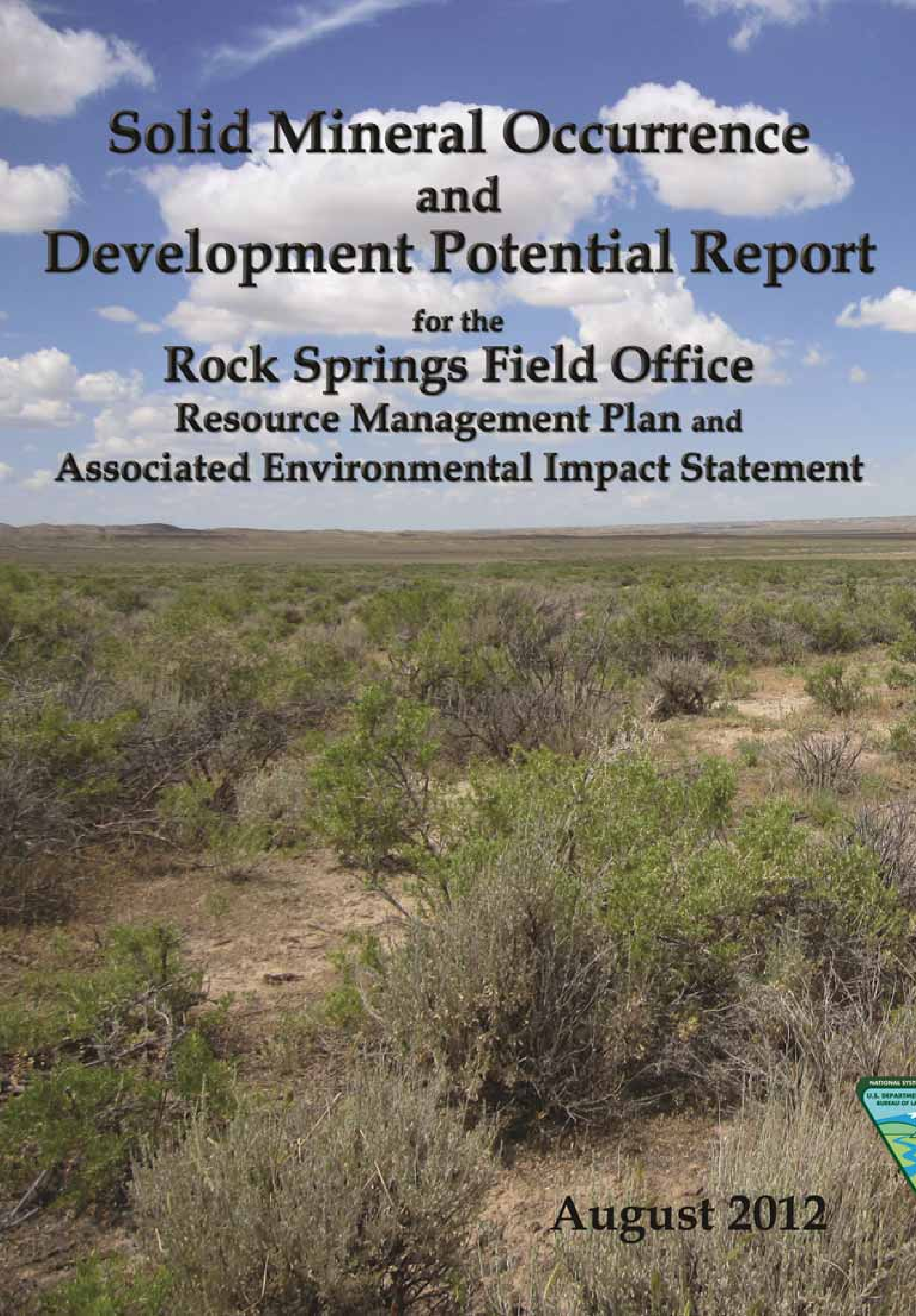

Solid Mineral Occurrence and Development Potential Report

for the

Rock Springs Field Office

Resource Management Plan and Associated Environmental Impact Statement

August 2012

BLM

Wyoming High Desert District – Rock Springs Field Office

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U.S. DEPARTMENT OF THE INTERIOR
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SOLID MINERAL OCCURRENCE

AND

DEVELOPMENT POTENTIAL REPORT

for the

Rock Springs Field Office
Resource Management Plan and
Associated Environmental Impact Statement

United States Department of the Interior
Bureau of Land Management
Wyoming High Desert District
Rock Springs Field Office

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ACRONYMS

AMS	Analysis of Management Situation
b.y.a.	Billion Years Ago
BBCC	Black Butte Coal Company
BCC	Bridger Coal Company
bgs	Below ground surface
BLM	Bureau of Land Management
btus	British Thermal Units
CBNG	Coalbed Natural Gas
CFR	Code of Federal Regulations
CODPA	Coal Occurrence Development Potential Area
EIS	Environmental Impact Statement
FUP	Free Use Permit
g	Gravity
gpt	Gallons Per Ton
ISR	In-situ Recovery
KSLA	Known Sodium Leasing Area
lb	Pound
LHM	Leucite Hills Mine
LQD	Land Quality Division
MMBO	Million Barrels of Oil
MMTA	Mechanically Minable Trona Area
N/D	Not Determined
PEIS	Programmatic Environmental Impact Statement
R&D	Research and Development
RD&D	Research, Development, and Demonstration
RFD	Reasonably Foreseeable Development
RMP	Resource Management Plan
ROD	Record of Decision
ROW	Right of Way
RSFO	Rock Springs Field Office
RSPA	Rock Springs Planning Area
U.S.	United States
UBC	Unified Building Code
USBM	United States Bureau of Mines
USGS	United States Geological Survey
WDEQ	Wyoming Department of Environmental Quality

EXECUTIVE SUMMARY

This Solid Mineral Occurrence and Development Potential Report (Report) was prepared to support the process of revising the Resource Management Plan (RMP) for the Bureau of Land Management (BLM) Rock Springs Field Office, Wyoming. The Rock Springs RMP will replace the Green River RMP (1997). The Rock Springs planning area (RSPA) encompasses most of Sweetwater and portions of Sublette, Fremont, Lincoln and Uinta Counties, Wyoming. This Report provides an assessment of solid leasable, locatable and saleable minerals (mineral materials) within the RSPA as prescribed in BLM Manual 3031, Energy and Mineral Assessment (BLM 1985). Information provided in this Report will be incorporated into the RMP and the Environmental Impact Statement (EIS) for the RMP revision.

Oil, gas, and coalbed natural gas (CBNG) resources in the RSPA are to be addressed separately in a Reasonably Foreseeable Oil and Gas Development (RFD) Potential Report (currently under development) and in the Summary of the Analysis of the Management Situation (AMS) (BLM 2012a). As a result, these energy resources are not addressed in this Report.

This Report provides an understanding of solid mineral resources in the planning area and the importance of these resources in future land use decisions. This Report identifies solid mineral resource occurrence and development potential. Preparation for this Report involved reviewing published data and selecting internal data for use in this document, but no fieldwork was performed in the preparation of this Report. This Report is developed for use in the preparation of the EIS and for revising the RMP.

The Rock Springs Field Office manages approximately 3,607,400 acres of public surface land and 3,779,557 acres of federal mineral estate. There are approximately 3,013,913 acres of federal mineral ownership in Sweetwater County, 456,067 acres in Sublette County, 47,004 acres in Lincoln County, 82,158 acres in Uinta County, and 180,415 acres in Fremont County. Federal solid minerals within the Rock Springs planning area are classified into three major categories: 1) Solid leasable minerals – coal, trona, oil shale, sodium carbonate brine, and phosphate; 2) Locatable minerals – uranium, gold, diamond, zeolite, nephrite jade, and titaniferous sands; and 3) saleable minerals (also referred to as mineral materials) – sand and gravel, decorative and dimension stone, and topsoil. This Report addresses solid mineral resource occurrences and development potential of these minerals in the RSPA.

The RSPA is comprised of three major geologic features including the Rock Springs Uplift in the central portion, the Green River Basin on the west flank of the uplift, the Great Divide Basin on the northeast flank of the uplift and the Washakie Basin on the southeast flank of the uplift. The planning area is also bounded on the north by the southeastern extremity of the Wind River Mountains and on the south by the Uinta Mountains in Utah and the Sand Wash Basin in Colorado.

Future mineral development in the RSPA is influenced by a number of factors, including the price of commodities, management conflicts, laws, and regulations. With all commodities, whether they are locatable, solid leasable, or saleable minerals, the level of potential for development can be difficult to predict, even with extensive geological studies.

Coal and trona are the only solid leasable minerals being mined and produced in the RSPA. Coal production in support of the Jim Bridger power plant is expected to continue at current levels of approximately 9 million tons per year from both federal and private lands for the planning period. However, if new access to Asian export markets opens up at facilities currently under development in the Northwest by one of the owners of the Black Butte mine, both production and leasing could increase. Additionally, industry interest in developing deep coal resources for *in situ* coal gasification submitted during scoping for this plan revision, as well as development of a coal-to-liquids production facility outside the RSPA, could result in leasing proposals in areas outside the Coal Occurrence Development Potential Area (CODPA), which are not currently available for leasing.

Trona production is expected to continue at existing or somewhat higher levels. While no new mines are expected to be proposed and developed during the planning period, additional leasing and expansion of existing mines can be expected. In addition, if the soda ash industry recovery from the global economic downturn surges, new proposals for in situ recovery can be expected. While no commercial development of sodium carbonate brines is expected during the planning period, continued soda ash market recovery and oil price increases could result in new exploration and resource assessment activities during the next planning cycle.

The RSPA is underlain by extensive oil shale resources. However, higher quality resources in Colorado and Utah have been the focus of the companies involved in developing technologies to extract the oil. BLM is preparing a new Programmatic Environmental Impact Statement (PEIS) to re-evaluate the leasing process and the public lands available for leasing. However, due to the low resource quality of Wyoming oil shale, no leasing or development of oil shale is expected during the planning period.

A phosphate bearing formation underlies portions of the planning area, but it is buried deep beneath other strata and is not exposed at the surface. No active phosphate mines are found anywhere in Wyoming and no exploration for or development of phosphate is expected to occur in the planning area during the planning period.

The locatable minerals that have received the greatest interest in the planning area are uranium and gold. However, despite dramatic gold price increases over the past four years, the level of exploration and development activity has not increased significantly. Additionally, the price for uranium has decreased recently, and correspondingly, so has U.S. production. No commercial development of uranium or gold is expected to take place over the next planning cycle and only limited exploration for these minerals is expected to occur on federal land. Activity is expected to be in line with, or slightly higher than, current levels.

The remaining locatable minerals of interest in the RSPA include diamonds, nephrite jade, zeolites, titaniferous sands and rare earth elements (REE). Diamonds and nephrite jade have been the object of recreational and hobby collection. For the planning period, the level of collection activity is expected to continue at current levels. No commercial development of diamonds, nephrite jade, titaniferous sands or REE is expected to take place over that period. Limited exploration for titaniferous sands and REE can be expected on federal lands during the planning period.

Demand for sand and gravel, decorative stone and dimension stone will remain steady to increasing over the planning period. Expansion of existing pits or development of new sand and gravel sources on federal lands is expected during the planning period due to depletion of existing pits. Demand for decorative and dimension stone is expected to remain at or close to current levels for the planning period and the potential for development of new sources is low.

There has been interest in the leasing of deep coal resources outside of the currently defined CODPA for development of in situ coal gasification. Before a leasing proposal could be considered, RSFO needs to conduct the coal screening process in accordance with the regulations at 43 CFR Part 3420 and the BLM Land Use Planning Handbook H-1601-1, Appendix C section II.F. Developing *in situ* coal gasification technology is expected to render coal resources previously inaccessible to conventional mining techniques available for economic development. The extent of deep coal resources outside the CODPA that may be developable by *in situ* technologies is not well documented or understood. A comprehensive study of oil and gas and other well logs and cores should be undertaken in the near future to assess the extent, quality and nature of coal resources below 3,000 feet below ground surface (bgs) throughout the RSPA for use in the evaluation of future potential leasing proposals and determinations of fair market value for competitive leasing.

CHAPTER 1 INTRODUCTION

1.1 PURPOSE OF REPORT

This Mineral Potential Report (Report) was prepared to support the preparation of the Resource Management Plan (RMP) revision for the Bureau of Land Management (BLM) Rock Springs Field Office (RSFO), Wyoming. The Rock Springs RMP will replace the Green River RMP (1997). As part of the RMP process and in order to support decisions regarding the availability of lands for mineral exploration and development, the BLM is required to prepare a Mineral Potential Report providing specific information about mineral occurrences and development potential within the Rock Springs Planning Area (RSPA). BLM Manual 3031, Energy and Mineral Resource Assessment (1985), requires that an intermediate level of information on mineral resources be included in reports that support decisions that would result in special restrictions being placed on mineral activities, such as land use planning decisions. This Report provides an understanding of the occurrence and development potential of locatable, solid leasable, and saleable minerals (also known as mineral materials) within the Rock Springs planning area. The RSPA is separately preparing information on mineral occurrence, development potential, and Reasonable Foreseeable Development (RFD) Scenarios for oil and gas resources and these resources are not addressed in this Report. Information provided in this Report will be incorporated into the RMP revision and the associated Environmental Impact Statement (EIS).

1.1.1 Terminology

This Report describes known and potential mineral occurrences and mineral deposits. According to the United States Geological Survey (USGS) (Cox and Singer, 1986) and BLM Manual 3031 (BLM 1985), mineral occurrences, mineral deposits, the potential for mineral resources, and mineral resource development potential are defined as follows:

A "mineral occurrence" is usually a concentration of a mineral such as coal, trona, or gold that is considered valuable, or that is of scientific or technical interest (Cox and Singer 1986). Rutile-bearing black sand is an example of an exception to the concept of a “concentration” as the rutile may not even be concentrated above its average crustal abundance.

A "mineral deposit" is a mineral occurrence of sufficient size and grade that, under favorable circumstances, may be considered to have economic potential (Cox and Singer 1986).

An "ore deposit" is a mineral deposit that is known to be of sufficient size, grade, and accessibility that it can be produced at a profit (Cox and Singer 1986).

The “potential for mineral resources” is a prediction of the likelihood of the occurrence of these resources (BLM 1985). The occurrence of a mineral resource does not necessarily imply that the mineral can be economically exploited or is likely to be developed. The mineral resource potential is based on knowledge of the geology in the study area, and does not imply that the quality or quantity of the resource is known.

“Mineral resource development potential” is a prediction of the likelihood that a mineral occurrence will be developed within a certain timeframe under specific geologic and other assumptions and conditions. Economic potential means whether or not a mineral occurrence can be developed under current or foreseeable economic conditions (BLM 1985). Future development potential is influenced by the specific qualities and characteristics of the mineral resource being studied, price of commodities, as well as the effects of land use allocation decisions, decisions to impose measures to protect other resource values, laws and regulations that may restrict development. For all mineral commodities, whether they are locatable, solid leasable, or saleable, the level of resource potential can be difficult to predict, even with extensive geological studies.

1.1.2 Organization

This Report is organized into seven chapters and an appendix.

Chapter 1.0 – Introduction

Chapter 2.0 − Description of Geology: This Chapter summarizes the geology of the Rock Springs planning area. It is subdivided into separate discussions of physiography, stratigraphy, historical geology, structural geology and tectonics, seismicity and geologic hazards.

Chapter 3.0 – Description of Energy and Mineral Resources: This chapter addresses the nature and occurrence of the locatable, solid leasable, and saleable mineral resources known to exist within the planning area.

Chapter 4.0 – Mineral Exploration, Development and Production History: This chapter discusses the history of exploration, development, and production of the mineral resources, including current and historical mines and production levels.

Chapter 5.0 – Potential for Occurrence and Development: This chapter describes the development potential for locatable, solid leasable, and saleable mineral resources within the planning area.

Chapter 6.0 – Conclusions and Recommendations: This chapter discusses the formation of recommendations regarding future development of locatable, solid leasable, and saleable mineral resources for the planning area.

Chapter 7.0 – References: This chapter lists references used in the development of the Report.

1.2 LANDS INVOLVED AND RECORD DATA

Located within southwest Wyoming, the RSPA (Figure 1-1) covers 3,607,400 acres of public surface land and 3,779,557 acres of federal mineral estate in portions of Fremont, Lincoln, Sublette, Sweetwater, and Uinta counties (Table 1-1). Approximately the northern third and the southern quarter of the planning area are primarily BLM-administered surface and mineral estate lands intermingled with scattered state and private lands. Along the northwest boundary of the planning area that adjoins the Kemmerer Field Office boundary, the Bureau of Reclamation manages the surface of a block of contiguous federal land, as well as additional, nearby lands east and south of Farson. The most notable land ownership feature in the RSPA is a swath of lands across the central portion that is 40 miles wide; 20 miles to the north and south of the Union Pacific Railroad right-of-way known as the "railroad checkerboard lands." This swath occupies approximately 40% of the planning area stretching from the eastern to the western Field Office boundaries. Every other section of land for 20 miles on either side of the railroad right-of-way is privately owned. These lands were originally granted to the Union Pacific Railroad by the federal government under the Pacific Railway Acts of 1862 and 1864 as a means for the railroad to raise capital for the construction of the transcontinental railroad route (Flores and Bader 1999).

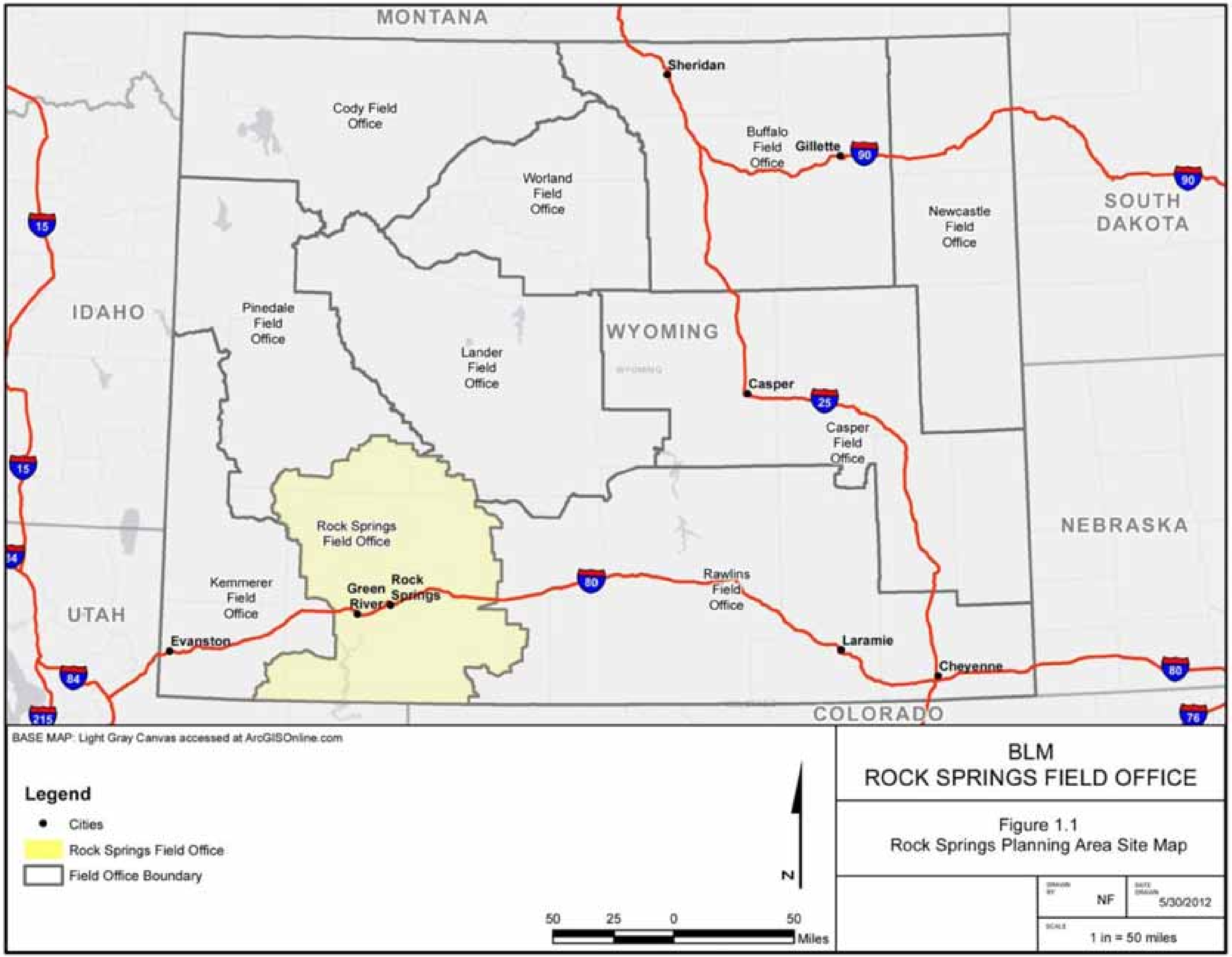
The majority of the RSPA is located in the Greater Green River Basin, which is a structural basin covering southwestern Wyoming and extending into northeastern Utah and northwestern Colorado. The Greater Green River Basin is bordered by the north-south trending Wyoming Range of the Wyoming Thrust Belt on the west, by the northwest-southeast trending Wind River Range on the north, by the Ferris Mountains on the northeast, by the Rawlins Uplift and Sierra Madre Park Range on the east, and by the Uinta Range and Axial Basin Uplift on the south in Utah and Colorado respectively. In Wyoming, the basin is subdivided into three smaller basins separated by the Rock Springs Uplift, which is located in the central portion of the planning area. The Green River Basin is located on the west side of the uplift and planning area, the Great Divide Basin is located on the northeast side of the planning area, and the Washakie Basin is located on the southeast side of the planning area (Flores and Bader 1999). Most of the BLM-administered land in the area is managed by the BLM Rock Springs Field Office.

Table 1-1 Acres of Federal Surface Lands and Federal Mineral Estate within the Planning Area

County	BLM Public Lands (in Planning area)	Other (private, state, other federal)	Total All Ownerships	Federal Minerals (sub-surface)
Sweetwater	2,866,264	1,597,147	4,463,411	3,013,913
Sublette	451,253	58,068	509,321	456,067
Lincoln	42,585	2,106	44,691	47,004
Uinta	74,983	22,648	97,631	82,158
Fremont	172,315	28,510	200,825	180,415
TOTAL	3,607,400	1,708,479	5,315,879	3,779,557

Source: BLM 2012a.

Figure 1-1 Rock Springs Field Office Area Map



CHAPTER 2 DESCRIPTION OF GEOLOGY

2.1 PHYSIOGRAPHY

Most of the RSPA, with the exception of a small area along the Colorado border that falls into the Northern Rocky Mountain Province, resides in the Wyoming Basin (Sullivan 1980). Portions of this physiographic province lay partially or entirely within the boundary of the RSPA. They include the Green River, the Great Divide, the Washakie Basins and the Rock Springs Uplift (Figure 2-1). This province is made up of high plains and plateau areas and is bordered by mountain ranges and major uplifts of the Central Rocky Mountain Province. The southern end of the Wind River Range extends into the RSPA on its northern border. Surface features reflect erosion by wind and water in an arid, cold-temperature environment. In some instances, they have been modified by faulting or volcanic activity (BLM 2012a). A general geologic map of the RSPA is shown in Figure 2-2.

2.2 GENERAL GEOLOGY

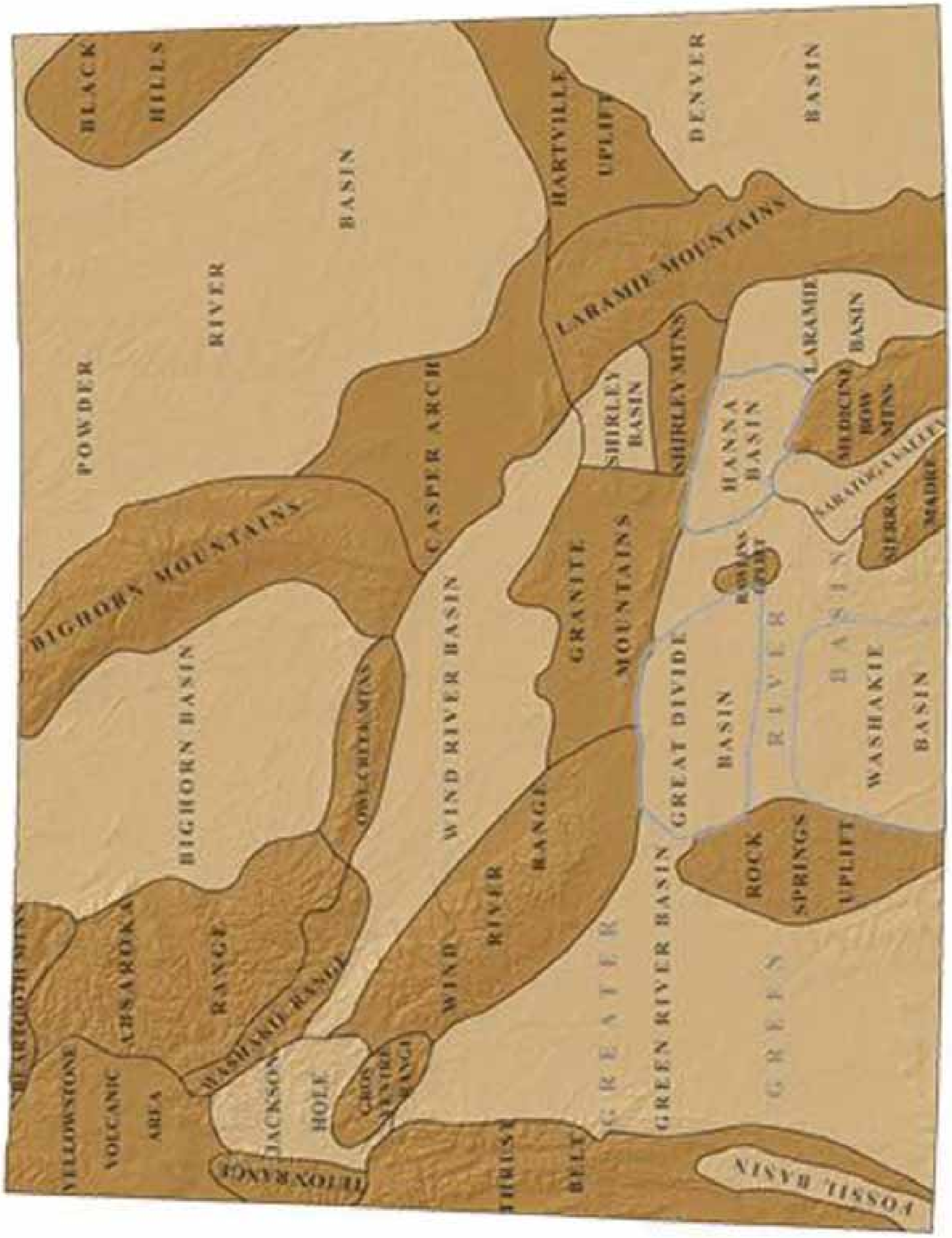
2.2.1 Green River Basin

The Green River Basin is a large structural and topographic basin drained by the Green River and its tributaries. The northern portion of the basin is a broad shallow valley, while in the south it becomes a canyon that reaches a depth of 1,000 feet. The floor of the basin lies between 6,000 and 8,000 feet above sea level, and is a primarily flat to gently rolling plain. Underlying Tertiary sediments in the basin are predominantly soft to weak, with only a few beds that are more resistant. Where the rocks are flat-lying, the resistant beds cap low, flat tablelands and buttes (BLM 2012a).

The margin of the Green River Basin is defined by numerous escarpments formed by tilted beds of the Green River and Wasatch Formations (BLM 1997). North of the town of Green River, the main escarpment forms a bluff known as White Mountain. The flat-lying strata of the Green River Basin exert little geologic control on the drainage, resulting in a dendritic drainage pattern. Gravel terraces have developed along most of the major streams, and their elevations range from 5 to 10 feet above the river level to as much as 500 feet. The lowest terraces are slightly modified by erosion and are younger than the last glacial period. Higher and older terraces formed as a result of fluctuations in sedimentation brought on by successive glacial advances and retreats. They are progressively more modified by erosion and are commonly cut by canyons and deep ravines so that only scattered remnants remain. Most gravel pits in the RSPA have been located on these terraces (BLM 2012a).

Extensive erosion has shaped the floor of the Green River Basin and resulted in the development of large areas of intricately dissected badlands. These badlands developed in the soft, weak, mudstone of the Bridger Formation, which is relatively impervious and prevents infiltration of rain water resulting in overland flow of precipitation (BLM 2012a).

Figure 2-1 Physiographic Provinces of the RSFO and Surrounding Area



(Source: WSGS 2011a)

Figure 2-2a Geologic Map of RSPA – North Half

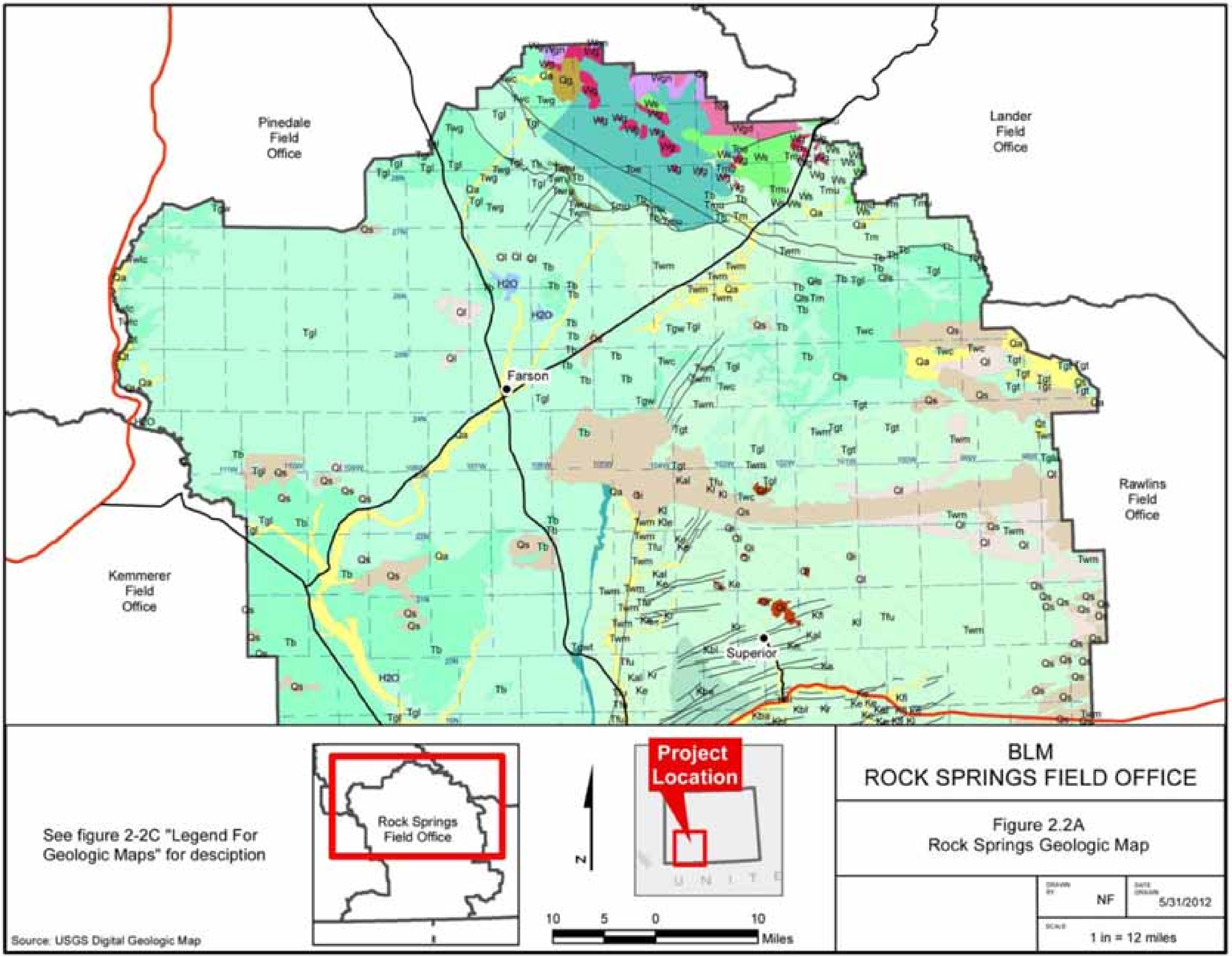


Figure 2-2b Geologic Map of RSPA - South Half

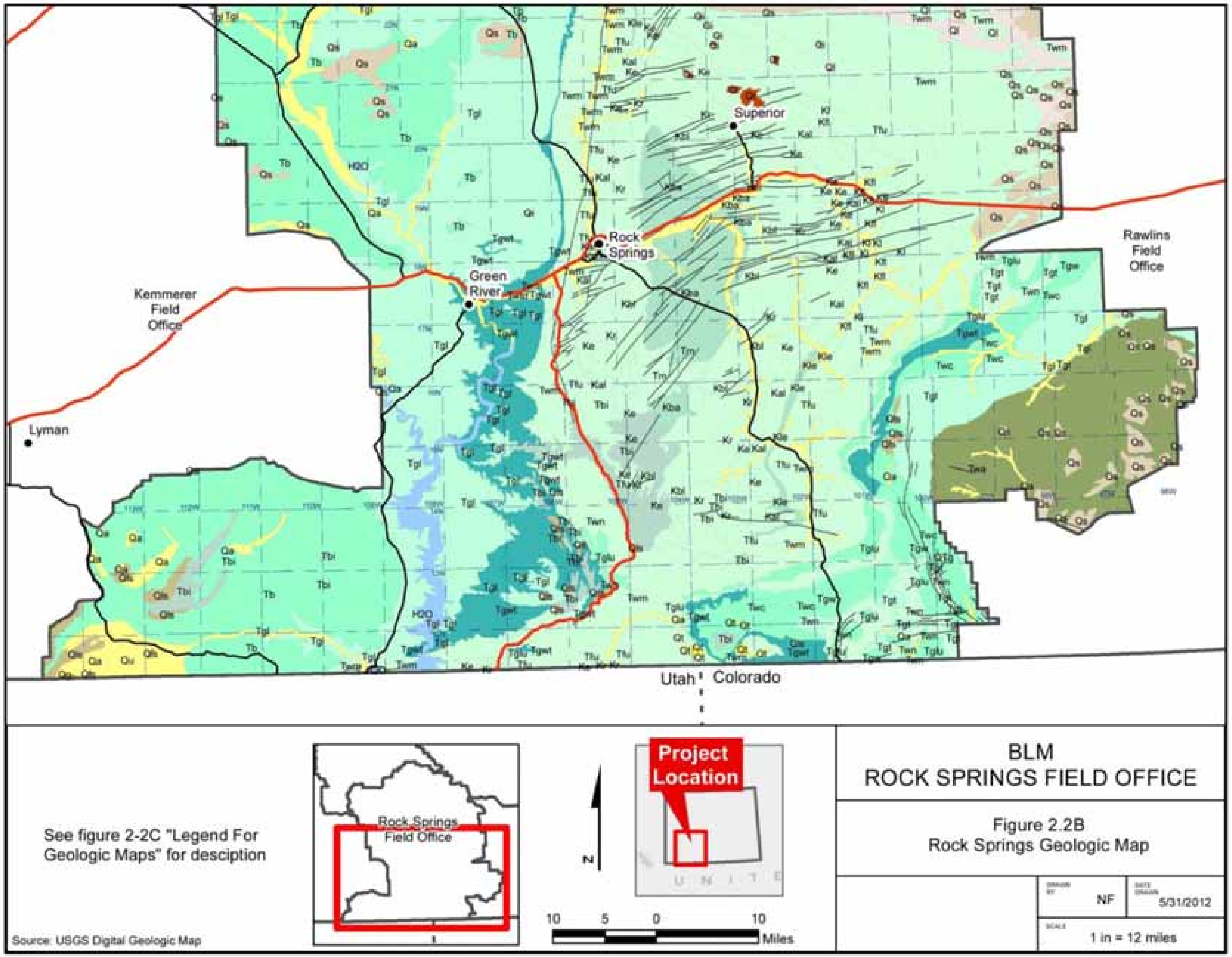


Figure 2-2c Geologic Map of RSPA - Legend

	Symbol	Formation	Member
Cenozoic	Qa	Alluvium and Colluvium	
	Qt	Gravel, Pediment, and Colluvium	
	Qg	Glacial Deposits	
	Qls	Landslide Deposits	
	Qs	Dune Sands and Loess	
	Ql	Playa Lake and other Lacustrine Deposits	
	Qu	Undivided Surficial Deposits	
	[illegible]	Alkalic Extrusive and Intrusive Igneous Rocks	
	QTg	Terrace Gravel	
Cenozoic	Tm	Browns Park Formation	
	Tmu	North Park Formation	
	Tbi	Bishop Conglomerate	
	Twru	White River Formation	Upper Conglomerate Member
	Toe	Oligocene and or Upper Middle Eocene Rocks	
	Twa	Washakie Formation	
	Tb	Bridger Formation	
	Tgl	Green River Formation	Laney Member
	Tgw	Green River Formation	Wilkins Peak Member
Cenozoic	Tgwt	Green River Formation	Wilkins Peak Member and Tipton Shale Member or Tongue
	Tgt	Green River Formation	Tipton Shale Member or Tongue
	Twg	Wasatch and Green River Formations	New fork Tongue of Wasatch Form. & Fontenelle Tongue of Green River Form.
	Tglu	Green River Formation	Luman Tongue
	Twc	Wasatch Formation	Cathedral Bluffs Tongue
	Twn	Wasatch Formation	Niland Tongue
	Twm	Wasatch Formation	Main Body of Wasatch Formation
	Twle	Wasatch Formation	La Barge and Chappo Members
	Tfu	Fort Union Formation	
Mesozoic	Kl	Lance Formation	
	Kfl	Fox Hills Sand Stone and Lewis Shale	
	Kle	Lewis Shale	
	Kal	Mesa Verde Group	Almond Formation
	Ke	Mesa Verde Group	Ericson Formation
	Kr	Mesa Verde Group	Rock Springs Formation
	Kbl	Mesa Verde Group	Blair Formation
	Kba	Baxter Shale	
PreCambrian	Wgn	Granite Gneiss	
	Ws	Metasedimentary Rocks at least 2,800 Ma.	
	Wg	Granitic Rocks of 2,600- Ma Age Group	
	Wgd	Granodiorite rocks of the Louis Lake Pluton	

Figure 2-2C Legend for Geologic Maps

2.2.2 Rock Springs Uplift

The Rock Springs Uplift is a broad, elliptical anticline that began to form after the Lance Formation was deposited in the late Cretaceous. Erosion has uncovered a sequence of Tertiary and Upper Cretaceous rocks. The rocks exposed on the uplift are cut by a number of faults and data indicate that the west flank of the uplift is bounded by a thrust fault that does not reach the surface. The crest of the Rock Springs Uplift is occupied by a large depression, called the Baxter Basin, which is carved into the soft weak rocks of the Baxter Shale. The Baxter Basin is about 15 miles wide and 40 miles long and its floor is primarily a flat, featureless plain interrupted by considerable expanses of dissected badlands. This basin is enclosed by a series of concentric ridges formed by tilted, relatively resistant sandstone beds exposed on the flanks or the uplift. The ridges are separated by valleys that are eroded into softer beds of shale and coal. Bitter Creek, a tributary to the Green River, flows entirely across the uplift in a westerly direction. It cuts through notches almost 1,000 feet deep on the west flank of the Rock Springs Uplift (BLM 2012a).

