REASONABLE FORESEEABLE DEVELOPMENT SCENARIO FOR OIL AND GAS ACTIVITES IN THE BLM WHITE RIVER FIELD OFFICE: RIO BLANCO, MOFFAT AND GARFIELD COUNTIES, COLORADO

U.S. Department of the Interior
Bureau of Land Management
White River Field Office
220 E. Market St.
Meeker, Colorado

September 10, 2007

TECHNICAL REPORT PREPARED BY:

MARVIN HENDRICKS, PETROLEUM ENGINEER
PAMELA LESCHAK, GEOLOGIST
BLM WHITE RIVER FIELD OFFICE, MEEKER, COLORADO

REVIEWED BY:

DUANE SPENCER, FLUID MINERALS BRANCH CHIEF, BLM COLORADO STATE OFFICE
7/26/07 (SIGNATURE AND DATE)

HANK SZYMANSKI, PETROLEUM ENGINEER, BLM COLORADO STATE OFFICE
26 July 07 (SIGNATURE AND DATE)

MARION MALINOWSKI, GEOLOGIST, BLM COLORADO STATE OFFICE
7/26/07 (SIGNATURE AND DATE)

TABLE OF CONTENTS

Page

I. EXECUTIVE SUMMARY 1

II. INTRODUCTION 4

III. DESCRIPTION OF GEOLOGY 9

IV. OIL AND GAS RESOURCE POTENTIAL 11

V. HISTORICAL AND CURRENT DRILLING ACTIVITY 19

VI. OIL AND GAS OCCURRENCE POTENTIAL 22

VII. OIL AND GAS DEVELOPMENT POTENTIAL 23

VIII. CURRENT OPERATIONS ACTIVITY IN THE NORTHERN PICEANCE BASIN 29

IX. RATIONALE FOR PREPARING THE WHITE RIVER FIELD OFFICE REASONABLE FORESEEABLE DEVELOPMENT SCENARIO 33

X. REASONABLE FORESEEABLE DEVELOPMENT SCENARIO DRILLING FORECAST 35

XI. REFERENCES 44

XII. APPENDIX A: WRFO TOTAL PETROLEUM SYSTEM AND ASSESSMENT UNIT MAPS 48

XIII. APPENDIX B: EPCA TOTAL OIL AND GAS VOLUME RESOURCE MAPS 56

XIV. APPENDIX C: REASONABLE FORESEEABLE DEVELOPMENT SCENARIO ASSUMPTIONS 60

ADDENDUM: INDUSTRY DEVELOPMENT SCENARIO 61

REASONABLE FORESEEABLE DEVELOPMENT SCENARIO FOR OIL AND GAS ACTIVITES IN THE BLM WHITE RIVER FIELD OFFICE: RIO BLANCO, MOFFAT AND GARFIELD COUNTIES, COLORADO

I. EXECUTIVE SUMMARY

The White River Field Office (WRFO) encompasses 2.675 million acres of land located in northwestern Colorado, primarily in Rio Blanco County, but also includes a small portion of Garfield and Moffat counties. Approximately 2.2 million acres (83%) overlie federal mineral estate of which approximately 1.6 million acres, or 80% of the federal lands available for oil and gas leasing, are currently under federal oil and gas leases. Nearly 294,899 acres of federal lands, including lands in the National Park System, USFS designated wilderness areas and BLM wilderness study areas are not available for oil and gas leasing.

The WRFO has a long history of oil and gas drilling and production activity, with nearly 5,800 wells having been drilled since the early 1920's. Many of those wells are located on the western portion of the WRFO in the Rangely oil field. Extensive natural gas resources have also long been known to exist in the geologic Piceance Basin covering much of the WRFO. However, past conventional drilling and extraction technologies have not been successful in producing the unique geologic traps containing the gas. This factor combined with the historic low prices and demand for natural gas, means this large reserve has remained essentially untapped. Only in the past several years has new technology been developed that, combined with much greater demand for and higher natural gas prices, has stimulated significant interest by the energy industry in developing those extensive natural gas resources. In concert with these factors, two new inter-state natural gas pipelines have been completed into the northern Piceance Basin in just the last two years which will allow the gas to be moved to markets around the country.

Since 1997, when the current Resource Management Plan was completed, the White River Field Office has experienced a three-fold increase in oil and gas drilling activity, much of it located on public lands administered by the BLM. In fact, most of that growth has occurred over the past four years. The number of drilling permits approved by the WRFO has risen from 58 in 2001 to over 200 in 2006. Industry has been submitting increasing numbers of multiple well projects over the past 4 years for the area and discussions with energy companies indicates a long term and continuing significant increase in drilling applications for the WRFO. In this context, BLM decided that a amendment of the 1997 Resource Management Plan was required to address the potential environmental and socioeconomic impacts of such development, determine how best to protect other important resource values through mitigation and best management practices, and

how to best manage the timing and location of this significantly increasing energy development activity.

This Reasonable Foreseeable Development (RFD) scenario projects the maximum levels and types of industry activity, and the associated surface disturbance that might occur on all land ownerships in the WRFO during the twenty year period from 2009 through 2028. The RFD scenario uses the following key assumptions: 1) all potentially productive areas, except those areas designated as closed to leasing by law, regulation or executive order, are open to leasing and development; and 2) only standard lease terms and conditions would be imposed, affording minimum protections to other important resource values. These assumptions, while unrealistic, are necessary to project the maximum potential levels of development activity for environmental analysis purposes and provide full disclosure to the public. Through the public land use planning and NEPA process, BLM will ultimately determine how much and when land is made available for development and will require specific lease stipulations, best management practices and Conditions Of Approval (COA) that will protect other important resource values. The RFD scenario provides the data to be analyzed under various alternatives in the National Environmental Policy Act (NEPA), Environmental Impact Statement (EIS) analysis document supporting the RMP Amendment. This analysis will disclose to the public the potential impacts of a full range of development scenarios as well as possible effects that a range of discretionary management actions to protect other resource values will have in the context of projected possible oil and gas activity. The final decision for the RMP Amendment will determine the appropriate balance of protecting other important resource values, such as wildlife habitat, public health and safety, and local community concerns with the need to meet the nation's energy demands.

Forecasting how much drilling activity that could possibly occur in the next twenty years on federal, state and private lands within WRFO boundaries is largely speculative, and is primarily dependent upon drilling rig availability, product pricing and domestic energy needs during this period in the WRFO. The drilling for oil has largely discontinued except for a modest infill drilling program for the next 15 years in the Rangely oil field. Further, there is a limited amount of coalbed methane (CBM) drilling activity ongoing in the western portion of WRFO lands that may increase modestly if an environmentally acceptable method to dispose of high volumes of produced water can be found. The drilling of oil wells and CBM wells is expected to account for only 5% of all future drilling activity in this RFD forecast. Very limited drilling is expected to occur on United States Forest Service lands (including portions of the White River National Forest) due to the low potential for hydrocarbons occurring in these portions of the WRFO.

The Mesaverde Play area for natural gas located in the northern Piceance Basin is in the early stages of development and actual production information from the operators is limited. The Mesaverde Play Area is characterized by Upper Cretaceous tight gas sand reservoirs occurring in a concentrated area involving 712,190 acres in the central portion of the field office in the northern Piceance Basin. Current development activities in the WRFO are an extension of the drilling taking place in the southern Piceance Basin, within the Glenwood Springs and Grand Junction Field Offices. The drilling of medium-deep to deep (9,000' to 16,500') Mesaverde wells, averaging 8 wells per pad, is anticipated to be the dominant activity in the foreseeable future. Natural gas operators active in the northern Piceance Basin are planning for the

aggressive drilling and development of the Mesaverde Play Area. The drilling of Mesaverde natural gas wells is projected to account for 95% of all future drilling activity in the WRFO.

The majority of northern Piceance Basin natural gas operators are expected to be drilling on 10 acre downhole spacing by 2016. The numbers of new drilling wells are expected to increase continuously each year from 2009 through 2028. In preparation of this analysis, WRFO technical staff took into account the historical drilling activity of similar medium-deep gas drilling located in 1) western Wyoming's Jonah and Pinedale Anticline areas of the Green River Basin, and 2) Colorado's southern Piceance Basin. An analysis of anticipated drilling constraints was also factored into the final projections.

WRFO technical staff also took into account an industry development forecast. This forecast consisted of the original projections from the oil companies for a total of 2,556 multiple well pads projected to be needed over a period of twenty years. The associated surface disturbance for this level of activity was estimated to be 31,257 acres or about 4.4% of the Mesaverde Play Area, or 1.2% of the total land base in the WRFO. The description and analysis for this scenario is attached to this report as an addendum.

The WRFO RFD scenario projects the potential need for 2,146 multiple well pads (averaging 8 wells per pad) by the end of 2028 to develop the natural gas resource to the maximum extent while minimizing protection of other resource values. Detailed further, 1716 multiple well pads are projected to be potentially needed on Federal lands and 430 multiple well pads potentially on fee lands (no wells are projected to be drilled on State of Colorado lands due to the limited acreage that exists). With this level of projected possible activity, a cumulative total of 26,465 acres of associated surface disturbance (construction of well pads, roads, gas plants, pipelines, and other infrastructure) could be expected which translates to about 3.7% of the Mesaverde Play Area, or 1% of the total land base of the WRFO.

It is critical to remember that forecasting how much drilling activity could possibly occur in the next twenty years on federal, state and private lands within WRFO boundaries is highly speculative, and is primarily dependent upon the economics of natural gas markets, the national demand for natural gas, and drilling rig availability during this period. All of these factors are subject to significant changes over time. At this time, the WRFO is processing on the order of 220 drilling permits per year. If this known rate were to continue over the next 20 years, there would be a need for only about 550 multiple well pads with an associated surface disturbance of 6,725 acres. Therefore the overall range of potential natural gas development activity within the WRFO for the period 2009 - 2028 could fall within a range of between 550 multiple well pads and 6,725 acres of associated disturbance and 2,556 multiple well pads and 31,257 acres of associated surface disturbance. Again, the upper range forecast makes unrealistic assumptions of imposing minimum protections for other resources and all potentially productive lands leased and developed to the maximum possible extent. The bottom line is that through the public land use planning and NEPA processes, BLM will ultimately determine how much and when and where development can occur and will require specific lease stipulations, best management practices and Conditions Of Approval (COA) that will protect other important resource values. The BLM's final revised RMP will determine the appropriate balance of protecting other

important resource values, such as wildlife habitat, ensuring public health and safety, and addressing local community concerns with meeting the nation's energy demands.

II. INTRODUCTION

Land Status Overview: The Bureau of Land Management (BLM) White River Field Office (WRFO) area encompasses a total of 2.67 million acres across portions of three counties (Rio Blanco, Moffat, and Garfield Counties) in northwestern Colorado (Figure 1). The federal government holds roughly 71% of the surface land ownership in the WRFO (Table 1). These federal lands are administered by the Bureau of Land Management (BLM), the U.S. Forest Service (USFS), and the National Park Service (NPS). Combined state and county surface ownership comprises less than 3% of the field office area while private ownership accounts for the remaining 26% of the surface land. Most private land ownership occurs in the area just south of the NPS' Dinosaur National Monument and proximal to the towns of Meeker and Rangely. A substantial amount of private real estate is also concentrated in Garfield County along the south-central boundary of the WRFO. Much of the private land in this region is fee acreage held by several oil and gas companies that are currently operating in the area.

Federal oil and gas mineral estate lands comprise over 83% of the WRFO (Figure 2, Table 1). This percentage is slightly higher than the federal surface land area estimate due to the inclusion of split estate acreage. The actual amount of "leasable" federal oil and gas mineral estate, however, is somewhat lower. More specifically, only 72% of the WRFO is available to oil and gas exploration and development on federal lands after the deduction of several "no lease" statute lands such as the USFS Flat Tops Wilderness Area, six BLM Wilderness Study Areas (WSA's), and the NPS' Dinosaur National Monument. The BLM manages oil and gas operations occurring on this federal "leasable" mineral estate. About 50% of acreage in the WRFO is currently leased (Figure 2). This percentage of federal leased acreage represents almost 80% of BLM's "leasable" oil and gas mineral estate in the WRFO (Figure 3). Given the high proportion of leased public lands in the field office, the forecasting of oil and gas exploration and development activities is crucial to the future management of the multiple resources in the region.

White River Field Office (WRFO) Surface Land Status

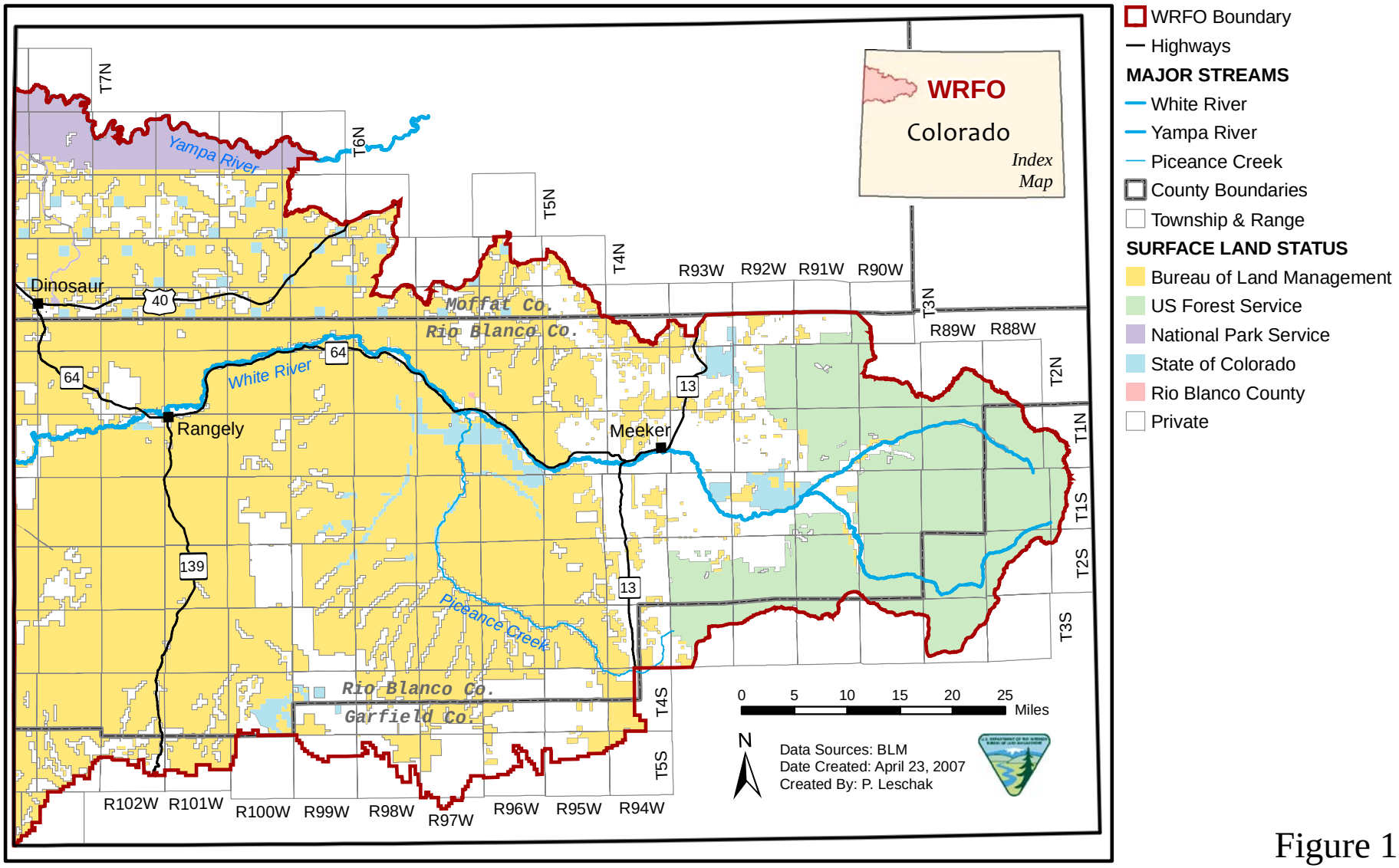


Figure 1

WRFO - Total Area Cited in 1997 WRFO RMP (Acres)	2,675,360
Surface Land Status	
Bureau of Land Management (Acres)	1,460,117
U.S. Forest Service (Acres)	375,762
National Park Service (Acres)	71,090
State of Colorado (Acres)	66,457
Rio Blanco County (Acres)	221
Private (Acres)	699,541
Federal Oil & Gas Mineral Estate (Acres)	2,224,499
Non-Federal Oil & Gas Mineral Estate (Acres)	450,579
Federal "No Lease" Oil & Gas Mineral Estate	
BLM Wilderness Study Areas (Acres)	81,693
USFS Flat Tops Wilderness Area (Acres)	142,106
NPS Dinosaur National Monument (Acres)	71,090
Federal "Leasable" Oil & Gas Mineral Estate (Acres)	1,929,610
Currently Open Acreage	579,236
Currently Leased Acreage	1,350,374
BLM Oil & Gas Mineral Estate	1,777,349
BLM "Leasable" Oil & Gas Mineral Estate (Acres)	1,697,510
Currently Open Acreage	362,287
Currently Leased Acreage	1,335,223
BLM Oil Spring Mountain WSA Leases (Acres)	9,739
WRFO Mesaverde Gas Play Area (Acres)	712,190

Table 1: White River Field Office surface and mineral management status categories and estimated acreages.

WRFO Federal Oil & Gas Mineral Estate

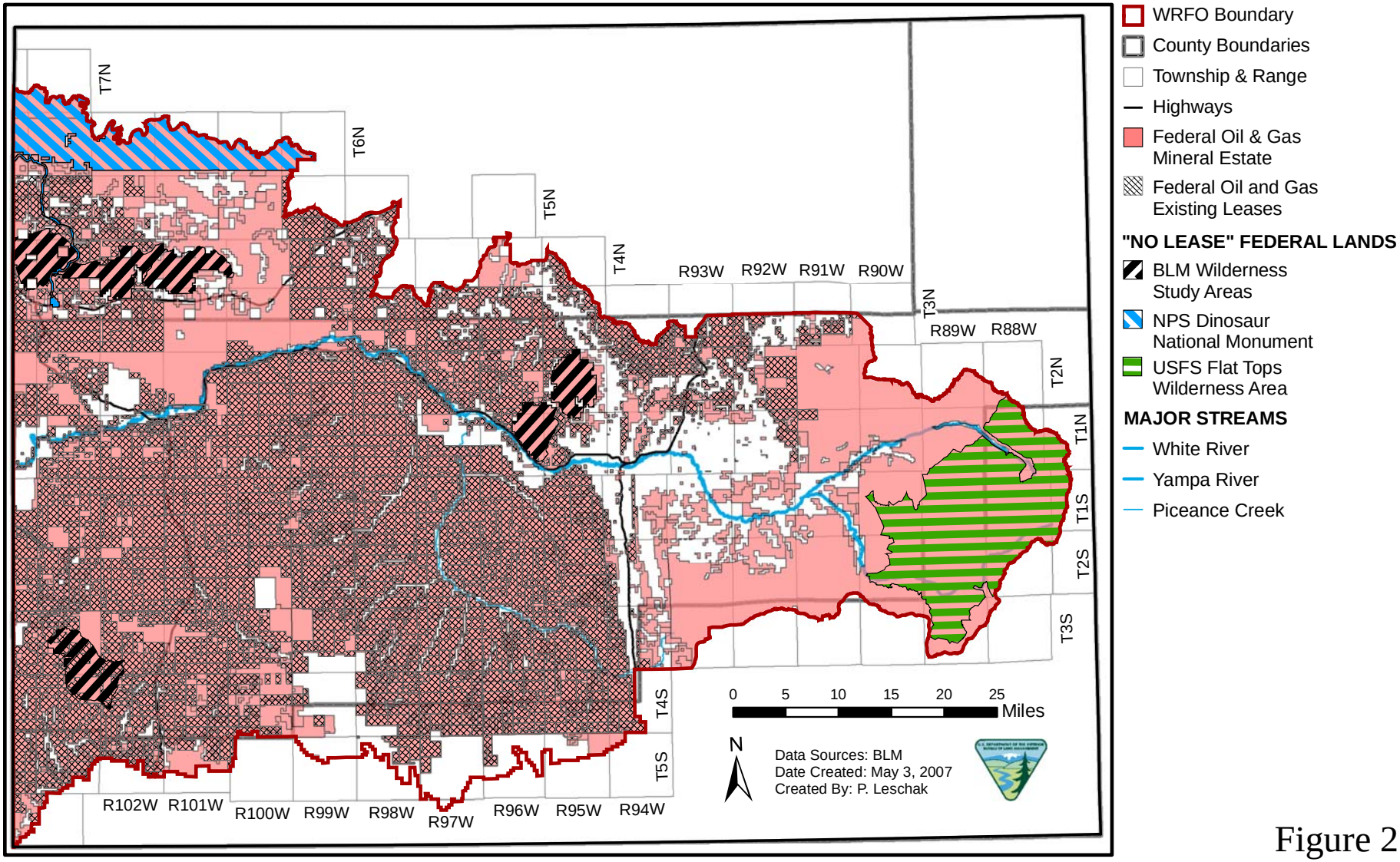


Figure 2

WRFO BLM Oil & Gas Mineral Estate

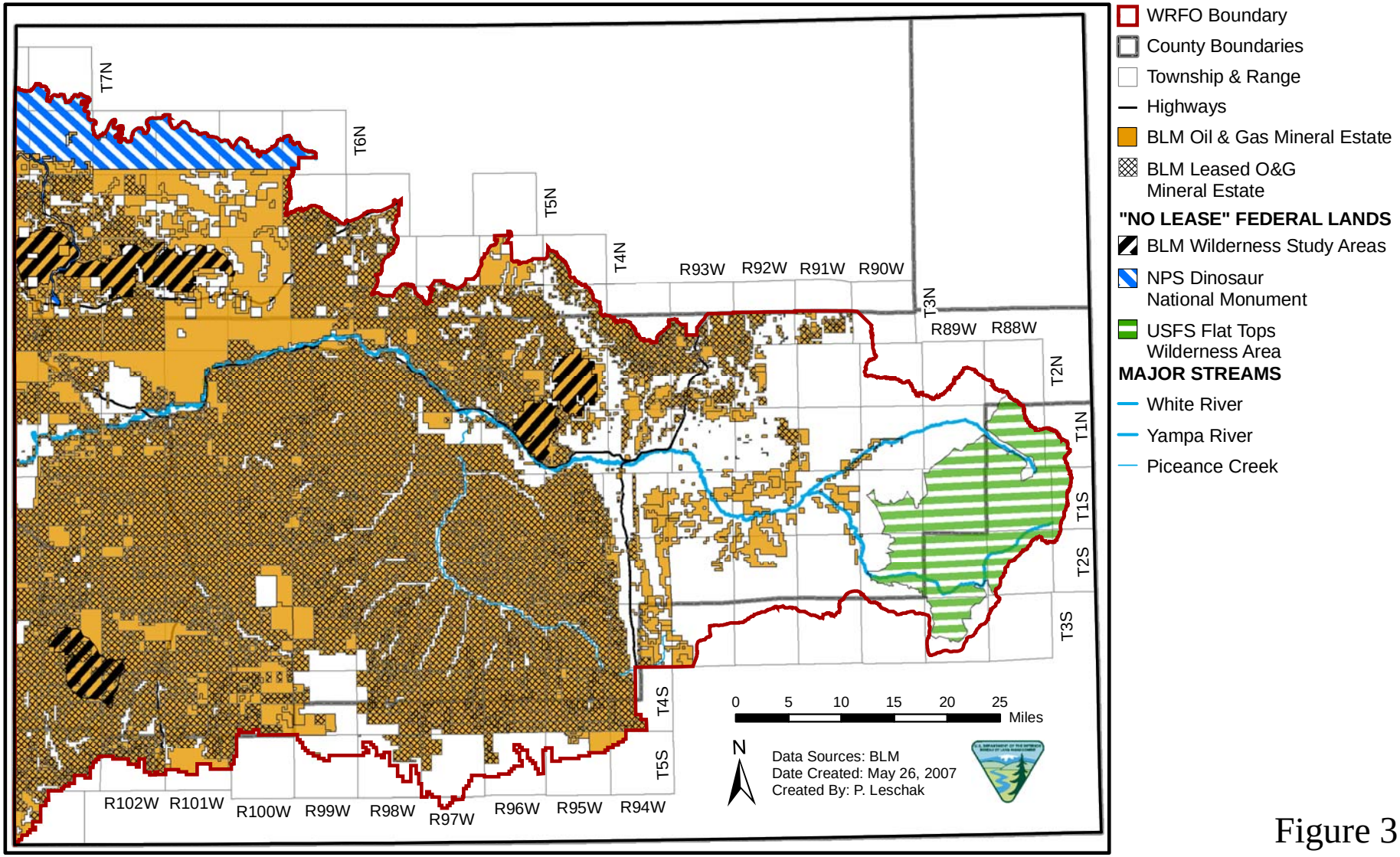


Figure 3

Other BLM field offices in northwestern Colorado are involved in similar forecasting and planning efforts in response to the recent upswing in energy development. To the north, the Little Snake Field Office (LSFO) (Figure 4) is in the process of finalizing a Draft RMP and anticipates that 3,031 wells will be drilled during the next twenty years. To the south, the Glenwood Springs Field Office (GSFO) is involved in revising the existing RMP and RFD across their entire field office area.

