BUREAU OF LAND MANAGEMENT
SOCORRO FIELD OFFICE
RESOURCE MANAGEMENT PLAN REVISION
AND ENVIRONMENTAL IMPACT STATEMENT

ENERGY AND MINERAL RESOURCE POTENTIAL REPORT

Prepared for:

U.S. Department of the Interior
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Prepared by:

URS Corporation

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LIST OF ACRONYMS

BLM	Bureau of Land Management
Btu	British thermal units
°C	degrees Centigrade
CBM	coalbed methane
CFR	Code of Federal Regulations
CO_2	carbon dioxide
CO_2/He	carbon dioxide/helium
DOE	U.S. Department of Energy
EIS	Environmental Impact Statement
EOI	Expression of Interest
°F	degrees Fahrenheit
FEMP	Federal Emergency Management Program
FLPMA	Federal Land Policy and Management Act
GSD	gross surface disturbance
HDR	hot dry rock
He	helium
KGRA	Known Geothermal Resource Area
kV	kilovolt
mcf	thousand cubic feet
MSHA	Mine Safety and Health Administration
NEPA	National Environmental Policy Act
NMBGMR	New Mexico Bureau of Geology and Mineral Resources
NMED	New Mexico Environment Department
NMEMNRD	New Mexico Energy, Minerals and Natural Resources Department
NMHD	New Mexico Highway Department
NREL	National Renewable Energy Laboratory
NSD	net surface disturbance
PI	Petroleum Information

REDTT	Rural Economic Development Through Tourism
RFD	Reasonable Foreseeable Development
RMFLF	Rocky Mountain Federal Leadership Forum
RMP	Resource Management Plan
RMPR	Resource Management Plan Revision
SMA	Special Management Areas
SRP	Salt River Project
SWTDI	Southwest Technology Development Institute
TAI	Thermal Alteration Index
USGS	U.S. Geological Survey
W/m^2	watts per square meter
$Wh/m^2/day$	watts-hours per square meter per day

EXECUTIVE SUMMARY

The Bureau of Land Management (BLM) Socorro Field Office is preparing a Resource Management Plan Revision (RMPR) and Environmental Impact Statement (EIS) for the public land within Socorro and Catron Counties, New Mexico. One goal of the RMPR/EIS is to assess current and future energy and mineral resource potential and update the existing Resource Management Plan in response to changing demands on development of those resources. The RMPR/EIS assesses energy and mineral potential within Socorro and Catron Counties, referred to as the Planning Area. This resource assessment consisted of collecting relevant information, researching published documents, and interviewing Federal, State, and industry experts on resources in the Planning Area to characterize the area geology, type and occurrence of each resource, resource potential, and reasonable foreseeable development of those energy and mineral resources. This report presents the results of the energy and mineral resource potential assessment.

Three distinct physiographic provinces have influenced the geologic history and rock types in the Planning Area. In northwestern Socorro and northern Catron Counties, thick sequences of Permian and Cretaceous marine and continental sedimentary rocks characterize the stable platform of the Colorado Plateau province. In east-central Socorro and southern Catron Counties, Pennsylvanian marine and Permian marine and continental sediments were uplifted and exposed in mountain ranges characteristic of the Basin and Range province. A Transitional province between the stable Colorado Plateau and the structurally complex Basin and Range provinces is characterized by large blocks of Colorado Plateau terrain separated from the craton by block-faulted grabens and basins. The Tertiary-age opening of the Rio Grande Rift through central New Mexico combined with Basin and Range extension to generate massive intrusives and volcanic activity through western Socorro County and much of Catron County. Tertiary alluvial sediments and volcanic plugs, flows, and ash-flow tuffs constitute most of the basin-fill material in the Transitional province.

Geologic conditions are suitable for the potential occurrence of leasable fluid minerals, which include energy minerals oil and gas, and nonenergy minerals carbon dioxide (CO_2) and helium. Mature and moderately mature petroleum source rocks are present in Pennsylvanian, Permian, and/or Cretaceous marine shales in structural basins in central, eastern and northern Socorro County and northern Catron County. Sandstones and limestones contain reservoir-quality porosity for fluid minerals to accumulate beneath structural and within stratigraphic traps. Although there has not been economic production, moderate oil and gas potential is mapped in the Chupadera Mesa, Albuquerque-Belen Basin, Acoma Basin, Zuni Basin, northern San Agustin Basin, Carrizozo Basin, and Jornada del Muerto Basin, where shows have been encountered in exploratory wells. There is significant interest in leasing State Trust Land and BLM-administered (public) land in northwest Catron County where there is high potential for occurrence of CO_2 and helium resources in and south of the Zuni Basin. There also is high potential for occurrence of CO_2 and helium resources in the Chupadera Mesa and Carrizozo Basin areas.

Recent mining and test burning have proven the potential for occurrence of leasable solid energy coal minerals in the Salt Lake coal field in northwest Catron County. Coal resource potential also exists in the Datil Mountains coal field and in three small fields in east-central Socorro County. The demand for coal to fuel power plants in the Southwest should increase the potential for mining in these coal fields. Economic development of coalbed methane resources in nearby San Juan Basin may generate interest in exploiting the extensive coalbed methane potential in similar Late Cretaceous coal-bearing formations in Socorro and northern Catron Counties.

Geothermal energy resource potential exists throughout most of the Planning Area. A high potential for occurrence exists for using low-temperature geothermal energy in one hydrothermal area west of Socorro and two hot springs areas in southern Catron County. Moderate potential for occurrence of geothermal energy resources is present west of the Rio Grande where several isolated locations for low-temperature geothermal energy have been mapped.

Solar and wind energy are renewable resources with high potential for occurrence in the Planning Area. With a climate and elevation ideal for exploiting solar energy resources, the Planning Area has high solar energy potential. Flat-plate collectors or solar concentrators could generate an average of at least 6,000 watt-hours per square meter of collector surface per day. Wind energy resource potential is concentrated in the upper elevations of mountain ranges. For commercial wind turbine application, the upper elevations of the Oscura, Magdalena, San Mateo, and Mogollon Mountains have high potential for converting wind energy into electricity. However, for small-scale and noncommercial applications, any area within the Planning Area is suitable for wind energy usage.

There are 33 mineral mining districts mapped in Socorro and Catron Counties. The types of mineral deposits in those districts include volcanic-epithermal, placer, vein, Precambrian vein/replacement, and alteration of sedimentary rocks. Past mining for metallic minerals has primarily produced gold, silver, copper, lead, manganese, zinc, tin, and uranium. None of those mines are active, but there is high potential for occurrence of those and other metallic mineral resources. Historical mining for nonmetallic minerals includes barite, fluorite, gemstones, kaolin, limestone, clay, zeolites, and perlite. Perlite still is being mined today. There is high potential for occurrence of those nonmetallic mineral resources in the Planning Area.

Salable mineral materials are found at rock outcrops and in extensive Quaternary deposits of alluvial sand and gravel, piedmont alluvium, colluvium, and eolian sand throughout the Planning Area. Pits, quarries, and prospects for salable minerals are mapped to show the potential for occurrence of salable mineral resources. Prospects for travertine, where used for building stone, are found in outcrops in northern Socorro and northwestern Catron Counties. These salable minerals have high potential for occurrence in the Planning Area.

1.0 INTRODUCTION

This report presents an assessment of the potential for occurrence and reasonable foreseeable development of energy and mineral resources in Socorro and Catron Counties, New Mexico, hereinafter referred to as the Planning Area.

It is useful to note that there are two terms used in this report to describe the areas addressed—Planning Area and Decision Area. The Planning Area encompasses the entirety of Socorro and Catron Counties regardless of jurisdiction or ownership. The Decision Area for the majority of resources or resource uses refers to public land (i.e., land administered by the Bureau of Land Management [BLM]) in Socorro and Catron Counties. However, in addressing Federal minerals and the decision on whether to lease or not to lease these minerals, BLM's Decision Area extends to split estate (areas where BLM administers Federal subsurface minerals, but the surface is owned by private or State entities). Federal energy and mineral resources in the Planning Area are managed by the BLM Socorro Field Office under a land use plan provided in the 1989 Resource Management Plan (RMP) (BLM 1989). In the years since the RMP was implemented, certain changes in BLM management policy and resource conditions have identified the need to revise the RMP. This energy and mineral resource assessment was completed for use in the RMP Revision as required by the Federal Land Policy and Management Act of 1976 and preparation of the Environmental Impact Statement as required by the National Environmental Policy Act.

This resource assessment consisted of reviewing published data, interviewing resource specialists and scientists having a working knowledge of the Planning Area, and selecting relevant data for use in the assessment. The assessment did not include field studies or original investigations of resource conditions. The assessment consisted of evaluating the areal and historical development of energy and mineral resources and preparing maps showing the location of existing resources and the potential for occurrence of those resources. Finally, the Reasonable Foreseeable Development (RFD) of each energy and mineral resource was assessed. The RFD is the professional opinion of the mineral report preparer based on the historic, current, and projected (15 years) demands and markets for those resources. The report will provide the BLM decision maker a better understanding of energy and mineral resources in the area such that the importance of those energy and mineral resources can be evaluated during future land use decisions.

1.1 DEFINITION OF ENERGY AND MINERAL RESOURCES

The BLM has established the following categories for energy and mineral resources on public lands:

- Leasable minerals – include fluid minerals such as oil, gas, coalbed methane, carbon dioxide (CO_2), and geothermal resources; and solid minerals such as coal, sodium, and potash. Although not a leasable mineral, helium is included in this category because it is associated with CO_2 exploration and development.
- Locatable minerals – include metallic minerals such as gold, silver, tin and uranium; and nonmetallic minerals such as gemstones, kaolin, and perlite.
- Salable minerals – include construction materials such as sand, gravel, limestone, cinders, and building stone.

Renewable energy sources such as wind and solar energy are included in this discussion because right-of-way permits may be obtained to construct collection facilities on public land.

1.2 GUIDANCE DOCUMENTS

This assessment was conducted at a level of detail in accordance with guidance provided in BLM Manual 3031 – Energy and Mineral Resource Assessment and BLM Handbook H-1624-1 – Planning for Fluid Mineral Resources. The potential for energy or mineral resources was predicted by collecting and evaluating available information for each resource in the area of interest. The potential is an assessment of the likelihood that a resource will occur in the area of interest based on the information available. The potential occurrence of the resource depends on whether the geologic or environmental conditions are present to increase the likelihood of the occurrence of the resource. The potential for the resource to occur does not take into account the likelihood that the resource will be developed or is economically exploitable.

The format for this report conforms to requirements for Mineral Assessment Reports outlined in Illustration 4 of BLM Manual 3060 – Mineral Reports-Preparation and Review. The report includes the following sections:

- Executive Summary for Managers
- Section 1: Introduction – this section lists the types of energy and mineral resources assessed in the report, and guidance documents that describe the methodology to be used for the resource assessment.
- Section 2: Description of Geology – this section includes discussions on physiography, lithology and stratigraphy, structural geology and tectonics, and historical geology.
- Section 3: Description of Energy and Mineral Resources – this section includes known leasable, locatable, and salable mineral deposits; known prospects, mineral occurrences, and mineralized areas; mining claims, leases, and material sites; types of mineral deposits in the area of interest; and mineral economics including strategic and critical minerals. This section includes separate subsections for coal, oil and gas, geothermal, CO_2 and helium, coalbed methane, metallic minerals, nonmetallic minerals/industrial minerals, and other resources such as wind and solar energy.
- Section 4: Potential for Occurrence of Mineral Resources – this section includes separate subsections for coal, oil and gas, geothermal, CO_2 and helium, coalbed methane, metallic minerals (including uranium), nonmetallic minerals/industrial minerals, salable minerals, and other resources such as wind and solar energy.
- Section 5: Reasonable Foreseeable Development – this section describes the RFD for the next 15 years including separate subsections for coal, oil and gas, geothermal, CO_2 and helium, coalbed methane, metallic minerals (including uranium), nonmetallic minerals/industrial minerals, salable minerals, and other resources such as wind and solar energy.
- Section 6: References and Selected Bibliography
- Tables, Figures, Maps, and Appendices

2.0 DESCRIPTION OF GEOLOGY

2.1 PHYSIOGRAPHY

New Mexico is unique in that four major physiographic provinces intersect within its boundaries—Colorado Plateau, Basin and Range, Southern Rocky Mountains, and Great Plains. As shown on Map 1, the area within Socorro and Catron Counties has characteristics of the Colorado Plateau and the Basin and Range physiographic provinces, and a so-called Transition province having characteristics intermediate between the Colorado Plateau and the Basin and Range provinces (Chamberlin and Cather 1994; Grant and Foster 1989). The intersection of these physiographic provinces has had a profound influence on the geomorphic features and geologic history of the Planning Area.

2.1.1 <u>Colorado Plateau Province</u>

The Colorado Plateau physiographic province occupies the northwestern corner of Socorro County and the northern half of Catron County. Distinctive characteristics of the Colorado Plateau include thick sequences of Paleozoic and Mesozoic sedimentary rocks, and a relatively stable cratonic platform having few significant tectonic features. In the Planning Area, Colorado Plateau sedimentary rocks of the Pennsylvanian and Permian ages are present, as are Triassic- and Cretaceous-age sedimentary rocks.

2.1.2 <u>Basin and Range Province</u>

The Basin and Range physiographic province occupies the majority of Socorro County and the southeastern corner of Catron County. The Basin and Range province is characterized by north-trending block-faulted mountain ranges separated by deep, alluvium-filled basins. The mountain ranges typically are composed of a Precambrian (Proterozoic) igneous or metamorphic core complex bounded by block-faulted and folded Paleozoic and Mesozoic sedimentary rocks. The deep basins generally contain Paleozoic and Mesozoic sedimentary rocks, formerly part of the Colorado Plateau, which were faulted and folded during the Tertiary, then overlain by Tertiary sedimentary and volcanic sequences that thicken to the west.

