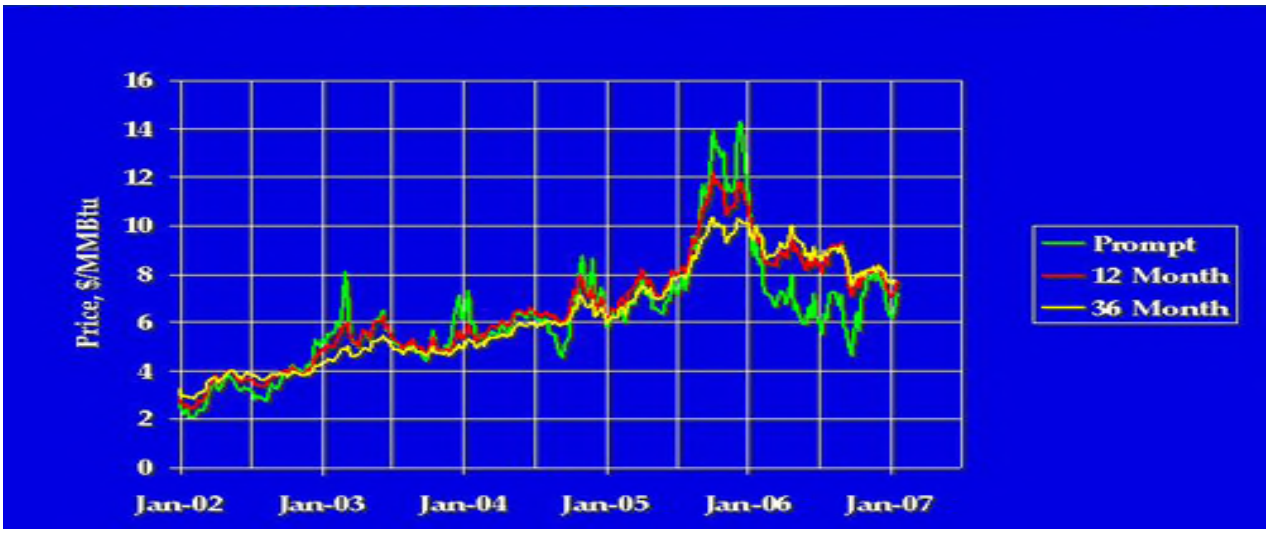

Figure 12. NYMEX natural gas prices, Rocky Mountain region.

The cost of finding and development natural gas and oil is somewhat fixed, although the recent upswing in activity has led to a shortage in equipment and labor. Today's cost is about $125 per foot for drilling and $100 per foot for completion, depending on the total depth.

Operators estimate that the direct field operating cost in the GSFO area is $0.33 per MCF (before taxes). Salt water disposal and gas processing are two of the major cost items included in these costs.

5.6 Compression and Transmission Costs

These costs are dependent on in-field processing and compression. An average of $0.90 per MCF is typical.

5.7 Field Production Equipment and Field Operation Practices

For a multi-well pad, construction and reclamation costs are estimated at $100,000. The size and configuration of the well pad could cause this estimation to vary. The cost to equip a single well to produce to a sales line averages $70,000. This includes three-phase separation equipment (natural gas, condensate, and water), metering hookup, liquid storage tanks, and labor.

The natural gas from each well is individually measured after passing through the separation equipment on the well pad and then transported by pipeline to a processing plant. Associated condensate is collected and gauged in storage tanks, then trucked to an offsite sales collection facility. A portion of the gas is used at the facility to operate fired vessels, control systems, pumps, compressors, gas-lift systems, etc. Sometimes, the gas may be flared or vented.

5.8 Gas Transportation Pipelines

After gas is individually treated, separated and measured, it travels through a 4-inch to 8-inch diameter steel line (line pressures range: 100 psi to 1,000 psi) from the well pad to field compression facilities and then to a buried cross country trunk pipeline. Trunk pipelines in the area have diameters between 12 and 36 inches and can cost as much as $2,000,000 per mile for a 36-inch line. The trunk pipelines carry wet, unprocessed gas to gas treatment facilities. After processing, the dry gas is transported to local markets our out of the Piceance Basin in one of several 24-inch lines. These are the Trans-Colorado, REX (Rocky Mountain Express), CIG, PSCo (Xcel Energy), Rocky Mountain Natural Gas, Questar, and Northwest pipelines.

5.9 Gas Compression Facilities

Typically, two types of gas compression facilities are used in the area. Gas-driven compression can either be a permanent or temporary installation, whereas electric-driven compression is normally a permanent installation. A major variance is the lack of emissions with the electric driven compressors. The limitations of electric-driven compressors are power supply requirements and installation costs. These costs are typically 30% higher than gas-driven compressors.

Approximately 125 compressors are currently being used in the area, comprising both field and regional compressors. The demand for future compressors is directly proportional to the volume of gas produced.

5.10 Electrical Powerlines, Generators, and Roads

The need for electrical power on a well pad is minimal in the area. Power is supplied by natural gas generators. The majority of the field compressors are natural gas driven; however; as stated above, electric-driven compressors have recently been introduced.

Roads used for oil and gas operations require an average 35-foot-wide right-of-way. The major road infrastructure is in place in the GSFO area. Hence, this document uses an average road length of 1.0 mile to reach the future wells planned. The amount of roads needed would depend on the well spacing, the amount of use of multi-well pads, terrain, environmental constraints, land ownership patterns, and existing road infrastructure. The topography of the area has an impact on the length of road needed and the cost. Hilly terrain would need a road to fit the terrain and cut-and fill construction to meet slope requirements.

The GSFO requires that oil and gas operators use existing roads and two-tracks where possible to minimize surface disturbance. Flat blading is allowed and crowned, and ditched roads are not always required for wildcat wells (except on National Forest lands) to encourage minimal disturbance to the surface estate. The reasoning is that if the well is a dry hole, reclamation is more efficient and cost effective. If a wildcat well proves to be productive, the road must be upgraded to an all-weather road and meet more stringent construction standards.

5.11 Conflicts with Other Mineral Development

Oil and gas development conflicting with other mineral development has not been a problem over the last 20 years. Saleable minerals such as sand and gravel are plentiful in northwest Colorado, but they are widely scattered throughout the GSFO. These small mining operations can easily be avoided by oil and gas operators and, as a result, conflicts do not exist. Conflicts between oil and

gas and coal should not occur but, if they were to occur, would be governed by an NSO stipulation (Stip. Code: CO-01) listed in the Record of Decision (1991) for the Oil and Gas Development and Leasing EIS. This stipulation has worked well in the past the few times it has had to be used. It is recommended that this stipulation continue to be used in the new RMP Revision.

Future conflicts between oil shale development and gas development on the Roan Plateau could arise. There will be limited drilling opportunity on top of the Roan Plateau as a result of the stipulations and other restrictions incorporated into the RMPA. At any given time, only about 1% of the top of the plateau can be in a disturbed condition as a result of unreclaimed oil and gas activities. Therefore, current restrictions will not allow for both the extraction of natural gas and oil shale from the surface. If new technologies allow oil shale to be economically developed using underground mining or in-situ techniques, this could be done in conjunction with gas development. A stipulation similar to that for coal mining conflicts could also be fashioned to mitigate significant loss of the oil shale resources.

5.12 Gas Storage Fields, Operations, and Facilities

The GSFO area includes one large natural gas storage area (GSA) (Map 23). This is known as the Wolf Creek GSA and is run by Kinder Morgan Retail Energy Services. The Wolf Creek gas field was converted to gas storage in June 1972. Gas is stored in the Mesaverde Group sandstones. This area is located on the White River National Forest within T8S and T9S, R89W and R90W. The GSA consists of seven active natural gas injection/extraction wells, three observation wells, one drilled and abandoned well, gathering pipelines, and ancillary surface equipment. The wells associated with the GSA have been active as early as 1966 when the wells were originally drilled for natural gas extractive purposes. As the wells were becoming depleted the storage potential of the field was identified and put to use as a storage field in 1976.

The purpose of the GSA is to inject and store natural gas during off-peak demand periods (typically May through October) and to utilize the gas during peak demand periods (typically November through April). Injection and extraction of the natural gas associated with the GSA averages between 1 to 1.5 MCFG per year. The working storage capacity of the GSA is 3.0 MCFG with a reserve capacity of 7.4 MCFG. This GSA is critical for the reliable distribution of natural gas to retail customers primarily within Pitkin and Garfield counties. The Wolf Creek GSA is regulated by the U.S. Department of Transportation; only natural gas that has been processed, odorized, and meets appropriate gas specifications for retail delivery is stored in the GSA. Some of the other anticlinal structures within the GSFO with good porosities and excellent sealing mechanisms may be good future storage fields once their gas reserves are depleted.

6. OIL AND GAS OCCURRENCE POTENTIAL

6.1 Review of RFD Prepared for Areas Adjacent to the Study Area

Management plans and/or RFDs for BLM's White River Field Office, Grand Junction Field Office, Kremmling Field Office, Little Snake Field Office, Uncompahgre Field Office, Gunnison Field Office, Royal Gorge Field Office, and the Roan Plateau planning area, and forest plans for the White River and GMUG (Grand Mesa / Uncompahgre / Gunnison) National Forests were reviewed. This review provided information helpful in looking at adjacent oil and gas exploration and development that may affect the GSFO RFD. In addition, basin-wide studies performed by the National Petroleum Council and the USGS, and the EPCA study were reviewed to enhance the quality of the GSFO RFD. GSFO staff members also review RMPs for

surrounding field offices and are looking for consistencies, inconsistencies, and new approaches and ideas to mitigating impacts from oil and gas exploration and development activities. This should facilitate consistency by BLM in managing oil and gas resources across field office boundaries.

6.2 Resources, Plays, and Oil and Gas Assessments

As previously discussed in section III, five total petroleum systems (TPSs) and 20 analysis units (AUs) extend into the Piceance Basin (Maps 3 through 15). The western portion of the GSFO (including the Grand Hogback) is the Piceance Basin proper (Map 2), which is a southeastern portion of a greater geologic basin known as the Uinta-Piceance Basin. Most of the hydrocarbon production in GSFO is natural gas with very little associated oil, natural gas liquids, and water. The gas production is from the Tertiary Wasatch and Cretaceous Mesaverde Group formations.

6.2.1 Eagle Basin

The eastern three-fourths of the GSFO (east of the Grand Hogback) consist of the Eagle Basin, the White River Uplift, and mountain ranges to the south and east. Outside of this report no oil and gas assessment has been completed for this area. The Eagle Basin is primarily a Pennsylvanian-age depositional basin located in a structurally complex area. This basin has relatively low potential for the discovery of significant gas based on available well data (subsurface data) and surface data. The basin has very low potential for discovery of economic oil accumulations due to very high thermal maturity of most Paleozoic rocks and the presence of only small areas containing younger rocks with oil source beds.

6.2.2 USGS Assessment of Undiscovered Resources

The USGS (2002) assessed *undiscovered* technically recoverable resources, conventional oil and gas, continuous oil and gas, and coalbed gas in AUs within their associated TPS. For gas fields, all liquids are included under the NGL (natural gas liquids) category. F95 denotes a 95% chance of at least the amount tabulated. Other fractiles, such as F50 and F5, are defined similarly. Fractiles are additive only under the assumption of perfect positive correlation. Coalbed gas (CBG) is the same as the coalbed methane (CBM) terminology, and both are used throughout this report.

Table 4 shows the estimated assessment results for the GSFO portion of the Piceance Basin. The TPS and associated AU GIS data were downloaded from the USGS website. These shape files delineate the TPS and AU areal extents within the GSFO (Maps 3 through 15). The data were then re-projected from decimal degrees to UTM Zone 13 NAD 83 and overlain on GSFO GIS data, which included the field office boundary and Geographic Coordinate Database Data (GCDB). TPSs and AUs with an insignificant presence in the Piceance Basin were not mapped for this RFD study. Area percentages were approximated using the overlays in GIS. These were then multiplied by the USGS assessment results to derive the GSFO portion of the undiscovered oil and gas resources, assuming a homogeneous distribution of resources. Table 4 is a detailed breakout of undiscovered resources by TPS and AU, which the EPCA study did not show. Of the AUs that are assessed, one—the Mancos/Mowry Transitional and Migrated Gas AU (Map 10)—was not calculated by the BLM, since so little (<1%) of the AU is located within the GSFO boundary.

6.2.3 EPCA Oil and Gas Resources Inventory

Table 5 shows the EPCA study's undiscovered technically recoverable resources and reserves growth broken out for the Piceance Basin within the GSFO boundary. The resources identified in the table are oil, natural gas liquids (NGL), associated dissolved (AD) gas, nonassociated (NA) gas, and liquids associated with natural gas reservoirs. Associated dissolved gas is produced from oil production, whereas nonassociated gas is that produced dry from gas production. NGL are in the gas phase in the reservoir but when produced at the surface change to liquids.

Table 5 excludes resources within USFS jurisdiction, since they are not broken out within the GSFO boundary. The undiscovered technically recoverable (UTR) resources as defined in the EPCA study are hydrocarbon resources that, on the basis of geologic information and theory, are estimated to exist outside known producing fields and are undiscovered and unproven resources. These resources can be produced by current technology but without regard to economic profitability. Thy can be expected to be explored and developed over a life cycle measured in decades. Reserves on the other hand, are the unproduced but technically recoverable oil or gas in a formation that has been proved by production.

6.2.4 BLM Glenwood Springs Energy Office Gas Resources Estimates

The EIA proved gas reserves for the entire Uinta-Piceance Basin is 7.2 TCF. The USGS 2002 Assessment for the gas resources in the entire Uinta-Piceance Basin is 21 TCF. The Roan Plateau RFD, which is based on very local data such as production curves and existing wells, estimates 15.4 TCF gas within the Roan PA. A detailed production analysis recently completed by BLM Energy Office staff shows the EPCA/USGS estimates to be considerably low.

Table 4. USGS assessment of undiscovered technically recoverable resources in the Piceance Basin.

Total Petroleum Systems (TPS) and Assessment Units (AU) for the Piceance Basin	Field Type	Total Undiscovered Resources*											
		Oil (MMBO)				Gas (MCFG)				NGL (MMBNGL)			
		F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Phosphoria TPS													
Hanging Wall AU	Oil	0.18	0.41	0.84	0.45	0.05	0.12	0.27	0.13	0.00	0.01	0.02	0.01
	Gas	Not applicable				1.05	2.48	5.03	2.68	0.03	0.08	0.17	0.09
Paleozoic/Mesozoic AU	Oil	0.13	0.29	0.58	0.31	0.04	0.09	0.18	0.09	0.00	0.01	0.01	0.01
	Gas					0.79	2.19	4.72	2.40	0.02	0.07	0.16	0.08
Mesaverde TPS													
Mesaverde Sandstone Gas AU	Gas	Not applicable				1.07	3.54	8.41	3.98	0.01	0.03	0.07	0.03
Green River TPS													
Green River Conventional Oil & Gas AU	Oil	0.30	1.01	2.26	1.06	0.83	2.73	7.01	3.18	0.05	0.16	0.44	0.20
Total Conventional Resources		**0.61**	**1.71**	**3.68**	**1.82**	**0.92**	**2.94**	**7.46**	**3.40**	**0.05**	**0.17**	**0.47**	**0.22**
Mancos/Mowry TPS													
M/M Continuous Gas AU	Gas	Not applicable				162.33	365.77	824.22	413.23	0.15	0.36	0.86	0.41
Transitional and Migrated Gas AU	Gas	Not calculated – Insignificant occurrence in NW part of GSFO											
Mesaverde TPS													
Mesaverde Continuous Gas AU	Gas	Not applicable				570.67	836.85	1378.20	919.28	1.50	2.61	4.53	2.76
Mesaverde Transitional Gas Au	Gas	Not applicable				48.52	85.34	150.01	90.52	0.09	0.17	0.32	0.18
Mesaverde Coalbed Gas AU	Gas	Not applicable				13.87	32.24	74.94	36.78	0.00	0.00	0.00	0.00
Total Continuous Resources		**0.00**	**0.00**	**0.00**	**0.00**	**795.39**	**1320.20**	**2427.37**	**1459.81**	**1.74**	**3.14**	**5.71**	**3.35**
TOTAL UNDISCOVERED O&G RESOURCES		**0.61**	**1.71**	**3.68**	**1.82**	**796.31**	**1323.14**	**2434.83**	**1463.21**	**1.79**	**3.31**	**6.18**	**3.57**

*MMBO = million barrels of oil; BCFG = billion cubic feet of gas; MMBNGL = million barrels of natural gas liquids; CBG = coalbed gas. For gas fields, all liquids are included under the NGL (natural gas liquids) category. F95 denotes a 95% chance of at least the amount tabulated. Other fractiles are defined similarly. Fractiles are additive only under the assumption of perfect positive correlation. The Piceance Basin (within the GSFO) assessments results are a fraction of the results taken from Kirschbaum 2002. The TPS and associated AU data were downloaded from the USGS website. The data were then reprojected from decimal degrees to UTM Zone 13 and overlain on GSFO GIS data, which included field office boundary and Geographic Coordinate Database Data (GCDB). Area percentages were approximated using overlays in GIS. These were then multiplied by the USGS assessment results to derive the GSFO portion of undiscovered oil and gas resources.

Table 5. EPCA estimates of undiscovered technically recoverable resources for Federal mineral estate lands in the GSFO (Federal surface + split estate).

Product	Estimated Resources*
Oil	0.3 MMBBL
Natural Gas Liquids	0.0 MMBBL
Liquids	1.7 MMBBL
Reserve Growth Liquids	2.3 MMBBL
Total Liquids	**4.3 MMBBL**
Gas, associated dissolved	0.1 BCF
Gas, nonassociated	663.2 BCF
Reserve Growth Gas	28.6 BCF
Total Gas	**691.9 BCF**

* MMBBL = million barrels; BCF = billion cubic feet

The Energy Office estimates that the lands within the high potential area of the GSFO and outside the Roan Plateau area contain upwards of 40.3 TCF[5] gas. This is based on the fact that the Mesaverde TPS (continuous tight gas play) underlies this entire area, 10-acre bottom hole density will be required to drain the gas, and a typical well has an EUR of 1.15 BCFG. The Wasatch may be developed throughout the entire area on 160-acre spacing, and a typical well has an EUR of 0.7 BCFG. Newer estimates of gas resources in the Piceance Basin approach 300 TCF (USDOE 2004). The gas in the Mesaverde is tight gas and is most highly concentrated in the southern portion of the basin, particularly in the stacked, lenticular sands of the Williams Fork Formation. This type of gas resource is typical of the resources being developed in the Rulison, Parachute, and Grand Valley fields. Table 6 (below) presents a BLM estimate for the GSFO.

Table 6. BLM natural gas resource estimates for all mineral estates (Federal + private) in the GSFO.

Portion of GSEO Area	Estimated Gas Resources*
Roan Plateau Planning Area (RPPA)	15.4 TCF
Remainder of high potential area in GSFO	40.3 TCF
High potential area in GSFO including RPPA	55.7 TCF
Piceance Basin (highest concentration of gas in the southern part of the basin)	300 TCF

*TCF = trillion cubic feet

[5] 464,733 acres-Mesaverde continuous gas AU – 127,009 acres Roan PA = 337,724 acres ÷ 10-acre well spacing (Mesaverde well) = 33,772 wells x 1.15 BCF EUR/well = 38.8 TCF gas/Mesaverde gas; 337,724 acres ÷ 160 well spacing (Wasatch well) = 2,110 wells x .7 BCF EUR/well = 1.5 TCF gas/Wasatch gas: 38.8 TCF + 1.5 TCF = 40.3 TCF gas

Other formations contain oil and gas resources but are thought to be insignificant compared to the Mesaverde Group Formations and the Wasatch Formation. The BLM estimate for the Williams Fork may be high since it assumes a homogenous gas resource within the Mesaverde Continuous Gas AU, but any shortfall of the estimate may be made up or even exceeded by gas resources in other formations. Resource estimations for the other formation are highly uncertain at this time. More accurate predictions will be possible after more drilling and completions take place within these underexplored formations. The Mancos Shale and the Niobrara are formations that hold promise for future oil and gas discoveries.

Map of Occurrence Potential

Maps 24 and 25 (see Appendix) show the estimated areas of relative oil and gas occurrence potential. Within the GSFO, 20%[6] of the area is rated as high, 12%[7] is rated as medium, 46%[8] is rated as low, and 22%[9] is rate as no known occurrence potential.

Rationale for Selecting Values for Occurrence Potential and Certainty

The rationale for selecting values of occurrence potential and certainty is discussed below. The classification was modified from the BLM Handbook H-1624-1, dated May 7, 1990, and derived from a variety of sources, such as the EPCA inventory resource density polygons, reserve estimates from PI Dwight's Digital Well Data and Production Data, USGS TPS and AU maps, and USGS geologic maps.

- High – Demonstrate existence of source rock, thermal maturation, reservoir strata possessing suitable permeability and porosity, and traps. Demonstrated existence is defined by physical evidence or documentation in the literature. Occurs in areas inside total petroleum systems and geologic basins with extensive Cretaceous and Tertiary sediments such as the Piceance Basin within the GSFO boundary.

- Medium – Geophysical or geological indications that the following may be present: source rock, thermal maturation, reservoir strata possessing suitable permeability and porosity, and traps. Geologic indication is defined by geological inference based on direct and/or indirect evidence. Occurs in the Eagle Basin, which is known to be marginal for the economic occurrence for oil and gas, areas of thick sediment that contain some lower Mesozoic sediments along with Paleozoic sediments, and areas where existing well data show some evidence of hydrocarbons.

- Low – Specific indications that one or more of the following may not be present: source rock, thermal maturation, or reservoir strata possessing permeability and porosity, and traps. Occurs in areas outside USGS petroleum system and productive basin margins, where little or no hydrocarbon resources are indicated by existing well data. Also in areas where the basin sediments are less than 5,000 feet thick and consist mostly of Jurassic and older rocks as evidenced by existing well data.

- No Known Potential – Demonstrate absence of source rock, thermal maturation, reservoir rock, and traps. Demonstrated absence is defined by physical evidence or documentation in the literature. Occurs in areas outside the EPCA resource boundaries and USGS TPS and productive basin margins.

[6] 586,029 high potential acres ÷ 2.9 million acres = 20% high potential
[7] 342,430 medium potential acres ÷ 2.9 million acres = 12% medium potential
[8] 1,337,865 low potential acres ÷ 2.9 million acres = 46% low potential
[9] 660,979 no known potential acres ÷ 2.9 million acres = 22% no known potential

Also in areas of Cambrian and Precambrian igneous and metamorphic rocks, not overlying favorable sedimentary environments. These areas may be unconformably overlain by thin younger sediments.

Note: Inclusion of an area in a USGS oil and gas play defined in the 2002 national assessment should be considered in determining potential for oil and gas occurrence. However, because the USGS assesses speculative plays, play definition alone should not be the only criterion for determining occurrence potential. The Eagle Basin due to its marginal potential for the economic occurrence of oil and gas resources was excluded from the USGS National Oil and Gas Assessment program and the EPCA inventory study.

7. OIL AND GAS DEVELOPMENT POTENTIAL

7.1 RFD Scenarios for Plan Revisions

Three BLM field offices share similar geology and oil and gas potential, since all three are located within the southern Piceance Basin. The White River Field Office (WRFO) is currently working on an RFD for the Plan Revision. Their estimated oil and gas activity is greater than that predicted for the GSFO. The Grand Junction Field Office (GJFO) will be starting a Plan Revision in approximately 2 years. Their new RFD will most likely reflect an increase in oil and gas activity, as seen now in increased drilling and leasing activity. Operators in the GSFO are moving west into the GJFO. The White River National Forest which is a large part of the surface area within the GSFO and the WRFO is working closely with both BLM offices to revise their predicted oil and gas activity. There should be no conflict of estimates for development potential between the BLM and USFS offices.