III. DESCRIPTION OF GEOLOGY

Previous Work: Regional appraisals related to the hydrocarbon resources that underlie federal lands in the western United States have been the focus of two major federal assessment efforts. First, the U.S. Geological Survey (USGS) National Assessment Project has evaluated the distribution, quantity, and availability of technically recoverable oil and gas resources that could be added to the proved reserves of the United States for numerous onshore sedimentary basins with known hydrocarbon potential. The USGS National Assessment Team released their initial document in 1995 (USGS, 1995) and later updated their results for the Uinta-Piceance Basin in a 2003 report (USGS, 2003). The USGS National Assessment Project became the foundation for a second federal energy appraisal effort commonly referred to as the "EPCA Study." In order to comply with the Energy Policy and Conservation Act (EPCA) Amendments of 2000, the U.S. Departments of Interior, Agriculture, and Energy analyzed the USGS' technically recoverable resource estimates in relation to federal actions that inhibit access to these resources on public lands. The initial (Phase I) EPCA study was released in 2003 (U.S. Departments of the Interior, Agriculture, and Energy, 2003); a second report was introduced in 2006 (U.S. Departments of the Interior, Agriculture, and Energy, 2006). The EPCA Studies were intended to provide energy policymakers and federal land managers with quantitative information to assist them in making complex decisions regarding oil and gas activities on public lands.

Geologic Setting: Most of the WRFO overlaps two USGS petroleum resource assessment provinces: the Uinta-Piceance Province and Greater Green River Province (USGS, 1995 and 2003) (Figure 4). Regionally, the WRFO is situated near or along the northern and northeastern limits of the Uinta-Piceance Basin with about 86% of the field office included in this sedimentary province. A very small section of the Greater Green River Basin occurs in the easternmost part of the field office area and covers less than 2% of the WRFO (Figure 4). This small portion of the Greater Green River Basin is characterized by relatively low hydrocarbon potential, extremely sparse well control (i.e. a single dry hole), very few existing oil and gas leases, and an absence of drilling activity within the last 50 years. As such, the resource potential of the Greater Green River Basin has not been considered in this WRFO RFD forecast analysis.

The term "Piceance Basin" has been used interchangeably in describing structural, depositional, and surface drainage basins in this portion of northwest Colorado. Structurally, the Piceance Basin is a northwest-trending, asymmetrical downwarp that is surrounded tectonic uplifts. Depositionally, the basin represents the resultant depression

Northwest Colorado BLM Field Offices & Geologic Basins

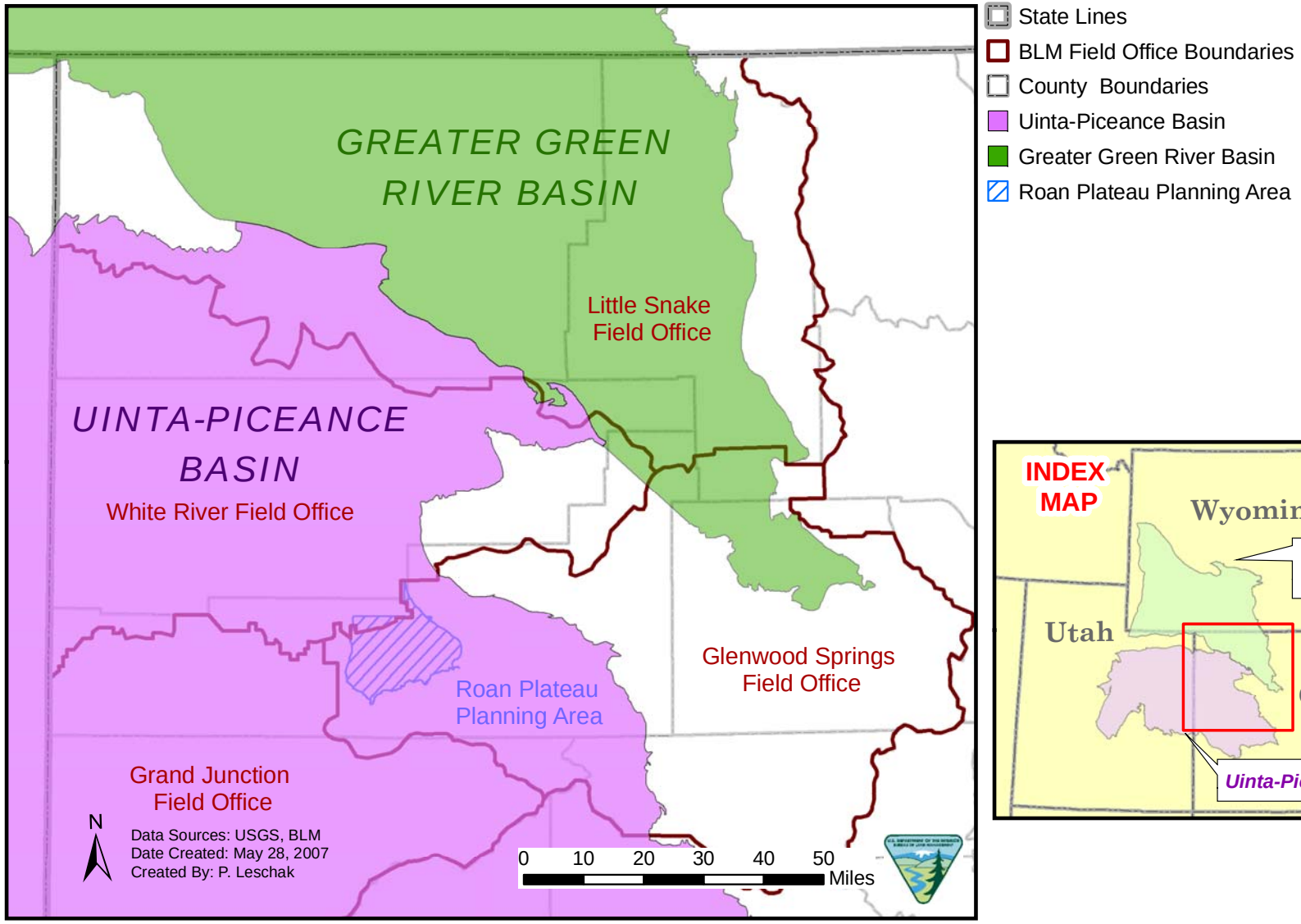


Figure 4

formed between these uplifts that gradually infilled with a thick sequence of sedimentary rocks. Lastly, the Piceance Creek surface drainage system is defined by the Piceance Creek streambed and its associated tributaries. This system predominantly drains surface exposures of the Eocene Uinta Formation in the central part of the WRFO (Figure 5).

Several major physiographic-tectonic features outline the extent of the Piceance Basin (Figure 5). These features are defined by the surface geology combined with structurally-controlled topographic patterns in the region. To the west, the Piceance Basin is separated from the Uinta Basin by the north-south trending Douglas Creek Arch and the Rangely Anticline. Jurassic and older sedimentary rocks define the Yampa Plateau uplift which bounds the Piceance Basin to the north. The northeastern limit of the basin is defined by a complex set of closely spaced folds in the northern Danforth Hills area, separating the Piceance and Greater Green River Basins more or less along the administrative boundary of the WRFO. The steeply dipping eastern flank of the Piceance Basin is manifested by sharply upturned Cretaceous beds of the Grand Hogback monocline which define the western edge of the White River Uplift. The structural axis of the Piceance Basin occurs just west of and closely parallels the general trend of the Grand Hogback. Toward the south, the Piceance Basin extends beyond the WRFO administrative boundary and into central portions of western Colorado. The interior of the northern Piceance Basin is characterized by a system of broad, northwest-southeast trending folds in the eastern and central parts of the study area (the largest of which is the Rangely Anticline), and a series of northeast-southwest extensional normal faults over the Douglas Creek Arch (Figure 6).

Surface rock exposures within the WRFO range from Precambrian to Tertiary in age and include igneous volcanic rocks, clastic and carbonate sedimentary deposits, and metamorphosed crystalline basement rocks. A generalized stratigraphic column for the Uinta-Piceance province is presented in Figure 7. This diagram identifies the established stratigraphic nomenclature, the major hiatus' (episodes of non-deposition and/or erosion), and the principal source rocks and productive formations of the Piceance Basin in northwestern Colorado.

IV. OIL AND GAS RESOURCE POTENTIAL

2003 USGS National Assessment Project Summary: The USGS has provided a comprehensive geological assessment of the undiscovered, technically-recoverable oil and gas resources (i.e. potential additions to reserves) for the Uinta-Piceance Basin (USGS, 2003). This quantitative estimation was based on the "total petroleum system" concept. A total petroleum system describes genetically-related petroleum accumulations across a distinct geographic area sharing common source rock, reservoir rock, and hydrocarbon trap characteristics. The areal extent of a TPS includes proven hydrocarbon accumulations, as well as potential oil and gas migration pathways. Individual TPS' consists of one or more assessment units (AU's). An assessment unit is a single, mappable rock volume that contains hydrocarbon accumulations with similar geologic characteristics within a given TPS. The USGS (2003) identified five TPS' in

WRFO Major Tectonic/Physiographic Features & Surface Geology

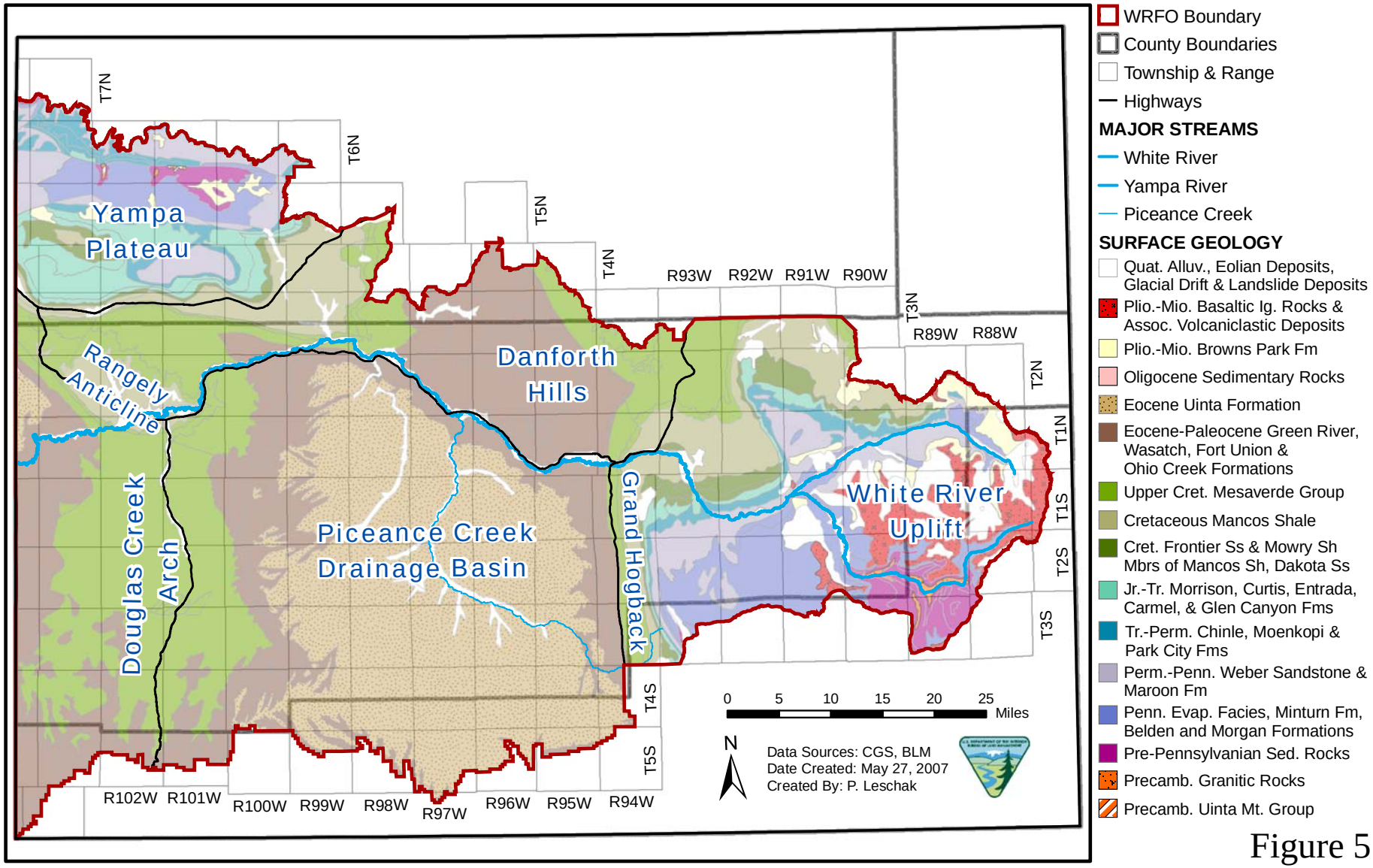


Figure 5

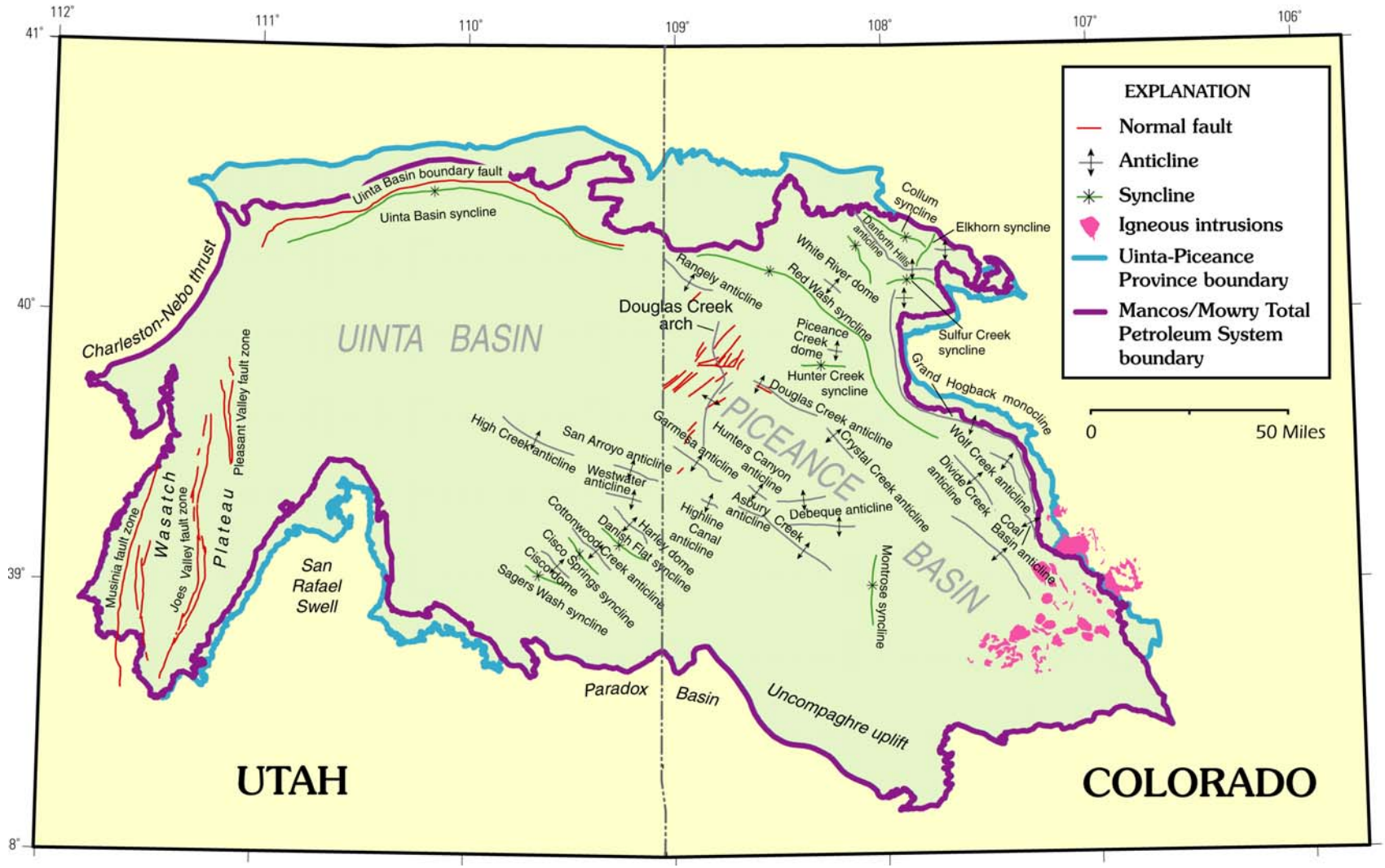


Figure 6: Major structural features and igneous intrusions in the Uinta-Piceance Province (from U.S. Geological Survey, 2003).

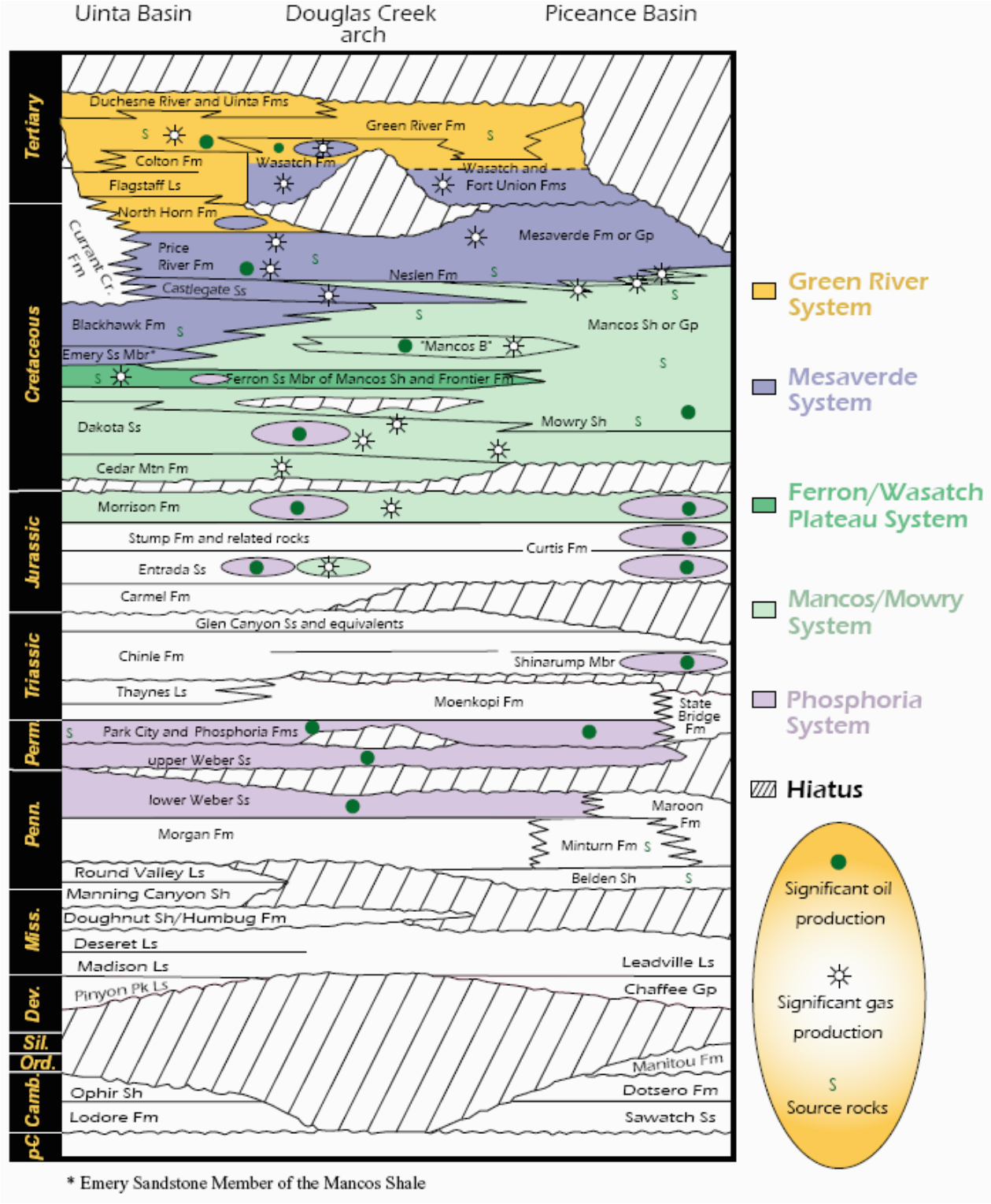


Figure 7: Generalized stratigraphic column showing the reservoir rocks that contain significant amounts of oil and gas derived from the five major total petroleum systems contributing hydrocarbons to the Uinta-Piceance Province (from U.S. Geological Survey, 2003).

the Uinta-Piceance Basin (Figure 7), four of which occur in the WRFO: the Green River TPS, the Mesaverde TPS, the Mancos/Mowry TPS, and the Phosphoria TPS. Eleven major AU's occur within these four TPS' in the study area (Appendix A). The individual assessment units each represent "conventional," "continuous," or "transitional" hydrocarbon accumulations (Figure 8). Conventional traps possess discrete geographic limits with well-defined hydrocarbon-water contacts. In contrast, continuous (also known as "unconventional") accumulations are regionally-extensive with indefinite boundaries and they generally lack obvious hydrocarbon-water contacts (e.g. coalbed gas, tight sand reservoirs, basin-centered accumulations, self-sourced shale reservoirs, etc.). At their edges, continuous accumulations commonly grade or are "transitional" into updip areas dominated by conventional structural and/or stratigraphic traps.