Remnants of a Quaternary volcanic field are found in the Leucite Hills, which are located at the north end of the Rock Springs Uplift. These hills form a series of buttes that rise precipitously above the surrounding plains. Steamboat Mountain and South Table Mountain are buttes capped with high potassium lava flows. Boars Tusk, just northwest of the northern end of the uplift, is the remnant of a volcanic neck, as is Pilot Butte, the westernmost volcanic outcrop (BLM 2012a).

On the far northern end of the Rock Springs Uplift in the Great Divide Basin, is an extensive dune field called the Killpecker Dunes. This dune field is at the western end of a narrow belt of dunes that stretches 150 miles to the east. The outer margins of the field are occupied primarily by dormant dunes, while active dunes are found in the central portion of the field (BLM 2012a).

2.2.3 Great Divide Basin

The Great Divide Basin is a structural basin underlying a topographic and internally drained basin. The Basin sits atop the Continental Divide which in fact the Basin causes to split into two branches. The Continental Divide splits at the west end of the Basin near the southeast end of the Wind River Range and converges again at the east end of the Basin and the north end of the Sierra Madre Mountains. Lake, swamp, and stream deposits of Tertiary age make up most of the bedrock and surficial deposits and are predominantly soft and weak, causing the basin to be nearly flat and featureless, with occasional intermittent lakes and dry flats in the lowest areas. Low hills and ridges form the high ground that marks the two branches of the Continental Divide. Altitudes range from 6,500 to 7,500 above sea level (BLM 2012a).

The largest, most conspicuous features of the Great Divide Basin are dry-lake flats. These broad shallow depressions are the sites of former lakes that are being filled in by debris washed in from the surrounding highlands. Isolated sand and gravel terraces deposits with at least eight different terrace levels have been recognized. The youngest features are the Killpecker Dunes which extend across this basin. The Wamsutter Arch is a low relief anticline, extending eastward from the Rock Springs Uplift and separates the Great Divide and Washakie Basins (BLM 2012a).

2.2.4 Washakie Basin

The Washakie Basin is a structural and topographic basin, south of Interstate 80 and east of the Rock Springs Uplift. The overall configuration of the basin is that of a very broad, roughly square bowl shape with an outward facing escarpment, developed on the Laney Shale Member of the Green River Formation. On the west the escarpment is known as Kinney Rim and on the north it is known as Laney

Rim. Altitudes above sea level range from 6,100 feet in the drainage to 8,700 feet on Pine Butte (BLM 2012a).

Lake and river deposits of Tertiary age are exposed in badlands such as Adobe Town and on ridges across the Washakie Basin. Younger sediment and sand dunes fill the stream valleys and cover some areas of low relief. Only intermittent streams drain this basin. Most, such as Shell Creek and Sand Creek, are tributaries to the Little Snake River in Colorado. The north end of this basin drains into Bitter Creek, a tributary of the Green River (BLM 2012a).

2.2.5 Wind River Range

At the northeast edge of the planning area is the Southern Wind River Range. The dominant feature of this range is a very gently dipping erosion surface comprised of Tertiary sediments. This surface blends the Precambrian core of the range with the Rock Springs Uplift and Green River Basin to the south and southwest. Relief in these foothills is 300 to 500 feet. The Sweetwater River and its tributaries drain the area and flow northeastward to the Missouri River. This range is one of the most spectacular of the Precambrian uplifts in the state. It is basically a huge block of granite that has been moved by faulting south-westward over the Green River Basin. This fault is called the Wind River thrust fault and is covered by sediments on its southern end where it extends into the RSPA (BLM 2012a).

2.3 STRATIGRAPHY

The following are summaries of lithologic and stratigraphic information for the formations and associated members found within the RSPA using the Geologic Map of Wyoming (Love and Christiansen 1985). Rocks of all of the geologic periods outcrop within the RSPA with exception of the Paleozoic which has been either eroded away or is buried and has no surficial expression. The major geologic formations occurring in the Wyoming Basin, along with their sequences and ages of deposition, are shown in this figure and described in the text. The lithological descriptions below come from Love and Christiansen 1985 unless otherwise cited.

If a formation in the following lithologic and stratigraphic information does not have a map symbol associated with it, then the Love and Christiansen 1985 map used does not map on the surface.

2.3.1 Pre-Cambrian Era (> 570 Million Years Ago)

Pre-Cambrian rocks located in the RSPA are listed below. A stratigraphic column is not available.

Granite Gneiss (Wgn) (Late Archean)

The gneiss is layered to massive, locally migmatic and commonly interspersed with metasedimentary and metavolcanic rocks locally.

Metasedimentary Rocks (Ws) (Late Archean)

These rocks include metagraywacke, pelitic schist, metaconglomerate, graphitic schist, and iron-formation, with local meta-andesite.

Granitic Rocks (Wg) (Late Archean)

These rocks include granodiorite to porphyritic and equigranular granite.

Granodiorite Rocks of the Louis Lake Pluton (Wgd) (Late Archean)

These granodiorite rocks are equigranular and locally gneissic.

2.3.2 Paleozoic Era (570 – 240 Million Years Ago)

A stratigraphic column of the Paleozoic Era can be found in Figure 2-3.

Bighorn Dolomite (Upper Ordovician)

The Bighorn Dolomite consists of gray, massive, cliff-forming siliceous dolomite rocks and locally dolomitic limestone in the Thrust belt. This sequence of rock strata is only found in the northwest part of the RSPA (USGS 2012a).

Amsden Formation (Upper Mississippian, Lower Pennsylvanian, and Middle Pennsylvanian)

This formation is comprised of a sandstone unit at its base that may have been derived from emergent areas of the Precambrian rock sequences in southeastern Wyoming and the basal sandstone unit is overlain by a middle unit of red shale, siltstone and sandstone. There is further evidence for this uplift, as seen by the presence of an erosion surface occurring within the Amsden. The upper part of the formation is made up of an interbedded limestone, dolomite, siltstone or sandstone, and gray shale (BLM 1997).

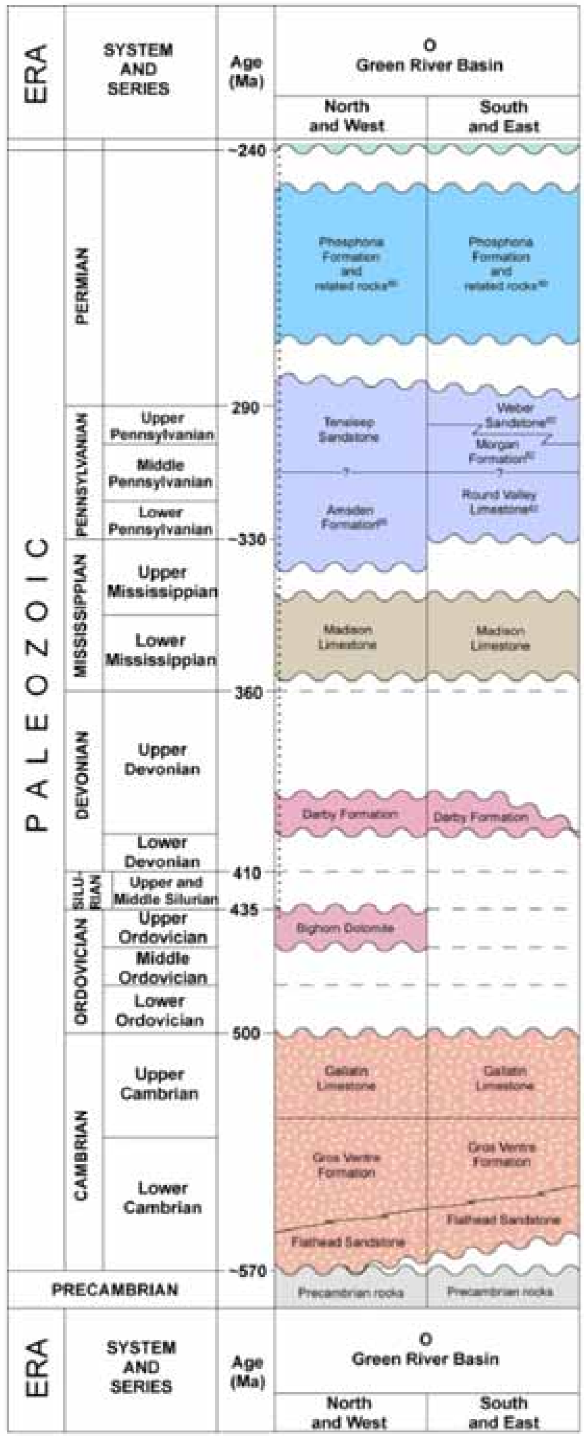
Tensleep Sandstone (Middle Pennsylvanian, Upper Pennsylvanian, and Permian)

The Tensleep is a white to gray sandstone rock unit that contains thin limestone and dolomite beds. Permian fossils have been found in the uppermost beds of the Formation in some locations in the Washakie Range (USGS 2012a). The last major marine invasion spread across the area after deposition of this sandstone.

Phosphoria Formation (Permian)

The upper part of the formation is dark- to light-gray chert and shale with black shale and phosphorite. The lower part is black shale, phosphorite, and cherty dolomite. A carbonate deposition predominated over a broad zone that extended across the RSPA (USGS 2012a).

Figure 2-3 Paleozoic Era Stratigraphic Column



SOURCE: WSGS 2011

(Source: WSGS 2011a)

2.3.3 Mesozoic Era (240 – 66 Million Years Ago)

A stratigraphic column of the Mesozoic Era can be found in Figure 2-4.

Dinwoody Formation (Lower Triassic)

This is a drab-olive dolomitic siltstone that is hard and thin-bedded (USGS 2012a).

Chugwater Formation (Lower and Upper Triassic)

The Chugwater is a red siltstone and shale with thin gypsum partings near the base of the formation. The Alcova Limestone Member occurs in the upper middle part of the formation (USGS 2012a).

This formation is equivalent to the Woodside Shale, the Thaynes Limestone, and the Ankareh Formation as described in the Over Thrust Belt.

Nugget Formation (Triassic)

This formation was deposited as coastal dunes. It consists of buff to pink crossbedded well-sized and well-sorted quartz sandstone and quartzite. In some locations in the Thrust Belt it is known to have oil and copper-silver-zinc mineralization (USGS 2012a).

Gypsum Spring Formation (Middle Jurassic)

The Gypsum Spring Formation is primarily composed of massive gypsum and dolomite interbedded with soft red shale and siltstone. This formation consists of limestones and shales to the north and west; however, it changes into red silty shales and anhydrites to the east and south (USGS 2012a).

Sundance Formation (Middle and Upper Jurassic)

This is a greenish-gray glauconitic sandstone and shale that is underlain by red and gray non-glauconitic sandstone and shale, interbedded marine and non-marine sandstones and siltstones (USGS 2012a).

Morrison Formation (Upper Cretaceous)

The Morrison is a dully variegated claystone, nodular white limestone, and grey silty sandstone.

Mowry Shale (Upper Cretaceous)

The Mowry is a silvery-gray, hard siliceous shale which contains abundant fish scales and bentonite beds.

Frontier Formation (Upper Cretaceous)

The Frontier is a gray sandstone and sandy shale.

Baxter Shale (Kba) (Upper Cretaceous)

The Baxter consists of a gray to black soft shale and shaley sandstone.

Blair Formation - Mesa Verde Group (Kbl) (Upper Cretaceous)

This formation is a drab-yellow and brown sandstone and sandy shale.

Rock Springs Formation - Mesa Verde Group (Kr) (Upper Cretaceous)

The Rock Springs is a white to brown sandstone, shale and sandstone with numerous coal beds.

The continental part of the formation occupied the northwest part of the Rock Springs uplift and is represented by river sandstone, carbonaceous shale and coal beds. Traveling southeastward these rocks undergo a change to beach and barrier island sands, and offshore sands and marine shale (BLM 2012a).

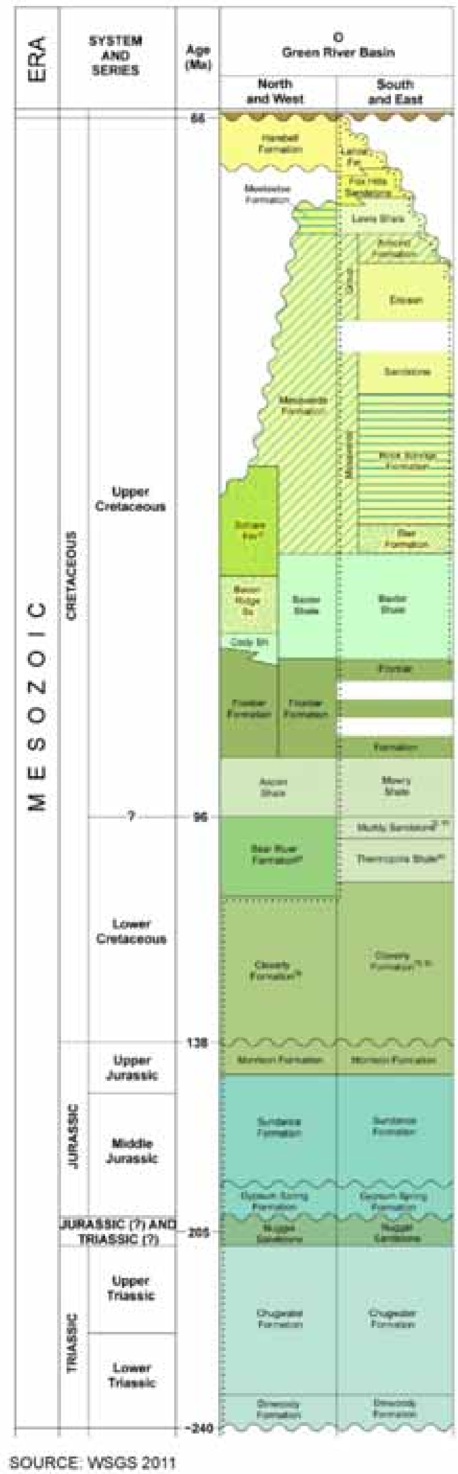
Ericson Formation - Mesa Verde Group (Ke) (Upper Cretaceous)

This formation is a massive, white sandstone with lenticular chert-grit conglomerate in upper part of the formation.

Almond Formation - Mesa Verde Group (Kal) (Upper Cretaceous)

The Almond consists of white and brown soft sandstone with gray sandy shale and interbedded coal and carbonaceous shale.

Figure 2-4 Mesozoic Era Stratigraphic Column



(Source: WSGS 2011a)

Lewis Shale (Kle) (Upper Cretaceous)

This is a gray marine shale containing many gray and brown lenticular concretion-rich sandstone beds.

Fox Hills Sand Stone and Lewis Shale (Kfl) (Upper Cretaceous)

The Fox Hills consists of light colored sandstone and gray sandy shale containing marine fossils. It also includes gray marine shale containing many gray and brown lenticular concretion-rich sandstone beds.

Lance Formation (Kl) (Upper Cretaceous)

This formation consists of brown and gray sandstone and shale beds interbedded with thin coal and carbonaceous shale beds.

2.3.4 Cenozoic Era (66 Million Years Ago – Present)

A stratigraphic column of the Cenozoic Era can be found in Figure 2-5.

Fort Union Formation (Tfu) (Paleocene)

The Fort Union Formation is composed chiefly of white quartzite and coarse arkosic sandstones and conglomerates. Additionally, gray-green, tan-maroon carbonaceous shales are present with thin interbedded coal seams (Sullivan 1980).

Wasatch Formation - La Barge and Chappo Members (Twlc) (Paleocene-Eocene)

These members consist of red, gray, and brown mudstones and conglomerates with yellow sandstones. The lower part of the Chappo Member is Paleocene.

Main Body of the Wasatch Formation - Wasatch Formation (Twm) (Paleocene-Eocene)

The Wasatch consists of drab sandstone, drab to variegated claystone and siltstone with locally derived conglomerate around the basin margins. The lower part of the Wasatch is Paleocene.

The main body of the Wasatch was laid down in a large depositional center in southwestern Wyoming in the Green River basin. In the northern part on the basin the formation is over 12,000 feet thick and in the southern part of the basin it is over 7,000 feet thick. The lithology of the formation in the Green River Basin generally consists of heterogeneous sequence of rocks. The more vividly colored rocks usually consist of variegated mudstones with many shades of orange, red and purple. The more muted color rock types are pale yellow tan, gray, tan, brown and green which grade vertically and laterally through the formation (Sullivan 1980).

Niland Tongue - Wasatch Formation (Twn) (Eocene)

The Niland Tongue typically consists of drab brown sandstone, siltstone, carbonaceous shale, and coal beds. The maximum thickness reaches over 400 feet in the Green River Basin (BLM 2011).

Cathedral Bluffs Tongue - Wasatch Formation (Twc) (Eocene)

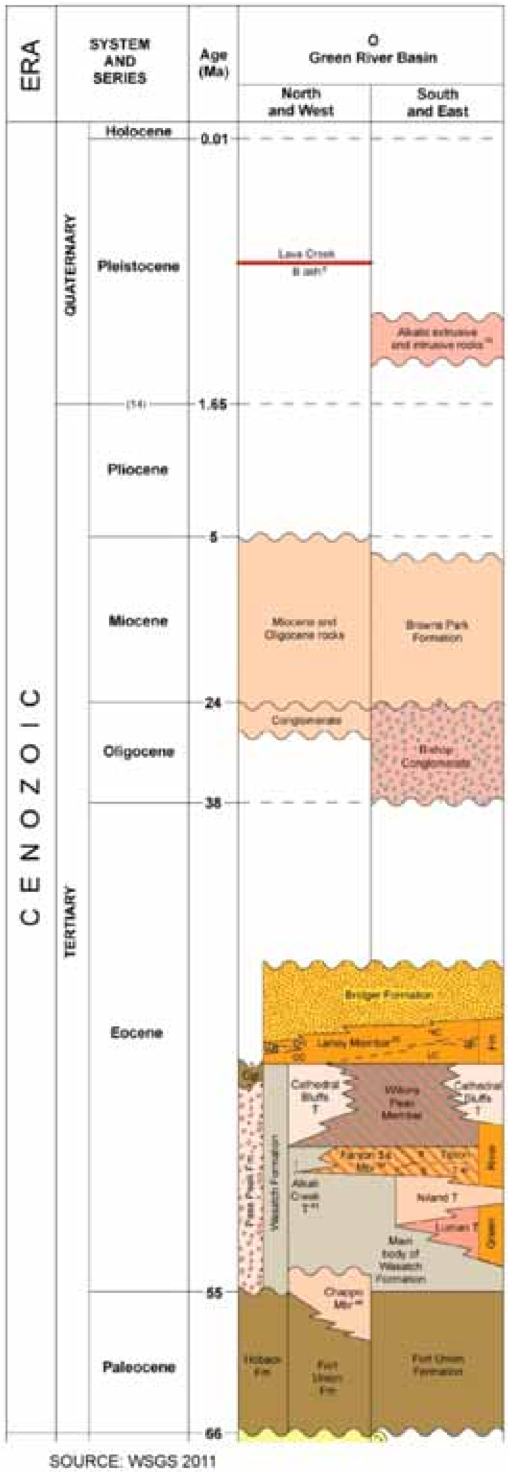
The Cathedral Bluffs Tongue consists of variegated claystone and lenticular sandstone.

There are two major depositional units of the Cathedral Bluffs Tongue, however only one lies within the boundaries or the Rock Springs Boundary so it is the only one to be described. It is a red mudstone facies that dominates the western and northern portions of the Washakie Basin. This facies originated in an alluvial plain and is composed of variegated mudstone and siltstone of green and red hues. Lenses on greenish brown sandstone are intercalated within the facies. The thickness is over 600 feet thick within the Rock Springs Field Office Boundary (Sullivan 1980).

Luman Tongue - Green River Formation (Tglu) (Eocene)

The Luman consists of oil shale, marlstone, limestone, and siltstone. It occurs along Green and North Fork Rivers and on west side of Green River Basin from T. 33 N. south to and lensing out in T. 17 N.

Figure 2-5 Cenozoic Era Stratigraphic Column



(Source: WSGS 2011a)

New Fork Tongue of the Wasatch Formation and the Fontenelle Tongue of the Green River Formation - Wasatch and Green River Formations (Twg) (Eocene)

The New Fork and Fontenelle Tongues consist of dull-red and green mudstone, brown sandstone and thin limestone beds, merging southward in T. 23 N. with other units.

This formation is the lowermost of a series of clastic wedges of the Wasatch Formation located on the western edges of the Green River Basin. It has a wide distribution over the northern portion of the Green River Basin. This formation consists as two distinct lobes, the western facies and the eastern (arkosic) facies . The western facies is fluviatile, non-red and composed of the local Paleozoic and Mesozoic source rocks. The eastern (arkosic) facies is a sequence of red, fluvial arkosic rocks with their source being Precambrian rocks from the Wind River Mountains. Both facies have a maximum thickness of about 400 feet in the northern portions of the Green River Basin (Sullivan 1980).

Tipton Shale Member or Tongue - Green River Formation (Tgt) (Eocene)

The Tipton consists of oil shale, sandstone and marlstone. This rock member gradually grades from a laminated carbonaceous shale at the center of the unit, into carbonate shale on its margins and then finally into the sandstone/mudstone of the Wasatch Formation. The Tipton is over 400 feet thick in the eastern Green River Basin and 100-200 feet over the rest of the basin (Sullivan 1980).

Wilkins Peak Member and Tipton Shale Member or Tongue - Green River Formation (Tgwt) (Eocene)

The Wilkins Peak Member consists of green, brown, and gray tuffaceous sandstone, shale, and marlstone. It also contains evaporites in the subsurface section. It is described in detail in the next subsection.

The Tipton Member consists of laminated carbonaceous shale at the center of the unit, grading into carbonate shale on the margins and then finally grading into the sandstone/mudstone of the Wasatch Formation. The Tipton is over 400 feet thick in the eastern Green River Basin and 100-200 feet over the rest of the basin (Sullivan 1980).

Wilkins Peak Member - Green River Formation (Tgw) (Eocene)

The Wilkins Peak Member is the host rock to the trona deposits in the Green River Basin. There are marker beds of volcanic tuff and clastic units that can be traced for hundreds of miles across the southeastern portion of the Green River Basin . The dating of these beds indicates that the saline deposition started 49my ago and ended 48my ago . This member reaches thicknesses of up to 1,300 feet in the Green River Basin. While the member is present in the Great Divide and Washakie Basins it consists of dolomitic mudstone and sandstone about 200 feet thick and then intertongues to the east with the Cathedral Bluffs and becomes fluvial (Sullivan 1980).

Laney Member - Green River Formation (Tgl) (Eocene)

The Laney Member is the thickest and most extensive of the Green River Formation units (Sullivan 1980). It developed chiefly in two areas, the Washakie Basin at 1,800 feet thick and Green River Basins at 1,000 feet thick. A thickness of 200 feet is present in the Great Divide Basin. In southwest Wyoming the Laney Member consists of two units. The lower portion is composed of laminated carbonate shale (oil shale). The upper portion consists of volcanic sandstone of sandstone and mudstone facies. An occurrence of an evaporate facies in the middle of the lower unit has been observed in the Washakie and eastern Green River Basins (Sullivan 1980). This facies is similar to that of the Wilkins Peak Member.

Bridger Formation (Tb) (Eocene)

The Bridger is a greenish gray, olive-drab, and white tuffaceous sandstone and claystone containing lenticular marlstone and conglomerate.

The Bridger Formation is the time and stratigraphic equivalent of the Washakie Formation but, unlike the Washakie, the rocks are non-red fluviatile sandstone mudstone facies with a thickness of about 2,000 feet and source rocks from the Wind River (BLM 1997).

Washakie Formation (Twa) (Eocene)

This formation consists of gray, green, tan, and dull-red tufficaceous arkosic sandstone and claystone.

The Washakie Formation is the time and stratigraphic equivalent the Bridger Formation but, unlike the Bridger the rocks are brightly colored and full of arkosic sediments with source rocks from the Sierra Madre that are Paleozoic and Mesozoic sedimentary and volcanic rocks. The maximum thickness on the east side of the Rock Springs Uplift is 3,200 feet (BLM 1997).

Fowkes Formation (Middle Eocene to Upper Miocene?) **or Norwood Tuff** (Upper Eocene to Lower Oligocene)

The Fowkes consists of light-colored tuffaceous sandstone and siltstone, fine to medium grained with some volcanics, and is locally conglomeratic. In some locations the Fowkes is designated by some as the Norwood Tuff (USGS 2012A).

Oligocene and or Upper Middle Eocene Rocks (Toe) (Eocene-Oligocene)

The Oligocene includes light-gray tuffs, arkosic sandstones, and lenticular conglomerates.

White River Formation - Upper Conglomerate Member (Twru) (Oligocene)

The White River consists of light gray soft conglomeratic tuffaceous sandstone and conglomerate of Precambrian clasts.

Bishop Conglomerate (Tbi) (Oligocene)

The Bishop Conglomerate is composed of a conglomerate comprised of red quartzite, gray chert, and limestone clasts in a gray to white tufficaceous sandstone matrix.

North Park Formation (Tmu) (Upper Miocene)

The North Park consists of a white to greenish-gray tufficaceous sandstone, siltstone, and claystone and is locally conglomeratic.

Browns Park Formation (Tm) (Miocene)

The Browns Park consists of white massive soft tufficaceous sandstone and lesser amounts of white marl, the lower part of which is conglomeratic. This formation underlies the North Park Formation in the Saratoga Valley.

Terrace Gravel (QTg) (Pliocene-Pleistocene)

Partly consolidated gravel above and flanking some major streams.

Alkalic Extrusive and Intrusive Igneous Rocks (Qi) (Pleistocene)

This unit includes but is not limited to leucite- and nepheline-rich flows, scoria, and necks.

Undivided Surficial Deposits (Qu) (Pleistocene-Holocene)

These deposits consist mostly of alluvium, colluvium, and glacial and landslide deposits.

Playa Lake and other Lacustrine Deposits (Ql) (Pleistocene-Holocene:

These deposits are comprised chiefly of clay, silt and fine sand. This formation also includes travertine deposits.

Dune Sands and Loess (Qs) (Pleistocene-Holocene)

This unit includes active and dormant sand dunes.

Landslide Deposits (Qls) (Pleistocene-Holocene)

These deposits locally include intermixed landslides and glacial deposits, talus, and rock-glacier deposits.

Glacial Deposits (Qg) (Pleistocene-Holocene)

These deposits include till and outwash of sand, gravel, and boulders.

Gravel, Pediment, and Colluvium (Qt) (Pleistocene-Holocene)

These deposits consist mostly of locally derived material and in local areas include some Tertiary gravel.

Alluvium and Colluvium (Qa) (Pleistocene-Holocene)

These deposits consist of clay, silt, sand, and gravel in flood plains, fans, terraces, and slopes.

2.4 HISTORICAL GEOLOGY

2.4.1 Pre-Cambrian Era

Some of the oldest portions of the continental crust in North America can be found in the Wyoming Province. Evidence thru radiometric dating indicates that the supracrustal rocks, in the South Pass area in the southern Wind River Range, must have been exposed during the Early to Middle Archean times because this is when the granitic magmas and mafic dikes were emplaced (2.64 - 2.67 billion years ago (b.y.a.). This means that the supracrustal rocks were emplaced more than 2.67 b.y.a.

2.4.2 Paleozoic Era

For most of the Paleozoic era, lands now in the RSPA were situated just east of a marine basin located close to the equator. It was frequently covered by warm shallow seas and was predominately the site of carbonate deposition with a high percentage of clastic sediment. Depositional sequences were interrupted by several withdrawals of the sea, followed by erosional periods. The boundary between the marine basin and the shallow water mirrors the present arcuate trend of the Thrust Belt, which lies just west of the RSPA.

The area was emergent following the Precambrian and was gradually covered by a sea extending from the west and first depositing the Flathead Sandstone (of Middle Cambrian age). Next the Gros Ventre Formation shales (of Middle to Upper Cambrian ages) were deposited. These get thinner as they extend eastward across the region. Finally the carbonate sequences of the Gallatin Limestone (of Upper Cambrian age) were laid down.

Additional sequences may have been deposited over the region, but were then removed by erosion after the withdrawal of the sea. As a new sea began to invade the continent, the Bighorn Dolomite (of Upper Ordovician age) was deposited. This sequence of rock strata is found only in the northwest part of the RSPA. Deposition in a near-shore marine environment persisted for a long period of time, but a new period of withdrawal of the sea was followed by an extensive period of erosion that removed all of the sediments deposited after the Bighorn dolomite.

As the marine waters again moved into the area they deposited carbonate sediments (Darby Formation, of Upper Devonian age) in a shallow marine setting. The Darby was probably deposited in the Great Divide and Washakie Basin areas, but later removed by erosion. The overlying Madison Limestone (of Lower to Upper Mississippian ages) was deposited in an open marine environment in its lower part and shows evidence of a shallower sea environment being deposited in the west. There is evidence of erosion taking place on the top of the Madison after its deposition.

Above the Madison, the Amsden Formation (of Upper Mississippian, Lower Pennsylvanian, and Middle Pennsylvanian ages) contains a widespread sandstone unit, that is present at its base, and then overlain by a middle unit of red shale, siltstone and sandstone that may have been derived from emergent areas of the Precambrian rock sequences in southeastern Wyoming. There is further evidence for this uplift, as seen by the presence of an erosion surface occurring within the Amsden. The upper part of this formation is made up of an interbedded limestone, dolomite, siltstone or sandstone, and gray shale (BLM 1997).

Above the Amsden lies the Tensleep Sandstone (of Middle Pennsylvanian, Upper Pennsylvanian, and Permian age). The last major marine invasion spread across the area after deposition of this sandstone. During the deposition of the overlying Phosphoria Formation (of Permian age), a deep marine basin persisted to the west and shallow marine conditions persisted across the RSPA to a shoreline in central Wyoming. East of the marine basin, the Phosphoria Formation carbonate deposition predominated over a broad zone that extended across the RSPA. Intertonguing sandstones in the carbonate sequences represents clastic shoreline sands being transported into the northern part of the RSPA (BLM 2012a).

2.4.3 Mesozoic Era

During the Mesozoic era, the North American continent gradually drifted into the northern latitudes. Most of the sediments deposited during this time within the RSPA were deposited in a northern subtropical environment. A Thrust Belt mountain building event and other mountain building events in the rest of the state had a profound effect during the Late Mesozoic and the Early Cenozoic times.

An erosion surface separates the Paleozoic and Mesozoic rocks indicating that the region was emergent at that time. Later, marine conditions returned to the area depositing the Dinwoody Formation of Lower Triassic age. Intertonguing of marine carbonates and clastics within the Dinwoody reflect sea level fluctuations during deposition. The Dinwoody intertongues with the continental red bed of the Chugwater Formation of Lower and Upper Triassic age as the sequences of the Chugwater are traced to the southeast. The Chugwater Formation in most of the RSPA is equivalent to the Woodside Shale, the Thaynes Limestone, and the Ankareh Formation as described in the Over Thrust Belt. Marine sedimentation persisted with later deposition of carbonate and siltstone units of the Thaynes Limestone and the lower Ankareh Formation.

Regional uplift then began and permanently changed the depositional patterns that had dominated the region. The region became emergent and a widespread erosion surface separated the lower Ankareh marine sequences from the continental deposits of the upper Ankareh. Terrestrial conditions persisted, after the Ankareh deposition as shown by widespread deposits of the Nugget Formation of Upper Triassic or Lower Jurassic age. The Nugget Sandstone is a vast blanket of sand that was deposited in coastal dunes.

Overlying the Nugget Sandstone are limestones and shales of the Gypsum Spring Formation of Middle Jurassic age that were deposited when marine conditions returned. The Gypsum Springs changes to the east and south into red silty shales and anhydrites. As the sea retreated interbeds of marine and non-marine sandstones and siltstones of the Sundance Formation (of Middle and Upper Jurassic age) were deposited. After the sea's withdrawal, the lower part of the Morrison Formation (of Jurassic age) was deposited.

During the Cretaceous age, episodic eastward faulting associated with mountain building continued in the Over Thrust Belt. Sediments derived from faulting accumulated in a depression extending across the RSPA. Deposition was controlled by the interaction between mountain building pulses of clastic sedimentation and a fluctuating sea level. These deposits are thereby made up of clastic marine, transitional marine and non-marine units. In contrast to earlier periods when sedimentation occurred in a shallow sea located generally to the east of the RSPA, these clastic source areas are located generally to the west.

The Upper Morrison Formation of Early Cretaceous age was laid down as a sequence of river and lake deposits. Thrust fault activity to the west initiated several periods of accelerated deposition of clastic sediments in this area. During times when faulting slowed, fine-grained clastic sediments were deposited in a brackish coastal region or marine environments. These units make up the Dakota Formation and the Mowry Shale. The Frontier Formation overlies the Mowry and is made up of predominantly river deposits in its lower part and mixed river and marine in its upper parts. There were two delta complexes that delivered Frontier sediment into the RSPA. A western delta drained the Thrust Belt, and a northern one drained the area of the present day Wind River Range.

The next marine incursion came from the east across the region and resulted in the deposition of the thick Baxter (Hilliard) Shale. Movement on the Rock Springs Uplift began during the deposition of the Baxter. The uplift continued to be a positive area during the deposition of the Blair Formation. The overlying Rock Springs Formation was deposited along a northeast-southwest shoreline that transected the uplift area. The continental part of the formation occupied the northwest part of the uplift and is represented by river sandstone, carbonaceous shale and coal beds. Southeastward these rocks undergo a change to beach and barrier island sands, and offshore sands and marine shale.

These lacustrine materials were deposited across the Rock Springs Uplift area. The Almond Formation marks a change from stream sedimentation of the Ericson to a swampy lowland deposition. Throughout much of the uplift, the Almond Formation is divisible into a lower part including floodplain, channel, swamp, and lake deposits, and an upper sequence of marsh, mudflat, lagoonal-bay, barrier beach and offshore marine deposits.

The Lewis Shale represents the last major invasion of a seaway into the area and only covered the area from the Rock Springs Uplift, eastward. Then there was a nearly complete withdrawal of the seaway that occurred during the deposition of the overlying Lance Formation. This depositional phase was brought to an end by mountain building and ultimate complete withdrawal of the seas. By the end of the era, the North American continent was approaching its present day latitudes (BLM 2012a).

2.4.4 Cenozoic Era

At the onset of the Cenozoic era, the Thrust Belt was in a late stage of development and the ancestral structures of the Uinta Mountains, Wind River Range, Sierra Madre Range, and the Granite Mountains had formed on the margins of the Green River, Great Divide, and Washakie Basins. These basinal areas were then largely filled with river and lake deposits nearly burying these mountain ranges. Volcanism to the north contributed large amounts of volcanic sediments to these basins. The climate started out warm-humid to arid-subtropical but then gradually cooled. Finally, a period of large-scale regional uplifts re-excavated the region and brought about the present day relief.

During the Tertiary era, the basin floors and slopes of the surrounding mountains were probably heavily forested and well populated with mammals, reptiles, and other vertebrates. Streams flowing from the mountains distributed sediments in the flood plains that were on the basin floors. The low-lying areas were occupied by swamps, ponds, and lakes. These sediments are represented in the Fort Union of Paleocene age and the Wasatch Formation of Eocene age. After their deposition, the Lake Goshute system developed, laying down sediments of the Green River Formation. The climate changed markedly to more arid cycles, and primates and other mammals, as well as crocodiles and turtles, began to disappear from the area.

The onset of volcanic activity in the Absaroka-Yellowstone region resulted in large amounts of volcanic debris being introduced by streams into these basins. This influx of sediment, coupled with the decline in mountain building activity, caused the basins in the area to be filled. Late Tertiary time brought about the end of this depositional cycle with a second major uplift of the Rocky Mountains. With the uplift, streams that had been flowing southward across the plain-like surfaces began to cut downward. These sediments are represented by the Bridger Formation (Middle and Upper Eocene), the Fowkes Formation (Middle Eocene to Upper Miocene), the Norwood Tuff (Upper Eocene to Lower Oligocene), the Bishop Conglomerate (Oligocene), Browns Park Formation (Oligocene and Miocene), the Arikaree Formation (Miocene), and the South Pass Formation (Miocene and Pliocene). During the Quaternary there was a series of volcanic extrusions that resulted in 3 basic types of volcanic rocks to be formed: Wyomingite, Orendite, and Madupite. These are found in scattered groups of lava-capped buttes and mesas that are located near the north end of the Rock Springs Uplift. These rocks make up Steamboat Mountain, Boars Tusk, Pilot Butte and several other buttes. They also formed the Leucite Hills. Radiometric dating indicates an age of 1.25 million years.

During the Quaternary period the older structures were gradually worn down and exposed. The surrounding mountains were exhumed and the basins re-excavated to their present forms. The high mountains were glaciated several times with some of the glaciers reaching the edge of the basin and deposit sediments around its margin. Local volcanic centers developed, as well as Sand Dune fields such as the Killpecker Dune Field (BLM 2012a).

2.5 STRUCTURAL GEOLOGY

2.5.1 Structure

2.5.1.1 Green River Basin

The Green River Basin is located in the western region of the RSPA. The Moxa Arch lies in the western part of the Green River Basin. It is a large anticline that extends northward from the north flank of the Uinta Mountains at the Bridger Lake gas field to the Big Piney-LaBarge gas field (BLM 1997). Folding of the arch involved Precambrian basement rocks and subsurface data indicate that the main folding event occurred in the late Cretaceous, causing erosion of the older Mesaverde rocks on the crest of the arch. Younger Cretaceous and Tertiary rocks were then deposited across the unconformity and are not folded.

The Pinedale anticline located north of the Moxa Arch in the northern Green River Basin is a large structure, approximately 45 miles in length and 6 miles in width. The flanks appear to be relatively symmetrical, but the west limb may be a reverse fault (BLM 1997). The structure probably formed during the uplift of the Wind River Mountains. Only the southern end of the anticline lies within the RSPA.

The 55 mile long Continental Fault begins east of the RSPA, then passes between South Pass City and Oregon Buttes, and crosses into the RSPA at its western end (Bradley l964). The 20 mile long Henry's Fork Fault is mostly located outside of Wyoming in Utah. However, a 4 mile long section of the fault, which may have had as much as 12,000 feet of vertical movement (BLM 1997), lies in the southern portion of the RSPA.

2.5.1.2 Rock Springs Uplift

The Rock Springs uplift is a large, complex asymmetric anticline, with its western flank steeper than its eastern flank. The anticlinal axis plunges on both the north and south ends of the structure and a westward-directed thrust fault on the western flank occurs at depth below the surface outcrops. This uplift is a miniature version of some Wyoming mountain ranges, except that when it formed during the Late Cretaceous and early Tertiary, it was not uplifted enough to expose the Precambrian core as in the larger mountain ranges. The oldest rocks exposed in the center of the uplift are Upper Cretaceous marine shales and sandstones, with progressively younger sedimentary rocks forming bands of outcrops around the uplift. The uplift is cut by a number of east- and northeast-trending faults that displace the outcrops by varying amounts (BLM 2012a).

2.5.1.3 Great Divide Basin

The Great Divide Basin, located in the northeast on the RSPA, is situated on the Continental Divide. It is a hydrologic basin containing shallow lakes which has no outlet. This basin is separated from the Washakie Basin to the south by the east-west-trending Wamsutter arch and is bordered to the east by the Rawlins uplift.

The location of the Great Divide Basin on the Continental Divide, in a low spot, between the Overthrust Belt and Wind River Range in Wyoming to the north and the Uinta mountains in Utah to the south; combined with the fact that no high mountain masses exist to the west or the east, means there are no restriction to westerly airflow across this large region. Thus, wind flow is directed through southwestern Wyoming between the mountain masses. Many of the rock formations there being poorly cemented and with the region being arid, this unobstructed wind flow has easily eroded sand-sized grains and deposited them downwind in sand dunes. It is therefore no accident that the Great Divide Basin is home to the Killpecker dune field the largest continuous area of sand dunes in the U.S. (WSGS 2011a).