7.2 Proven Reserves, Field Outlines, and Wells by Completion Status

Development within the GSFO will continue to take place in the areas that are currently being developed. Infill drilling and step out drilling will be the major portion of future activity. Although drilling of proven reserves will continue, some interest is being shown by Industry for the USGS resource plays (other than the Mesaverde and Wasatch Formations). These interests are for the coalbed natural gas plays and for the Niobrara play. It is estimated that 99% of the drilling will occur in the area mapped as high potential for the occurrence of oil and gas resources. Approximately 1% of future drilling activity will occur in areas of medium and low potential and no drilling activity is predicted in the areas mapped as no known potential.

Located in the Appendix are maps showing outlines of oil and gas fields (Map 21) and wells by completion status (Map 20). Maps showing TPSs and associated AUs are also provided in the Appendix.

7.2.1 Rational for Selecting Values for Development Potential and Certainty

The rationale for selecting values of development potential and certainty are similar to the occurrence potential with the addition of leasing information. It is felt that areas that are currently leased are the areas with the greatest development potential. Almost of the existing leases and future leases will occur in the area mapped as high potential. The areas mapped as medium and low potential have few leases. The existing leases, in the area mapped as low potential, will most likely not be drilled and have an even slighter chance of producing hydrocarbons. The area within the Roan Plateau that may be leased in the future may be drilled based on constraints addressed in the Roan Plateau Plan. The Roan planning area has significant reserves and will certainly produce gas. See Map 26 for an overlay of current oil and gas leases on the oil and gas occurrence potential areas.

Based on historical well distribution throughout the four occurrence potential areas[10], it is estimated that 99% of future development activity will occur in the area mapped as high occurrence potential and that 1% of development will occur within the areas mapped as medium and low occurrence potential. No exploration or development activities are projected for areas mapped as no known occurrence potential (Table 7). This development potential distribution corresponds well with the existing oil and gas field locations, the identified USGS plays, and the Industry plays discussed previously in section III.

Table 7. Development potential for oil and gas, by occurrence potential category.

Occurrence Potential	Development Potential (% of wells drilled)	Number of BLM wells projected (5,768)
High	99%	≈5,710
Medium/Low	1%	≈58
No Known	0%	0

Most of the existing wells are on fee minerals, with an increase on Federal minerals occurring presently and projected to increase in the near future. Industry will continue to drill heavily on fee minerals and as they drill out the fee mineral estate a significant increase of drilling on Federal mineral estate will occur. This will also happen as a result of the BLM leasing lands within the Roan Planning Area that currently are not leased.

Increased drilling will also occur on National Forest System (NFS) lands, as half of the lands identified as available for leasing in the 1995 Oil and Gas Leasing Record of Decision for the White River National Forest are currently leased. Much of the unleased NFS land (59,040 acres) within the high potential area is in Inventoried Roadless Areas (IRAs). Currently, under the FS 2001 Roadless Area Conservation Rule, these lands may be identified as available for lease, but they cannot be leased without prohibitions on road construction and reconstruction. With road construction and reconstruction in IRAs prohibited, the number of wells that could be drilled on NFS lands is estimated at a lower level.

Operators submitted well numbers based on the acreage they have leased and the stipulations on their leases. The number of Mesaverde wells (694) divided into the leased acreage yields an average of 1 well per 169 acres, indicating that Industry may develop their leases on NFS lands more slowly over the life of the Plan Revision. There is also a small number of Niobrara wells forecasted.

In compliance with Washington IM 2004-089, in this RFD it is estimated that NFS lands could be developed under standard lease terms and conditions except those areas classified as IRAs and those areas designated as closed to leasing by law, regulation or executive order, and that 10-acre spacing would be required to deplete the resources estimated for the area. Since 176,231 acres is the combined area of leased and unleased acreage available within the high potential area, it is estimated that it would take 17,623 wells (assuming unconstrained access) to deplete the gas resources under NFS lands within the high potential area of the GSFO. The current lessees estimate that they will drill 722 wells within the life of the RMP Revision. Taking into account that of the unleased 59,040 acres, some 33,781 acres are in IRAs, it is safe to assume that only 25,259 acres (high degree of certainty) may be available for development within the life of the RMP Revision. There is a high degree of uncertainty surrounding

[10] 44 medium/low potential area wells ÷ ≈3500 total historical wells ≈ 1%; 0 wells in no known potential area ÷ ≈3500 total historical wells = 0%; 100% of wells – 1% of medium/low potential area wells – 0% no known potential area wells = 99% high potential area wells.

whether the IRAs will be leased. If the IRAs are leased, access to the leases and the building of the necessary infrastructure could be a problem.

Assuming the same development pace that Industry is indicating on the NFS leased acreage, it is estimated that the unleased acreage (25,259 acres) outside of IRAs may see a total of 150[11] wells. This RFD is neither a planning decision nor the "No Action Alternative' and this RFD baseline scenario can be adjusted under each alternative for any future FS NEPA documents it may support. See Table 8 for a breakdown of the estimated wells to be drilled on the different mineral estates.

Table 8. Number of wells projected to be drilled over the life of the Plan Revision.

Mineral Ownership	Number of Wells
Federal (total)	**5,768***
BLM (surface + minerals)	3,297
BLM (split estate)	2,021
BLM (upper Roan Plateau)	450**
USFS	872***
Private	**9,024**

*3,297 Federal + 2,021 Split Estate + 450 Top of Roan = 5,768 Federal wells in 20 years
**450 wells taken from the RPPA Plan Amendment RFD. The preferred alternative proposes only 210 wells on 13 pads. There is currently a bill in congress advocating no drilling on the top of the Roan Plateau.
***694 MV wells + 28 Niobrara wells + 150 unleased area wells = 872 total wells over 20 years

7.2.2 Determination of Reasonableness

Development Trends

It is estimated that 15,664 wells will be drilled over the life of the plan which should be 20 years. This is an average of 783 well drilled per year. As depicted in Table 9, this is virtually the exact number of wells spud in each year of 2005 and 2006 within Garfield County. Approximately 93% of the wells drilled within Garfield County are drilled with the GSFO boundary. This rate of drilling should continue with some fluctuations due to price, pipeline capacity and other circumstances. It is also estimated that 5,768 BLM wells will be drilled over the life of the Plan Revision which equates to an average of 288 wells drilled per annum. This is very close to the number of BLM wells that have been drilled in each of 2005 and 2006.

[11] 25,259 unleased non-Roadless acres ÷ 169 acre development pace over 20 years = 150 wells.

Table 9. Recent oil and gas activity in Garfield County (Federal + Private).

Year	APDs	Wells Spud	Wells Completed
2001	308	257	227
2002	305	257	273
2003	487	432	365
2004	712	594	556
2005	1406	768	692
2006	1564	788	767

Infrastructure

There currently are 55 drilling rigs operating within the GSFO. These include approximately 20 new high-tech flex rigs that can drill up to 22 wells without the need to break down the rig for each well move. The addition of more flex rigs will continue since the preferred method of development within the GSFO is multiple wells per pad and development on 10-acre spacing.

On average it takes 15 days to drill the average total depth of 7,500 feet (Mesaverde Formation). This equates to one rig drilling a maximum of 24 wells per year. This many wells times 55 drilling rigs equates to a maximum of 26,400 wells that could be drilled over a 20-year span. This maximum number does not take into account seasonal restrictions, breaking down-moving-setting up operations, and down time due to maintenance issues. If the current number of rigs continues throughout the life of the plan, it will be more than enough rigs to drill the 15,644 wells projected.

Seven transportation pipelines currently convey gas out of the Piceance Basin or to local markets within the GSFO. Although extensive, existing compression and pipeline capacity will have to be increased to account for the increase in production.

Reserves

Based on Industry and BLM analysis, a typical Mesaverde well will produce about 1.15 BCFG over its life. This equates to 18 TCFG of reserves to be produced from the 15,664 projected wells. The ultimate reserve for the existing 3,000+ producing wells is estimated at approximately 3.5 TCFG. This is a combined ultimate reserve estimate of 21.5 TCFG for existing wells and projected wells for Mesaverde production which is approximately 39% of the 55.7 TCFG estimated to exists within the GSFO boundary.

Spacing

The Mesaverde continuous gas AU is estimated to occupy about 464,733 acres within the GSFO. As discussed previously, this area contains an estimated 55.7 TCF of gas within the Wasatch and Mesaverde Group formations. The projected wells to be drilled over the next 20 years will drain only about 35% of the estimated remaining reserves. Assuming a homogeneous gas resource throughout the Mesaverde AU, and the probability of 10-acre spacing to produce this gas, it would take 46,473 wells to deplete the gas resource and only 15,664 wells are projected to be drilled over the next twenty years.

Leased Acreage

A total of 5,768 wells are projected to be drilled on 200,937 acres of BLM mineral estate. On the 139,005 leased BLM acres, Industry estimates that approximately 5,318 wells will be drilled over the next 20 years. This equates to about 38% of the total wells needed to drain the leased acreage assuming development on 10-acre spacing.

8. RFD BASELINE SCENARIO ASSUMPTIONS AND DISCUSSIONS

8.1 Assumes All Potentially Productive Areas are Open under Standard Lease Terms

The baseline for projecting an accurate RFD for the life of the RMP is based on all potentially productive areas being open for leasing under the standard lease terms and conditions, except those areas designated as closed to leasing by law, regulation, or executive order. The top of the Roan Plateau is currently not being leased but, based on the Roan Plateau Planning Area EIS, leasing is likely to be allowed in the future, with constraints. As a result, the Roan Plateau is included in this RFD as a potentially productive area that will be leased and developed in the future and within the timeframes of the GSFO RMP Revision. Another assumption is that all of the lands in the White River National Forest that lie within the Glenwood Springs Energy Office boundary and identified as being available for leasing will be allowed to be leased in the future.

8.2 Normalized Decline Curve Analysis for the Piceance Basin (Portion within Glenwood Springs Field Office Jurisdiction)

A normalized decline curve was generated using PowerTools analytical software to estimate the gas production rates for a typical Mesaverde well within the Glenwood Springs Field Office jurisdiction. Gas production from approximately 2900 wells was analyzed to generate the curve. Production start dates beginning in January 2000 were used to represent similar completion technologies that are present today. Cross linked fracturing fluids were widely used in the 1990's, whereas; slick water fracturing fluid has been the norm 2000-1 to the present. The gas production rates were plotted versus time on a semi-logarithmic scale. The curve, shown below, approximates what a typical well could produce.

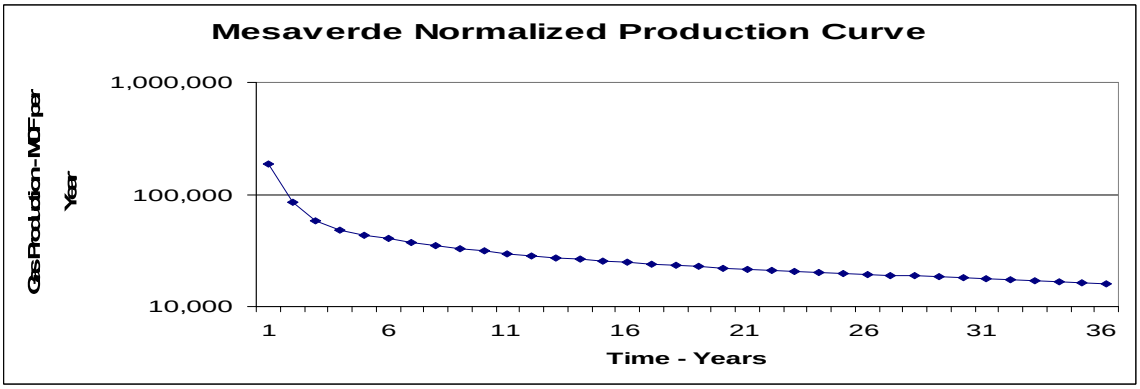

Figure 13. GSFO Area Mesaverde type curves.

The decline curve shows a typical Mesaverde well having an initial production of about 185,500 MCF per year (508 MCF per day) and a final abandonment production rate of about 16,100 MCF

per year (44 MCF per day), resulting in a well life of 36 years. Using these parameters, a typical Mesaverde well could ultimately recover approximately 1.15 BCF. This ultimate recovery determination favorably compares with the Roan Plateau ultimate recovery of 1.17 BCF per well.

Since January 2000, initial production rates from the Mesaverde formation have varied from 300 MCF per day to 1,500 MCF per day. These initial rates depend primarily on geologic parameters, reservoir pressures and pipe line pressures. And, depending on the gas well operator, final abandonment rates range from 25 MCF per day to 45 MCF per day. These abandonment rates are mostly a function of lease operating costs and gas prices.

Similarly, a plot of annual volumes on a logarithmic scale versus time (decline curve) was developed (Figure 14) for the Wasatch formation. The result is a single gas decline curve that approximates what an average well might produce. A typical well would have an initial production (IP) of about 95,000 MCF per year (60 MCF per day) and decline to an abandonment rate of 9,125 MCF per year (25 MCF per day). At this rate a typical well would ultimately produce about 0.7 BCF. The life of this typical Wasatch well is about 18 years. Gas and water produced from a Wasatch well is negligible.

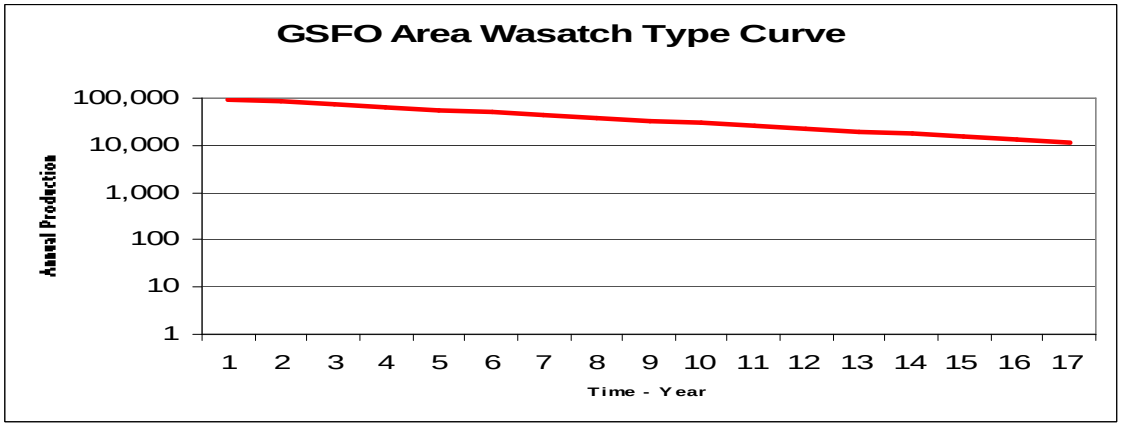

Figure 14. GSFO Area Wasatch type curve.

8.3 Assumptions Made in Determining the Type and Level of Projected Activity

Development on the top of the Roan Plateau will be limited by the constraints of the newly completed Roan Plateau Planning Area EIS. It is assumed that all other productive areas are open under standard lease terms and conditions. The EUR for Wasatch wells will be 0.7 BCF per well, development will occur on 160-acre spacing and that these wells in many cases will be co-located on pads constructed for Mesaverde wells. The EUR for Mesaverde wells will be 1.15 BCFG and development will occur on 10-acre spacing throughout most of the GSFO. The development tendency will be to drill infill wells and expand on existing fields before moving into less known areas. Multiple wells from a single pad will continue to be the trend. Well pads will range from 1 well per pad up to 22+ wells per pad with an average of 7 wells per pad. Most wells will continue to be directionally drilled with the majority of horizontal displacements being less than 2500 feet. It is assumed that wells will be drilled form existing locations where possible and existing roads and facilities will be used where possible.

8.3.1 Increased Exploration and Development as a Result of Higher Oil and Gas Prices

It is assumed that gas and oil prices will increase over the life of the RMP Revision. See previous **section V. Oil and Gas Prices** for a detailed discussion of actual prices. Supply and demand will be the two main price controllers. It is assumed that demand will continue to outstrip supply: the closer these two match, the more moderate the price and the farther apart the greater the price. Access to the Rocky Mountain region's gas resources and reserves will also determine prices. The greater amount of area opened for exploration and development and the easier the access (minimizing stipulations and seasonal restrictions), the greater the amount of resource will be discovered and developed ensuring supplies to satisfy demand and moderate prices. Imports from Canada and Alaska as well as increasing use of Liquefied Natural Gas imports may help moderate prices. Increasing gas prices (Figure 12) favor continued exploration for gas within the Piceance basin and nationally.

8.3.2 Industry Development Scenarios

Fourteen operators within the GSFO gave input to the RFD scenario. This input included lease acreage, development of the leases (well count) over the next 20 years, reserve estimates and surface disturbance estimates. A decrease in domestic oil and gas supply and increase in prices, consumption, and/or drilling activity all point to an increase in future exploration and drilling.

The following information summarizes the operator input, which the BLM has analyzed and accepted. These companies have existing production, existing large leasehold positions, and have been actively drilling and/or actively acquiring oil and gas leases in the GSFO. The total number of development wells is estimated at 15,664 wells. A breakdown of number of wells by operator is not included in this RFD scenario. This was done to protect the confidentiality of the companies and was necessary to secure their cooperation. Virtually all of the wells will be targeting natural gas, including coalbed gas, within the Mesaverde Group. Two exceptions are the Niobrara play discussed previously and the Wasatch Formation. It is also estimated that at least 160 wells of the 15,664 wells, or 1% of the industry total will be drilled in wildcat areas with medium and low potential, such as the areas along the Grand Hogback and areas within the Eagle Basin. This assumption is based on historical well distribution throughout the GSFO.

A study of historical well activity was completed for the Piceance Basin within the GSFO using IHS Well Data. This study showed that all of the producing wells are classified as gas wells. For wells drilled since 2000 the success rate of economical production exceeds 98 percent.

8.3.3 Amount of Surface Disturbance Associated with Oil and Gas Exploration and Development

The amount of disturbance caused by oil and gas activity is calculated using estimated disturbances in acres taken from a variety of sources: recent APDs, seismic survey applications, Industry estimates, knowledge of experienced Natural Resource Specialists that have worked in this area for years, disturbance estimates from the 1999 Glenwood Springs Oil and Gas Development and Leasing Supplemental EIS, and disturbance estimates from the Roan Plateau RMPA were used. Average disturbances for the GSFO are 6 acres for a drill pad and 9 acres for the access road to each drill pad. The 6 acres per drill pad takes into consideration cut-and-fill slopes and disturbance activity outside the pad boundary needed to maneuver heavy equipment and on lease transmission lines and pipelines. An average of 5 wells per pad was assumed for existing wells. Some new APDs being received by the Energy Office call for as many as 22 wells per pad. Operators participating in the RFD process with the BLM submitted numbers that average 7 wells per pad for wells projected wells to be drilled over the life of the Plan Revision.

Offsite or central facilities required for compressors, dehydrators/separators, liquid storage or injection, and metering facilities were also estimated. Since central facilities are usually lease or unit operations, they are analyzed in this RFD. The GSFO currently contains 8 existing facilities—four gas processing plants, two gas gathering systems, and two gas compressor stations—averaging 10 acres of disturbance per facility. All are located on private surface. It is estimated that an additional 8 facilities will be constructed over the life of the plan and that these will also be built on private surface. These facilities service both Federal and fee wells.

Non-lease and non-unit transmission lines and pipelines are most often granted rights-of-way by the BLM and as such are permitted as "realty" actions separate form oil and gas operations. These actions are being considered separately in the RMP Revision. The USFS permits these actions as surface use plans of operation (SUPO).

Future seismic surveys will most likely be 3D surveys. Within the GSFO, seismic operations are averaging around 8,300 acres per survey, but the actual surface disturbance is a small fraction of that. Contractors, where possible, must stay on existing roads and trails, and use helicopters when needed. Much of the work is done on foot and or with minimal impact ATVs. In developing this RFD, it was assumed that slopes of 30% or greater will be avoided. Seismic surveys disturb much less area, and at a lower intensity of disturbance, than typically is the case with oil and gas drilling and production activities. Much of the land within the GSFO is a checkerboard mix of Federal and private lands. Recent survey areas involve significant amounts of private surface estate. As a result it is estimated that about 3,320 acres land (fee and federal) will actually see low grade disturbance from future surveys (Table 17). Greater amounts of disturbance may occur due to unique circumstances, more interest in undefined structural plays, lack of existing roads or two tracks, and/or unusually rough terrain

8.3.4 Surface and Mineral Estate Ownership

The GSFO boundary includes a total of 2,906,659 acres, of which 567,395 acres is Federal surface administered by BLM. The Federal mineral estate for all minerals totals 776,008 acres, of which 748,228 acres is Federal fluid minerals (oil and gas) (Map 27). Split estates with private surface, but Federal oil and gas, includes 180,833 acres. Table 10 shows a breakout of lands in the GSFO jurisdiction area by surface ownership and/or management. See Tables 2a, 2b, and 2c, for leasing activity and Table 7 for projected development activity under different mineral estate ownerships.

Table 10. Surface land ownership/management in the GSFO.

Surface Owner/Manager	Acres
Bureau of Land Management	567,395
Bureau of Reclamation	1,585
Department of Energy	205
White River National Forest	1,499,827
Colorado Division of Wildlife	514
Other State Lands	28,266
Private	808,867
TOTAL	**2,906,659**

9. SURFACE DISTURBANCE DUE TO OIL AND GAS ACTIVITY ON ALL LANDS

9.1 Existing and Future Net and Gross Surface Disturbance

It is estimated that 15,644 fee and Federal wells will be drilled over the next twenty years. This is an average of approximately 782[12] wells per year over the planned life of the RMP Revision. This is only an average, and it is more likely that an uneven distribution of wells will be drilled each year, depending on market forces, lands available for leasing, and political constraints. All wells are forecast to be gas wells (both coalbed natural gas and conventional natural gas), and many will have associated natural gas fluids (condensate) and, in some cases, produced water. However, over time and with an increase in exploring marginal USGS plays, some primary oil wells may also be developed. Most of the activity (approximately 99%) will take place in the area classified as high potential for occurrence of oil and gas resources, and the remaining 1% will take place in areas classified as medium or low potential. No wells are forecast for the area mapped as having no known potential.

Tables 11 through 17 present estimates of current and future surface disturbance associated with well pads, access roads (including collocated pipelines, and central facilities. Data presented includes gross disturbance (including both temporary and long-term), reclamation (including both interim and final), and net disturbance (gross disturbance minus reclamation). Interim reclamation is conducted following completion of a wellpad and reduces the disturbed footprint to the amount needed for ongoing production and periodic workover operations. Final reclamation occurs after a pad no longer has producing wells. Surface from seismic exploration activities are presented in Table 18.

Assumptions used in preparing Tables 11 through 17 are based on BLM experience from historical exploration and development in the GSFO and from Industry input and are as follows:

- Existing pads are assumed to average 5 wells per pad of gross disturbance.
- Plugged & Abandoned numbers in Table 11 are assumed to be one well per 3 acre pad.
- Plugged and abandoned reclamation assumes 75% reclaimed (pad and road), but FAN not approved.
- Existing multi-well pads and future wells pad averaging 7 wells per pad are assumed to be 6 acres in size.
- Roads are estimated to vary in length from 0.5 miles for development wells to 4 miles in areas with new activity. An average of 1 mile of road per pad is used for this RFD: 5,280 feet x 1 mile x 75 feet wide ÷ 43,560 square feet per acre ≈ 9 acres of road per pad.
- The 8 central facilities are assumed to average 10 acres per facility. It is assumed that the number of central facilities will double over the life of the RMP Revision. Since 35% of the projected wells are Federal, it is assumed that 35% of the central facilities will service Federal wells. The central facilities are expected to be developed on private land.
- Gross disturbance well numbers include wells of all status including producing, temporary abandoned, abandoned, service, and drilling.
- Existing surface disturbance in Table 11 involves all Federal wells including the USFS since so few wells are USFS wells.
- Treatment facility surface disturbance is included in the wellpad figures.