This geologically-based conceptual framework and the resultant TPS' and AU's enabled the estimation of mean undiscovered, technically-recoverable oil and gas resources in the Uinta-Piceance Basin (USGS, 2003). Estimated mean recoverable reserves for the Uinta-Piceance Province are 21 trillion cubic feet of gas (TCFG), 59 million barrels of oil (MMBO), and 43 million barrels of natural gas liquids (MMBNGL), derived from a summation of the individual assessment unit resource estimates in all five TPS'. Nearly all of the gas resource is from continuous reservoirs, with 62% from the Mesaverde TPS and another 33% from the Mancos/Mowry TPS in Utah and Colorado. Given that the Piceance Basin in the WRFO is primarily a gas-producing region comprising about 12% of the total area of the Uinta-Piceance province, the estimated mean recoverable gas resource volume in the WRFO may be order of 2.5 TCFG. This estimate varies significantly from those cited in other technical reports, to be discussed in greater detail later in this document.

2006 EPCA Study Summary: In the 2006 EPCA Study, the USGS' mean undiscovered technically-recoverable oil and gas volumes were added to proved-reserve estimates generated by the Energy Information Administration (EIA) in order to assess the total oil and gas resource potential for the Uinta-Piceance Basin. Total hydrocarbon density maps were used to illustrate the distribution of potential resources across the basin (Maps G and H of Appendix B). These maps were primarily based on a stacking of the resource volumes associated with each of the USGS assessment units. The highest gas resource potential (1225-2460 million cubic feet of gas per square mile) (MMCFG/mi^2) in the WRFO was associated with the Piceance Creek Drainage Basin. Moderate gas densities were attributed to Douglas Creek Arch (150-349 MMCF/mi^2) with only minor volumes (0-58 MMCF/mi^2) along the margins of the Uinta-Piceance Province. Total oil volume maps revealed a similar pattern, with elevated oil densities (5-12 thousand barrels of oil per square mile) (MBO/ mi^2) localized in the Piceance Creek Drainage Basin and little to no oil potential (0-4 MBO/ mi^2) expected in the remainder of the study area. Thus, the 2006 EPCA study predicts greatest hydrocarbon resource potential in the Piceance Creek Drainage Basin of the central WRFO, and that the bulk of these petroleum resources will occur as natural gas in the northern Piceance Basin.

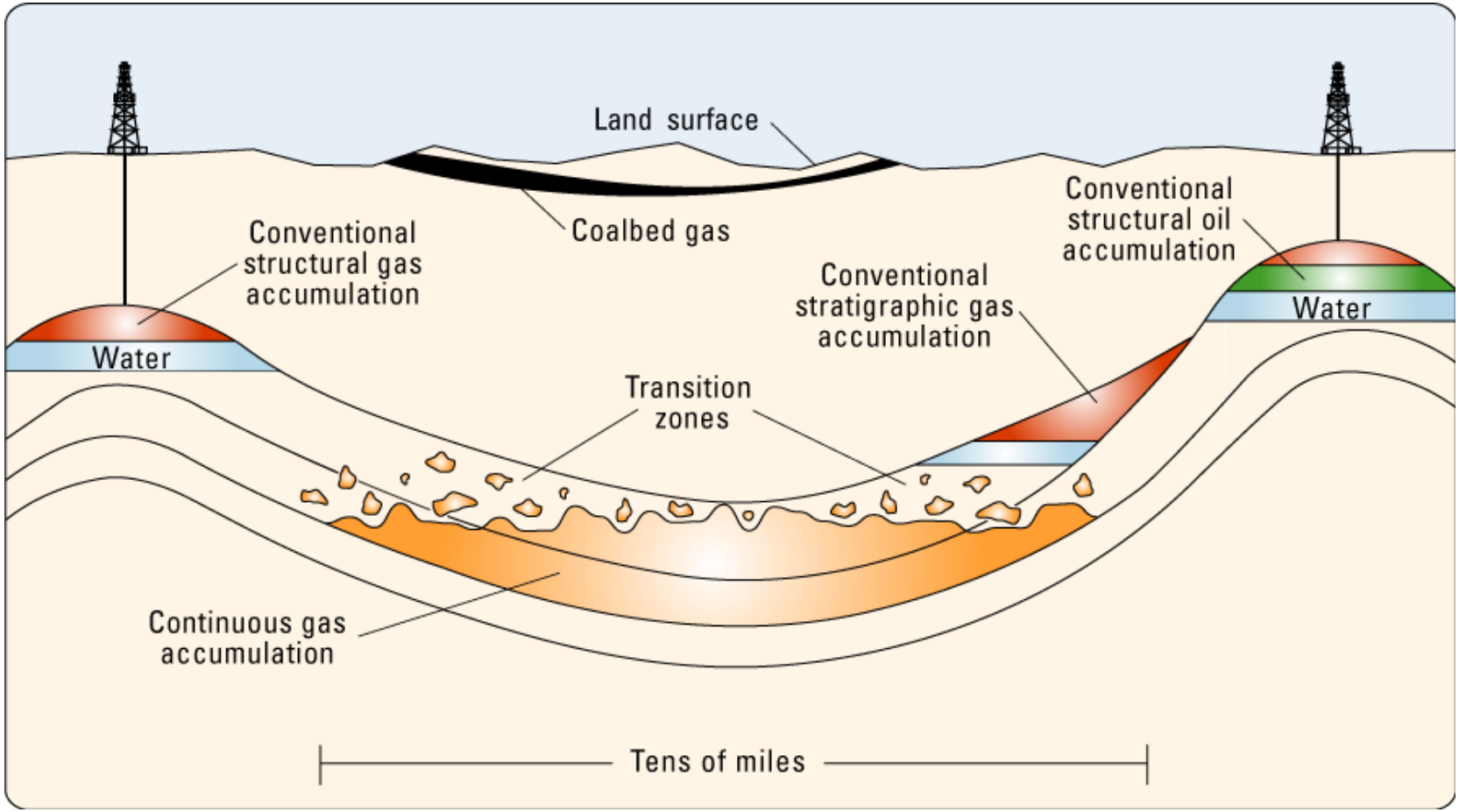


Figure 8: Schematic diagram of the types of oil and gas resources in the USGS assessment (from U.S. Geological Survey, 2003).

Upper Cretaceous Mesaverde Reservoirs: The primary productive reservoir interval in the Piceance Creek Drainage Basin are sandstones (and adjacent coals) of the Upper Cretaceous Mesaverde Group. The overall stratigraphic section consists of largely regressive, fluvial to marginal marine sands, siltstones, shales and coals. Approximate depth to the top of the Mesaverde Group in the central part of the WRFO ranges between 6,000 and 9,000 feet and the interval demonstrates a gross stratigraphic thickness of between 3,000 feet (on the uplifted margins of the basin) to 7,000 feet (along the basin axis). In descending stratigraphic occurrence, the major reservoir units within the Mesaverde Group include: the Williams Fork Formation and basal Cameo Coal Zone; the Rollins, Cozzette, and Corcoran Sandstone Members of the Iles Formation; the Sego and Castlegate Formations; and the upper part of the Mancos Shale. Most of the gas-bearing sands exhibit relatively low porosities (<13%) and permeabilities (<0.1 md). The majority of the reservoirs are isolated to semi-amalgamated, lenticular sands deposited in alluvial and coastal plain channelized systems. The performance of the Mesaverde reservoirs is largely controlled by this segregated reservoir geometry (and its inherent internal stratigraphic heterogeneities), as well as the distribution of secondary fractures and degree of free water saturation that occurs in these rocks. Hydrocarbon trap types are highly variable, ranging from localized, conventional oil and gas accumulations with combined structural-stratigraphic trap configurations (mostly near the margins of the Piceance Creek Drainage Basin) to the more regionally-extensive, transitional and continuous basin-centered gas plays for these discrete reservoir units in the structurally-deeper, central portions of the basin. Although the upper surface of the Mesaverde interval generally coincides with the top of a thick (>5,000 feet), gas-saturated section that is commonly associated with this rock unit, the top of continuous gas surface actually cuts across major stratigraphic boundaries near the uplifted margins of the basin (Figure 9). This is a feature commonly associated with continuous gas traps. Lastly, it is the Mesaverde continuous, basin-centered, tight sand gas accumulation that contains the bulk of the technically recoverable reserves in the basin. These gas reserves have increasingly becoming the focus of present-day industry activity in the WRFO.

Self-sourced coalbed gas (CBG) reservoirs of the Douglas Creek Arch and southern Danforth Hills regions are also stratigraphically associated with Upper Cretaceous Mesaverde Group. The primary CBG reservoir is the Cameo Coal Zone at the base of the Williams Fork Formation, ranging in gross thickness from 300 to 600 feet with net coal thicknesses of 80 to 150 feet thick. These reservoirs are often perforated and downhole commingled with reserves from the adjacent Williams Fork sandstones. Additional CBG zones are also noted in the underlying Iles Formation. In general, depths to the top of the Mesaverde CBG reservoirs range from 0 feet at surface outcrops around the basin margins to more than 12,000 feet over the basin axis. About two-thirds of the CBG reservoirs occur at depths of at least 5,000 feet (EPA, 2004). In general, these deep, continuous CBG accumulations are characterized by very low permeability coal reservoirs (sometimes with permeabilities greater than those in adjacent, Mesaverde gas-bearing sands) in overpressured hydrocarbon systems within the Piceance Basin interior. Similar to the continuous Mesaverde gas sand reservoirs, the production performance of CBG reservoirs is largely controlled by both the natural fracture and movable water saturation properties of the rock.

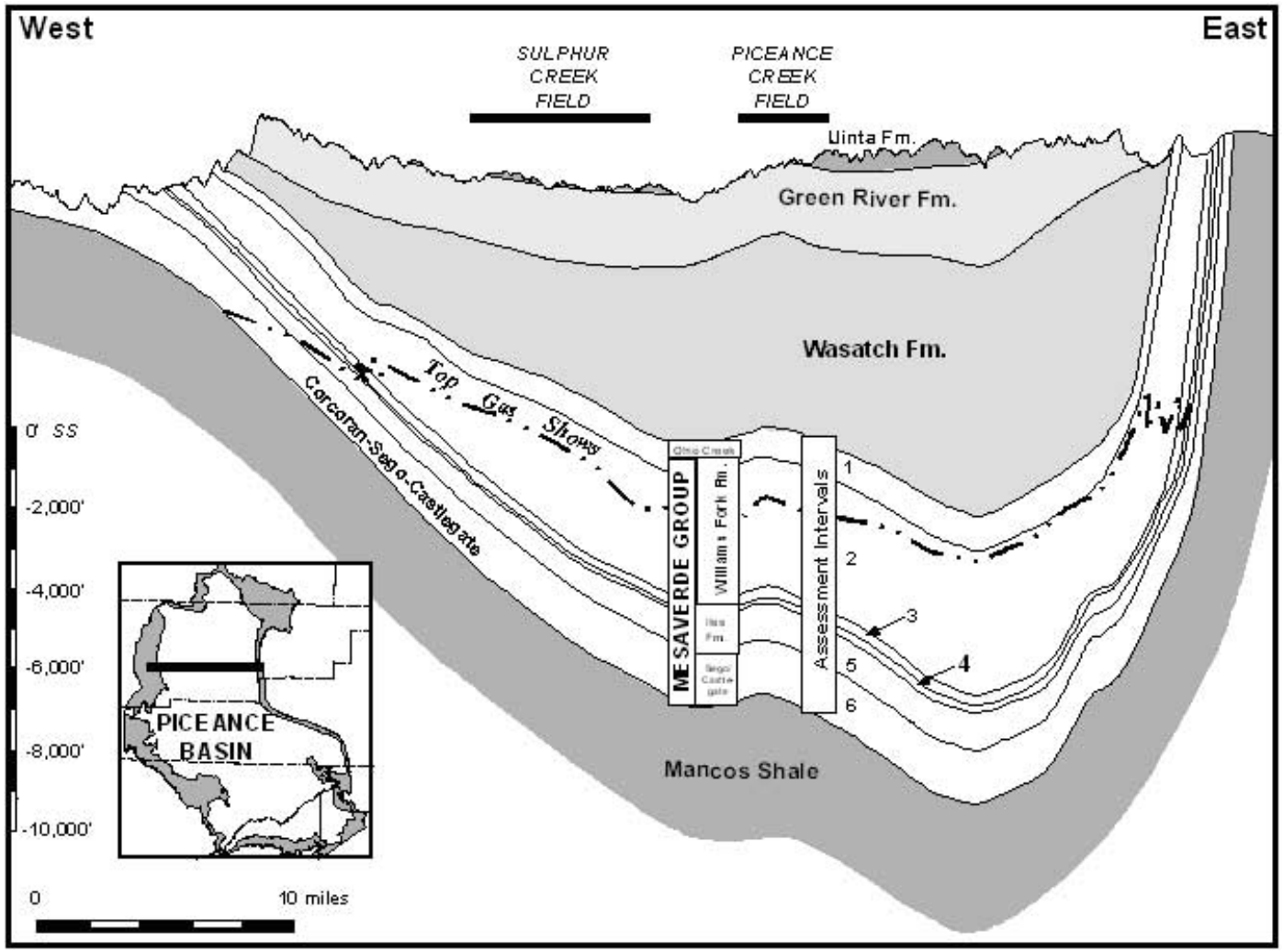


Figure 9: East-west cross-section through the northern Piceance Basin showing the six major reservoir assessment intervals as well as the mapped top of gas surface in the Mesaverde Basin-Center Gas Play, northern Piceance Basin, Colorado (Hood and Yurewicz, 2005).

Other Significant Reservoirs: There are a number of additional proven oil and gas reservoirs in the WRFO. The most significant of these is the Cretaceous Mancos Shale (which includes the Mowry Shale, Mancos "B" and associated isolated sandstone members). The Mancos reservoirs are geographically concentrated in the Rangely Anticline area, where they are primarily oil-bearing, and over the Douglas Creek Arch, where these reservoirs are largely gas-productive. The Upper Cretaceous Dakota Sandstone and Permian-Pennsylvanian Weber Sandstone are also productive in this part of the WRFO, although they are largely associated with conventional-type (structural and stratigraphic) traps in the basin. To the east in the Piceance Creek Drainage Basin area, the Tertiary (Paleocene) Wasatch Formation is an important uphole, secondary target for deeper Mesaverde well penetrations. It is primarily a gas-bearing unit associated with conventional-type accumulations exhibiting strong stratigraphic trap elements.

V. HISTORICAL AND CURRENT DRILLING ACTIVITY

Historical Activity: The WRFO contains almost 5,800 existing boreholes in more than 60 proven fields (Figure 10). Initial exploration activity began in the late 1800's with the drilling of oil seeps and structural uplifts having obvious surface expression. The first well drilled in the region spudded in 1890 on the White River Dome (T2N, R96W) in the central part of the field office area, where gas was discovered in shallow sandstones of the Tertiary Wasatch Formation. In 1902, oil was encountered in shallow fractured shales of the Cretaceous Mancos Formation near surface seeps on the Rangely Anticline. Twenty years later, deeper oil reserves were first completed in the Permian-Pennsylvanian Weber sandstone at Rangely Field. Since that time, the Rangely oil accumulation has proven to be the largest field in the province and, with estimated recoverable reserves of 804 million barrels of oil equivalent (MMBOE), is ranked 46th in the top 100 giant fields of North America (Hyne, 1991). The Rangely Anticline has contributed about 90% of the total oil volume produced in the WRFO; most of that production is from the Weber sandstone.

Between 1900 and 1930, overall drilling activity in the WRFO was relatively low with less than a dozen or so wells spudding annually. Most of the rank wildcat drilling was concentrated in the northern part of study area with very limited success rates of about 15%. The largest wildcat discovery during this timeframe proved gas reserves in the Weber sandstone in the Thornburg Field (T3N, R91W) on the northeastern boundary of the WRFO. Most of the development activity throughout the thirty year period was localized in both the Rangely and White River Dome Fields where only about half of these penetrations were ultimately completed and produced. Limited drilling continued into the 1930's with largely similar results. In 1930, a notable gas discovery well was drilled in the central part of the WRFO on the Piceance Creek Dome (T2S, R96W) in the Tertiary Wasatch Formation. In addition, exploration efforts initiated earlier in the 1920's in the Wilson Creek area (T3N, R94W) finally proved successful in 1938 with the discovery of oil reserves in the Jurassic Morrison Formation. Exploratory drilling activity in the 1940's remained relatively low - fewer than a dozen wildcat wells were spudded annually, with disappointing overall results. One important wildcat discovery,

WRFO Oil & Gas Fields and Existing Wells

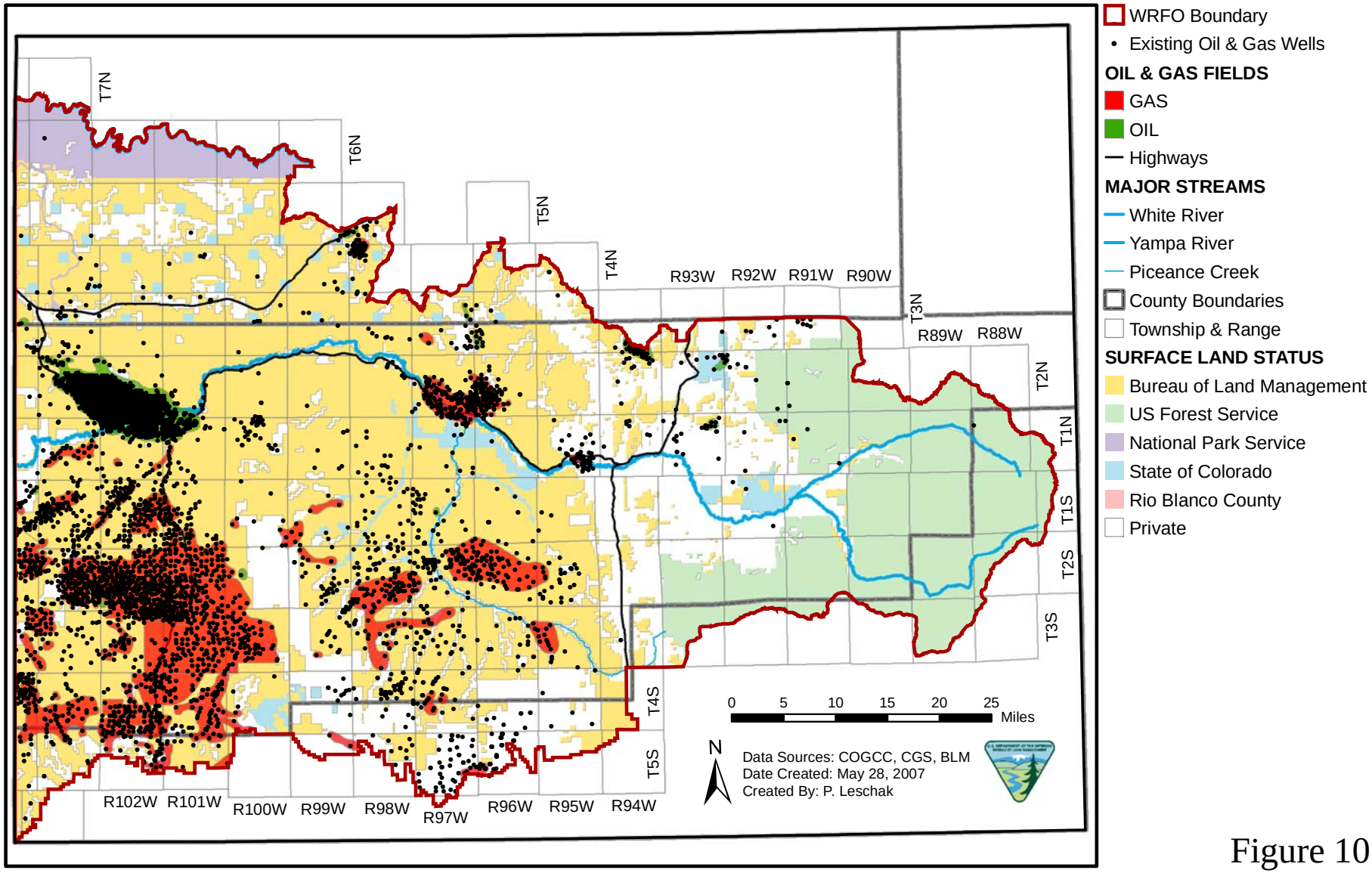


Figure 10

however, was drilled and completed in the Douglas Creek Arch area, where commercial gas reserves were encountered fractured reservoirs of the Upper Cretaceous Mancos Shale. In contract to exploratory activity, development drilling was accelerated in the WRFO during the 1940's, particularly on the Rangely Anticline. Approximately 438 of the almost 600 development wells drilled (74%) were completed in the Rangely Field during this period. Limited development activities were also pursued the Wilson Oil Field where operators attained a 100% success rate for the 31 wells completed in the Upper Jurassic reservoirs.

Wildcat drilling activity slightly increased throughout the 1950's and 1960's and an average of 16 exploratory wells spudded annually. Much of the exploratory drilling was concentrated in the Douglas Creek Arch area targeting Lower Cretaceous Dakota and younger Mancos "B" reservoirs. Fewer than 22% of the wildcat penetrations drilled on the arch proved commercially successful during this twenty year period. To the east, exploratory and development drilling of Tertiary oil and gas reservoirs in the Piceance Creek Drainage Basin was also important. The first Mesaverde tight gas sand well was completed in 1957, although subsequent drilling for these reservoirs was hindered by the low flow rates characteristic of these completions. Other areas of significant development activity during the 1950's and 1960's included the targeting of Weber oil reservoirs in the Rangely Field, although the total number of wells drilled on the anticline declined by about half with a substantially lower average success rate (47%) as compared to that of the preceding two decades. It should be mentioned that by the 1960's, subsurface seismic imaging and mapping techniques began to be utilized in the region. This technology rapidly enhanced industry's understanding of trap complexity in the northern Piceance Basin and refined the positioning of exploratory and development wells in the WRFO.