In the Planning Area, the Basin and Range province has been subjected to intense tectonic activity along the Rio Grande Rift that increased the geological complexity. The Rio Grande Rift is a major feature of the Basin and Range province. It is a north-trending block-faulted rift that effectively bisects New Mexico, separating the Colorado Plateau and Basin and Range provinces from the Great Plains province to the east. The Rio Grande Rift is characterized by deep, sediment-filled block-faulted grabens, uplifts that expose Precambrian basement rocks, and tilted block faults caused by crustal extension along the north-south rift trend. The northeast-southwest trending San Agustin Basin/Reserve graben trend separates stable blocks of Colorado Plateau sediments from the Colorado Plateau province (Chamberlin and Cather 1994).

2.1.3 <u>Transitional Province</u>

The Transitional province is present in the southwestern quarter of Catron County. The Transition province is a geologically complex area combining the characteristics of the Colorado Plateau and the Basin and Range provinces. The Transitional province is characterized by large, relatively stable blocks of Colorado Plateau sediments separated from the Colorado Plateau province by northeast-southwest trending block-faulted grabens, which are interpreted as an arm of the Rio Grande Rift (Chamberlin and Cather 1994).

2.2 ROCK UNITS

The lithology, areal extent, and thickness of the major rock types present in New Mexico are described by Grant and Foster (1989) in an introduction to their discussion of future petroleum provinces. A general stratigraphic chart for the Socorro region, prepared by Osburn and Lochman-Balk (1983), is presented on Figure 1. A geologic map of Catron and Socorro Counties prepared by the U.S. Geological Survey (USGS 1997) is provided on Map 2. An explanation of the symbols for the geologic formations shown on Map 2 is provided in Appendix A. It is useful to mention that the formation names for Figure 1 may not match those for Map 2 and Appendix A because the USGS geologic map includes formation names for age-correlative formations in other areas of New Mexico. Detailed lithologic descriptions were prepared by Osburn (1984) for a geologic map of Socorro County. A detailed geologic map has not been completed for Catron County. This report describes the rock types, areal extent, stratigraphic thicknesses, and general thickness trends for the Planning Area beginning with the oldest known rocks.

2.2.1 Precambrian (Proterozoic)

Precambrian rocks exposed in the Planning Area include granites, quartzites, gabbros, metasedimentary, and metavolcanics. In Socorro County, significant exposures of Precambrian rocks are found in the Ladron, Lemitar, Los Pinos, Magdalena, Mockingbird, Oscura, and Sierra Cuchillo Mountains; and in Socorro Peak (Osburn 1984). There are no reports of Precambrian rocks exposed in Catron County. Precambrian rocks typically host metallic and other locatable minerals and have been mined for gold, silver, gems, and other minerals at several locations in the Planning Area.

2.2.2 Cambrian – Ordovician

Sedimentary rocks of Cambrian through Ordovician age are exposed in the Mockingbird Mountains located in extreme southeastern Socorro County, where they are less than 250 feet thick (Grant and Foster 1989). These same rocks that are outcropping in the eastern San Mateo Mountains are less than 100 feet thick. Formations include the following:

- **Upper Cambrian-Lower Ordovician Bliss Formation** – a tightly cemented quartz sandstone containing glauconite, hematite, and feldspar that overlies the Precambrian basement.
- **Lower Ordovician El Paso Formation** – a limestone and dolomite of marine origin (Ellenburger equivalent) having intercrystalline and vuggy porosity.
- **Middle Ordovician Montoya Group** – units in this group include the basal Cable Canyon Sandstone overlain by vuggy dolomites of the Upham, Aleman, and Cutter Formations.

2.2.3 Silurian – Devonian

Sedimentary rocks of Silurian through Devonian age outcrop in the Sierra Cuchillo Mountains located in extreme southwestern Socorro County, where they are less than 50 feet thick. These sediments reportedly are present in the subsurface in southwestern Socorro County and extreme southern Catron County (Grant and Foster 1989). Formations include the following:

- **Silurian Fusselman Formation** – a porous, dark gray-brown cherty dolomite.
- **Late Devonian Percha Formation** – a greenish-black to black organic shale, possible source rock and a trapping seal for underlying reservoir rock such as the Fusselman Formation.

2.2.4 Mississippian

Rocks of Mississippian age are exposed in the Chupadera, Magdalena, and Ladron Mountains of Socorro County and generally are less than 100 feet thick (Grant and Foster 1989). No outcrops are reported in Catron County, although isopach maps show that subsurface Mississippian rocks may be greater than 100 feet thick in the southernmost part of that County. Formations include the following:

- **Lake Valley Formation** – a dark, argillaceous cherty limestone varying to a light gray crinoidal limestone; marine shelf deposits have possible source rock potential, but generally lack porosity. This unit is named the Caloso Formation in the Magdalena Mountains where it generally is mapped undifferentiated with Pennsylvanian rocks.

2.2.5 Pennsylvanian

The abundance of isolated outcrops of Pennsylvanian strata in New Mexico that resulted from the complex geological history of the region has led to a confusion of multiple names and descriptions for Pennsylvanian sediments that are difficult to correlate. Grant and Foster (1989) observed that extensive tectonism during the Pennsylvanian orogeny “resulted in the accumulation of a varied suite of rocks.” The variation in Pennsylvanian-age rocks is evident in the long list of Pennsylvanian formations that follows.

Sedimentary rocks of Pennsylvanian age are exposed in outcrop through northern and eastern Socorro County and have been penetrated by the drill bit in much of the Planning Area. Isopach maps of the Pennsylvanian System show a sedimentary sequence in the Rio Grande Rift ranging from 1,500 to more than 2,600 feet thick (Grant and Foster 1989). Compression toward the rift caused thrust faulting and thickening of the Pennsylvanian section in deep basins of central Socorro County. Uplift of the Zuni Massive resulted in thinning and nondeposition of Middle and Late Pennsylvanian sediments in the northern half of Catron County. Formations include the following:

- **Middle Pennsylvanian Sandia Formation** – sandstones, siltstones, and shales of marine origin with minor occurrences of sandy limestone; possible reservoir-quality porosity. The Sandia Formation is exposed in the Los Pinos, Magdalena, and Mockingbird Mountains. Isopach maps show the total Pennsylvanian System ranging from approximately 900 to more than 2,000 feet in those areas (Grant and Foster 1989).

- **Middle and Upper Pennsylvanian Madera Formation** – limestones, sandstones, siltstones, and shales of marine origin; possible reservoir-quality porosity. Outcrops are mapped in the Magdalena and Los Pinos Mountains.

- **Upper Pennsylvanian Lead Camp Limestone and Panther Seep Formation** – these undifferentiated units of marine limestone are located in the Mockingbird Mountains where the Pennsylvanian System has a combined thickness of approximately 2,200 feet (Grant and Foster 1989).

Undifferentiated Pennsylvanian rocks are mapped in several localities including the Magdalena and Lemitar Mountains, Socorro Peak, Joyita Hills, and east of the Oscura Mountains. These occurrences are not reported as formation names by Osburn (1984) or Grant and Foster (1989). As previously mentioned, Pennsylvanian rocks are mapped undifferentiated with Mississippian rocks at several locations in the Planning Area.

2.2.6 Permian

Rocks of Permian age are present in outcrops throughout northern and eastern Socorro County and are common throughout the Planning Area in subsurface rocks penetrated by the drill bit during oil and gas exploration. An isopach map of the Permian System shows sediment thicknesses ranging from 2,000 feet in eastern Socorro County and northern and southwestern Catron County to more than 3,000 feet in southwestern Socorro County and southeastern Catron County (Grant and Foster 1989). Formations include the following:

- **Upper Pennsylvanian - Lower Permian Bursum Formation** – dark, purplish red and green shales probably having low organic content, interbedded with nodular limestone; grading upward to reddish arkosic sandstones and conglomerates as the unit transitions from Pennsylvanian marine limestones and shales to Permian continental red beds (Butler 1996).

- **Lower Permian Abo Formation** – dark reddish-brown, fine-grained sandstones interbedded with siltstones and mudstones of continental origin. Locally this formation has low-permeability, reservoir-quality rock (Broadhead et al. 2002a).

- **Lower Permian Yeso Formation** – consists of four members that grade upward from a medium- to fine-grained sandstone (Meseta Blanco) to interbedded sandstone, shale, gypsum, and limestone (Torres) to gypsum limestone and siltstone (Canas) and back to a quartzose sandstone (Joyita). The Yeso is approximately 2,500 feet thick in northern Catron County and is known for reservoir-quality rock in other parts of New Mexico (Grant and Foster 1989).

- **Lower Permian Glorieta Formation** – a well-sorted, cross-bedded quartz sandstone that typically is 200 feet thick in the Planning Area and is reservoir-quality rock in other parts of New Mexico (Grant and Foster 1989).

- **Middle Permian San Andres Limestone** – a marine limestone that extends over much of eastern Socorro County at the surface and shallow subsurface. This unit has reservoir-quality porosity and is greater than 300 feet thick in the northern part of the Planning Area (Grant and Foster 1989).

2.2.7 Triassic

A northward-thickening wedge of Triassic-age rocks up to 1,000 feet thick are exposed in Socorro and northern Catron Counties, and they attain thicknesses greater than 250 feet in the subsurface of eastern Socorro County (Grant and Foster 1989). Formations include the following:

- **Upper Triassic Santa Rosa Sandstone –** a thin, coarse-grained conglomerate or conglomeratic sandstone that may be up to 100 feet thick. The Santa Rosa locally may contain reservoir-quality porosity, but probably is better known for deposits of uranium.

- **Upper Triassic Chinle Formation** – a gray to greenish-purple siltstone and mudstone containing thin beds of volcanic ash deposited in a continental environment. The Chinle is not noted for reservoir quality or source rock potential.

2.2.8 Jurassic

No Jurassic rocks have been mapped in the Planning Area.

2.2.9 Cretaceous

Rocks of Cretaceous age are exposed along the northern boundary of the Planning Area and in parts of eastern Socorro County, and attain subsurface thicknesses of up to 2,000 feet in western Socorro and north-central Catron Counties (Grant and Foster 1989). Cretaceous sediments generally thicken to the northeast. There are numerous Cretaceous formations that have been grouped into depositional packages associated with a series of transgressive-regressive marine shoreline features (Figure 2). Formations include the following:

- **Upper Cretaceous Dakota Formation** – a fine- to coarse-grained, cross-bedded sandstone of marine origin overlain by the Mancos Shale and the Tres Hermanos Formation. In Socorro County the Tres Hermanos consists of interbedded sandstone, siltstone, marine shale, and thin coal layers. The same sedimentary sequence is present in western Catron County, but is designated the Moreno Hill Formation. The sandstones have reservoir-quality porosity. The marine shales are good source rock for hydrocarbons (Broadhead et al. 1998). The coal layers may contain mineable exposures of coal as well as provide a source for coalbed methane (Brister and Hoffman 2002).

- **Upper Cretaceous Mesaverde Group** – this group includes the Gallup Sandstone, which is similar to the Dakota Formation, and a coal-bearing unit named the Crevasse Canyon Formation. This sequence thins to the west-southwest due to erosion and is absent in the western half of Catron County.

2.2.10 Tertiary

Outcrops of Tertiary-age rocks are extensive throughout the Planning Area. An isopach map of the Tertiary System is incomplete in western Catron County because of limited penetrations by the drill bit through a thick layer of volcanic rocks. The Tertiary rocks in west-central New Mexico are a complex suite of sedimentary and volcanic rocks with sequences up to 5,000 feet thick in the San Agustin Basin. In the Rio Grande Rift basins the Tertiary System can be greater than 2,500 feet thick (Grant and Foster 1989). Formations include the following:

- **Tertiary Intrusives** – these intrusive rocks include stocks and plutons of granite, monzonite, and rhyolite composition having various ages. In some localities the stock or pluton has been separated by lithology or by individual body and given a name (Grant and Foster 1989). The thickness of each intrusive generally is unknown unless investigated by drilling for mineral exploration. Tertiary intrusives can be associated with locatable mineral deposits.

- **Eocene Baca Formation** – consists of red to buff fine-grained sandstones and mudstones and minor conglomerates deposited in a lacustrine deltaic environment. Outcrops of Baca sediments are found in the Gallinas Mountains and Bear Mountains in Socorro County, and north and west of Quemado in Catron County. The Baca Formation is approximately 900 feet thick in the Gallinas Mountains area (Cather 1983). These thin-bedded rocks are not considered reservoir-quality or source rocks.

- **Tertiary Volcanics** – these extrusive rocks include lavas and tuffs of various ages ranging from Oligocene to Pleistocene. These rocks outcrop over western Socorro County and much of Catron County, and in the Mogollon-Datil Volcanic Field are often associated with cauldrons (Osburn and Chapin 1983). The volcanic rocks have been separated by age-dating and lithology into several correlative units including the Datil Group, a suite of unnamed ash-flow tuffs, and the

Santa Fe Group. The thickness of those units generally ranges from hundreds to more than 1,000 feet thick (Osburn and Chapin 1983).

- **Miocene-Pliocene Popotosa Formation** – a sequence of fanglomerates, sandstones, mudstones, and mudflow deposits locally interbedded with volcanic rocks. This formation interfingers regionally with piedmont-slope and alluvial fan deposits and is characteristic of bolson and playa deposits. The Popotosa Formation generally constitutes the beginning basin fill of the Rio Grande Rift, and can attain thicknesses of up to 3,000 feet (Osburn 1984).

- **Plio-Pleistocene Sierra Ladrones Formation** – a sequence of poorly indurated fanglomerates, intertonguing sandstones, siltstones, and mudstones locally interbedded with volcanic rocks. This formation consists primarily of piedmont-slope and coarse-grained fan deposits characteristic of alluvial fans and river sandstones within the Rio Grande Rift. The Sierra Ladrones Formation generally constitutes the basin fill of the Rio Grande Rift and can attain thicknesses of up to 1,000 feet (Osburn 1984).