[12] 15,644 total wells drilled ÷ 20 year lifespan of plan = 782.2 wells per year average

- Pipelines, gathering lines, and powerlines that are approved as a lease or unit action are included in this RFD surface disturbance acreage and are largely included in the access road corridor. Pipelines that require right-of-way approvals are realty actions not oil and gas operations; as a result are not included in this RFD.
- Approximately 2% of wells drilled from 2000 to 2006 were dry holes. As a result of drilling multiple wells per pad, future well pads and access roads are assumed to not be affected if a well is plugged and abandoned or drilled and abandoned. Hence, future dry hole reclamation acreage is not considered.
- Interim reclamation assumes that 2.5 acres of the original 6 acres is reclaimed (42% reclamation factor) and that the access road ROW is reclaimed from 75 feet to 25 feet (67% reclamation factor).
- Final abandonment assumes 100% reclamation and final abandonment notice (FAN) approved. Abandoned Fee wells are assumed to be final abandoned.

Table 11. Existing surface disturbance, Federal wells (acres).

Component	Gross Disturbance (875 wells, 202 pads[13])	Reclaimed to Date				Net Disturbance (Gross – Reclaimed to Date)
		Plugged & Abandoned (21wells)	Final Abandoned (13 wells)	Interim Reclamation (841 wells[14], 168 pads[15])	Total Reclamation	
Well Pads	1,110[16]	47[17]	39[18]	420[19]	506	604
Access Road	1,818[20]	142[21]	117[22]	1013[23]	1,272	546
Central Facilities	0	0	0	0	0	0
TOTAL (ac)	**2,928**	**189**	**156**	**1,433**	**1,778**	**1,150**

[13] **34** single 3 ac single well pads + (841 wells on 6 ac multi-well pads ÷ 5 wells per pad) = 34+ 168 = 202 pads
[14] 875 total wells – 21 P&A wells – 13 Final abd wells = 841 wells
[15] 841 wells ÷ 5 wells per pad = 168 pads
[16] 168 pads x 6 acres per pad + 34 pads x 3 acres = 1,110 acres of gross disturbance
[17] 21 partially reclaimed P&A wells x 3 acres per well pad x 75% = 47 reclaimed acres
[18] 13 fully reclaimed final abandoned wells x 3 acres per pad = 32 reclaimed acres
[19] 168 pads x 2.5 acres per pad of interim reclamation = 420 reclaimed acres
[20] 202 pads x 9 acres of road per pad = 1,818 acres of roads
[21] 21 wells (1 well per pad) x 9 acres of partially reclaimed road per pad x 75% reclamation = 142 reclaimed acres
[22] 13 wells (1 well per pad) x 9 acres of fully reclaimed road = 117 reclaimed acres
[23] 168 pads x 9 acres per pad x 67% reclamation factor = 1013 reclaimed acres

Table 12. Existing disturbance, non-Federal wells (acres).

Component	Gross Disturbance (2,625[24] wells 565[25] pads)	Reclaimed to Date			Net Disturbance (Gross – Reclaimed to Date)
		Final Abandoned (59[26] wells)	Interim Reclamation (2,566[27] wells 506[28] pads)	Total	
Well pads	3,255[29]	177[30]	1,265[31]	1,442	1,813
Access Roads	5,085	531	3,051	3,582	1,503
Central Facilities	80	0	0	0	80
TOTAL (ac)	**8,420**	**708**	**4,316**	**5,024**	**3,396**

Table 13. Existing surface disturbance, all wells (acres).

Component	Gross Disturbance (3,500 wells, 767pads)		Reclaimed to Date			Net Disturbance (Gross – Reclaimed to Date)
		Final Abandoned (72 wells)	Plugged & Abandoned (21wells)	Interim Reclamation (3,407 wells, 674pads)	Total	
Well Pads	4,881[32]	216	47[33]	1,685	1,948	2,933
Access Roads	6,903	648	142[34]	4,064	4,854	2,049
Central Facilities	80	0	0	0	0	80
TOTAL (ac)	**11,864**	**864**	**189**	**5,749**	**6,802**	**5,062**

[24] 3500 total wells – 875 Federal wells = 2,625 wells
[25] 59 single 3 ac single well pads + (2532 wells on 6 ac multi-well pads ÷ 5 wells per pad) + 59 + 506 = 565 pads
[26] 93 total abd wells – 34 Federal abd wells = 59 fee abandoned wells
[27] 2625 total wells – 59 P & A wells = 2,566 wells
[28] 565 pads ÷ 59 pads = 506 pads
[29] 513 pads x 6 acres per pad + 59 pads x 3 acres = 3,255 acres of gross disturbance
[30] 59 fully reclaimed final abandoned wells x 3 acres per pad = 177 reclaimed acres
[31] 506 pads x 2.5 acres per pad of interim reclamation = 1265 reclaimed acres
[32] 767 pads x 6 acres per pad + 93 pads x 3 acres = 4881 acres of gross disturbance
[33] 21 partially reclaimed P&A wells x 3 acres per well pad x 75% = 47 reclaimed acres
[34] 21 wells (1 well per pad) x 9 acres of partially reclaimed road per pad x 75% reclamation = 142 reclaimed acres

Table 14. Estimated future surface disturbance, BLM wells.

Component	Number	Acres per Site	Gross Disturbance (acres)	Interim Reclamation (acres)	Net Disturbance (Gross – Interim Reclamation) (acres)
Well Pads	824[35]	6	4,944	2,060[36]	2,884
Access Roads	824 (miles)	9	7,416	4,969[37]	2,447
Central Facilities	0	0	0	0	0
TOTAL (ac)			**12,360**	**7,029**	**5,331**

Table 15. Estimated future surface disturbance, all wells.

Component	Number	Gross Disturbance per Site (acres)	Gross Disturbance (acres)	Interim Reclamation (acres)	Net Disturbance (Gross – Reclaimed) (acres)
Well Pads	2,238[38]	6	13,428	5,595	7,833
Access Roads	2,238 (miles)	9	20,142	13,495	6,647
Central Facilities	8	10	80	0	80
TOTAL (ac)			**33,650**	**19,090**	**14,560**

Table 16. Combined existing and future net surface disturbance, BLM wells (acres).

Component	Table 11 Existing Net Disturbance	Table 14 Future Net Disturbance	Total
Well pads	604	2,884	3,488
Access Roads	546	2,447	2,993
Central Facilities	0	0	0
TOTAL (ac)	**1,150**	**5,331**	**6,481**

[35] 5768 BLM wells ÷ 7 wells per pad = 824 pads
[36] 824 pads x 2.5 acres interim reclamation per pad = 2060 interim reclaimed acres
[37] 824 miles of roads x 9 acres per mile x .67 reclamation factor = 4969 reclaimed acres
[38] 15,664 wells ÷ 7 wells per pad = 2238 pads

Table 17. Combined existing and future net surface disturbance, all wells (acres).

Component	Table 13 Existing Net Disturbance	Table 15 Future Net Disturbance	Total
Well pads	2,933	7,833	10,766
Access Roads	2,049	6,647	8,696
Central Facilities	80	80	160
TOTAL (ac)	**5,062**	**14,560**	**19,622**

9.2 Seismic Activity Surface Disturbance

Table 18 displays the future short-term surface disturbance estimated to accompany seismic exploration activities within the GSFO. Recent 3D surveys have averaged around 8,300 acres, but the actual surface disturbance is a small fraction of that. Contractors, where possible, must stay on existing roads and trails, and use helicopters when needed to avoid steep slopes and other sensitive areas. Much of the work is done on foot and or with minimal impact ATVs. What little area is disturbed is of much lower intensity and much more temporal in nature, than that seen with oil and gas drilling and production activities. Much of the land within the GSFO is a checker board mix of Federal and private lands, and as a result much of the survey area will involve private lands and mineral estate.

Over the last 4 years, a total of six permits have been issued, and another six are pending. That is an average of three permits per year, but as more land is surveyed and drilled the demand for new seismic surveys should decrease over time to an average of two surveys per year over the 20-year life of the plan. It is estimated by the BLM staff that approximately 1% of the total survey area is actually disturbed by the seismic activities. Since 3D seismic surveys are a reliable and cost-effective method of optimizing field development and management, it is assumed that 2D surveys may not occur as often. If they do occur, they will be take place within the scope of the projected number of 3D surveys and resultant surface disturbance.

Table 18. Estimated future surface disturbance for seismic surveys, all lands.

Type	Number	Acres per Survey	Disturbed Acres per Survey*	Reclaimed Acres per Survey*	Total Temporary Disturbance	Total Long-term Disturbance
3D	40	8,300	83	83	3,320	0

*Assumes that 1% of survey area is disturbed and that all disturbances are reclaimed as soon as practicable following completion of survey.

9.3 Increases in Compressors and Oil and Gas Activity that Impact Air Quality

It is estimated that an increase in drilling activity and associated production facilities will occur over the life of the RMP Revision. The demand for future compressors is directly proportional to the volume of gas produced. Air emissions will be controlled using the "Best Available Controlled Technology" to minimize pollutants from the compressors.

It is estimated 10% of the compressors in the GSFO area will be electric-driven within the next 5 years. As previously mentioned, the major point in utilizing electric driven compression is the reduction of air emissions to zero.

9.4 Produced Water Disposal

Currently, the BLM surface lands do not have permitted surface discharge, only contained produced water disposal in approved pits or tanks or approved trucking of produced water to approved disposal facilities. Both the BLM and the State of Colorado have jurisdiction over surface discharge (retention ponds, skimmer pits and equipment, tanks, and any additional surface disturbance) and approves surface discharge permits. Operations from the point of origin to the point of discharge are under the jurisdiction of the BLM. Operations from the point of discharge downstream are under the jurisdiction of the State of Colorado. The State of Colorado approves the underground injection of water into the disposal wells. Water quality has to meet their minimum standards for fresh water (<3,500 mg/L TDS) before it is allowed to be surfaced discharged. Water quality within the GSFO ranges in quality from potable to well over 25,000 mg/L of total dissolve solids (TDS). In the Rulison field, produced water from the Williams Fork Formation is around 3,000 mg/L TDS; in the Parachute field it is around 4,200 mg/L TDS; and in the Grand Valley field it is around 21,400 mg/L TDS. Typically the deeper the formation and the closer to the basin center, the poorer the quality of water. Formations in these areas usually contain connate water, marine in origin and very briny (>10,000 mg/L TDS). If the water is lacustrine or fluvial in origin, it is somewhat fresh (1,500 to 10,000 mg/L TDS). Shallow formations, formations near the basin margin recharge zones, and formations with conduits for fresh water recharge (i.e., faults) can contain very fresh to potable meteoric water (<1,500 mg/L TDS). Nearly 10 million barrels of water (see Figure 15) have been produced within the GSFO. Much of the future produced water may come from fee CBM wells. Fortunately most of the gas wells in the GSFO do not produce a lot of water. Other methods of water disposal used within the GSFO are reinjection, disposal into evaporation pits, and trucking to approved disposal facilities. See Map 29 for produced water/waste disposal facilities.

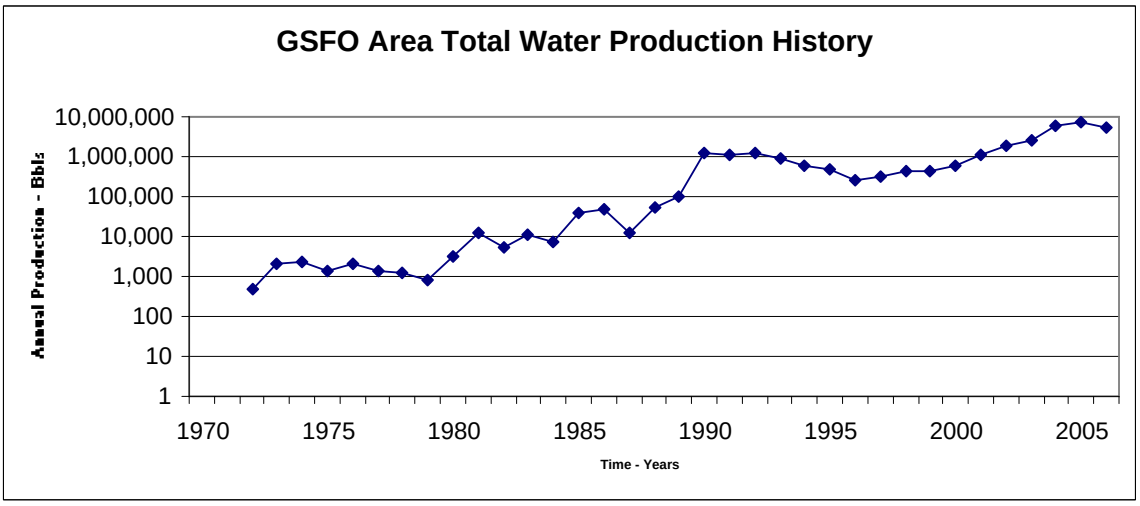

Figure 15. GSFO Area total water production history (Source: PI Dwights).

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11. APPENDIX

ACRONYMS

B = billion
BLM = Bureau of Land Management
BO = barrels of oil
BOE = barrels of oil equivalent
BOPD = barrels of oil per day
BWPD = barrels of water per day
CBG = coalbed gas
CBM = coalbed methane (same as coalbed gas)
CFG = cubic feet of gas
DOE = Department of Energy
EIA = Energy Information Administration
EUR = estimated ultimate recovery
GSFO = Glenwood Springs Field Office
M = thousand
MCF = thousand cubic feet
md = millidarcy
MM = million
NGL = natural gas liquids
PD = per day
PSI = pounds per square inch
RFD = Reasonable Foreseeable Development Scenario
RMP = Resource Management Plan
T = trillion
U.S. = United States
USGS = United States Geological Survey
USFS = United States Forest Service

TERMS AND DEFINITIONS

Accumulation: One or more reservoirs of petroleum that share a particular trap, charge, and set of reservoir characteristics.

Assessment Unit: A mappable part of a total petroleum system in which discovered and undiscovered oil and gas accumulations constitute a single relatively homogeneous population for which the methodology of resource assessment is applicable.

Associated Gas: Natural gas that occurs with oil.

Barrels of Oil Equivalent (BOE): A unit of petroleum volume in which the gas portion is expressed in terms of its energy equivalent in barrels of oil. For this assessment, 6,000 cubic feet of gas equals 1 barrel of oil equivalent (BOE).

Composite Total Petroleum System: A mappable entity encompassing all or a portion of two or more petroleum systems.

Continuous Accumulation: An accumulation consisting of areally extensive reservoirs of petroleum not necessarily related to conventional structural or stratigraphic traps.

Conventional Accumulations: An accumulation associated with structural or stratigraphic traps, commonly bounded by a down-dip water contact, and therefore affected by the buoyancy of petroleum in water.

Economically Recoverable Resources: Are a subset of the technically recoverable that includes only that oil and gas that is expected to be producible at a profit. This is a very dynamic category, changing not only with increasing knowledge and technology, but also with the rapid and sometimes unpredictable changes in economic conditions, prices, and regulation.

Economic Limit: The economic limit is the point in time when the revenue from the production stream will balance such variables as the costs and taxes paid for that production. As these variables and resource dollar values change, so do oil and gas economically recoverable resource estimations.

Effective Date: The effective date is the month in which economic projections begin. Economic values and remaining reserves are determined from this date until the economic limit is reached (or, alternatively, until the optional economic cutoff – stop date or stop rate is reached).

Field: An area consisting of a single reservoir or multiple reservoirs of petroleum, all grouped on, or related to, a single geological structural and (or) stratigraphic feature. Individual reservoirs in a single field may be separated vertically by impervious strata or laterally by local geologic barriers (American Petroleum Institute, 1995). When projected to the surface, the reservoir(s) within the field form a contiguous area that can be circumscribed.

In-place Resource: Is the total volume of oil and gas thought to exist (both discovered and yet-to-be discovered) without regard to the ability to either access or produce it. Although the in-place resource is primarily a fixed, unchanging volume, the current understanding of that volume is continually changing as technology improves.

Nonassociated Gas: Natural gas that occurs alone (without oil).

Play: A set of known or postulated oil and gas accumulations sharing similar geologic, geographic, and temporal properties, such as source rock, migration pathway, timing, trapping mechanism, and hydrocarbon type. A play may or may not differ from an assessment unit, which in turn can include one or more plays.

Reserves: Are oil and gas that has been proven by drilling and is available for profitable production. Reserves are also subject to economic conditions.

Reserves Growth: The increases in known petroleum volume that commonly occur as oil and gas accumulations are developed and produced; synonymous with field growth.

Technically Recoverable Resources: Are a subset of the in-place resources that includes only that oil and gas (both discovered and undiscovered) that is expected to be producible given available technology with no regard to current costs. Technically recoverable resources are therefore dynamic, constantly changing to reflect our increased understanding of both the in-place resource as well as the likely nature of future technology.

Total Petroleum System: A mappable entity encompassing genetically related petroleum that occurs in seeps, shows, and accumulations (discovered or undiscovered) that have been generated by a pod or by closely related pods of mature source rock, together with the essential mappable geologic elements (source, reservoir, seal, and overburden rocks) that controlled fundamental process of generation, migration, entrapment, and preservation of petroleum.

Unconventional Accumulations: (1) generally, very large accumulations occupying the more central, deeper parts of basins, (2) absence of down-dip water contacts, (3) abnormally over- or under-pressured, (4) gas is the pressuring phase, (5) produce little or no water, (6) permeability less than 0.1 md, (7) overlain by a normally pressured transition zone containing gas and water, (8) contain thermogenic gas,

9) source of gas is local--either from interbedded or adjacent lithologies, (10) top of accumulations occur at 0.75 to 0.9 percent vitrinite reflectance, (11) structural and stratigraphic trapping aspects are of secondary importance, (12) the "seal" for these gas accumulations is due to the presence of multiple fluid phases in low-permeability reservoirs; it is a relative permeability barrier.

GIS LAYERS

USGS GIS data downloaded from http://energy.cr.usgs.gov/oilgs/noga/: Data included TPS and AU shape files in decimal degree projection. USGS Uinta-Piceance Basin Province study was completed in 2002.

GSFO GIS map base data from GSFO server T:/gisdata. Data has various dates and authors.

GIS oil and gas wells, leases, units, CAs, and facilities data were downloaded from the COGCC GIS website. Data was captured in the fall of 2006.

GIS geologic data and oil and gas fields were taken from the Colorado Geological Survey CD ROM disk dated September 2003.

CONTACTS

Industry*

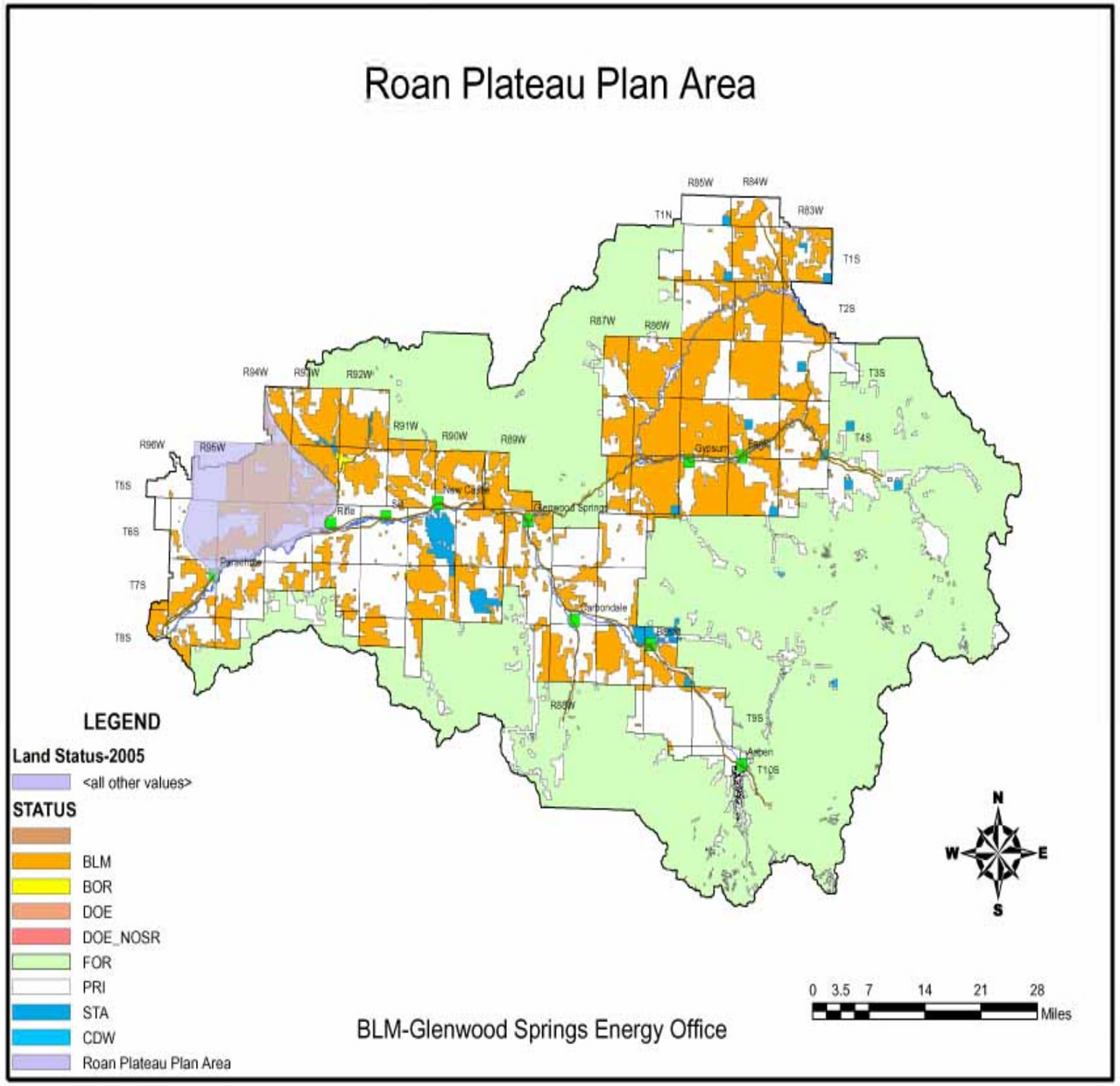
- Williams Production RMT Co
- Encana Oil and Gas (USA) Inc.
- Petrogulf Corporation
- Windsor Energy Group LLC
- Laramie Energy LLC
- Barrett Resources Corp.
- Petroleum Development Corp
- Presco Inc.
- Piceance Gas
- Oxy USA WTP LP
- Antero Resources
- Noble Energy Inc.
- Berry Petroleum
- Conoco/PPCO

*Individual names from each company are not disclosed in the RFD to honor the request of the operators to remain anonymous and for their specific information to remain confidential.