During the 1970's and 1980's, exploratory drilling remained relatively constant although development operations increased by about 30% as compared to industry activity levels of the 1950's and 1960's. Drilling activity in the Douglas Creek Arch area was intense and accounted for about half of the approximately 2,000 total wells spudded during this period. Almost one in five of the wells drilled on this structural arch were exploratory penetrations with an increased average wildcat success rate of over 60% in this area. The remaining wells spudded in the Douglas Creek Arch area were development penetrations in which operators attained a slightly higher success rate of about 75%. Development drilling in the Rangely Field accounted for about one-third of the total wells spudded in the WRFO during the 1970's and 1980's. Roughly 65% of these penetrations proved commercially productive.

In the 1990's and early part of the 2000's, about half of the total drilling continued to be concentrated in the Douglas Creek Arch with an overall success rate of more than 85%.
Although development drilling continued in the Rangely Oil Field, this activity accounted for only 5% of the total wells spudded during this period. This significant decline in activity was slightly offset by the increased success rate (86%) attained in the field. Other significant operations included the 1991 discovery of deeper gas reserves in the Mesaverde Group (Williams Fork Sandstones and the Cameo Coal Zone) at the White River Dome Field. Subsequent infill drilling of both Wasatch and Mesaverde reservoirs in this area represented about 10% of the total wells spudded in the WRFO during the 1990's and early 2000's. A similar level of drilling activity was observed in the Piceance Creek Drainage Basin, where operators targeted both stratigraphically-trapped shallow Wasatch sand reservoirs and deeper

Mesaverde tight gas sand accumulations. More than half of this activity involved exploratory drilling and about two-thirds of the wildcat penetrations were completed in the region around the turn of this century.

Present Activity: Beginning in 2004, the WRFO has undergone a dramatic increase in drilling activity. Roughly 70% of the current operations are centered in the Piceance Creek Drainage Basin (focused on the thick, gas-saturated Mesaverde tight sand play), about 20% in the Douglas Creek Arch area (primarily drilling Cretaceous sand, shale, and coalbed gas reservoirs), and the remaining 10% in the Rangley Field (targeting the Weber oil sand). The emerging interest in the Mesaverde basin-centered play in the central part of the WRFO is principally related to the development of new completion technology (i.e. modern hydraulic fracturing techniques) coupled with the sustained elevation in gas prices (>$5.00/thousand cubic feet of gas) over the past few years. Operators have aggressively pursued both exploration and development drilling activities in the Piceance Creek area. Exploratory outpost or new field wildcat wells account for roughly 30% of the wells drilled in this region, with an average success rate of 88% over the past four years. The remaining 70% of the penetrations drilled in the Piceance Creek area were infill development wells and nearly all (97%) of these boreholes have been successfully perforated and completed. In the Douglas Creek Arch area, overall drilling activity is currently in decline and this is probably in response to difficulties in the effective disposal of high volumes of produced water in this maturely-developed part of the northern Piceance Basin. Since 2004, exploratory drilling has represented only about 10% of the recent wells spudded in this westernmost region; operators have attained nearly a 90% average success rate in drilling these "riskier" opportunities. Most of the wells drilled on the Douglas Creek Arch, however, have been infill development penetrations; these exploitation programs have achieved an average success rate of about 96%. Lastly, the Rangely Field has been characterized by an absence of exploratory activity. Development operations on the anticline have also continued to steeply decline. Relatively few development wells (less than 30) have been drilled since 2004 but nearly all of them (94%) were successfully perforated and completed. Although limited future activity is anticipated for the Rangely Field, enhanced recovery operations (carbon dioxide and water injection methods) will continue to help sustain the production of liquid hydrocarbons from this world-class accumulation.

VI. OIL AND GAS OCCURRENCE POTENTIAL

An oil and gas occurrence potential map was constructed for this report in order to categorize the likelihood of encountering hydrocarbon-bearing rocks across the WRFO (Figure 11). This geologic interpretation utilized several types of data for the prediction of hydrocarbon occurrence. First, the USGS Total Petroleum System and Assessment Unit maps for the Uinta-Piceance Basin (USGS, 2003) were overlain and served as a general guideline to define four major classes (High, Medium, Low, and No Known) of hydrocarbon occurrence potential. Second, the boundaries between these major classes were further refined based on patterns associated with the generalized surface geology in the area. This approach was especially helpful in delineating the "low" and "no know" potential areas which contained extremely thin (less than 1,000 feet) or absent accumulations of sedimentary rock in tectonically uplifted regions of the study area (e.g. Yampa Plateau, White River Uplift, Grand Hogback). The

resultant potential map was then compared to the distribution of existing wells in the region in order to validate these interpretations. Lastly, the map was compared to the hydrocarbon occurrence potential maps for adjacent field offices (i.e. the LSFO and GSFO) in order to ensure consistency of BLM technical assessments throughout northwest Colorado.

In general, "high" potential areas are defined by the presence of proven source and reservoir-quality rocks that have experienced a favorable thermal maturation history for the generation and trapping of significant hydrocarbon accumulations. "Moderate" potential areas are those characterized by geophysical or geological indications of the presence of source and reservoir-quality rocks which may have undergone a favorable thermal maturation history for the generation and trapping of hydrocarbon accumulations. "Low" potential areas possess an absence of one or more of the previously described variables (e.g. source rocks, reservoir rocks, thermal maturation, trap presence). Areas of "no known" or "no" hydrocarbon occurrence potential are those with an absence of source rock, reservoir rock, thermal maturation, and trap presence, essentially excluding the occurrence of hydrocarbons in a particular area.

The oil and gas occurrence potential map presented in this report shows that most (approximately 77%) of the WRFO has a moderate to high chance of encountering hydrocarbon-bearing rocks in the subsurface (Figure 11). Only the two major tectonic uplifts, the Yampa Plateau and White River Uplift, in the WRFO are characterized by lesser hydrocarbon occurrence potential; most of the unleased federal mineral estate occurs in these two regions. To the northwest, the Yampa Plateau structural uplift exhibits a relatively limited stratigraphic column of primarily Paleozoic and older rocks (Figure 5). Only a single USGS Uinta-Piceance Assessment Unit extends into this region (Map F of Appendix A). The White River Uplift in the eastern part of the study area also possesses a thin section of Paleozoic sedimentary rocks, sometimes unconformably overlain by Tertiary rocks of volcanic origin (Figure 5), and a single Assessment Unit extends into this region of lesser occurrence potential (Map F of Appendix A). Historically, these two areas of limited hydrocarbon occurrence potential in the WRFO have demonstrated relatively low levels of drilling activity (Figure 10) and an absence of significant, commercial hydrocarbon production.

VII. OIL AND GAS DEVELOPMENT POTENTIAL

There are several important indicators of future oil and gas development activity within the WRFO. These include the historical and geospatial distribution of existing oil and gas boreholes and fields, the density and location of currently permitted (but not yet drilled) wells, geologically-controlled variations in hydrocarbon occurrence potential, and the presence of distinct tectonic/physiographic features across the field office area. The BLM's understanding of future industry operations has also been enhanced by input from numerous operators that are currently active in northwestern Colorado.

WRFO Oil & Gas Occurrence Potential Map

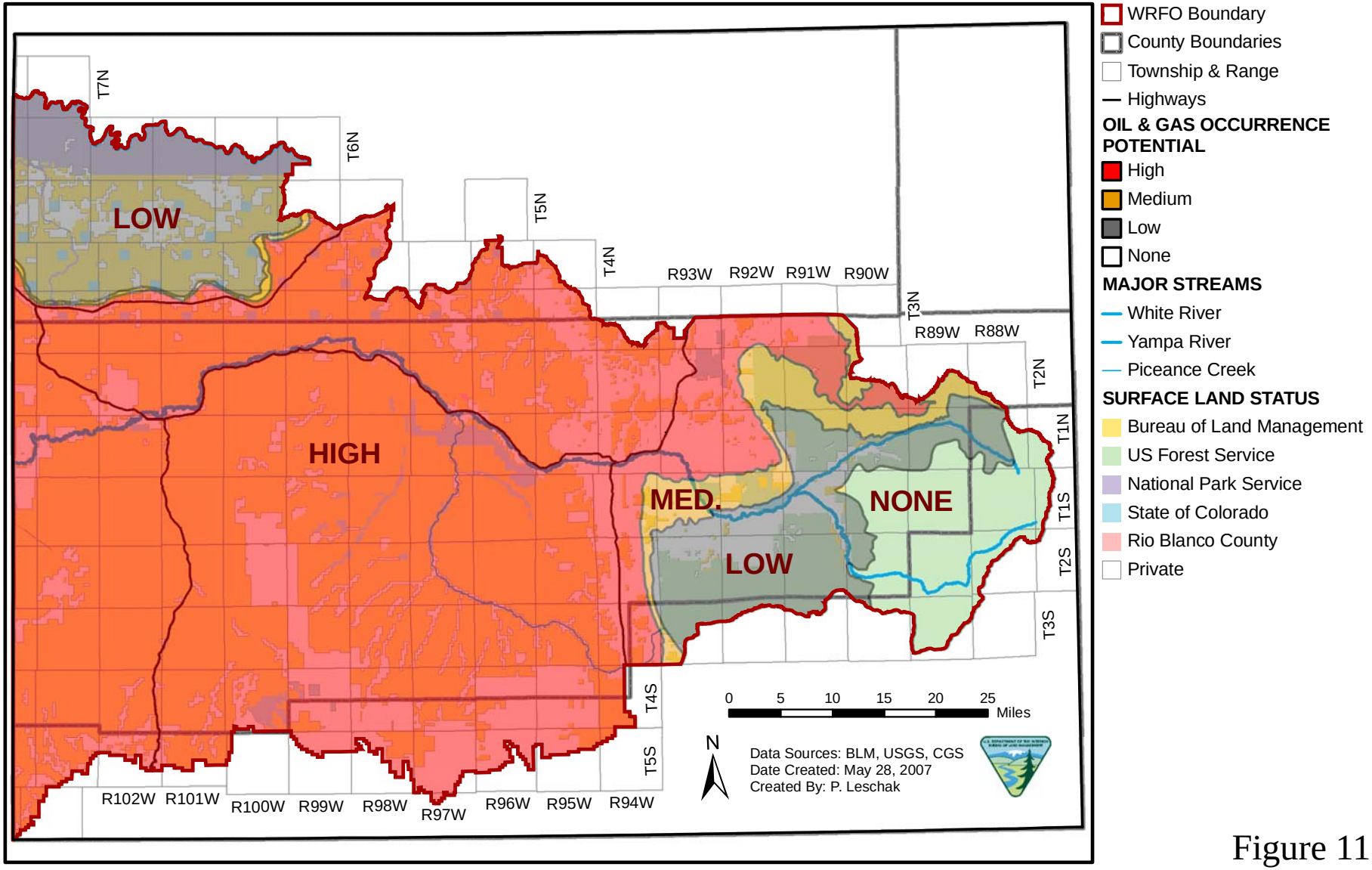


Figure 11

Consideration of this information enabled the identification of four major oil and gas play categories in the WRFO. A "play" refers to a group of hydrocarbon accumulations with a combination of common geologic, geographic, and/or temporal properties (e.g. source rock, migration pathway, timing, trap style, reservoir rock, hydrocarbon type, etc.) that have proven to be commercially productive in a given area. The four major play categories of the WRFO are: (1) the Mesaverde Gas Plays; (2) Conventional Oil Plays; (3) Coalbed Gas Plays; and (4) Other Fringing Area Plays. It should be noted that these four play categories are highly generalized groupings identified across the region and each includes one or more of the individual assessment units (AU's) described by the USGS (2003).

First, the Mesaverde Gas Plays of the WRFO include both conventional and continuous (also known as "unconventional") gas reserves throughout a thick interval involving multiple reservoirs and varying lithologies of the Upper Cretaceous Mesaverde Group. These plays are primarily located across the Piceance Creek Drainage Basin and southern Danforth Hill areas. This region is more generally referred to as the "Mesaverde Gas Play Area" for the purposes of this RFD (Figure 12). The Mesaverde Gas Play Area covers an estimated area of 712,190 acres (or about 27%) of the WRFO. The play trend contains over 75% of the existing wells drilled since 2004 and 85% of the new well locations currently permitted in the WRFO. Recent downhole well spacing approvals in the region are transitioning from 40 to 20 acres, and 10 acre downhole well spacing densities are expected in the future. Nearly 68% of the Mesaverde Play Area consists of federal mineral estate lands; almost all of this federal acreage is currently leased. This study fully anticipates that the Mesaverde Gas Play Area will continue to experience increasing activity levels and remain the primary focus of future industry interest over the next twenty years.

Second, Coalbed Gas Plays characterize the Douglas Creek Arch and southern Danforth Hills (i.e. White River Dome Field) areas. It should be mentioned that in the WRFO, some coalbed gas (CBG) has been simultaneously produced and commingled with thick intervals of interbedded Mesaverde sandstone reservoirs since the onset of historical Mesaverde production in the basin. In such cases these "hybrid" CBG wells have been included as part of the Mesaverde Gas Plays category because: (a) their geographic distribution coincides with that of the Mesaverde Gas Play Area; and (b) their production profiles match that of the Mesaverde tight gas sand wells rather than that of typical CBG wells. Even with the exclusion of these "hybrid" wells, as much as 15% of the drilling activity since 2004 has been in the CBG-producing areas of the WRFO. Only 3% of the currently permitted wells, however, target Coalbed Gas Plays and recent industry activity in these trends has significantly decreased over the past year or so. As stated previously,

WRFO Mesaverde Gas Play Area

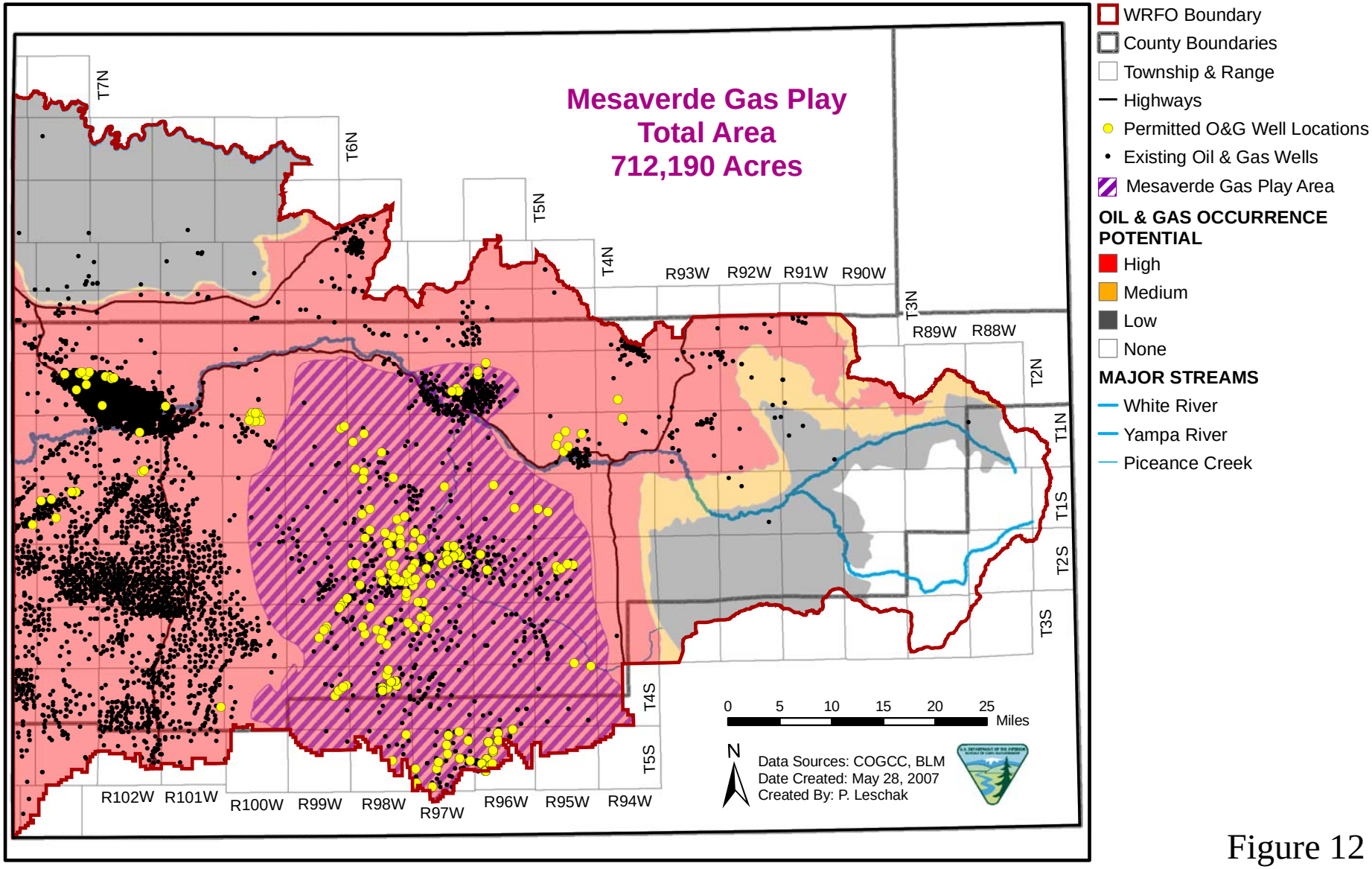


Figure 12

the diminished activity is primarily attributed to problems in disposing of the large produced water volumes that sometimes characterize these wells, particularly in the Douglas Creek Arch area. It is expected that produced water disposal issues will continue to be problematic in the WRFO. As a result, this report forecasts a constant level of activity, comparable to that of the present day, over the next 20 years for the Coalbed Gas Plays of the northern Piceance Basin. Of the four major play categories in the WRFO, the activity forecast for this play possesses the greatest uncertainty and the drilling of these reservoirs will be highly dependent on both changing regulations and emerging technologies related to produced water treatment and disposal methods.

Conventional Oil Plays are also an important segment of industry activity in the WRFO. These plays occur in the Rangely Anticline and northern Danforth Hills regions. Although almost 8% of the existing wells drilled since 2004 in the WRFO were spudded in these areas, only 4% of the currently permitted well locations target Conventional Oil Plays. Such data support inferences of a systematic decline in drilling activity for this play category. Historical infill drilling and production in these two areas has been both sustained and intense, particularly on the Rangely Anticline. Only limited volumes of economically recoverable oil reserves remain in these parts of the northern Piceance Basin, with very few undeveloped conventional oil plays anticipated elsewhere in the field office area.

Lastly, Other Fringing Area Plays encompass a variety of Paleozoic reservoirs and trap styles associated with the limited hydrocarbon occurrence potential regions of the Yampa Plateau and White River Uplift. No oil and gas wells have been drilled since 2004 and there is currently an absence of permitted well locations in the two areas. In addition, well control is extremely sparse and no significant hydrocarbon production has been established to date in either of these areas. Potential traps in Yampa Plateau and White River Uplift probably have small areal extents with complex stratigraphic, structural, and thermal histories. As such, only extremely limited exploration and development activity is expected for the Other Fringing Area play category in the WRFO over the twenty year life of the RFD.

Future drilling activity estimates were developed for the four major play categories in the WRFO based on the observations and inferences discussed above (Table 2). These relative proportional estimates effectively forecast both the general geographic occurrence and relative density of future wells drilled in the field office area between 2009 and 2028.

WRFO Play Category	**% of Future Drilling Activity**
Mesaverde Gas Plays	95.0%
Coalbed Gas Plays	3.5%
Conventional Oil Plays	1.0%
Other Fringing Area Plays	0.5%

TABLE 2: Projected Drilling Activity for the WRFO Play Categories.

The relative proportions of future exploratory and development well classes and their average success rates have also been forecasted for each of the major play categories in this analysis (Table 3). In short, 5% of future wells drilled in the proven Mesaverde Gas, Coalbed Methane,

and Conventional Oil Plays will be low-risk (75% probability of success) exploratory (field wildcats, deeper pool tests, etc.) wells. Most of the wells drilled in these three play categories will be development (field extension, infill) wells with success rates of at least 95%. Development wells in the Mesaverde Gas Play Area were assigned a slightly higher probability of success (97%) because some active operators have demonstrated success rates of up to 100% over the last five years. The extremely thick, gas-saturated interval of the Upper Cretaceous section coupled with the geographically-pervasive nature of the tight, basin-centered gas across the Mesaverde Gas Play makes this one of the lowest-risk hydrocarbon plays in the Rocky Mountain region. In contrast, future drilling activity associated with Other Fringing Area Plays is projected with equal proportions of exploratory (rank wildcats with a 30% average probability of success) and development (confirmation/appraisal penetrations with a 75% average probability of success) wells in this higher-risk, lower potential play category.

	Exploratory Drilling		**Development Drilling**	
WRFO Play Category	**% of Wells**	***P(s)***	**% of Wells**	***P(s)***
Mesaverde Gas Plays	5%	*75%*	95%	*97%*
Coalbed Gas Plays	5%	*75%*	95%	*95%*
Conventional Oil Plays	5%	*75%*	95%	*95%*
Other Fringing Area Plays	50%	*30%*	50%	*75%*

TABLE 3: Exploratory and Development Drilling Projections and Associated Probability of Success [P(s)] Estimates for the WRFO Play Categories.

In summary, it is predicted that there will be substantial increases in oil and gas drilling activity in the WRFO through the twenty year life of this RFD forecast scenario. Most of the future wells will target low-risk development opportunities within the Mesaverde Gas Play Area. Leasing activity is expected to be minimal because most of the federal mineral estate in the Mesaverde Gas Play area is currently leased, gas-producing acreage. Seismic operations on federal lands in the WRFO currently average only one or two surveys annually and this level of activity is expected to remain constant over the life of the RFD due to the high expenses, technical challenges, and regulatory constraints associated with the acquisition of such data on federal lands. The presence of existing geophysical surveys in critical areas of development also diminishes the need for additional data acquisition on federal lands. Although the overall level of seismic activity is not projected to significantly change, future operations will involve fewer 2D seismic programs and a corresponding increase in the utilization of 3D geophysical surveys and borehole vertical seismic profiles (VSP's). Lastly, future oil and gas operations may be impacted by conflicts in the exploration and development of competing mineral resources on federal lands.

VIII. CURRENT OPERATIONS ACTIVITY IN THE NORTHERN PICEANCE BASIN

Northern Piceance Basin Development: Development and infill drilling of the Mesaverde Play Area (712,190 acres) is seen as an extension of the Mesaverde drilling activity viewed in the southern Piceance Basin along the I-70 corridor. Developmental drilling levels are increasing and progressing in a north to northwesterly direction, and are encompassing the entire Piceance Basin. Over time, additional rigs will be brought north as drilling opportunities diminish to the south of WRFO administered lands with the emergence of full development. It is anticipated that 16,832 Mesaverde wells will be drilled in the next twenty years, or 95% of the 17,800 well WRFO RFD.

As noted earlier, there is much more risk in drilling wells located in the northern Piceance Basin due to the highly variable and complex geology that exists, the deeper depths of the wells being drilled (from 9,000' to 16,500'), and the extreme lost circulation problems that are routinely encountered from surface in the Green River formation through the Ohio Creek formation. Development costs (including drilling and completion costs and facilities infrastructure), natural gas prices, and existing gas markets all must be considered when a company evaluates a tight gas play[1].