2.2.11 Quaternary

Rocks of Quaternary age in the Planning Area are diverse, widespread, and have a range of thickness up to a few hundred feet. Quaternary deposits include alluvial and colluvial sands, silts, and gravels; piedmont slope and valley border fanglomerates grading from proximal bouldery alluvium to distal sand-silt-clay mixtures; basin floor playa and lacustrine mudstones and siltstones; fine-grained eolian sand sheets and dunes; terrace, valley fill, floodplain, and channel sand, silt and clay deposits along major streams; angular cobble- and boulder-size talus deposits; and basalt flows (Osburn 1984). Quaternary deposits locally may intertongue with Plio-Pleistocene Sierra Ladrones Formation deposits. The surface accumulation and local abundance of these sediments make them preferred sources for construction aggregate and other industrial materials.

2.3 STRUCTURAL GEOLOGY AND TECTONICS

The location of the Planning Area at the intersection of the Colorado Plateau, Basin and Range, and Transitional physiographic provinces has resulted in a complex structural regime (Butler 1996; Chamberlin and Cather 1994; Grant and Foster 1989). The structural geology is different for each province. Tectonic features in the Planning Area are shown on Map 1.

The northwestern part of the Planning Area is characterized by the Zuni and Lucero Uplifts that bound the Zuni and Acoma Basins on the relatively stable crust of the Colorado Plateau province. Those basins are relatively small, north-south trending structural lows on the stable platform (refer to Map 1).

The western two-thirds of Socorro County is in the Basin and Range province, but has been subjected to severe deformation by Cenozoic extensional tectonism associated with the Rio Grande Rift. The Rio Grande Rift was superimposed on a weakened crustal region of block faults and thrust faults that were active during Pennsylvanian-age tectonism. The rift is characterized by deep, asymmetric north-trending horsts, grabens, and half-grabens superimposed on the older structure (Butler 1996). The deep Jornada del Muerto and Carrizozo Basins, the shallow La Jencia and Socorro Basins, and the southern end of the Albuquerque-Belen Basin in Socorro County are all part of the extensional rift zone (refer to Map 1). Block-faulted, uplifted mountains are located on both sides of the Rio Grande Rift and expose Precambrian granite and metamorphic basement rocks near the center of the Oscura, Los Pinos, Chupadera, and Ladron Mountains.

The southwestern part of the Planning Area is a zone of transition between the stable Colorado Plateau and the block-faulted crust of the Basin and Range province. Here are isolated, stable blocks of Colorado Plateau crust separated by northeast-trending block-faulted graben features such as the Reserve Graben in southern Catron County (Chamberlin and Cather 1994). That graben and basin trend is considered an arm of the Rio Grande Rift. The Transitional province includes the Mogollon-Datil Volcanic Field, which is a major Cenozoic volcanic area. Extensional tectonics resulted in extensive Tertiary intrusives, and a large number of volcanic vents, flows, and other features occur in western Socorro County and through much of Catron County (refer to Map 2/Appendix A).

2.4 HISTORICAL GEOLOGY

The region within Socorro and Catron Counties has a complex geological history dominated by three tectonic events: formation of the Ancestral Rocky Mountains, the Laramide orogeny, and crustal extension and rifting in the Rio Grande valley.

2.4.1 Paleozoic

The Planning Area was part of a northeast-trending transcontinental arch during much of the early Paleozoic era. During Cambrian through Mississippian time, seas transgressed onto the relatively stable arch from the south and deposited limestones and some sandstones in the southern half of Socorro and Catron Counties.

Beginning in Early Pennsylvanian time, convergence of the North and South American tectonic plates resulted in intracrustal deformation that impacted the area and formed the ancestral Rocky Mountains (Butler 1996). Compressional tectonism resulted in eastward thrust faulting in central Socorro County, forming deep basins to the east. Rapid rise of the Zuni Uplift in Catron County and similar uplifts to the north, east, and south exposed basement rock and formed basin features between the uplifts. The exposed basement provided Middle and Late Pennsylvanian clastic sediments that filled the adjoining basins. As the tectonic activity subsided, erosion of the uplifts continued into the Permian. Thick sequences of continental red bed sandstones and shales were deposited in the basins. The red beds were overlain by a transgressional sequence of Permian restricted-shelf evaporites, dolomites and sands, followed by nearshore and shelf sandstones and marine limestones.

2.4.2 Mesozoic

During the Triassic and Jurassic, the area was an exposed erosional surface being weathered from highlands to interior lowlands and coastal plains (Butler 1996). Cretaceous rifting at the beginning of the Laramide orogeny began to open the Gulf of Mexico, and by the Late Cretaceous, an interior seaway had submerged much of New Mexico. The shoreline of the interior seaway regressed to the northeast and transgressed to the southwest over much of New Mexico, which changed the depositional environment from nonmarine to marine. Five transgressive-regressive cycles are recognized in New Mexico. The two oldest cycles deposited a thick sequence of Late Cretaceous marine sands and shales, shoreline and fluvial clastics, and thin beds of coal across the Planning Area as the seas transgressed and regressed from the northeast to the southwest (Grant and Foster 1989).

2.4.3 Tertiary

Continuation of the Laramide orogeny into the early Tertiary initiated a new episode of uplift and basin formation in the region. The faulted Pennsylvanian basins and overthrusts were reactivated by compression from the southwest to create uplifts of Precambrian basement rock (Butler 1996). These uplifts formed the Oscura, Ladron, Magdalena, and Lemitar Mountains. Erosion of these uplifted mountains deposited alluvial fan gravels and fluvial-deltaic clastics into the continental basins. Early to Middle Tertiary plutonic rocks were intruded through much of the area (Butler 1996).

Oligocene extensional basin and range tectonics and the opening of the Rio Grande Rift from south to north formed a series of north-trending block-faulted basins in Socorro County. The southwest-trending San Agustin Basin and Reserve Graben in Catron County are considered an arm of the rift system. Those basins and grabens were filled with continental deposits: alluvial fan gravels and sands; fluvial sands, silts and clay; and Tertiary volcanics. Miocene to Pliocene volcanism caused by crustal extension deposited large volumes of ash-flow tuffs and basalts in the grabens and basins of the rift system (McMillan 1998).

Small isolated or enclosed basins were locations for deposition of lacustrine siltstones and mudstones such as the Eocene Baca Formation in the San Agustin Basin (Cather 1983).

2.4.4 Quaternary

Erosion of the highlands and deposition in the intermontane basins continued into the Quaternary. Continent-derived sediments include alluvial and colluvial sand and gravel deposits, fluvial sediments, basin-floor and piedmont-slope sediments, and localized fine-grained eolian sands or lacustrine silts and muds. The predominantly alluvial sediments may intertongue with an occasional basalt flow or cinder deposit (Osburn 1984).

3.0 DESCRIPTION OF ENERGY AND MINERAL RESOURCES

There are three basic types of Federal minerals on public lands: locatable, leasable, and salable. These minerals have been defined by Federal laws, regulations, and legal decisions (Bureau of Land Management [BLM] 1997).

Leasable minerals discussed in this section include the following:

- Nonrenewable energy fluid minerals – oil and natural gas (gas), including natural gas from coalbeds (coalbed methane [CBM]), and geothermal
- Nonrenewable solid energy minerals – coal
- Nonrenewable nonenergy fluid minerals – carbon dioxide ($CO_{2)}$ and helium

Although not leasable, renewable solar and wind energy resources are discussed here because right-of-way permits may be obtained to construct renewable energy collection facilities on public land. Helium typically is associated with CO_2 gas and for the purposes of this report the two gases are considered one resource; however, helium is developed under extraction and sales contracts between the developer and the BLM instead of sales royalties under standard oil and gas leases.

Locatable mineral resources discussed in this section include the following:

- Metallic minerals – e.g., gold, silver, uranium
- Nonmetallic minerals – e.g., gemstones, fluorspar, perlite

Salable mineral resources discussed in this section include sand, gravel, limestone, cinders, and building stone.

The resource discussions include known prospects, mineral occurrences, and mineralized areas; mining claims, leases, and material sites; types of mineral deposits in the area of interest; and mineral economics, which include strategic and critical minerals.

3.1 LEASABLE MINERALS

Leasable minerals are fluid or solid minerals that can be developed on public land after obtaining a lease from BLM. Leasable fluid minerals include oil, gas, geothermal, and CO_2. Leasable solid minerals include coal, potash, sulfur, and sodium. Leasing of public land for mineral development may be accomplished by competitive bid, as typically is the case for oil and gas. A lease sale may be initiated by an Expression of Interest (EOI) nomination, wherein an interested party nominates a parcel for exploration and development. If there is no interest in the competitive lease of a parcel, the interested party may obtain a noncompetitive lease. Leasing of coal in New Mexico is by the Lease by Application procedure.

A successful lessee for oil and gas leases is required to pay rent on the leased parcel. Rental costs range from $1.50 per acre per year for the first five years to $2.00 per acre per year for the last five years. Competitive bonus bids are determined by oral auction on a per-acre basis, and range from approximately $1.00 per acre for a parcel having little or no competitive interest up to $10.00 per acre for a parcel having high competitive interest. The lessee also is required to pay royalties on the sale of mineral resources produced from the leased parcel. Oil and gas royalties are 12.5 percent of sales. Royalty payments are paid to the U.S. General Revenue Fund.

Coal lease sales are by sealed competitive bid, with the winning bid being the highest one that meets or exceeds the "fair market value" established prior to the bid and kept confidential by the BLM. For coal leases, rental costs are $3.00 per acre per year. Coal royalties are 12.5 percent for surface-mined coal and 8 percent for coal extracted from the subsurface. Royalty payments are paid to the U.S. General Revenue Fund.

3.1.1 <u>Oil and Gas</u>

Oil and gas are nonrenewable energy fluid mineral resources that typically are discovered and exploited by drilling exploratory and development wells into oil- and/or gas-bearing sedimentary rocks. Sedimentary rocks that have reservoir-quality porosity are proximal to petroleum source rocks, such as organic-rich shale or coal, and have formed a structural or stratigraphic trap that may accumulate oil and/or gas. From the early 1920s to the present there have been 45 exploratory wells drilled in Socorro County and 40 exploratory wells drilled in Catron County (New Mexico Energy, Minerals and Natural Resources Department [NMEMNRD] 2002; Petroleum Information [PI]/Dwights 2002). Those well locations are shown on Map 3 and listed in Table 1. Although there have been shows of oil and gas reported in several of those wells in each county, there has been no economic production to date.

CBM is a nonrenewable leasable energy fluid mineral resource. Approximately 5.5 percent of domestic natural gas in the United States is produced from coal-bearing geologic formations by tapping into porous rock that has trapped the methane generated in coalbeds (Rice et al. 2002). Prolific production of CBM in the San Juan Basin of New Mexico and in other coal-bearing regions of the United States has stimulated interest in this nonrenewable leasable energy resource. CBM is discovered and developed by drilling a well through the coal-bearing formation and completing the well in coal seams or other gas-bearing reservoir rocks. Typical CBM production requires removing the formation fluids (dewatering) to reduce the pressure within the coal seam, which then releases the gas within the coalbed. Late Cretaceous coal-bearing rocks in the Planning Area are potential targets for development of CBM.

3.1.1.1 Known Occurrences and Prospects

Oil and gas exploration has been conducted in several basin plays (prospects) within the Planning Area since the 1920s. Seventeen wells were drilled in the 1920s and 1930s, 24 wells in the 1940s through 1960s, 21 wells in the 1970s, 9 wells in the 1980s, 8 wells in the 1990s, and 6 wells in the 2000s (NMEMNRD 2002; PI/Dwights 2002).

Chupadera Mesa – This basin in eastern Socorro County first was tested for oil and gas in the 1920s. Oil and/or gas shows were encountered in four wells drilled during the 1950s and 1960s, and two wells tested oil and/or gas shows in the 1970s (Broadhead 1983). Two wells were drilled at Chupadera Mesa in the early 1990s, and the Mountain States-Chupadera No.1 had a gas show. Shows were present in lower Pennsylvanian sands and/or fractured Precambrian basement (Broadhead et al. 2002a).

Carrizozo Basin – Within the past six years, two wells were drilled in the Carrizozo Basin east of Chupadera Mesa. The Carrizozo Basin is a deep "elevator basin" reported to contain mature Permian and Pennsylvanian sediments (Broadhead 2001). The Manzano Oil-Cathead Mesa No.1 drilled a horst structure and had a gas show in Precambrian basement, and recently was re-entered and deepened by Primero. That well had shows of methane, nitrogen, CO_2 and helium, and a completion attempt has been reported (Johnson 2002). The Primero Operating-Jackson Ranch Federal No.1 in adjacent Lincoln County reportedly contains mature source rock (Geochem 1999).

Albuquerque-Belen Basin – In the late 1930s to 1940s, six wells were drilled in the Albuquerque-Belen Basin in northern Socorro County, three of which had oil shows. Sporadic drilling activity since the late 1970s chased oil shows reported in previous exploration wells (Broadhead 1983). The Belen Oil-Seidle No.1 had a deep oil show in an unreported formation. Three wells drilled since 1996 have tested Tertiary sediments with no shows reported, although one well was abandoned temporarily and one attempted a completion. There have been many oil and gas shows in Cretaceous rocks in the Albuquerque Basin north of Socorro County (Black 1982). A deep test in the Albuquerque-Belen Basin reportedly is underway at this time (Johnson 2002).

Socorro Basin, San Marcial Basin, and La Jencia Basin – Three wells were drilled in the Socorro Basin during the 1920s and 1930s and reported oil and/or gas shows. No exploration has occurred in that basin or the adjacent basins since. These basins are in the Rio Grande Rift and the structural complexity, depth of suitable reservoir rock, and possible release of hydrocarbons along faults and fractures may be a deterrent to exploration.