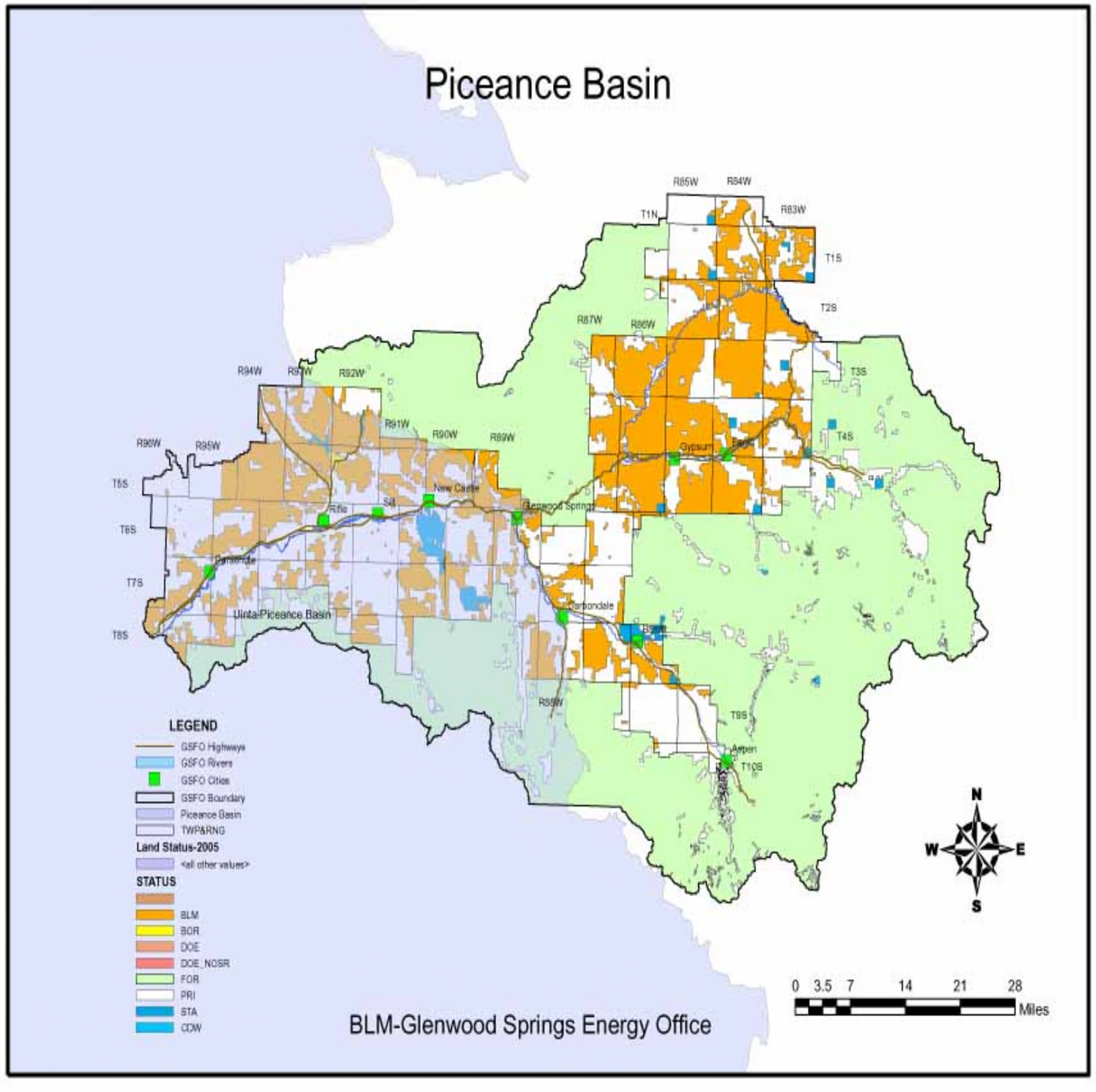
BLM Colorado State Office Reservoir Team

- Hank Szymanski
- Marion Malinowski
- Pat Gallagher
- Duane Spencer

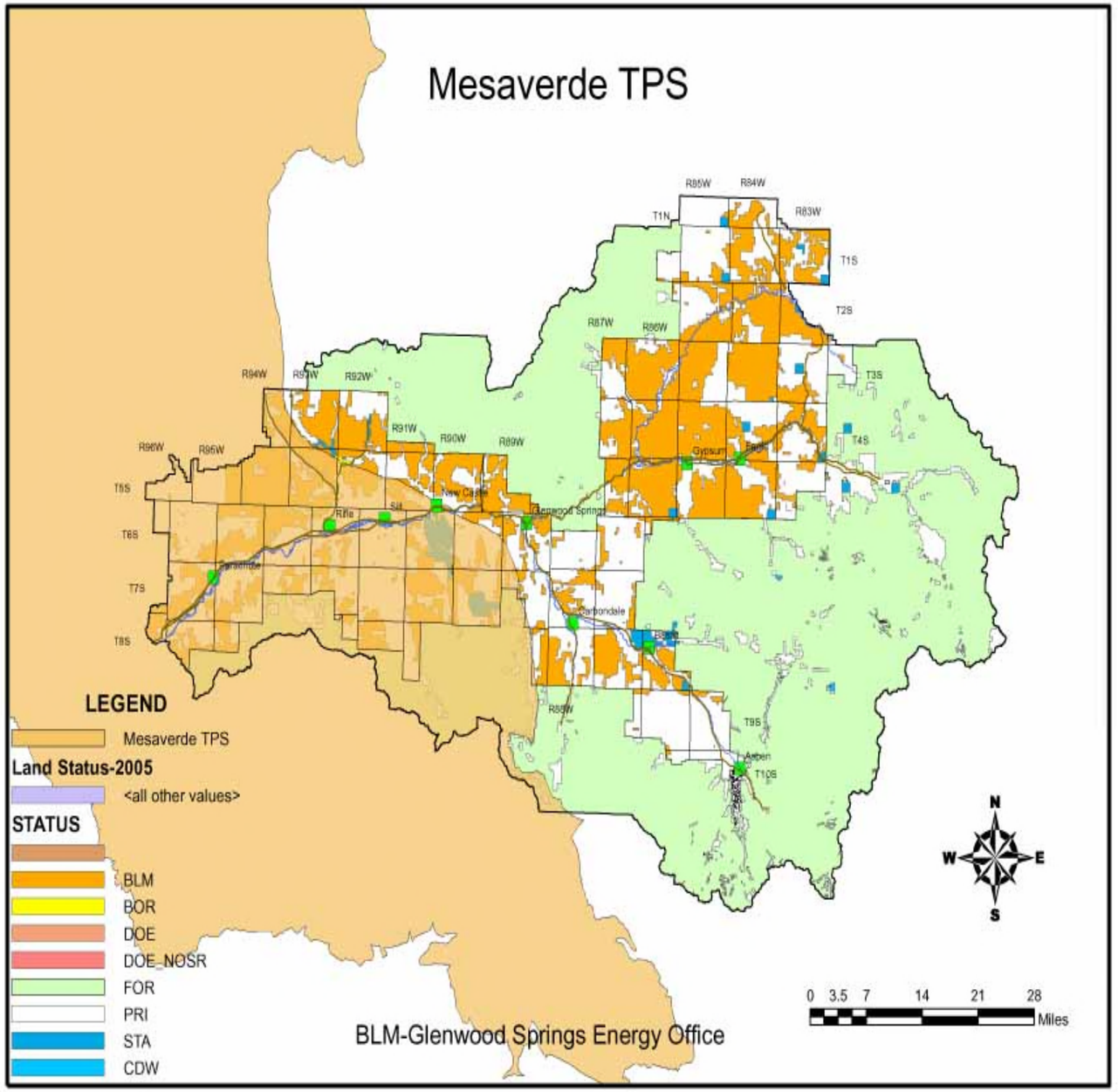
Map 1.


Roan Plateau Plan Area
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
T5S
T6S
T7S
T8S
Rifle
New Castle
Glenwood Springs
Gypsum
Eagle
Carbondale
R88W
T9S
Aspen
T10S
LEGEND
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
Roan Plateau Plan Area
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

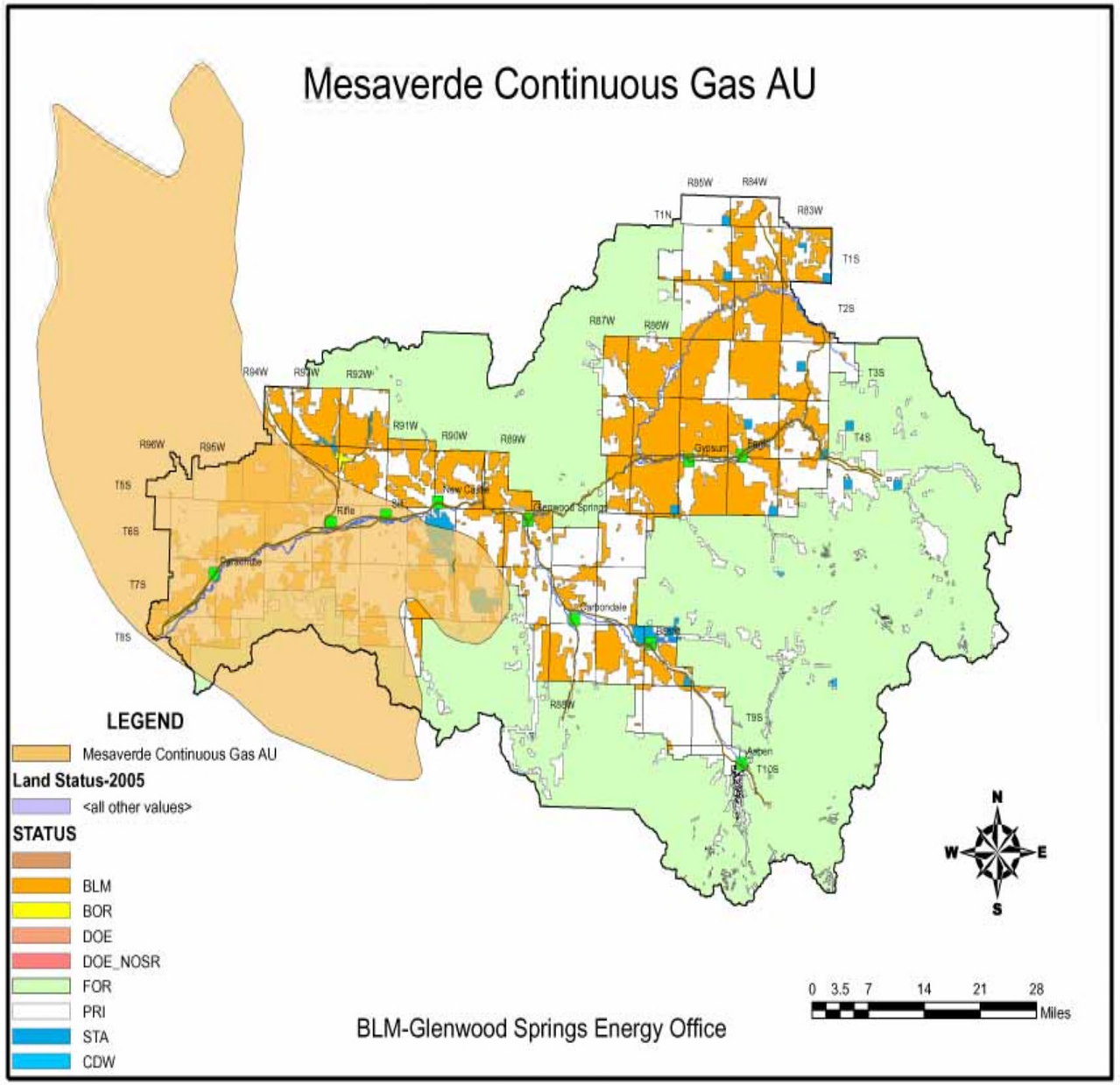
Map 2.


Piceance Basin
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
T5S
T6S
T7S
T8S
Gypsum
Eagle
New Castle
Rifle
Silt
Glenwood Springs
Parachute
Carbondale
Uinta Piceance Basin
Basalt
R88W
T9S
Aspen
T10S
LEGEND
GSFO Highways
GSFO Rivers
GSFO Cities
GSFO Boundary
Piceance Basin
TWP&RNG
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

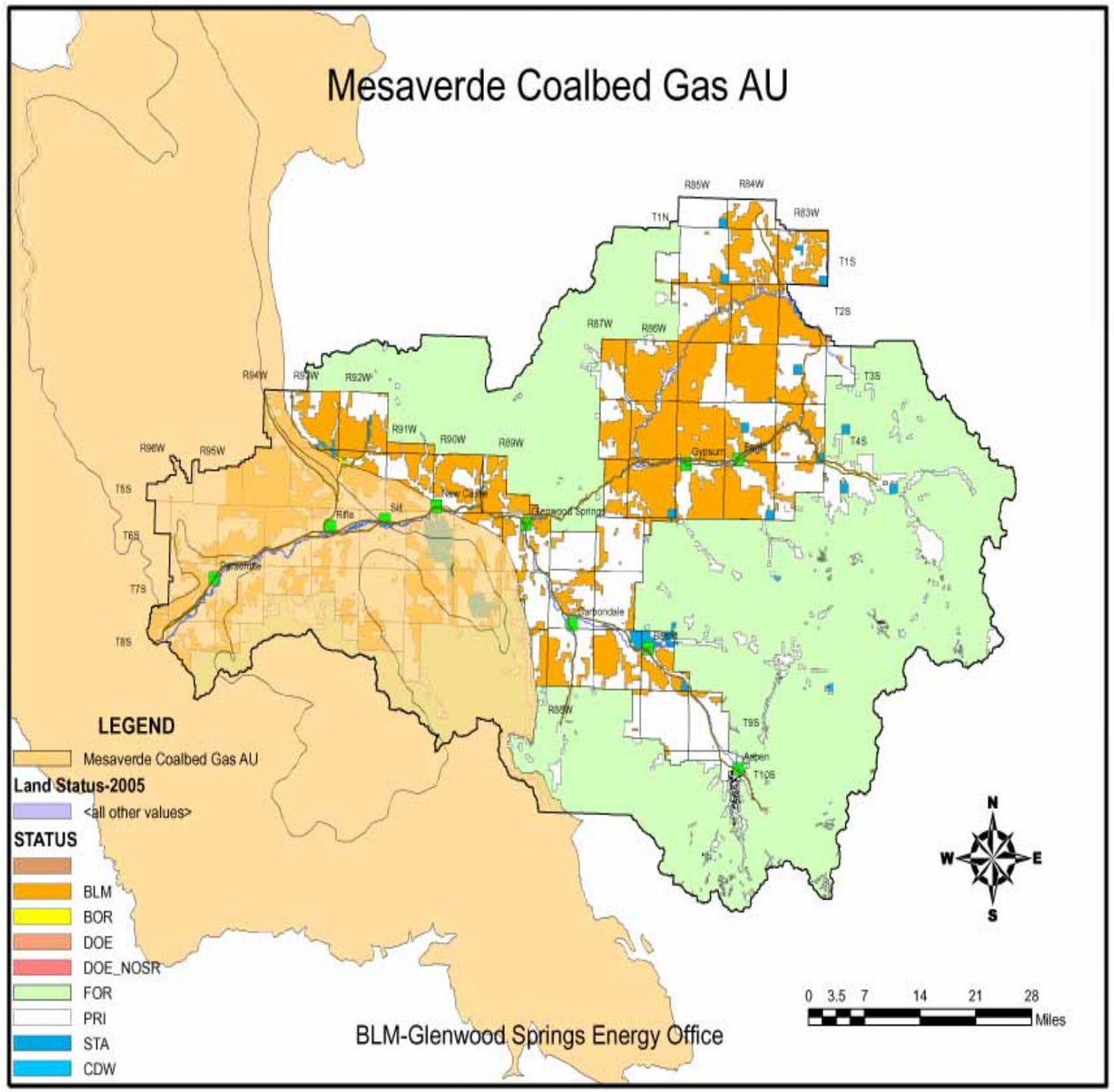
Map 3.


Mesaverde TPS
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
T5S
T6S
T7S
T8S
T9S
T10S
R88W
Rifle
Silt
New Castle
Glenwood Springs
Gypsum
Eagle
Carbondale
Aspen
LEGEND
Mesaverde TPS
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

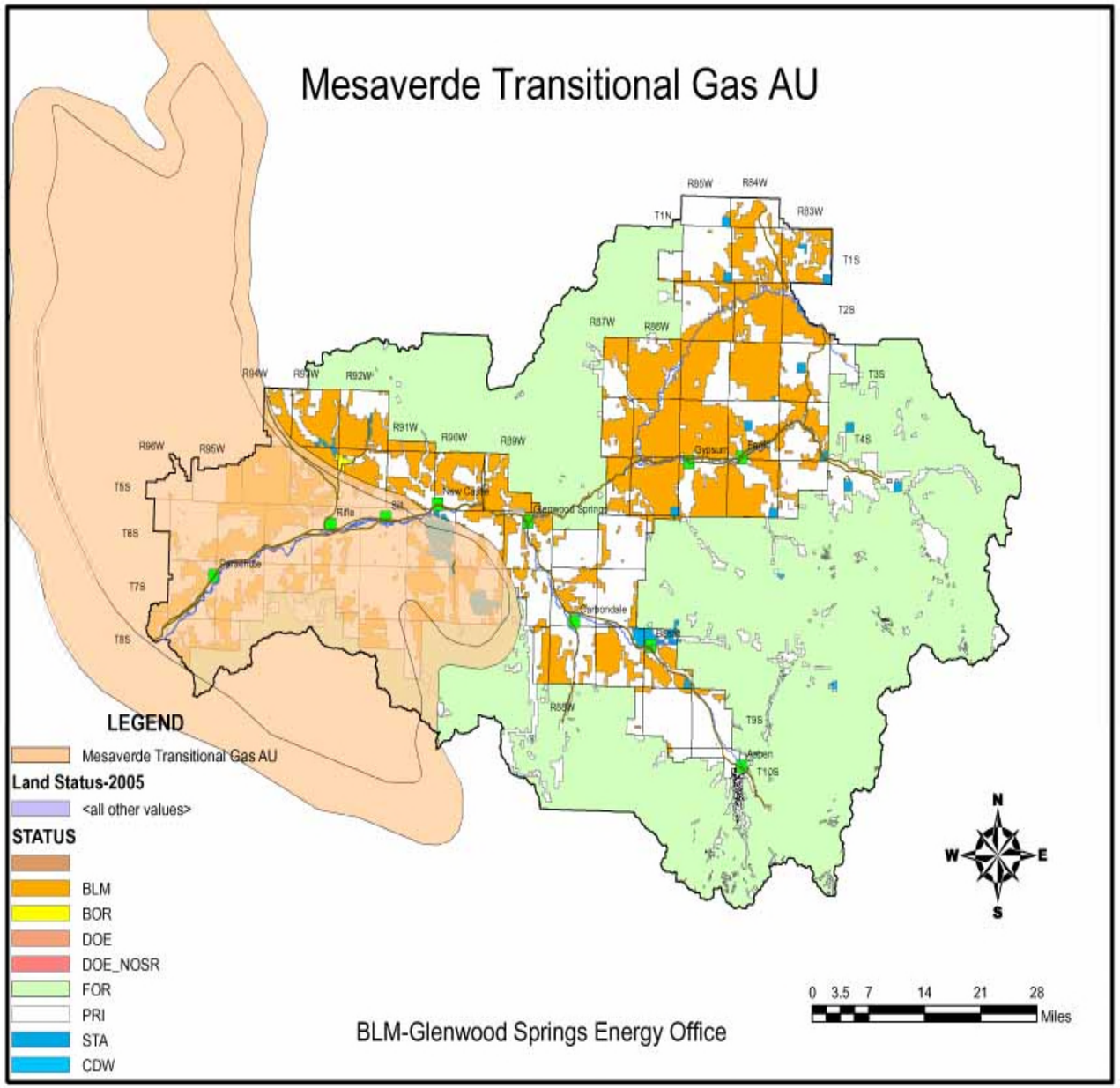
Map 4.


Mesaverde Continuous Gas AU
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
T5S
T6S
T7S
T8S
Gypsum
Eagle
New Castle
Glenwood Springs
Rifle
Carbondale
Aspen
R88W
T9S
T10S
LEGEND
Mesaverde Continuous Gas AU
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

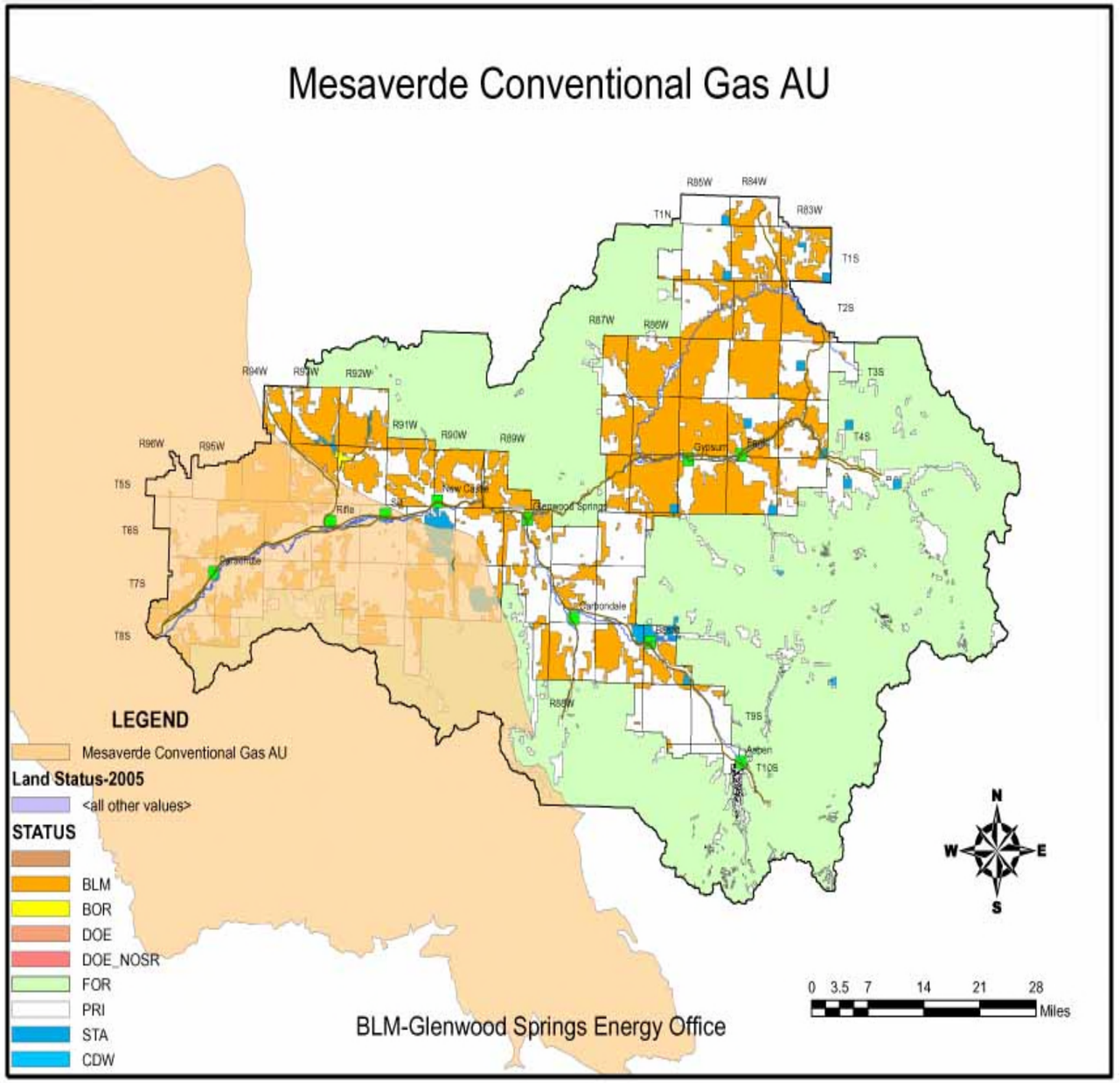
Map 5.