In the north and east portions of the Mesaverde Play Area, operator production and revenues tend to be greater due to the naturally fractured geology that is believed present. Preliminary decline analysis from available production information that has been reported indicate the reserves for a well located here are projected to double in comparison to wells located elsewhere in the Mesaverde Play Area. This observation has been confirmed by some of the companies operating in this area.

In addition, feedback from active oil and gas operators indicate that future wells located on fee acreage (found primarily in the southern portions of the WRFO) and state lands can be expected to be drilled in advance of wells that could be drilled on BLM lands, due to anticipated lower development costs.

Applications for Permit to Drill (APD) Activity: The number of drilling permits issued in the State of Colorado by the COGCC continue to trend upward significantly, with 5,904 Applications for Permit to Drill (APDs) approved in 2006. This relates to a 35% increase over 2005 (4,373 permits) and a 102% increase over 2004 (2,917 permits), with nearly 40% of these located in northwestern Colorado. Permits issued for locations in Rio Blanco County totaled 343 in 2006, compared to 161 in 2005 for a 113% increase[2]. To date, the number of APDs submitted to the WRFO for fiscal year 2007 were nearly 33% less compared to the same period in fiscal year 2006, however the number of APDs that were submitted in June 2007 have increased considerably, and this brisk pace is expected to continue for the remainder of the year.

Mesaverde Drilling: In the northern Piceance Basin, lost circulation problems are routinely encountered in the wellbore from near the surface portion of the well to just above the Mesaverde formation, which greatly increases the costs in drilling a well, and substantially affects the economics and potential payout of a well. Some wells have been known to lose tens

of thousands of barrels of drilling fluid to lost circulation zones located primarily below the surface in the Green River formation and down through the Ohio Creek formation (to 7,500 feet). Losses have also been realized in the Mesaverde formation, but tend to be relatively minor in comparison. Complications often occur that can lead to hole instability such that wellbore integrity could be jeopardized.

Operators have been actively drilling the Mesaverde/Williams Fork formation for the past three to four years, and continue to encounter problems after this length of time. The geology (and lost circulation intervals) tends to vary significantly from wellbore to wellbore. As a result, prior drilling experience can play a relatively small part in the successful drilling of a well. Each well that is drilled can be considered to be geologically unique in comparison with other wells, including those on the same well pad. Companies continue to refine and alter their drilling practices, in attempts to improve efficiencies and further reduce fluid loss impacts. Established fields located on the northern periphery of the Mesaverde Play Area (such as the White River Dome Field) are shallower in depth, and experience less drilling fluid losses.

Depending upon where a company's acreage is located in the Mesaverde Play Area, the total depth required to drill a well varies considerably. The depth of the well influences the casing design as some companies run surface and production casing only, while other companies include an intermediate string. In a few instances, two intermediate casing strings were required to protect the stability of the wellbore in order to reach total depth. Adding additional strings of casing (along with the cementing of these strings) to a well significantly increases the costs of drilling a well.

The cost to drill and complete a typical Mesaverde well in 2007 is between $2 to $4 million dollars based on information provided by northern Piceance Basin operators. These estimates are dependent upon each operator's geographic location and preferred drilling and completion practices. Average development costs have reduced considerably in the past three years as additional drilling experience is gained.

Drilling Success Rates: Most wells drilled to date in the Mesaverde/Williams Fork formation have encountered economically recoverable volumes of gas despite the presence of lost circulation zones, resulting in a low number of wells that is projected to be plugged and abandoned in the future. Wells that have been plugged are primarily due to exploration efforts that have resulted in wells not being drilled through all the productive pay intervals or have encountered substantial amounts of water on the fringes of the play area. In addition, several wellbores experienced mechanical failures downhole that required the abandonment of the well.

As the boundaries of the Mesaverde Play Area are further defined and drilling/completion techniques improve, it is estimated there will be a 97% successful drilling rate in the future for operators exploiting the Mesaverde sands. In some operator's corporate websites, it is stated that their drilling successes thus far in the Piceance Basin are 100% with no "dry holes" having been drilled yet, therefore the chance of not encountering gas is seen as minimal. Future drilling in the northern Piceance Basin's Mesaverde play is largely viewed by industry as being developmental in nature, although not without risk.

Although the presence of gas is relatively well-defined in the Mesaverde Play Area, it should be noted that considerable economic risk remains in recovering sufficient quantities of gas to cover development costs. As one company geologist states "The risk in this play isn't drilling a dry hole; the risk is all technical. Very simply, we have to pay attention to drilling and completing our wells properly, and the better we get at that, the better our economics become"[3].The WRFO technical staff agree with this assessment. As more becomes known about the complexities typifying the northern Piceance Basin geology, the optimization of drilling and completion practices will continue.

Well Completion Techniques: Optimizing completion strategies to maximize natural gas production rates and ultimate recoveries can best be described as a learning curve experience, and the degree of success varies from operator to operator. Initially, most operators perforated and stimulated all sand intervals having a six foot minimum thickness within the Mesaverde/ Williams Fork sequence, which resulted in considerable water production.

In the past two years, some operators have resorted to well-log analyses and spinner surveys to identify sand intervals that contribute large volumes of produced water and marginal volumes of produced gas, and have since modified their completion techniques to exclude these intervals[4]. Some operators are opting to open these water-laden intervals later in the life of the well after current productive zones deplete.

Mesaverde wells typically produce high volumes of brackish water (having high levels of total dissolved solids ranging from 12,000 to 16,000 milligrams per liter) along with the produced gas, and for most operators, reservoir pressures are usually sufficient to help remove the water from the wellbore. As a rule-of-thumb, for every 1000 MCF of gas that is produced, there are 80 to 110 barrels of water that are correspondingly produced.

For other operators, reservoir pressures are lower (or water volumes may be higher), and a well having problems unloading the water must resort to downhole equipment to help lift the water to surface. Produced water from a well commonly varies from 50 to 500 barrels of water per day. It should be noted the Mesaverde formation does not exhibit tendencies to de-water over time when this analysis was prepared.

A consequence of the total amount of water that is produced from natural gas production operators is the adequate disposal of the water. Water handling options will likely vary by operator for the near future, and may include trucking to approved commercial facilities in Rangely and Roosevelt, Utah at a current cost of $10 per barrel (plus diesel costs), downhole disposal in injection wells, water treatment, and surface evaporation ponds. As a temporary water management measure, several operators have found they can use produced water in their intermediate to deep drilling operations as well as in their completion operations, but ultimately this water will need to be disposed. A long-term disposal solution applicable to all operators is not yet at-hand, but several operators have had success injecting water downhole into the Wasatch formation.

Gas-In-Place: Estimates of natural gas in-place from tight gas sands occurring in the Piceance Basin have varied tremendously in the past twenty years, and only in recent years have relatively

consistent estimates begun to be made available to the public. This is due to the fact that the Piceance Basin was largely misunderstood and overlooked, as early Piceance extraction technologies were not capable of economically recovering the gas present. It may also be due to forward-thinking companies understanding the significance (and the risks) associated with the gas known present from internal reservoir modeling runs, and making the decision to acquire leases in speculation that future technologies may be able to recover this gas.

Having limited production information from wells that were drilled in the northern Piceance Basin, and the difficulties in estimating accurate volumes from lenticular (compartmentalized, non-blanket) sands that may, or may not, appear in adjacent wellbores also hinder verifiable gas-in-place (GIP) estimates.

One of the earliest assessments of gas-in-place resulted from a United States Geological Survey study performed for the Department of Energy in 1987 that concluded there were 423 trillion cubic feet (TCF) of gas resource located in the Piceance Basin[5]. This estimate can be compared to GIP estimates suggested by Tyler et al in 1998 of between 80 TCF and 136 TCF that were attributed to deep coalbed methane gas located in the Cameo Coal interval of the Mesaverde formation[6].

A recent article appeared in the August 2005 issue of the Oil and Gas Investor and stated "With as much as an estimated 300-plus trillion cubic feet of gas resource in place, Colorado's Piceance Basin may well be the largest natural gas play in North America[3]". This article also references one operator (EnCana) in the Piceance Basin having an estimated 90 TCF of GIP from the properties that they lease or own.

For the Mesaverde Play Area (where 95% of the RFD drilling is forecasted in a 712,190 acre area), WRFO technical staff estimates 100 TCF of GIP based on existing production and decline analysis using type curves. Projected GIP under all WRFO lands (Federal, fee and State) is estimated to be 115 TCF (and includes the 100 TCF in the Mesaverde Play Area) in 2.675 million acres. Piceance Basin GIP estimates will continue to evolve and solidify for the next several years as more production information is compiled.

Mesaverde Reserve Estimates: Most producing wells in the Mesaverde Play Area of the northern Piceance Basin have been drilled within the past three to four years and limited production histories consisting of one to three years are available, which makes it difficult to accurately estimate recoverable reserves over a large geographic area.

Actual production volumes from wells of the most active operators were examined, and all producing wells tended to follow a hyperbolic decline typical of fracture-stimulated wells producing from tight gas sand formations[1]. By the end of the first year, Mesaverde well production rates normally average 25% of initial production rates that typically range from 1000 to 5000 million cubic feet per day (MCFPD) when a well is first brought online. After four years of production, Mesaverde wells usually follow an exponential, or constant rate decline approximating 10% per year for the remainder of the life of the well.

With only one to three years of actual production information available per well, an industry-developed type curve for southern Piceance Basin Mesaverde wells was used in an attempt to model the production performance of northern Piceance Basin well in the estimation of recoverable reserves. After working with the production histories of several wells, it was determined the type curve was a remarkably good match to existing well production from northern Piceance Basin wells, but this wasn't the case for all wells.

Mesaverde well production declines that matched the type curve for southern Piceance Basin wells can be expected to achieve 1.6 billion cubic feet of gas (BCF) over a 45-year economic life of a well. However, for many of the higher-volume producing wells, the type curve approximation was off significantly. It was determined that if the values in the original type curve were doubled, a close fit could be found that described the decline behavior of the higher producing wells. For these wells, recoverable reserves of 3.2 BCF per well over a 52-year economic life were assigned.

The initial production rate seen after completing a new well is key in determining the amount of recoverable reserves associated with that particular well. Thus far, three operators have repeatedly experienced initial production rates from wells averaging between 3,000 to 5,000 MCFPD, and this information supports the 3.2 BCF estimate in recoverable reserves derived above. It is believed the presence of "sweet spots" involving naturally fractured geology may be the reason why these wells tend to perform better, however one operator has publicly stated its new completion techniques may also be partly responsible for the increased production rates[6]. Additional time and analysis will be needed to verify the validity of both of these theories.

From the production model that was subsequently created and the from the decline analysis work that was performed by WRFO technical staff, 4,954 Mesaverde wells (or 30% of all Mesaverde wells) were assigned reserves of 3.2 BCF, while the remaining 11,878 wells (or 70% of all Mesaverde wells) were assigned 1.6 BCF in reserves.

Downhole Spacing: At the time of this writing, northern Piceance Basin operators are currently drilling on 20- to 40- acre downhole spacing, with drilling on 10 acre downhole spacing seen as imminent in the next year or two for several of the most active operators.

In the southern Piceance Basin, drilling Mesaverde wells on 10 acre downhole spacing is widespread and supported by numerous spacing rulings set by the State of Colorado Oil and Gas Conservation Commission (COGCC). With similar reservoir characteristics present in the northern Piceance Basin, this confirms the future of WRFO Mesaverde drilling will likely be drilled on 10 acre spacing.

Included in the RFD drilling assumptions, some of the active operators are projected to start drilling on 10 acre spacing beginning in 2009, with 16 wells drilled over the life of the pad. Less active operators are projected to be drilling on 10 acre spacing in 2016.

IX. RATIONALE FOR PREPARING THE WHITE RIVER FIELD OFFICE REASONABLE FORESEEABLE DEVELOPMENT SCENARIO

After requesting and receiving twenty year drilling projections from industry operators, WRFO fluid minerals staff wanted to assess the reasonableness of industry's forecast of 21,200 wells. As a check against industry's drilling numbers, WRFO technical staff analyzed the historical development pace of the medium-deep gas drilling operations occurring in western Wyoming's Jonah and Pinedale Anticline areas, and Colorado's southern Piceance Basin to establish a baseline of the number of wells that reasonably could be projected to be drilled in the northern Piceance Basin (Figure 13).

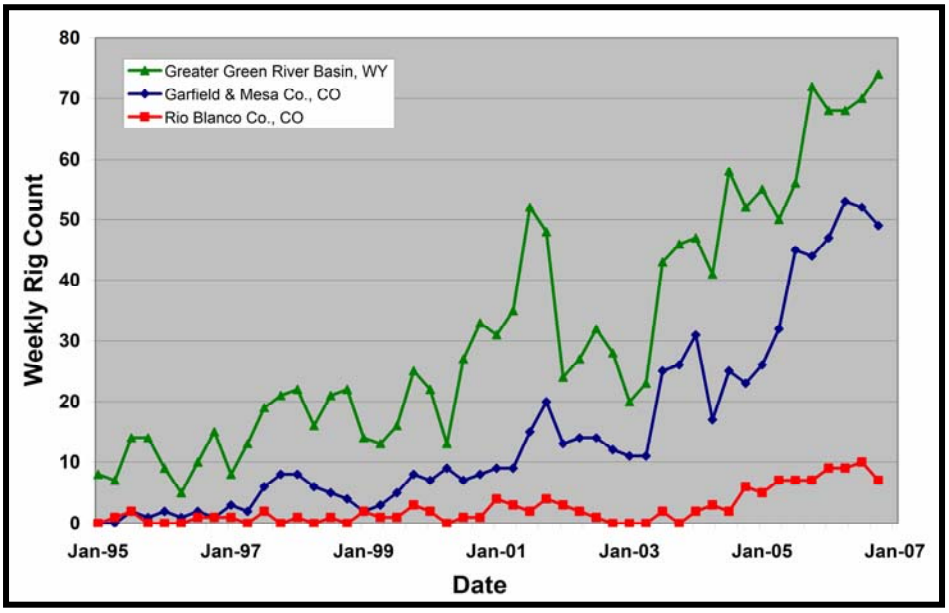


Figure 13. Historical Drilling Activity in the Green River and Piceance Basins.

Using peak drilling rig counts of 75 for the Green River Basin and 53 for the southern Piceance Basin, and using an estimate of drilling one well per month, this led to a baseline of 10,900 wells that could be expected to be drilled on WRFO lands in twenty years, assuming development here were to occur under similar conditions. Although similar, drilling in the northern Piceance Basin is much more difficult than drilling in the southern Piceance Basin or the Jonah and Pinedale Anticline areas. The use of historical drilling data in the development of other major basins is a key assumption in the WRFO RFD analysis, and was also used as the basis for looking at other RFD alternatives.

Major constraints to future WRFO drilling activity were identified to include rig availability and natural gas price, as drilling is more challenging and costly due to the lost circulation problems and deep Mesaverde geology that exists. Taking these factors into account, and also accounting for the likelihood of favorable technological advancements in the future and increased migration of drilling rigs to the northern Piceance Basin, an initial internal forecast of 14,400 wells (32% above the development pace of the Green River and southern Piceance Basins) was determined to be fair and reasonable.

The initial RFD forecast was revised upwards to a final WRFO RFD of 17,800 wells (63% above the development pace of the Green River and southern Piceance Basins), as a result of meetings

with both industry (in December 2006) and COGCC representatives (in January 2007) in considering 1) additional technological advancements in reducing the time to drill a well from one month to three weeks, and 2) additional increases in the number of rigs drilling in the northern Piceance Basin. For the 17,800 wells projected to be drilled, 2,146 wellpads would need to be constructed, and 26,465 acres of related development disturbance could be expected to occur, as detailed in the Table 4.

Surface Disturbance Type	Acres Projected to be Disturbed
Wellpads	15,611
Roads	3,457
Pipelines, Gas Plants	7,397
Total	26,465

TABLE 4: Estimated Acres of Disturbance from WRFO RFD Scenario.

X. REASONABLE FORESEEABLE DEVELOPMENT SCENARIO DRILLING FORECAST

RFD Number of Wells, Wellpads and Drill Rigs: Each operator's RFD drilling forecast that was submitted to the WRFO was entered into a spreadsheet for further analysis. For each year of an operator's forecast, information was input for the number of wells to be drilled, the number of wellpads to be constructed, plus the number of acres of disturbance that was expected to occur for the construction of wellpads, roads, pipelines and gas plants. Estimates were made by WRFO technical staff if data was not supplied in the operator's RFD, or if the information was determined to be incomplete or inaccurate. Also forecasted were the number of rigs that were projected each year for every operator.

Based on each company's RFD and the knowledge of each company's drilling practices, a systematic development approach was used that captured a company drilling one well per pad initially (on 20 or 40-acre downhole spacing), then progressing to an average of eight wells drilled per pad (on 20 acre downhole spacing), then ultimately drilling an average of 16 wells per pad (on 10 acre downhole spacing). This approach may not exactly match an operator's specific drilling plans for the future, but it provides a reasonable approximation of the overall drilling activity that is anticipated.

One, possibly two, of the most active northern Piceance Basin operators are expected to be drilling on 10 acre downhole spacing in 2009 with 16 (or more) wells per pad, while other active operators are anticipated to follow suit within 2 to 3 years (Table 5). Less active operators are expected to begin drilling on 10 acre downhole spacing in 2016.

Operator Type	Drilling on 10 Acre Spacing in Year:
Most Active Operators	2009
Active Operators	2011

Less Active Operators	2016

TABLE 5: Projected Year That Operators Will Start Drilling on 10 Acre Downhole Spacing

In addition, a reduction in drilling time from one month to three weeks for drilling a typical Mesaverde well was factored in for the majority of northern Piceance Basin operators that would result from improved drilling technologies. It was also assumed more drilling rigs would migrate into this area from other states.

Based on analysis completed by WRFO technical staff, it is projected that 17,800 wells would be drilled on 2,146 wellpads in the twenty year period from 2009 through 2028. Of this total number wells, 15,743 wells are projected to be drilled on Federal lands and 2,057 wells on private lands. No wells are anticipated to be drilled on State of Colorado lands due to the limited acreage that exists within the WRFO.

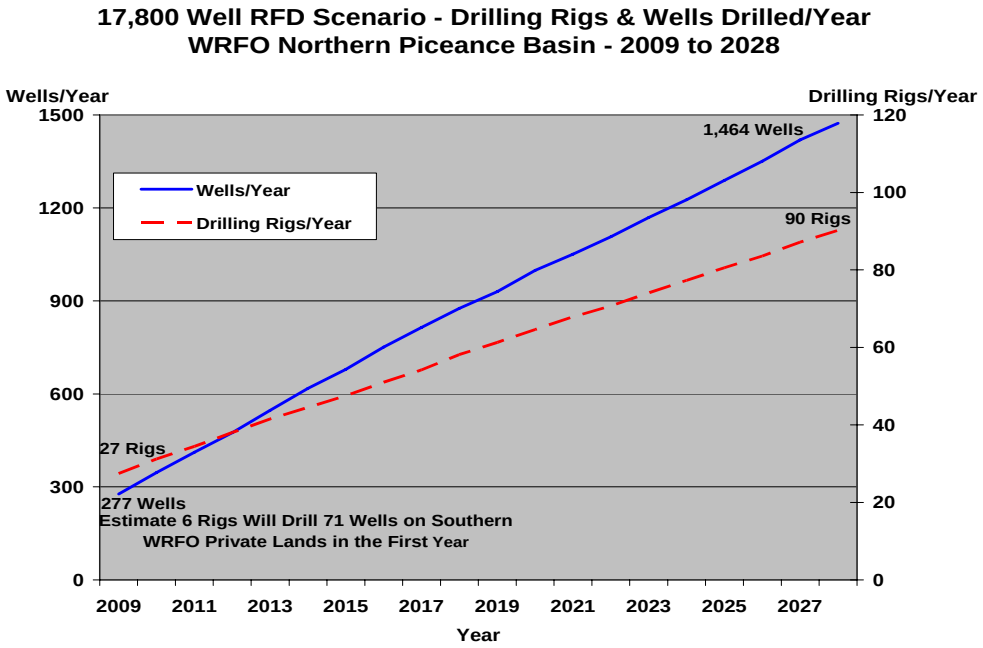


Figure 14. Number of rigs and wells per year projected in the 17,800 Well RFD Scenario.

Year twenty of the forecast is assumed to be the most active drilling year with an estimated 1,464 wells drilled using a total of 90 drill rigs (Figure 14).

Surface Disturbance Estimates Associated With RFD Drilling Activity: The associated disturbance in undertaking the 17,800 well RFD scenario is estimated to be 26,465 acres, and is detailed into the following types of construction activity (Figure 15):

- 15,611 acres for 2,146 wellpads (an average of 7.3 acres per wellpad)
- 3,457 acres (951 miles) of roads

- 7,397 acres of pipelines, gas plants, compressor stations and other infrastructure

Surface disturbance estimates provided by operators for wellpad size were generally underestimated, and the following assumptions were used in drilling Mesaverde wells:

- For a one-well pad, an average pad size of 4 acres was used
- For an eight-well pad, an average pad size of 8 acres was used
- For a sixteen-well pad, and average pad size of 12 acres was used

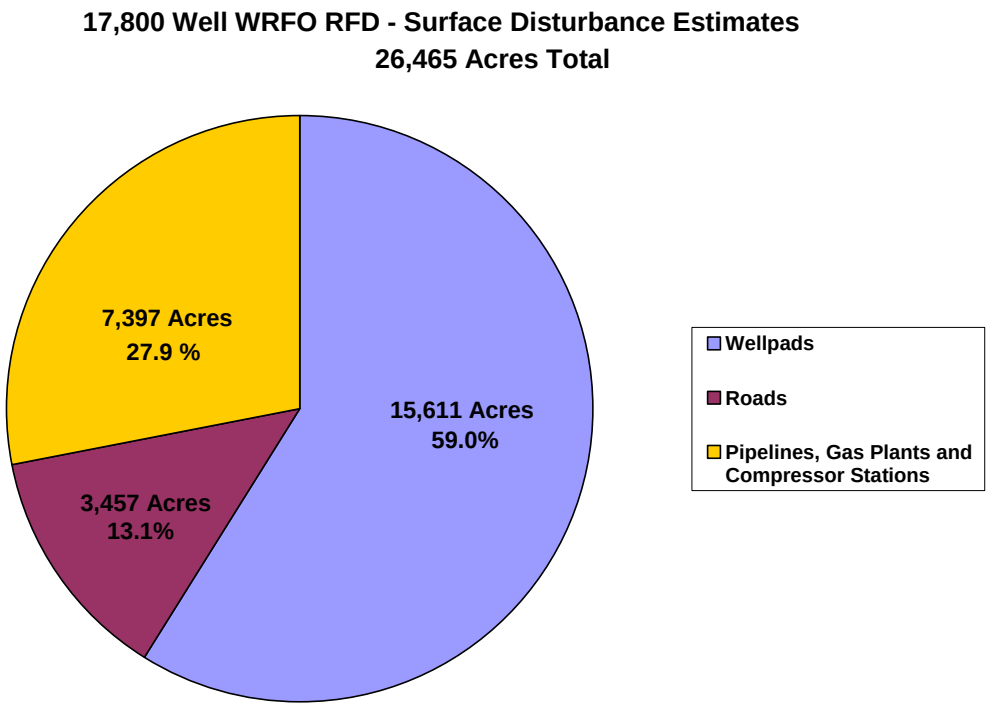


Figure 15. Pie chart illustrating surface disturbance estimates projected in the 17,800 Well RFD Scenario.