Jornada del Muerto Basin – Three dry holes were drilled in this basin: one in 1948, one in 1955, and one in 1989. The lack of exploration in this basin may be due to the absence of suitable structural or stratigraphic traps. In addition, the White Sands Missile Range occupies a large portion of the basin and is excluded from exploration.

Acoma Basin – This basin in northwestern Socorro and northeastern Catron Counties has been extensively tested by the drill bit since the 1920s. Shows of oil were reported from the Cretaceous Dakota Formation in two wells: Red Feather Oil-Cow Springs No.2 in 1926, and Spanel & Heinze-Santa Fe No.1-9609 in 1959. Shows of oil and gas were reported in 1959 from the Permian San Andres Formation in Spanel & Heinze-Santa Fe No.1-9617 (Broadhead and Black 1989; Foster 1964). Those wells were drilled in the 1950s. However, no shows were reported in seven wells drilled between 1978 and 1987.

Zuni Uplift – In the western end of the Zuni Uplift in Catron County, two wells drilled during the 1930s reported oil and gas shows in Cretaceous rocks. Three wells drilled in this basin during the 1920s and 1930s had oil and/or gas shows. Four dry holes were drilled in the 1970s. Exploration activity by Shell Oil Company and others in central Catron County during the 1980s tested the Zuni Uplift (Shell’s “Magic” area) and the western San Agustin Basin. Oil and gas shows were reported from the Permian San Andres Formation in the Hunt Oil-State No.1, and thin beds of thermally mature Permian source rocks were encountered (Broadhead 1994). The Shell Western-SWEPI State No.1 reported CO_2 from two drill stem tests of the Permian Yeso Formation (Johnson 2002). The results from the Shell well indicated there is CO_2 and possibly helium potential in this area (refer to Section 3.1.2).

Zuni Basin – Six wells drilled in the Zuni Basin during the 1950s through the 1970s tested that area and no shows were reported (PI/Dwights 2002). However, oil and gas shows have been reported in the adjacent Holbrook Basin in Arizona (Heylmun 1997). The region in and south of the Zuni Basin has tested producible quantities of CO_2 and helium, which are discussed in Section 3.1.2.

San Agustin Basin – The Sun Oil-San Agustin No.1 well drilled in this basin during 1966 encountered gas shows. One dry hole was drilled in 1977. The Pennsylvanian and Cretaceous sections contain possible petroleum source rocks (Broadhead et al. 2002a). There is high potential for occurrence of CO_2 and helium resources in and south of the Zuni Basin. CBM resources generally are located sufficiently downdip from outcrops of coal resources and coal fields in Socorro and Catron Counties such that overlying rocks provide the pressure to trap CBM within the coal-bearing formation (Map 4). Coal resources are discussed in Section 3.1.3. These coals generally are too deep to mine and therefore are valuable for the generation of methane gas only. There is currently no known CBM activity in the Planning Area. Prospective areas for CBM development are shown on Map 4 and discussed below.

Catron County has two known occurrences of coal resources: Salt Lake coal field and the Datil Mountains coal field. Coal-bearing units are found in the Late Cretaceous Moreno Hill Formation. Coal seams average 5 feet thick and can be up to 14 feet thick. Outcrops of the Moreno Hill Formation form an arcuate belt open to the west that is centered around Zuni Salt Lake. Coalbeds dip to the southeast at 3 to 5 degrees. Faulting has caused minor displacement of coal-bearing units in parts of the field. Prospects for CBM development are located south and east of the delineation of the Salt Lake coal field. The southern limit of the prospect is uncertain but generally would conform to the basal Tertiary erosional unconformity (Broadhead et al. 2002a) (refer to Map 4).

In the Datil Mountains coal field, coal-bearing units are found in the Late Cretaceous Tres Hermanos and Crevasse Canyon Formations. Coalbeds average less than 3 feet thick and can be up to 7 feet thick. Faulting and folding have affected the lateral continuity of the beds, and the coal field has been impacted by several Tertiary intrusive bodies. Prospects for CBM development are located south and east of the delineation of the Datil Mountains coal field. The southern limit of the prospect is uncertain but generally would conform to the basal Tertiary erosional unconformity (Broadhead et al. 2002a). The eastern limit would correspond to the boundary between the Colorado Plateau and Rio Grande Rift provinces (refer to Map 4).

The Jornada del Muerto coal field contains coal-bearing units found in Late Cretaceous Mesaverde Group sedimentary rocks. Coalbeds typically are less than 3 feet thick. The coal-bearing units dip steeply to the west and west-southwest at 24 to 45 degrees. The section also is faulted such that displacement of the coal seams has affected mining activity. Prospects for CBM development are located west of the outcrop of Mesaverde Group rocks. The westward extent of the prospect is unknown due to lack of subsurface information, but CBM potential may exist in large portions of the Jornada del Muerto Basin containing Cretaceous strata.

In the Carthage coal field, coal-bearing units are found in the Late Cretaceous Mesaverde Group. Coalbeds range from 4 to 7 feet thick. Faulting has divided the field into small blocks that disrupt the lateral continuity of the beds. The dip direction of the coalbeds is south to southwest in the southern part of the Carthage coal field (Erdmann 1941). Prospects for CBM development probably are located west and southwest of the outcrop. The subsurface extent of the prospect is unknown due to lack of information.

An unnamed outcrop of coalbeds is located near La Joya in the Sevilleta National Wildlife Refuge in northeastern Socorro County (refer to Map 4). Coal-bearing units are found in the Late Cretaceous Tres Hermanos and Crevasse Canyon Formations. Prospects for development of that resource are unknown.

3.1.1.2 Leasing Activity

Regulations applicable to oil and gas leasing on Federal land in the Planning Area include the Mineral Leasing Act of 1920, the Mineral Leasing Act of 1947, Mining and Minerals Policy Act of 1970, Federal Onshore Oil and Gas Leasing Reform Act of 1987, and 43 Code of Federal Regulations (CFR) 3100 – Oil and Gas Leasing. Regulations specific to BLM include BLM Manual 1601 – Land Use Planning, BLM Manual Section 1624-2 – Supplemental Program Guidance for Fluid Minerals, and BLM Manual Series 3100 – Onshore Oil and Gas Leasing.

Leasing of Federal minerals for exploration and development of oil and gas is stimulated by the submittal to the New Mexico State Office of the BLM of an EOI. The EOI is an informal nomination by an interested entity, such as an energy company, to request that certain lands be included in a competitive lease sale. BLM administers competitive lease sales, which are held on a quarterly schedule following public notification of the sale. Permitting for oil and gas exploration and drilling within the State is administered by the New Mexico Oil Conservation Division.

Current oil and gas leasing activity in the Planning Area includes EOIs for parcels in both counties. Those lease nominations are pending and have not yet been offered for sale (Stephens 2003). Active leasing is reported on State land in the Jornada del Muerto Basin near Bingham. In eastern Socorro County, leasing of fee (private) land for oil and gas exploration is currently active in the Chupadera Mesa-Carrizozo Basin area. Fee leasing and drilling activity is ongoing in the Albuquerque-Belen Basin in northern Socorro County (Johnson 2002).

Much of the State and public land in the northwestern corner of Catron County has been leased. Leases of public land are pending in and around the Zuni Basin for CO_2 and helium exploration and development (Stephens 2003).

Regulations applicable to CBM leasing on public land in the Planning Area include the Mineral Leasing Act of 1947, Mining and Minerals Policy Act of 1970, Federal Onshore Oil and Gas Leasing Reform Act of 1987, and 43 CFR 3100 – Oil and Gas Leasing. Regulations specific to BLM include BLM Manual 1601 – Land Use Planning, BLM Manual Section 1624-2 – Supplemental Program Guidance for Fluid Minerals, and BLM Manual Series 3100 – Onshore Oil and Gas Leasing.

Leasing of Federal lands for exploration and development of CBM is stimulated by the submittal to the New Mexico State Office of the BLM of an EOI. The EOI is an informal nomination by an interested entity, such as an energy company, to request that certain lands be included in a competitive lease sale. BLM administers competitive lease sales, which are held on a quarterly schedule following public notification of the sale. Permitting for CBM exploration and drilling within the State is administered by the New Mexico Oil Conservation Division. There is no reported leasing activity for CBM in the Planning Area.

3.1.1.3 Mineralized Areas and Types

For the purposes of this report, oil and gas mineralized areas are characterized as plays or geologic basins having reported oil and/or gas shows in exploration wells; or evidence for, or reports of encountering and testing thermally mature or moderately mature petroleum source rock. The oil and gas potential for mineralized areas in the Planning Area is shown on Map 3.

Socorro County – Oil and/or gas shows reported in exploration wells characterize the Chupadera Mesa, Carrizozo Basin, Albuquerque Basin, and Acoma Basin plays as mineralized for oil and/or gas.

The San Marcial Basin that extends south into Sierra County has not been tested by the drill bit. However, a hydrocarbon source rock evaluation was completed on drill cuttings from the Getty Oil-West Elephant Butte Federal 7 No. 1 well, located in section 7, T. 12 S., R. 4 W., Sierra County, which is 13 miles south of the Socorro County line. Samples from that well tested for a Thermal Alteration Index (TAI) of 2.9 or greater, and indicated thermal maturity for oil in Pennsylvanian and Mississippian sediments (Muckelroy et al. 1983). The prevalence of volcanic activity in the San Marcial Basin, as well as in the adjacent La Jencia and Socorro Basins, may have overcooked the petroleum source rocks and destroyed oil and gas potential, or possibly generated CO_2 that diluted hydrocarbons (Broadhead et al. 2002a).

There is no information to characterize mineralization in the Jornada del Muerto Basin. However, gas shows in the adjacent Chupadera Mesa, and the presence of coal in the Jornada del Muerto coal field and the nearby Carthage coal field, suggest that there is potential for gas mineralization in the basin. The extent of the Cretaceous coal deposits is unknown due to lack of subsurface information, but CBM potential may exist in large portions of the Jornada del Muerto Basin where Cretaceous strata are present in the subsurface.

Catron County – Oil and/or gas shows reported in exploration wells characterize the Acoma Basin, San Agustin Basin, and eastern Zuni Basin plays as mineralized for oil and/or gas. There is no information documenting oil and/or gas mineralization in the western part of the Zuni Basin, but shows have been reported in the Holbrook Basin to the west. The Zuni Basin area has tested for CO_2 and helium mineralization (refer to Section 3.1.2). Areas south of the Zuni Basin and west of the San Agustin Basin have not been tested. It is suspected that organic-rich source rocks beneath the thick volcanic sequences of the Mogollon-Datil Volcanic Field locally have been thermally altered to maturity by volcanic intrusives, and may have oil and/or gas potential in selected areas (Broadhead 1994). There is evidence for this locally enhanced mineralization in the Hunt Oil-State No.1-16 well located in the northern San Agustin Basin.

CBM mineralized areas are correlative with the known occurrences and prospects downdip from coal-bearing outcrops. In some cases, the target coal-bearing formations can be subdivided into members containing one or more individual coal seams. However, there are insufficient subsurface data to refine the lateral extent and thickness of individual coal seams in the mineralized areas.

To define the mineralized type of CBM resources, the mineralized areas must be evaluated for their potential to produce CBM. Based on detailed research of CBM occurrence and development in the San Juan Basin, the following five characteristics that relate to controls on the occurrence or productivity of CBM are recognized (Ayers and Kaiser 1994):

- Tectonic setting, including regional tectonic controls on depositional systems and coalbed attitude (strike and dip)
- Depositional setting, including structural controls to deposition, lateral and vertical relationships of coal-bearing formations, net thicknesses, number of coal seams, etc.
- Fracture patterns, including lineament analysis and cleat trends
- Hydrology, to understand and predict regional hydrodynamics
- Coal rank, gas composition, and thermal maturity, to understand coalbed gas content and composition

These geologic and hydrologic characteristics were studied and the results integrated to determine the distribution of mineralized types for the Fruitland Formation in the San Juan Basin. The study used approximately 2,500 well logs, computer-generated cross sections, isopach maps, and depositional system analysis (Ayers et al. 1994; Kaiser and Ayers 1994). The successful production of CBM in the San Juan Basin suggests that coal fields having similar mineralized types or characteristics may realize comparable productivity (Broadhead et al. 2002b). Using the Fruitland Formation as a model, the geologic and hydrologic characteristics of other CBM prospect areas can be studied and the results integrated to determine the mineralized types present in those prospect areas.

A comprehensive evaluation of CBM mineralized types in the Planning Area has not been conducted, and is outside the scope of this report. However, based on the limited information available for the coal fields in Socorro and Catron Counties, and by comparison to the known characteristics of the Fruitland Formation, gross estimates of the CBM mineralized type for each prospect area have been completed. The characteristics used to evaluate CBM, and estimates of the CBM mineralized type, are summarized in Table 2.

3.1.1.4 Mineral Economics

Exploration for oil and gas is a high-risk venture requiring large, up-front capital expenditures for leasing prospects, drilling and testing, production, and transportation pipelines (Brister and Price 2002). The level of risk is weighed against the current market value of oil (in dollars per barrel) and gas (in dollars per million British thermal units [Btu]). When market prices are high, the level of risk may be lowered enough that oil companies will drill new or more risky exploration plays. The lack of success and the limited understanding of oil maturation, migration, and accumulation in the existing plays in Socorro and Catron Counties present a high level of risk under current market conditions. If market demands for oil and/or gas change substantially, more exploratory drilling activity could be expected in the Planning Area.

Development of CBM resources is a relatively new venture. Resource characterization and exploitation methods are being refined and applied in several CBM resource areas. The economics of CBM development must consider several factors, including the availability of large acreage for leasing, coal rank and thermal maturity, net coal thickness, formation depth, fracture potential, optimal drilling technology, and disposal of produced water. The limited knowledge of some of those factors in the CBM prospects in Socorro and Catron Counties presents a relatively moderate level of risk under current market conditions. However, with increasing demand for natural gas supplies, and innovative methods, an aggressive exploitation of CBM resources could occur in the Planning Area.