Mesaverde Coalbed Gas AU
LEGEND
Mesaverde Coalbed Gas AU
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
BLM-Glenwood Springs Energy Office
0 3.5 7 14 21 28
Miles
N
S
E
W

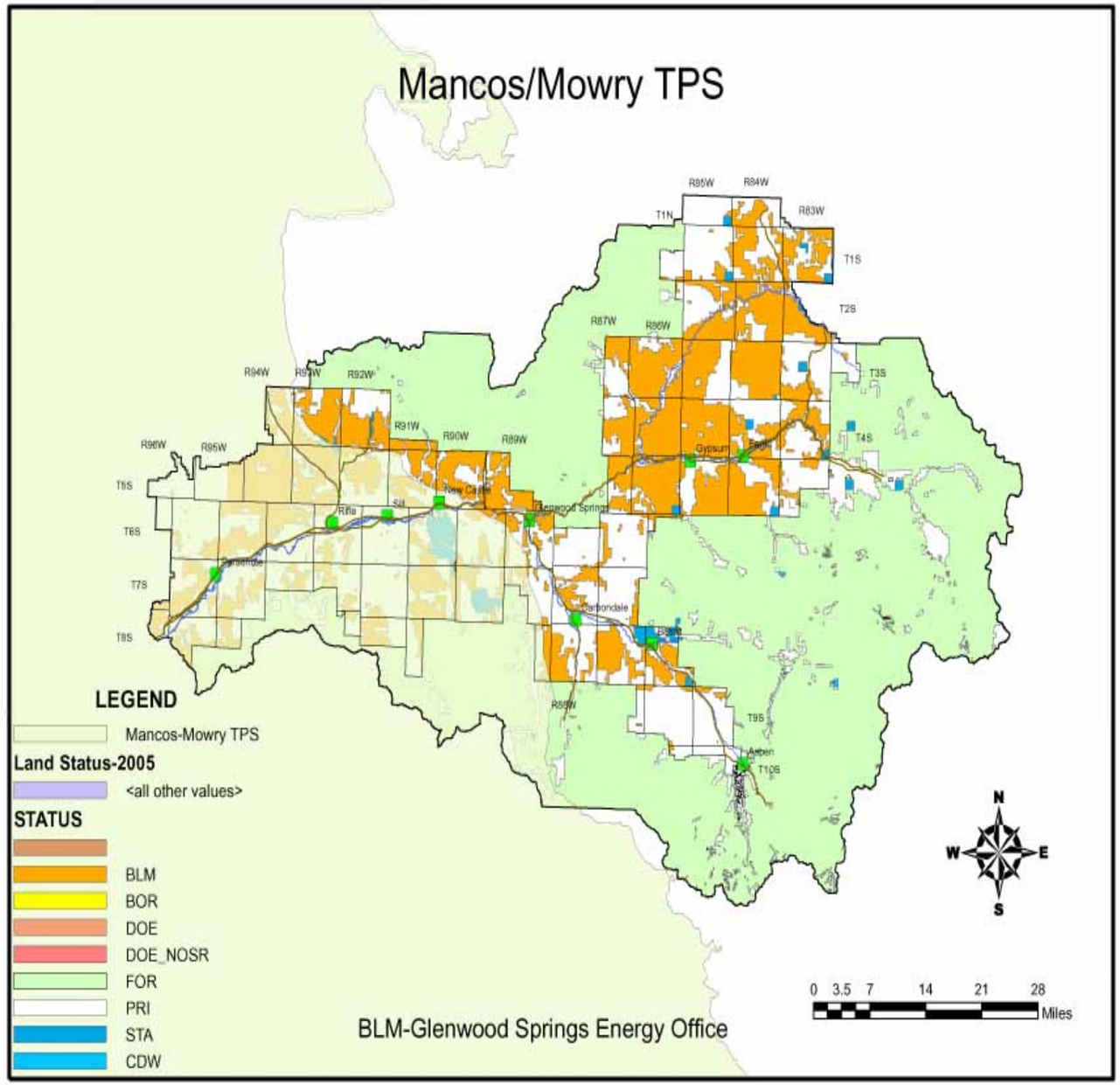
Map 6.


Mesaverde Transitional Gas AU
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
T5S
T6S
T7S
T8S
Gypsum
Rifle
Silt
New Castle
Glenwood Springs
Carbondale
Basalt
Aspen
T9S
T10S
R88W
LEGEND
Mesaverde Transitional Gas AU
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

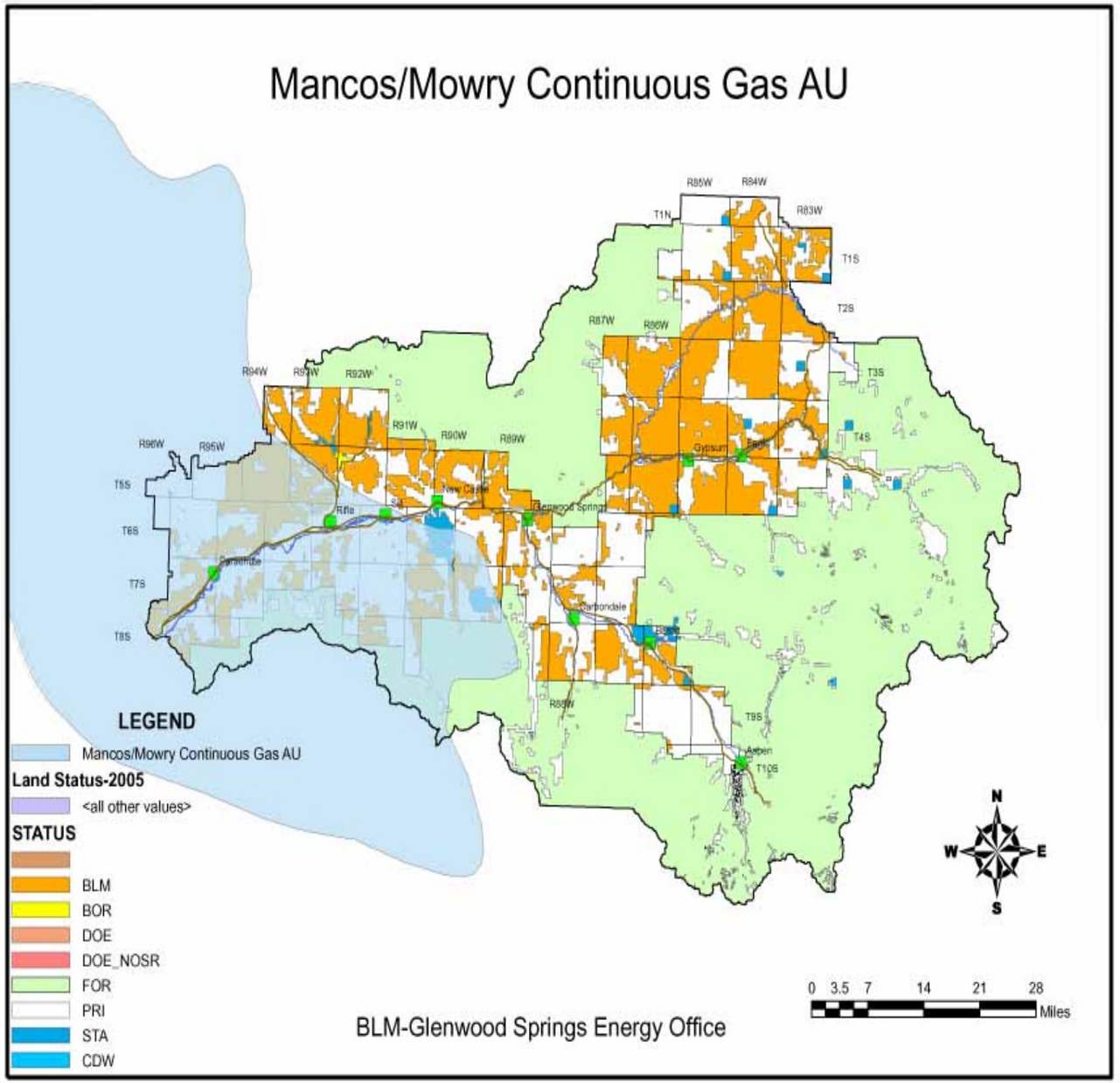
Map 7.


Mesaverde Conventional Gas AU
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
T5S
T6S
T7S
T8S
Gypsum
Eagle
New Castle
Rifle
Glenwood Springs
Carbondale
Aspen
T9S
T10S
R88W
LEGEND
Mesaverde Conventional Gas AU
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

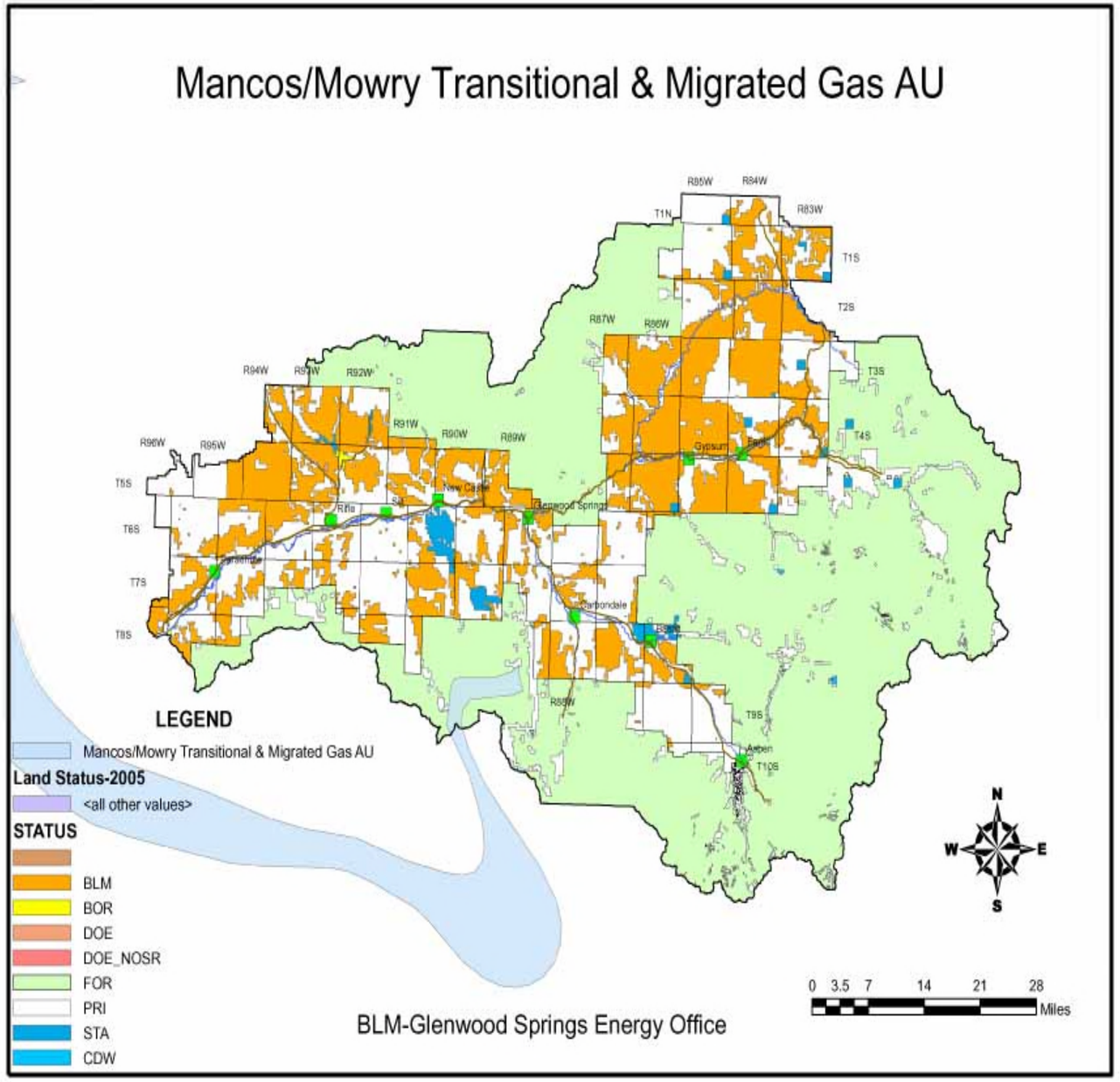
Map 8.


Mancos/Mowry TPS
R85W
R84W
R83W
T1N
T1S
T2S
R87W
R86W
T3S
R94W
R93W
R92W
R91W
R90W
R89W
T4S
R96W
R95W
T5S
T6S
T7S
T8S
Rifle
Silt
New Castle
Glenwood Springs
Gypsum
Eagle
Carbondale
Basalt
R88W
T9S
Aspen
T10S
LEGEND
Mancos-Mowry TPS
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

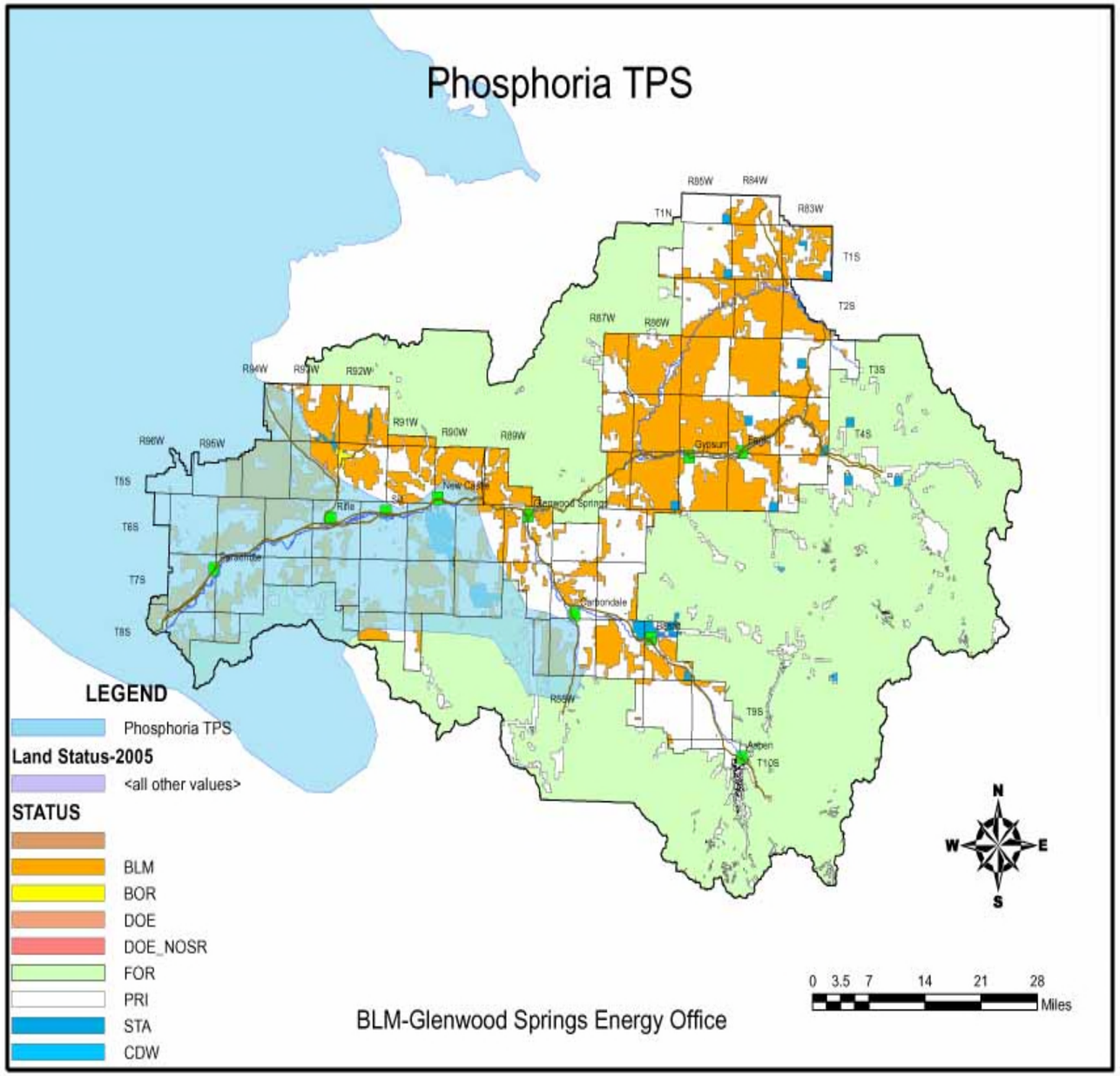
Map 9.


Mancos/Mowry Continuous Gas AU
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
T5S
T6S
T7S
T8S
T9S
T10S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R88W
R96W
R95W
Gypsum
Eagle
New Castle
Glenwood Springs
Rifle
Silt
Carbondale
Aspen
LEGEND
Mancos/Mowry Continuous Gas AU
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

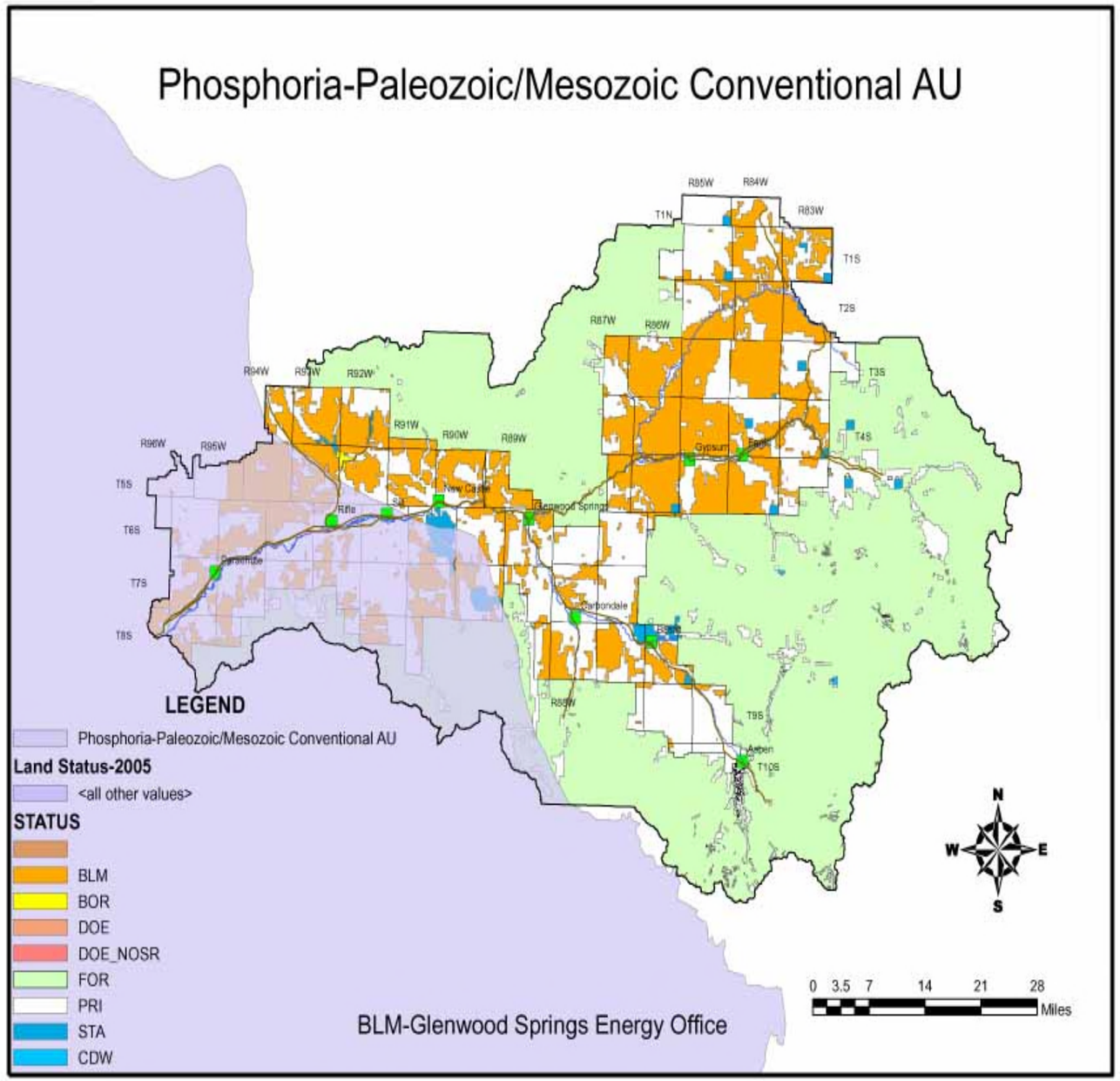
Map 10.


Mancos/Mowry Transitional & Migrated Gas AU
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
T5S
T6S
T7S
T8S
Rifle
New Castle
Glenwood Springs
Carbondale
Gypsum
Eagle
R88W
T9S
Aspen
T10S
N
W
E
S
LEGEND
Mancos/Mowry Transitional & Migrated Gas AU
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

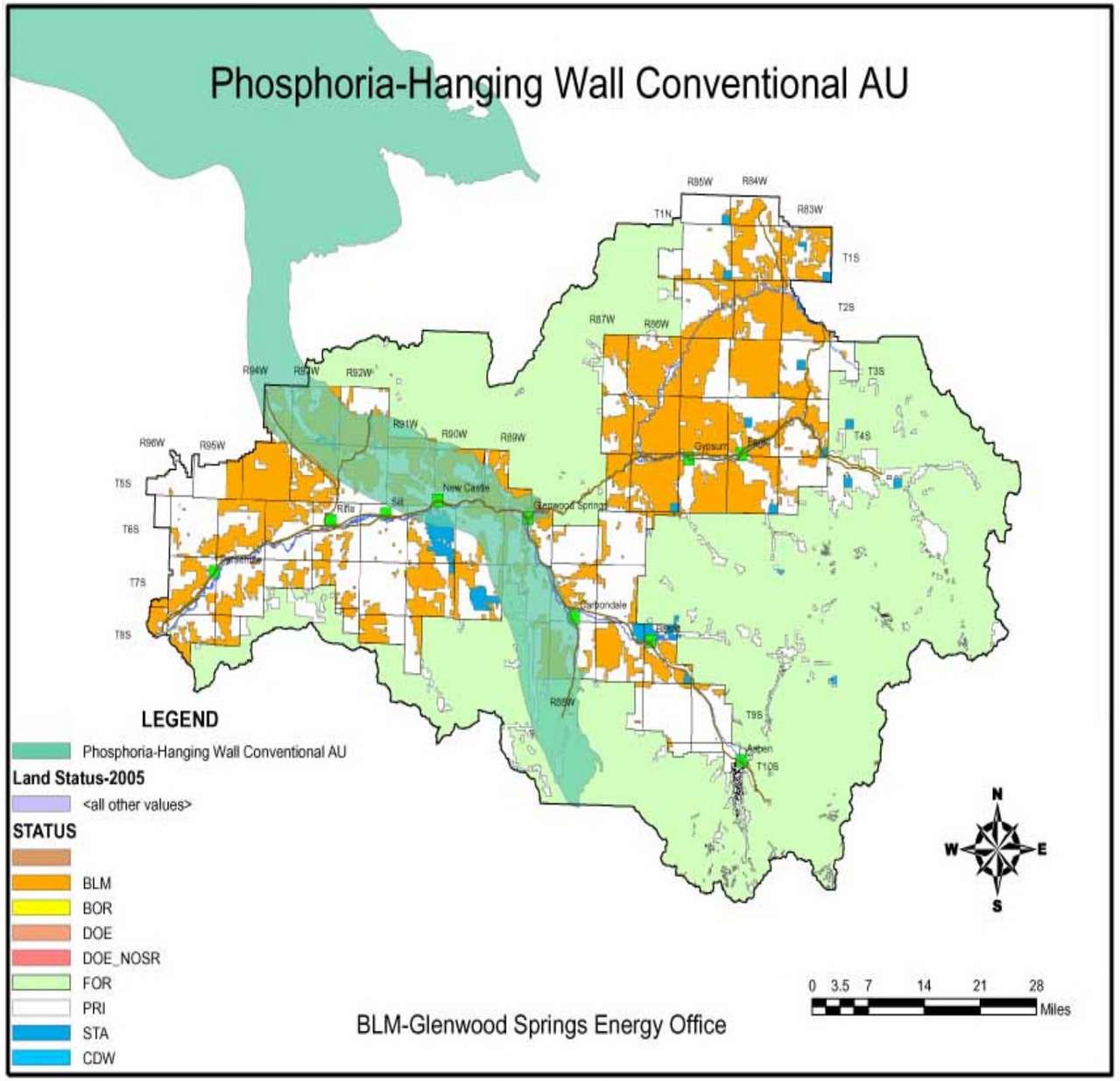
Map 11.