2.5.1.4 Washakie Basin

The Washakie Basin is located in the southeast region of the RSPA, east of the Rock Springs Uplift and south of the Great Divide Basin. The southern border of this basin is the structural arch called the Cherokee Ridge that separates the Great Divide Basin and the Sand Wash Basin in Colorado. The northern border of the Washakie Basin is the Wamsutter Arch. The interior of the basin contains an area greater than 28 square miles of very unique landforms with particular geological value called Adobe Town (WSGS 2011a).

2.5.1.5 Wind River Range

Only the southern extent of the Wind River Mountains is located in the northern portion of the RSPA. The range is one of the most impressive Precambrian basement uplifts in the Rocky Mountain Foreland. These mountains are essentially a huge block of granitic rock that has been thrust south-westward over the Green River Basin.

The southwestern edge of the Wind River Range is a fault for the Wind River thrust which it is entirely covered by Tertiary deposits in the RSPA. The fault has an average dip of 30 to 35 degrees and appears to have a minimum horizontal displacement of 13 miles and a minimum vertical displacement of 8 miles. It appears that the Wind River Uplift is the result of extensive horizontal compression probably related to major plate movements (BLM 2011).

2.5.2 Seismicity

Earthquakes are not common place in the RSPA and those that occur are often due to manmade events such as blasting at mines, mine collapses, or explosions. However earthquakes in adjacent regions may directly affect this area. Active faulting is limited to the perimeter of the planning area, and historical seismicity shows no major earthquakes within the planning area (BLM 2012a).

The current Unified Building Code (UBC) Seismic Zones have five seismic zones, ranging from Zone 0 to Zone 4. The seismic zones are in part defined by the probability of having a certain level of ground shaking (horizontal acceleration) within a 50 year timespan. The criteria used for defining boundaries on the Seismic Zones were established by the Seismology Committee of the Structural Engineers Association of California (BLM 1997). The criteria they developed are as follows:

Zone Effective Peak Acceleration, % gravity (g)

- Zone 4: 30% and greater
- Zone 3: 20% to less than 30%
- Zone 2: 10% to less than 20%
- Zone 1: 5% to less than 10%
- Zone 0: less than 5%

The committee assumed that there was a 90% probability that the above values would not be exceeded in 50 years, or a 100% probability that the values would be exceeded in 475 to 500 years.

Most of the RSPA is in Sweetwater County with the remainder being in Uinta, Lincoln, Sublette and Fremont Counties. Minus the lands in Uinta, Lincoln, south-central Sublette and extreme western Sweetwater Counties which are in the UBC Seismic Zone 2. The RSPA is in UBC Zone 1 (Case and Kirkwood 2002).

Thirty magnitude 2.0 and greater earthquakes have been recorded in Sweetwater County since the first earthquake was reported on April 28, 1888, exclusive of the trona mine region west of Green River.

A recent earthquake occurred on April 5, 1999 with a magnitude 4.3 in southwestern Carbon County, approximately 20 miles southeast of Wamsutter. The event was felt in Rawlins, Sinclair, Baggs, Wamsutter, and Rock Springs. Residents of Rawlins reported that pictures fell off walls. The most significant damage occurred between Baggs and Creston Junction, and at Wamsutter. The owner of a ranch house, located approximately 30 miles north of Baggs, reported that cinder block walls in the basement of the home cracked, separated, and may have to be replaced. A motel and associated residence in Wamsutter also suffered cracks in the cinder-block walls of the basement.

The only major fault that is located in the RSPA is the Continental fault. The fault is considered to be a late Cenozoic normal fault reactivation of an early Eocene tear fault bordering the southern margin of the Wind River thrust fault. This reactivation was in a down-to-the-northeast direction (reversal from previous sense) and may be related to the middle Miocene collapse of the Wind River uplift. Reconnaissance studies show no evidence (aerial or ground-based) for surface rupturing in the late Quaternary or Quaternary. However, some authors argue for Quaternary displacement on the basis of offset high-level terrace gravel and anomalous drainage patterns. No detailed studies have been performed on this fault that proves Quaternary movement. Thus, the fault is considered to be a Class B structure of potential, but unproven Quaternary age (USGS 2012b).

2.6 Geologic Hazards

There are several types of geologic hazards present in the RSPA. The primary hazards of concern include:

- hydrogen sulfide,
- earthquakes,
- landslides

In localized regions of the RSPA there are other geologic hazards that include:

- windblown deposits,
- coal fires,
- subsidence
- methane

Geo/Resource Consultants (1984) prepared an analysis of the above hazards, with the exception of the hydrogen sulfide, coal fires, and methane hazards. Figures 2-6a and 2-6b show the locations of active faults, landslides, and windblown sand that are present within the RSPA.

Hydrogen sulfide is a heavier-than-air gas, smelling of rotten eggs, which is present in some deep producing oil and gas wells. It is both an irritant and a chemical asphyxiant with effects both on the oxygen absorption and the central nervous system.

Low concentrations irritate the eyes, nose, throat and respiratory system (e.g., burning/ tearing of eyes, cough, shortness of breath). Asthmatics may experience breathing difficulties. The effects can be delayed for several hours, or sometimes several days, when working in low-level concentrations. Repeated or prolonged exposures may cause eye inflammation, headache, fatigue, irritability, insomnia, digestive disturbances, and weight loss.

Moderate concentrations can cause more severe eye and respiratory irritation (including coughing, difficulty breathing, and accumulation of fluid in the lungs), headache, dizziness, nausea, vomiting, staggering, and excitability.

High concentrations can cause shock, convulsions, inability to breathe, extremely rapid unconsciousness, coma, and death. Effects can occur within a few breaths, and possibly a single breath.

Landslides are relatively limited in the RSPA. There are some unstable slopes in poorly consolidated glacial deposits and on steeper margins of gravel-capped buttes and mesas in the southern RSPA. However, most of the landforms in the RSRA are flat to gently sloping and are thus relatively stable.

Blowing sand is an issue at the Killpecker dune field that is located in the Great Divide Basin and encompasses about 170 square miles. It is located in both the RSPA and the Rawlins Field Office planning area to the east. Prevailing wind directions from the west-northwest erode poorly consolidated rocks, as discussed above. These conditions become hazardous when dunes migrate, causing poor visibility and barriers across roadways (Geo/Resource Consultants 1984). There are no major highways near the dunes, although there are numerous small, graveled county roads that are affected by shifting sand.

Subsidence may be a result of past underground mining activity and typically occurs in localized areas. These depressions will typically form directly over mined-out areas when subsidence occurs in cone-shaped depressions (Geo/Resource Consultants 1984). Significant subsidence issues have occurred over time in Rock Springs and surrounding areas where poorly planned and mapped underground mining took place between the 1800s and the mid-1900s (WOHS 2011).

Methane is a colorless and odorless gas that is extremely flammable and at certain concentrations when mixed with air can cause an explosion. It is also an asphyxiant and can displace oxygen in enclosed spaces (Palmer Undated). The Mine Safety and Health Administration (MSHA) classifies U.S. mines as either gassy or non-gassy based on specific criteria identified in the regulations at 30 Code of Federal Regulations (CFR) Subpart 57. Gassy mines must meet specific safety standards (Palmer Undated). Methane has been encountered during mining in the RSPA trona mines. Oil shale beds and organic marlstones are likely the source for the methane. The methane is a significant enough problem that MSHA has classified the trona mines as gassy (Wiig et. al. 1995).

Figure 2-6a Geologic Hazards in the RSPA - North

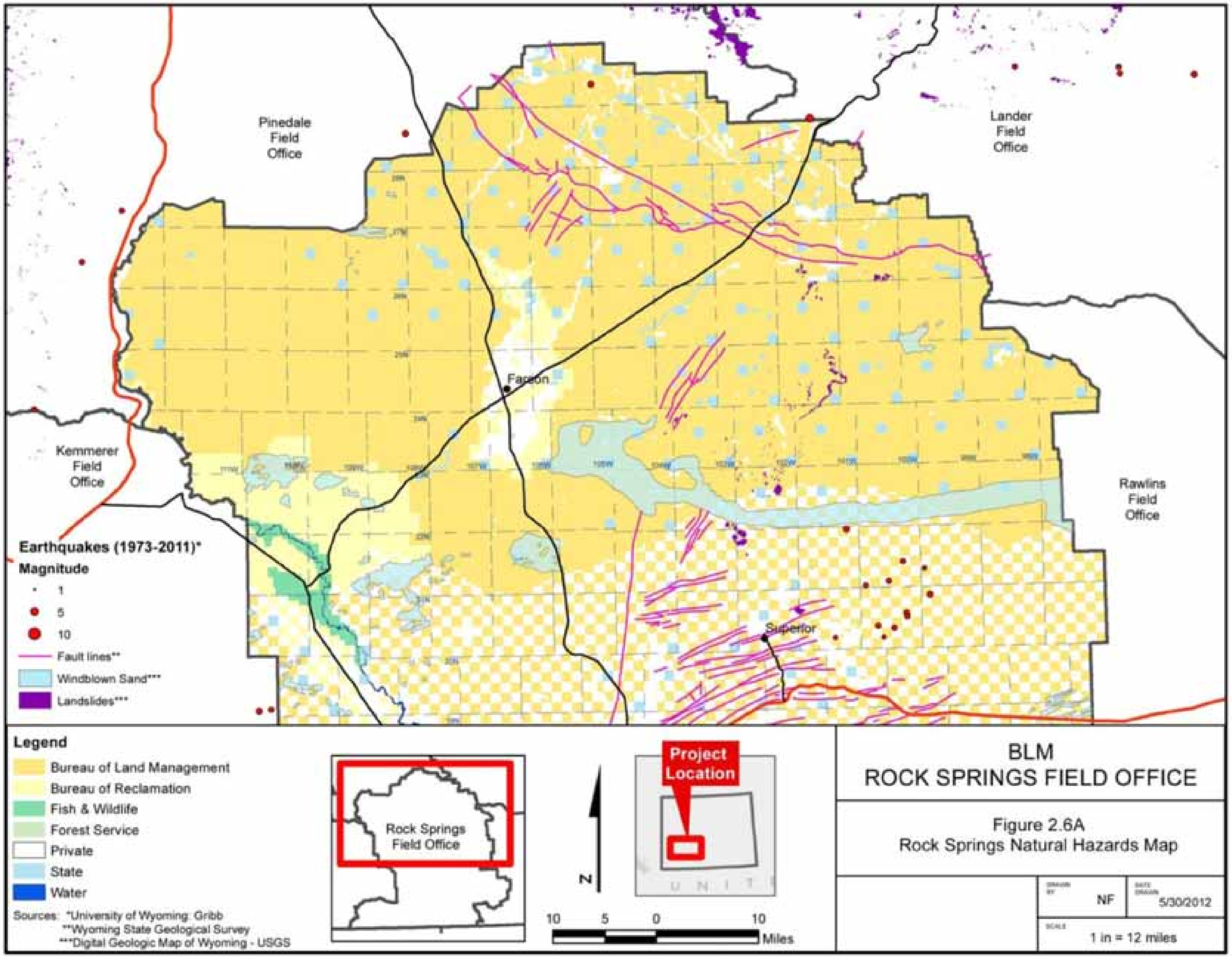
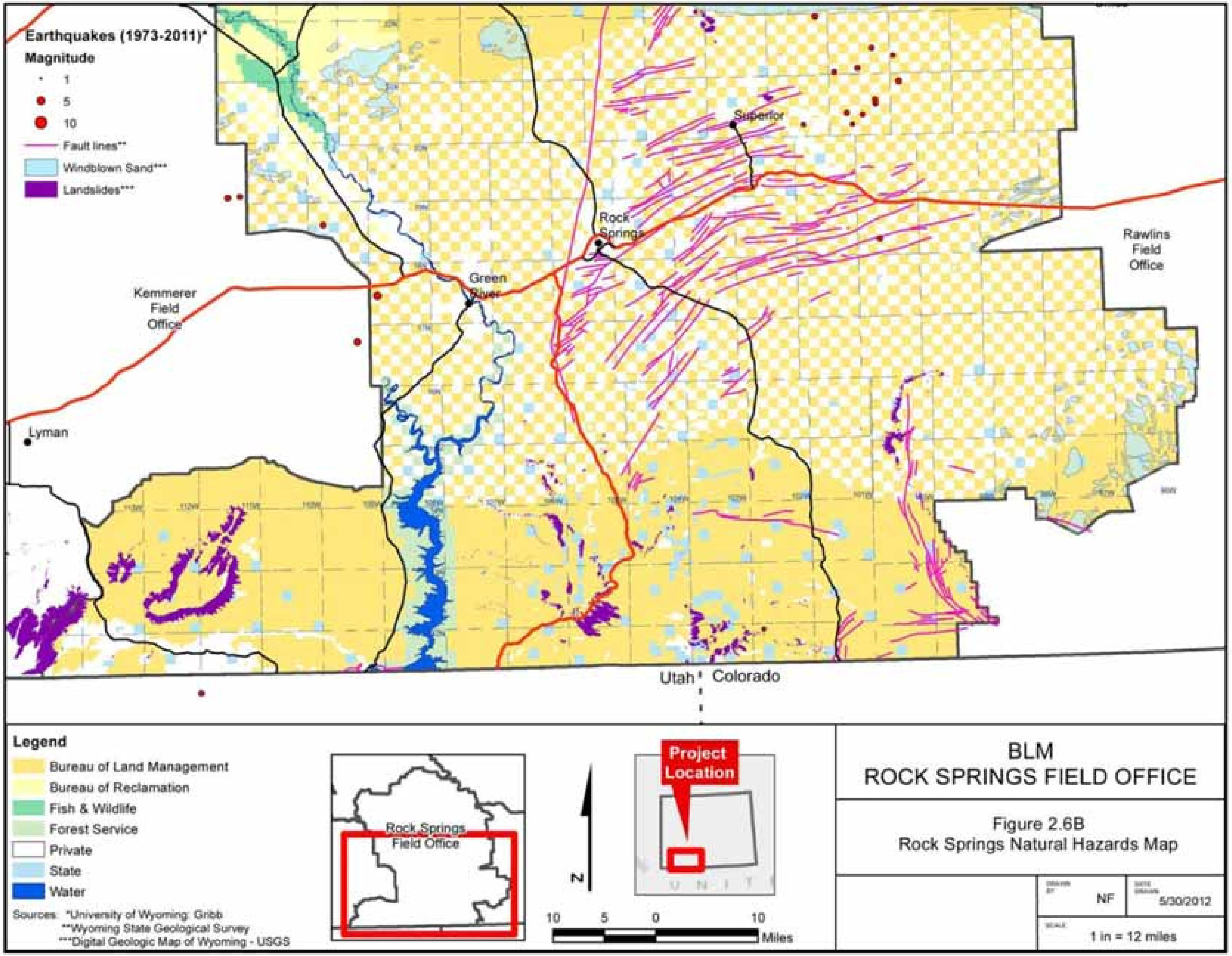


Figure 2-6b Geologic Hazards in the RSPA - South



CHAPTER 3 DESCRIPTION OF ENERGY AND MINERAL RESOURCES

Known leasable solid minerals, locatable, and saleable minerals within the RSPA are addressed in this section.

3.1 LEASABLE SOLID MINERALS

Coal and Trona are the most significant solid leasable mineral resources found in the RSPA and have been produced commercially for several decades in the planning area. In addition, oil shale resources, also managed as a solid leasable mineral by BLM, are present in potentially commercial quantities, though oil shale has not yet been developed (BLM 2012a).

3.1.1 Coal

Coal on federal lands is managed by the BLM as a leasable solid mineral under the Mineral Leasing Act of 1920. The BLM manages coal leasing as well as other administrative duties related to coal production from federal coal lands throughout the United States (U.S.) pursuant to the 43 Code of Federal Regulations (CFR) Part 3400, Coal Management regulations. Wyoming has the largest federal coal program in the BLM. Coal mining is a significant part of the economy in Sweetwater County Wyoming. In the RSPA, coal mining occurs on federal, state, and private lands.

Mineral Description

Coal is a combustible stratified organic sedimentary rock used in electric power generation as well as numerous industrial and domestic heating operations. It is composed of decomposed plant remains from freshwater sources and includes varying minor amounts of inorganic material. Different types of coals are classified by their degree of metamorphism in accordance with standard specifications of the American Society for Testing Materials. Generally higher rank coals are also higher quality coals and have higher calorific values (USGS 2005a). Anthracite and High volatile A-C bituminous coals are the highest quality coals with a calorific value of between 11,500 and 16,000 British Thermal Units (btus) per pound (lb). Subbituminous A-C coals are the mid quality range coals with calorific values ranging from 8,300btus/lb to 11,5000 btus/lb, and lignite coals are the lowest quality with calorific values below 8,300 btus/lb. .Within the planning area, coals are subbituminous C to high volatile C bituminous in rank (Glass 1978). Older Cretaceous coals are higher rank .

Geology/Mineral Occurrence in the RSPA

Coal deposits underlie a large portion of the RSPA, but vary in depth, thickness and quality. Most of today's economically important coal deposits occur on the flanks of the Rock Springs Uplift (Figure 3-1). The Rock Springs Uplift in Sweetwater County, Wyoming, is a large, doubly plunging anticlinal dome that is approximately 60 miles long, 40 miles wide and trends north-south. The Uplift, located in the central portion of the Greater Green River Basin, separates the Green River Basin on the west flank from the Great Divide and Washakie Basins on the northeast and southeast flanks respectively (Figure 3-2). Many northeast trending normal and strike-slip faults radiate outward from the center of the uplift (Flores et. al. 1999). The strike-slip faults trend at right angles to the strike of the rocks and have horizontal displacement of up to three miles. Vertical movement on the normal faults is generally less than 100 feet (BBCC 1987).

Figure 3-1 Coal Resources in the Rock Springs Field Office Area

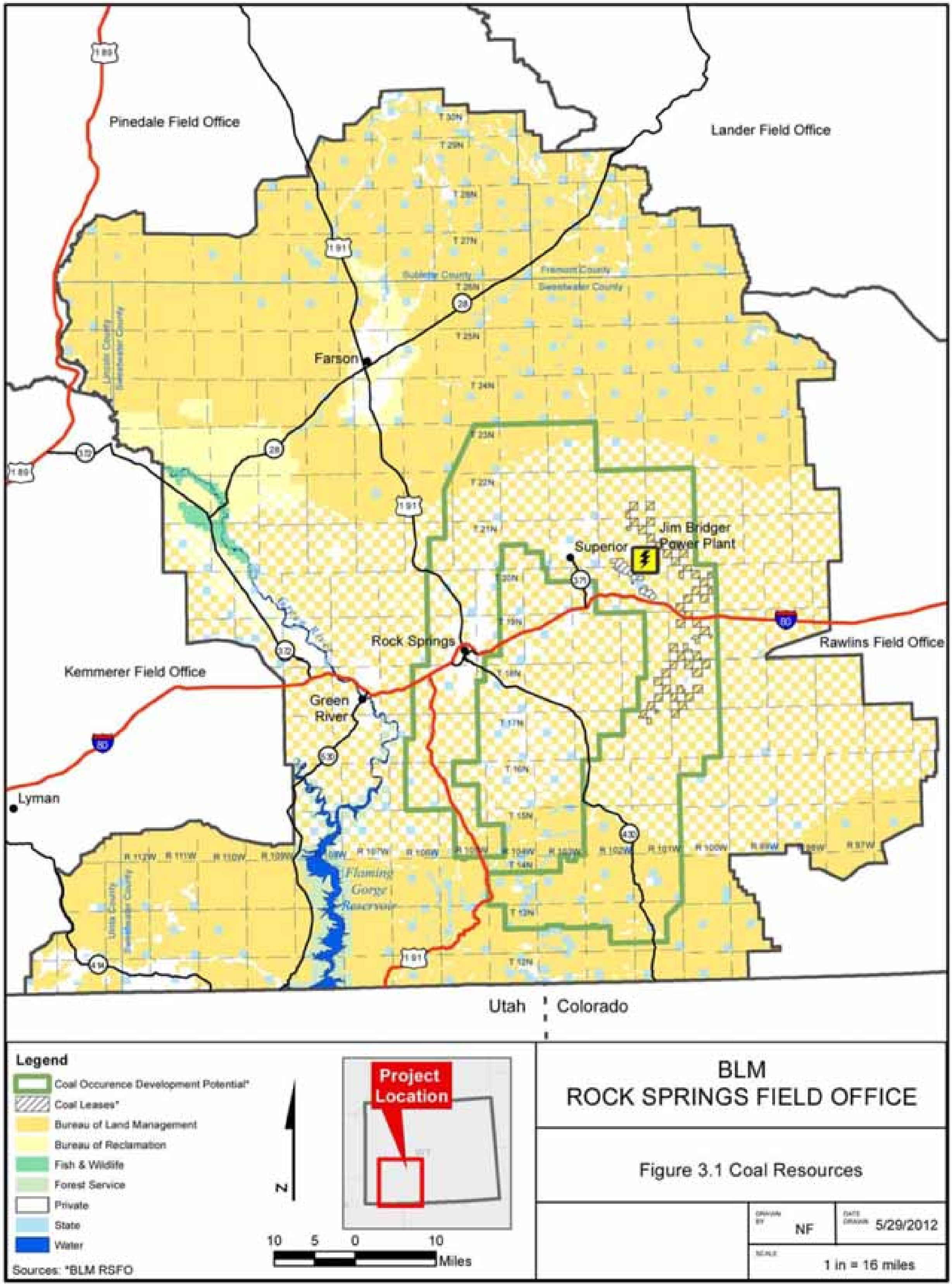
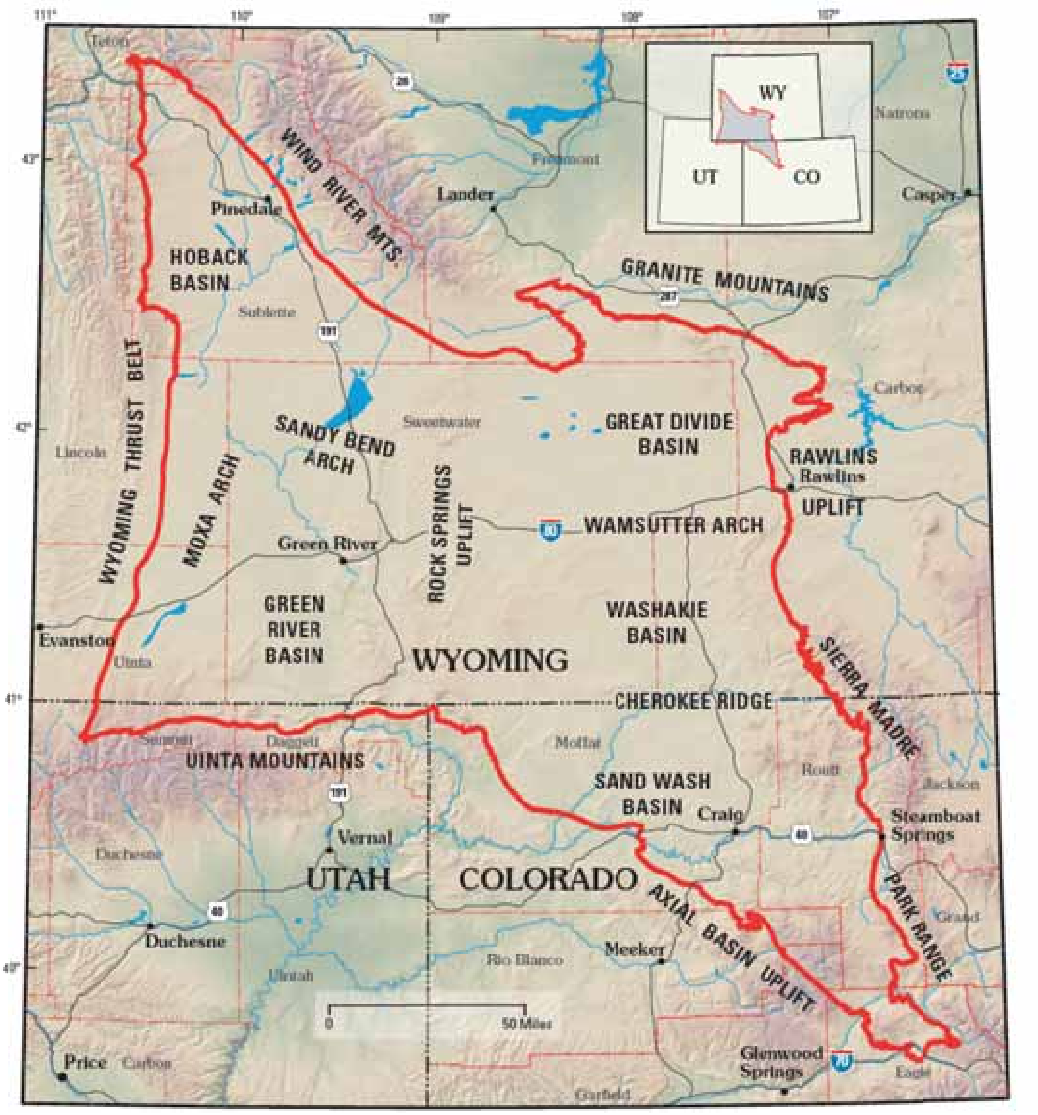


Figure 3-2 Generalized Map of the Greater Green River Basin in South-Central Wyoming Showing Associated Basins, Geologic Structures, and Surrounding Mountains and Uplifts



(Source: USGS 2005b)

Within the planning area, the primary coal beds of economic interest occur in the Cretaceous Lance and Almond Formations, and the Paleocene Fort Union Formation. Coal is currently being recovered from the Almond and the Fort Union Formations by operations located on the northeastern flank of the Rock Springs Uplift using surface and underground mining techniques. Coal also occurs in the Wasatch Formation, but it is of very low quality and is thus far uneconomical to mine (BLM 2012a). The characteristics of the coal bearing units in the area of Point of Rocks have been extensively studied as this is where current coal mining occurs. These characteristics are summarized below.

Almond Formation

The Almond Formation is an upper Cretaceous sedimentary unit of varying lithology within the Mesaverde Group. In the Greater Green River Basin, the Mesaverde Group consists of sandstone, carbonaceous shale, and coal (USGS 2010a).

On the east side of the Rock Springs Uplift, the Almond Formation is overlain by the Cretaceous-aged Lewis Shale, Fox Hills Sandstone, and the Lance Formation as well as thin deposits of Quaternary alluvium, colluvium, and aeolian sediments (Roehler 1973). Outcrops of the Almond Formation have a bedding dip between three and 10 degrees. The Almond Formation thickness averages 325 feet consisting of three distinct units, based on differing lithology. The lower unit is a dark gray shale interbedded with a similarly-colored fine, grained sandstone approximately 100 feet thick. The middle unit is made of 75 feet of dark gray shale and interbedded gray siltstone, gray, fine-grained sandstone, gray and brown carbonaceous shale, and coal. The upper unit is 150 feet of dark-gray shale, light-gray sandstone, and siltstone (BBCC 1987). Coal beds within the Almond Formation are subbituminous coals with individual bed thicknesses up to 12 feet thick (Glass 1978).

Lance Formation

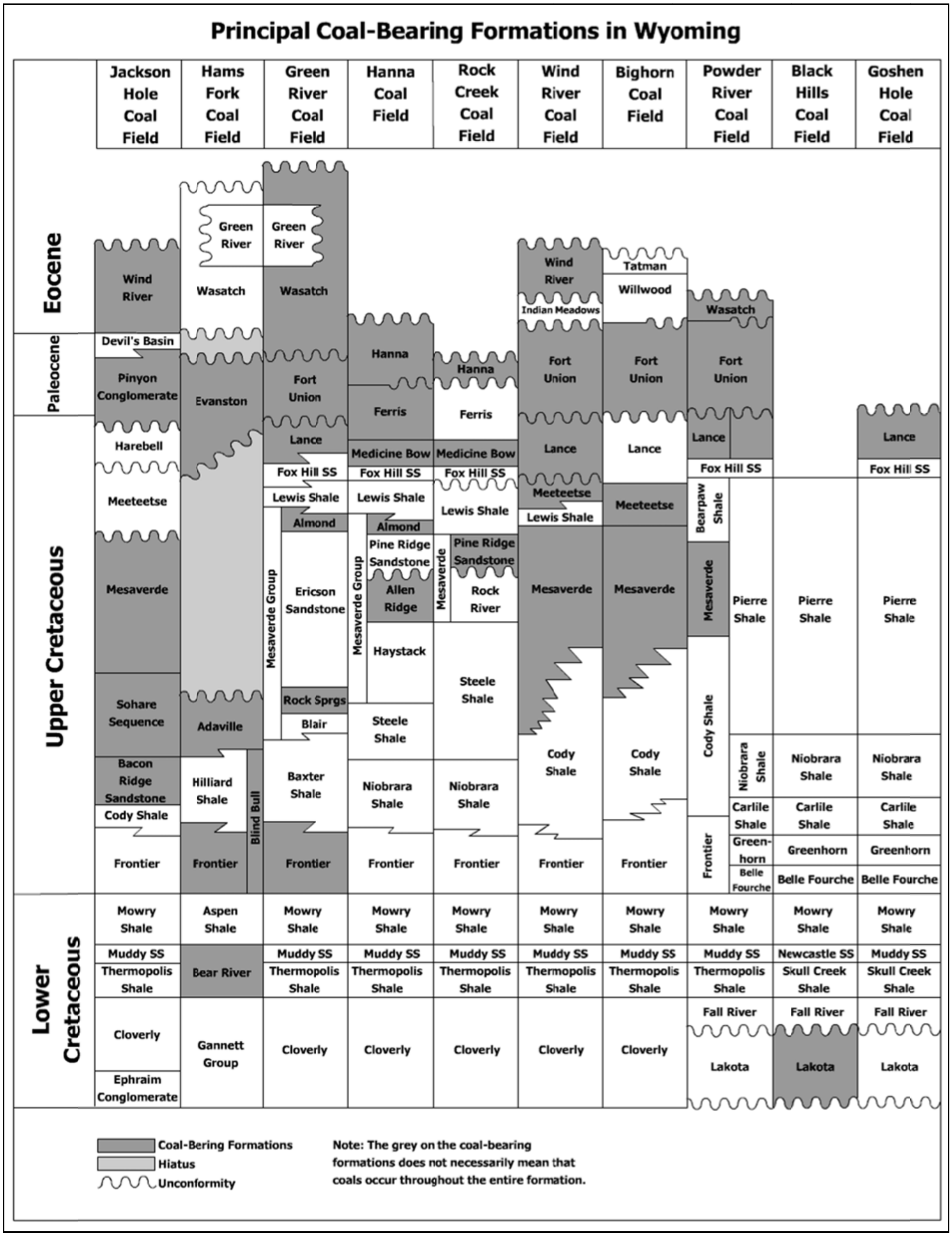
The late Cretaceous Lance Formation underlies the Fort Union Formation and rests on top of the Fox Hills and Mesa Verde Group. It is composed of a drab-colored sequence of interbedded sandstone and shale with a few thin beds of carbonaceous shale and coal. Sandstone is the dominant lithology at most localities, along with some lenses of coarse pebble conglomerate. It was laid down during the Laramide Orogeny (BLM 2009). Lance Formation coal reportedly averages 5 to 10 feet thick on the east flank of the Rock Springs Uplift. The Lance coals average 20.8% moisture, 5.5% ash, 0.77% sulfur, with a heating value of 9,780 btus/lb (Glass 1978). These coals are in the mid range of the coal rank classification system (USGS 2005a).

Fort Union Formation

Where the current mining operations are located on the east side of the Rock Springs Uplift, there are three coal zones: the Deadman, and two unnamed zones. These have been identified in the Paleocene Fort Union Formation which crops out on the eastern flank of the Rock Springs Uplift. The Fort Union covers an area of approximately 26,000 square miles and reaches a thickness of greater than 3,000 feet in the central portion of the basin. On the flank of the uplift, the formation is between 1,059 and 1,800 feet thick. The formation dips between 2.5 degrees and about 8 degrees at the surface on the east flank of the Rock Springs Uplift.. Generally the formation is characterized by a lower coal section, a middle sandstone section, and an upper coal section. The middle sandstone section is as much as 800 feet thick with no coal beds. Within the lower and upper coal sections, coal beds are found with thickness ranging up to 30 feet (Flores et.al. 1999).

Within the Point of Rocks - Black Butte Coalfield on the eastern flank of the Rock Springs Uplift, the Deadman Coal Zone occurs in the lower 200 feet of the Fort Union Formation and wraps around the east flank of the Rock Springs Uplift. In this area, the coal zone consists of five coal beds (referred to as D1-D5) that reach a maximum thickness of 26 feet. The beds split and merge in a north-south direction and occur as five separate beds and as few as one merged bed. The Jim Bridger Mine is located in this portion of the coal zone. On the southeast side of the uplift, the coal zone is comprised of either two or three beds (referred to as A-C), again the result of splitting and merging. The beds in this portion of the coalfield reach as much as 33 feet in thickness. The Black Butte Mine is located in this part of the Deadman coal zone. The splitting and merging of the beds throughout the coal zone is indicative of a fluvial depositional environment in eastward flowing and meandering streams, characterized by peat swamps on fluvial floodplains and in abandoned fluvial channels (Flores et. al. 1999). Figure 3-3a shows the Wyoming area coal-bearing formations. Coal managed by the RSFO is shown in the third column from the left, labeled the Green River Coal Field. Figure 3-3b shows a geologic column representing the Point of Rocks area.

Figure 3-3a Principle Coal-bearing Formations in Wyoming



(Source: WSGS 2002)

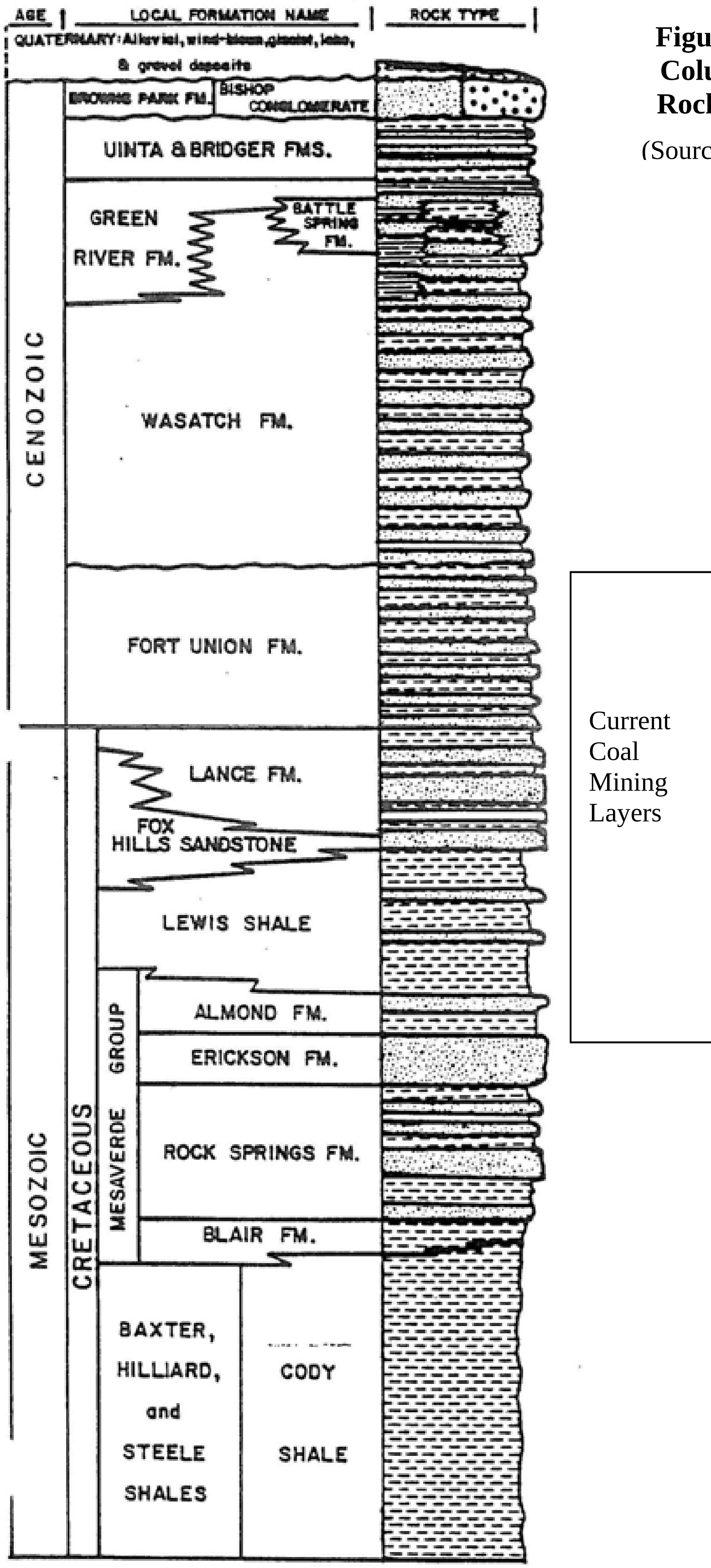


Figure 3-3b: Geologic Column from Point of Rocks, Wyoming Area

(Source: BBCC 1987, Figure

There are no recent studies that project the potential reserves within the planning area. In 1978 and 1979, the USGS engaged Dames and Moore to estimate the in-place coal resources within the known coal areas within the Rock Springs Field Office in coal beds at least 5 feet thick, and characterize these resources by development potential. For this effort, an evaluation was made on the coal resources for each of thirty-seven 7.5 minute quadrangles that are contained within the coal development potential area shown on Figure 3-1. This effort is summarized in Table 3-1.

Table 3-1 Coal Resources within the Rock Springs Coal Occurrence/Development Potential Area by Development Potential

Reserve Base Category	Reserve Base (million short tons)
Surface mineable	617.1
Underground mineable	1,715.2
Total	2,332.3

Source: USGS 1978a-1978i, 1979a-bb.

In 1999, the available coal resources in the Deadman coal zone at Point of Rocks in the Jim-Bridger / Black Butte area were estimated by the U.S. Geological Survey for those seams that are at least 2.5 feet thick. These figures are listed in Table 4.5 below.

Table 3-2 Coal Resources in Deadman Coal Zone near Point of Rocks, Wyoming

Study Area	7.5-minute Quadrangle Name	Total (million short tons)
Black Butte	Antelope Flats	2.6
	Bitter Creek	450
	Bitter Creek NE	120
	Bitter Creek NW	25
	Black Buttes	94
	Cooper Ridge NE	10
	Sand Butte Rim NW	250
TOTAL Black Butte		960
Jim Bridger	Bitter Creek NE	480
	Bitter Creek NW	210
	Black Rock South	420
	Tenmile Rim	570
	Twelvemile Well	32
TOTAL Jim Bridger		1,700
GRAND TOTAL		2,700

Source: Ellis et. al. 1999. Chapter GN *in* USGS Professional Paper 1625-A.

The 1999 USGS study looked at a smaller area, but estimated in-place resources for all coal beds at least 2.5 feet thick. The earlier Dames and Moore study covered a much larger area, but used more restrictive criteria to define a reserve base for the defined coal occurrence/development potential area. The area contains significant potential coal reserves, in excess of 2 billion tons, but additional evaluation would be necessary to define the potential reserves within the planning area that can be recovered by surface and/or underground mining methods.