Oil, gas, and CBM exploration and development provide economic benefits to Federal, State, and local governments as well as to the public. Annual lease rent and royalties on sales of mineral resources generate considerable revenue to the general fund of the surface owner. The local economy also benefits through additional jobs and purchase of goods and services such as food, lodging, and supplies by oil field contracting companies and personnel. The State realizes additional revenue from taxes on those sales. The above benefits have a net positive impact on the State and local economy.

3.1.2 Carbon Dioxide and Helium

CO_2 and helium (CO_2/He) are nonrenewable nonenergy fluid mineral resources typically discovered by exploratory oil and gas wells that encounter natural gas or nonflammable gas. Helium typically is associated with CO_2 gas and for the purposes of this report the two gases are considered one resource. If CO_2/He can be economically separated, collected, and delivered to a market, then a CO_2/He gas field is developed. From the early 1920s to the present there have been 45 exploratory oil and gas wells drilled in Socorro County and 40 exploratory oil and gas wells drilled in Catron County (Map 5). Economic amounts of CO_2/He have been discovered in five wells, and gas shows that may contain CO_2/He have been reported in 11 wells (Table 3).

3.1.2.1 Known Occurrences and Prospects

Oil and gas exploration has occurred in several basin plays (prospects) within the Planning Area since the 1920s. Seventeen wells were drilled in the 1920s and 1930s, 24 wells in the 1940s through 1960s, 21 wells in the 1970s, 9 wells in the 1980s, 8 wells in the 1990s, and 6 wells in the 2000s (NMEMNRD 2002; PI/Dwights 2002) (refer to Map 5). Although CO_2/He were not primary targets for exploration until the late 1990s, several wells reported shows of CO_2/He in gas analysis reports (Johnson 2002).

Chupadera Mesa – This basin in eastern Socorro County first was tested for oil and gas in the 1920s. Gas shows were encountered in two wells drilled during the 1950s and 1960s, and two wells tested gas shows in the 1970s (Broadhead 1983). Two wells were drilled at Chupadera Mesa in the early 1990s. The Mountain States-Chupadera No.1 had gas shows present in lower Pennsylvanian sands and/or fractured Precambrian basement (Broadhead et al. 2002a). The gas shows were not tested for helium (Johnson 2002).

Carrizozo Basin – Within the past six years, two wells were drilled in the Carrizozo Basin east of Chupadera Mesa. The Carrizozo Basin is a deep "elevator basin" reported to contain mature Permian and Pennsylvanian sediments (Broadhead 2001). The Manzano Oil-Cathead Mesa No.1 drilled a horst structure and had a gas show in Precambrian basement, and recently was re-entered and deepened by Primero. That well had shows of methane, nitrogen, CO_2, and helium, and a completion attempt has been reported (Johnson 2002). Primero also drilled the Dulce Draw No.1 in this basin and reported CO_2/He shows.

Albuquerque-Belen Basin – In the late 1930s to 1940s, four wells were drilled in the Albuquerque-Belen Basin in northern Socorro County, none of which had gas shows. Sporadic drilling activity since the late 1970s resulted in two more dry holes (Broadhead 1983). Three wells drilled since 1996 have tested Tertiary sediments with no shows reported, although one well was abandoned temporarily and one attempted a completion. There have been many gas shows in Cretaceous rocks in the Albuquerque Basin north of Socorro County with no reports of CO_2/He present (Black 1982). A deep test in the Albuquerque-Belen Basin is reportedly underway at this time (Johnson 2002).

Socorro Basin, San Marcial Basin, and La Jencia Basin – Three wells were drilled in the Socorro Basin during the 1920s and 1930s and the Arnold-Apache No.2 reported gas shows. There is no information that CO_2/He was present in the gas. No exploration has occurred in that basin or the adjacent basins since. These basins are in the Rio Grande Rift and the structural complexity, depth of suitable reservoir rock, and possible release of hydrocarbons along faults and fractures may be a deterrent to exploration.

Jornada del Muerto Basin – Three dry holes were drilled in this basin: one in 1948, one in 1955, and one in 1989. The lack of exploration in this basin may be due to the absence of suitable structural or stratigraphic traps. In addition, the White Sands Missile Range occupies a large portion of the basin and is excluded from exploration.

Acoma Basin – This basin in northwestern Socorro and northeastern Catron Counties has been extensively tested by the drill bit since the 1920s. Gas shows were reported in 1959 from Precambrian rocks in the JTB Oil-Santa Fe Pacific No.1 (Broadhead and Black 1989). No gas shows were reported in seven wells drilled between 1978 and 1987. However, in the Acoma Basin in adjacent Cibola County (T. 7 N., R. 7 W.), Sun Oil Company reported CO_2/He in gas recovered from a drill-stem test. The results from the Sun Oil Company well indicate there is CO_2 and possibly helium potential in this area (Broadhead et al. 2002b).

Zuni Uplift – In the western end of the Zuni Uplift in Catron County, five wells were drilled during the 1920s and 1930s and one reportedly had a gas show in an unknown formation. Four dry holes were drilled in the 1950s through the 1970s. Exploration activity by Shell Oil Company and others in central Catron County during the 1980s tested the Zuni Uplift (Shell's "Magic" area) and the western San Agustin Basin. Gas shows were reported from the Permian San Andres Formation in the Hunt Oil-State No.1 well, and thin beds of thermally mature Permian source rocks were encountered (Broadhead 1994). The Shell Western-SWEPI State No.1 reported CO_2 from two drill stem tests of the Permian Yeso Formation (Johnson 2002). The results from the Shell Oil Company well indicate there is CO_2 and possibly helium potential in this area (Broadhead et al. 2002b).

Zuni Basin – Six wells drilled in the Zuni Basin during the 1950s through the 1970s tested that area and no shows were reported (PI/Dwights 2002). The region in and adjacent to the southwestern end of the Zuni Basin on the Arizona-New Mexico border has shown significant CO_2/He activity (refer to Map 5). This play by Ridgeway Arizona Oil Corporation (Ridgeway) is an extension of the St. Johns CO_2 play begun in the eastern Holbrook Basin of Arizona (refer to Map 5). Five wells have tested producible quantities of CO_2/He (refer to Table 3).

San Agustin Basin – The Sun Oil-San Agustin No.1 well drilled in this basin during 1966 encountered gas shows. One dry hole was drilled in 1977. Broadhead et al. (2002a) suggests that volcanic activity in the vicinity of this basin may have "cooked" the source rock and rendered any hydrocarbons overmature and not likely to generate oil and gas. However, reservoir-quality rock in this basin may have been charged by volcanic gases sourced in the upper mantle (Staudacher 1987).

3.1.2.2 Leasing Activity

Regulations applicable to CO_2 leasing in the Planning Area include the Mineral Leasing Act of 1920, Mineral Leasing Act of 1947, Mining and Minerals Policy Act of 1970,and Federal Onshore Oil and Gas Leasing Reform Act of 1987. Regulations specific to BLM include BLM Manual 1601 – Land Use Planning, BLM Manual Section 1624-2 – Supplemental Program Guidance for Fluid Minerals, and BLM Manual Series 3100 – Onshore Oil and Gas Leasing.

Exploration and development for CO_2 is conducted under standard oil and gas leasing procedures. Leasing is stimulated by the submittal to the New Mexico State Office of the BLM of an EOI. The EOI is an informal nomination by an interested entity, such as an energy company, to request that certain lands be included in a competitive lease sale. BLM administers competitive lease sales, which are held on a quarterly schedule following public notification of the sale. Permitting for CO_2 exploration and drilling within the State is administered by the New Mexico Oil Conservation Division.

In eastern Socorro County, leasing for oil and gas exploration currently is active in the Chupadera Mesa-Carrizozo Basin area. Active leasing also is reported on State Trust Land in the Jornada del Muerto Basin near Bingham. Leasing and drilling activity is ongoing in the Albuquerque-Belen Basin in northern Socorro County (Johnson 2002).

In Catron County, there is leasing activity in the Zuni Basin area specifically targeting CO_2 exploration and development (Johnson 2002).

Although helium is an important component of CO_2 gas it is not a leasable mineral. Helium is developed under extraction and sales contracts between the developer and the BLM instead of sales royalties under standard oil and gas leases.

3.1.2.3 Mineralized Areas and Types

For the purposes of this report, CO_2/He mineralized areas are characterized as plays or geologic basins having reported CO_2/He or undifferentiated gas shows in exploration wells (refer to Map 5). Potential CO_2/He mineralized areas also may include basins near volcanic activity where reservoir-quality rock has been charged by volcanic gases sourced in the upper mantle.

Socorro County – Gas shows reported in exploration wells characterize the Chupadera Mesa, Carrizozo Basin, and Acoma Basin plays as mineralized for CO_2/He (refer to Map 5).

There is no information to characterize CO_2/He mineralization in the Jornada del Muerto Basin. However, gas shows in the adjacent Chupadera Mesa, and the presence of coal in the Jornada del Muerto coal field and the nearby Carthage coal field, suggest that there is potential for gas mineralization in the basin.

Catron County – CO_2/He shows reported in exploration wells characterize the Acoma Basin, San Agustin Basin, and Zuni Basin plays as mineralized for oil and/or gas. There is information from adjacent Cibola County that supports CO_2/He mineralization in the Acoma Basin. Areas south of the Zuni Basin and west of the San Agustin Basin have not been tested. It is anticipated the thick volcanic sequences of the Mogollon-Datil Volcanic Field locally may have charged reservoir-quality sediments with CO_2 gas in the northern San Agustin Basin as far east as the Rio Grande Rift (Broadhead et al. 2002a).

3.1.2.4 Mineral Economics

The current market demand for CO_2/He favors the development of those resources in the Planning Area. Helium currently sells for $52.50 per thousand cubic feet (mcf) and CO_2 sells for $0.75 per mcf (Ridgeway 2003).

The large proven reserves of CO_2 in western Catron County are well-suited for use in enhanced oil recovery programs at depleted oil fields in California and Texas. The limiting factor to development of those resources is the construction of pipelines to deliver CO_2 to the user. Ridgeway is actively negotiating delivery contracts that will support the construction of a CO_2/He processing plant in eastern Arizona and a CO_2 pipeline to California (Ridgeway 2003). The processing plant will extract and collect helium before the CO_2 enters the pipeline. It is anticipated that this activity will stimulate exploration and development of CO_2/He resources in the Planning Area.

CO_2 exploration and development provides economic benefits to Federal, State, and local governments as well as to the public. Annual lease rent and royalties on sales of mineral resources generate considerable revenue to the surface owner. The local economy also benefits through additional jobs and purchase of goods and services such as food, lodging and supplies by contracting companies and personnel. The State realizes additional revenue from taxes on those sales. The above benefits have a net positive impact on the State and local economy.
The Helium Privatization Act of 1996 directed that the Federal government no longer pay for the extraction and storage of helium for national security. With this artificial demand for helium closed, and declines in production from the largest helium gas fields in Kansas and Texas, the helium supply will decrease (Gage and Driskill 2001). Helium demand will continue to increase for a multitude of industrial applications, and this impetus to develop new reserves could result in more drilling activity in the Planning Area.

Helium is an important component of CO_2 production. It is separated at a processing plant and sold separately from the CO_2. Revenue generated by helium development and sales are negotiated through contracts directly with the surface owner instead of through royalties. The local economy also benefits through additional jobs and purchase of goods and services such as food, lodging and supplies by contracting companies and personnel. The State realizes additional revenue from taxes on those sales. These benefits have a net positive impact on the State and local economy.

3.1.3 Coal

Coal is a nonrenewable, leasable, solid energy mineral resource. Coal resources typically are exposed in outcrops of coal-bearing sedimentary formations. Locations where coal resources occur and can be mined are designated as coal fields. Coal fields are present in Late Cretaceous sedimentary rock in both Socorro and Catron Counties (refer to Map 4).

3.1.3.1 Known Occurrences and Prospects

Catron County has two known occurrences of coal resources: Salt Lake coal field and the Datil Mountains coal field. The Salt Lake coal field covers approximately 120,000 acres in the northwestern corner of the County, and the field extends north into Cibola County. Coal-bearing units are found in the Late Cretaceous Moreno Hill Formation. Coal seams average 5 feet thick and can be up to 14 feet thick. Outcrops of the Moreno Hill Formation form an arcuate belt open to the west that is centered around Zuni Salt Lake. Coalbeds dip to the southeast at 3 to 5 degrees. Faulting has caused minor displacement of coal-bearing units in parts of the field. Mining in the coal field was conducted by the Phoenix-based utility Salt River Project (SRP) in 1987 for a test burn at its Coronado Generating Station in Arizona. Approximately 100 short tons of coal were extracted from the Fence Lake mine located in the field (Hoffman 2002a).

The Datil Mountains coal field covers approximately 202,000 acres in northwestern Socorro and northeastern Catron Counties. This field also extends north into Cibola County. Coal-bearing units are found in the Late Cretaceous Tres Hermanos and Crevasse Canyon Formations. Coalbeds average less than 3 feet thick and can be up to 7 feet thick. Faulting and folding have affected the lateral continuity of the beds, and the field has been impacted by several Tertiary intrusive bodies. Several old mines reportedly operated in the field, but the mines are abandoned and information on production is limited (Hoffman 2002a).

The Jornada del Muerto coal field covers approximately 11,900 acres in east-central Socorro County. Coal-bearing units are found in the Late Cretaceous Mesaverde Group. Coalbeds typically are less than 3 feet thick. The coal-bearing units dip steeply to the west and west-southwest at 24 to 45 degrees. The section also is faulted such that displacement of the coal seams has affected mining activity. Two small mines reportedly operated in the field, but there is no information on production (Tabet 1979).