Phosphoria TPS
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
T5S
T6S
T7S
T8S
Rifle
New Castle
Glenwood Springs
Carbondale
Gypsum
Eagle
Aspen
T9S
T10S
R88W
LEGEND
Phosphoria TPS
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

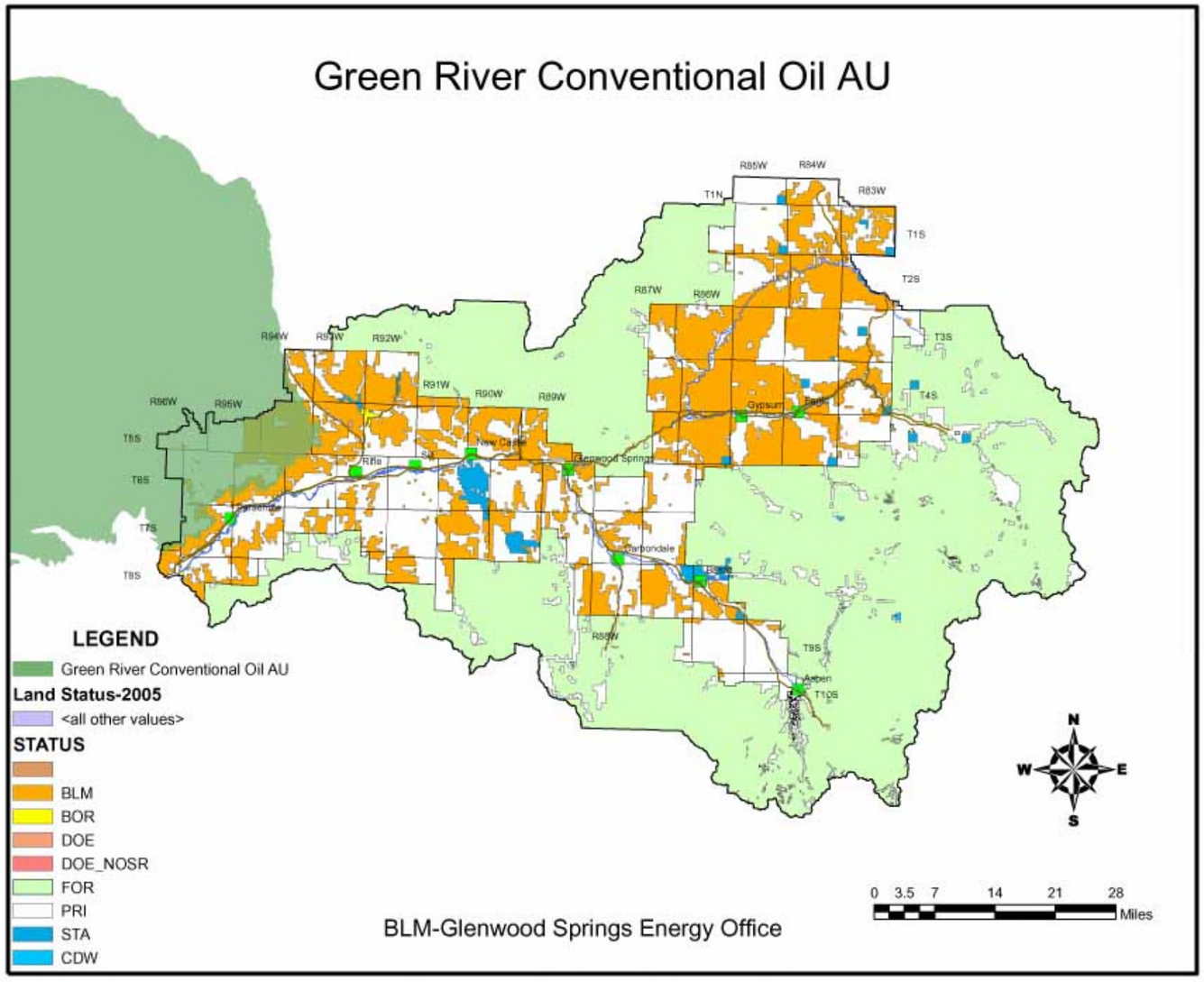
Map 12.


Phosphoria-Paleozoic/Mesozoic Conventional AU
R85W
R84W
R83W
T1N
T1S
T2S
R87W
R86W
T3S
R94W
R93W
R92W
R91W
R90W
R89W
T4S
R96W
R95W
T5S
T6S
T7S
T8S
Rifle
New Castle
Glenwood Springs
Carbondale
Gypsum
Eagle
Aspen
T9S
T10S
R88W
LEGEND
Phosphoria-Paleozoic/Mesozoic Conventional AU
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

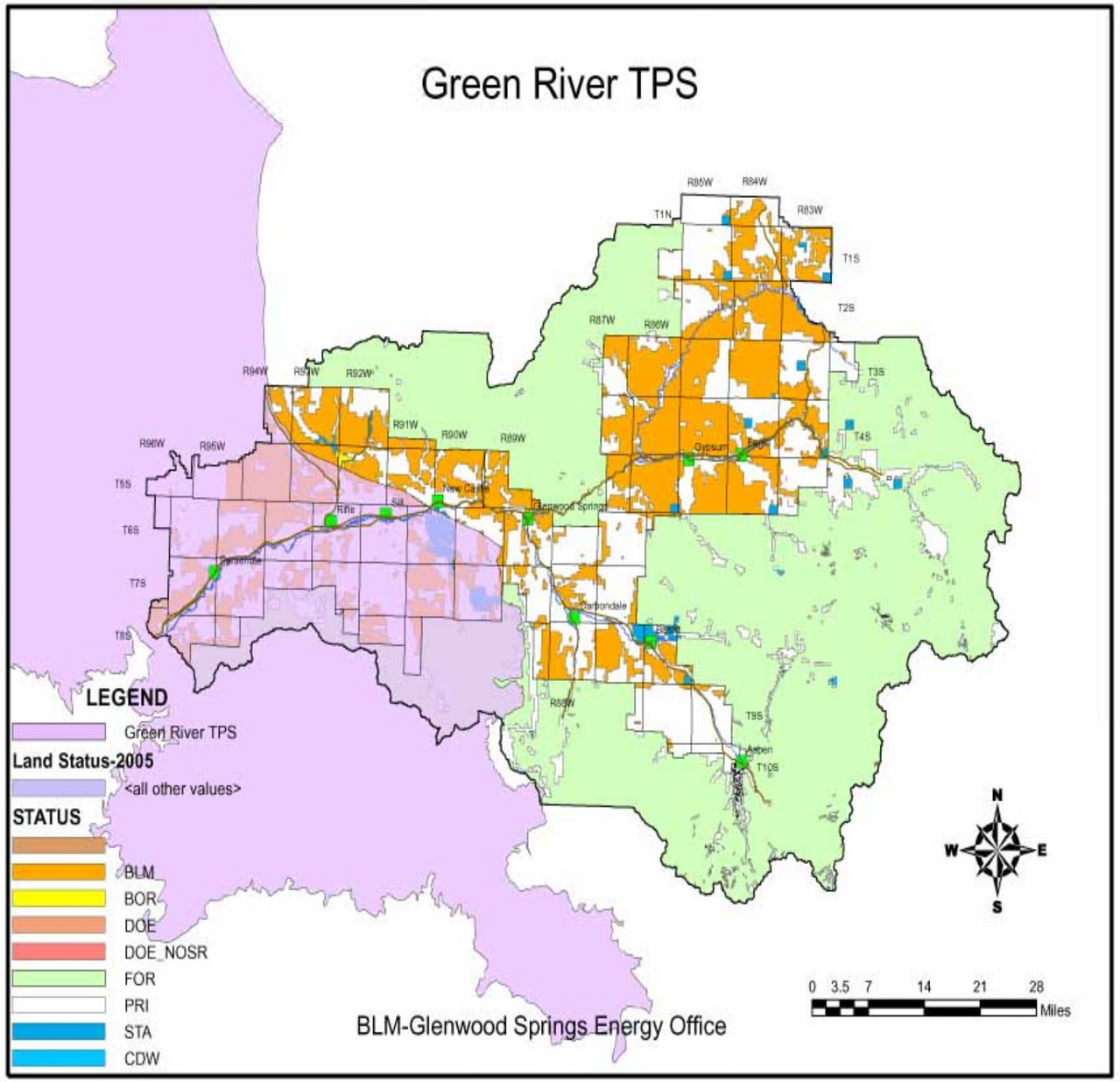
Map 13.


Phosphoria-Hanging Wall Conventional AU
R85W
R84W
R83W
T1N
T1S
T2S
R87W
R86W
T3S
R94W
R93W
R92W
R91W
R90W
R89W
T4S
R96W
R95W
T5S
T6S
T7S
T8S
Rifle
Silt
New Castle
Glenwood Springs
Gypsum
Eagle
Carbondale
Basalt
R88W
T9S
Aspen
T10S
LEGEND
Phosphoria-Hanging Wall Conventional AU
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

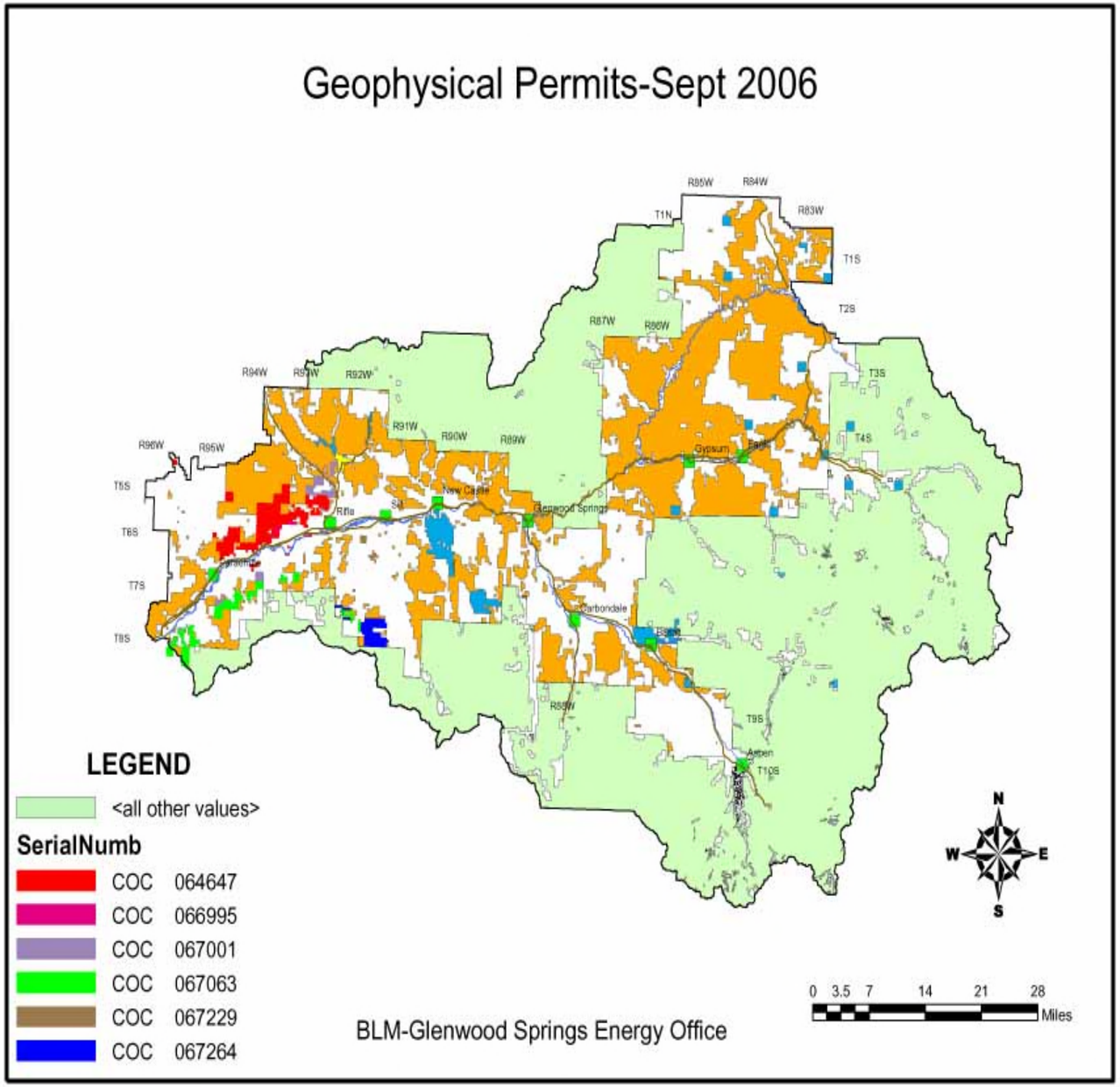
Map 14.


Green River Conventional Oil AU
LEGEND
Green River Conventional Oil AU
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
0 3.5 7 14 21 28
Miles
N
S
E
W
BLM-Glenwood Springs Energy Office

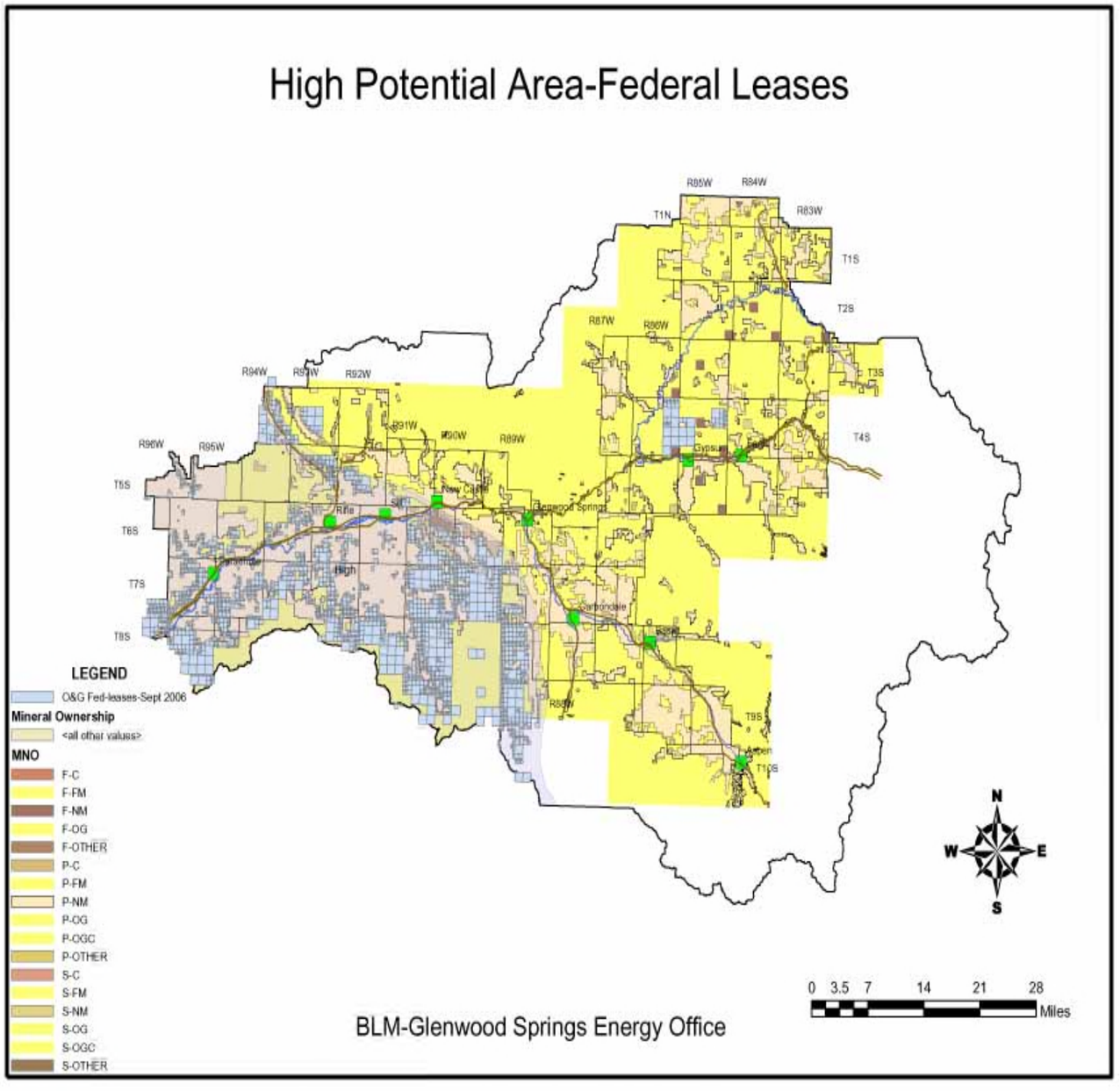
Map 15.


Green River TPS
R85W
R84W
R83W
T1N
T1S
T2S
R87W
R86W
T3S
R94W
R93W
R92W
R91W
R90W
R89W
T4S
R98W
R96W
T5S
T6S
T7S
T8S
Gypsum
Eagle
Rifle
Silt
New Castle
Glenwood Springs
Carbondale
Basalt
R88W
T9S
Aspen
T10S
LEGEND
Green River TPS
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

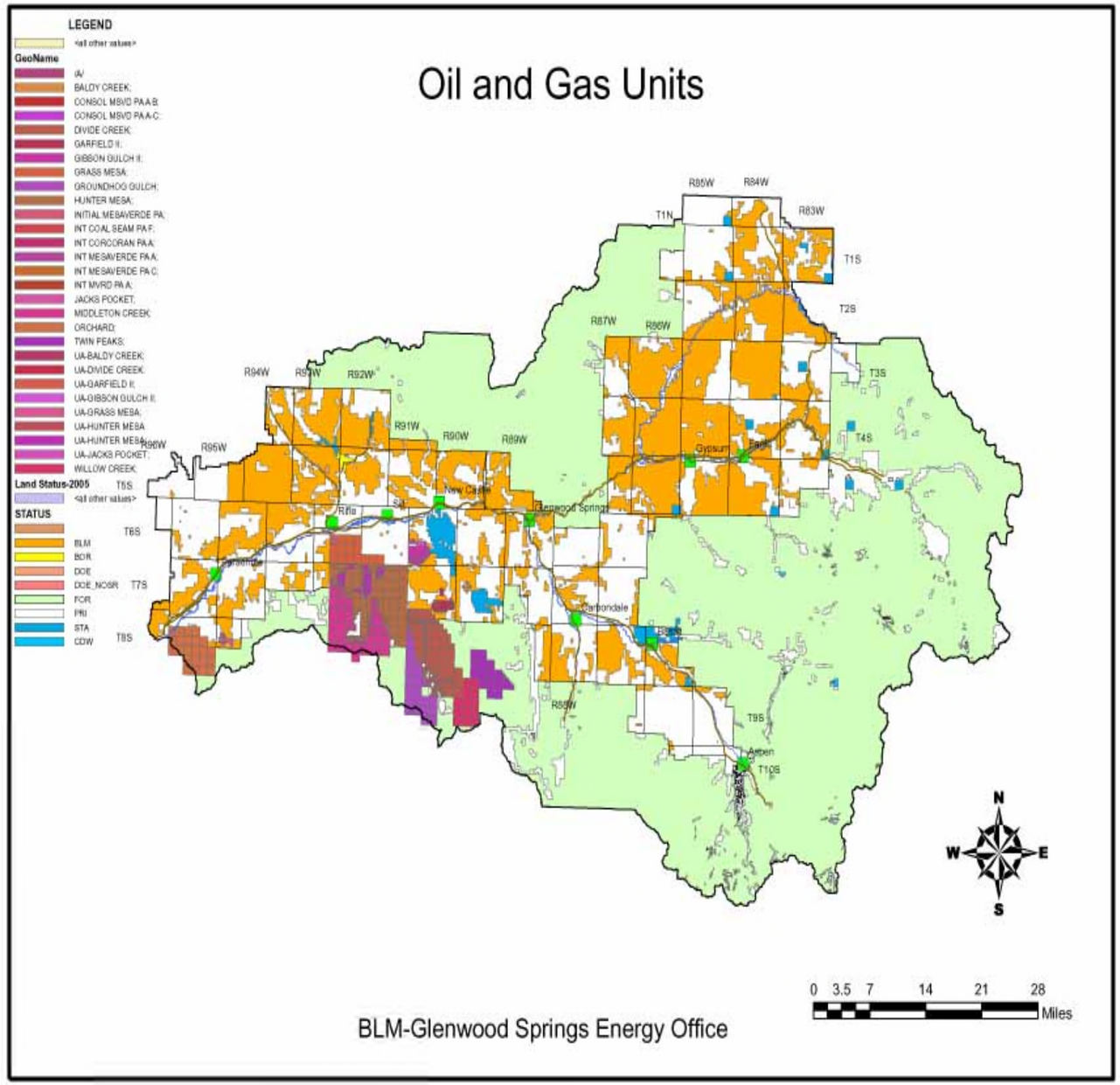
Map 16.


Geophysical Permits-Sept 2006
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
T5S
T6S
T7S
T8S
Rifle
New Castle
Glenwood Springs
Gypsum
Eagle
Carbondale
R88W
T9S
Aspen
T10S
LEGEND
<all other values>
SerialNumb
COC 064647
COC 066995
COC 067001
COC 067063
COC 067229
COC 067264
BLM-Glenwood Springs Energy Office
N
W
E
S
0 3.5 7 14 21 28
Miles

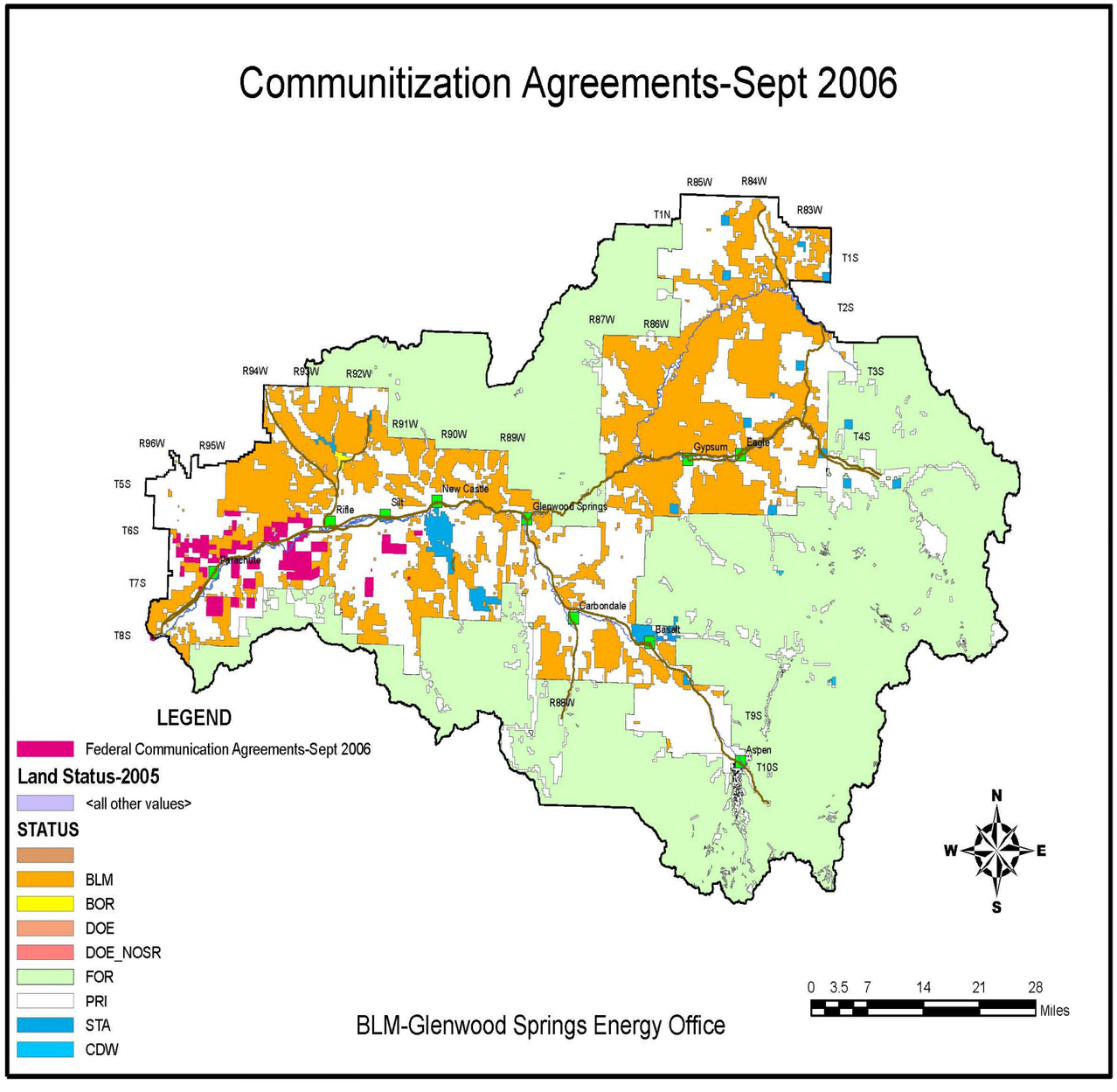
Map 17.