3.1.2 Trona

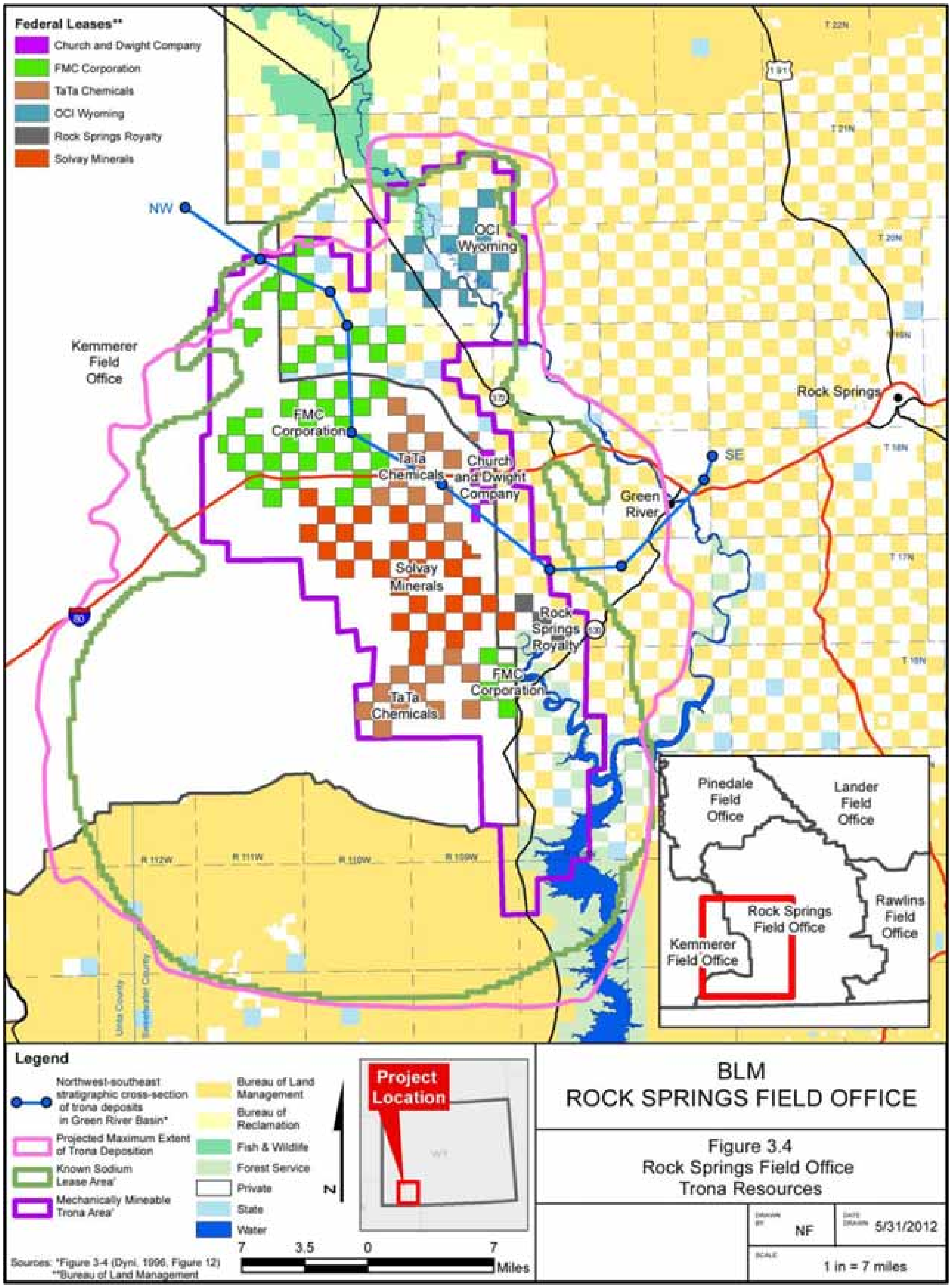
Trona is a relatively rare sodium carbonate mineral with wide geographic distribution. It is found in Africa, China, Turkey, Mexico as well as the U.S. (BLM 2012a). In the U.S., trona deposits are found in California, Nevada, Utah, Colorado, and Wyoming. However, Wyoming, and specifically the Rock Springs and Kemmerer Field Offices, are home to the largest known trona deposits in the world. Trona is used to produce soda ash, an important non-hydrocarbon mineral that is used in many applications including the manufacturing of glass, chemicals, paper, detergents, food processing, feed stuffs, as well as in flue gas desulfurization and water conditioning. Soda ash may be best known as its pure form, baking soda (sodium bicarbonate). It can be synthetically produced or mined and the U.S. and China are the main producers of trona (WMA 2008; WMA undated). Like coal, trona is managed as a leasable solid mineral under the Mineral Leasing Act of 1920, as amended and the regulations at 43 CFR 3500.

Mineral Description

Trona is a sodium carbonate mineral (Na2CO3.NaHCO3.2H2O) that occurs as an evaporite mineral deposited primarily in saline lakes. Trona is currently being deposited in saline lakes in Africa and California. The Eocene Green River Formation, located in the Green River Basin in southwest Wyoming, contains the world's largest known deposit of trona. The trona was deposited in ancient Lake Gosiute which covered most of SW Wyoming at that time. During a number of dry periods, Lake Gosiute's level dropped and as the water increased in salinity, trona and other evaporite minerals such as halite were deposited (Wiig et. al. 1995). This deposit is located in the southwest quarter of the planning area (Figure 3-4), principally within the checkerboard lands discussed under section 1.1 of the Introduction.

In March 1954, the U.S. Geological Survey established the Known Sodium Leasing Area (KSLA) which defines an area in the Green River Basin where developable trona deposits are known to occur that are at least four feet in thickness (see Figure 3-4). The KSLA was last updated in 1978 and covers an area of about 684,180 acres, of which 356,960 acres are included in the Planning Area (Wiig et. al. 1995). The ownership of the trona resources outlined in the KSLA includes the Federal Government at 55.7percent, Union Pacific Resources under a historic railroad land grant from the federal government at 38.1 percent, and the State of Wyoming at 6.2 percent (Dyni 1996).

Figure 3-4 Trona Resources in the RSPA



Trona is mined using two very different methods, mechanical and dissolution. The most common method is by conventional underground room and pillar or longwall mining technologies using continuous miners and retreat longwall miners. The ore is loaded onto conveyor belts and transported out of the mine workings to a processing plant on the surface. A second method is by dissolution of the trona known as in-situ mining. This method involves drilling wells into the trona deposit and injecting a solution which dissolves the mineral. A third method is flooding the previously mined area to dissolve the remaining trona left behind as pillars, and recovering the trona solution.The trona-saturated solution is then pumped back out through recovery wells and piped to a processing facility on the surface. Some mines use the first and third methods to increase recovery. At this time the in-situ production method is not being employed in the KSLA. The mechanical mining method recovers an average of 45% which is higher than the 30% average mining recovery from solution mining (USGS 2012c).

In 1993, BLM delineated the Mechanically Minable Trona Area (MMTA) in order to generally define "an area underlain by trona deposits of the proper depth, thickness, and quality that will support ore extraction by mining techniques that require an underground workforce" (Figure 3-4). The specific criteria for establishing the MMTA boundary include the presence of one or more trona beds with a thickness of at least 8 feet at a depth of less than 2000' and composed of at least 85% trona with less than 2% halite content. The current MMTA boundary encloses about 315,511.28 total acres, of which 141,100 acres are within the RSPA with the remainder in the Kemmerer Field Office. Table 3-3 shows a breakdown of BLM acreage versus private and state land acreage for the KSlA and the MMTA. All unleased public lands within this area are available for sodium leasing consideration (BLM 2012a).

Table 3-3 Acreage within the Known Sodium Leasing Areas and Mechanically Minable Trona Areas and Ownership Breakdown

Land Ownership and Lease Status	Acres
BLM land within Known Sodium Leasing Area (KSLA)	203,308.83
Leased	17,026.92
Not Leased	186,281.91
Private & State land within KSLA	154,463.26
Total Acreage of KSLA within RSPA	357,772.09
BLM Land within Mechanically Mineable Trona Area (MMTA)	42,930.87
Leased	17,026.92
Not Leased	25,903.95
Private & State land within the MMTA	272,580.41
Total Acreage of MMTA	315,511.28

Source: BLM RSFO GIS data

While unleased public lands within the MMTA area are available for sodium leasing consideration, these lands are administratively unavailable for new fluid mineral leasing (i.e. oil and gas) by the BLM until it can be satisfactorily demonstrated that the oil and gas resource can be recovered without compromising the safety of underground miners and mine workings. Existing federal oil and gas leases inside the MMTA have also been suspended from development in the KSLA for an indefinite period (BLM 2012a).

Geology/Mineral Occurrence in the RSPA

Wyoming's trona resources were deposited in three main geologic formations, the Wasatch, Green River, and Bridger Formations, in the Green River Basin. The Green River Basin is a northeast-southeast trending broad synclinal basin which is located west of the Rock Springs Uplift. The beds in this basin are relatively flat-lying, and generally dip toward the center at less than two degrees. These formations are derived from lacustrine and fluvial sediments that were laid down during the Eocene (Paraday 2006).

The oldest of these, the Wasatch Formation, is dominated by sandstones, conglomerates, carbonaceous shales, and coal. The Eocene Green River Formation intertongues with members of the Wasatch Formation. It is characterized by mudstones, siltstones, shales, and evaporitic minerals such as trona. Above the Green River Formation is the Bridger Formation, which is found near the Basin's center. It is comprised of a mixture of fluvial sandy mudstones, sandstones, limestones, and marlstones (Paraday 2006).

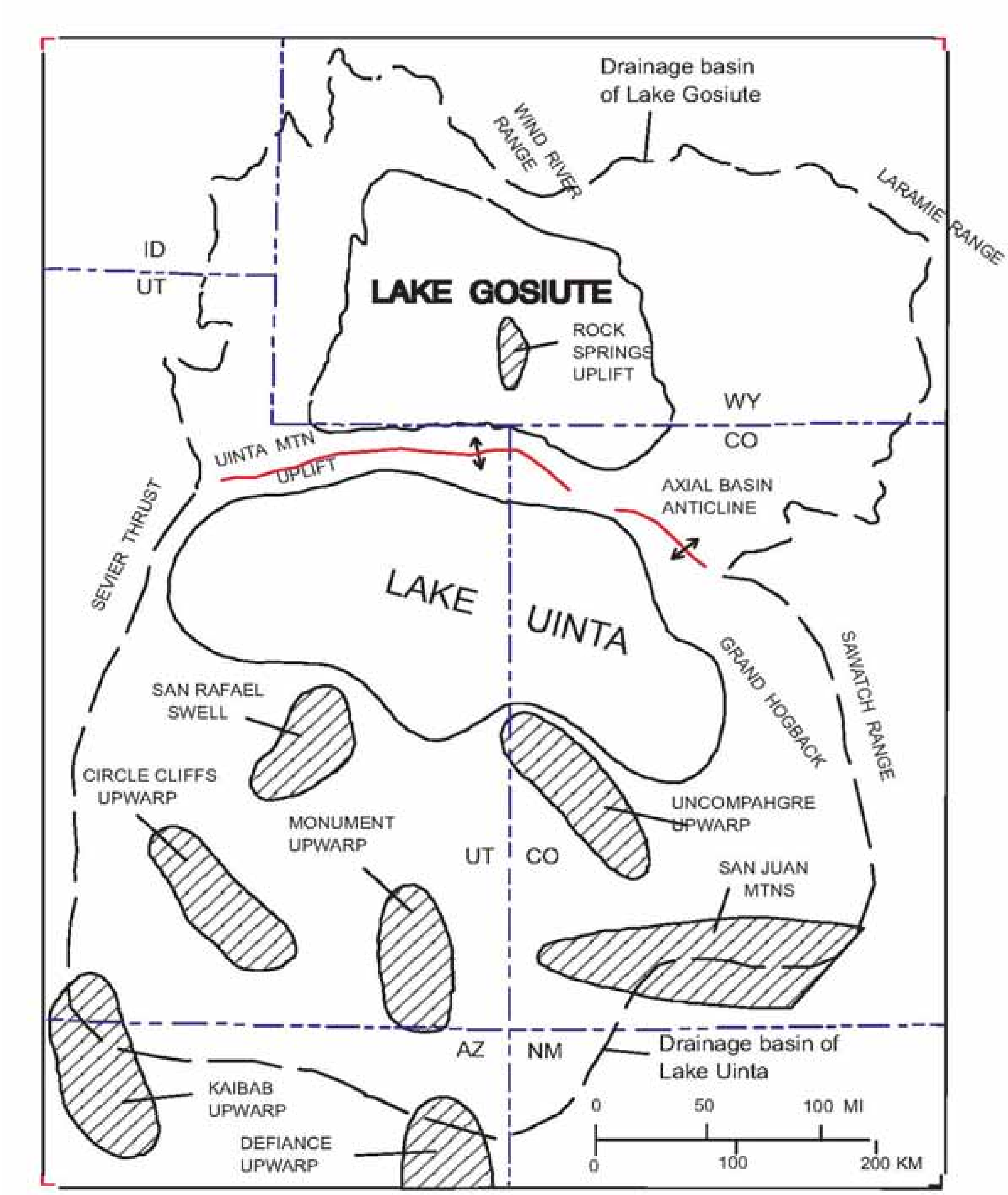
The trona beds of economic interest are found in the Wilkins Peak Member of the Green River Formation which was deposited in an extensive saline lake, Lake Gosiute, which covered the Green River and Washakie Basins in Wyoming and the Sand Wash Basin in northern Colorado during the Eocene (Fig 3-5). It was subjected to wide fluctuations in lake level due to regional climatic variations (Dyni 1996). Marlstone, siltstone, mudstone and oil shale were deposited on the lake floor during wet periods while evaporites, in particular trona, were deposited during arid periods. Several different processes contributed to produce these carbonate deposits, including reduction of sulfate by bacteria, calcium carbonate precipitation by algae, hydrolysis of silicate minerals and volcanic ash, as well as the introduction of dissolved bicarbonate into the lake from stream water sources. During dry periods of climatic variations when the lake level lowered and the water became highly saline, trona and a wide variety of other carbonate minerals precipitated from the lake brines. Beds as much as 35 feet thick extending over more than 1,000 square miles were formed. More than 42 trona beds have been recognized in the Green River Formation (Wiig et. al. 1995).

Green River Formation

The Eocene Green River Formation, as much as 2,400 feet thick in the southern part of the basin is comprised, from oldest to youngest, of the Tipton Shale, Wilkins Peak, and Laney Shale Members. The Wilkins Peak Member, which contains trona and halite beds in the middle and lower portions, thins from a maximum of 1,350 feet thick in the south to 600 feet thick in the northern part of the basin. Figure 3-6 shows a representative stratigraphic cross section of the Wilkins Peak Member. The location of this cross-section relative to the KSLA and MMTA is shown on Figure 3-4.

More than 42 beds of trona and inter-bedded trona and halite have been identified. The 25 thickest trona beds, ranging from 5 to 35 feet in thickness, have been numbered 1 - 25 from oldest to youngest respectively. Figure 3-7 shows a well log of the lithology and the numbered trona beds 1-23. The trona beds are generally flat lying, thickest and youngest in the northern portion of the Green River Basin, and thin to the southern margin of the basin Initially, halite was not deposited with the trona but by the time bed 5 was deposited, halite began to be deposited simultaneously and in some places a significant amount of halite was deposited, especially in the deeper portions of the lake. Over time, trona deposition moved from the deeper southern portion of the basin to the northern portion as sediments filled the southern part. The northern and latter trona deposition was free of halite (Wiig et. al. 1995).

Figure 3-5 Paleogeographic Map Showing the Approximate Maximum Extent of Lake Gosiute and the Surrounding Drainage Basin



(Source: Dyni 1996, Figure 2)

Figure 3-6 Northwest-Southeast Stratigraphic Cross-Section of Trona Deposits in Green River Basin

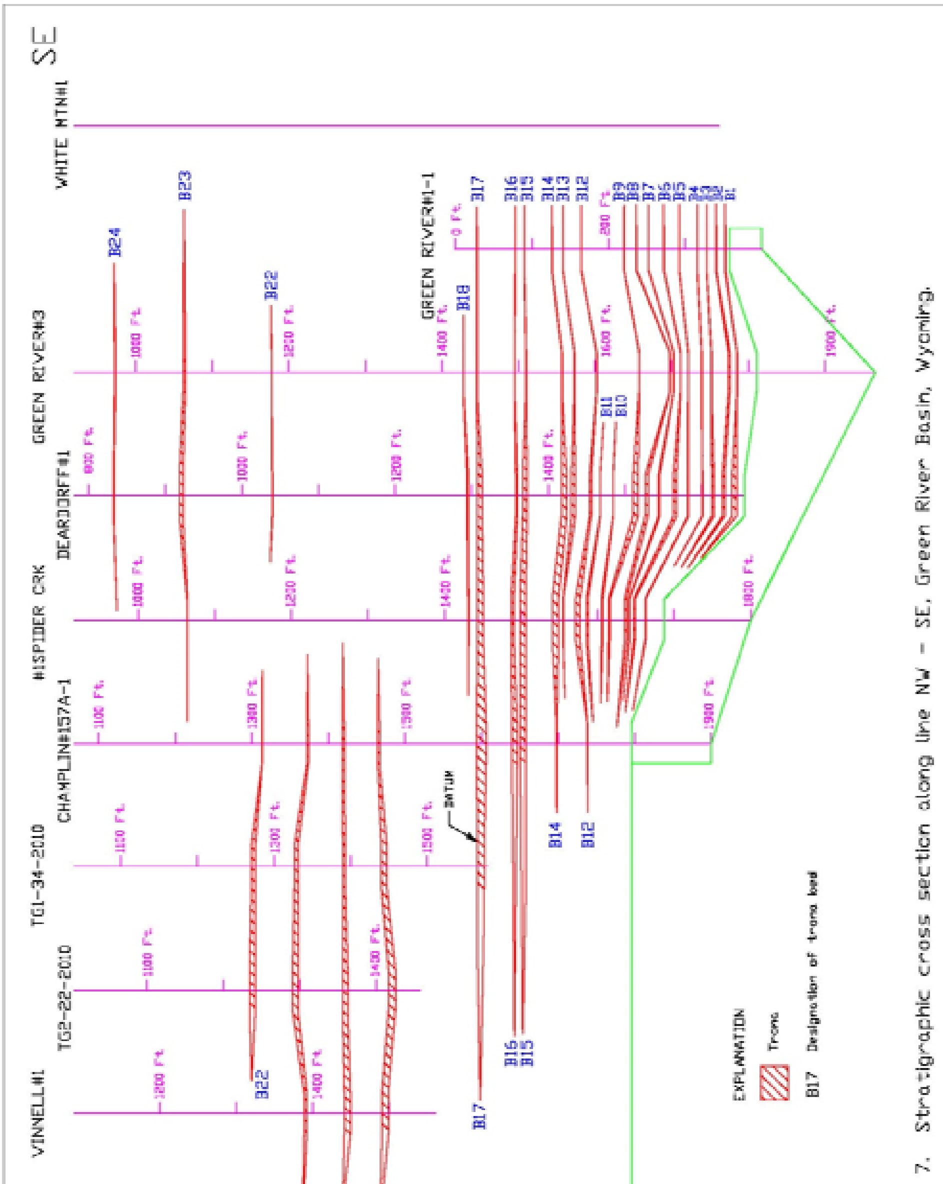
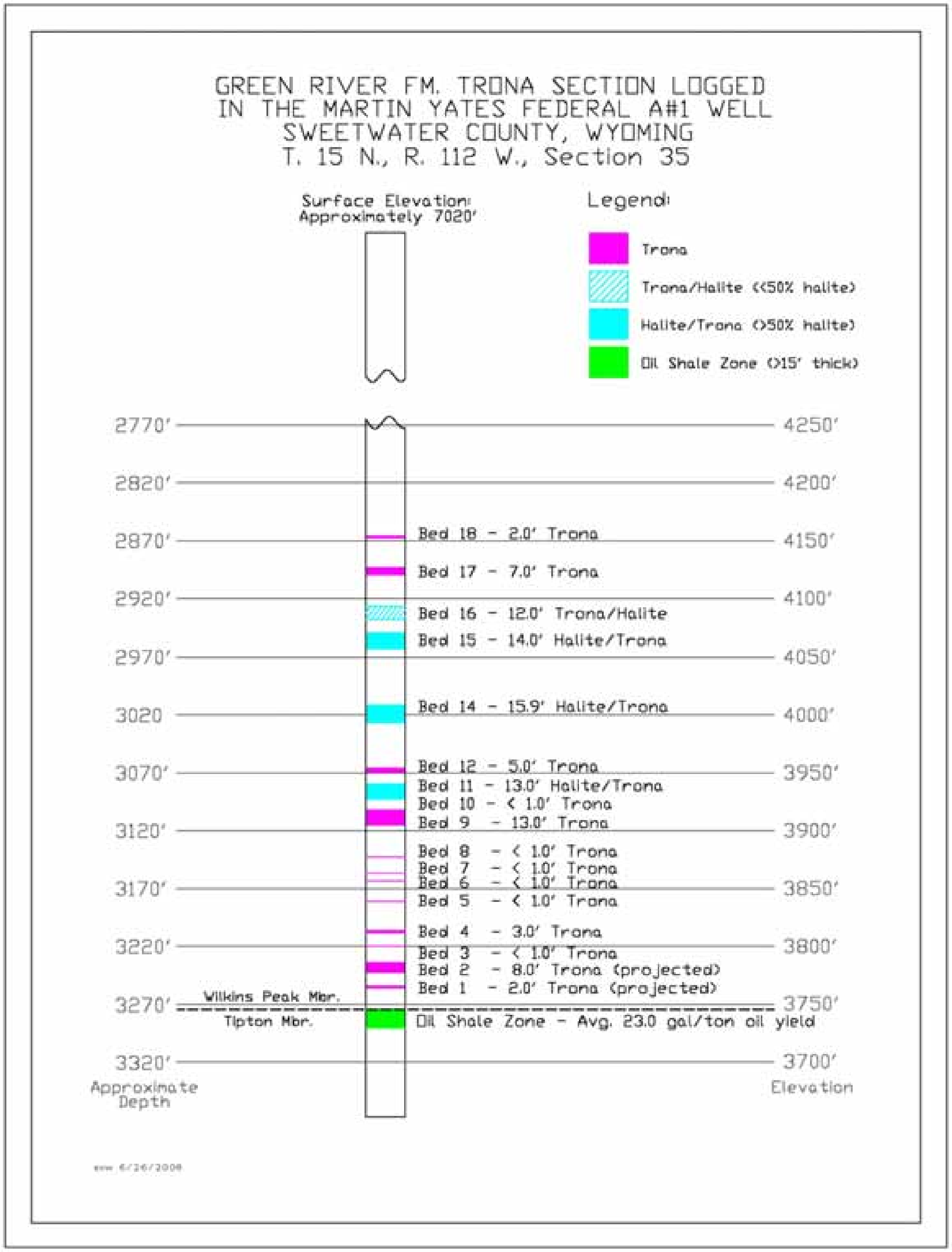


Figure 7. Stratigraphic cross section along line NW - SE, Green River Basin, Wyoming.

(Source: Wiig 2012)

Figure 3-7 Generalized Lithologic Log of Green River Formation at Martin Yates Federal A#1 Well, located in the Section 35, T.15N. R.112W. in Sweetwater County, Wyoming



(Source: Wiig 2012)

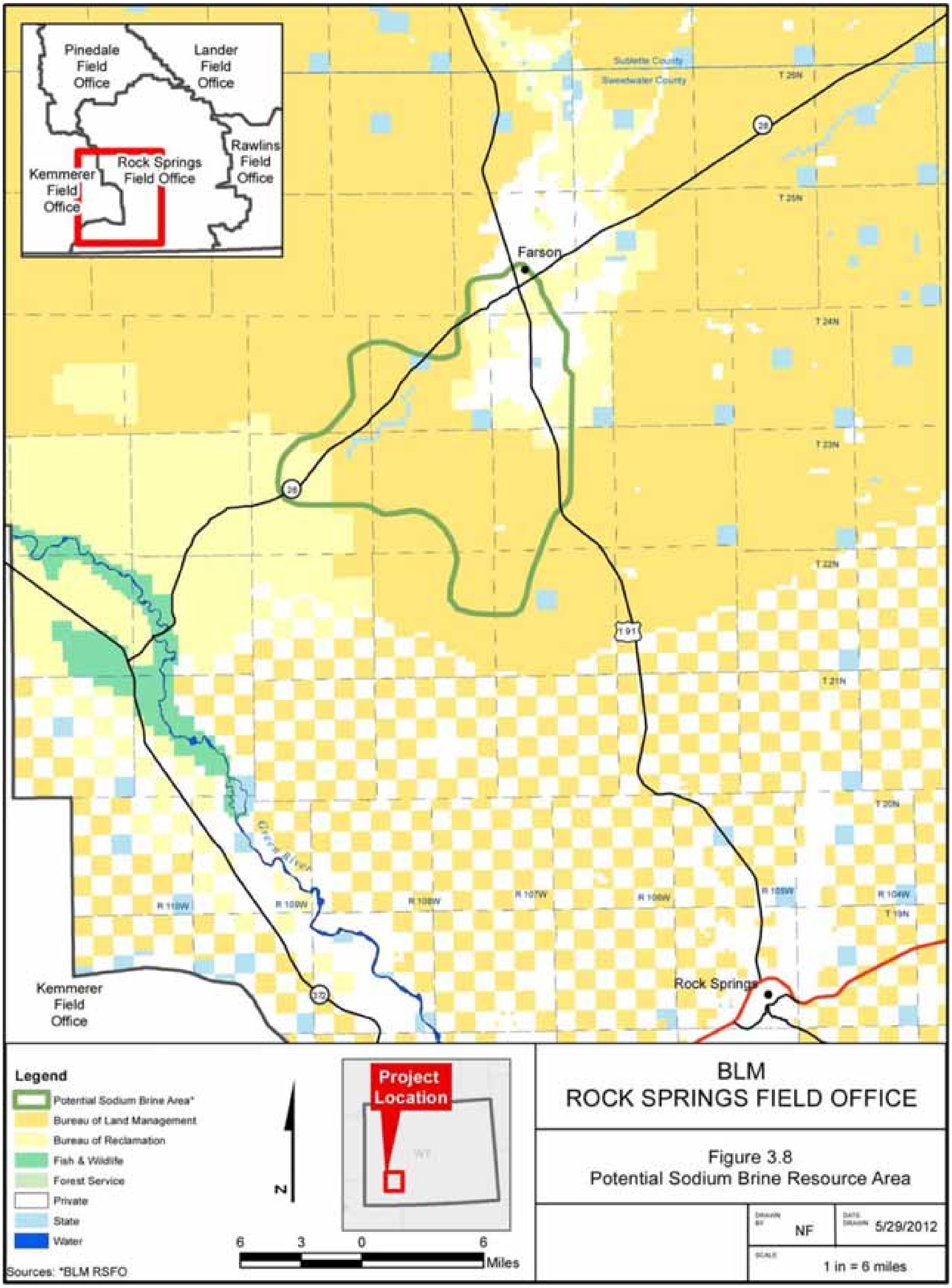
Twenty two of the twenty five numbered beds underlie areas varying from 50 to 775 square miles at depths between 650 and 3,000 feet and are estimated to contain more than 127 billion tons of trona ore including 76 billion tons of ore with less than 2% halite (Wiig et. al. 1995). Five of the beds (17, 19, 20, 24 and 25) are currently being mined, while Bed 14 is proposed for future mining (BLM 2012a). Trona Bed 17, which ranges from 4 to 17 feet in thickness and underlies the largest area, is one of the most economically important beds (Dyni 1996).

In addition to the trona beds, the Wilkins Peak contains beds of marlstone, oil shale, siltstone, mudstone and volcanic tuffs. The volcanic tuffs are widespread, serve as effective stratigraphic markers in the trona mines and were derived from late Eocene volcanic eruptions to the northwest of Lake Gosiute. The oil shale beds and organic marlstones are likely the source for the methane which is encountered in the trona mines. The methane is a significant enough problem that the Mine Health and Safety Administration has classified the trona mines as gassy (Wiig et. al. 1995).

Sodium Carbonate Brines

A second occurrence and potential source of developable sodium carbonate in the form of sodium carbonate brine is found within the RSPA near the communities of Farson and Eden approximately 30 miles north of Rock Springs (Figure 3-8). The black sodium carbonate brine was discovered in exploratory wells in 1938 and has been found in numerous subsequent exploratory wells in the area at a depth of between 400 to 600 feet. The brine occurs and appears to be confined within oil shale of the Wilkins Peak Member. The origin of the brine is uncertain but it has been suggested that it is from the dissolution of shortite (Na2Ca2(CO3)3), another sodium carbonate mineral that occurs in saline marlstones of the Green River Formation. The lack of indications of salt cavities in well cores in the Farson – Eden area suggests the brine may have formed elsewhere, possibly in the southern part of the basin, and migrated up-dip within the oil shale beds to the vicinity of Eden. The brines contain substantial amounts of sodium carbonate and also organic acids which when destructively distilled have yielded as much as 73.3 percent oil. Aside from yielding oil, the organic acids may also be useful for specialized uses such as soil conditioner (Dyni 1996).

Figure 3-8 Potential Sodium Brine Area within the RSPA



3.1.3 Oil Shale

Oil shale is considered a leasable solid mineral under the Mineral Leasing Act of 1920, as amended, and the Energy Policy Act of 2005. The BLM manages oil shale leasing, research and development (R&D), production, and other administrative duties related to oil shale production on federal lands in the western U.S. under the regulations at 43 CFR 3900. Oil shale is different from shale gas, production of which is increasing significantly in different areas of the U.S. and is considered a fluid mineral. Shale gas is not discussed here.

The United States holds more than 50 percent of the world's known oil shale resources. U.S. resources are estimated to be 2.6 trillion barrels of in-place oil, and 1.5 trillion barrels of recoverable oil. Most U.S. oil shale resources are found in Colorado, Utah, and Wyoming in a 16,000 square mile area (BLM 2012a).

Mineral Description

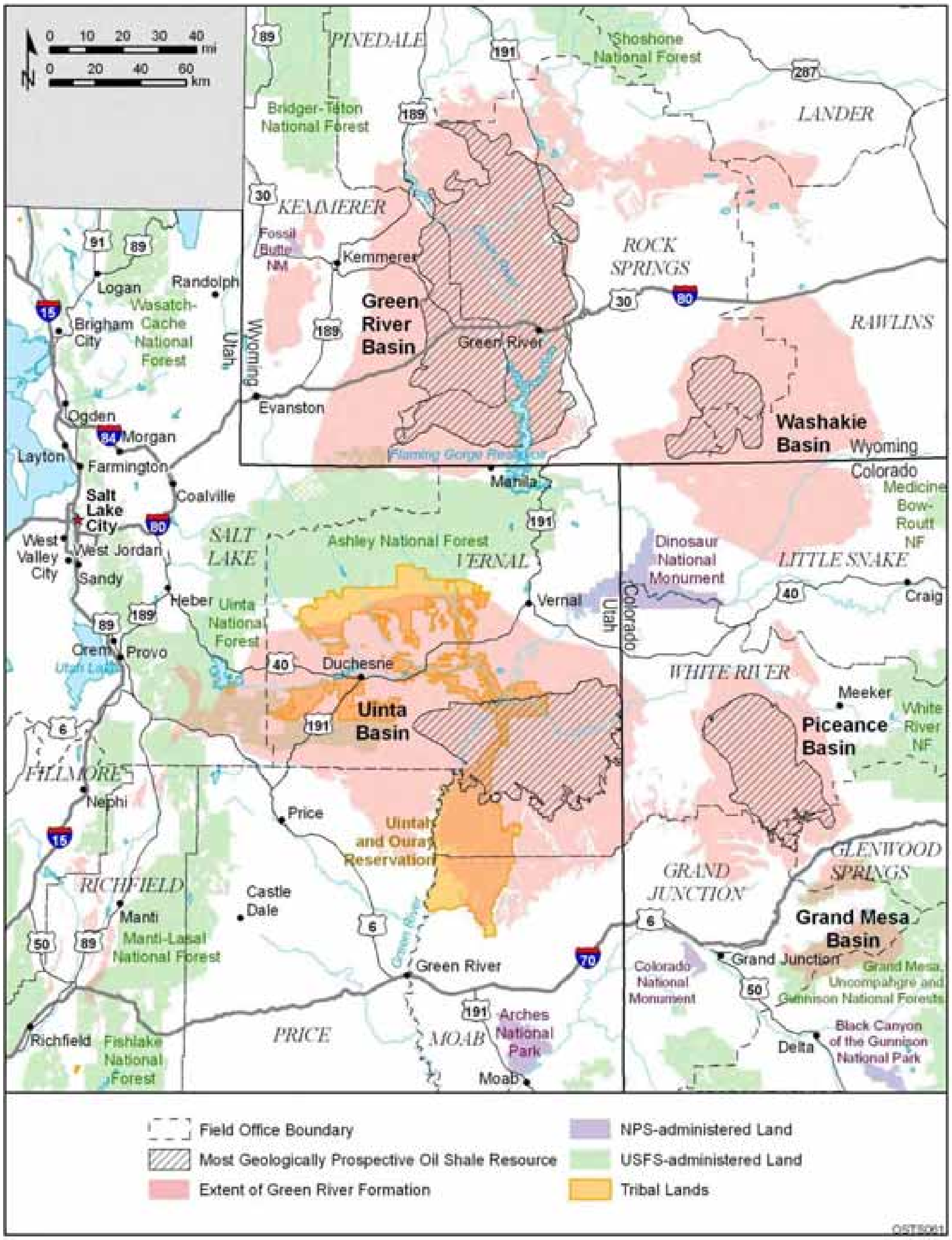
Oil shale is a fine grained sedimentary rock containing substantial amounts of insoluble organic matter that when subjected to destructive distillation yields significant amounts of oil and combustible natural gas. The oil in oil shale is contained within a waxy, bituminous substance called kerogen. In order to release the kerogen from the oil shale, the rock must be heated to about 650 to 700 degrees Fahrenheit (BLM 2012a). The organic matter in oil shale is derived mainly from various marine and lacustrine algae. Higher forms of plant debris as well as bacterial remains also contribute to the makeup of the organic mixture that created the kerogen (Dyni 2005).

Oil shales can vary significantly in their organic content and in their yield of oil upon distillation but generally a commercial grade of oil shale would yield a minimum of about 40 liters (10.5 gallons) of oil for each metric ton of rock. In addition, a potentially economic deposit of oil shale should be capable of being mined by open pit methods, conventional underground mining techniques, or by in-situ methods (Dyni 2005).

Geology/Mineral Occurrence in the RSPA

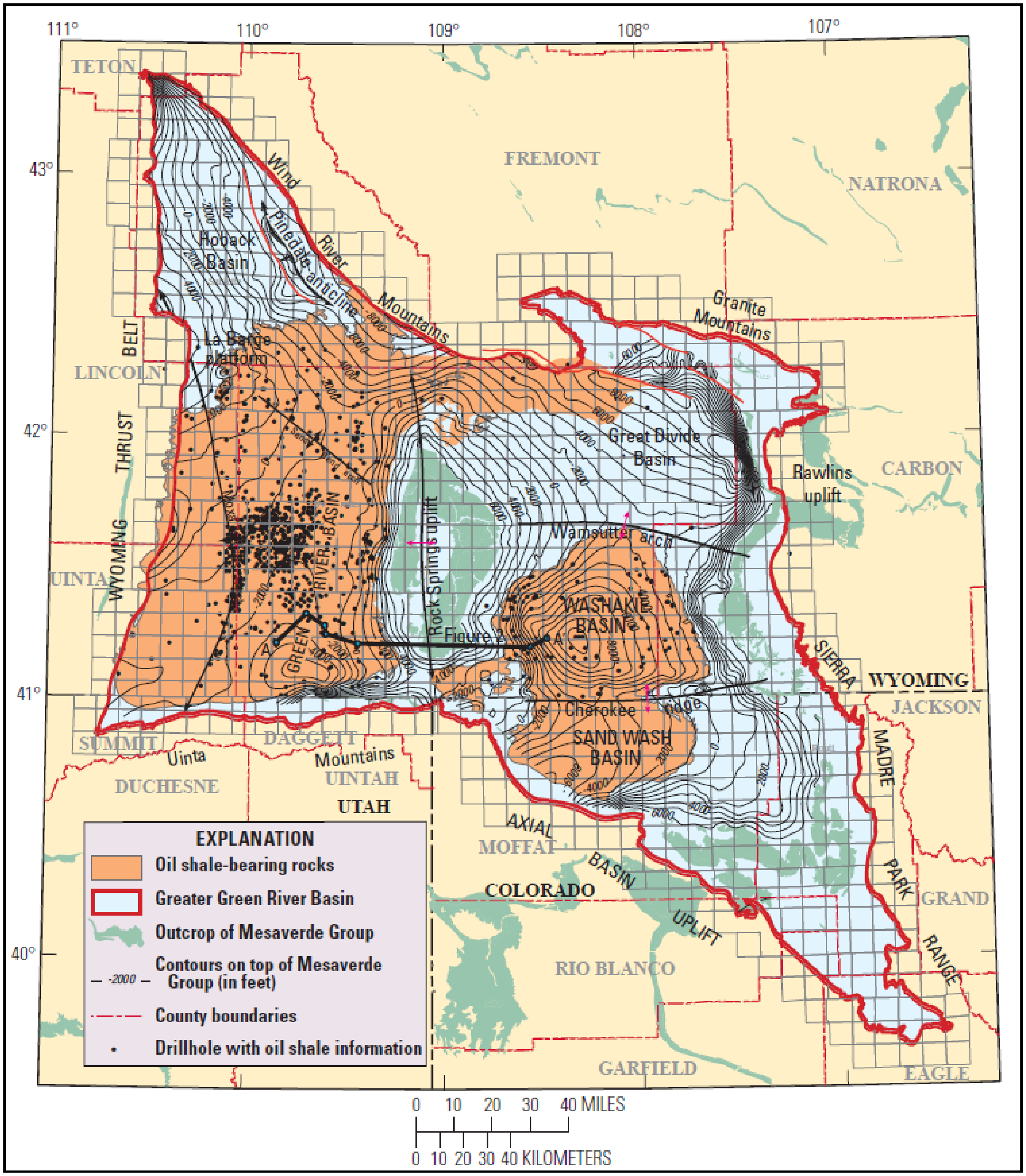
The oil shale is contained in the Eocene Green River Formation in three major adjacent sedimentary basins, the Piceance Basin in northwestern Colorado, the Uinta Basin in northeastern Utah, and the Green River Basin in southwestern Wyoming (Figure 3-9). The oil shale deposits of Wyoming are located predominantly within Sweetwater County, and to a lesser extent within Uinta, Lincoln, Sublette, and Carbon Counties (Figure 3-10). Oil shale beds are found almost exclusively in the Upper Eocene rocks of the Green River Formation in the Green River Basin, the Washakie Basin, and the Fossil Basin of southwestern Wyoming (Johnson et. al. 2011).