The Carthage coal field covers approximately 5,700 acres in east-central Socorro County and is located approximately 6 miles southwest of the center of the Jornada del Muerto coal field. Coal-bearing units are found in the Late Cretaceous Mesaverde Group. Coalbeds range from 4 to 7 feet thick. Faulting has divided the field into small blocks that disrupt the lateral continuity of the beds, which increases mining expenses (Osburn 1983). The field reportedly was mined economically through the early 1900s, but since 1950 mining has been intermittent and of a small scale (Hoffman 2002a).

An outcrop of coalbeds is located near La Joya in the Sevilleta National Wildlife Refuge in northeastern Socorro County (refer to Map 4). This coal field covers approximately 5,700 acres in east-central Socorro

County. Coal-bearing units are found in the Late Cretaceous Tres Hermanos and Crevasse Canyon Formations. There is no information that the La Joya area was mined for coal.

3.1.3.2 Leasing Activity

Regulations applicable to leasing of Federal coal minerals in the Planning Area include the Mineral Leasing Act of 1947 and Federal Coal Leasing Amendments Acts of 1976, and 43CFR 3400. Regulations specific to BLM include BLM Manual 1601 – Land Use Planning and BLM Manual Series 3400 – Federal Coal Leasing.

Exploration for coal on Federal lands is conducted using an "exploration license" obtained from the BLM. Following exploration activities, which delineate the coal reserves present in an exploration area, coal land can be leased by submitting a "Lease by Application" to the BLM. The coal land can be leased following public notification of the sale. If other parties express an interest in the coal land, then the land is leased by competitive bidding. Permits for coal mining are administered by the New Mexico Mining and Minerals Division, which regulates coal mining in the State.

SRP has leased 18,000 acres of State and Federal land for its Fence Lake Mine in the Salt Lake coal field. Reserves are estimated at 120 millionshort tons (Hoffman 2002a). The State issued a mining permit to SRP, but SRP decided to obtain coal from a source outside the Planning Area (Salt River Project 2003).

No other leasing activity is reported for coal resources in the Planning Area.

3.1.3.3 Mineralized Areas and Types

Mineralized areas are correlative with the known occurrences and prospects of coal-bearing formations discussed above. In some cases, the coal-bearing formations can be subdivided into members containing one or more individual coal seams. However, there are insufficient subsurface data to refine the lateral extent and thickness of individual coal seams in the mineralized areas.

To define the mineralized type of coal resources, coal types can be classified by the quality (or grade) of coal in the seam. Coal grades range from high-quality anthracite, to moderate-quality bituminous, to low-quality lignite. Coal grades in the Planning Area are in the bituminous to sub-bituminous range. The quality of coal also can be measured by its burn effectiveness, called Calorific value (measured in Btu per pound); percent moisture; and the percentage of undesirable by-products of combustion, such as ash and sulfur. The best quality coals have a high Calorific value and low percentages of ash and sulfur. Coal grades and laboratory analyses that characterize the average quality of coal in each coal field are presented in Table 4.

3.1.3.4 Mineral Economics

There is a steady market for coal resources in the southwestern United States because several electric power companies operate coal-fired power plants in remote areas of New Mexico and Arizona. Profitable mining of coal depends on many factors, including proximity of the coal resource to existing or proposed power plants, the mode of transporting coal to the power plant, coal field leasing costs, estimated volume of coal reserves, and coal quality (Hoffman 2002b). The quality of coal in the Planning Area coal fields is suitable for use in power plants, as shown by the tests of coal from the Fence Lake Mine. Mining costs are an uncertain variable because the geologic conditions at a coal field can impact mining costs. Economical mining of coal depends in part on the thickness, lateral extent, and number of coal seams; the amount of overburden that must be removed; the amount of waste rock between coal seams; and the geologic structure of the field, such as bed dips or faulting that can displace the coal seam beyond the range of mining equipment. The continuing demand for coal in the Southwest may stimulate more leasing activity in the Planning Area coal fields.

Development of coal resources provides economic benefits to Federal, State, and local governments as well as to the public. Annual lease rent and royalties on the sale of coal generates considerable revenue to the general fund of the surface owner. The local economy also benefits through additional jobs and purchase of goods and services such as food, lodging, and supplies by mining companies and personnel. The State realizes additional revenue from taxes on those sales. The above benefits have a net positive impact on the State and local economy.

3.1.4 Geothermal

Geothermal resources are nonrenewable leasable energy fluid resources with a history of successful application in New Mexico. Sources of geothermal energy include artesian hot springs and wells that tap into groundwater or dry rock at elevated temperatures resulting from high heat flow gradients in the subsurface. New sources of geothermal energy have been discovered by drilling exploratory wells in areas of known or suspected high temperature gradients, or by coincidence during drilling for water resources. There currently are 16 geothermal resource locations in Socorro County and 23 geothermal resource locations in Catron County (Map 6). Current uses in New Mexico include residential and commercial space heating, greenhousing, aquaculture, crop and food processing, and heated swimming pools and spas. Geothermal resources in the Planning Area are not applicable for power generation because the temperatures are not high enough to produce steam (Witcher 1995).

3.1.4.1 Known Occurrences and Prospects

Information on the known occurrences of geothermal energy resources in the Planning Area are available in the Geothermal Resource Data Base for New Mexico prepared by the Southwest Technology Development Institute (SWTDI) at New Mexico State University (Witcher 1995). The database reports sites with measured temperatures greater than 30 degrees Centigrade (ºC)/86 degrees Fahrenheit (ºF). The geothermal energy resources are presented in Table 5, and the reference numbers listed on those tables correspond to the site locations posted on Map 6.

Geothermal energy resources in Socorro County range in temperature from 24.0 to 42.2 ºC (75.2 to 107.9 ºF). Eleven of the 16 known occurrences are at isolated locations within the County (refer to Map 6). The remaining five reported geothermal energy resources are clustered in a Known Geothermal Resource Area (KGRA) west of Socorro (U.S. Department of Energy [DOE] 2003). The hydrogeothermal regime in that area has been extensively studied (Barroll 1989). None of the geothermal energy resources in Socorro County have been developed.

Geothermal energy resources in Catron County range from 26.0 to 64.8 ºC (78.8 to 148.6 ºF). Six of the 23 known occurrences are at isolated locations within the county (refer to Map 6). The remaining 17 reported geothermal energy resources are located in two KGRA, as follows:

- There are 12 reported locations along the Middle Fork of the Gila River in extreme southeastern Catron County, near the Gila Cliff Dwellings National Monument. Ten of those locations are hot springs or seeps; the remaining two are wells drilled to 182 meters (600 feet). Most of the hot springs have been incorporated into resort or spa facilities (Rural Economic Development Through Tourism [REDTT] 2002).

- There are five reported hot spring locations along the San Francisco River in the southwestern part of the County south of Glenwood. The hot springs have been incorporated into resort or spa facilities (REDTT 2002; DOE 2003).

3.1.4.2 Leasing Activity

Regulations applicable to geothermal leasing of Federal minerals in the Planning Area include the Mineral Leasing Act of 1920, Mineral Leasing Act of 1947, Mining and Minerals Policy Act of 1970, Geothermal Steam Act of 1970, and 43 CFR 3200. Regulations specific to BLM include BLM Manual 1601 – Land Use Planning, BLM Manual Section 1624-2 – Supplemental Program Guidance for Fluid Minerals, and BLM Manual Series 3200 – Geothermal Resource Leasing.

Leasing of public land for geothermal exploration and development is noncompetitive unless the land is within a KGRA. A noncompetitive lease pays $1.00 per acre and is generally limited to a 640- to 2,560-acre lease. Competitive or KGRA lease sales are by sealed bid following a sale notice. The BLM will establish "fair market value" as a minimum bid for the lease acreage. Leases are held for a 10-year term, or longer if proven commercially productive. Royalties range from 10 to 15 percent of commercial energy production, and 5 percent of byproduct sales, such as produced minerals and demineralized water.

Leasing for geothermal exploration and development on Forest Service land is through a permit process in accordance with Forest Service Manual 2821. Permitting for geothermal exploration and drilling within the State is administered by the New Mexico Oil Conservation Division.

There is no reported leasing or development activity for geothermal energy resources in the Planning Area. There are two locations in the Planning Area where geothermal leases have expired: the KGRA east of Socorro, and an area adjacent to the north and west sides of the San Mateo Mountains that extends from Socorro County into Catron County (DOE 2003). SWTDI has identified eight locations in New Mexico as priority sites for geothermal resource utilization (Witcher 1995). None of those locations are in or near the Planning Area.

3.1.4.3 Mineralized Areas and Types

For the purposes of this report, a geothermal energy mineralized area refers to an area characterized by known occurrences of geothermal energy resources, or where geologic conditions are conducive for generating geothermal gradients that could develop into a geothermal energy resource. Geothermal energy mineralized areas include the known occurrences described above.

Geothermal energy resource mineralized types can be classified by the temperature range, fluid phase, and geologic setting.

Temperature – Mineralized types based on temperature range are as follows (SWTDI 1999):

- Low-temperature resources – less than 90 ºC (194 ºF)
- Moderate-temperature resources – range from 90 to 150 ºC (194 to 302 ºF)
- High-temperature resources – greater than 150 ºC (302 ºF)

Geologic Setting – The temperature of the resource is dependent on the geologic setting, or tectonic diversity, in the resource area. The tectonic diversity includes the geologic structure, geologic history, hydrology, topography, climate, and rocks characteristic of the physiographic province. Mineralized types based on geologic setting include the following (SWTDI 1999):

- Magma or magmatic resources –have magma as the direct heat source

- Convective resources –have deep-circulating groundwater that flows to the surface and produce thermal gradients greater than the normal 1.8 to 3.6 ºC per 100 meters (1 to 2 ºF per 100 feet)

- Conductive resources – confined hot water aquifers or hot rock at a depth associated with a normal thermal gradient

- Geopressured resources – have highly pressured hot brines with dissolved methane

Fluid Phase – The fluid phase produced by the geothermal energy resource also helps define the mineralized type, including the following:

- Liquid-dominated resources – have water or a combination of steam and water
- Vapor-dominated resources – have only steam
- Hot dry rock (HDR) resources – have only hot, deep-seated rock

The preceding categories were used to identify the mineralized type for each geothermal energy resource listed in Table 5. The mineralized type, if known, is included in that table. It is important to note that all geothermal energy resources in the Planning Area are low-temperature and liquid-dominated.

3.1.4.4 Mineral Economics

With a geologic terrain known to produce low-temperature geothermal energy resources throughout the Planning Area, conditions are favorable for exploitation of the known occurrences and exploration for new resources (Witcher 2002). Low-temperature resources are best suited for heating needs, but insufficient for generating electricity. Exploitation likely will be focused on local heating needs where geothermal resources are available. Exploration and development of more significant commercial resources may be limited by the expense of drilling and completing wells to tap into the conductive geothermal resources beneath the Planning Area.

Geothermal exploration and development provide economic benefits to Federal, State, and local governments as well as to the public. Annual lease rent and royalties on sales of geothermal resources may generate limited revenue to the general fund of the surface owner. The local economy also may benefit through additional jobs and purchase of goods and services such as food, lodging, and supplies by geothermal contracting companies and personnel. Development of low-temperature geothermal resources for space heating, aquaculture, or spas will generate revenue through sales of those products. The State realizes additional revenue from taxes on those sales. The above benefits have a net positive impact on the state and local economy.

3.1.5 Solar Energy

A recent report prepared by DOE in cooperation with the BLM identified the Planning Area as having a large total land area for high-potential concentrating solar power and/or photovoltaic sites (DOE 2003).

Solar energy is a renewable energy resource that has excellent potential for generating electricity in Socorro and Catron Counties. Installation of solar energy facilities on public lands requires a right-of-way permit instead of a lease. Rental costs may range from $1,000 per year or more depending on the permitted acreage.

Electricity is generated when sunlight contacts a photovoltaic cell that transforms solar energy to electricity. Solar energy resources are classified based on the amount of solar radiation that contacts the ground surface in a specified area. Solar radiation is measured in units of watt-hours per square meter per day (Wh/m^2/day). The amount of solar energy resource available at a specific location varies with the latitude of that location, the season, and the time of day. Annual average solar radiation for the United States is shown in Map 7.

3.1.5.1 Known Occurrences and Prospects

The solar energy resource map on Map 7 was prepared by the DOE National Renewable Energy Laboratory (NREL) (DOE 2001a, 2003). The map shows known occurrences of solar energy resources in the United States. The annual average solar radiation in New Mexico is relatively uniform at 6,000 to 7,000 Wh/m^2/day. In addition to varying by latitude, season, and time of day, the amount of solar radiation available at known occurrences of solar energy resources is dependent on the type of collector used. The two basic designs of solar collectors are flat-plate collectors and solar concentrators.

The flat-plate collector is a fixed panel containing photovoltaic cells or solar water heaters. The flat-plate panels collect sunlight and convert it to electricity or heat. The flat panel is installed where no obstructions will block sunlight from reaching the panel. A flat-plate collector generally receives the most sun when it is tilted towards the south at an angle equal to the latitude of the location. The solar energy resource available to a flat-plate collector is shown on Map 8.

The solar concentrator is a flat panel of photovoltaic cells or a concave arrangement of mirrors that concentrate sunlight onto a collector. The concentrator is attached to a motor-driven tracking mechanism. It is installed where no obstructions will block sunlight from reaching the concentrator, and uses the tracking mechanism to follow the sun as it crosses the sky each day. The tracking mechanism adjusts for seasonal variations in the Sun’s azimuth and allows the solar concentrator to collect the maximum amount of direct sunlight. The solar concentrator is more effective at collecting solar radiation than the flat-plate collector. The solar energy resource available to a solar concentrator is shown on Map 8.