The pad sizes used in the RFD analysis are in line with the pad sizes now being built in the northern Piceance Basin, southern Piceance Basin and Wyoming's Green River Basin. The size of a pad is primarily determined by the capacity of the reserve pits to hold the cuttings from all wells drilled on the pad, as well as having sufficient room for drilling and well completion operations. For the RFD, all drill cuttings are assumed to remain on the pad. Note: pad sizes in other areas may be smaller in comparison, however, the operator would have received regulatory approval (and possibly private landowner approval) to move the drill cuttings elsewhere from the current drill pad.

The number of gas processing plants and compressor stations in operator development plans were also understated, and sometimes omitted in the RFD's that were submitted. Estimates were made by WRFO technical staff to determine the additional support facilities that would be

needed (and the correlating disturbance) based on the knowledge of each company's operations and projected production estimates.

RFD Production Estimates: Historical and projected natural gas production from the Mesaverde Play Area included in the 17,800 well RFD is shown in Figure 16. Using the drilling schedule that was created in support of the, and 1.6 BCF reserves estimates for a typical Mesaverde well and 3.2 BCF for a well that is believed to be influenced by natural fractures, it is projected that 19.8 TCF of natural gas will be produced in the WRFO during the RFD timeframe.

Production from the 224 Mesaverde wells drilled in the first year (2009) is estimated to be 94 BCF, while 567 BCF of natural gas is expected to be produced in 2015. The final year (2028) of production is projected to be 2.0 TCF from a total of 1,451 Mesaverde wells that would be drilled (Figure 17). The average life of a 1.6 BCF well is projected to be 45 years (using a 100 MCF per month economic limit), while a 3.2 BCF well is projected to have a 52 year economic life.

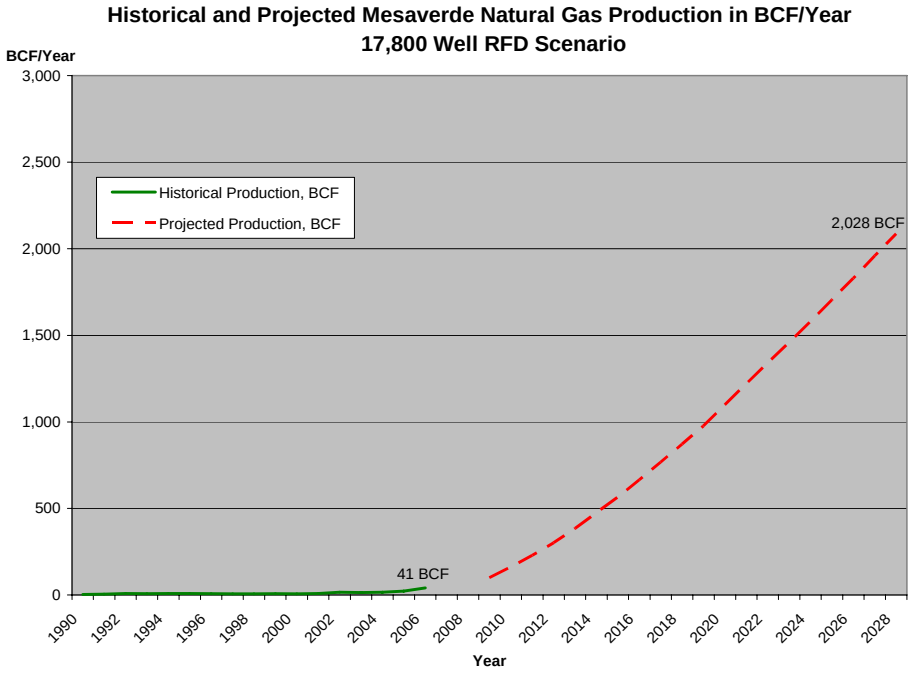


Figure 16. Past and projected Mesaverde gas production from the 17,800 Well WRFO RFD Scenario.

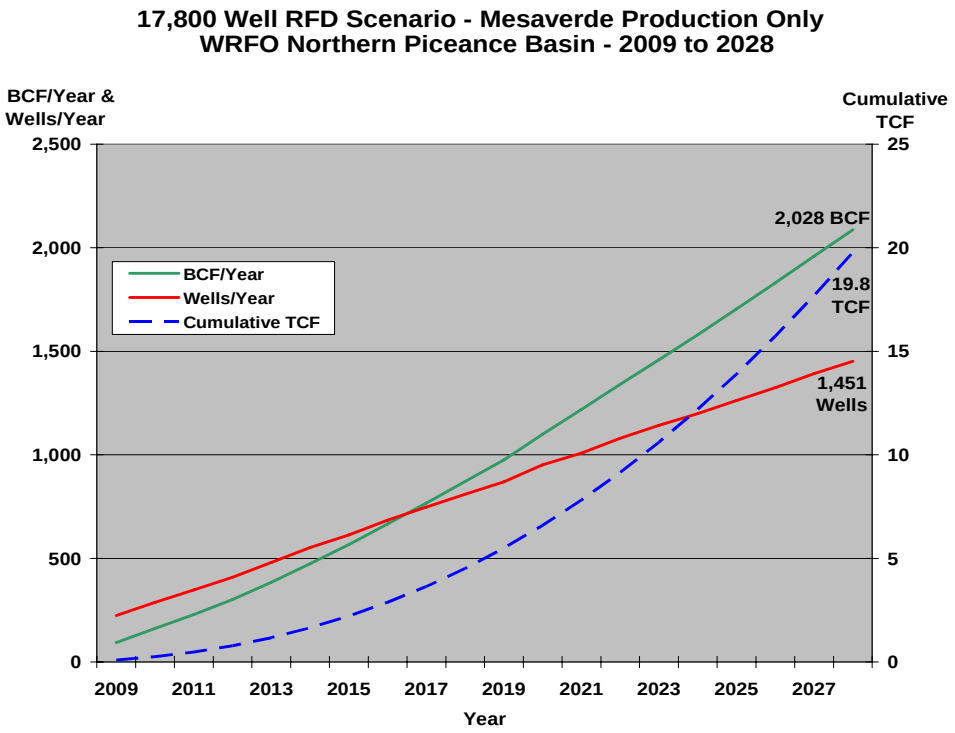


Figure 17. Projected Mesaverde gas production from the 17,800 Well WRFO RFD Scenario.

RFD Drilling Constraints:

- Drilling Rig Availability – At the time the WRFO RFD analysis began (spring 2006), drilling rig availability was a very important consideration as there were 17 rigs drilling in the northern Piceance Basin. At that time, all rigs in the Basin were under long-term contract with little flexibility built-in. By the fall of 2006, the demand for rigs eased as natural gas prices relaxed, and in June 2007 there are 10 rigs drilling on federal lands. Rig availability will continue to be an influential factor in the future in regard to how fast WRFO development will occur, especially if gas prices trend upward.

- Natural Gas Prices – Along with drill rig availability, natural gas prices are an equally important factor that will either limit or encourage further drilling activity in the Basin. When gas prices peaked in November 2005, Mesaverde drilling activity was at its highest level ever in the northern Piceance Basin (Figure 18). However, when gas prices softened in the summer and fall of 2006, drilling activity softened as well as wellhead prices nearing $5.00 per MCF approached the profitability margin for some companies[8]. Should natural gas prices stay above $6.00 per MCF, long-term development in the WRFO should continue as long as rig availability needs are met.

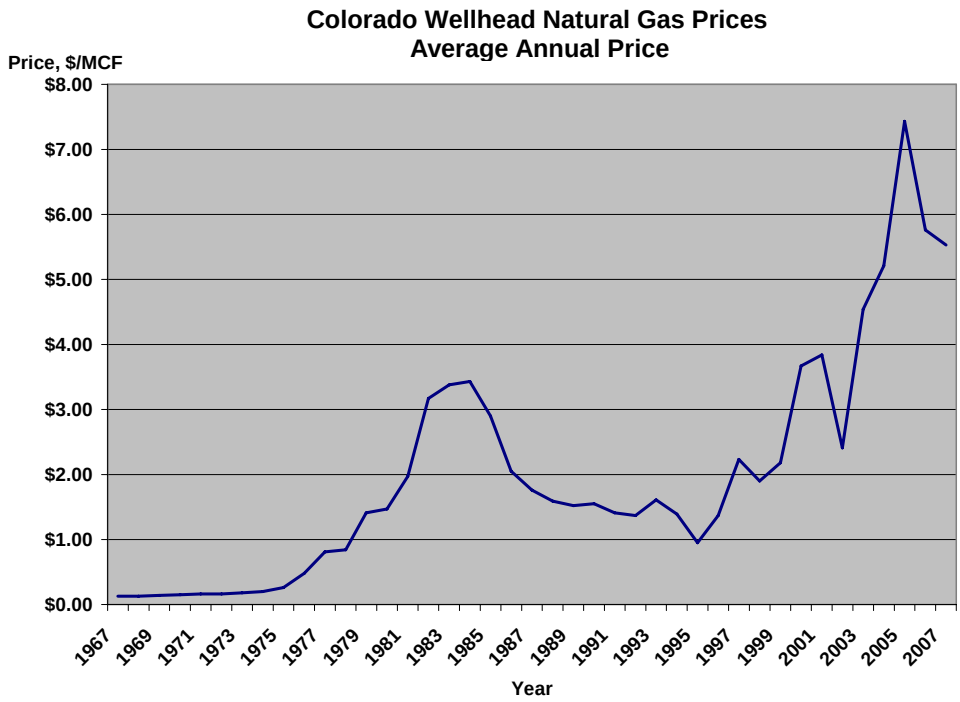


Figure 18. Historical average annual wellhead gas prices in Colorado.

- BLM Lease Stipulations – Existing lease stipulations and APD Conditions of Approval (COAs) may alter a company's drilling plans by moving the rig to less sensitive areas of the operator's acreage position or by releasing the rig till such time the stipulations are no longer in effect. Increasingly, operators are drilling year-round and will usually work with their BLM counterparts to plan around areas having severe winter range or wildlife stipulations to minimize impacts from drilling.

- Produced Water Handling – As mentioned previously, substantial amounts of water are produced along with the natural gas that is produced. Historically, some operators have been forced to shut-in their wells until a solution could be found to alleviate the problem. Some operators attempt to solve this problem by recycling the water so it can be used in deep drilling or completion operations, by trucking the water to commercial disposal facilities, or by injecting downhole in a disposal well. Operators have also sought approval in using surface evaporation ponds for water disposal, however this method has not been approved by the WRFO. At this time, each of the companies are attempting to solve this problem individually, whereas long-term solutions may exist if the companies chose to combine their resources to address this problem.

- Fresh Water Requirements – It can be foreseen that continued and future industrial operations in the northern Piceance Basin that rely on sources of fresh water may be impacted if commercial quantities are diminished. Fresh water is needed for surface drilling operations on Mesaverde wells, in addition to cementing requirements for all casing strings that are run. A source of fresh water not yet exploited could be the treatment of water produced from natural gas production operations.

- Slope Considerations – Much of the topography of the northern Piceance Basin is highly variable, and can be typified as steep rolling hills (Figure 5). This makes it difficult in determining suitable locations for drilling, as most wellpads will be constructed initially on the flat ridgelines or in the bottoms of drainage areas. The number of optimal locations is finitely limited, therefore operators will need to optimize the location of future roads and wellpads for maximum benefit, and utilize directional drilling technology to target bottom-hole locations where there is steep terrain overhead. From the review of Mesaverde Play Area topographical maps, it is estimated by WRFO technical staff that there are 128,000 acres in the northern Piceance Basin having greater than 35% slope (18% of the 712,190 acre Mesaverde Play Area) (Figure 19).

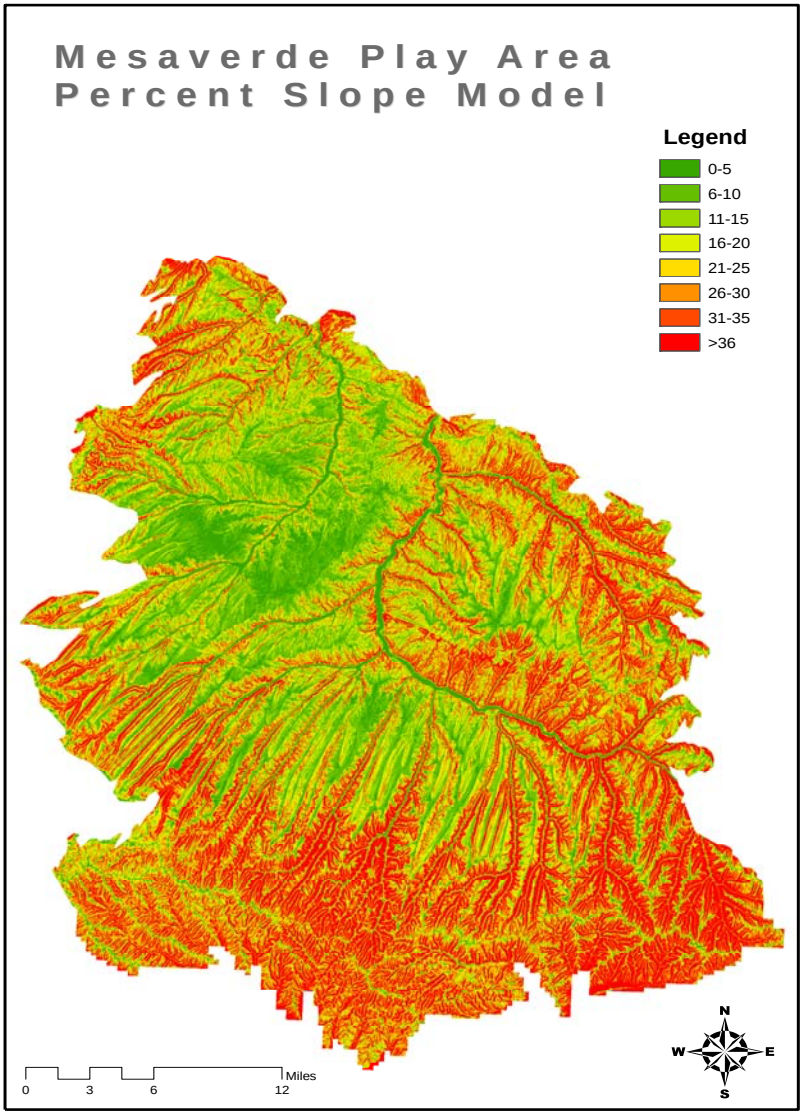


Figure 19. Slope model for the general Mesaverde Play Area.

- Cumulative Air Emissions Effects –Northern Piceance Basin operators may be required to implement mitigation measures soon that could possibly include diesel-electric powered drill rigs, and electric motors for gas plants and compressor stations.

- Natural Gas Market/Pipeline Infrastructure – Operators continue to research market alternatives that will hopefully bring a higher price for the product that is sold. However, if no new gas transmission lines are built in the future to add new markets, there exists a risk that the future drilling activity forecasted in this RFD may result in new production filling existing pipelines to capacity at some point. Should this happen, the drilling plans for some companies may be impacted until transportation capacity can be expanded.

- Northern Piceance Basin and Northwest Colorado Road Infrastructure – County roads leading into the northern Piceance Basin will need to be upgraded significantly to handle the drilling activity that is projected. At current drilling levels, road use by local ranchers, drilling rig hands, construction crews, pipeline crews, service company personnel and water hauling trucks is approaching full utilization.

- Availability of Service Company Services – Drilling and completion support services are in high demand with the activity now being seen in the Piceance Basin. Service companies that provide well logging, cementing, acid stimulations and fracture stimulation services are many times unavailable, and operators sometimes must wait until a crew completes another job. These companies are taking steps to bring in additional equipment and personnel to handle the existing and future demand.

- Experienced Drilling and Service Company Personnel – This is a long-standing problem that affects the petroleum industry nationwide. Working in the oilfield is demanding and sometimes dangerous, especially if a person works on a drilling rig or for a service company, both of which are on the go 24 hours a day, 7 days a week. There is a considerable turnover in employees due to the demanding nature of the work, and companies are always looking to hire additional help from both experienced and non-experienced workers.

Influence of New Technology: In the mid 1980s, production from wells located in tight gas sand reservoirs were then considered uneconomic until such time new technology was developed to economically recover sufficient quantities of gas to pay for drilling and completion costs[9]. Looking backwards in modern day time, it can be seen that technological advancements have been made over the years, as it has been demonstrated in recent years that the Mesaverde tight gas sands can now be economically exploited.

Industry is experimenting with enhanced completion technologies involving the fracture stimulation of all open intervals at the same time (called multi-zone stimulation technology), that is hoped to increase ultimate recoveries of natural gas by 25 percent[7].

Advancements in drilling technology are also expected. One company recently announced the development of a process that is expected to increase the rate of drilling penetration up to 100% by incorporating real time information on rock physics. Rigs using this technology are expected

to drill wells 35% faster overall, and it is anticipated technologies such as these will be adapted soon for use in the northern Piceance Basin[10].

Feedback solicited from industry is strong in the belief that technologies such as these will be successfully developed, and will reduce the average time now needed to drill a well from one-month to three weeks time. These anticipated improvements were included in WRFO RFD drilling analysis in select areas of the northern Piceance Basin where it logically made sense.

Environmental technologies are also being developed and utilized more. Some companies operating in the southern Piceance Basin near the towns of Rulison and Parachute are using closed loop drilling mud systems that will eliminate the need for building large reserve pits. Although drill cuttings still need to be disposed of in a responsible manner (with the approval of regulatory agencies and surface owners, as applicable), the actual surface disturbance is reduced considerably in regard to how large a wellpad needs to be constructed. Another anticipated area of improvement is meeting stringent air quality requirements, and it is believed industry will cooperate with the increased use of diesel electric drilling rigs, as well as the increased use of electric motors in gas plants and compressor stations.

XI. REFERENCES

Sections I-VII

Bureau of Land Management (BLM), 1990. Planning for Fluid Mineral Resources. BLM Handbook H-1624-1, Washington, D.C.

Bureau of Land Management (BLM), 1997, White River Record of Decision and Approved Resource Management Plan (ROD/RMP), White River Field Office, Meeker, Colorado.

Bureau of Land Management (BLM). 2004. Instruction Memorandum No. 2004-089, Policy for Reasonably Foreseeable Development (RFD) Scenario for Oil and Gas, Washington, D.C.

Bureau of Land Management (BLM). 2005. Reasonable Foreseeable Development: Oil and Gas in the Little Snake Field Office Administrative Boundary Area (LSFO). Little Snake Field Office, Craig, Colorado.

Bureau of Land Management (BLM). 2006. Roan Plateau Planning Area Oil and Gas Reasonable Foreseeable Development (RFD). Volume III, Appendix H in Roan Plateau Planning Area Resource Management Plan Amendment & Environmental Impact Statement. Glenwood Springs Field Office, Glenwood Springs, Colorado.

Colorado Oil and Gas Conservation Commission (COGCC), Division of the Colorado Department of Natural Resources. 1120 Lincoln Street, Suite 801, Denver, Colorado 80203. Website: http://oil-gas.state.co.us.

Durham, Louise S., 2007, Rockies Living up to Promise: AAPG Explorer, American Association of Petroleum Geologists, Volume 28, No. 5, p. 8,-12.

Environment Protection Agency, 2004, Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs, Attachment A: EPA Report 816-R-04-003.

Hyne, Norman J., 1991, Dictionary of Petroleum Exploration, Drilling, & Production, Penwell Publishing Company, Tulsa, OK, 625 p.

IHS Energy Group, 2006, Petroleum Information/Dwights Plus Production Data on CD ROM: Released April 26, 2006: IHS Energy Group, 15 Inverness Way East, Englewood, CO.

IHS Energy Group, 2007, Petroleum Information/Dwights Plus Well Data on CD ROM: Released May 1, 2007: IHS Energy Group, 15 Inverness Way East, Englewood, CO.

Smith International, Inc., 2007, Smith Tool Activity Tracking System (S.T.A.T.S.) Report Center, http://www.smith.com/stats/new/.

U.S. Departments of the Interior, Agriculture, and Energy, 2003, Scientific Inventory of Onshore Federal Lands' Oil and Gas Resources and Reserves and the Extent and Nature of Restrictions or Impediments to their Development. Phase I Inventory: The Paradox/San Juan, Uinta/Piceance, Greater Green River, and Powder River Basins and the Montana Thrust Belt, In compliance with the Energy Policy and Conservation Act Amendments of 2000; *also commonly known as the 2003 EPCA Study*.

U.S. Departments of the Interior, Agriculture, and Energy, 2006, Scientific Inventory of Onshore Federal Lands' Oil and Gas Resources and Reserves and the Extent and Nature of Restrictions or Impediments to their Development. Phase II Cumulative Inventory: Northern Alaska, Montana Thrust Belt, Powder River Basin, Wyoming Thrust Belt, Greater Green River Basin, Denver Basin, Uinta-Piceance Basin, Paradox/San Juan Basins, Appalachian Basin, Black Warrior Basin and the Florida Peninsula, In compliance with the Energy Act of 2000 as Amended by the Energy Policy Act of 2005 ; *also commonly known as the 2006 EPCA Study*.

U.S. Geological Survey, 1995, 1995 National Assessment of United States Oil and Gas Resources, National Oil and Gas Resource Assessment Team: U.S. Geological Survey Circular 1118, U.S. Government Printing Office, Washington, D.C., 20 p.

U.S. Geological Survey, 2003, National Assessment of Oil and Gas Project: Petroleum Systems and Geologic Assessment of Oil and Gas in the Uinta-Piceance Province, Utah and Colorado, Digital Data Series DDS-69-B, Washington, D.C.