Figure 3-9 Three-State Oil Shale Relief Map



(Source: BLM 2012b)

Figure 3-10 Oil Shale Resource Locations of the Green River Formation



(Source: USGS 2011a)

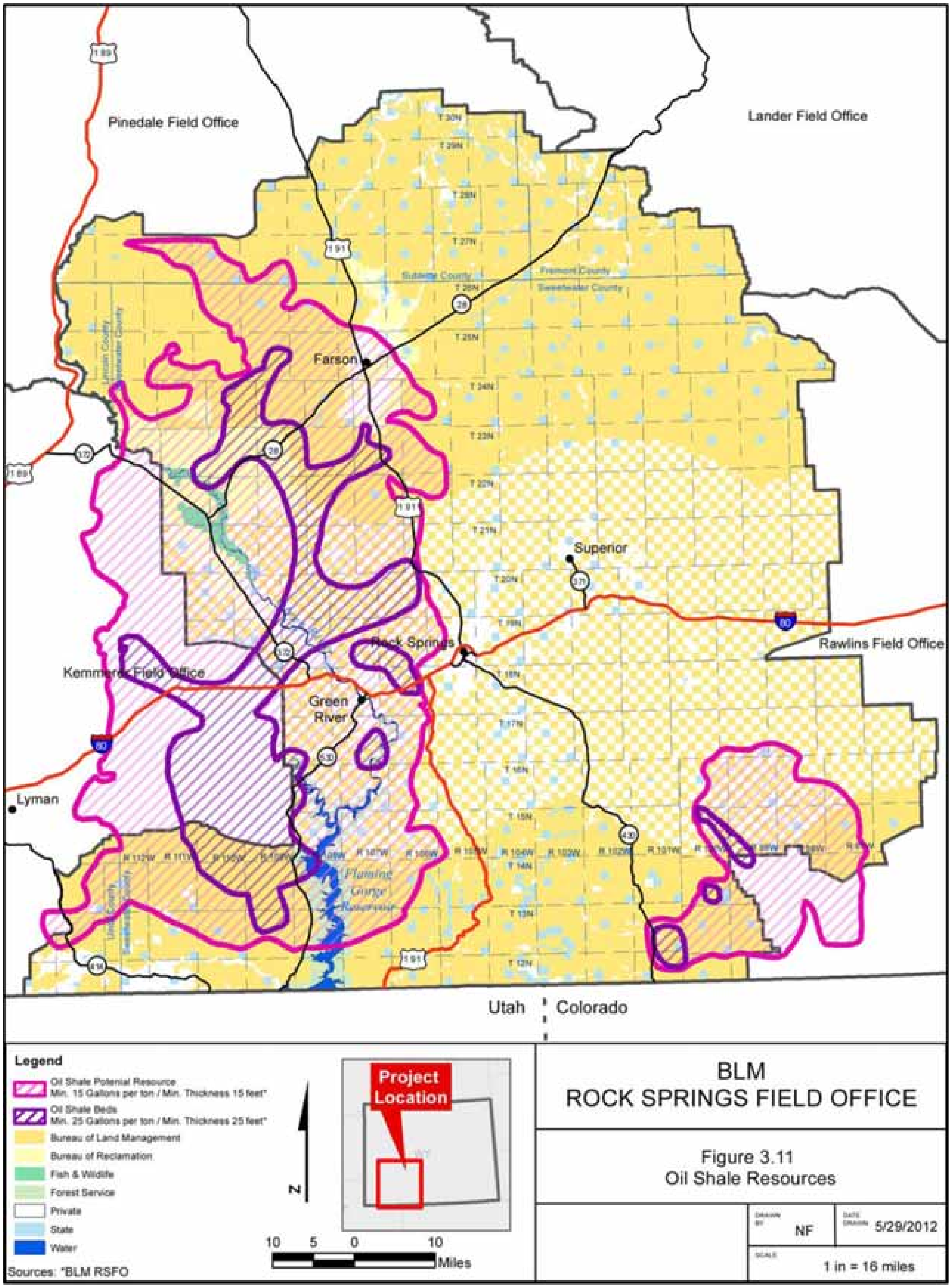
The majority of the oil shale is found in three members of the Green River Formation. Listed in ascending order, these are the Tipton Shale Member, the Wilkins Peak Member, and the LaClede Bed of the Laney Member. These units were deposited as lacustrine and fluvial-lacustrine sediments in and around Lake Gosiute, which covered much of southwestern Wyoming during the Eocene. The three members containing oil shale correspond to significant fluctuations in the lake level with the Tipton Shale and Laney Members deposited during major expansions of the lake level. As a result, these members cover the largest portions of the Greater Green River Basin and contain the richest oil shale beds. The Wilkins Peak Member was deposited during a major regression of the lake level and therefore covers a much smaller area than the other two members, although it also contains significant amounts of oil shale. The richest oil shale beds are found in the LaClede Bed of the Laney Member, in the basal portion of that Member (Johnson et. al. 2011).

The oil shale beds are highly variable in thickness, and range from several feet to several hundred feet in thickness. Bed quality is also highly variable from area to area. Classifiable oil shale deposits are defined as those containing oil shale beds that are at least 15 feet in thickness that will yield a minimum of 15 gallons of oil per ton of shale, which is the average yield for all of southwest Wyoming's oil shale. The depths to the oil shale beds range from zero feet at the outcrop to well over 3,000 feet below the surface at the depositional center of the basins (BLM 2012a).

The USGS has estimated that the Tipton Shale, Wilkins Peak and Laney Members of the Green River Formation contain a total of 1.45 trillion barrels of in-place oil. Those oil resources are divided as follows: 362,800 million barrels of oil (MMBO) in the Tipton Shale Member; 711,4001 MMBO in the Wilkins Peak Member; and 377,200 MMBO in the Laney Member. USGS has further estimated that 906 billion barrels (about 62%) of in-place oil are in federal ownership within the Green River and Washakie Basins, most of which is contained within the RSPA planning area. Of that total, approximately 72 billion barrels are contained within rock that potentially would yield 15 gallons per ton (gpt) of oil (USGS 2011c). Figure 3-11 shows potential oil shale resources in the RSPA that would yield a minimum of 15 gpt from beds that are a minimum thickness of 15 feet.

Areas with the richest oil shale resources in the RSPA are located along White Mountain west of the city of Rock Springs, southwest of the town of Farson in the northern part of Sweetwater County, and in the Kinney Rim area on the western flank of the Washakie Basin. The western Washakie basin is most promising. This area contains an estimated 55 billion barrels of in-place oil and covers roughly 302,470 acres (BLM 2012a). However, the oil shale deposits in the Green River Basin of Wyoming are the lowest grade of the three basins (USGS 2011b).

Figure 3-11 RSPA and Oil Shale Occurrence Development Potential Area



3.1.4 Phosphate

Phosphate is classified by BLM as a non-energy solid leasable mineral and is leased under the Mineral Leasing Act of 1920, as amended, and is not directly related to energy production. Like trona, phosphate is administered by BLM pursuant to 43 CFR Part 3500 – Leasing of Solid Minerals Other Than Coal and Oil Shale regulations.

Mineral Description

In its elemental form, phosphorus is an essential element for plant and animal nutrition and is one of three main nutrients in most fertilizers. The U.S. is the world's leading producer and consumer of phosphate rock (USGS 2012d). Most phosphate rock is mined in Florida and North Carolina; however, mines in southeast Idaho and northeast Utah add significantly to the U.S. phosphate supply. More than 95 percent of the phosphate mined in the U.S. in 2010 was used to manufacture wet-process phosphoric acid and superphosphoric acid, which are used to manufacture granular and liquid ammonium phosphate fertilizers and feed supplements. Almost half of this production was exported. The remainder of the phosphate rock mined was used to make phosphorus compounds used in food additives and industrial applications (USGS 2011a).

Geology/Mineral Occurrence in the RSPA

In Idaho, Utah, and Wyoming the principle phosphate-bearing geologic layer is the Phosphoria formation, a very light-colored, cliff-forming sandstone. This Permian rock is wide-spread in Wyoming and is found in the overthrust belt of western Wyoming and the flanks of each of the major mountain ranges in the state but does not outcrop in the RSPA and instead is deeply buried under more recent sediments (Love and Christensen 1985).

3.2 LOCATABLE MINERALS

Locatable minerals include both metallic minerals (e.g. gold, silver, lead) and nonmetallic minerals (e.g. fluorspar, asbestos, mica, gemstones.) administered by BLM on federal lands under the Mining Law of 1872. The law provided for the filing of mining claims to explore for and produce these minerals. Originally, all minerals except for coal were administered under the Mining Law of 1872; however, through passage of the Mineral Leasing Act of 1920 and other subsequent laws Congress has removed certain minerals (e.g. the solid leasable minerals) from the operation of the General Mining Law. Locatable minerals are managed by BLM under the regulations at 43 CFR 3800. The most common locatable minerals found in the RSPA are placer gold, uranium, diamonds, zeolites, and jadeite. (BLM 2012a).

3.2.1 Uranium

Wyoming has been the nation's leading producer of uranium since 1995, and was a significant player in the uranium industry long before that date

Mineral Description

Uranium is the heaviest naturally occurring element. It is radioactive and can be found in low concentrations (a few parts per million) in many parts of the U.S. and world in rock, soil and groundwater. It is softer than steel, malleable, and ductile. It is silvery white in its natural form. However, after milling it takes on a yellow hue and is sometimes called "yellowcake" (Hore-Lacy 2011).

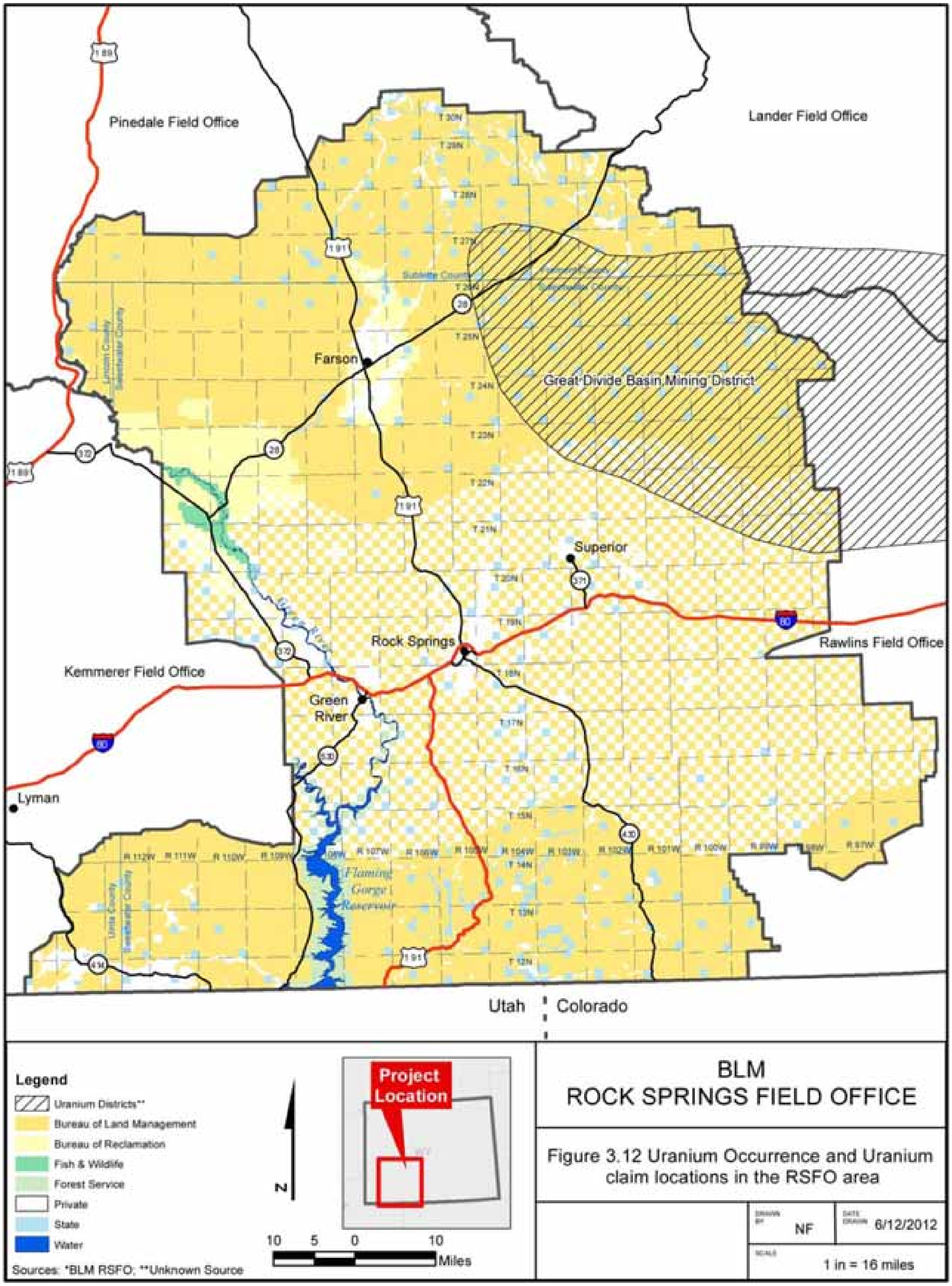
Geology/Mineral Occurrence in the RSPA

The host rock for uranium is apparently a course-grained sandstone conglomerate of the Wasatch Formation and Battle Springs Formation. It is equivalent to, and lithologically similar to, locally derived basin-margin conglomerates of the Wasatch Formation. Further south, the Battle Spring Formation merges with the main body of the Wasatch Formation (Gregory 2010; USGS 2010a).

Uranium in Wyoming is typically deposited as a roll-front in Tertiary sandstone deposits found in fluvial basins. Uranium-bearing ground waters in porous sandstone entered a reducing (low-pH) environment where the uranium concentrated over time (Finch 1996). Two probable sources of the uranium were (1) uraniferous Precambrian granite that provided sediment for the host sandstone, such as the ancient Wind River, Granite, Seminoe, and other mountains of central Wyoming and (2) overlying Oligocene volcanic ash sediments from the Yellowstone volcanic fields.

Most of the uranium mines that have operated in Wyoming are managed by the Casper or Rawlins Field Offices of the BLM. This includes the Gas Hills, Powder River Basin, Shirley Basin, and Pumpkin Buttes. None of these areas are managed by the RSPA office. Uranium minerals are found in the northeastern portions of the RSPA in the Great Divide Basin on the southeast edge of the Prospect Mountains, and near Dickie Springs; both areas are near the southern terminus of the Wind River Mountains and South Pass (Figure 3-12).

Figure 3-12 Uranium Occurrence and Uranium Claim Locations in the RSPA



3.2.2 Gold

Gold has been valued since ancient times for its beauty and permanence. It has been used around the world as a monetary metal since ancient times, and is stored by governments, banks, and investors today (USGS 2012e). Historic gold mining districts are located in numerous locations in southeastern, central, and northwestern Wyoming as well as in the extreme northeastern corner of the state. Gold occurs in and around many mountain ranges in primary and placer deposits (WSGS 2011a). Gold can be found in stream placer deposits recreationally by panning or using a small suction dredge in streams (WDEQ/LQD 2006). Material collected by a suction dredge is fed through a rocker box or sluice to separate the gold particles from the lighter waste rock (West 1971).

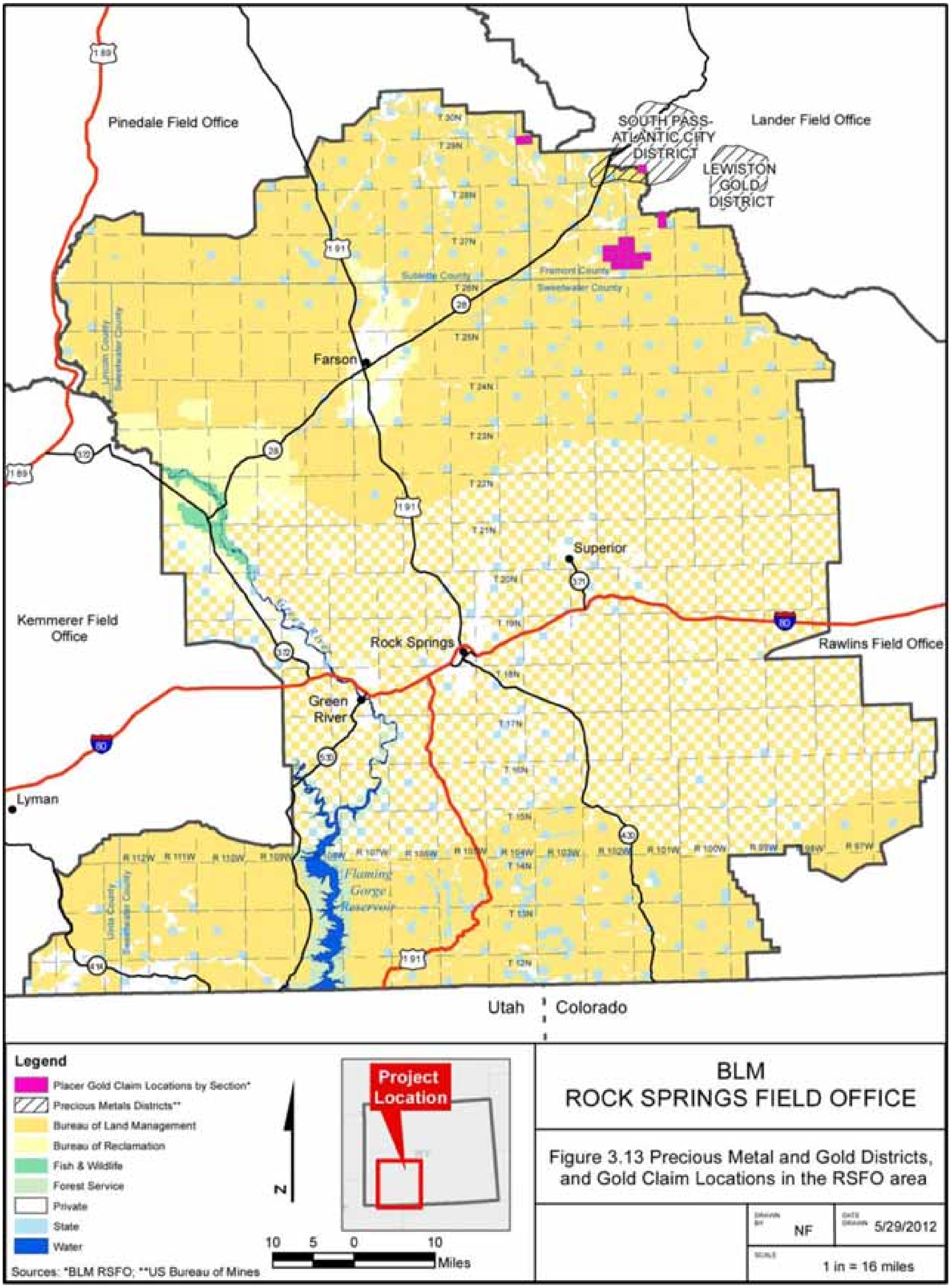
Mineral Description

Gold is a stable, non-reactive, malleable, and ductile metal with a bright yellow and almost universally attractive luster. Most of the gold mined today is used to make jewelry. However, it is also an important industrial metal. It has superior electrical conductivity and resistance to corrosion. It is used in computer circuitry, communications equipment, spacecraft, jet aircraft engines, and many other products (USGS 2012e).

Geology/Mineral Occurrence in the RSPA

Gold occurs in primary vein deposits, in placer deposits and in disseminated deposits. In the RSPA it occurs primarily in placer deposits. A placer deposit is a concentration of natural material that has accumulated in unconsolidated sediments of streambed, beach, or area where sediments collect. It has been moved from its original location in solid rock (the lode) by weathering, and accumulates in placer deposits because of its weight and resistance to corrosion (Kirkemo 1991). The northeast corner of the RSPA contains rocks of the Tertiary age unconformably overlying Precambrian rocks. Here, placer gold is found in the Wasatch sandstone, and alluvium derived from this sandstone. The Wasatch Formation in this area is characterized by granitic boulders in a conglomerate of feldspar-rich sandstones and claystones. The boulders in this formation and in this area are as much as 25 feet in diameter. Gold found in this area to-date is finely disseminated throughout the bouldery material and thus is diffuse and difficult to mine. (Hausel Undated). Placer gold is found in the northeast corner of the RSPA in the Dickie Springs-Oregon Gulch area near South Pass (Figure 3-13).

Figure 3-13 Precious Metal and Gold Districts, Gold Claim Locations in the RSPA



3.2.3 Diamonds

Diamonds form deep in the earth under extremely high temperatures and pressures. They are only found at the earth's surface because of volcanic processes that carry them upward from the earth's mantle in rare magmas (melted rocks) known as kimberlites or lamproites (WSGS 2011b). Diamonds are primarily used in jewelry and as gemstones. However, the hardness and durability of diamonds also makes them desirable for industrial applications in cutting, grinding, drilling and polishing (USGS 2011c).

Mineral Description

Diamond is composed of pure carbon and is the hardest naturally occurring mineral found on earth, listed as a hardness of 10 on Mohs' scale (WSGS 2011b). It is an isometric crystal that cleaves in four directions. While transparent over a broad spectrum of light, it refracts light when cut as a gemstone, splitting sunlight that passes through its angles into a rainbow. Its luster and shininess defines the word "adamantine". Its thermal conductivity is four times greater than copper, while its electrical conductivity defines it as an insulator (Info Diamond 2012).

Geology/Mineral Occurrence in the RSPA

Diamonds are formed at extremely high temperatures (2000 degrees Fahrenheit) and pressures about 100 miles below the surface of the earth in the mantle. The source material for diamonds is likely carbon trapped in the interior of the earth during the formation of the planet. The diamonds are carried to the surface by kimberlite magma in blocks of solid mantle rock called xenoliths (Geology.com 2012). The xenoliths are found in Kimberlite pipes which were the conduits for the kimberlite magma. As the energy moving the magma upwards waned, the magma cooled and solidified inside the conduit. The Wyoming Province in which the RSPA is located is a part of the ancient core of the North American Continent, more than 2.5 billion years old. Diamond deposits are more commonly found in such ancient terrains. However kimberlite and related diamond host rocks are difficult to locate because they tend to weather more easily and deeply than surrounding rocks, leaving a slight depression overlain with deep clay soils. Certain other minerals contained within kimberlite, including pyrope garnets and chromian diopside, can become concentrated in the soils around kimberlite pipes. These minerals serve as indicators of nearby kimberlite pipes. In Wyoming, a sampling program to locate these indicator minerals is the first step in finding diamond deposits. The Wyoming State Geological Survey (WSGS) has identified several hundred concentrations of kimberlite indicator minerals over the last 20 years during surface surveys. (WSGS 2011b).

In 2010, WSGS diamond exploration activities reported identifying placer diamonds in the RSPA at the Cedar Mountain breccia pipes located southwest of Green River (identified as Kimberlite Indicator Mineral area on Figure 3-14), and near South Pass in the northeastern corner of the PA. Other exploration areas where WSGS reported finding placer diamonds included the Sierra Madre, Medicine Bow, and Laramie mountains in southeast Wyoming, the northern Wind River and Gros Ventre Ranges in northwestern Wyoming, and near Gillette in northeastern Wyoming (WSGS 2011b).

Diamonds are also found in the rare lamproite-based rocks of the Leucite Hills (Figure 3-14). These relatively young volcanic cones, flows, and necks include well-known landmarks found north of Rock Springs such as the Boars Tusk and Pilot Butte. Although tests for diamonds in the Leucite hills have had negative results, sampling and testing has been minimal (Snoke et. al. 1993).

3.2.4 Zeolites

Mineral Description

Zeolite is a clay mineral derived from altered volcanic tuffs that have been exposed to alkaline waters; typically lake deposits (USGS 2011a). Zeolites were mined in 2010 in New Mexico, Idaho, Texas, Arizona, and California. The top five uses of Zeolites are for animal feed, odor control, pet litter, water purification, and carriers for pesticides.

Geology/Mineral Occurrence in the RSPA

Zeolites are formed as the devitrification product of volcanic glass in tuffs which occurs when the glass comes in contact with saline waters. In the Fort LaClede area of eastern Sweetwater County, the zeolite Clinoptilolite occurs in the Eocene Adobe Town Member, a volcanic tuff in the Washakie Formation (Figure 3-14). Clinoptilolite is a hydrated Sodium Potassium Calcium Aluminum Silicate ((Na, K, Ca)2 - 3Al3(Al, Si)2Si13O36-12H2O) and is used as a chemical sieve, gas absorber, livestock feed additive, odor control agent and as a water filter. The tuff was laid down in Lake Gosiute which underwent extensive lake level fluctuations due to climatic changes. During dry periods the lake was highly saline. At Fort LaClede the volcanic beds are almost completely altered to clinoptilolite forming zeolite beds up to 3.7 m in thickness containing several million tons of high grade ore. A zeolite mine has operated in Section 1, T.16N., R.98W., of the Fort LaClede area but is currently inactive. The mineral has been under study for use in treating waters produced during production of coal bed natural gas in the Powder River Basin (Vance et. al. 2006).

3.2.5 Nephrite Jade

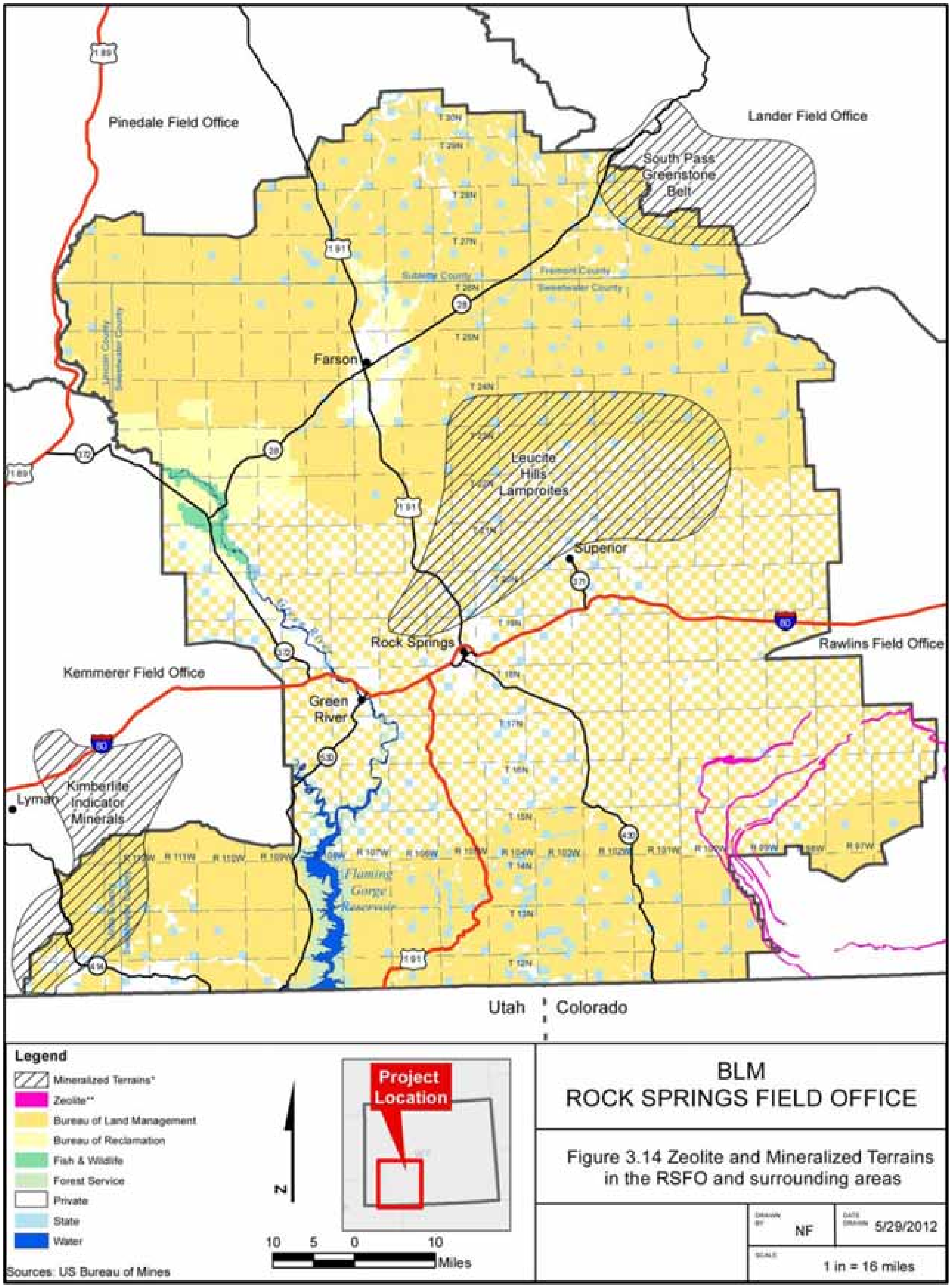
Mineral Description

Nephrite jade, also referred to as Wyoming Jade, is one of two distinct and unrelated mineral species to which the term “jade” is applied, the other being the mineral jadeite. Nephrite jade is an amphibole comprised of dense and compact actinolite and tremolite fibers. It is a calcium magnesium silicate [Ca2(Fe,Mg)5Si8O22(OH)2]. On the other hand, jadeite is a pyroxene of the augite series composed of aggregates of dense interlocking crystals and the two greenish, lustrous minerals are nearly impossible to distinguish in a hand specimen. However, Jadeite is not found in Wyoming, whereas Wyoming Jade is considered to be some of the finest nephrite in the world. Wyoming Jade is used in jewelry, and also occurs in shades of black, olive green, emerald green, light apple green, and sometimes gray to white. The lighter colors of jade, especially apple green, are most in demand for gemstones (WSGS 2011c).

Geology/Mineral Occurrence in the RSPA

Nephrite (Wyoming) jade occurs as detrital material, commonly known as jade float, in the area of the Granite Mountains on the very northeastern edge of the RSPA, mainly in Tertiary conglomerates and Quaternary colluvial, elluvial and alluvial deposits. The Granite Mountains have been identified as a primary source of the detrital nephrite jade. Amphibolite inclusions in Archean granite gneisses at the core of the range were altered to nephrite during regional metamorphism. The nephrite is eroded from the primary source areas and deposited in the various types of surficial materials, in some cases at great distances from the primary sources. The Tin Cup district, located northwest of the RSPA, contains the most extensive primary deposits (WSGS 2011c). Wyoming jade is found in a rectangular band that runs from Farson, eastward through the Red Desert in Sweetwater County to Seminoe Dam, north to Alcova, westward through Lander and back to Farson (WSG&MS 2009).

Figure 3-14 Zeolite and Mineralized Terrains in the RSPA and Surrounding Areas



3.2.6 Titaniferous Sand

Mineral Description

Titaniferous sand or black sand deposits that are composed of high concentrations of the minerals ilmenite (FeTiO3), zircon and monazite (Ce, La, Nd, Th)(PO4) have been found in several locations in the RSPA. Titanium is used in paint pigments, as a component of catalysts, and to produce metal alloys to make strong lightweight alloys for aerospace, military and industrial applications, medical prostheses and orthopedic implants, sporting equipment, as well as other applications (Root et. al. 1973).

Geology/Mineral Occurrence in the RSPA

Titaniferous (black) sands occur in the planning area in the form of moderately to strongly indurated black sandstones of the Late Cretaceous Mesaverde Group. They are found about 40 miles south of Rock Springs, east of Richards Mountain near the Colorado border, about 25 miles south-southeast of Rock Springs, and about 15 miles east-southeast of Rock Springs (Root et. al. 1973).

3.2.7 Rare Earth Elements

Mineral Description

The rare earth elements (REE) are comprised of fifteen elements with atomic numbers 57 through 71, from lanthanum to lutetium. These elements are also commonly referred to as “lanthanides.” Yttrium (atomic number = 39) is also included with the REE group, because it shares chemical and physical similarities with the lanthanides (USGS 2010b). Although the geochemical properties of REEs are similar, their metallurgical, chemical, catalytic, electrical, magnetic, and optical properties vary. These unique properties and differences have lead to the prominence for the use of REE in a variety of emerging technologies (Verplanck and Van Gosen 2011). REE are essential for a wide range of high-technology applications including magnets, metal alloys for batteries and light-weight structures, and phosphors which are essential for many current and emerging alternative energy technologies, such as electric vehicles, energy-efficient lighting, and wind power. REE are also critical for a number of key defense systems and other advanced materials. At the present time, the United States obtains its REE raw materials from foreign sources, almost exclusively from China which produces more than 95 percent of the world’s supply of REEs. Domestic REE resources are modest in extent and of uncertain value when considered in the context of other deposits occurring globally (USGS 2010b).

Geology/Mineral Occurrence in the RSPA

While REE are relatively abundant in the rocks of the Earth’s crust, they are rarely concentrated into mineable ore deposits. The estimated average concentration of the REE in crustal rocks, which ranges from around 150 to 220 parts per million, exceeds that of many other metals that are mined on an industrial scale, such as copper (55 parts per million) and zinc (70 parts per million).. The principal concentrations of rare earth elements are associated with uncommon varieties of igneous rocks, namely alkaline rocks and carbonatites (USGS 2010b). The greatest production of REEs comes from mineral deposits associated with carbonatites. The Mountain Pass Mine in southern California, which was the largest producer of REE in the world until the late 1980’s, is a carbonatite deposit. Potentially useful concentrations of REE-bearing minerals are also found in placer deposits, residual deposits formed from deep weathering of igneous rocks, pegmatites, iron-oxide copper-gold deposits, and marine phosphates (USGS 2010b).

In Wyoming, the USGS has identified the southern Bear Lodge Mountains in the extreme northeastern corner of the state as one of the principal REE deposits in the United States. In this deposit, carbonatite dikes rich in REE intruded middle Tertiary alkaline intrusive rocks resulting in low grade REE mineralization of the adjacent host alkaline intrusive (USGS 2010b). In addition, a Cambrian paleo-placer monazite resource containing REE has been identified at Bald Mountain near the north end of the Bighorn Mountains (Castor and Hedrick, 2006).

Economic concentrations of REEs have not been reported within the RSPA, according to the Wyoming State Geological Survey. However, there has been little sampling and analysis for REEs in the RSPA. Elevated values have been found in the alkaline volcanic rocks of the Leucite Hills as well as the Cedar Mountain breccia pipe on the Uinta and Sweetwater county line. In addition, Mesozoic black sands in the Rock Springs Formation exposed in the Rock Springs Uplift (described in section 3.2.6 above), include 8 localities, most of which have thorium and titanium values, 5 of which have lanthanum values, and 4 of which have yttrium values . No analyses are known for the other REE at these sites. WSGS has identified some REE locations in the RSPA based solely on their thorium values, which are sometimes associated with REE values. However, no element analyses for REE were conducted for these locations. REE-bearing carbonate minerals have also been reported from 10 locations within the Eocene-aged Wilkins Peak Formation (BLM 2012a).

The WSGS is currently conducting a study of REE deposits in Wyoming. The study will include investigations and analyses of the deposits as well as where they occur in the state and their associated geologic environments. A final Report of Investigation will be available to the public in June 2013, along with maps, a website and an electronic database (WSGS 2011g).

3.3 SALEABLE MINERALS

Saleable minerals, also known as mineral materials, include common varieties of sand, gravel, decorative stone, dimension stone, pumice, clay, and rock. These materials are typically used in various construction, agriculture, and decorative building or landscaping applications. Management of saleable minerals in the planning area must comply with the Material Sales Act of 1947, Mining and Mineral Policy Act of 1970, and all other relevant state and federal laws. Through the Mineral Materials Program BLM manages the exploration, development and disposal of saleable minerals managed either by sales contracts or free use permits under the regulations at43 CFR 3600. Recreational collecting of this material is also allowed up to a specified volume (generally about one cubic yard); larger volumes require a mineral materials sale. Saleable mineral permit applications, as well as internal BLM proposals to establish free-use collection areas, are reviewed on a case-by-case basis, with stipulations added to protect other resources (BLM 2012a).

The primary saleable minerals found in commercial quantities in the RSPA are sand and gravel (aggregates), decorative stone (“moss rock”), dimension stone (flagstone), and to a lesser extent, topsoil and decorative boulders. (BLM 2012a).

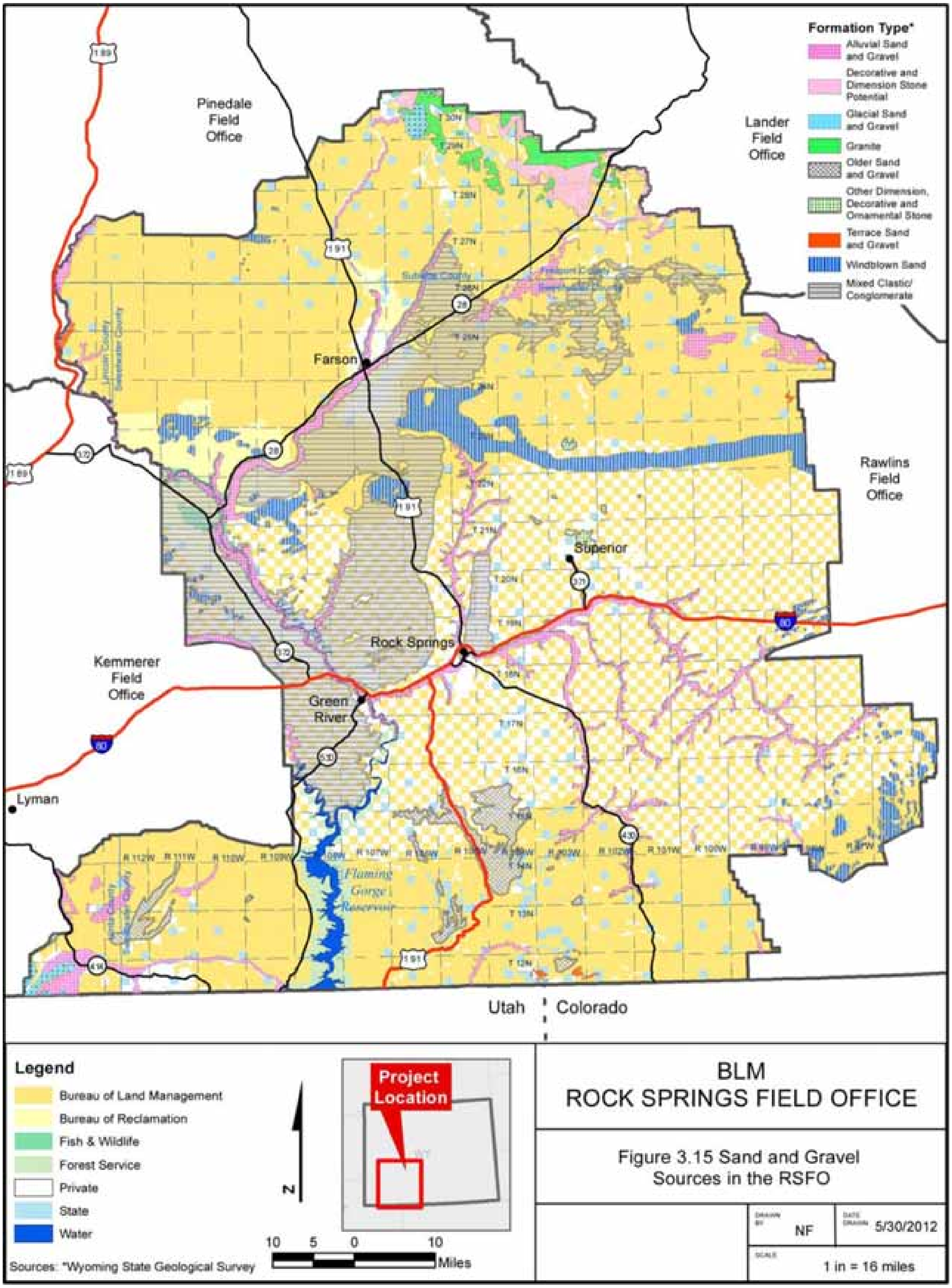
3.3.1 Sand and Gravel

Most of the aggregates mined in the RSPA are used for road construction and maintenance. Decorative and dimensional stone is generally used for commercial and residential construction in the region and beyond. Figure 3-15 shows locations of sand and gravel sources in the RSPA.

Mineral Description

Construction aggregate is the sized, or crushed and sized, rock material used in a variety of construction products. About 52% of all construction aggregate is crushed stone, while 48% of the remaining is sand and gravel (WSGS 2011d).