High Potential Area-Federal Leases
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
T5S
T6S
T7S
T8S
Rifle
New Castle
Glenwood Springs
Carbondale
Gypsum
R88W
T9S
T10S
LEGEND
O&G Fed-leases-Sept 2006
Mineral Ownership
<all other values>
MNO
F-C
F-FM
F-NM
F-OG
F-OTHER
P-C
P-FM
P-NM
P-OG
P-OGC
P-OTHER
S-C
S-FM
S-NM
S-OG
S-OGC
S-OTHER
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

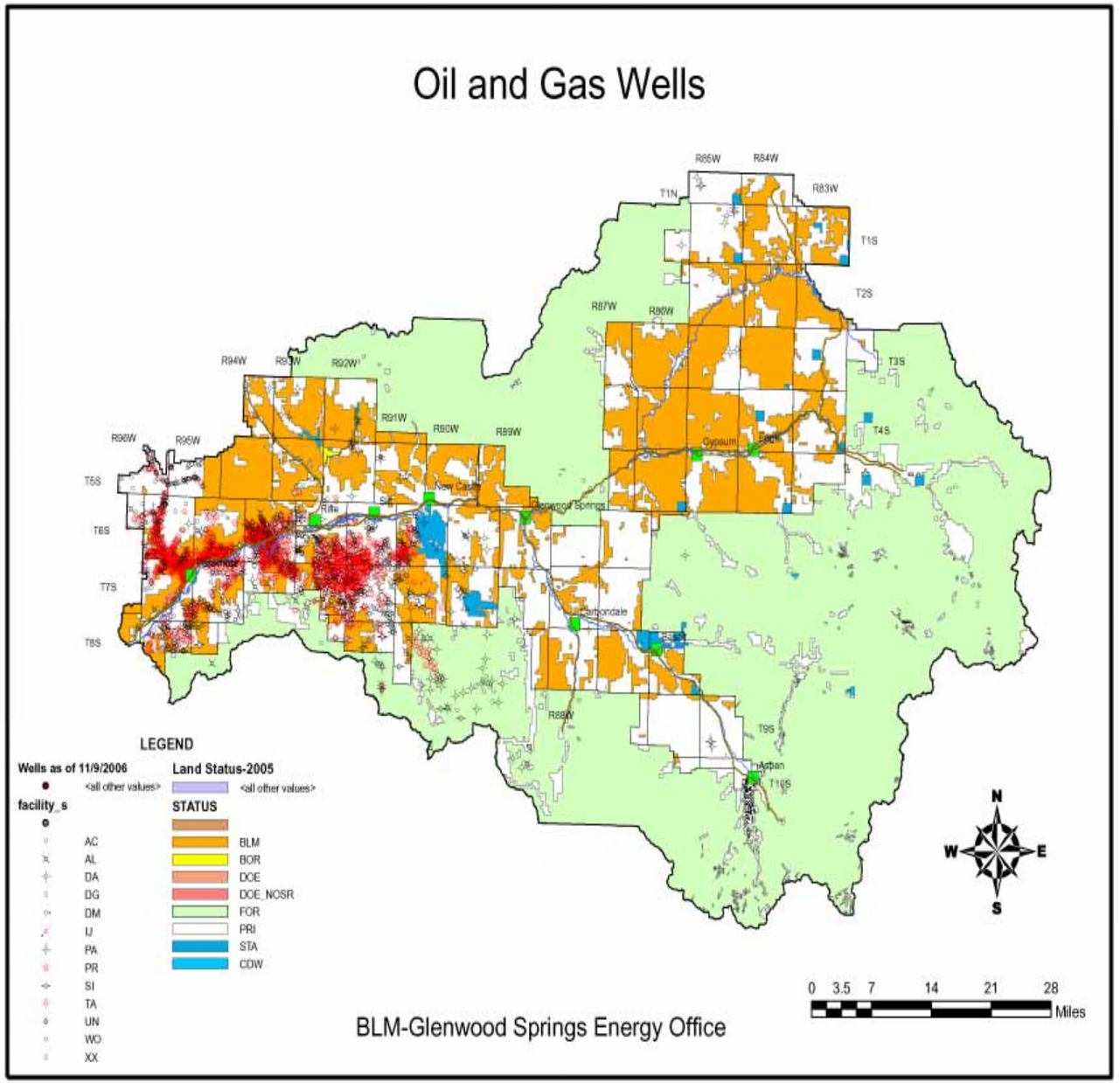
Map 18.


Oil and Gas Units
LEGEND
<all other values>
GeoName
IA/
BALDY CREEK;
CONSOL MSVD PA A B;
CONSOL MSVD PA A-C;
DIVIDE CREEK;
GARFIELD II;
GIBSON GULCH II;
GRASS MESA;
GROUNDHOG GULCH;
HUNTER MESA;
INITIAL MESAVERDE PA;
INT COAL SEAM PA F;
INT CORCORAN PA A;
INT MESAVERDE PA A;
INT MESAVERDE PA C;
INT MVRD PA A;
JACKS POCKET;
MIDDLETON CREEK;
ORCHARD;
TWIN PEAKS;
UA-BALDY CREEK;
UA-DIVIDE CREEK;
UA-GARFIELD II;
UA-GIBSON GULCH II;
UA-GRASS MESA;
UA-HUNTER MESA
UA-HUNTER MESA
UA-JACKS POCKET;
WILLOW CREEK;
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
T5S
T6S
T7S
T8S
T9S
T10S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
R88W
Gypsum
New Castle
Glenwood Springs
Rifle
Carbondale
Aspen
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

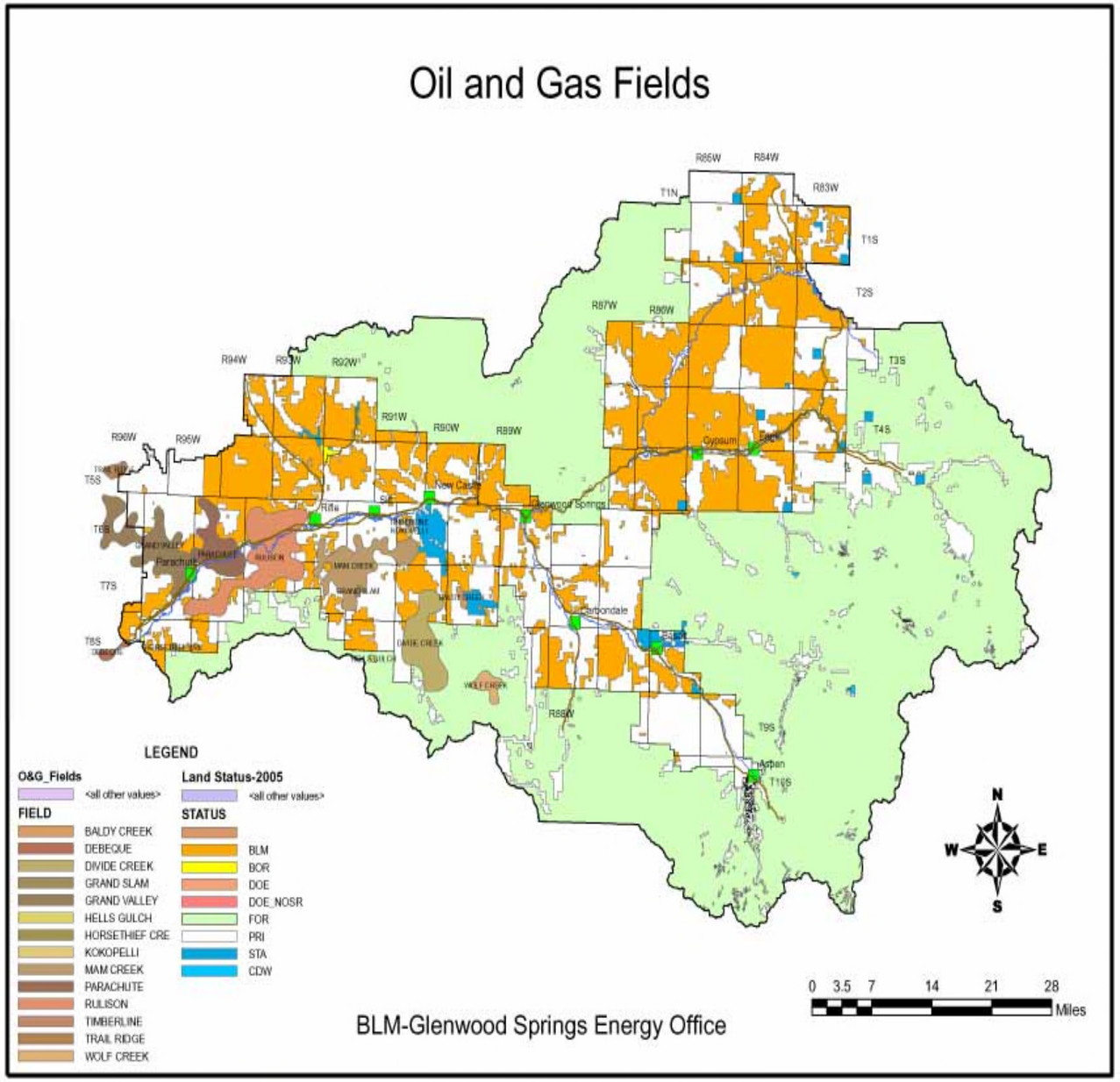
Map 19.


Communitization Agreements-Sept 2006
R85W
R84W
R83W
T1N
T1S
T2S
R87W
R86W
T3S
R94W
R93W
R92W
R91W
R90W
R89W
T4S
R96W
R95W
Gypsum
Eagle
T5S
New Castle
Rifle
Silt
Glenwood Springs
T6S
Parachute
T7S
Carbondale
Basalt
T8S
R88W
T9S
Aspen
T10S
N
W
E
S
LEGEND
Federal Communication Agreements-Sept 2006
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

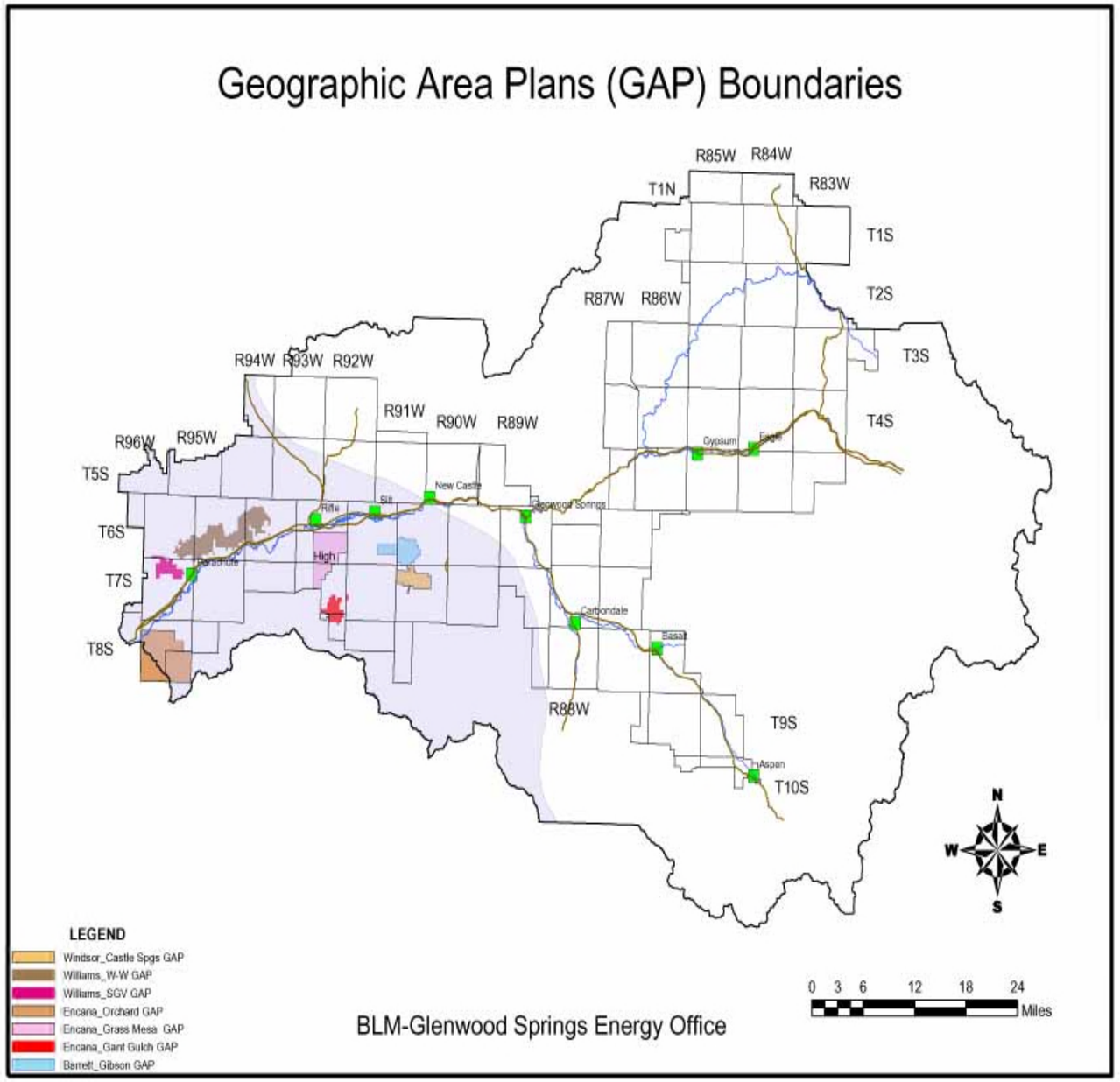
Map 20.


Oil and Gas Wells
R85W
R84W
R83W
T1N
T1S
T2S
R87W
R86W
T3S
R94W
R93W
R92W
R91W
R90W
R89W
T4S
R96W
R95W
T5S
T6S
T7S
T8S
Rifle
Silt
New Castle
Glenwood Springs
Carbondale
Basalt
Aspen
T9S
T10S
R88W
N
W
E
S
LEGEND
Wells as of 11/9/2006
<all other values>
facility_s
AC
AL
DA
DG
DM
IJ
PA
PR
SI
TA
UN
WO
XX
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

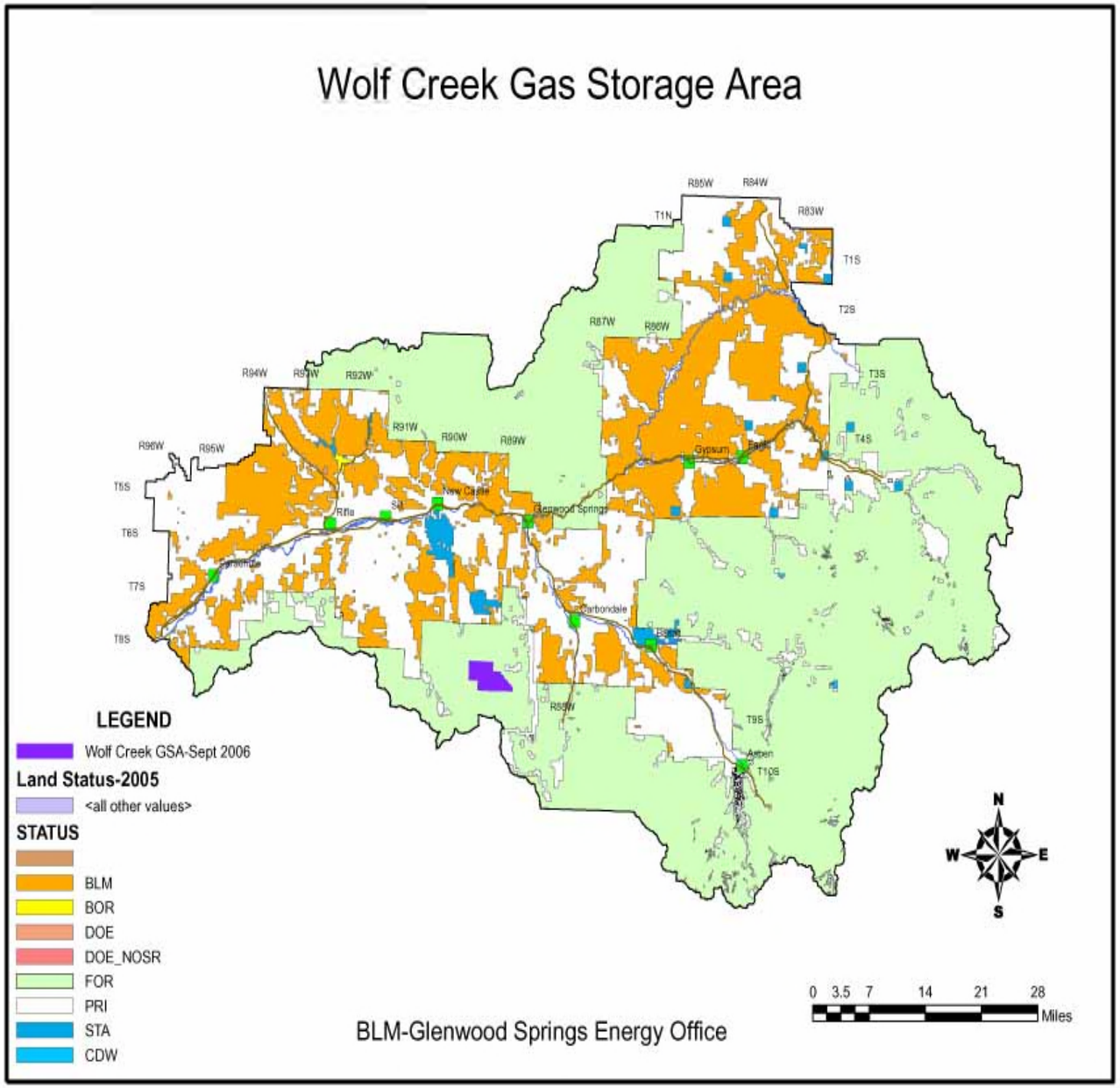
Map 21.


Oil and Gas Fields
R85W
R84W
R83W
T1N
T1S
T2S
R87W
R86W
T3S
R94W
R93W
R92W
R91W
R90W
R89W
T4S
R96W
R95W
T5S
T6S
T7S
T8S
T9S
T10S
R88W
Gypsum
Eagle
New Castle
Glenwood Springs
Rifle
Parachute
Carbondale
Aspen
LEGEND
O&G_Fields
<all other values>
FIELD
BALDY CREEK
DEBEQUE
DIVIDE CREEK
GRAND SLAM
GRAND VALLEY
HELLS GULCH
HORSETHIEF CRE
KOKOPELLI
MAM CREEK
PARACHUTE
RULISON
TIMBERLINE
TRAIL RIDGE
WOLF CREEK
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

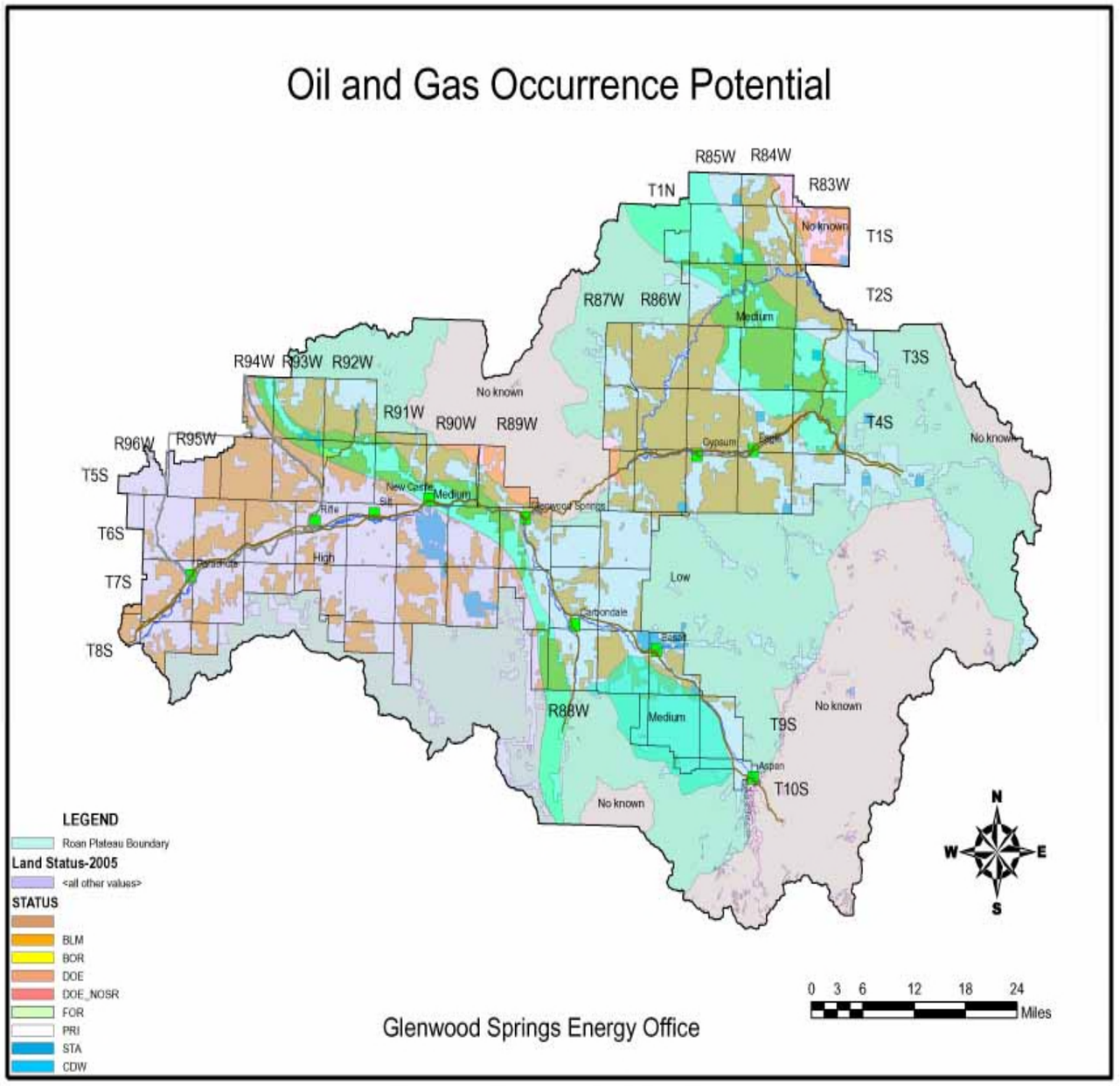
Map 22.