Commercial solar generating stations have been constructed and operated in other states, particularly in desert locations. Existing solar array technology can place approximately 125 to 150 kilowatts of photovoltaic cells per acre. Such an array will generate 250 to 300 megawatt-hours of electricity per year (Arizona Public Service 2002; GlobalSolar 2002).

3.1.5.2 Leasing Activity

Regulations applicable to solar arrays on public lands in the Planning Area include the Federal Land Policy and Management Act of 1976 and 43 CFR 2800 – Public Lands: Interior: Rights of Way, Principles and Procedures. Regulations specific to BLM include BLM Manual 1601 – Land Use Planning and BLM Manual 2801 – Rights-of-Way.

There is no established guidance for procedures to install solar energy arrays on BLM-administered land. However, it is anticipated that use of BLM-administered land must be authorized by application for a right-of-way permit at the appropriate BLM Field Office in accordance with BLM Instruction Memorandum No. 2002-011. If land use planning has identified a specific area for competitive leasing, or sufficient interest is recognized for a specific area, then competitive leasing may be required for a right-of-way permit.

There is no reported permitting activity on public lands for the testing or exploitation of commercial-scale solar resources in the Planning Area.

3.1.5.3 Prospective Areas and Types

For the purposes of this report, a solar energy prospective area refers to a solar energy resource area characterized by the amount of solar radiation collectable by the two types of collectors described above. The solar energy resources in the Planning Area are considered adequate for generating electricity using photovoltaic cells (DOE 2001a, 2003).

Based on the use of flat-plate collectors to generate electricity, the entire Planning Area is considered a solar energy resource area. The solar energy resource for a flat-plate collector ranges from 6,000 to 6,500 $Wh/m^2/day$.

Based on the use of solar concentrators to generate electricity, the entire Planning Area is considered a solar energy resource area. The solar energy resource for a solar concentrator ranges from 6,500 to 7,000 $Wh/m^2/day$.

3.1.5.4 Mineral Economics

As shown above, solar energy is a viable resource throughout the Planning Area. However, current costs to generate electricity using solar energy are more expensive, generally 25 to 50 cents per kilowatt-hour, and not competitive with conventional generation methods (Federal Energy Management Program [FEMP] 2003). Development of solar energy resources requires capital expenditures for research to develop efficient solar collectors and energy storage facilities, leasing of suitable land for siting commercial size collection systems, and construction of power transmission lines to the customer or to an existing power network (Wentz 2002).

Research and development to design efficient solar collection systems continues to progress with funding by the energy industry and DOE. In fact, Congress is planning to increase levels of funding for research on renewable energy resources to help reduce dependence on foreign oil imports. The New Mexico Energy Conservation and Management Division continues to develop projects that use solar energy resources (Pfeil 2001). As more efficient solar collectors are developed, and with possible government subsidies or tax breaks for clean energy sources, the incentive for using solar energy resources should increase (New Mexico Environment Department [NMED] 2000).

Development of renewable solar energy resources provides economic benefits to Federal, State, and local governments as well as to the public. Annual rent for right-of-way permits and annual rent for commercial production of solar energy will generate revenue to the surface owner. The local economy also may benefit through additional jobs and purchase of goods and services such as food, lodging, and supplies by commercial solar energy companies and personnel. The State realizes additional revenue from taxes on those sales. The above benefits have a net positive impact on the State and local economy.

3.1.6 Wind Energy

Wind energy is a renewable energy resource that has excellent potential for generating electricity. Wind resources are classified based on the typical wind speed measured at a location or area. The wind power classification developed by the NREL establishes seven wind classes based on the wind power density at a height of 50 meters, measured in W/m^2. Wind power classes range from lowest (Class 1) to highest (Class 7). Wind power is considered economic for large turbines (utilities-scale) at Class 3 and higher, although a small turbine can be used at Class 1. Wind resources for New Mexico are shown on Map 9. Installation of wind energy facilities on public lands requires a right-of-way permit instead of a lease. Rental costs may range from $50 per tower or installation up to $1,000 per year or more depending on the permitted acreage.

3.1.6.1 Known Occurrences and Prospects

Map 9 was prepared by the DOE NREL (DOE 2001b). The map shows that there are four wind power classes available in the Planning Area: Class 4, Class 3, Class 2, and Class 1. Values are estimates of wind power at ridge crest locations where the local relief is greater than 1,000 feet. The areas having the highest wind power class correspond to areas of higher elevation and higher relief as well as higher wind velocity. The locations for each wind power class in the Planning Area are as follows:

- **Class 4** – includes the Oscura Mountains in southeastern Socorro County, which jut up from the flat Jornada del Muerto and Tularosa Valley; and the peak elevations in the Magdalena, Mogollon, and San Mateo Mountains. Wind energy resources range from 400 to 500 W/m^2 at a turbine elevation of 50 meters (165 feet).

- **Class 3** – includes the upper elevations of the San Mateo and Magdalena Mountains in southwestern Socorro County. This class includes the upper elevations of the mountain ranges in central and southern Catron County that follow the general trend of the continental divide, including the Gallo, Tularosa, and Mogollon Mountains, and the Black Range. Those ranges are within the Apache and Gila National Forests. Wind energy resources range from 300 to 400 W/m^2 at a turbine elevation of 50 meters.

- **Class 2** – includes the lower elevations of the mountain ranges in central and southern Catron County that follow the general trend of the continental divide including the Gallo, Tularosa, and Mogollon Mountains, and the Black Range. This class includes the lower elevations of the San Mateo and Magdalena Mountains in southwestern Socorro County, and the upper elevations of lesser mountains in eastern Socorro County and throughout Catron County. Wind energy resources range from 200 to 300 W/m^2 at a turbine elevation of 50 meters.

- **Class 1** – includes the low-lying areas west of the Rio Grande River in Socorro and Catron Counties, and the relatively flat mesas and valleys east of the Rio Grande, including the Jornada del Muerto, Tularosa Valley, and Chupadera Mesa. Wind energy resources are less than 200 W/m^2 at a turbine elevation of 50 meters.

Commercial wind generating facilities are operating in other states. The San Gorgonio Pass wind resource area near Palm Springs, California has more than 1,500 wind turbine towers that can generate in excess of 588 megawatts. That resource area has an electricity output of more than 805 kilowatt-hours (American Wind Energy Association 2002). One wind turbine tower occupies approximately one acre of land and can generate 100 to more than several hundred kilowatts depending on the size of the turbine. In addition, most of the ground surface around the towers may be available for other uses, such as farming or grazing.

3.1.6.2 Leasing Activity

Regulations applicable to wind farms on public lands in the Planning Area include the Federal Land Policy and Management Act of 1976 and 43 CFR 2800 – Public Lands: Interior: Rights of Way, Principles and Procedures. Regulations specific to BLM include BLM Manual 1601 – Land Use Planning, BLM Manual 2801 – Rights-of-Way, and BLM Instruction Memorandum No. 2002-020 – Interim Wind Energy Development Policy.

Wind energy site testing, monitoring, and development on BLM-administered land is authorized by application for a right-of-way permit at the appropriate BLM Field Office. If land use planning has identified a specific area for competitive leasing, or sufficient interest is recognized for a specific area, then competitive leasing may be required for a right-of-way permit.

At this time, there are no monitoring sites, commercial operations, or permitting activity reported in the Planning Area. Two commercial wind turbines are operated by Sandia National Laboratory at a site near Clovis, New Mexico (DOE 2001c). Wind energy still is in the research stage in New Mexico. Resource assessments are in progress to identify sites for commercial development (Pfeil 2001).

3.1.6.3 Prospective Areas and Types

For the purposes of this report, a wind energy prospective area refers to a wind energy resource area as characterized by the wind power class ratings described above. Areas of Class 3 or greater are considered usable for generating wind power with large turbines (DOE 2001b). Based on the nonindustrial use of small turbines to generate electricity, the entire Planning Area is considered a wind resource area. Based on the industrial use of large turbines to generate electricity, there are two wind energy resource areas in the Planning Area, as follows:

- The Class 4 wind energy resource area in the Oscura Mountains of southeastern Socorro County and the peak elevations of the Magdalena, Mogollon, and San Mateo Mountains.

- The Class 3 wind energy resource area incorporated in the upper elevations of the mountains of southern Catron County that generally correspond to the continental divide, and the upper elevations of the Magdalena, Mogollon and San Mateo Mountains.

3.1.6.4 Mineral Economics

As shown above, the Planning Area has several areas where wind energy resources can be exploited. Current costs to generate electricity using wind energy range from 4 to 30 cents per kilowatt-hour depending on the size of the wind turbines and the grid setup of the wind farm (FEMP 2003). Development of wind energy resources requires capital expenditures for research to develop efficient wind turbines, turbine and grid design and construction, purchasing or leasing of suitable land for siting wind turbines, siting studies, and construction of power transmission lines to the customer or to an existing power network (Wentz 2002). Research and development to design efficient turbines continues to progress with funding by the energy industry and DOE. In fact, Congress is planning to increase levels of funding for research on renewable energy resources to help reduce our dependence on foreign oil imports (Pfeil 2001). As more efficient and low-cost turbines come on the market, and with possible government subsidies or tax breaks for clean energy sources, the incentive to construct and operate wind energy generating facilities will become competitive with conventional power generating facilities (NMED 2000).

Development of renewable wind energy resources provides economic benefits to Federal, State, and local governments as well as to the public. Annual rent for right-of-way permits and annual rent for commercial production of wind energy will generate revenue to the surface owner. The local economy also may benefit through additional jobs and purchase of goods and services such as food, lodging, and supplies by commercial wind energy companies and personnel. The State realizes additional revenue from taxes on those sales. The above benefits have a net positive impact on the State and local economy.

3.2 LOCATABLE MINERALS

Locatable minerals are defined as those minerals that make the land more valuable because of their existence, are recognized as a mineral by the standard experts, and are not subject to disposal under some other law. Most solid minerals are locatable, but due to complexities in the law there are exceptions (such as coal, potash, sulfur, and sodium). Locatable minerals include both metallic minerals (e.g., gold, silver, lead) and nonmetallic minerals (e.g., gemstones, kaolin, perlite). Locatable minerals can be obtained by filing a mining claim and can be extracted by mining or quarrying methods.

3.2.1 Metallic Locatable Minerals

Socorro and Catron Counties have many areas historically designated as metallic mineral mining districts, as shown on Map 10. File and Northrup (1966) identified 28 metallic mining districts in Socorro County and 5 metallic mining districts in Catron County. The General Land Office-BLM recognizes 18 mining districts in Socorro County and 3 mining districts in Catron County on public land (Sitzler 2003). Detailed historical reviews of mineral exploration and development in the Planning Area by the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) have documented commodity types and production data for 33 mining districts (McLemore 2002a). Most of the NMBGMR mining districts correspond to the mining districts established by File and Northrup (1966), and many of those districts are correlative with the 21 mining districts recognized by the BLM. Most of the districts have been mined historically and are no longer active; four are known prospects that have not been mined (McLemore 2002a). Commodities historically produced by each mining district are posted on Map 10 and presented in Table 6.

3.2.1.1 Known Occurrences and Prospects

Map 10 shows the locations of metallic mineral mining districts in Socorro and Catron Counties, of which 33 have geologic information and production data (McLemore 2002a). Four of these districts are known prospects and have not been mined. Six mining districts extend south into Sierra County, two districts extend south into Grants County, and one district extends north into Torrance County (refer to Map 10). Table 6 lists each district, the commodities (metallic minerals) that have been mined, commodities that are present but have not been mined (prospects), and the type of geologic deposit that characterizes each district.

Rocks exposed in the mining districts range from Middle Proterozoic (Precambrian) to Quaternary. Geologic formations or rock types reported to be present in the mining districts are listed in Table 6 and presented below.

Precambrian rocks in the mining districts include plutonic rocks younger than 1600 million years old, such as the Capirote Pluton, Landron Pluton, and Magdalena Granite. Precambrian metavolcanic and metasedimentary rocks also are found in outcrop.

Paleozoic rocks in the mining districts are of Mississippian, Pennsylvanian, and Permian age. Mississippian rocks include undivided rock types ranging in age from Cambrian to Mississippian. Pennsylvanian rock groups include the Sandia Formation, Madera Formation, and Pennsylvanian undivided rocks. Permian rock groups include the Abo Formation, Yeso Formation, San Andreas Limestone, Glorieta Sandstone, and Permian undivided rocks.

Mesozoic rocks in the mining districts are of Triassic and Cretaceous age. Triassic rocks include the Triassic Chinle Group. Cretaceous rocks include the intertongued Dakota Sandstone-Mancos Shale-Gallup Sandstone sequence, Tres Hermanos Formation, Moreno Hill Formation, Crevasse Canyon Formation, and the Mesaverde Group (undifferentiated).

Tertiary rocks are of Eocene, Oligocene, Miocene, and middle Quaternary age. Tertiary rocks include undifferentiated intrusives; Paleogene sedimentary units; Eocene to Lower Oligocene andesite and basaltic andesite flows, sedimentary and volcaniclastic sedimentary rocks, and silicic pyroclastic flows (ash-flow tuffs); Upper Oligocene silicic or felsic flows, masses, and associated rhyolitic pyroclastic rocks (ash-flow tuffs); Lower Miocene basaltic andesites and volcaniclastic rocks; Neogene basalt and andesite flows; and Santa Fe Group sedimentary rocks (locally undivided).

Quaternary rock groups include piedmont alluvial deposits, Gila Group sedimentary deposits, landslide deposits, colluvium, and alluvium.

Several rock types listed above are intruded locally by silicic to felsic plugs and dikes, some of which are associated with epithermal vein formation (McLemore 2001).

There are no known active metallic mineral mines in the Planning Area.