Figure 3-15 Sand and Gravel Sources in the RSPA



Geology/Mineral Occurrence in the RSPA

Aggregate resources come from many geographic and geologic formations including current stream-formed floodplains and gravel bars, ancient gravel deposits, or hard rock formations of fractured or massive granite, quartzite, limestone, or conglomerates. Sand and gravel resources are found along drainage channels, particularly the Green River and its tributaries. Sand and gravel is also found in outwash material originating from glaciations and erosion of the Wind River and Uinta Mountains. Buttes and plateaus capped by the Bishop Conglomerate are also sources of sand and gravel (BLM 2012a).

3.3.2 Other Saleable Minerals

Decorative stone ("moss rock"), dimension stone (flagstone), and decorative boulders are also present in the RSPA (BLM 2012a).

Mineral Description

Decorative and dimension stone are typically composed of sandstone, granite or limestone slabs partially covered with colorful lichens (not moss), or in some instances, not covered at all. Landscape boulders usually consist of large blocks of granitic rocks (BLM 2012a).

Geology/Mineral Occurrence in the RSPA

Decorative and dimension stone may be derived from any number of rock types. Moss rock and dimension stone are typically collected from one or more sandstones found in the RSPA. Dimension stone is generally derived from calcareous or tuffaceous sandstones, limestones, or massive shales and siltstones that cleave on predictable planes. Resources are diverse and widespread within the RSPA (Bautz 2012).

Landscape boulders are found in the vicinity of the South Pass area in the Wind River Mountains. Currently, the BLM maintains a common use (non-exclusive sale) area for decorative and dimension stone on Aspen Mountain located south of the city of Rock Springs. There is also a small common use area for topsoil material located near Highway 191 South in the Miller Mountain area. Non-exclusive sales are conducted mostly with local residents seeking landscaping materials and topsoil for their private property. Collection of material from both these sites is restricted to hand tools only; no mechanized earth-moving equipment is allowed (BLM 2012a).

CHAPTER 4 MINERAL EXPLORATION, DEVELOPMENT AND PRODUCTION HISTORY

There are many valuable solid minerals that have been mined at a commercial scale in the RSPA. The most notable of these are coal, trona, and sand and gravel. Exploration for many other minerals indicates a variety of mineral types are present in the RSPA but as of yet, commercial development has not been feasible. Changing economics and market conditions, and technological advances in exploration and mining equipment and methods may make these other minerals worthy of development.

4.1 LEASABLE MINERALS

4.1.1 Coal

Historical Exploration and Mining Activity

Coal was first discovered in southwest Wyoming by Europeans when Howard Stansbury surveyed the lands along the Overland Trail during 1848 - 1850 for the U.S. Bureau of Topographic Engineers. The first formal geological mapping of southwest Wyoming took place during the Hayden Survey of 1877 (Flores and Bader 1999).

Stansbury's 1848 -1850 Overland Trail survey identified coal outcrops along Bitter Creek, which flows through present-day Rock Springs, and at Point of Rocks, an early stagecoach station located about thirty miles east of Rock Springs and the location of current southwest Wyoming coal mines. All the coal identified was associated with the Rock Springs Uplift (Flores and Bader 1999).

Small scale coal mining in southwest Wyoming began around 1859 as a means to provide heating and blacksmithing coal at the numerous stage coach stations located along the Overland Trail. But a more efficient means of transporting goods across the U.S. was needed. Congress passed the Railroad Act of 1862, which allowed development of the Transcontinental Railroad. To sweeten the deal for the two major railroads constructing the railroad, the Union Pacific from the East and the Central Pacific from the West, the federal government granted 10 alternating sections of land (1 section = 1 square mile) in a checkerboard pattern along the Transcontinental Railroad route to the railroad companies for every mile of track laid. The Act was modified in 1864 to grant 20 alternating sections for every mile of track laid. These lands are sometimes known as the Checkerboard Lands. This arrangement made the UPRR the major landowner (other than the federal government) along the Transcontinental Railroad route through Wyoming. Because the route intersected many of the coal-bearing areas found in southwest Wyoming, the UPRR also gained control of the coal resources and thus had a monopoly on coal and coal transport from mines located in the area (Flores and Bader 1999).

Coal was originally extracted from underground mines, mostly located in the Rock Springs Formation. Figure 3-3 shows the Rock Springs formation and other principle coal-bearing formations in the Green River area. Many of these mines were located in and around the city of Rock Springs, on the northwest side of the Rock Springs Uplift and were identified by numbers: "No. 1 Mine", "No. 2 Mine" and so on (Dobson 2011a). Others were named after people, such as the Van Dyk, Blair, and Hall mines. The Hall mines were located near the town of Hallville, which today contains only broken down walls constructed of rough-cut stones. In 1870 the Hall mines, close to Point of Rocks and the present-day Black Butte mine, contributed one hundred train car loads of coal every week, but by 1889 these mines were abandoned (Flores and Bader 1999). Other mines took their place, however, and employed hundreds of miners and sold coal to customers as far away as Arkansas, Oklahoma, and Kansas. Demand for coal was great, and Rock Springs grew and flourished during the latter half of the 1800's (Dobson 2011a).

Three other major coal mining areas in southeast Wyoming were the Stansbury, Reliance, and Superior areas, located to the north and east of Rock Springs (Vine and Moore 1952). The mines located here flourished into the mid 20^{th} century, in part because operators took advantage of increasing mechanization that was available starting around 1892. Coal from the mines was used to produce electricity at coal-fired generating plants to power electric drills, cutting tools, and loading machines (Flores and Bader 1999). The introduction of diesel locomotives in the 1940s and 1950s sharply cut into the demand for coal. All but three UPRR mines closed by the end of 1954, and the last mine closed in 1962. However, after a short hiatus, coal mining returned: by the 1970s new surface mines were opened in response to the 1973 oil embargo and need for cheaper, domestic energy to fuel power plants (Flores and Bader 1999). These mines are discussed in the next section.

The effects of early underground mining continue to impact southwest Wyoming in the form of subsidence problems in and around the City of Rock Springs. Engineering and design work at early coal mines was sometimes minimal. During mining, directly after closure, or tens of years later, underground pillars left to hold the mine ceiling up during mining would fail or, in some cases, fires occurred that would destroy the pillars, themselves made of coal. The rock overlying the coal mine would collapse. When this collapse reached the surface, it would cause the surface to subside, leaving a pit or hole in the ground, sometimes subsuming buildings. Millions of dollars have been spent by federal and state agencies trying to seal or fill in old mine shafts and tunnels in and around Rock Springs and other coal mining areas of Wyoming (WOHS 2011).

Recent Exploration and Mining Activity

Current coal production in the RSPA is centered in the northeastern flank of the Rock Springs Uplift from the area designated by the USGS as the Point of Rocks-Black Butte coalfield (Ellis et. al. 1999). The north half of this coal field has been designated by the USGS as the Jim Bridger area, and the south half has been designated as the Black Butte area.

Coal is presently being mined in the Jim Bridger area by Bridger Coal Company (BCC) which is owned by Pacific Minerals Inc., a subsidiary of PacifiCorp (2/3) and Idaho Energy Resources, a subsidiary of Idaho Power Company (1/3). The Bridger Mine was the first mine to open in the Point of Rocks-Black Butte coalfield. This mine opened in 1974 as a surface mine operation that fed the Jim Bridger Power Plant, located adjacent to the mine (BLM 2012a). The mine now has both surface and underground operations and since 2002, Bridger Coal Company has produced an average of 5.6 million tons per year to supply the power plant. The underground coal mine started production in 2004, and has increased production to about 3 million tons per year as production at the surface mining operations has declined. This trend is expected to continue as the surface minable coal is exhausted, and the underground operations are projected to increase to 6 million tons per year. The Jim Bridger Mine is in the process of shifting its focus from surface coal recovery to underground mining at the recently opened Jim Bridger Underground Coal Mine facility (BLM 2012a). According to PacifiCorp financial filings, Bridger Coal Company has coal reserves totaling 120 million tons (PacifiCorp 2012). At the present and expected future level of production, Bridger Coal Company has sufficient reserves for a little over 20 years.

Black Butte Coal Company (BBCC), owned by Ambre Energy, an Australian Company, and Anadarko, operates the Black Butte Mine, which started producing coal in 1979, and the Leucite Hills Mine (LHM), which started producing coal in 1981 and which is now being reclaimed. The Black Butte Mine, located south of I-80 at Point of Rocks, recovers coal from the Almond, Lance, and Fort Union Formations. The operation consists of multiple pits. Since 2002, the Black Butte Mine has produced an average of 3.4

million tons per year. The Leucite Hills mine, located between the Black Butte Mine and Bridger Coal Mine on the north side of I-80, recovered coal from the Almond Formation (BBCC/LHM 1987). The Black Butte Coal Company opened a new pit (Pit 14) on the south end of their property in 2009 and is currently in the process of assessing the feasibility of opening another pit (Pit 15) on the north end of the property. These additions will be necessary in order to maintain the current overall production levels from the mine since coal recovery operations were ceased at Black Butte's Leucite Hills Mine in late 2009. Most of the production goes to the Jim Bridger Power Plant with a small amount going to other customers (BLM 2012a).

Although all three mines are primarily surface mines, the Jim Bridger Mine employs both underground mining and highwall mining on the pit highwall to extract coal. The Black Butte Mine attempted to conduct highwall mining but determined that geologic characteristics were not suitable for this type of mining in the pits where it was used. Mine operations at the three mines are described in the next paragraphs (Bautz 2012).

Almost all of the coal produced from these mines is shipped to the Jim Bridger Power Plant, while the remaining portion is sent to other customers. The combined coal production from all of the mines in the RSPA for the year 2009 totaled about 9.2 million tons, with approximately 2 million tons being mined from federal lands (BLM 2012a).

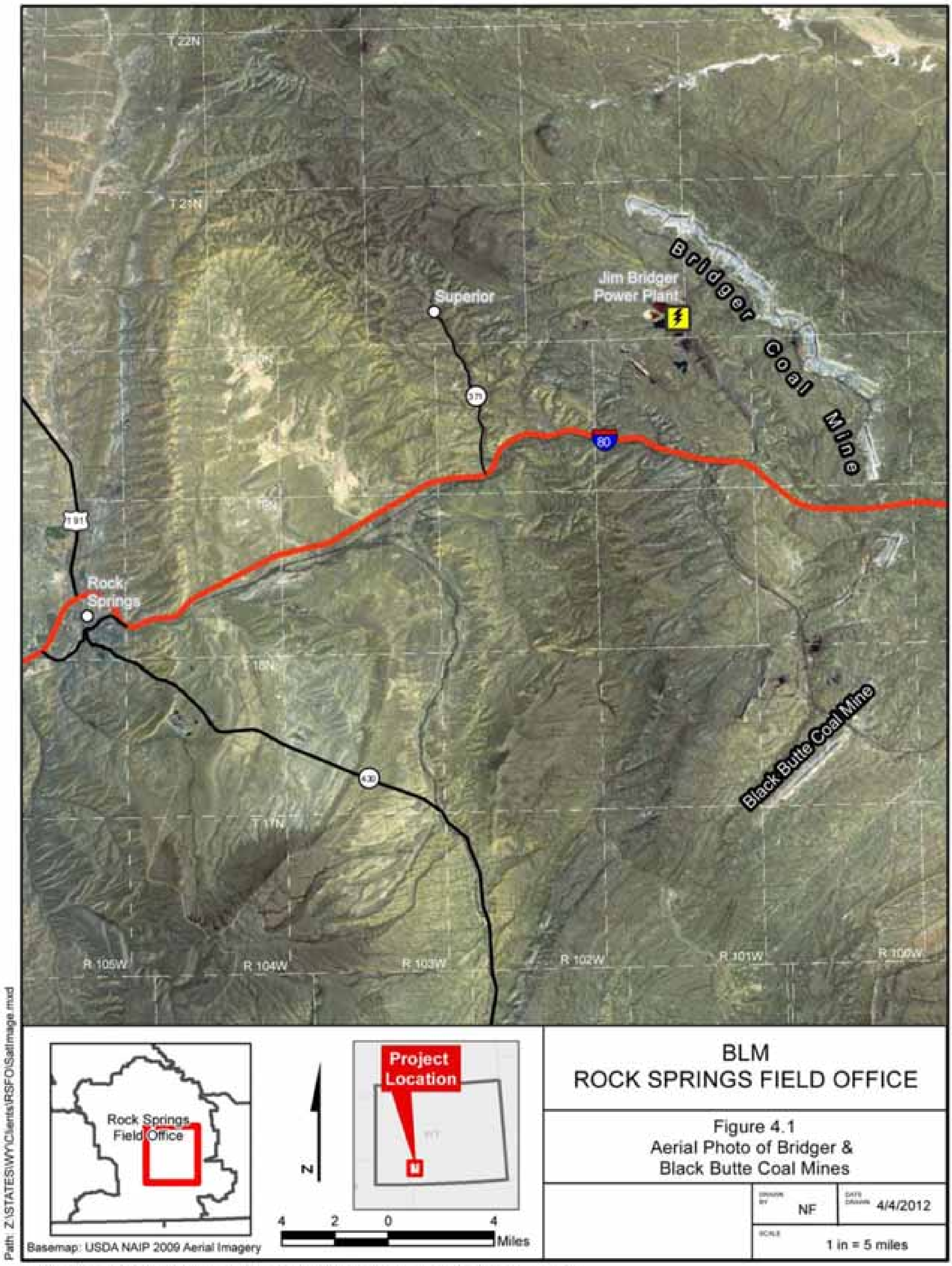
The Jim Bridger Mine, shown as a light-gray zigzag line on the satellite photo to the right (Figure 4-1), operates an 18-mile long surface mine with underground operation near the north end of the pit. The mine headquarters are located about 35 miles east of the city of Rock Springs and to the north of Interstate 80. Coal is mined exclusively from the Fort Union Formation at this operation, recovering up to five separate seams named the D5 to D1 seams of the Deadman group, named top to bottom. These seams have an average thickness of three to eight feet (BCC 1981). Surface mining is typically accomplished by a combination of hydraulic scrapers and dozers, used to first remove the topsoil; and draglines, hydraulic excavators and front-end loaders, used to remove overburden and interburden that overlies the coal seams. The coal in each individual seam is removed by a hydraulic excavator or front-end loader, loaded into haul trucks, and transported to the power plant. Blasting is used to loosen overburden, interburden, and coal layers. After the economically recoverable surface mined coal seams have been removed, additional coal reserves from selected seams may be recovered using underground or highwall mining techniques (BLM 2012a).

Underground mining at BCC involves personnel working underground, operating a longwall miner that uses spinning hydraulic shearers that passes back and forth across a wide working face (as much as 1,000 feet wide). The loosened coal falls onto a system of conveyors that moves the coal from the working face to the portal opening where the coal is stockpiled and then moved by surface equipment to the coal storage and shipping yard. The longwall miner has hydraulic roof supports under which the miners work. As the longwall mining equipment moves forward, overlying rock that is no longer supported by coal or roof supports is allowed to fall behind the operation in a controlled manner (TEEIC Undated).

Highwall mining at both BCC and BBCC is similar to longwall mining, but the coal shears cut a narrower adit in the coal seam, and no workers go underground. Instead, the cutter head drills remotely into a coal seam located at the base of an existing highwall. The coal falls onto remotely powered push-beam conveyors that are located behind the cutter head. The conveyors transport the coal backward to the opening at the highwall face where it is transferred to a stockpile area by other conveyors located on the surface (TEEIC Undated). From here the coal is transported to the coal storage and shipping yard.

Underground and highwall mining at the Jim Bridger Mine take place at the north end of the surface mine in the lower-most D4/1 Seam of the Fort Union Formation, which is up to 16 feet thick. Access to the coal reserves is achieved from a portal opened in the existing pit highwall. Coal is recovered using longwall mining techniques (BLM 2012a).

Figure 4-1 Aerial Photo of Bridger and Black Butte Coal Mines



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The Black Butte Coal Company operates the Black Butte surface mine located about 35 miles east of the city of Rock Springs and on the south side of Interstate 80, visible in the satellite photo above as several white and black patches due south of the Jim Bridger Mine. This mine has the potential to mine coal from three beds of the Fort Union Formation, ranging in thickness from 3.0 to 31.0 feet (Pits 1, 2, 4, 9, 10, and 11); from two to eleven coal beds of the Lance Formation, ranging in thickness from 1.0 to 13.0 feet (Pits 5, 6, 7, 12, and 13); and from four to seven seams of the Almond Formation, ranging from 2.0 to 15.0 feet thick (Pits 8 and 14) (BBCC 1987).

The Black Butte Coal Company also operated the Leucite Hills surface mine located near the town of Point of Rocks north of Interstate 80. This mine is visible in the satellite photo above as the white area with the black loop in it, just north of Interstate 80. This mine recovered coal from multiple pits in six seams of the Almond Formation that ranged in thickness from less than one foot to 9.2 feet. Techniques used were similar to those described above (BBCC/LHM 1987). As of December 31, 2009 the coal recovery operations ceased and the entire mine site began undergoing final reclamation (Bautz 2012).

Coal production in 2010 in Sweetwater County, which includes all mines located in the RSPA, was 8,942,410 Tons (Adcock 2010). Coal production in southwest Wyoming has been in decline over the past few years. This is primarily due to the maturing of the Jim Bridger and the Black Butte surface mines that have been in existence for over 30 years and have reached their economic stripping limits. However, underground mining at the Jim Bridger Mine will likely keep this mine in production for several years, and the Black Butte Coal Company opened a new pit (Pit 14) on the south end of their property in 2009 and is currently in the process of assessing the feasibility of opening another pit (Pit 15) on the north end of the property (BLM 2012a). Coal production since 1994 is shown in Table 4-1 below.

Table 4-1 Yearly Production at Southwest Wyoming Coal Mines, 1994 to 2010

Year	Black Butte Coal Company		Bridger Coal Company			
	Production (tons)	Employees	Production (tons)	Employees		
1994	4,029,069	274	7,036,084	392		
1995	2,155,632	182	6,967,096	375		
1996	1,857,145	109	6,293,172	390		
1997	1,900,000	109	5,920,376	404		
1998	2,800,000	123	6,439,566	383		
1999	3,086,646	144	6,300,944	375		
2000	3,453,105	144	6,506,632	358		
2001	3,406,256	163	6,110,696	350		
2002	2,817,419	115	5,782,014	357		
2003	2,940,330	134	5,604,516	355		
2004	3,805,230	171	5,597,531	318		
2005	3,773,760	176	5,391,902	243		
2006	3,410,309	172	5,414,423	230		
2007	3,657,726	162	6,473,810	446		
2008	3,687,169	173	5,667,021	423		
2009	3,876,766	178	5,195,094	422		
2010	3,128,758	180	5,813,643	409		

Source: WMA 2011

There are currently eight Federal coal leases totaling about 28,471 acres within the RSPA. Six of these leases are actively producing coal, one is currently not producing, and one is mined-out and in reclamation (Leucite Hills Mine). Table 4-2 lists the current Federal coal leases (BLM 2012a).

Table 4-2 Federal Coal Leases within the RSPA as of March 2012

Lessee	Lease Number	Lease Acreage (to the nearest acre)	Lease Status
Black Butte Coal Company	WYW6266	14,982	Producing
	WYW23411	611	Producing
	WYW160394	1,399	Producing
Bridger Coal Company	WYW0313558	4276	Producing
	WYW272	3,440	Producing
	WYW2728	1,440	Producing
	WYW154595	2,242	Producing
Lion Coal Company	WYW119606	81	Abandoned
RSPA Total		28,471	

Source: BLM 2012a

The BLM issues two-year term Exploration Licenses for the purpose of identifying and quantifying coal resources on public lands that could eventually be leased (Table 4-3). Currently, there are three active licenses: one with Black Butte Coal Co. and two with Bridger Coal Company. These cover 1,280 acres within the RSPA.

Table 4-3 Federal Coal Exploration Licenses within the RSPA

Licensee	Serial Number	Exploration License Acreage	License Effective Date	License Expiration Date	License Status
Black Butte Coal Co.	WYW172923	640.00	02/07/2007	02/07/2009	Expired
	WYW176446	319.83	07/11/2008	07/11-2010	Expired
	WYW179006	640.00	09/29/2010	09/29/2012	Active
Sub-Total		1,599.83			
Bridger Coal Co.	WYW163613	1,278.74	08/16/2005	08/16/2007	Expired
	WYW176465	7,050.90	09/26/2008	09/26/2010	Expired
	WYW178270	320.00	08/31/2009	08/31/2011	Active
	WYW179009	320.00	08/17/2010	08/17/2012	Active
Sub Total		8,969.64			
Planning Area Total		10,569.47			

Source: BLM 2012a

These lands are in the process of being explored by drilling and coring methods using truck-mounted rigs. The final results of these tests will be submitted to the BLM upon completion of the drilling programs. Should any new exploration licenses be received by the RSPA in the future they will be processed in the manner prescribed by the Coal Management Program regulations (BLM 2012).

Although there has been exploration activity on unleased federal lands, there are no outstanding or pending applications for new federal coal leases on lands within the RSPA at this time. No new start-up mining operations have been proposed (BLM, 2012). Coal exploration is also ongoing on private lands within the checkerboard area. This activity is managed by the State of Wyoming. Should any new lease applications be received by the RSPA in the future they will be processed in the manner prescribed by the Coal Management Program regulations at 43 CFR 3400 (BLM 2012a).

4.1.2 Trona

Historical Exploration and Mining Activity

Trona was discovered in Sweetwater County, Wyoming in 1938 during oil and gas exploration activities. In 1939 the U.S. Geological Survey began a strategic minerals study and later published a reference to the minerals found in 1938. The first mine shaft was excavated in 1946 by Westvaco Chemical Corporation, and commercial soda ash production began in 1948. Prior to the opening of the Sweetwater County trona mines, all trona was produced synthetically. Mined trona was cheaper to process into soda ash, and Wyoming's trona mines became an important world supplier of soda ash and related chemicals (WSGS 2011e).

Recent Exploration and Mining Activity

Wyoming is the U.S. and world leader in trona mining and soda ash production. Wyoming mines produced more than 95 percent of U.S. soda ash and 38 percent of the world's production of soda ash in 2006 (WSGS 2011e).

There are currently four operators mining trona and producing soda ash in the Green River Basin. These are: Solvay Chemicals; FMC Wyoming Corp., which operates at two mines – Westvaco and Granger; OCI Wyoming, L.P.; and Tata Chemicals (Bautz 2012). There are a total of 59 federal sodium leases in the KSLA area covering 69,345.61acres (see Figure 3-4). Fourteen of these leases (17,026.92 acres; Table 4-4) are within the RSPA (BLM 2011). In 2009, approximately 14.6 million tons of trona were mined and refined into 9.1 million tons of various grades of soda ash and other products (BLM 2012a). Total trona production in the Green River Basin for the year 2010 was approximately 16.5 million tons, about two million more tons than were mined in 2009 (WMA 2010).

Table 4-4 Federal Sodium Leases within the RSPA

Lessee	Number of Leases	Lease Acreage	Beginning Lease Dates	Lease Renewal Dates	Lease Status
FMC Wyoming Corp	6	6,205	1958, ’62, ’63, ’64, ’67	2016, 2017	Active, Inactive, Idle
Tata Chemicals	1	163	1957	2016	Inactive
OCI Wyoming, L.P.	5	7,934	1961, 1988	2017-2018	Active
Solvay Chemical	1	639	1996	2016	Inactive
Church & Dwight, Co.	1	166	1957	2016	Inactive
Rock Springs Royalty	1	1920	2006	2016	Inactive
RSPA Total	17	17,026.92			

Source: BLM 2012a

Trona mining occurs between 800 and 1600 feet underground using either continuous miners, borer miners, or longwall mining methods or solution mining methods. Continuous miners, borer miners, and longwall shearers are equipped with tungsten carbide bits to cut the trona from the exposed ore face. The ore is loaded into shuttle cars and then to conveyors which carry the ore to underground storage bins. The bins are lifted to the surface in buckets called “skips” through a mine shaft. Once on the surface the ore is conveyed to outdoor stockpiles or sent directly to the processing plant as demand indicates. Once in the processing plant, the ore is crushed and screened to exact specifications. Solution mining involves either drilling wells into the trona deposit and injecting a solution which dissolves the mineral, or injecting solution into underground mine workings which have already been first mined. The trona pillars which were left behind to hold the mine roof can be recovered by injecting a solution to dissolve the pillars, and pumping the solution back to the surface for processing into soda ash. The trona-saturated solution is then pumped back out through recovery wells and piped to a processing facility on the surface. In either case, the ore is sent to calciners to expel gasses and subsequently dissolved in water, purified, dried, and stored or shipped as demand indicates (GCIP Undated).

Trona ore production was 16,506,904 tons in 2010 (WMA 2010), as shown in Table 4-5. Approximately 9 million tons of various grades of soda ash and other products were produced in Wyoming in 2009 (Adcock 2010; BLM 2012a). Raw trona production has been flat in the last several years due to competition from synthetic trona produced in China and the global economic downturn that began in 2007 (Associated Press 2009). Trona demand was affected, in particular, by declines in demand for glass (such as automobile glass) and fiberglass (building insulation). In response to declining demand, FMC Granger suspended its solution mining operation, which was brought back into production in 2011 (BLM 2012a). However the U.S. soda ash export association raised the export price by $50 per ton effective July 1, 2011 citing that global soda ash demand was increasing (USGS 2012c).

Table 4-5 Yearly Production at Southwest Wyoming Trona Mines, 1994 to 2010

Year	FMC Granger Mine		FMC Westvaco Mine		OCI Wyoming Big Island Mine		Tata Chemicals (Soda Ash Partners)		Solvay Chemicals	
	Mine Production (Tons)	Employees (Mine+Plant)	Mine Production (Tons)	Employees (Mine+Plant)	Mine Production (Tons)	Employees (Mine+Plant)	Mine Production (Tons)	Employees (Mine+Plant)	Mine Production (Tons)	Employees (Mine+Plant)
1994	2,316,660	334	4,046,797	1,102	2,880,249	502	3,692,776	579	3,142,690	403
1995	2,497,422	375	4,718,823	1,109	3,344,664	503	4,303,711	586	3,306,637	418
1996	2,433,602	388	3,990,792	1,132	3,386,277	501	4,115,869	575	3,565,351	426
1997	2,476,766	392	4,445,846	1,060	3,425,557	485	4,135,020	606	3,598,695	428
1998	2,203,971	362	3,984,630	1,037	3,399,057	472	4,510,981	595	3,111,834	416
1999	969,763	352	4,592,902	1,108	3,479,978	519	4,294,659	590	3,424,265	416
2000	1,139,988	219	4,351,876	965	3,468,340	472	4,322,239	567	3.398,405	399
2001	280,619	94	4,482,531	992	3,544,283	415	4,547,431	550	3,539,006	416
2002	0	24	4,247,000	917	3,603,005	418	4,493,096	528	3,598,023	394
2003	0	11	4,500,242	856	3,627,384	403	4,281,000	507	3,894,847	388
2004	0	11	4,278,224	797	4,223,674	405	4,486,710	505	4,297,900	397
2005	0	36	4,675,504	797	4,135,888	417	4,715,905	510	4,332,068	428
2006	612,880	85	4,475,831	808	4,139,625	419	4,305,156	504	4,286,974	443
2007	0	92	4,193,113	792	3,974,256	420	4,651,171	495	4,371,462	426
2008	Not Listed	Not Listed	4,616,594	810	4,168,427	428	4,852,123	500	4,042,120	440
2009	Not Listed	Not Listed	3,828,737	833	3,185,089	403	3,517,596	473	4,053,175	432
2010	Not Listed	Not Listed	4,129,639	852	3,595,619	388	4,452,016	483	4,329,630	428

Source: WMA 2010.

4.1.3 Sodium Carbonate Brines

Historical Exploration and Mining Activity

In 1938, sodium carbonate brine was discovered in the area near Eden and Farson, about 30 miles north of Rock Springs, during the drilling of the John Hay water well. The brine was found at depths between 400 and 600 feet. Numerous exploratory wells drilled later in the area also encountered the sodium brines. Then in 1992, a shallow water well drilled about 6 miles southwest of the town of Eden encountered an artesian flow of sodium brine and in a 2 week timeframe produced approximately 29,000 barrels of brine while attempts were made to seal the well. Other wells in the Farson and Eden area have also shown artesian flow of sodium carbonate brine and one well reportedly is capable of flowing 6,800 – 6,900 barrels a day. The brines may also have value for the organic acids they contain. Those acids may be destructively distilled to yield oil and may also have value as soil conditioners. The high volume well mentioned above could potentially yield 62 tons of soda ash and 130 tons of organic acids per day. However, to date, the brines have not been developed for commercial use (Dyni 1996).

Recent Exploration and Mining Activity

The RSPA has delineated the Potential Sodium Brine Area, shown in Figure 3-8. Although some companies have expressed interest in the brine resources, no exploration or mining plans or notices have been submitted to the RSPA to-date (March 2012) (BLM 2012a). Potential brine areas have been defined by BLM based on the presence of sodium brines found and recorded on well logs from oil, gas, and other wells types drilled in the Farson-Eden area.

4.1.4 Oil Shale

Historical Exploration and Mining Activity

Historic mining for oil shale took place in Utah and Colorado as early as the 1920s in Utah (Aho 2007), but no records of oil shale mining in Wyoming have been found. Exploratory drilling, sponsored by the U.S. Bureau of Mines (USBM) took place between the 1940s and 1980s to evaluate the resource using Fischer Assays. A small oil shale in-situ retort test was conducted by the Department of Energy during the early 1980's west of the city of Rock Springs at the base of White Mountain. The results of the test were not encouraging enough to warrant a commercial development at that time. During the 1990s the U.S. Department of Energy digitized these and other data to create a National Oil Shale Database which is the basis for recent studies of oil shale resources in Wyoming, Utah and Colorado. Past studies found that the geology of the Green River and Washakie Basins in Wyoming is quite complex, with three oil shale bearing members identified (Tipton Shale, Wilkins Peak, and Laney Members of the Green River Formation). No mine development took place, however (Johnson et. al. 2011).

Section 369 of the Energy Policy Act of 2005 (Public Law 109-58) required BLM to offer lands for lease for Oil Shale Research, Development and Demonstration (RD&D). The law also required BLM to complete a PEIS to analyze the impacts of commercial scale leasing and development and to establish regulations for leasing and the regulation of oil shale operations.

BLM initiated the RD&D Leasing Program in 2005 with a call for nominations for RD&D leases. Of the twenty nominations received none were located in Wyoming. Ultimately six RD&D leases were issued on January 1, 2007, five in Colorado and one in Utah. In November 2008, the PEIS was completed which amended 10 BLM RMP's, including the Green River RMP, to provide for commercial leasing of oil shale. The ROD for the PEIS amended the Green River RMP to allocate 788,230 acres of federal lands and split estate mineral estate as available for commercial oil shale leasing (BLM 2008). The ROD also limited leasing for surface mining operations in the RSPA to about 240, 000 acres where the overburden is between 0 and 500 feet deep. On November 3, 2009, BLM held a second round of RD&D lease nominations and three were received, two in Colorado and one in Utah, but none in Wyoming (BLM 2012b).

Recent Exploration and Mining Activity

No exploration has occurred on federal lands in the most geologically prospective oil shale areas of the Green River Formation within the Green River and Washakie Basins (Figure 3-11). There are no leases or outstanding applications for oil shale development on federal lands within the RSPA as of March 2012. Research and Development activities have focused on Colorado and Utah, where higher grade oil shale exists.

Interest in oil shale resources on private lands located within the RSPA may be moving forward. (BLM 2012a). Recently, information has surfaced about the possibility of additional oil shale in-situ retort tests in the White Mountain vicinity on private lands north of Rock Springs.. However, there is no confirmation such tests have been conducted to date (BLM 2012a). The Wyoming Department of Environmental Quality reports that the agency has received one Drilling Notification under state regulations for a proposed oil shale well also on White Mountain (Boyle 2012).

4.1.5 Phosphate

Historical Exploration and Mining Activity

Phosphate was once mined west of Kemmerer in Lincoln County (overthrust area) near Leafe, but mining ceased in 1977 and the plant was closed in 1985 (Snoke et. al. 1993). The J.R. Simplot Company operates a fertilizer manufacturing plant at Rock Springs, WY using phosphate ore mined at Vernal, UT. Phosphate is also present in the volcanic rocks of the Leucite Hills, though no prospecting is known to have taken place here (Bautz 2012).

Recent Exploration and Mining Activity

Phosphate resources are not known to exist in currently economical minable quantities in the RSPA. No exploration or mining for phosphates has occurred in the RSPA, nor is occurring as of March 2012 (Bautz 2012).

4.2 LOCATABLE MINERALS

4.2.1 Uranium

Historical Exploration and Mining Activity

Wyoming’s first uranium discoveries were made near Lusk from tailings piles at the Silver Cliff mine. Later discoveries were made near Wamsutter (Lost Creek) and the Black Hills in Crook County. These were small-scale discoveries, however. In 1950 and 1952 Dr. John David Love and others successfully tested Love’s hypothesis that there would be uranium in the White River formation by completing aerial surveys in the Pumpkin Buttes area of Campbell County. This was during a time when the U.S. Atomic Energy Commission was purchasing uranium for its nuclear weapons program. This significant discovery was followed closely by others in the Gas Hills mining area of the Wind River Basin, Crooks Gap, Shirley Basin, and the Black Hills area (Figure 3-11). One of the most productive mines, the Lucky Mc mine, was located in the Gas Hills in Fremont County. Sampling for uranium in carbonaceous rocks in southwest Wyoming in 1952 and 1953 found that the coals associated with the Rock Springs Uplift east of Rock Springs contained elevated levels of uranium (Vine and Moore 1952), however, no significant discoveries have been made here (WSGS 2011f) and no mining has occurred in the RSPA.

Recent Exploration and Mining Activity

The mines noted above extracted uranium using conventional mining methods; that is, ore in a solid form was removed from the ground (either surface or underground mines) and processed at a mill. Generally, open pits are used when the deposit is 300 feet or less from the surface. In the 1990s, in-situ recovery (ISR) methods were tested. This type of mining can be used to extract any soluble mineral. In ISR, uranium is removed from in-place, underground host rock using water and sodium bicarbonate and/or gaseous carbon dioxide and oxygen via a series of injection wells where it flows through the existing aquifer to the ore deposit, dissolving the uranium. The uranium-rich solution (the *lixiviant*) is pumped back to the surface through extraction wells to a processing facility. One advantage of this process is that it does not have a large surface footprint. The Smith Ranch Highland ISR mine, located in west-central Converse County was operational in the 1990s until at least 2007 (WSGS 2011f).

Uranium exploration increased in the early 2000’s and then decreased when the economic downturn hit in 2008. This was followed in 2010 by a tsunami in Japan that damaged and ultimately led to the destruction of an operating nuclear power plant (BBC News 2011a). The Japanese incident has caused numerous countries to rethink their expansion or even continued use of nuclear power generation. As an example, in May 2011, Germany announced that it would phase out all of its nuclear power plants by 2022 (BBC News 2011b). Most of the recent Wyoming uranium exploration has taken place in previously studied areas. No new exploration or surveying has taken place in the RSPA (Bautz 2012). An ISR uranium operation is being evaluated at a pilot scale in the Great Divide Basin (Bowen et. al. 2011), as well as northeast of Casper, Wyoming. However, no current ISR or traditional uranium mines are operating, nor are there any known plans for uranium mines within the RSPA (Ingle 2012).

Currently there are 132 active lode mining claims for uranium staked on federal lands in the RSPA. There are 24 claims located in Fremont County, 20 claims in Sublette County, and 84 claims in Sweetwater County. Figure 3-11 shows the township, range and sections where the claims are located. RSFO approved one Notice-level operation under the regulations at 43 CFR 3809 in October 2007 to Tournigan USA, Inc. (Serial No. WYW-167518) for uranium exploration operations on their mining claims in section 18, T.28N, R.102W., section 13, T.28N, R.103W., and sections 26 and 35, T.29N., R.103.W. in Fremont and Sublette Counties (BLM Undated d1 through d10). No subsequent Notices or Plans of Operation have been filed for uranium exploration on mining claims in the RSPA.

4.2.2 Gold

Historical Exploration and Mining Activity

Placer gold was found in the Dickie Springs/Oregon Gulch area of the South Pass region (northeast corner of the RSPA) in 1863, although no mines were developed due to hostilities with Native Americans. More gold was discovered around 1865 just east of the RSPA eastern boundary at South Pass. Three mining towns grew up here: South Pass City, Atlantic City, and Miner’s Delight. The South Pass area was home to several gold rushes. The first rush began in 1867 when the gold discoveries were reported in the *Chicago Times*. Some of the notable mines that produced precious metals in the area included the Carissa Mine at the Carissa Lode, the Duncan Mine, the Shields Mine, the Diana Mine, the Garfield Mine, the Gold Dollar Mine, and Miner’s Delight Mine. Around 1870 it was reported that upwards of 5,000 people inhabited South Pass City and Atlantic City on top of the Continental Divide. However, some sources suggest these reports were exaggerated. Access to the South Pass area was via the Point of Rocks stage stop.(Dobson 2011b).

Although many mines were developed after the initial discovery in the greater South Pass area, the rush dwindled by 1873 and the Carissa and other mines at South Pass and Atlantic City were idled, although the Miner's Delight area held on until 1880. The Carissa Mine re-opened in 1901 and the shaft extended to a depth of 387 feet. Mining was short lived, however; by 1906 it had closed again. It opened one more time in 1946 but closed soon after. Atlantic City was home to the Dexter Mine in 1904, and the E.T. Fisher Company conducted placer operations beginning in the 1920's until the beginning of World War II. It is unknown how much gold was taken from the South Pass area, but several people made a fortune from the gold and from supporting industries such as food and lodging purveyors (Dobson 2011b). The South Pass area is now a state historic site.

Recent Exploration and Mining Activity

Figure 3-13 shows the general area of gold concentrations in the northeast corner of the RSPA in southwest Fremont County. A total of 62 active placer mining claims for gold are located in Fremont County within the RSPA (BLM Undated a through c). Figure 3-13 shows the townships, ranges and sections where the mining claims are located. The Wyoming Department of Environmental Quality/Land Quality Division (LQD) is aware of three active exploration operations in the Dickie Springs area on private land. The RSPA has approved three Plans of Operation for placer gold exploration operations under the regulations at 43 CFR 3809 since August of 2000 on mining claims also in the Dickie Springs area (see Table 4.8). In addition, RSPA approved a Notice level exploration operation for placer gold in July of 2011 on mining claims in the Oregon Gulch area. However, no new gold exploration or mining operations are known to be proposed or planned for the future in the RSPA or further to the east on South Pass (BLM 2012a; Bautz 2012).

Table 4-6 RSPA Approved and Active Gold Notice and Plan-Level Exploration Operations

BLM Serial No	Case Type	Commodity	Operator	County
WYW-140961	Plan of Operations	Placer Gold	Ronald Arland	Fremont
WYW-15769	Plan of Operations	Placer Gold	Dave Freitag	Fremont
WYW-160595	Plan of Operations	Placer Gold	Fremont Gold U.S., LLC	Fremont
WYW-167797	Notice of Intent	Placer Gold	Robert Jones	Fremont

BLM Undated a, BLM Undated b.

4.2.3 Diamonds

Historical Exploration and Mining Activity

Only limited exploration for diamond-indicating surface features and raw diamonds has occurred within the RSPA. A small diamond mining operation located in southeastern Wyoming, near Laramie, was active from 1996 to 2003 but has since closed. No diamond mines have operated within the RSPA (WSGS 2011b).