Geographic Area Plans (GAP) Boundaries
R85W
R84W
R83W
T1N
T1S
T2S
R87W
R86W
T3S
T4S
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
T5S
T6S
T7S
T8S
R88W
T9S
T10S
Gypsum
Eagle
New Castle
Rifle
Silt
Glenwood Springs
Parachute
Carbondale
Basalt
Aspen
N
W
E
S
LEGEND
Windsor_Castle Spgs GAP
Williams_W-W GAP
Williams_SGV GAP
Encana_Orchard GAP
Encana_Grass Mesa GAP
Encana_Gant Gulch GAP
Barrett_Gibson GAP
0 3 6 12 18 24
Miles
BLM-Glenwood Springs Energy Office

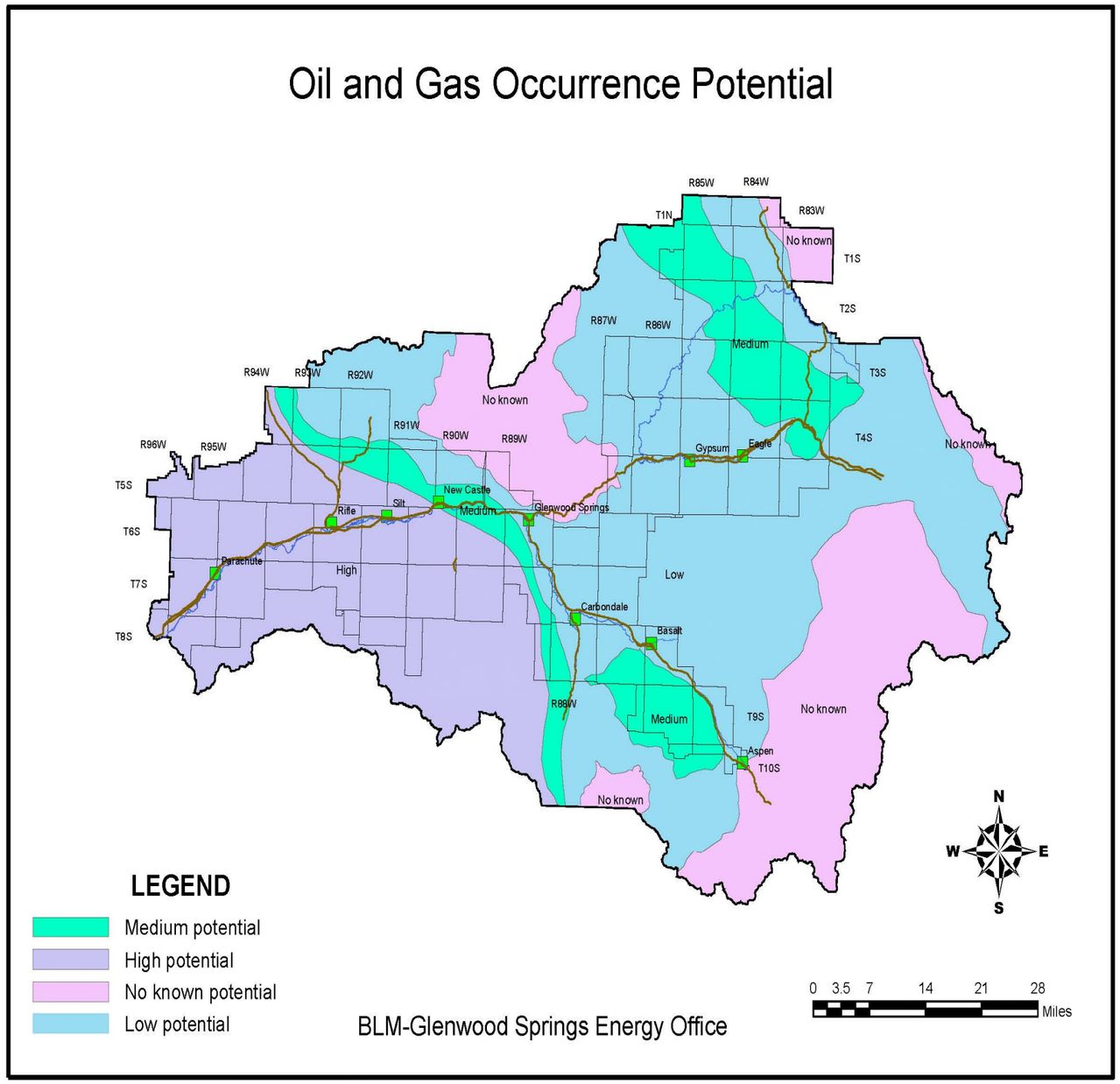
Map 23.


Wolf Creek Gas Storage Area
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
T5S
T6S
T7S
T8S
Rifle
New Castle
Glenwood Springs
Gypsum
Eagle
Carbondale
Aspen
R88W
T9S
T10S
LEGEND
Wolf Creek GSA-Sept 2006
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

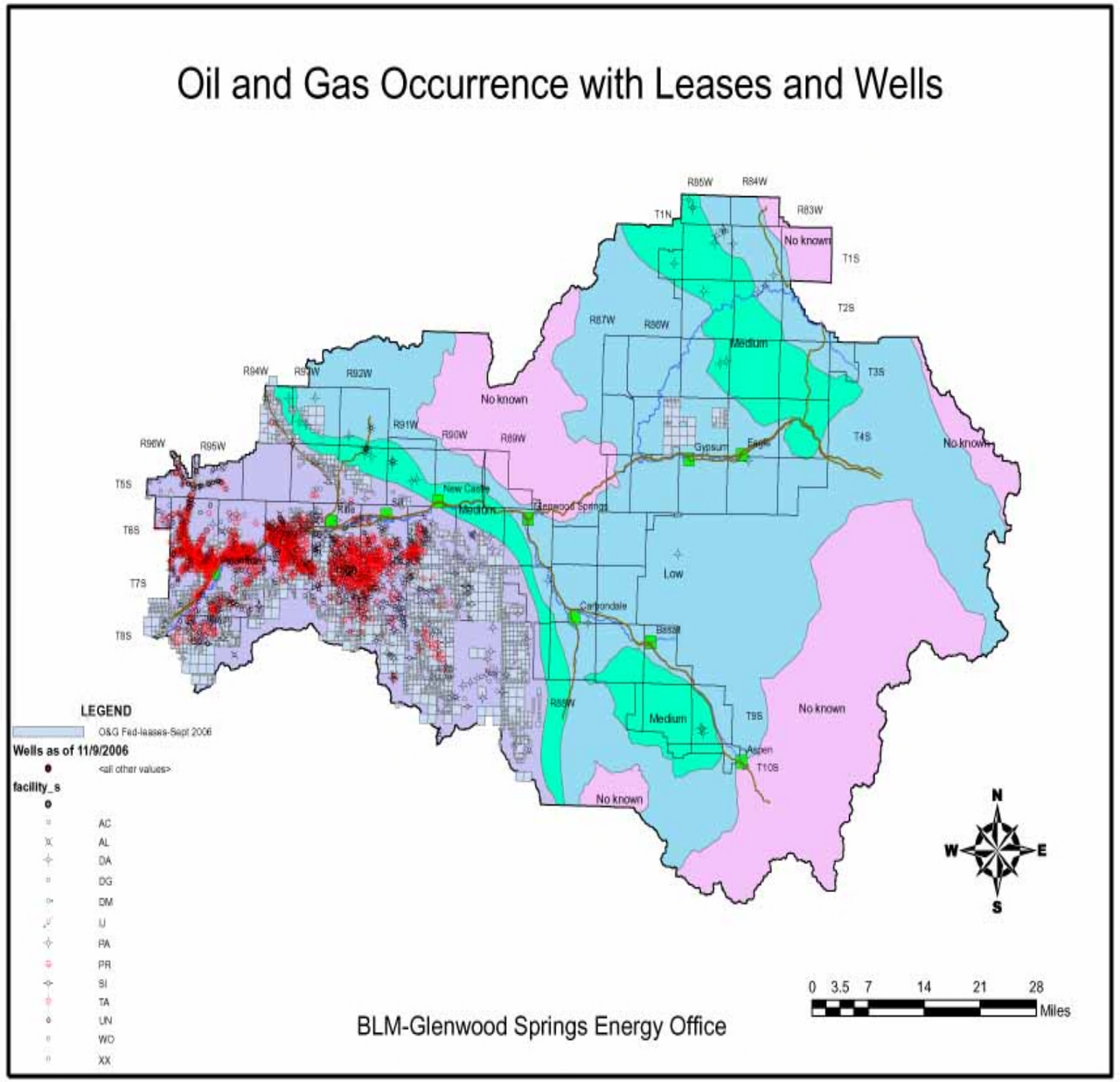
Map 24.


Oil and Gas Occurrence Potential
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
T5S
T6S
T7S
T8S
T9S
T10S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
R88W
No known
Medium
High
Low
Gypsum
Eagle
New Castle
Silt
Rifle
Glenwood Springs
Parachute
Carbondale
Basalt
Aspen
N
S
E
W
LEGEND
Roan Plateau Boundary
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
0 3 6 12 18 24
Miles
Glenwood Springs Energy Office

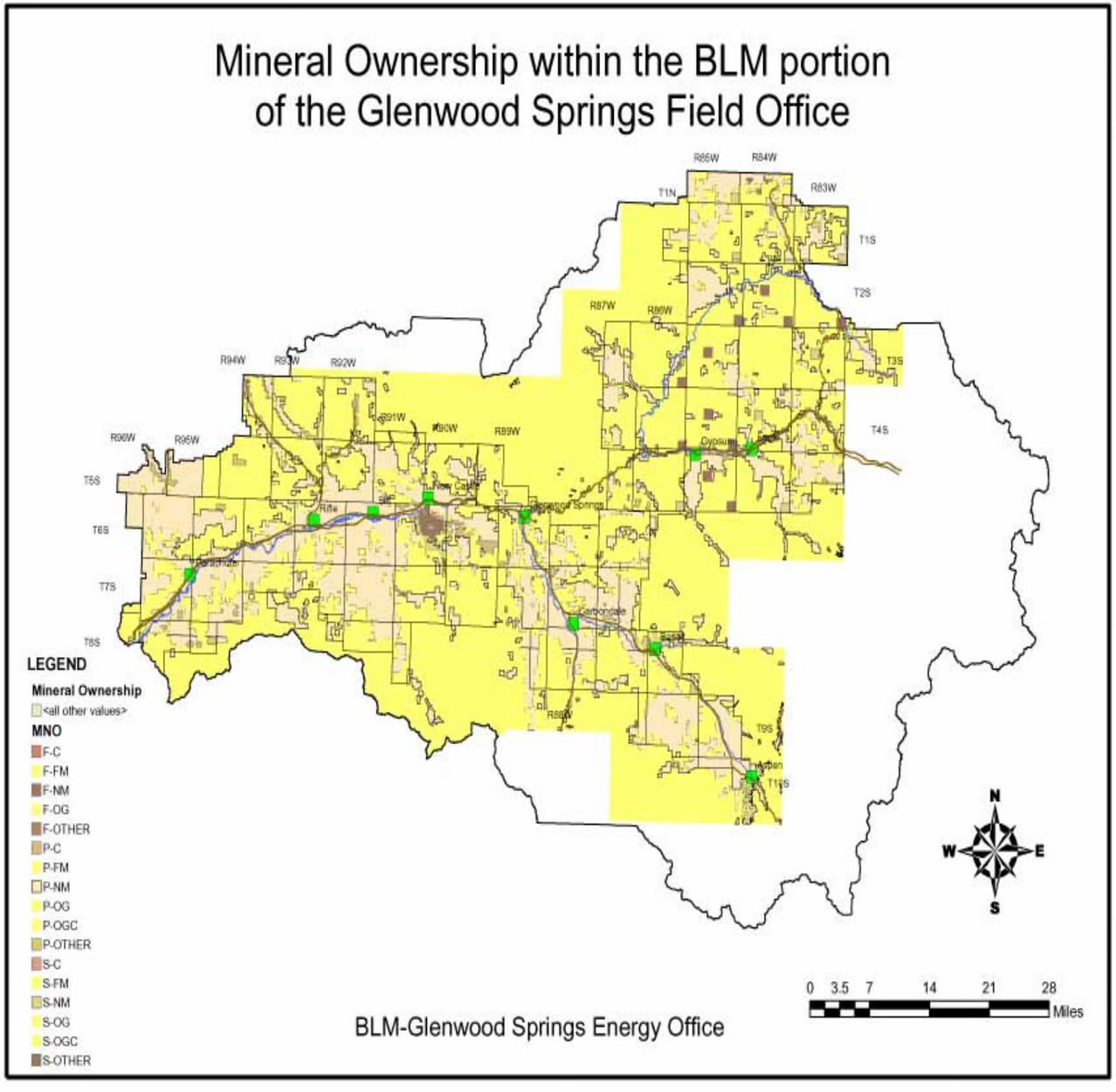
Map 25.


Oil and Gas Occurrence Potential
R85W
R84W
R83W
T1N
No known
T1S
T2S
R87W
R86W
Medium
T3S
R94W
R93W
R92W
No known
R91W
R90W
R89W
T4S
No known
R96W
R95W
Gypsum
Eagle
T5S
New Castle
Silt
Rifle
Medium
Glenwood Springs
T6S
Parachute
High
Low
T7S
Carbondale
Basalt
T8S
R88W
Medium
T9S
No known
Aspen
T10S
No known
N
W
E
S
LEGEND
Medium potential
High potential
No known potential
Low potential
BLM-Glenwood Springs Energy Office
0 3.5 7 14 21 28
Miles

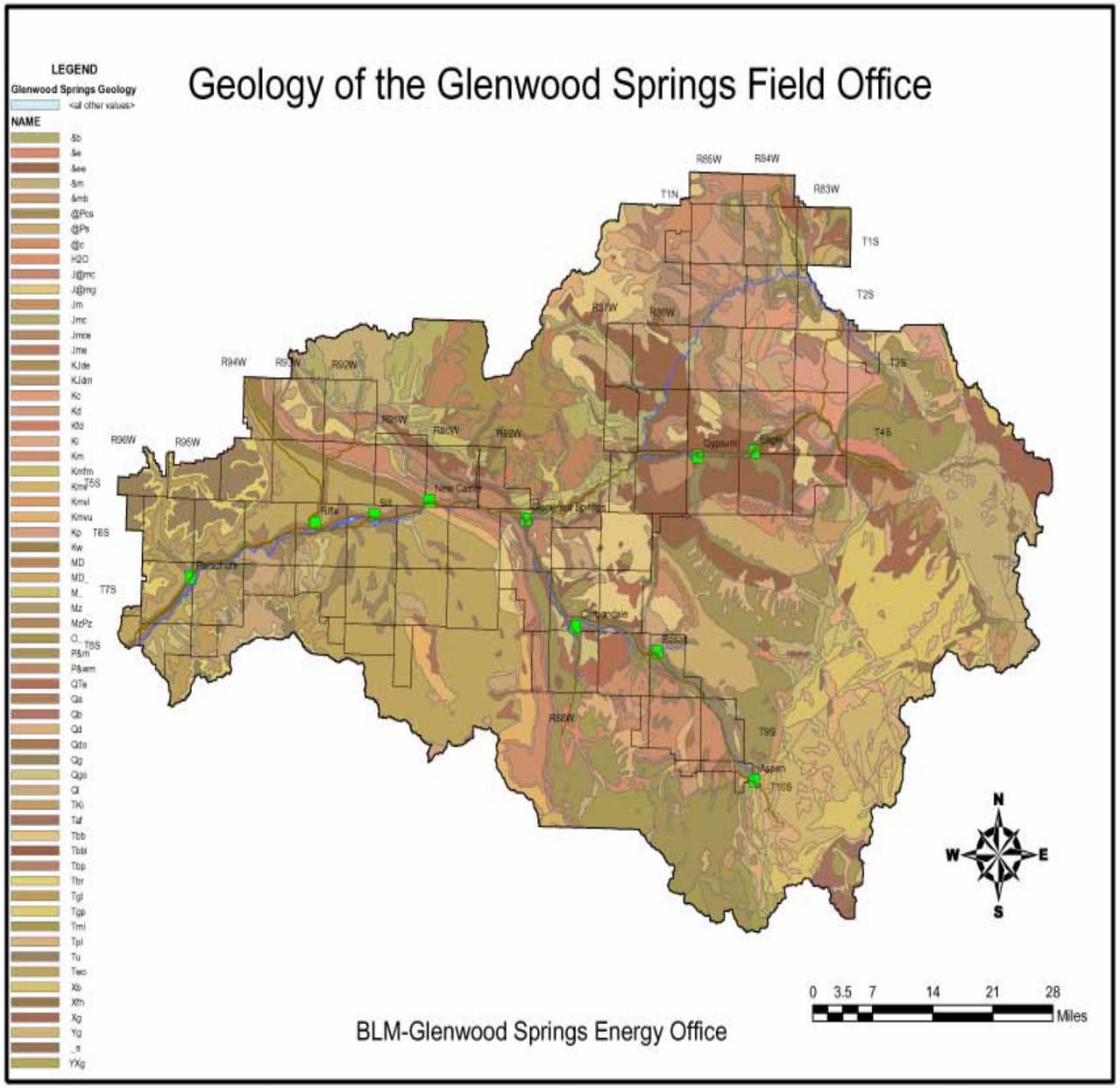
Map 26.


Oil and Gas Occurrence with Leases and Wells
R85W
R84W
R83W
T1N
No known
T1S
T2S
R87W
R86W
Medium
T3S
R94W
R93W
R92W
No known
R91W
R90W
R89W
T4S
No known
R96W
R95W
T5S
T6S
T7S
T8S
Gypsum
Eagle
New Castle
Rifle
Silt
Glenwood Springs
Low
Carbondale
Basalt
R88W
Medium
T9S
No known
Aspen
T10S
No known
LEGEND
O&G Fed-leases-Sept 2006
Wells as of 11/9/2006
<all other values>
facility_s
AC
AL
DA
DG
DM
U
PA
PR
SI
TA
UN
WO
XX
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

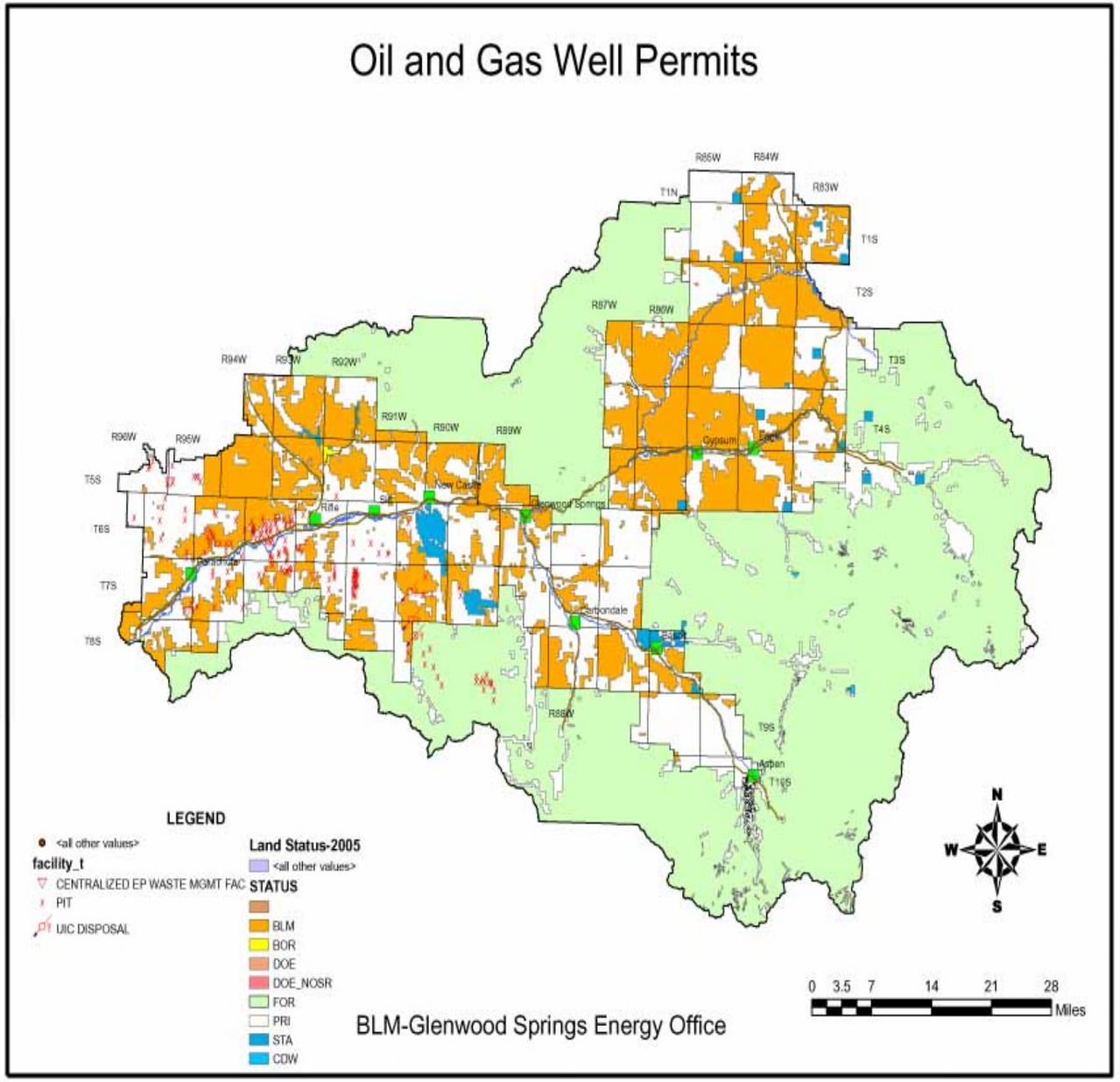
Map 27.


Mineral Ownership within the BLM portion
of the Glenwood Springs Field Office
R85W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
R87W
R86W
R94W
R93W
R92W
R91W
R90W
R89W
R96W
R95W
T5S
T6S
T7S
T8S
Rifle
New Castle
Glenwood Springs
Carbondale
Aspen
T9S
T10S
LEGEND
Mineral Ownership
<all other values>
MNO
F-C
F-FM
F-NM
F-OG
F-OTHER
P-C
P-FM
P-NM
P-OG
P-OGC
P-OTHER
S-C
S-FM
S-NM
S-OG
S-OGC
S-OTHER
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

Map 28.


Geology of the Glenwood Springs Field Office
LEGEND
Glenwood Springs Geology
NAME
R86W
R84W
R83W
T1N
T1S
T2S
T3S
T4S
T5S
T6S
T7S
T8S
T9S
T10S
R94W
R93W
R92W
R91W
R90W
R89W
R88W
R87W
R96W
R95W
Gypsum
Eagle
New Castle
Rifle
Silt
Glenwood Springs
Carbondale
Basalt
Aspen
N
W
E
S
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office

Map 29.


Oil and Gas Well Permits
R85W
R84W
R83W
T1N
T1S
T2S
R87W
R86W
T3S
R94W
R93W
R92W
R91W
R90W
R89W
T4S
R96W
R95W
T5S
T6S
T7S
T8S
Rifle
New Castle
Glenwood Springs
Carbondale
Gypsum
Eagle
R88W
T9S
Aspen
T10S
N
W
E
S
LEGEND
<all other values>
facility_t
CENTRALIZED EP WASTE MGMT FAC
PIT
UIC DISPOSAL
Land Status-2005
<all other values>
STATUS
BLM
BOR
DOE
DOE_NOSR
FOR
PRI
STA
CDW
0 3.5 7 14 21 28
Miles
BLM-Glenwood Springs Energy Office