Sections VIII –X

[1]Holditch, Stephen A. – Texas A & M University – Tight Gas Sands

[2]Denver Post – January 4, 2007 – Drilling Permits Gushed in 2006

[3]Oil and Gas Investor – August 2005 Article - With as much as an estimated 300-plus trillion cubic feet of gas resource in place, Colorado's Piceance Basin may well be the largest natural gas play in North America

[4]Hood, Ken and Yurewicz, Don – ExxonMobil Corporation - Assessing the Mesaverde Basin-Center Gas Play, Piceance Basin

[5]United States Geological Survey – 1987 Open-File Report 87-357 – An Assessment of Gas Resources in Low-Permeability Sandstones of the Upper Cretaceous Mesaverde Group, Piceance Basin, Colorado

[6]Tyler, R., Scott A.R., Kaiser, W.R. – 1998 - Defining Coalbed Methane Exploration Fairways: An Example From the Piceance Basin, Rocky Mountain Foreland

[7]Rocky Mountain News – June 24, 2006 – Exxon Puts the Squeeze on Gas

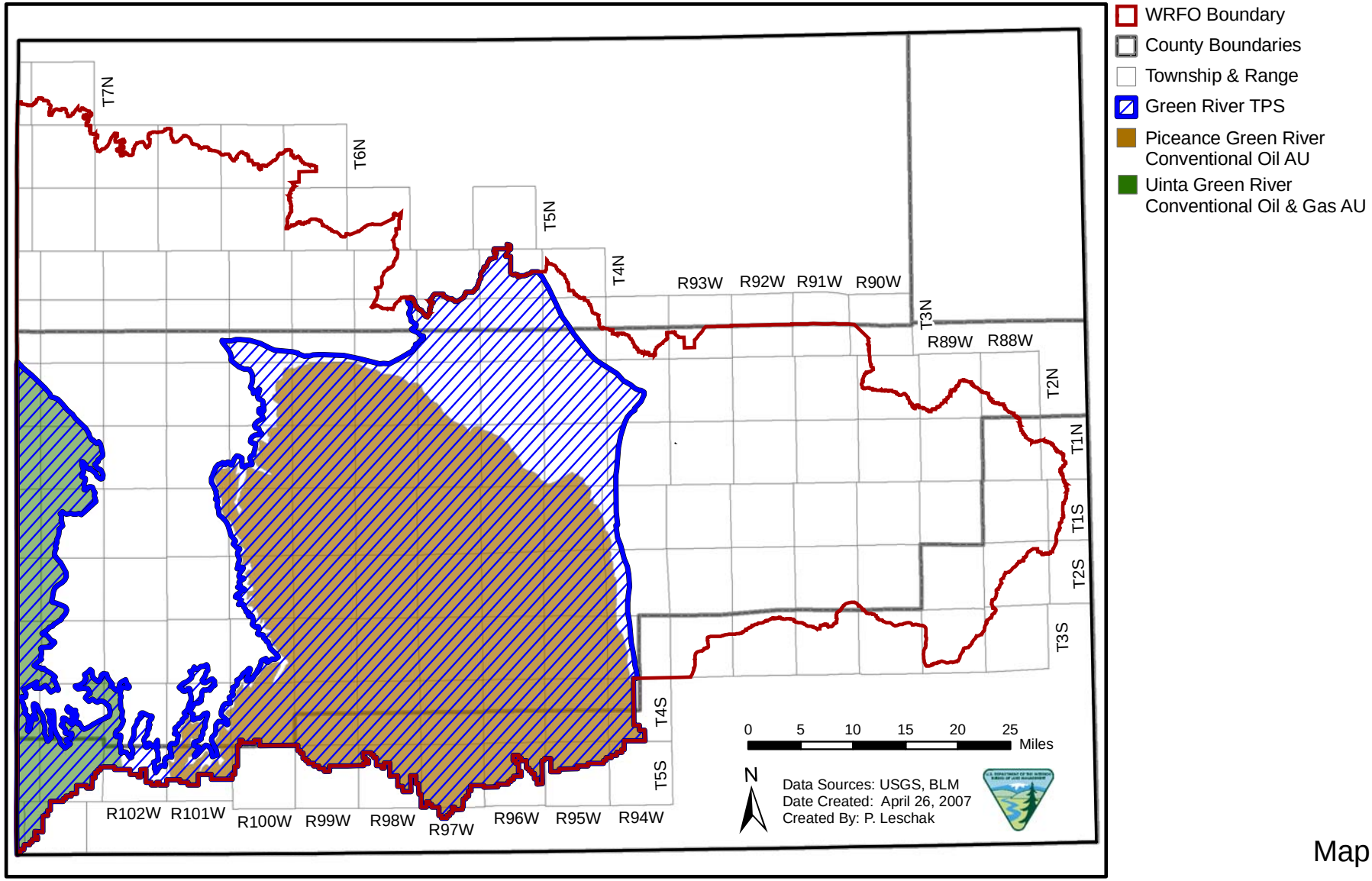
[8] Rocky Mountain News – November 1, 2006 – Energy Cool-down

[9]Gas Technology Institute - Fall 2004 Gas Tips – Unconventional Gas: Reserve Opportunities & Technology Needs

[10]ExxonMobil Corporation Stock Analyst Meeting – March 8, 2006, New York, New York

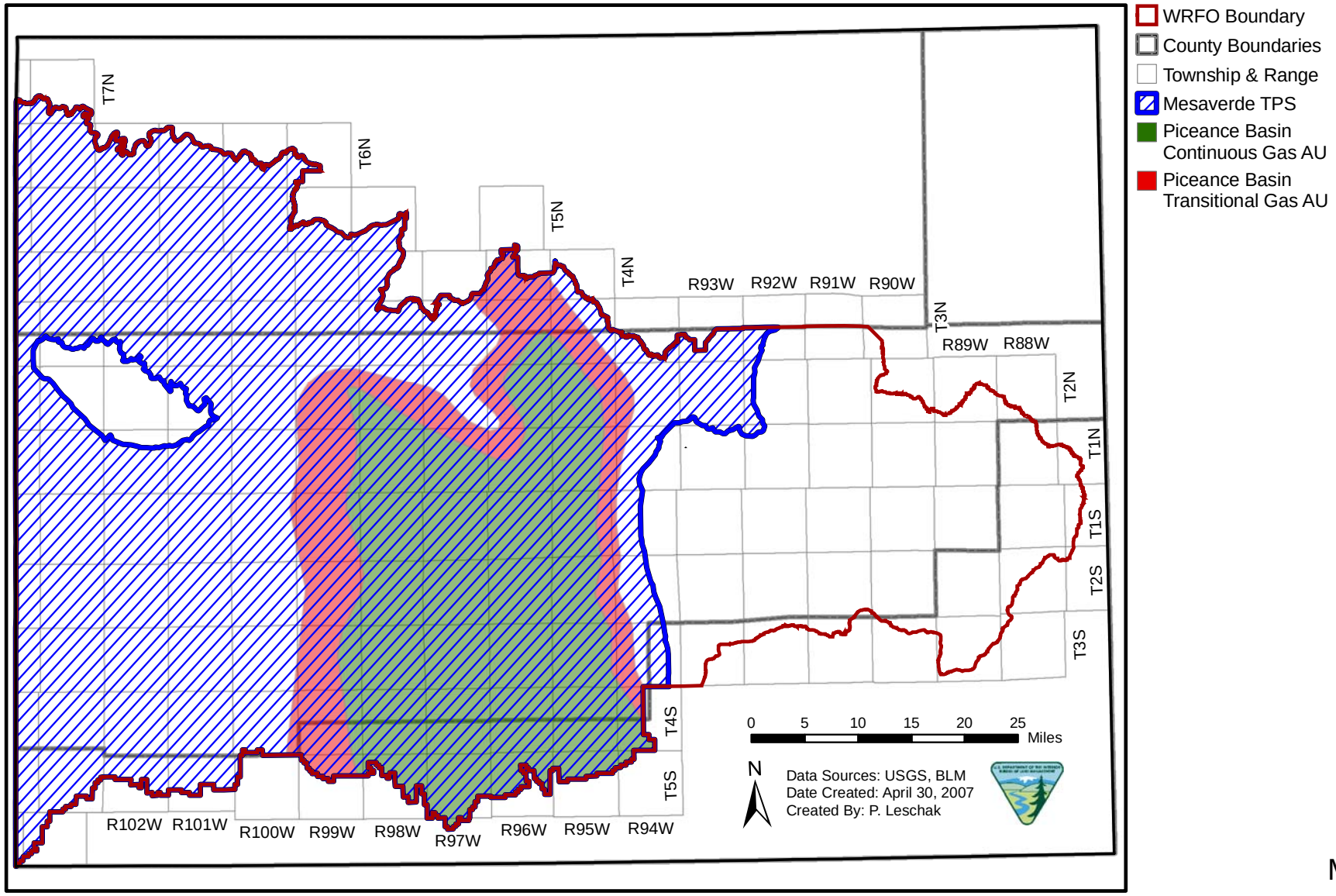
XII. APPENDIX A: WRFO Total Petroleum System and Assessment Unit Maps

WRFO Green River Total Petroleum System & Assessment Units



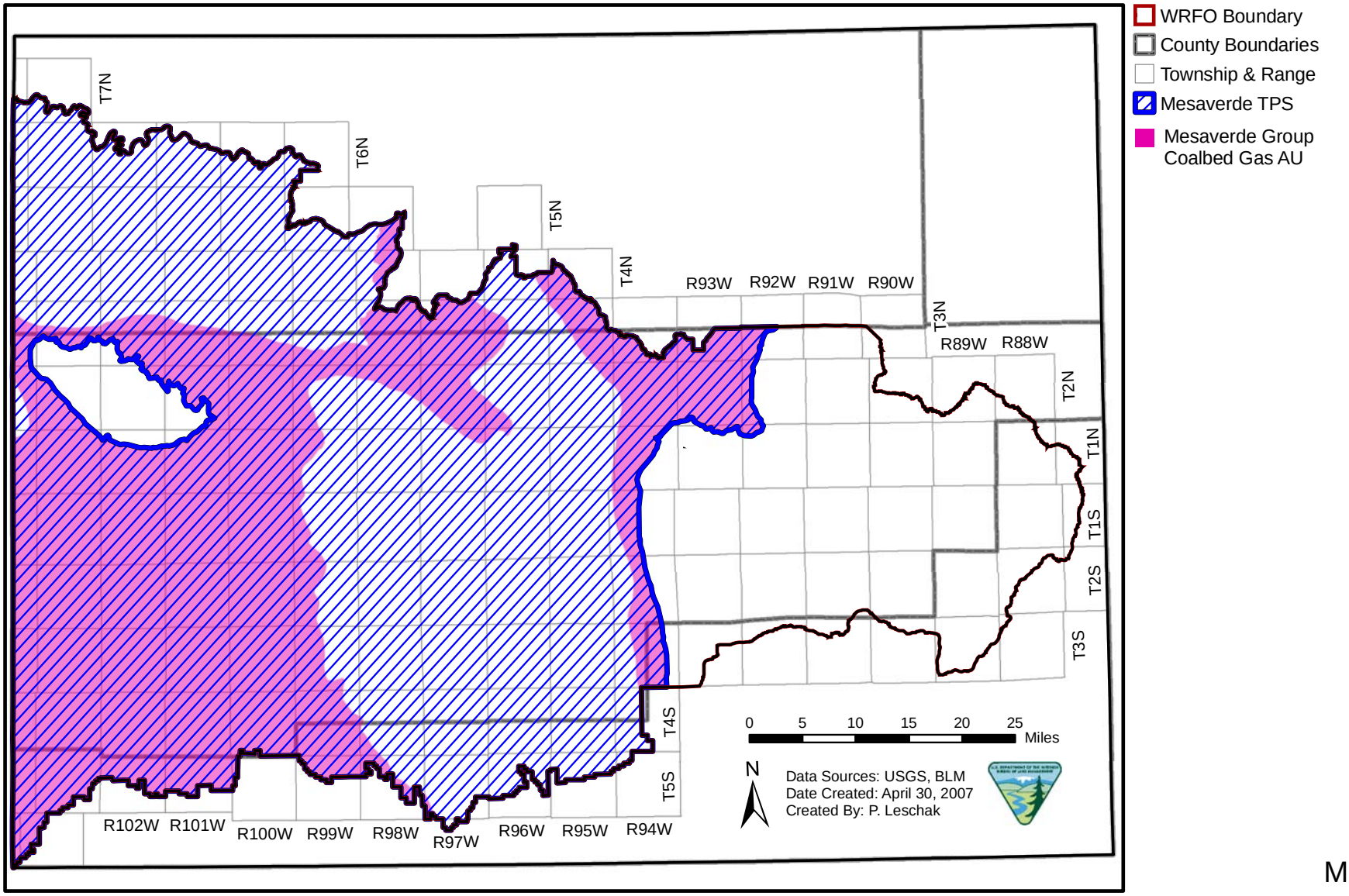
Map A

WRFO Mesaverde Total Petroleum System & Piceance Basin Assessment Units



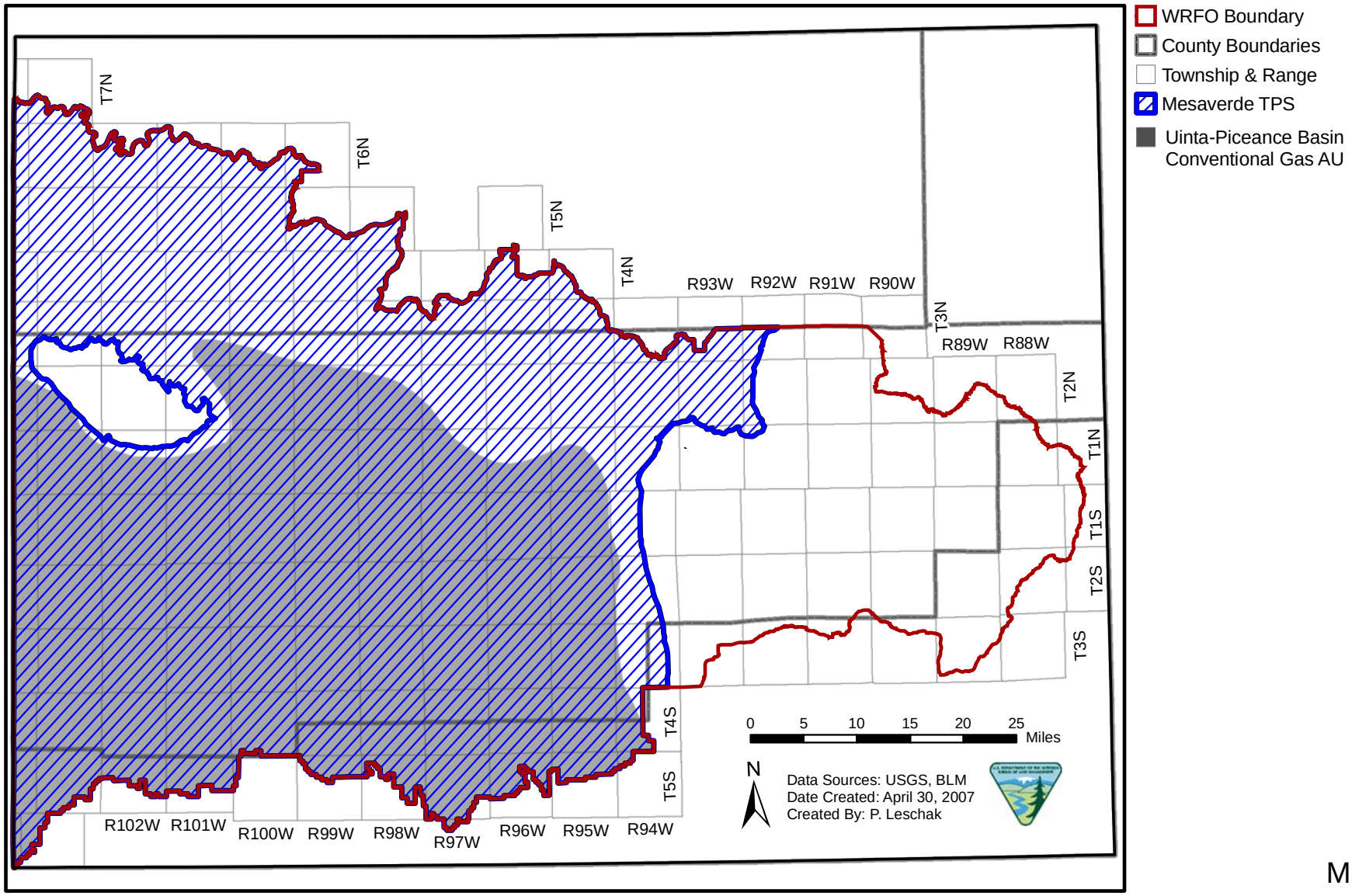
Map B

WRFO Mesaverde Total Petroleum System & Coalbed Gas Assessment Unit



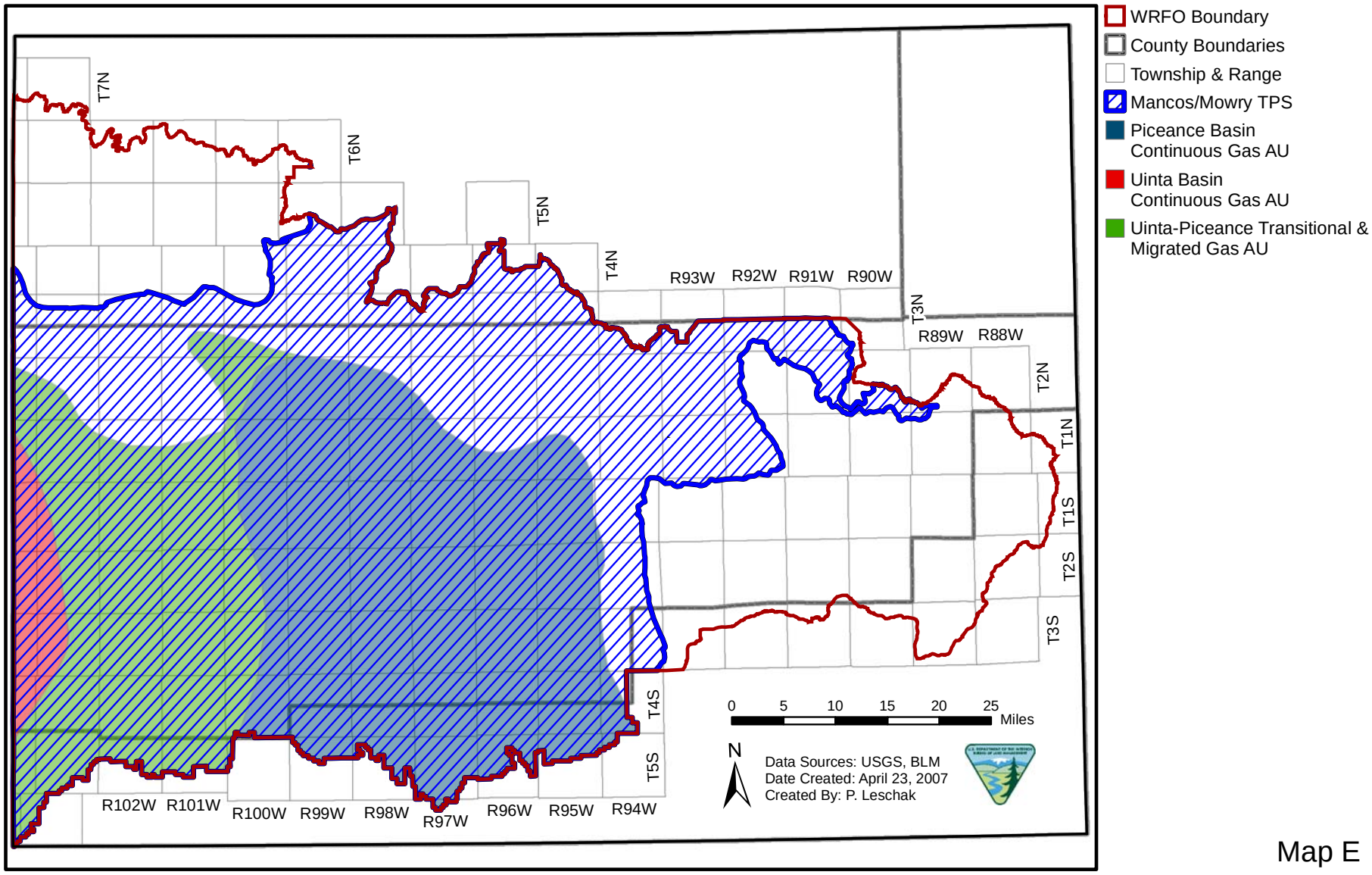
Map C

WRFO Mesaverde Total Petroleum System & Uinta-Piceance Basin Conventional Gas Assessment Unit