Recent Exploration and Mining Activity

In 2010, WSGS diamond exploration activities reported identifying placer diamonds in the RSPA at the Cedar Mountain breccia pipes located south of Green River, and near South Pass in the northeastern corner of the RSPA (Figure 3-14). Other exploration areas where WSGS reported finding placer diamonds included the Sierra Madre, Medicine Bow, and Laramie mountains in southeast Wyoming, the northern Wind River and Gros Ventre Ranges in northwestern Wyoming, and near Gillette in northeastern Wyoming (WSGS 2011b).

Diamonds also may be found in the rare lamproite-based rocks of the Leucite Hills located north of Rock Springs, based on the presence of indicator minerals there, such as pyrope garnet, chromium diopside, and ilmenite. These relatively young volcanic cones, flows, and necks include well-known landmarks found north of Rock Springs such as the Boars Tusk and Pilot Butte. Although tests for diamonds in the Leucite Hills have had negative results, sampling and testing has been minimal (Snoke et. al. 1993).

There are no current Notices or Plans of Operation to explore for or develop diamond resources within the RSPA.

4.2.4 Nephrite Jade

Historical Exploration and Mining Activity

There is no information on historical exploration and mining on public lands.

Recent Exploration and Mining Activity

There is no information on recent exploration and mining.

4.2.5 Titaniferous Sands

Historical Exploration and Mining Activity

There is no information on historical exploration or mining activity.

Recent Exploration and Mining Activity

There is no information on recent exploration and mining.

4.2.6 Zeolites

Historical Exploration and Mining Activity

A zeolite mine on private land has operated in Section 1, T.16N., R.98W., of the Fort LaClede area but is currently inactive.

Recent Exploration and Mining Activity

There is no information on recent exploration and mining.

4.2.7 Rare Earth Elements

Historical Exploration and Mining Activity

There is no information on historical exploration and mining activity for REE in the RSPA. The RSFO is not aware of any mining claims, or notice or plan level exploration work that has historically occurred in the RSPA for REE (Wiig 2012).

Recent Exploration and Mining Activity

There is no information available indicating that there has been recent exploration or mining activity for REEs in the RSPA. The RSFO is not aware of any mining claims, notice or plan level exploration work that are active or under application in the RSPA for REE.

4.3 SALEABLE MINERALS

4.3.1 Sand and Gravel

Sand and gravel are common minerals and although this resource has a low unit value compared to many other industrial minerals, the sand and gravel industry is very important to the economic development in the U.S. The aggregate industry accounts for roughly half of all mining volume in the U.S, and most of this material is used in the construction industry. In Wyoming, the value of mined construction aggregate is greater than the value of bentonite, gypsum, or uranium (WSGS 2011d).

More than 90% of asphalt pavement and 80% of concrete consist of construction aggregate. The remainder is a binder such as asphalt or cement. About 52% of all construction aggregate is crushed stone, while 48% of the remaining is sand and gravel (WSGS 2011d).

Because aggregates have a low unit value, it is important that transportation costs be minimized. Therefore, there are many aggregate mines, and most of the mines are located near population centers where demand is greater (WSGS 2011d).

Historical Exploration and Mining Activity

Mining for aggregates has occurred in Wyoming since humans first arrived in the region and constructed pit houses. The construction of the Transcontinental Railroad created a comparatively huge demand for railroad ballast, used as a base under railroad tracks. The Martin-Marietta quarry west of Cheyenne was constructed for this purpose and is still used for ballast today (WSGS 2011d).

Within the RSPA, sand and gravel has been the primary mineral material produced from federal lands and is used mainly for construction and road maintenance projects. BLM's Land and Mineral Legacy Rehost 2000 System (LR 2000) records show 62 authorizations for mineral materials sites on federal lands are currently in effect covering a total of 3,909.45 acres. The majority of authorizations (48) were issued in the form of Rights of Way (ROW) to the Wyoming Department of Transportation for highway construction and maintenance, with the earliest issued in 1939. However, not all of these pits are currently active. These ROW material pits range in size from 2.75 acres to 480 acres and cover a total of 3,295.45 acres within the RSPA (BLM Undated e1 through e10).

Recent Exploration and Mining Activity

Wyoming produced a record 23,352,427 short tons of gravel in 2007 but only 16,309,480 short tons in 2008 after the economic downturn (Table 4-7). Only four states currently produce less aggregate than Wyoming, even though Wyoming is the least populous of the 50 states. Major uses of Wyoming aggregate include railroad ballast, road base, road gravel, and concrete (WSGS 2011d).

Most of the 34 active sand and gravel operations located within the boundaries of the RSPA on both private and federal lands are less than 10 acres in size. More than half of these are on private land. Only one aggregate operation is considered a "Large Mine" under Wyoming state law. (Bautz 2012).

Table 4-7 Aggregate (Sand and Gravel) Production in Wyoming, 1995 to 2008

Year	Production (Short tons)
1995	8,793,098
1996	11,071,998
1997	10,419,971
1998	11,246,477
1999	15,206,461
2000	11,001,325
2001	16,053,510
2002	17,161,873
2003	15,122,188
2004	17,032,370
2005	18,368,440
2006	21,323,600
2007	23,352,427
2008	16,309,480

Includes sand and gravel, industrial sand, crushed stone reported as limestone and others; railroad ballast reported as granite and scoria (clinker) (Source: WSGS 2011d)

Sand and gravel production figures for 2010 for Sweetwater County are listed in Table 4-8 below. The data used did not delineate whether or not sand and gravel operations in Sublette, Carbon, or Uinta County operations figures were located within the RSPA, therefore those counties' production figures are not listed here.

Table 4-8 Sand and Gravel Production for 2010, Sweetwater County, WY

Sand and Gravel Production in Sweetwater County, 2006-2010						
Mine	Production by Year (tons)					Total
	2006	2007	2008	2009	2010	
Arrowhead Concrete Inc. - Mann Flats	0	0	69,611	0	60,352	129,963
Black Horse Construction, Inc. - Applequist Pit	139,354	62,597	55,080	11,793	0	268,824
First Energy Services	2,673	0	0	0	0	2,673
Gorge Rock Products, Inc. - Pioneer Trails Pit	0	0	0	0	53,000	53,000
Gorge Rock Products, Inc. - Layos Pit #1	0	87,077	0	0	0	87,077
Gorge Rock Products, Inc. - Layos Pits #2 & #3	0	129,774	0	0	0	129,774
Gorge Rock Products, Inc. - Pleasant Pit	0	0	0	0	64,000	64,000
H. B. Lee Construction Co., Inc Creston Pit	26,320	19,020	15,740	4,980	11,520	77,580
LeGrand Johnson Construction Co. - Fontenelle Pit	0	0	120,457	0	0	120,457
Lewis & Lewis, Inc.	162,316	564,164	554,717	377,971	385,290	2,044,458
Randy R Pit Construction	8,700	0	0	0	0	8,700
Rocks In Stones LLC - #1	0	0	1,920	0	3,000	4,920
Searle Brothers - Leucite Pit	0	0	0	145,253	107,241	252,494
Sweetwater CO. Road and Bridge - LaBarge Rd. Pit	0	16,831	13,317	5,632	0	35,780
Sweetwater CO. Road and Bridge - Middle Baxter Pit	0	0	10,948	16,742	0	27,690
Wylie Construction, Inc.	5,011	0	0	0	0	5,011
TOTAL Production in Tons	344,374	879,463	841,790	562,371	684,403	3,312,401

Source: Annual Report of the State Inspector of Mines of Wyoming, 2006 to 2010

There are seven BLM authorized free use permits (FUP) and two negotiated sales contracts with private entities for aggregate currently active in the RSPA. These authorizations are listed in Table 4-9. The FUP's cover a total of 320 acres and include approximately 349,000 in place tons of sand and gravel. They were issued to Sweetwater County, Sublette County and WYDOT primarily for road construction and maintenance activities. The negotiated sales contracts include a total of about 165,000 in-place tons of material, one with Rocks in Stones, Inc. covering 10 acres for sand and gravel and the other with FMC WY Corp. covering 160 acres for fill material (BLM 2012a).

Table 4-9 Active BLM RSPA Mineral Material Authorizations

BLM Serial No.	Authorization Type	County	Location	Total Acres	Operator
WYW-101907	Free Use Permit	Sweetwater	Sec. 30, T.15N., R.103W.	80	Sweetwater County
WYW-147661	Free Use Permit	Sublette	Sec. 13, T.28N., R. 105 W.	57.5	Sublette County Road and Bridge
WYW-153739	Free Use Permit	Sweetwater	Sec.22, T.18N., R. 104 W.	60	Sweetwater County
WYW- 162409	Free Use Permit	Sweetwater	Sec. 24, T.21N., R. 105 W.	40	Sweetwater County
WYW-163760	Free Use Permit	Sweetwater	Sec. 15, T.15N., R. 104 W.	40	Sweetwater County
WYW-163761	Free Use Permit	Sweetwater	Sec. 30, T.19N., R. 108 W.	40	Sweetwater
WYW-167646	Free Use Permit	Sweetwater	Sec. 8, T.19N., R. 105 W.	2.5	WYDOT
WYW-163794	Negotiated Sale Contract	Sweetwater	Sec. 25, T.15N., R. 104 W.	10	Rocks in Stones, Inc.
WYW-171305	Negotiated Sale Contract	Sweetwater	Sec. 22, T.19N., R. 110 W.	160	FMC WY Corp.
WYW-136612	Common Use Area	Sweetwater	Sec. 14, T.17N., R. 104 W.	60	N/A
WYW-137483	Common Use Area	Sweetwater	Sec. 18, T.14N., R. 104 W.	20	N/A

Source: BLM Undated d1 through d10.

4.3.2 Other Saleable Minerals

Decorative stone (moss rock), dimension stone (flagstone), landscape boulders, and topsoil are all examples of saleable minerals common within the RSPA. The first three are common, while the last two are rarer in the RSPA. BLM established two common use areas (CUA) in the RSPA in 1995 for non-exclusive small sales of mineral material to the public. No mechanized equipment is allowed for removing these materials. These sites are listed in Table 4-9 above. Currently developed and potential future sand and gravel resource locations are shown in Figure 3-15. The CUA at Aspen Mountain south of the City of Rock Springs is utilized for decorative rock and the CUA at Miller Mountain near Highway 191 South is used for topsoil (BLM 2012a).

CHAPTER 5 POTENTIAL FOR OCCURRENCE AND DEVELOPMENT

5.1 MINERAL RESOURCE POTENTIAL

The mineral occurrence potential for the RSPA is classified using the system outlined in Bureau of Land Management Manual 3031 (BLM 1985). Under this system, occurrence potential ratings are strictly based on the geologic likelihood of the mineral to be present in the area and do not address the economic feasibility of development of the resource. Also, the potential for the occurrence of a mineral resource does not imply that the quality and quantity of the resource are known. The categories used to classify the occurrence potential and the associated level of certainty of the supporting data are described in the following sections.

5.1.1 Level of Occurrence Potential and Certainty

Occurrence potential refers to the potential of the mineral in question to occur at a specific location or geologic environment. The levels are categorized as presented in Table 5-1.

Table 5-1 Mineral Occurrence Potential Categories

Level	Explanation
0	The geologic environment, the inferred geologic processes, and the lack of mineral occurrences do not indicate potential for the accumulation of mineral resources.
L	The geologic environment and the inferred geologic processes indicate low potential of accumulation of mineral resources.
M	The geologic environment, the inferred geologic processes, and the reported mineral occurrences or valid geochemical/geophysical anomalies, and the known mines or deposits indicate moderate potential for accumulation of mineral resources.
H	The geologic environment, the inferred geologic processes, and the reported mineral occurrences or valid geochemical/geophysical anomalies, and the known mines or deposits indicate high potential for accumulation of mineral resources. The known mines and deposits do not have to be within the area that is being classified, but have to be within the same type of geologic environment.
ND	Mineral potential not determined due to lack of useful data

The rating for level of certainty is presented in Table 5-2. Certainty is a measure of the confidence in the data that were available to determine the occurrence of a particular mineral resource in a particular area. The level of certainty is based on the nature and extent of the evidence for that occurrence actually being present within the planning area (e.g., exploration drilling, geologic mapping, published reports, or direct knowledge of the resource).

Table 5-2 Level of Occurrence Certainty Ratings

Level	Explanation
A	The available data are insufficient and/or cannot be considered as direct or indirect evidence to support or refute the possible existence of mineral resources within the respective area.
B	The available data provide indirect evidence to support or refute the possible existence of mineral resources.
C	The available data provide direct evidence but are quantitatively minimal to support or refute the possible existence of mineral resources
D	The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

5.2 LEASABLE SOLID MINERALS

5.2.1 Coal

Occurrence Potential

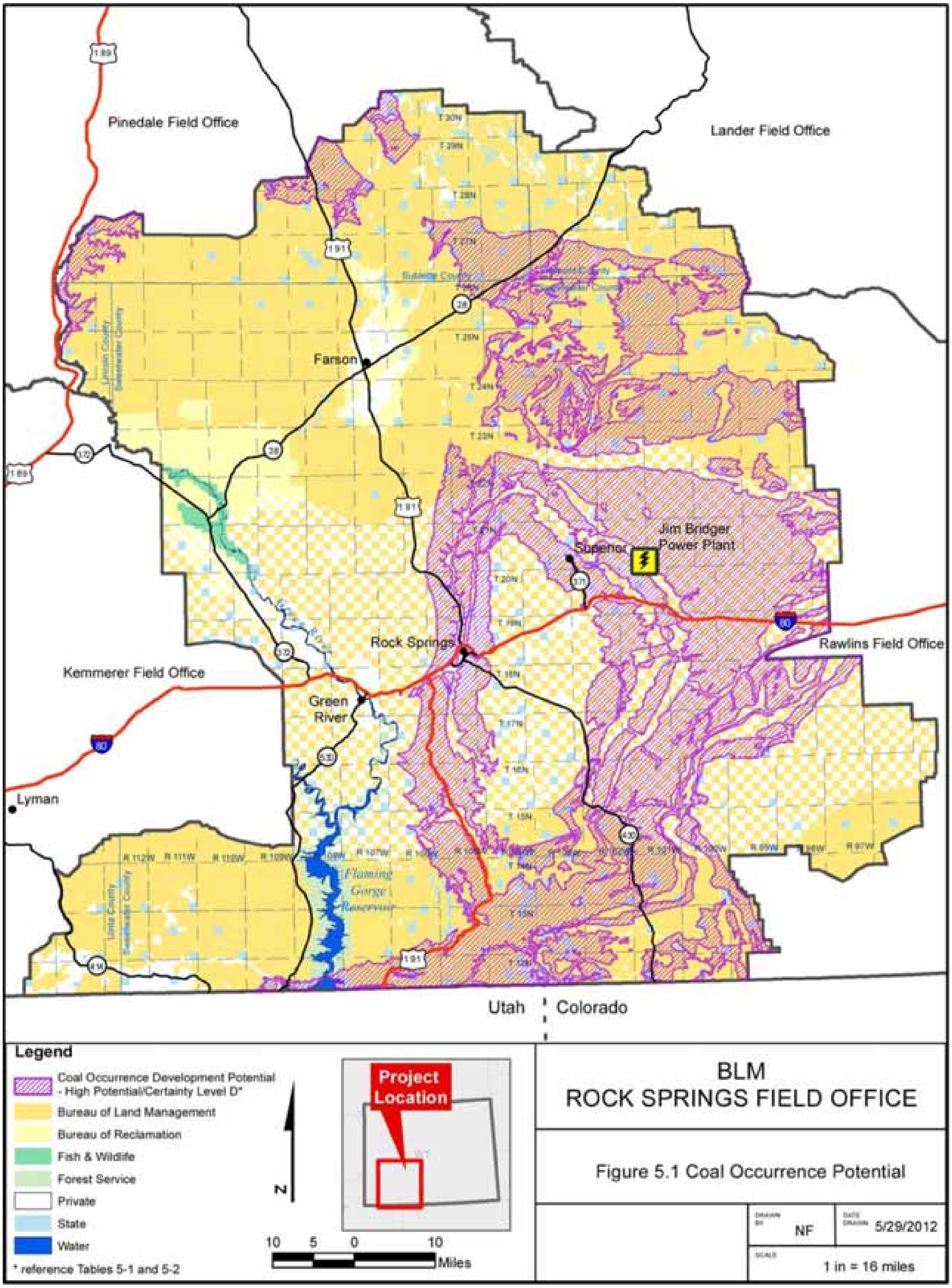
Within the RSPA, the existence of the coal resources is established and well documented by numerous published reports, mapping, exploration, and historic and current mining. This information provided the basis for the USGS to establish the Rock Springs Known Recoverable Coal Resource Area which is represented by the Coal Occurrence Development Potential Area described in Chapter 3 and shown in Figure 3-1. Outside of this area, coal deposits at depths greater than 3,000 feet have been identified by oil and gas drilling. Consequently, the potential for the occurrence of coal in the planning area in the areas underlain by Cretaceous and Tertiary coal bearing formations is classified as high based on abundant direct and indirect evidence to support the existence of the resource with a certainty level of D (H/D) (Figure 5-1).

Potential for Development

Coal is currently produced in the RSPA from the Bridger and Black Butte mines in the Point of Rocks-Black Butte coalfield. The Bridger Mine plans to continue to provide about 6 million tons a year to the Bridger Power Plant for the foreseeable future.. As the surface mine operation reserves are exhausted, Bridger plans to ramp up underground production from 3million tons per year to 6 million tons per year. With underground coal reserves totaling approximately 120 million tons, at the current and expected future production levels, Bridger Coal Company has sufficient reserves to feed the Bridger Power Plant for the next 20 years. The power plant is expected to be a steady and stable market for the Bridger Mine coal.

One of the owners of the Black Butte Mine, Ambre Energy Ltd., recently acquired their 50% interest in that mine. Ambre, an Australian Company, is presently pursuing the permitting and development of a coal loading facility near Longview, Washington and also a barge loading facility near Boardman, Oregon. The ultimate goal of these facilities is to export thermal coal from the western U.S. to Asia (Ambre Energy 2012). Successful completion of these ventures could result in an increased demand for coal from the Black Butte Area.

Figure 5-1 Coal Occurrence Potential



Under the present planning direction, the federal coal lands within the 422,000 acres identified as the Coal Occurrence and Development Potential Area (CODPA) (Figure 3-1), are open to further consideration for coal leasing and development (BLM 2012a). Within this area, the coal ownership is about evenly divided between the federal government and private land owners due to the checkerboard land ownership pattern. Any efforts to develop the federal coal lands will most likely be tied to the intervening private lands.

At the present time, there are no outstanding or pending applications for federal coal leases on lands within the RSPA. The two companies currently operating in the Point of Rocks - Black Butte Coalfield have been actively exploring federal lands adjacent to their operations through exploration licenses. Any near-term expansion of federal leases at these operations will be accommodated through lease modifications and processed in accordance with the regulations at 43 CFR 3400. A lease modification application may be forthcoming from the Black Butte Coal Company in the near future in regard to their proposed Pit 15 mine expansion (BLM 2012a). If any new coal lease applications are filed within the CODPA, they will also be processed in accordance with the BLM's regulations at 43 CFR 3400.

Projections of coal production from the planning area, based on the assumption that markets for southwestern Wyoming coal are limited to the Jim Bridger Power Plant and local industrial customers, are flat with the Black Butte and Bridger Mines continuing to produce around 9 million of tons per year. The Bridger Underground Mine is expected to increase production to 6 million tons per year to offset production declines at the Bridger Surface Mine. The Bridger Surface Mine is projected to cease production in 2014 as surface minable reserves are depleted (Wood Mackenzie 2011). The Black Butte Mine is projected to produce 3.6 million tons per year until 2018 and reduced production will continue through 2020 (Wood Mackenzie 2011). As the reserves are depleted at these mines, other sources of coal for the Jim Bridger power plant will be needed which could result in some additional leasing in the area.

Recent developments, however, indicate that coal market opportunities are developing that could result in an increased demand for southwestern Wyoming coal. If a proposed coal-to-liquids plant goes on line near Hanna, Wyoming, to the east of the planning area, coal production from southwestern Wyoming could increase from 12.2 to 21.2 million tons per year (Wood Mackenzie 2011). The initial increase in production to supply this plant is projected to come from mines outside of the RSPA, but the coal resources within the RSPA are suitable for coal to liquid applications and could become competitive in this new market if it develops. In addition, Ambre Energy’s proposed new coal terminal and barge loading facility in Washington would expand the demand for Wyoming coal in Asian markets (Ambre Energy 2012). Finally, at least one company is actively pursuing opportunities for an underground coal gasification project on private lands within the planning area. During scoping for the planning effort, the RSFO received comments that at least one party is interested in leasing deep federal coal to facilitate development of an underground (greater than 3,000 foot depth) in-situ coal gasification process on federal lands. The area identified through this comment covers some 27,000 acres in T. 22-23 N., R. 106-107 W. Due to the depth of the targeted coal, this area is outside of the CODPA and because these lands have not yet been evaluated by BLM through the coal screening process, they are currently not available for leasing.

Given the large coal resource base in the Rock Springs Planning Area, as discussed above, opportunities exist for future development as non-traditional market opportunities develop. It appears that market opportunities may be opening up within the planning period to export coal to Asia. Permitting to establish port facilities in the Northwest is ongoing as of March 2012. If port facilities are completed, this would facilitate access to new coal markets and would likely result in an expansion of coal mining in the RSFO. The areas most likely to be developed to meet this new demand are within the CODPA on the east flank of the Rock Springs Uplift. In addition, unconventional coal development opportunities such as coal-to-liquids and underground gasification could expand exploration, leasing and development in the RSPA outside of the CODPA, most likely northeast of the CODPA boundary, at least initially.

5.2.2 Trona

Occurrence Potential

Within the RSFO Planning Area, the existence of the trona resources is well established and documented by numerous published reports, mapping, and exploration. This information provided the basis for the USGS to establish the Known Sodium Leasing Area described in Chapter 3. Consequently, the potential for the occurrence of trona in the planning area within the KSLA is classified as high based on abundant direct and indirect evidence to support the existence of the resource with a certainty level of D (H/D) (Figure 5-2).

Potential for Development

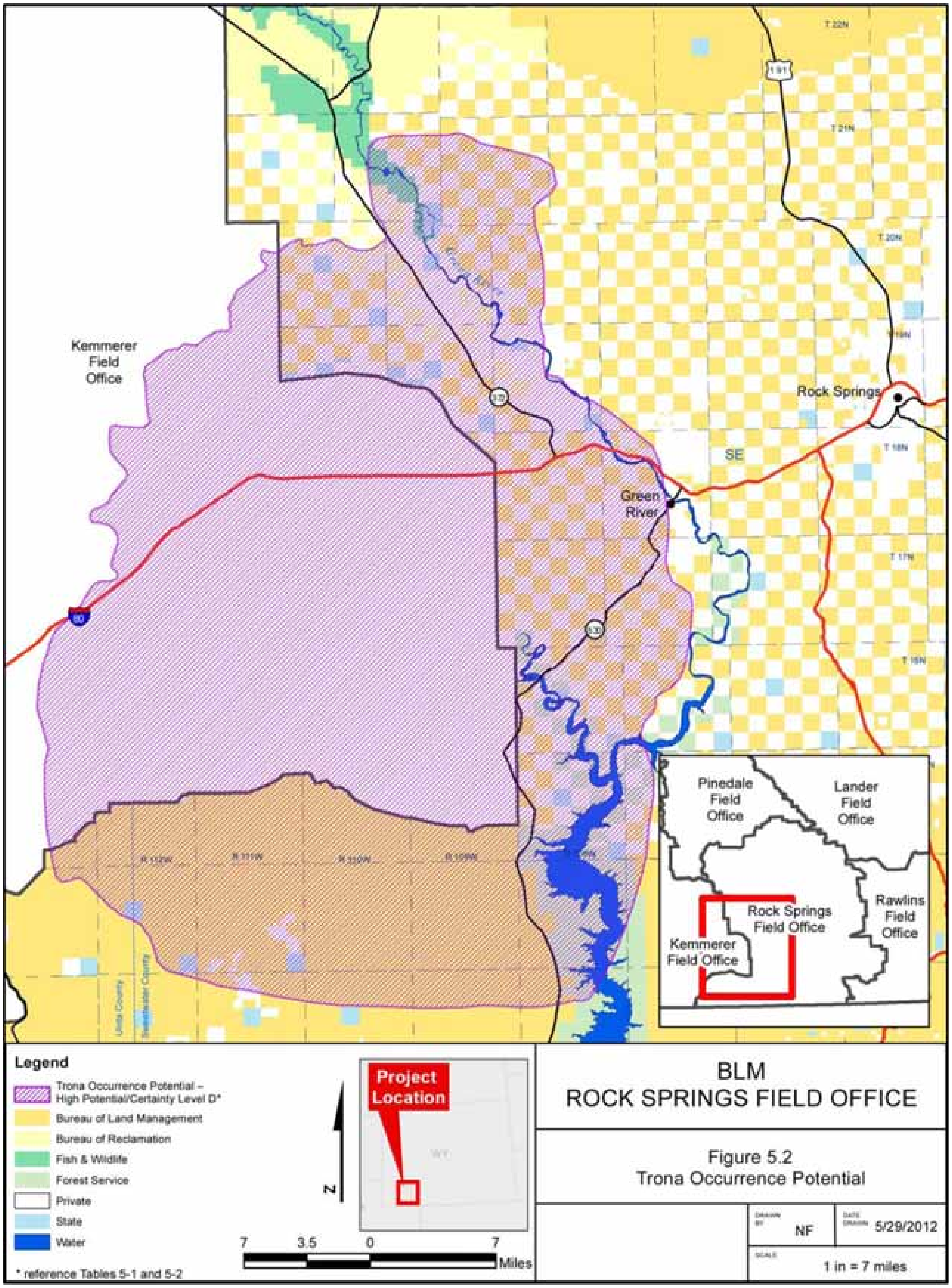
The rights to trona deposits on federal lands are obtained through sodium leases as provided in the federal regulations at 43 CFR 3500. Within the defined KSLA, leases can only be obtained through competitive bidding. Outside of this area, prospecting permits can be obtained to allow the deposits to be explored. If, during this exploration, the holder of a prospecting permit demonstrates a valuable deposit of sodium within the permit area, a preference right lease can be obtained for the sodium deposits. Most trona development would be expected in the KSLA, which covers an area of about 684,180 acres as shown on Figure 3-4. Only about 52% (356,960 acres) of this KSLA is within the RSFO planning area and the remaining KSLA lands are within the Kemmerer Field Office. All unleased public lands within the KSLA are available for leasing consideration (BLM 2012a).

At the present time, the four major operators (FMC Corp., Tata Chemicals (Soda Ash) Partners, Inc., OCI Wyoming LP, and Solvay Chemicals Inc.) are selling soda ash and associated products to both domestic and export markets. Between 2009 and 2010, Wyoming soda ash production increased by 13% , a fact which supports the conclusions of the most recent USGS Mineral Commodity Summaries for soda ash (USGS 2012c) that the global soda ash industry is continuing to recover from the world economic downturn. Along with the increase in demand, in 2011 soda ash prices increased $10 per ton in May, and $15 per ton effective November 1, and the U.S. soda ash export association raised the export price by $50 per ton effective July 1 (USGS 2012c). The USGS also projects that overall global demand for soda ash will grow from 1.5% to 2% annually for the next several years. As a result of this increase in demand, FMC has restarted its mothballed plant at Granger, Wyoming and the associated solution mining operation.

OCI Wyoming LP has recently expressed interest in obtaining an exploration license for unleased federal trona reserves adjacent to their current mining operation. If they do obtain this license, and the results of subsequent drilling operations are favorable, then a competitive lease application for these lands may be forthcoming at some point in the future, but it is not known at this time if this will actually occur. Several other current producers have made inquiries as to the viability of obtaining leases for federal trona reserves in the vicinity of their active mining operations, but no applications have been received to date (March 2012). Inquiries have also been made regarding the potential start-up of new solution mining operations on lands that are currently under federal lease, but no concrete proposals for any such new mining activities have been received to date (March 2012). Both the FMC Corp. and Tata Chemicals have conducted trona extraction through solution mining in the past on lands located south of Interstate 80. The FMC Corp.'s solution mine is currently not producing and Tata Chemicals' operation is undergoing final reclamation.

It is not anticipated that any new trona extraction operations, either by conventional mining or by solution mining, will be developed within the Green River Basin during the planning period. If the soda ash market undergoes a significant rebound during this time, then this situation could potentially change. Any new applications that may be submitted for prospecting permits, exploration licenses, competitive leases, lease modifications, or fringe acreage additions will be processed in the manner outlined by the 43 CFR 3500 regulations.

Figure 5-2 Trona Occurrence Potential



5.2.3 Sodium Carbonate Brine

Occurrence Potential

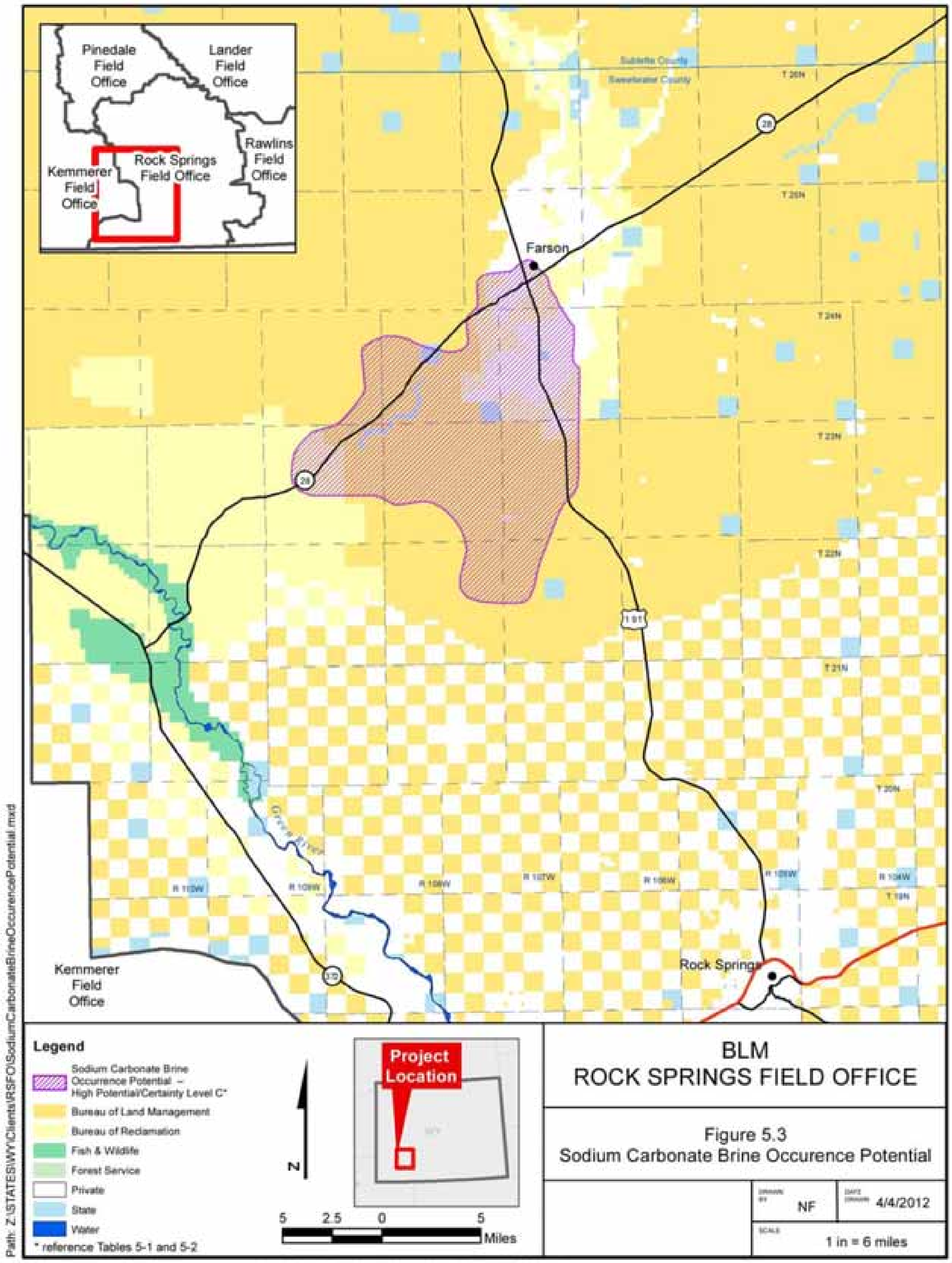
Known sodium carbonate brine occurrences are described in Chapter 3.1.2. Figure 3-8 shows the boundary of the Potential Sodium Brine Resource Area which encompasses approximately 87,464 acres. The boundary was drawn based on the presence of sodium carbonate brine in wells as identified in the associated well logs. Consequently, the potential for the occurrence of sodium carbonate brine within the Potential Sodium Brine Resource Area is classified as high with a certainty level of C (H/C) (Figure 5-3). This high occurrence potential is based on direct evidence to support the existence of the resource. The source of the brine is not established but Dyni (1996) has suggested that it may have formed down dip, deeper in the southern portion of the basin, and migrated up-dip to the Farson area. We are not aware of any systematic studies of well logs down dip or elsewhere to further determine the occurrence of the brine. Therefore all other portions of the RSPA are classified as “Not Determined” (N/D) due to lack of useful information.

Potential for Development

There is no current exploration or development activity related to the brines. In 1989, six Prospecting Permit applications were submitted to the RSFO under the regulations at 43 CFR 3500 for about 14,795 acres of land within the Potential Sodium Brine Resource Area. However no exploration work was done, the applications were withdrawn in 1993, and no further prospecting permit applications have been submitted to the RSFO to-date (March 2012). Five trona mines operate in the KSLA that account for nearly all of the U.S. soda ash production. Additional lands are still available for sodium leasing in the MMTA to allow for expansions of those mines or to develop new mines.

However, soda ash prices and demand are increasing (USGS 2012c). One high volume artesian well in the Potential Sodium Brine Resource Area is capable of producing 62 tons of soda ash a day (Dyni 1996). Given the positive market indicators for soda ash,industry interest may be renewed in evaluating the feasibility of developing the sodium carbonate brines. There is a moderate potential for new exploration activity within the Potential Sodium Carbonate Brine Resource Area to occur during the life of the RMP.

Figure 5-3 Sodium Carbonate Brine Potential



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5.2.4 Oil Shale

Occurrence Potential

Known oil shale deposits in the RSFO are described in Chapter 3.1.3. Oil shale beds are found almost exclusively in the Upper Eocene rocks of the Green River Formation, specifically the Tipton Shale, the Wilkins Peak Member, and the LaClede Bed of the Laney Member in the Green River and Washakie Basins respectively (Johnson et. al. 2011). Throughout those areas, the presence of oil shale has been identified and well documented in well logs. Consequently, the potential for occurrence of oil shale within the areas underlain by those rock units is classified as high with a certainty level of D (H/D) (Figure 5-4). All other areas in the RSPA are classified as O and do not indicate the potential for the occurrence of oil shale resources with a certainty level of B (O/B).

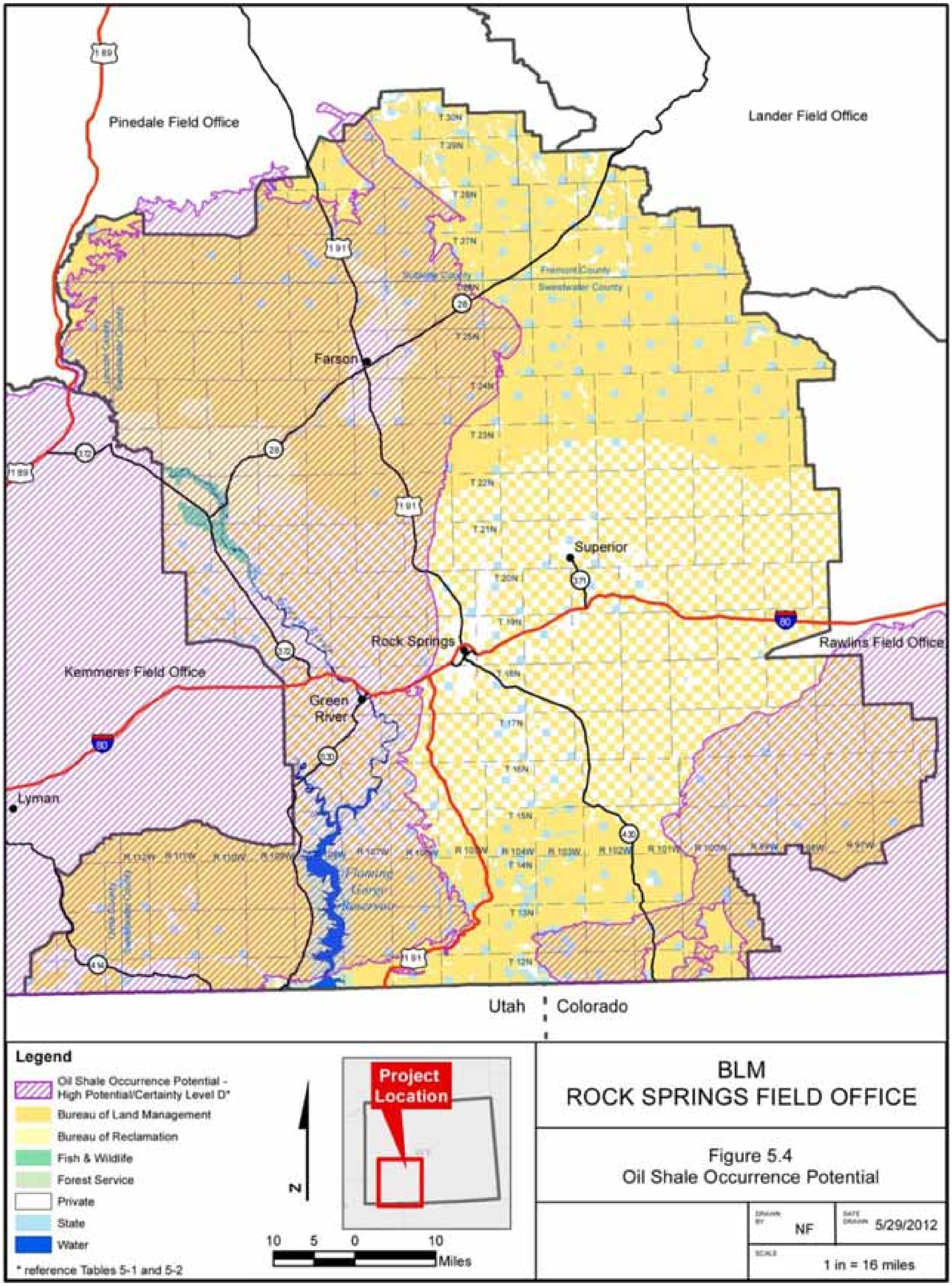
Potential for Development

The oil shale potential resource areas in the RSPA are classified as having oil shale beds that are at least 15 feet thick, and upon distillation would yield a minimum of 15 gpt of oil (See Figure 3-11). This area is considered to contain the most geologically prospective oil shale resources in the RSPA (BLM 2008). A portion of this area has been identified through well logs and Fisher Assays as having oil shale beds that are at least 25 feet thick and contain at least 25 gpt of oil (Figure 5-4). However, no exploration for development of oil shale has occurred to date on federal lands in Wyoming.

On February 15, 2011, BLM announced that it would take a second look at the 2008 PEIS decisions, including the associated plan amendments and prepare a new PEIS. Pending completion of the new PEIS and issuance of an ROD, no new RD&D or commercial leasing will occur. On February 3, 2012, BLM released the new Draft PEIS for public comment. The alternatives under consideration in the PEIS would allow oil shale leasing on anywhere from 0 to 1,000,574 acres in Wyoming. BLM has identified Alternative 2(b) as the preferred alternative. This alternative would only allow issuance of new RD&D leases, with the potential for conversion to commercial leases. In Wyoming, this alternative would allocate 174, 476 acres as available for RD&D leasing. The PEIS schedule indicates issuance of an ROD in December 2012 (BLM 2012b). No new RD&D calls for nominations will be initiated by BLM until the ROD is issued for the new PEIS.

BLM’s final decision for the PEIS will determine the amount and location of lands available for oil shale leasing in the RSPA. Since the oil shale resources in the RSPA are a lower grade than the resources in Colorado or Utah (USGS 2011b), exploration and development can be expected to occur in those states first. If environmentally and economically viable extractive processes are proven for those areas, then the technology would be available for application in the RSPA. Although no leasing is anticipated to occur on public lands in the RSPA during the planning period, if successful exploration and retort testing occurs on private lands, adjacent federal lands could be nominated for RD&D leasing. Given all of these factors, the potential for development of oil shale in the geologically most prospective oil shale resources area of the RSPA during the duration of the RMP is low.

Figure 5-4 Oil Shale Occurrence Potential



5.2.5 Phosphate

Occurrence Potential

The occurrence of phosphate in the RSPA is described in Chapter 3.1.4. The nearest mined phosphate deposits are found in the Phosphoria Formation in eastern Idaho and northeastern Utah. The formation does not outcrop in the RSPA and is buried deep beneath younger sediments. The areal extent of the Phosphoria underlying the RSPA is not well documented. There are no active phosphate mines in the RSPA or in Wyoming. Although there is a phosphate processing plant that produces fertilizer south of Rock Springs, the phosphate rock is mined in the vicinity of Vernal, Utah and is transported by slurry pipeline over the Uinta Mountains to the processing plant. Due to the lack of useful data on the areal extent of the Phosphoria Formation in the RSPA, the occurrence potential of phosphate is classified N/D.

Potential for Development

Given the facts that potential phosphate resources in the RSPA are deeply buried and there are no active phosphate mines elsewhere in Wyoming where the formation is at, or closer to, the surface, there is no potential for developing phosphate in the RSPA during the life of the RMP.

5.3 LOCATABLE MINERALS

5.3.1 Uranium

Occurrence Potential

The occurrence of uranium is described in Chapter 3.2.1. Uranium in Wyoming is typically deposited as a roll-front in Tertiary sandstone, conglomerate and tuffaceous deposits found in fluvial basins. While uranium is mined in areas of the Casper and Rawlins Field Offices, no current ISR or traditional uranium mines are operating, nor are there any known plans for uranium mines within the RSPA. However, uranium minerals are found in the Great Divide Basin within the Great Divide Mining District and in the northeastern portions of the RSPA near the southern terminus of the Wind River Range and South Pass (Bautz 2012) (Figure 3-12). The occurrence potential for uranium within the boundary of the Great Divide Mining District is classified as moderate with a certainty level of C (M/C) (Figure 5-5). The uranium occurrence potential for the portion of the RSPA underlain by Tertiary sedimentary units outside of the Great Divide Mining District is classified as low with a certainty level of B (L/B).

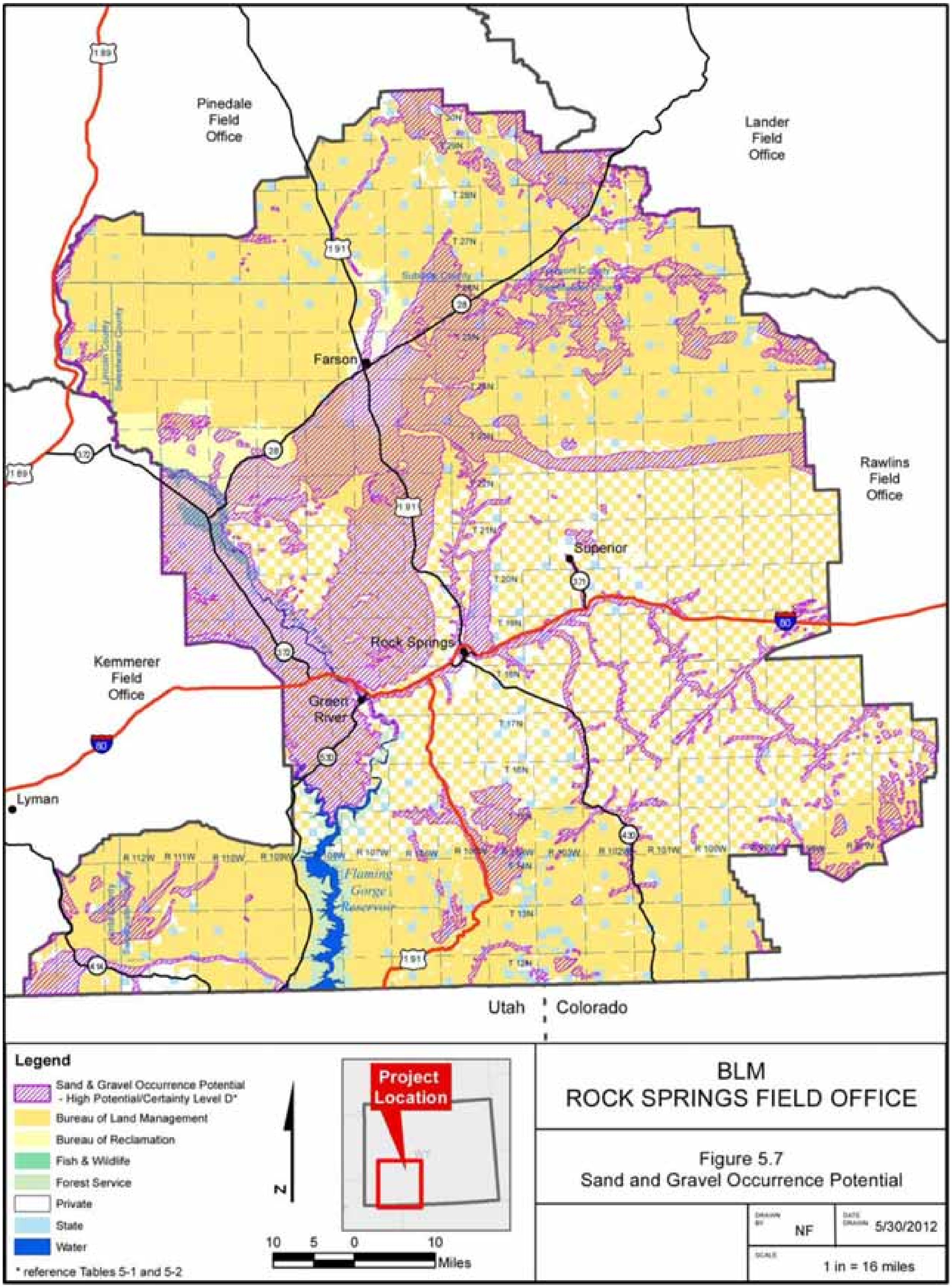
Potential for Development

Over the past year, uranium prices have fallen from $70.00 a pound to $51.00 a pound as of March 19, 2012 (Infomine 2012). Additionally, U.S. Uranium production was 6% lower in 2011 than in 2010 (EIA 2012). Finally, the world growth rate for nuclear energy consumption is projected to be only 2.4% between now and 2035 (EIA 2012). Most of the recent Wyoming uranium exploration has taken place in previously studied areas.

While there are 132 active lode claims for uranium in the RSPA, the last claims were filed in 2007. In addition, the latest NOI for uranium exploration operations was approved by the RSFO in October 2007. No new exploration or surveying for uranium has since taken place in the RSPA (Bautz 2012; BLM 2012a). An ISR uranium operation is being evaluated at a pilot scale in the Great Divide Basin east of the RSPA (Bowen et. al. 2011), as well as northeast of Casper, Wyoming. However, no current ISR or traditional uranium mines are operating, nor are there any known plans for uranium mines within the

RSPA (Ingle 2012). The potential for development of uranium is considered low within the RSPA during the life of the RMP. It is anticipated that industry interest in uranium will remain near or slightly above current levels, unless there is a significant change in uranium markets.

Figure 5-5 Uranium and Gold Occurrence Potential



5.3.2 Gold

Occurrence Potential

The occurrence of gold in the RSPA is described in Chapter 3.2.2. Gold occurs primarily in paleoplacer deposits and in present stream placer deposits in various locations within the Wasatch Formation in the northeastern portion of the RSPA (Figure 3-13). The deposits are localized and discontinuous within the formation. The occurrence potential for gold in the RSPA is classified as moderate for the areas underlain by the Wasatch Formation with a certainty level of B (M/B) (Figure 5-5). Areas underlain by other Tertiary sandstones and conglomerates in the northeastern portion of the planning area are classified as low occurrence potential with a certainty level of B (L/B).

Potential for Development

Placer gold is the only locatable mineral that has gained any significant interest by potential developers within the RSPA in recent times. A total of 62 active placer mining claims for gold are located in Fremont County within the RSPA. 22 of these claims were located between 2009 and 2011 and as recently as March of 2011 (BLM Undated a through c). Figure 3-12 shows the townships, ranges and sections where the mining claims are located. The Wyoming Department of Environmental Quality/Land Quality Division (LQD) is aware of three active exploration operations in the Dickie Springs area on private land (Hausel Undated). The RSFO has approved three Plans of Operation for placer gold exploration operations under the regulations at 43 CFR 3809 since August of 2000 on mining claims also in the Dickie Springs area (see Table 4.8). In addition, RSPA approved a Notice level exploration operation for placer gold in July of 2011 on mining claims in the Oregon Gulch area. There are no other proposed or outstanding Notices or Plans of Operation that are under consideration at this time according to current BLM records. Most of the activity concerning placer gold in the planning area involves recreational gold panning by local residents and tourists, which is considered to be casual use requiring no formal approval. There is currently one very small gold recovery operation active on mining claims in the northern portion of the RSPA. No new commercial gold mining operations are known to be proposed or planned for the future (BLM 2012a).

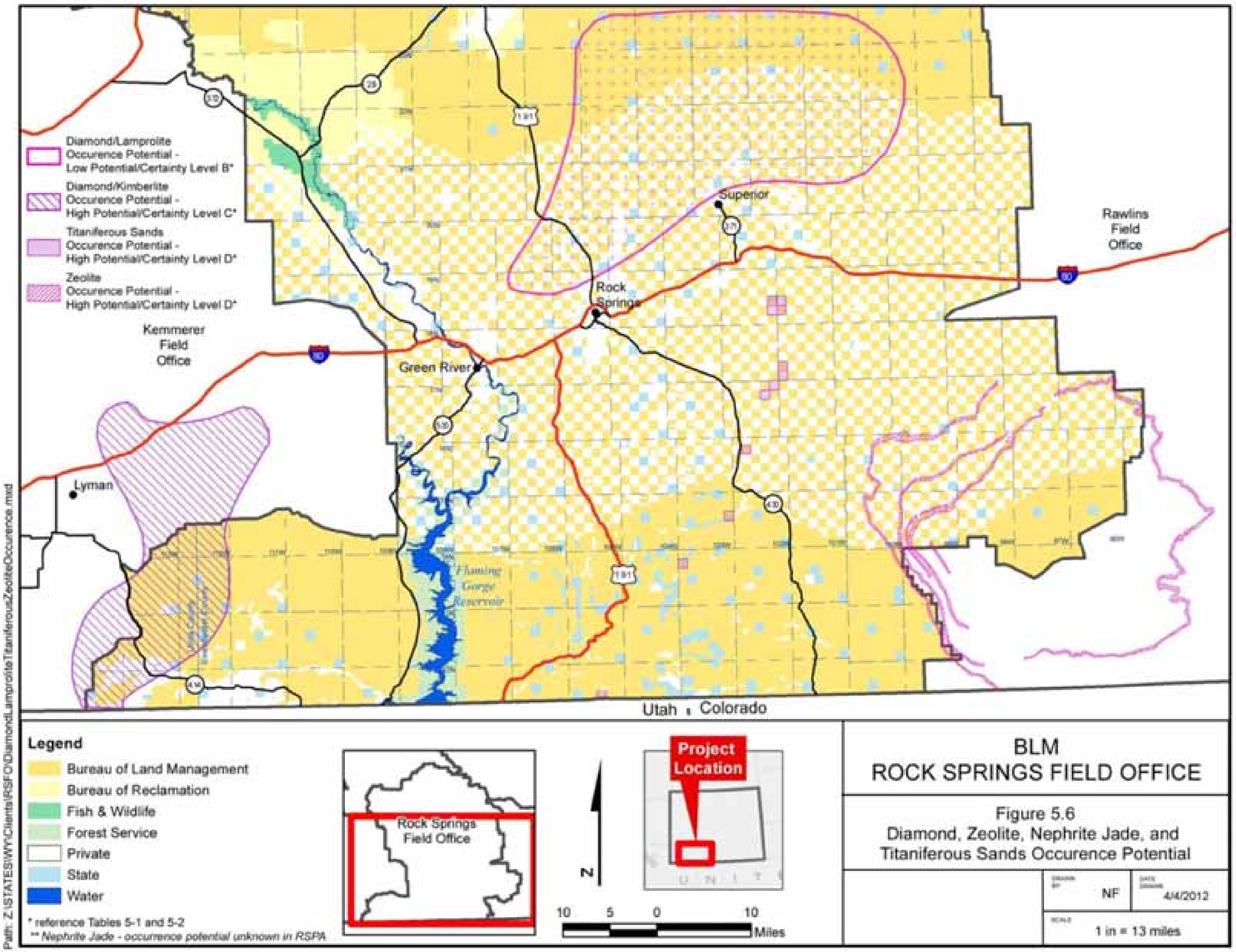
Gold prices have risen dramatically and more than doubled between 2007 when the price was $699 per ounce and 2011 when the average price was $1,600 per ounce (USGS 2012c). Although the potential for development of gold in the RSPA is considered low, the high price of gold and the current trend of continued price increases are expected to maintain interest in the deposits and claim activity is expected to remain near or slightly above current levels for the planning period.

5.3.3 Diamonds

Occurrence Potential

The occurrence of diamonds in the RSPA is described in Chapter 3.2.3. Diamond occurrences are associated with kimberlite pipes and with lamproite igneous rocks in the RSPA. The WSGS has identified diamonds in placer deposits at the Cedar Mountain breccia pipes southwest of the town of Green River (area identified as Kimberlite Indicator Mineral Area in Figure 3-14). This area is classified as having high potential for occurrence of diamonds with a certainty level of C (H/C) (Figure 5-6). The Leucite Hills lamproites north and northeast of Rock Springs are potential host rocks for diamonds. Diamond stability indicator minerals such as pyrope garnet and chrome diopside have been found there, although no diamonds have been discovered yet. The potential for the occurrence of diamonds in the Leucite Hills lamproites (as delineated in Figure 3-14) is classified as low with a certainty level of B (L/B).

Figure 5-6 Diamond, Zeolite, Nephrite Jade, & Titaniferous Sands Occurrence Potential



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Potential for Development

Although the Wyoming State Geological Survey has identified hundreds of locations of kimberlite indicator minerals over the past 20 years, as well as diamonds in placer deposits including at the Cedar Mountain breccia pipes in the RSPA, only one small diamond mine has operated in Wyoming in the State Line District on the border with Colorado south of Laramie. That mine shut down in 2003 as a result of legal problems after seven years in operation (WSGS 2011b). No further diamond mine development has occurred in the District since 2003. There are no current mining claims, Notices or Plans of Operation to explore for or develop diamond resources within the RSPA. The potential for commercial development of diamonds in the RSPA is considered very low. Recreational and hobby collection are expected to continue at the levels currently being experienced for the planning period.

5.3.4 Zeolites

Occurrence Potential

The occurrence of zeolites in the RSPA is described in Chapter 3.2.4. The zeolite clinoptilolite occurs near Fort LeClede in the southeastern portion of the RSPA. This zeolite is an almost complete alteration of the Eocene Adobe Town Member, a volcanic tuff in the Washakie Formation. A zeolite mine operated in this area in the past and substantial reserves of clinoptilolite still exist. The known zeolite deposits in this area are classified as high occurrence potential with a certainty level of D (H/D) (Figure 5-6). The area underlain by the Washakie Formation (Figure 2-2b) is classified as low potential with a certainty level of B (L/B).

Potential for Development

A zeolite mine has operated in Section 1, T.16N., R.98W., of the Fort LaClede area but is currently inactive. Zeolites have a number of uses and the Fort LaClede zeolites were under study six years ago for use in treating produced waters from coal bed natural gas development in the Powder River Basin (Vance et. al. 2006). So far that study has not resulted in renewed interest in mining zeolites in the RSPA. There are no current mining claims, Notices or Plans of Operation to explore for or develop zeolite resources within the RSPA. The potential for development of zeolite during the planning period is expected to be low.

5.3.5 Nephrite Jade

Occurrence Potential

The occurrence of in the RSPA is described in Chapter 3.2.5. Detrital (float) jade has been found in scattered locations in Tertiary conglomerates and Quaternary colluvial, elluvial and alluvial deposits the very northeast portion of the RSPA. The Wyoming State Geological Survey has identified an area of concentrated detrital jade immediately northeast of the RSFO boundary (WSGS 2011c). The Wyoming State Mineral and Gem Society has identified a general area of detrital jade that runs from Farson, eastward through the Red Desert in Sweetwater County to Seminoe Dam, north to Alcova, westward through Lander and southwest back to Farson (WSG&MS 2009). The portion of that area located within the RSPA is classified as moderate potential for occurrence of nephrite jade with a certainty level of B (M/B). Because available data are not highly detailed, no nephrite jade-bearing area is shown on Figure 5-6.

Potential for Development

Nephrite jade's primary use is as a gemstone for jewelry. Collection by hobbyists is expected to continue at the current levels during the planning period. The potential for development of nephrite jade at a commercial scale in the RSPA is considered to be very low during the planning period.

5.3.6 Titaniferous Sands

Occurrence Potential

The occurrence of titaniferous (black) sand deposits in the RSPA is described in Chapter 3.2.6. Titaniferous sands have been found in numerous locations south and east of Rock Springs. These identified deposits are classified as high potential for occurrence of titaniferous sands with a certainty level of D (H/D) (Figure 5-6). Areas within the RSPA underlain by the McCourt Tongue of the Rock Springs Formation are classified as having low occurrence potential with a certainty level of B (L/B). Since the titaniferous sands are found only in paleoplacers within the Rock Springs Formation, the remainder of the RSPA is classified as no potential (O) for the occurrence potential of titaniferous sands.

Potential for Development

There are no current mining claims, Notices or Plans of Operation on file or in process to explore for or develop titaniferous sand deposits within the RSPA. The development potential for titaniferous sands in the RSPA is considered very low for the planning period.

5.3.7 Rare Earth Elements

Occurrence Potential

The occurrence of REEs in the RSPA is described in Chapter 3.2.7. There are no known deposits of REE in the RSPA. To date there has been no systematic sampling for or evaluation of REE in the RSPA. However, the WSGS is currently conducting a statewide study, scheduled for completion in mid 2013, to identify, characterize and catalog REE deposits throughout the state.

REEs are ubiquitous in the rocks of the earth's crust but are rarely concentrated into minable deposits. There are some sampling sites in the RSPA with elevated levels of REE. Generally, these are located within the breccia pipes in the southwest corner of the RSPA, the alkaline volcanics of the Leucite Hills in the central portion of the RSPA , and the titaniferous sands east and southeast of Rock Springs (see Figure 5-6). However the data are sparse and incomplete and the occurrence potential for REEs is classified as ND, not determined, due to the lack of useful date.

Potential for Development

China produces about 95% of the world's REEs and 44% of that production is as a byproduct from an iron mine there. REE production in all other countries currently occurs as a byproduct of other mining and the USGS estimates that 90% of all REE production worldwide is as a byproduct (USGS 2010b). There has been only one U.S. REE mine in production recently, the Mountain Pass mine located in southern California. The mine closed in 2002 but continued to process ore that had been previously mined. In December 2010, the mine resumed production under new ownership (Molycorp 2012).

Discovered minable concentrations of REEs are generally less common than for most ores. The USGS has identified 23 principal known REE deposits discovered to date in the United States, located in 14 states, including Wyoming. The only REE deposit identified by the USGS in Wyoming is located in the Bear Lodge Mountains in extreme northeast Wyoming. Even for these known discovered resources, sufficient exploration and drilling, pilot plant testing and definitive economic analysis would be required to determine the deposit's economic viability before any development would be initiated. The Mountain Pass deposit in California is the only one of the 23 domestic deposits that meets all of those criteria and can be documented to contain a substantial reserve of REE- bearing ore (USGS 2010b).

Experience shows that the time required to develop new REE mines globally is in the range of a decade, and possibly much longer in the United States. Further, the domestic reserves and inferred resources associated with the 23 identified principal deposits are approximately 1.5 million tons. This is more than 100 times the annual U.S. consumption of REE in 2007 of 10,200 tons (USGS 2010b). However, in 2008 Molycorp estimated its known reserves at the Mountain Pass mine at more than 20 million tons which would significantly increase the ratio of the available U.S. REE reserves and inferred resources to the annual U.S. consumption (Molycorp 2012).

The importance of REEs to emerging technologies, especially in the defense and alternative energy sectors, coupled with the current overwhelming dependence of the U. S. supply on imports from China has likely spurred a continual increase in exploration for REE deposits in North America over the past few years. In the U.S. in 2011, economic assessments of mine development feasibility continued at the Bear Lodge Mountains in Wyoming, as well as at deposits in Idaho, Nebraska and on the Idaho-Montana border (USGS 2012c). Over the life of the RSFO RMP, it is likely that the Bear Lodge deposit and the 22 other discovered deposits in the U.S. would be developed well before any lesser defined and documented concentrations, such as those in the RSPA. Therefore the potential for the commercial development of REE during the planning period is considered to be very low. However, mining claim filings for REEs may be expected during the planning period, especially after completion and release of the WSGS Report of Investigation on REEs in 2013. Further, more detailed investigations and exploration of any sites with elevated REE levels identified by the WSGS study in the RSPA may also be expected with associated Notice and/or Plan level permit activity.

5.4 SALEABLE MINERALS

5.4.1 Sand and Gravel

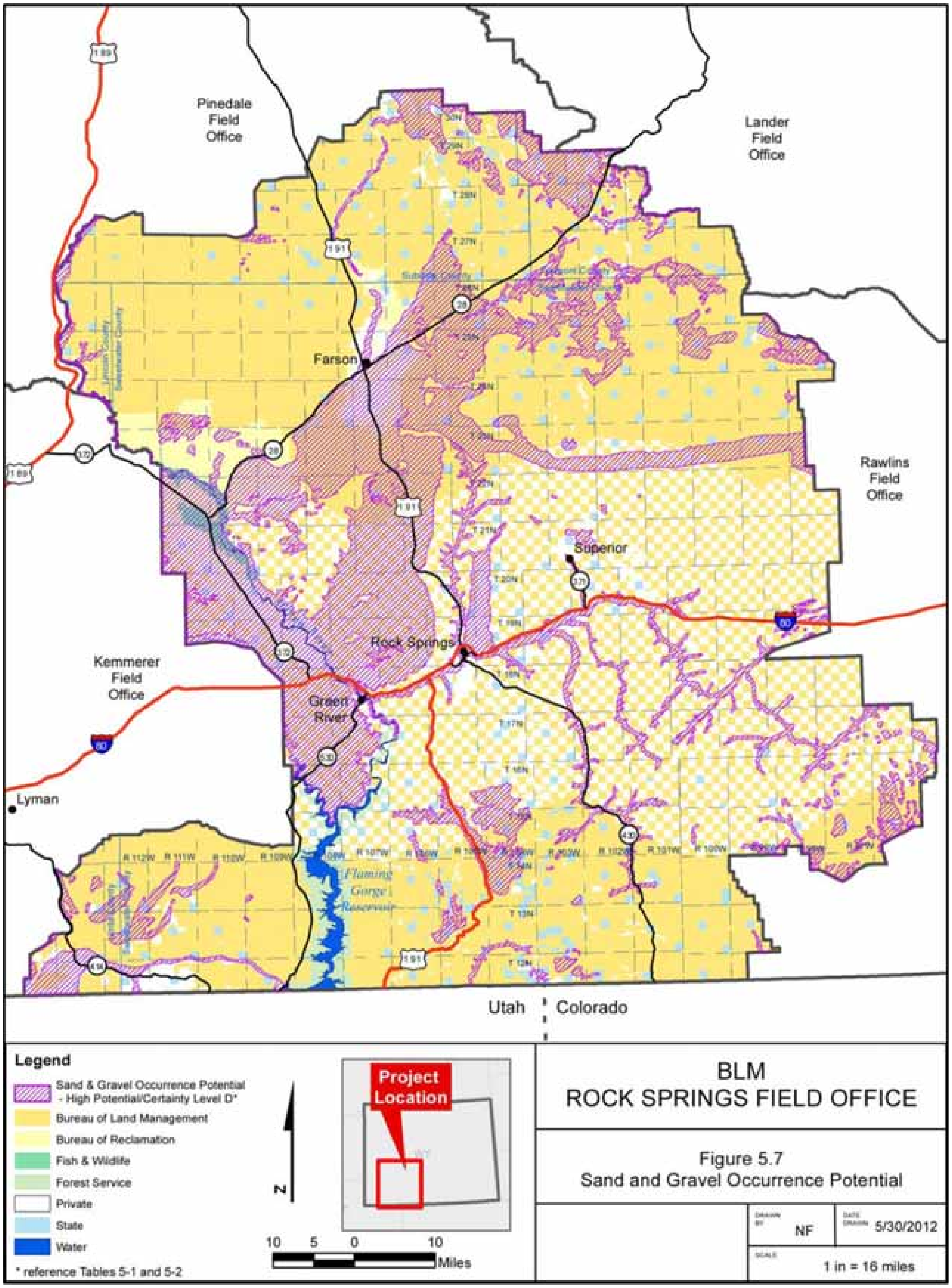
Occurrence Potential

The occurrence of sand and gravel in the RSPA is described in Chapter 3.3.1. Sand and gravel deposits are found in numerous geologic settings including: drainage channels of the Green River and its tributaries; glacial outwash material; plateaus capped by the Bishop Conglomerate; ancient gravel deposits; and weathered hard rock formations of granite, quartzite, limestone and conglomerates (BLM 2012a). The occurrence potential for sand and gravel is classified as high in these deposits with a certainty level of D (H/D) (Figure 5-7).

Potential for Development

The demand for construction aggregate in the RSPA is dependent primarily on the construction of new roads and maintenance projects by the local governments and in particular, those projects that support the oil and gas industry. As existing aggregate sources are being depleted, it becomes increasingly difficult to find new sources. It is expected that the demand for sand and gravel will remain at or close to current levels and the potential for development of sand and gravel resources is considered moderate for the planning period.

Figure 5-7 Sand and Gravel Occurrence Potential



5.5 OTHER SALEABLE MINERALS

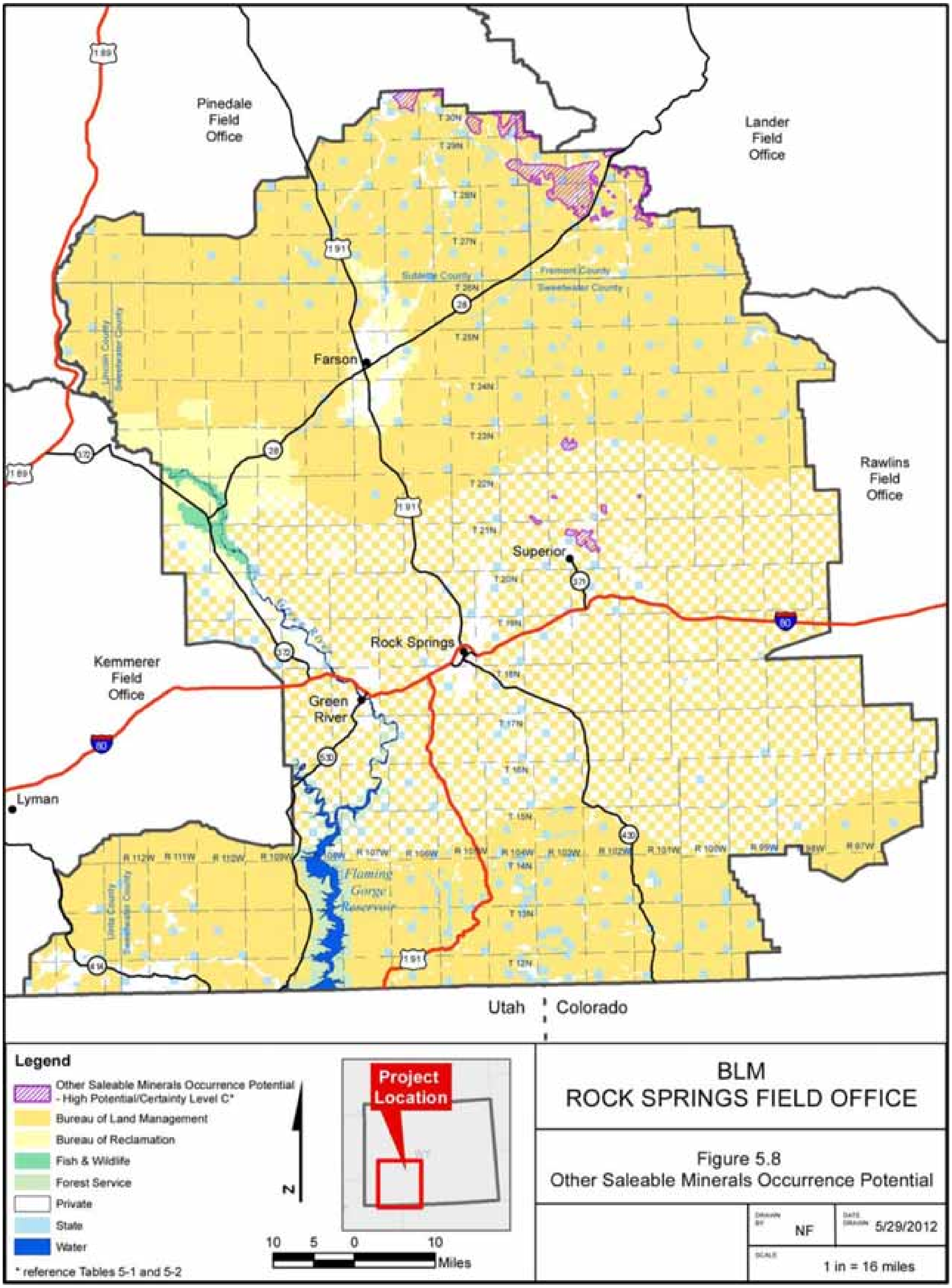
Occurrence Potential

The occurrence of other saleable minerals in the RSPA is described in Chapter 3.3.2. Various sedimentary rock formations, primarily sandstone, limestone, shale and siltstone, that outcrop in the RSPA provide potential sources of decorative and dimension stone. These sources are classified for occurrence potential of other saleable materials as high (H) with a certainty level of C (H/C) and are shown on Figure 5-8.

Potential for Development

Decorative and dimension stone have been used in the commercial and the residential construction industry throughout the region and beyond. BLM maintains a common use (non-exclusive sale) area for decorative and dimension stone on Aspen Mountain located south of the city of Rock Springs. There is also a small common use area for topsoil material located near Highway 191 South in the Miller Mountain area. The common use areas established in the planning area for decorative and dimension stone and topsoil continue to be used at a steady pace by the local residents as a source for landscaping material. The demand for these materials is expected to remain at current levels into the foreseeable future. Since the currently available resource supply should be adequate to meet the demand, establishing additional common use areas is not anticipated. The development potential for new decorative and dimension stone sources is considered low.

Figure 5-8 Other Saleable Minerals Occurrence Potential



5.6 SUMMARY OF SOLID MINERAL OCCURRENCE POTENTIAL AND DEVELOPMENT POTENTIAL

Solid leasable mineral occurrence and development potential in the RSPA has been analyzed for coal, trona, sodium carbonate brines, and oil shale. Potential occurrence and development of locatable minerals has been analyzed for uranium, gold, diamonds, zeolites, nephrite jade and titaniferous sands. Potential occurrence and development of saleable minerals has been analyzed for sand and gravel, decorative stone, and dimension stone. Table 5-3 summarizes the mineral occurrence potential and certainty level for each solid mineral resource described and discussed in this Report.

Table 5-3 Mineral Occurrence Potential and Certainty Level for Solid Minerals

Mineral	Mineral Occurrence Potential	Certainty Level
Coal	H	D
Trona	H	D
Sodium Brine	H	C
Oil Shale	H	D
Phosphate	ND	-
Uranium	M	C
Gold	L	B
Diamonds	L	B
Zeolite	H	D
Nephrite Jade	M	B
Titaniferous Sands	L	B
Sand and Gravel	H	D
Other Saleable Minerals	H	C

BLM Manual 3031 specifies the classification system to be used to determine mineral potential, and to rank the potential for presence or occurrence. It is not to be used to determine the potential for development or extraction of a given mineral resource. Based on the BLM classification system (BLM 1985), mineral potential classifications for pertinent mineral resources described above in the RSPA have been determined and are provided on applicable mineral resource maps (see Figures 5-1 through 5-8).

5.6.1 Leasable Solid Minerals

The primary markets for RSPA coal have been and continue to be the Jim Bridger power plant and other local industries. With these traditional markets coal production is expected to remain flat during the planning period. Under this scenario, mine expansions to maintain production levels as the existing mines are depleted would be accomplished through occasional lease modifications. However, the potential exists that Asian markets may open within the planning period for RSPA coal as one of the owners of the Black Butte mine is in the process of developing two new coal export facilities on the coasts of Washington and Oregon. If these or similar developments are successful, demand for Black Butte coal could increase with associated new leasing and mine expansion or new mine development.

While coal leasing is currently allowed on approximately 422,000 acres within the CODPA, where coal can be mined both by underground and surface mining methods, through the RMP scoping process, direct interest has been expressed for leasing deep coal (i.e. greater than 3000’ deep) outside of the CODPA.

The concept is to develop those coal resources though in-situ coal gasification technologies. If this development concept proves serious and moves forward, then additional leasing and coal development could potentially occur in new areas outside the CODPA during the planning period.

Although trona (soda ash) market demand decreased during the global economic slowdown starting in 2008, causing decreased prices and production, the global soda ash industry is showing positive signs of recovery. The 2010 production level at more than 16.5 million tons was up by more than 2 million tons over the 2009 level. In addition, several substantial soda ash price increases have already occurred in 2012. Along with the recovery has come interest by several producers in the possibility of future additional leasing adjacent to existing mines although no firm proposals have been submitted to date. It is expected that during the planning period, current mines or expansions to those mines could accommodate currently projected future demand increases and no new mines will be proposed. However, if the soda ash market undergoes a significant rebound during this time, the situation could change. In addition to new leasing to expand existing mines, new leasing and proposals for in situ recovery could be submitted for BLM consideration.

To date industry has shown very little interest in exploring for and developing sodium carbonate brines However, given the recovery of the soda ash industry, there is a moderate potential that new exploration operations could be proposed during the planning period.

The RSPA is underlain by extensive oil shale resources. However, higher quality resources in Colorado and Utah have been the focus of the companies involved in developing economic and environmentally sound technologies to extract the oil. Due to the low resource quality of Wyoming oil shale relative to that found in Colorado and Utah, these latter areas are expected to remain the focus of future research and development activities, as well as leasing, during the planning period. However, indications of interest in development on private lands north of Rock Springs could lead to interest in leasing on adjacent federal lands in Wyoming. The possibility of RSFO receiving a RD&D lease application during the planning period cannot be ruled out.

A phosphate-bearing formation underlies portions of the RSPA, however, the formation is buried deeply and no industry interest has been shown in developing the phosphate. There is little to no potential for developing phosphate in the RSPA during the planning period.

5.6.2 Locatable Minerals

Uranium and gold are the two locatable minerals that have commanded the greatest industry interest in the RSPA. Over the past year, uranium prices have dropped substantially and U.S production is down. The potential for uranium development is low and industry interest is expected to remain near or slightly above current levels.

Gold has received more recent interest than uranium However, despite a more than 100% rise in gold price over the last 4 years, the level of gold development activity in the RSPA has not increased dramatically in the same period. The development potential for gold is low and development activity is expected to remain at existing or slightly above for the planning period.

Diamonds and nephrite jade have received very limited interest. Potential for development of these minerals is very low and activity levels by collectors and hobbyists are expected to continue at current levels for the duration of the planning period.

Zeolites have been mined in the Fort LaClede area but the mine is not currently active. There are no active mining claims that have been located for zeolites and the potential for development is low during the planning period.

Geologic exploration for titaniferous sands occurred in the early to mid-20th century. However, there is no known development interest in the RSPA and the development potential for these occurrences is very low for the planning period.

5.6.3 Saleable Minerals

Demand for sand and gravel is expected to remain at or close to current moderate levels for the planning period. However, that demand is heavily dependent on construction and maintenance of roads for the oil and gas industry and an upswing in oil and gas development would increase demand for sand and gravel and development of new sources to replace depleting existing pits.

Demand for decorative and dimension stone is expected to remain at or close to current levels for the planning period and the potential for development of new sources is low.

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

BLM Manual 3060 (BLM 1994) requires that a mineral report prepared for use in a planning document should provide recommendations for further work, if necessary. Conclusions and recommendations relative to solid mineral resources in the RSPA are provided below. Recommendations relating to continued and future management of solid leasable, locatable and saleable mineral resources on federal lands within the planning area will also be developed during the resource management planning process.

6.1 CONCLUSIONS

1. Coal production in support of the Jim Bridger power plant is expected to continue at current levels for the planning period. However, if new access to Asian export markets opens up at facilities under development in the Northwest, both production and leasing could increase. Additionally, industry interest in developing deep coal resources for in situ coal gasification could result in leasing proposals in areas outside the CODPA not currently available for leasing.

2. Trona production is expected to continue at existing or somewhat higher levels. While no new mines are expected to be proposed and developed during the planning period, additional leasing and expansion of existing mines can be expected. In addition, if the soda ash recovery surges, new proposals for in situ recovery can be expected.

3. No commercial development of sodium carbonate brines is expected during the planning period but continued soda ash market recovery could result in new exploration and resource assessment activities during the next planning cycle.

4. No RD&D leasing or development of oil shale is expected during the planning period.

5. No exploration for or development of phosphate is expected to occur.

6. No commercial development of uranium or gold is expected to take place over the next planning cycle. Limited exploration for these minerals may occur on federal land.

7. No commercial development of diamonds or nephrite jade is expected to take place over the planning period and recreational and hobby collection is expected to continue at current levels.

8. No commercial development of REE is expected during the planning period. Limited exploration may occur on federal lands.

9. No development of titaniferous sands is expected to take place over the next planning cycle. Exploration, if it occurs, would be of limited extent.

10. Demand for sand and gravel, decorative stone and dimensions stone will remain steady to increasing over the planning period. Expansion of existing pits or development of new sand and gravel sources on federal lands is expected during the planning period due to depletion of existing pits.

6.2 RECOMMENDATIONS

1. Scoping comments indicate a strong interest in leasing deep coal resources outside of the CODPA for development of in situ coal gasification. Before a leasing proposal could be considered, RSFO would need to conduct the coal screening process in accordance with the regulations at 43 CFR Part 3420 and the BLM Land Use Planning Handbook H-1601-1, Appendix C. F.

2. Developing in situ coal gasification technology is expected to render coal resources previously inaccessible to conventional mining techniques available for economic development. The extent of deep coal resources outside the CODPA that may be developable by in situ technologies is not well documented or understood. A comprehensive study of oil and gas and other well logs and cores should be undertaken in the near future to assess the extent, quality, and nature of coal resources below 3,000 feet bgs throughout the RSPA for use in the evaluation of future potential leasing proposals and determinations of fair market value for competitive leasing.

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