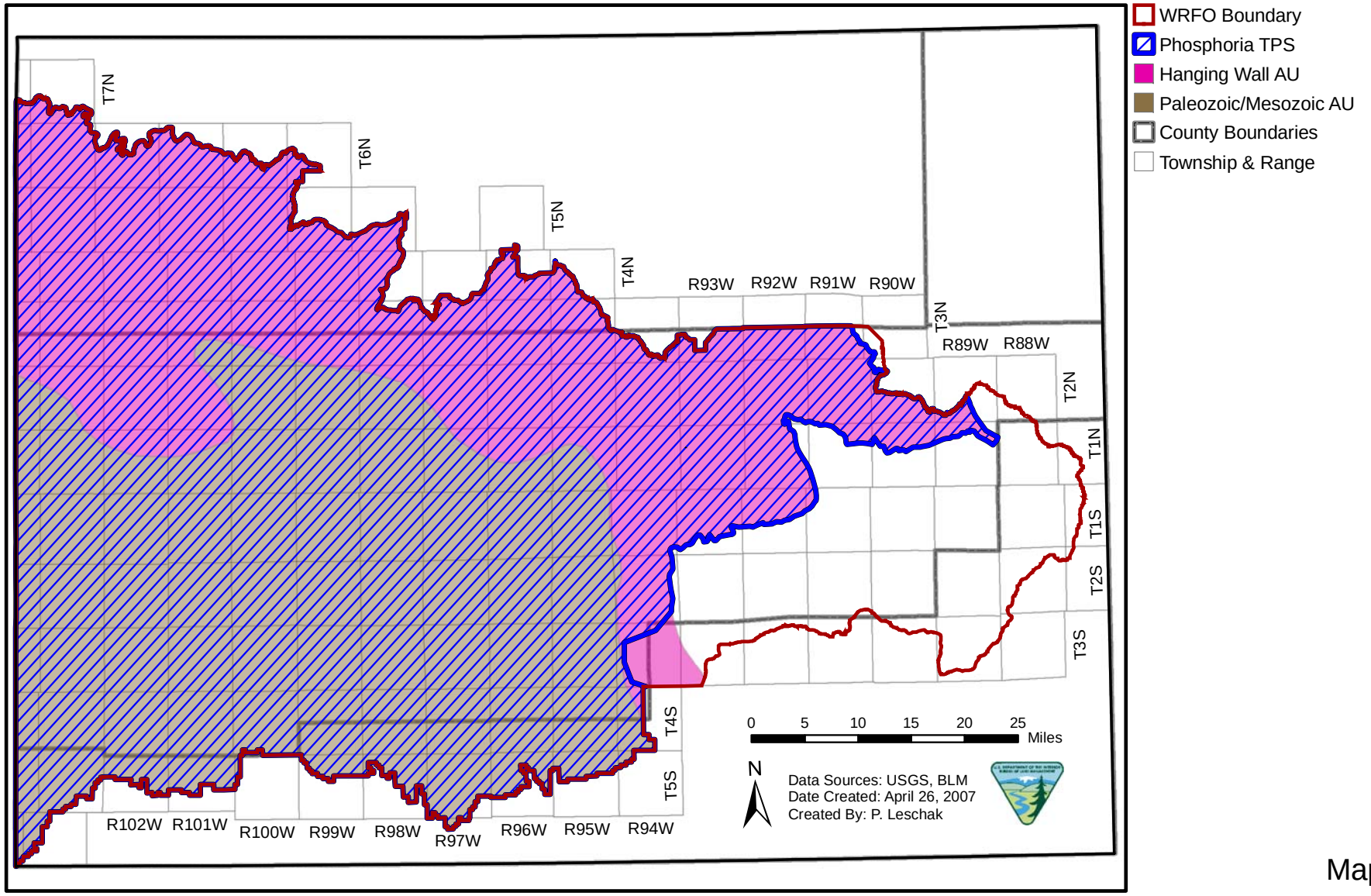
Map D

WRFO Mancos/Mowry Total Petroleum System & Assessment Units



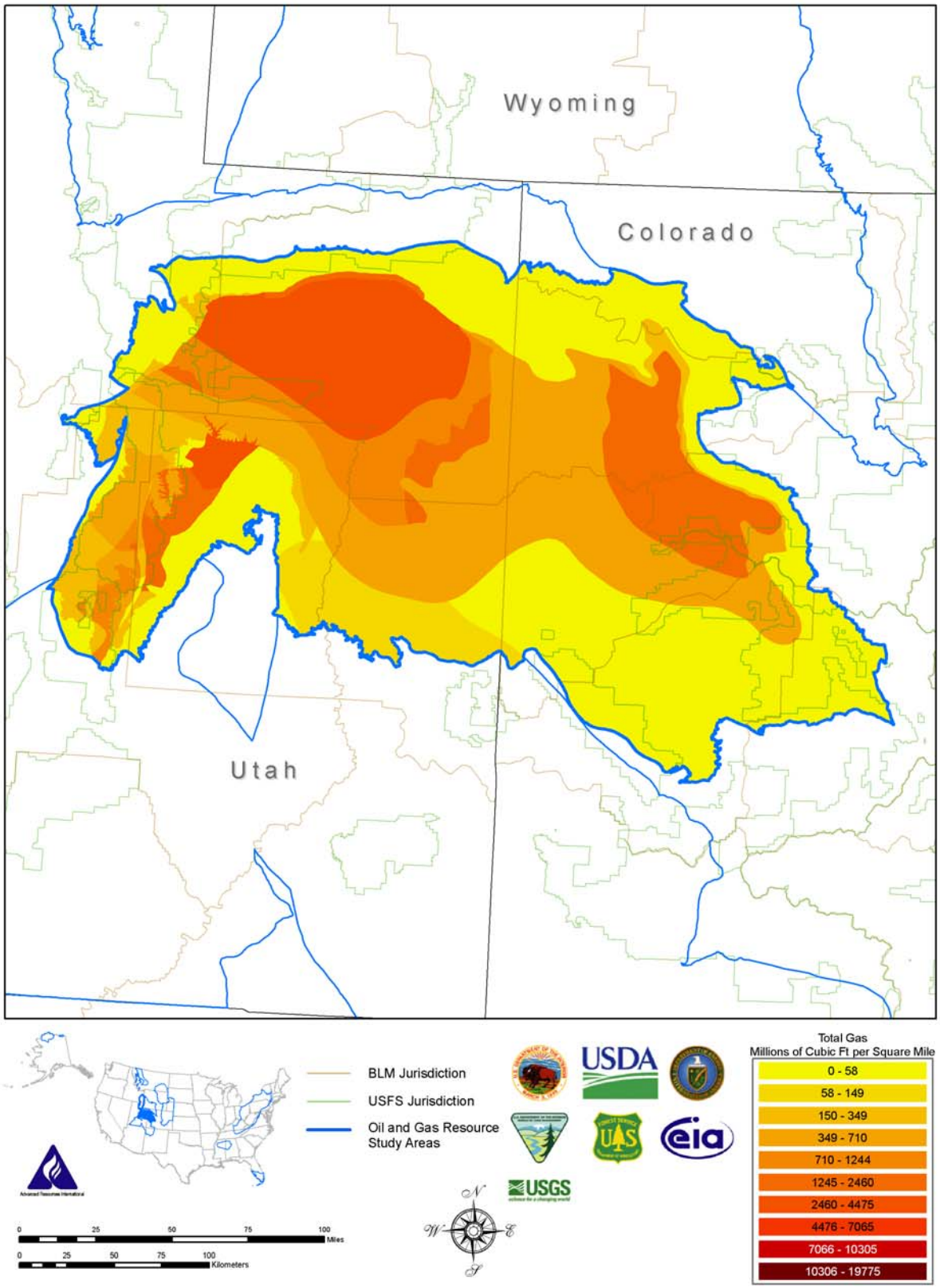
Map E

WRFO Phosphoria Total Petroleum System & Assessment Units

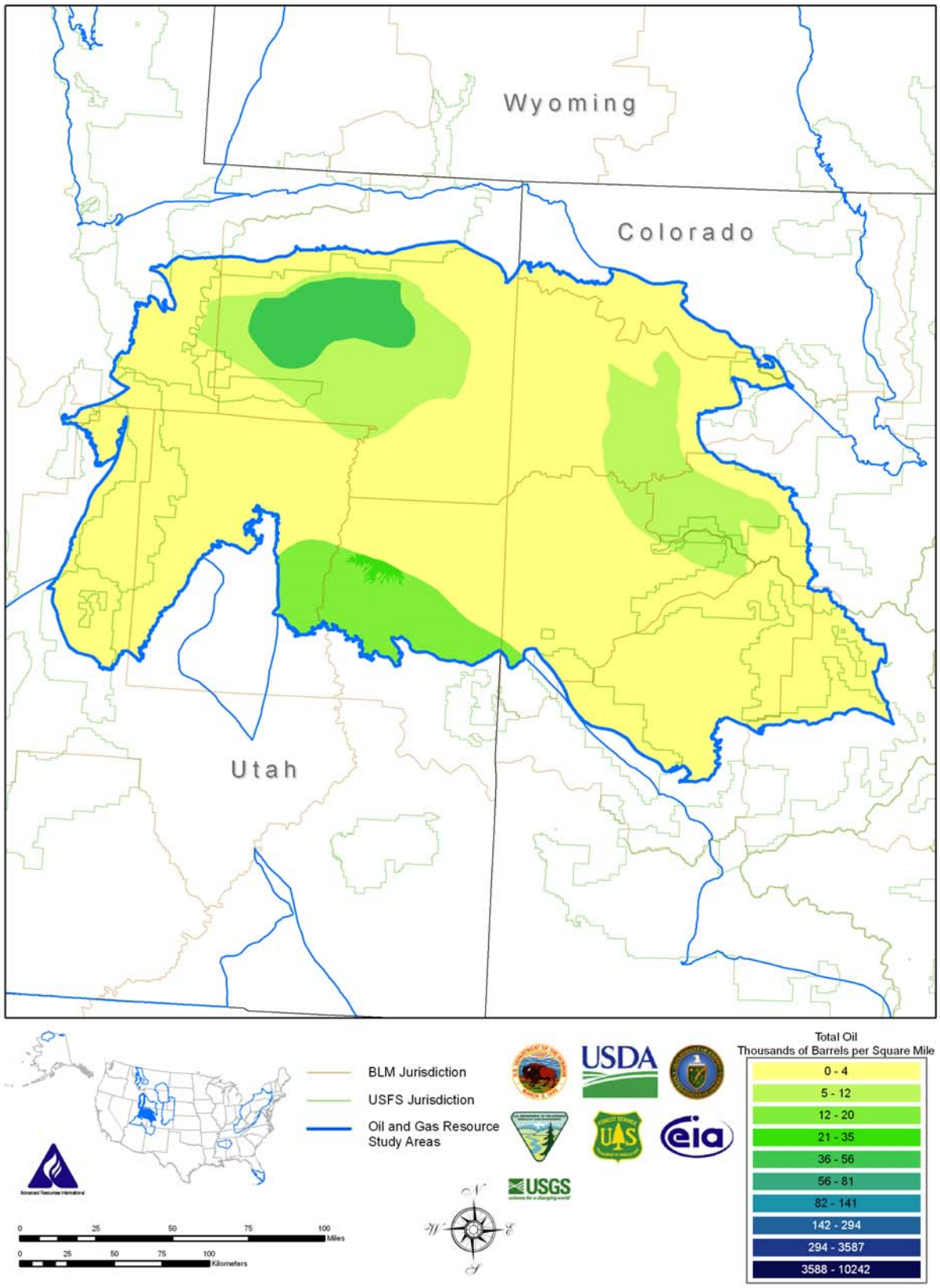


Map F

XIII. APPENDIX B: EPCA Total Oil and Gas Volume Resource Maps



EPCA 2006 Total Gas Volume Resource Map Map G



EPCA 2006 Total Oil Volume Resource Map Map H

XIV. APPENDIX C: Reasonable Foreseeable Development Scenario Assumptions

- Model WRFO RFD drilling activity after drilling development activity associated with western Wyoming's Jonah and Pinedale Anticline areas, and the southern Piceance Basin area
- Some of the Active Piceance Basin operators will begin drilling on 10 acre spacing in 2009, while less active operators will be drilling on 10 acre spacing in 2016
- Assign recoverable reserves of 1.6 BCF per well for the majority of Piceance wells drilled (70%), while 3.2 BCF per well were assigned for the remaining wells (30%)
- Major constraints to WRFO drilling activity were identified to include rig availability and natural gas price
- Less important constraints that may also impact future WRFO drilling activities include:
    - BLM Lease Stipulations
    - Produced Water Handling
    - Fresh Water Requirements
    - Slope Considerations
    - Cumulative Air Emissions Effects
    - Natural Gas Market/Pipeline Infrastructure
    - Northern Piceance Basin County Road and Northwest Colorado State Highway Infrastructure
    - Availability of Service Company Services
    - Experienced Drilling and Service Company Personnel
- Additional technological advancements in reducing the time to drill a well from one month to three weeks
- Additional increases in the number of rigs drilling in the northern Piceance Basin that arrive from other parts of the country
- The following assumptions were used in drilling Mesaverde wells:
    - For a one-well pad, an average pad size of 4 acres was used
    - For an eight-well pad, an average pad size of 8 acres was used
    - For a sixteen-well pad, and average pad size of 12 acres was used
- A systematic development approach was used that captured a company drilling one well per pad initially (on 20 or 40-acre downhole spacing), then progressing to an average of eight wells drilled per pad (on 20 acre downhole spacing), then ultimately drilling an average of 16 wells per pad (on 10 acre downhole spacing).

Industry Development Scenario – Addendum to the WRFO RFD

The second development scenario, the Industry Development forecast, includes the original RFD projections from the oil companies for a total of 21,200 wells that could be expected to be drilled on 2,556 wellpads over a twenty year period on lands within the White River Field Office (WRFO). The associated surface disturbance for this level of activity is estimated to be 31,257 acres, and this alternative may be used as the basis for the Resource Management Plan Amendment analysis.

In the 21,200 well development scenario, 18,750 wells could be projected to be drilled on Federal lands while 2,450 wells are anticipated to be drilled on private lands. No wells were forecasted to be drilled on State of Colorado lands due to the limited acreage that exists within the WRFO.

This Industry Development forecast was discounted initially by WRFO technical staff from 21,200 wells to 14,400 wells as a result of analyzing the number of drilling rigs and the actual development pace that took place in the Jonah and Pinedale Anticline areas of western Wyoming, which would entail an unprecedented level of deep-well drilling in the Rocky Mountains. A similar development pace applied to the WRFO would lead to a baseline of 10,900 wells that would be drilled in twenty years, and this projection was increased by WRFO technical staff to an initial RFD scenario of 14,400 wells assuming more rigs would be brought into the northern Piceance Basin and new drilling technologies would be developed to shorten drilling times. Major drilling constraints specific to the WRFO include drilling rig availability and fluctuations in natural gas price that would impact the economics of drilling in the northern Piceance Basin.

As a process check against the assumptions and projections used in preparing the 14,400 well RFD, WRFO technical staff presented their findings to industry on December 5, 2006 in Denver, Colorado to solicit support and feedback. The response received from industry was that the 14,400 well RFD forecast was deemed “light” for the twenty year period spanning 2009 through 2028, and the oil companies preferred the original 21,200 Industry Development forecast as being more representative of future drilling activity.

In support of their position, the oil companies believed additional wells could be drilled if 1) drilling technology improved that would reduce the average drilling time from one month to three weeks, and 2) additional drill rigs would come to the Rocky Mountains and the northern Piceance Basin from other oil & gas producing states. These recommendations were incorporated into the WRFO RFD analysis, and the 14,400 well forecast was revised to a 17,800 well RFD. This was determined by using the 10,900 well baseline and:

- adding 4,550 wells as a result of decreasing the time to drill a typical Mesaverde well from one month to three weeks time
- adding 2,350 wells as a result of increasing the number of drilling rigs in the northern Piceance Basin by 2028 from 60 to 80

The 17,800 well WRFO RFD and supporting analysis was presented to State of Colorado Oil & Gas Conservation Commission (COGCC) representatives on January 25, 2007, as a second external process check, and the response was that the 21,200 well Industry Development scenario was viewed as being closer to their projections for long-term Piceance Basin development. COGCC representatives stated they believed future rig availability would not be an issue as either more rigs would be built or be moved in from other states.

For the Industry Development scenario, year one begins with 331 wells (including Mesaverde wells) that are projected to be drilled using 30 drill rigs. Year twenty of the forecast is assumed to be the most active drilling year with an estimated 1,759 wells drilled using a total of 108 drill rigs (Figure 1). It is projected that 23.5 TCF of natural gas will be produced in the WRFO during the twenty year timeframe.

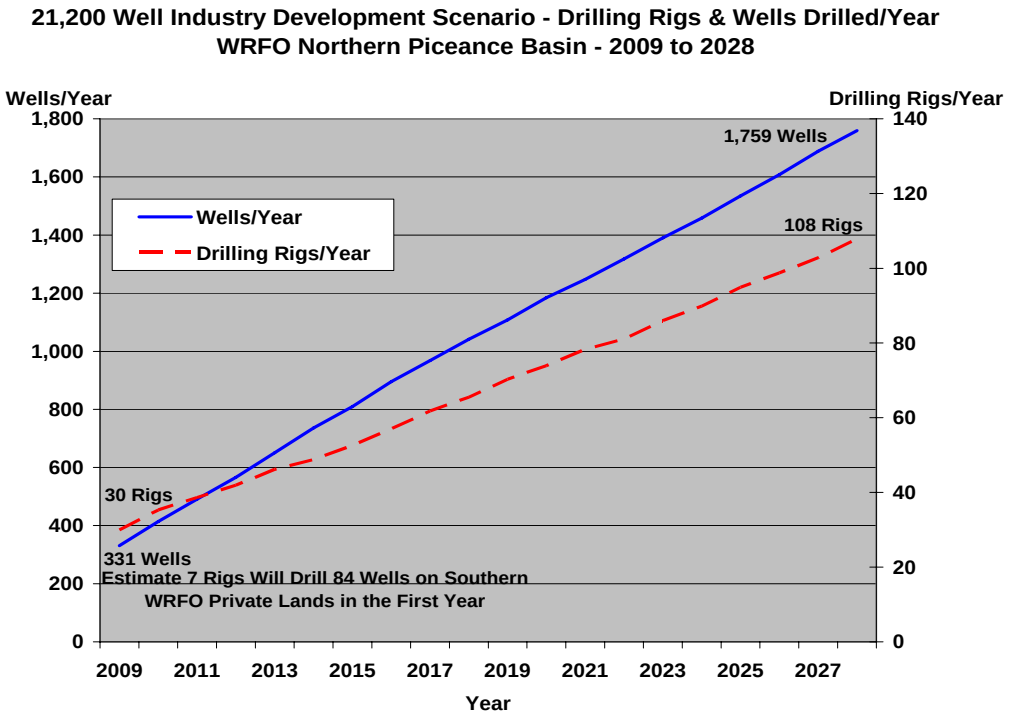


Figure 1. Number of rigs and wells projected in the 21,200 Well Industry Development Scenario.

Historical and projected natural gas production from the Mesaverde Play Area included in the 21,200 Well Industry Development Scenario is shown in Figure 2. Gas production from the 268 Mesaverde wells drilled in the first year (2009) is estimated to be 113 BCF, while 667 BCF of gas is projected to be produced in 2015. The final year of production is projected to be 2.5 TCF from a total of 1,728 Mesaverde wells that would be drilled in 2028 (Figure 3).

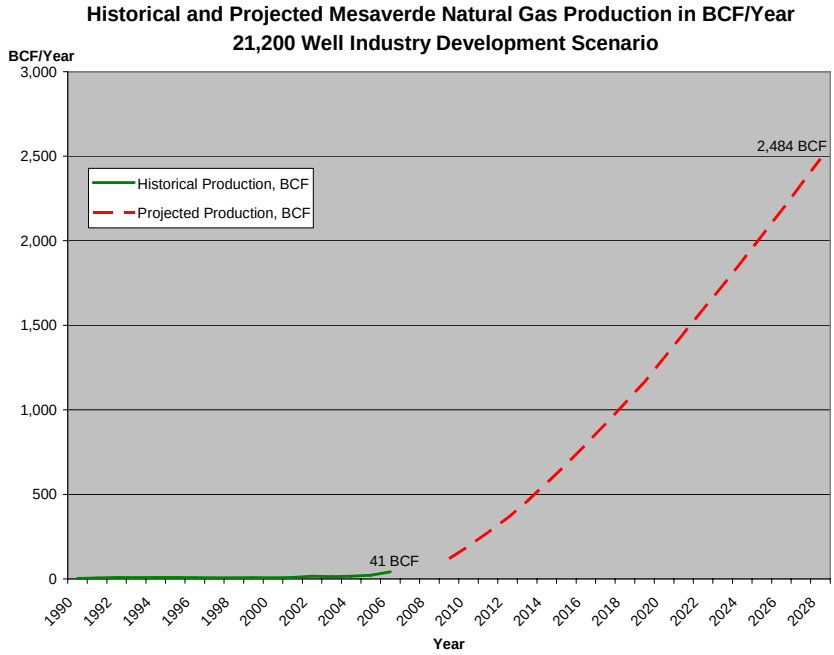


Figure 2. Past and projected Mesaverde gas production from the 21,200 Well Industry Development Scenario.

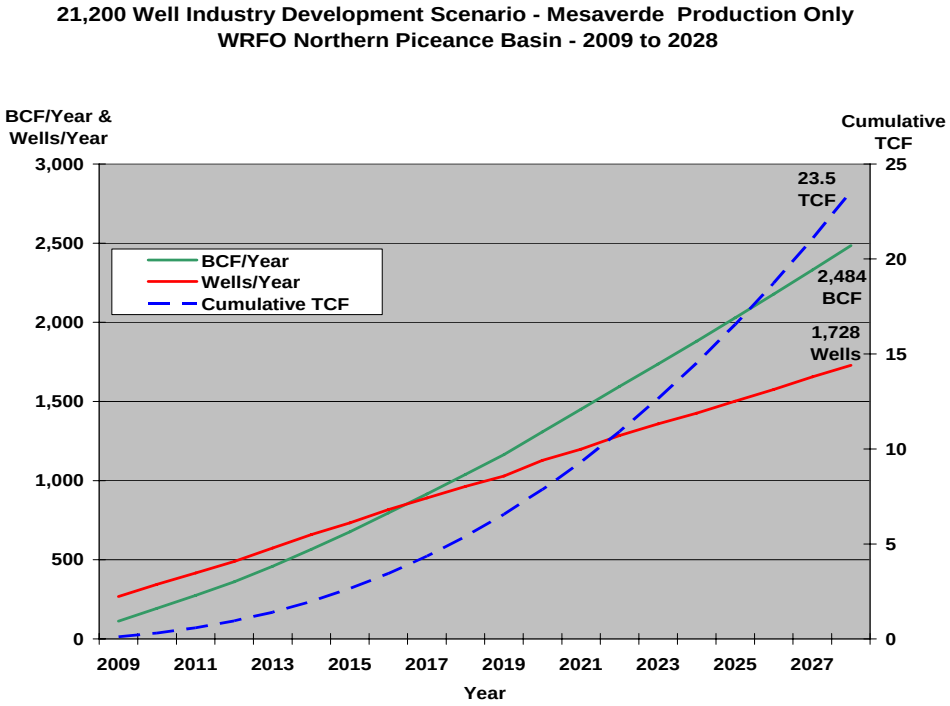


Figure 3. Mesaverde gas production from the 21,200 Well Industry Development Scenario

Surface disturbance impacts of 31,257 acres are projected to occur in implementing the 21,200 Well Industry Development forecast, as described below and in Figure 4:

- 18,510 acres for 2,556 wellpads
- 4,119 acres (1,133 miles) of roads
- 8,628 acres of pipelines, gas plants, compressor stations and other infrastructure

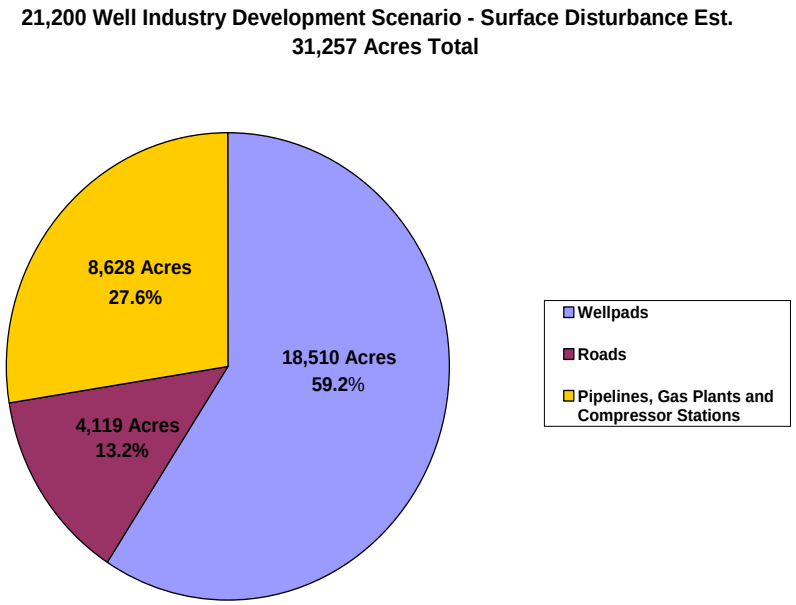


Figure 4. Disturbance estimates from the 21,200 Well Industry Development Scenario.

In March 2007, BLM management made the decision that the Industry Development scenario consisting of 21,200 wells on 2,556 wellpads and 31,257 acres of related surface disturbance that was submitted by the oil companies may be used as the basis for the Resource Management Plan Amendment analysis.

It should be noted in both the WRFO RFD and Industry Development scenarios, each scenario relied heavily upon future events and technology that has not yet been developed. In addition, the 21,200 well drilling scenario in the Industry Development forecast is unprecedented for medium-deep to deep drilling in the Rocky Mountains. The Industry Development scenario is based upon internal oil and gas company financial and technical information, and the WRFO technical staff was not able to verify this number.