3.2.1.2 Mineral Claims Activity

Regulations applicable to metallic mineral claims on public lands in the Planning Area include the General Mining Law of 1872, the Federal Land Policy and Management Act of 1976, 43 CFR 3700 – Multiple Use; Mining, and 43 CFR 3800 – Mining Claims under the General Mining Laws. Regulations specific to the BLM include BLM Manual 1601 – Land Use Planning and Instructions, BLM Handbook H-3042-1 – Solid Minerals Reclamation Handbook, and BLM Manual Sections 3700 and 3800.

A permit from the appropriate administrative entity (BLM or Forest Service) is not required to casually prospect on public lands that are open to mineral entry. Notification to the BLM is required 15 days prior to Notice-level work, wherein exploration and/or mining activities will cause unreclaimed surface disturbance to less than five acres of public land. A permit from the appropriate administrative entity (BLM or Forest Service) and a plan of operations is required for Plan-level work, in which activities will disturb an unreclaimed surface of more than five acres of public land. A claim is staked for a locatable metallic mineral and recorded at the appropriate County and BLM State Office. The claim is not recorded at the Forest Service; the BLM will inform them of an active claim. A permit to conduct mining operations at the claim must be obtained from the New Mexico Mining and Minerals Division.

There presently is no known mining claim activity for metallic locatable minerals in Socorro and Catron Counties.

3.2.1.3 Mineralized Areas and Types

Metallic and nonmetallic mineralized areas in the Planning Area are designated as mining districts (refer to Map 10). Mining districts are areas where prospects for mineral resources are located and/or mining has been conducted. Different geologic conditions and mechanisms of mineralization can account for the types of metallic minerals found in Socorro and Catron Counties. These mineralized types include volcanic-epithermal deposits, placer deposits, Precambrian vein/replacements, carbonatites, vein deposits, sedimentary deposits, and the Rio Grande Rift (McLemore 2002a).

Metallic mineral resources in 13 mining districts in Socorro County and 4 mining districts in Catron County formed as a result of volcanic-epithermal activity during the Upper Oligocene to the Upper Pliocene (McLemore 1994b). Formation of base and precious metallic mineralized types occurred when andesites, basaltic andesites, silicic and felsic flows, and/or pyroclastic rocks intruded the parent rock through dikes, plugs, and fissures (McLemore 1994b). As the volcanic rock intruded the parent rock, a combination of contact remineralization and the formation of epithermal veins occurred. Where the intrusive dike or plug intersected groundwater, fluids in the intrusive and the parent rock locally were boiled, cooled, and mixed. In the boiling and mixing reaction, remineralization occurred where silica replaced carbonate; for example, quartz after calcite. In-place mineral replacement, and fluid transport and formation of late-stage mineralization occurred, at which point the base and precious metals were formed. The epithermal veins subsequently were uplifted, eroded, and exposed at the surface.

There are three mining districts that contain placer deposits: one mining district each in Socorro and Catron Counties contains placer gold deposits, and one mining district in Catron County contains placer tin deposits (McLemore 2002a). Placer mineralized types formed as a result of weathering of a parent rock, probably containing volcanic-epithermal veins. The parent rock and veins containing gold and tin later were eroded and concentrated in alluvial deposits.

There are three mining districts in Socorro County that have lead and zinc deposits in carbonate rock (McLemore 2002a). This mineralized type commonly occurs when a magma body is rising to the surface and is intersected by a fault. As the magma body is intersected, it is dissimilated into the parent rock where the fault is located, in this case a limestone. Metallic minerals, such as lead and zinc, may fill voids in the limestone during fluid transport. Through uplift and erosion, these lead- and zinc-bearing carbonates are exposed at the surface.

Five mining districts in Socorro County have sedimentary copper and uranium deposits. The copper and uranium is found in sandstone in these districts. These deposits were formed by groundwaters enriched in copper and uranium that migrated through the sandstones and precipitated in reducing zone.

The Chupadera Mountains District and the Lemitar Mountains District in Socorro County contain carbonatites, which are carbonate-rich rocks that have a magmatic origin (McLemore 2002a). Carbonatites are valuable mineralized types because they may contain rare-earth elements, uranium, thorium, niobium, copper, titanium, strontium, and manganese (McLemore 1983). More than 100 carbonatite veins and dikes intrude Precambrian rocks in the Lemitar Mountains and more than 12 dikes intrude the Precambrian rocks in the Chupadera Mountains (McLemore 1982).

Four districts in Socorro County have Precambrian veins and corresponding mineral replacement deposits (McLemore 2002a). These mineralized types are believed to have originated during the cooling of Precambrian plutons. As the plutons intruded the parent rock, contact remineralization occurred through intrusive dike and vein formation. In-place mineral replacement, and fluid transport and formation of late-stage mineralization occurred, in which the base and precious metals are formed. These mineral-rich Precambrian veins were uplifted, eroded, and exposed at the surface.

3.2.2 Nonmetallic Locatable Minerals

There are several mining districts in the Planning Area that historically have mined nonmetallic locatable minerals. These nonmetallic minerals include gems, zeolite, gypsum, barite, fluorite, kaolin and other clays, and perlite. These mining districts are included in Table 6 and shown on Map 10.

3.2.2.1 Known Occurrences and Prospects

There are three known prospects for nonmetallic mineral resources in Catron County. The Chloride District in Catron County historically has been mined for zeolite and has a prospect for gems. Taylor Creek District is a known prospect for kaolin. Industrial-grade garnets are found in the Cuchillo District. In Socorro County, the Socorro Peak District historically has been mined for perlite and kaolin.

Rocks exposed in these mining districts range from Middle Pennsylvanian to Quaternary. Geologic formations or rock types reported to be present in these mining districts are discussed in Section 3.2.1.1. Rock types specific to the nonmetallic mineral occurrences are as follows:

- **Pennsylvanian** rocks include the Madera Limestone in the Taylor Creek District and exotic blocks in the Chloride District.

- **Tertiary** rocks are of Eocene, Oligocene, and Miocene age. The Tertiary rocks include Oligocene to Miocene silicic flows, basaltic andesites, rhyolite domes and associated pyroclastic rocks (tuffs) and intrusions; lower Miocene and Eocene undifferentiated volcanic rocks; and Miocene silicic to intermediate volcanic rocks.

- **Quaternary** rocks include piedmont alluvial deposits; Tertiary-Quaternary sedimentary rocks of the upper Santa Fe Group, which consist of basin fill sediments; and alluvium and colluvium.

The only known active nonmetallic mineral mine in the Planning Area is the Socorro Perlite Mine and Mill in Socorro County. Perlite is mined from a Miocene high-silica rhyolite lava dome or flow (Barker et al. 1996b).

3.2.2.2 Mineral Claims Activity

Regulations applicable to nonmetallic mineral claims on public lands in the Planning Area include the General Mining Law of 1872, the Federal Land Policy and Management Act of 1976, 43 CFR 3700 – Multiple Use; Mining, and 43 CFR 3800 – Mining Claims under the General Mining Laws. Regulations specific to the BLM include BLM Manual 1601 – Land Use Planning and Instructions, BLM Handbook H-3042-1 – Solid Minerals Reclamation Handbook, and BLM Manual Sections 3700 and 3800.
A permit from the appropriate administrative entity (BLM or Forest Service) is not required to casually prospect on public lands that are open to mineral entry. Notification to the BLM is required 15 days prior to Notice-level work, wherein exploration and/or mining activities will cause unreclaimed surface disturbance to less than five acres of public land. A permit from the appropriate administrative entity (BLM or Forest Service) and a plan of operations is required for Plan-level work, in which activities will disturb an unreclaimed surface of more than five acres of public land. A claim is staked for a locatable nonmetallic mineral and recorded at the appropriate County and BLM State Office. The claim is not

recorded at the Forest Service; the BLM will inform them of an active claim. A permit to conduct mining operations at certain nonmetallic mineral claims is required from the New Mexico Mining and Minerals Division, and that agency should be contacted for permit requirements.

There presently is small-scale mining activity for nonmetallic locatable minerals in Socorro and Catron Counties (Sitzler 2003).

3.2.2.3 Mineralized Areas and Types

Metallic and nonmetallic mineralized areas in the Planning Area are designated as mining districts (refer to Map 10). Mining districts are areas where prospects for mineral resources are located and/or mining has been conducted. Different geologic conditions and mechanisms of mineralization can account for the types of nonmetallic minerals found in Socorro and Catron Counties. These mineralized types include high-silica lava flows, volcanic-epithermal deposits, vein deposits, and sedimentary deposits (McLemore 2002a).

The development of kaolin, zeolite, and gems is associated with the Tertiary volcanic outcrops and sedimentary rocks in the mining districts in Socorro and Catron Counties. Kaolin is a group of clay minerals including kaolinite, typically derived from the weathering of alkali feldspars and micas in granite. In the Planning Area, it is found as hydrothermal alteration of Tertiary volcanic tuffs and rhyolite porphyry, or sedimentary deposits (Isik et al. 1994). Zeolites are aluminosilicate minerals that typically form as crystals in the cavities of basalt.

Gem-quality minerals can form in the volcanic-epithermal processes described above and in vein deposits. Industrial-grade garnets are found in the Cuchillo District (McLemore 2003).

Barite has been produced in several mineral districts, including Hansonburg, Lemitar and Mockingbird Gap. Fluorite has been produced in the Wilcox, Cuchillo, Mockingbird Gap, and Latron Mountains Districts (McLemore 2003).

Perlite is a volcanic glass with a high water content that is derived from high-silica rhyolite lava. When heated, perlite expands to many times the original volume, creating glass foam. Perlite is used in horticulture, lightweight construction material, and as a shipping material.

3.2.3 Mineral Economics

With the exception of perlite, the metallic and nonmetallic locatable mineral resources in the Planning Area are not being actively mined. Economic factors contributing to the lack of mining activity probably include one or more of the following: the assayed or mineralized value of the deposits; current market demand for those resources; and/or expenses for mining, processing, and transport of the mineral products. Mining of any of these mineral resources could commence if one or more of these factors change the economic value of the resource.

Development of locatable mineral resources provides economic benefits to Federal, State, and local governments as well as to the public. Annual rentals for mining claims generate limited revenue. There are no royalties or fees paid to the Federal minerals owner for the sale of locatable minerals extracted from a mineral claim. However, reclamation costs to reclaim public lands at the completion of mining activities are necessary. At this time, there is a moratorium on mineral patent applications. The local economy may benefit through jobs and purchase of goods and services such as food, lodging, and supplies by mining companies and personnel. The State realizes additional revenue from taxes on those sales. The above benefits have a net positive impact on the State and local economy.

3.3 SALABLE MINERALS

Since 1955, BLM defines common varieties of sand, gravel, stone, pumice, pumicite, cinders, and ordinary clay as salable, not locatable (BLM 1997). Salable minerals include materials used for building and construction, both commercially and privately. Sand, gravel, aggregate, lime (limestone), cinders, and building stone are the more common salable minerals. Use of salable minerals from public land requires either a sales contract or a free-use permit. Sales are at the appraised fair-market value. Under a free-use permit, salable minerals may be provided at no cost to local communities for use in public projects.

3.3.1 Known Occurrences and Prospects

The locations of known occurrences and prospects for salable minerals are too numerous to discuss on an individual basis. Instead a map and table of known occurrences and prospects for the Planning Area has been prepared (Map 11). An explanation of the symbols for the geologic formations is provided in Appendix A.

A search of Case Recordation files on the BLM Land and Mineral Records LR 2000 database identified 27 BLM salable mineral pits in the Planning Area. Those pits are shown on Map 11 and listed in Table 7. The LR 2000 lists the serial number of the pit, the commodity type and location, the name and address of the permittee, the volume and sales price of the commodity produced, and sales activity for the pit.

The New Mexico Highway Department (NMHD) has prepared a Geology and Aggregate Resources Manual describing known occurrences and prospects of sand, gravel, and aggregate resources adjacent to public roads for road construction. That manual was recently compiled on compact disk format by the NMBGMR. In addition to the BLM LR 2000 database, the NMHD Manual was used to locate and assess sand, gravel, and aggregate salable mineral resources on public lands in Socorro and Catron Counties (NMBGMR 2002). Those pits, quarries, and prospects are shown on Map 11. The NMHD Manual provides detailed information for each resource location, including pit number, township, range, section, county, rock type, quality of material, thickness of material, thickness of overburden, and estimated quantity of material (refer to Table 7). The NMHD Geology Unit rated the quality of material using categories with the following scale: excellent, good, fair, and poor.

Also shown on Map 11 are active commercial pits, quarries, and mines listed by Pfeil and Leavitt (2001). Known occurrences of travertine, commonly used for building stone, also are shown on Map 11 and listed in Table 7 (Barker et al. 1996a).

Most of the pits, quarries, and prospects listed by the BLM LR 2000 and NMHD Manual are Quaternary alluvial deposits consisting of unconsolidated sand and gravel adjacent to public roads. Other potential prospects for sand, gravel, and aggregate may include Quaternary sand and gravel deposits not listed in the NMHD Manual because those locations are not adjacent to public roads. Quaternary geologic formations described as alluvial sand and gravel, colluvium, and eolian sand are shown by a hachured pattern on Map 11 as high potential prospects for salable minerals. Quaternary-Tertiary sedimentary formations mentioned as prospect materials in the NMHD Manual are shown as moderate potential prospects. Localized occurrences of specialty stone, such as flagstone, are associated with outcrops of consolidated rock and not alluvial deposits.

3.3.2 Mineral Claims Activity

Regulations applicable to salable mineral claims on public lands in the Planning Area include the General Mining Law of 1872, Mineral Leasing Act of 1947, Mineral Materials Act of 1947, Mineral Materials Act of 1955, and Federal Land Policy and Management Act of 1976, and 43 CFR Part 3600. Regulations specific to BLM include BLM Manual 1601 – Land Use Planning, BLM Handbook H-3042-1 – Solid Minerals Reclamation Handbook, and BLM Manual and Handbook 3600.

Use of salable minerals from BLM-administered lands requires either a sales contract or a free use permit from the appropriate BLM Field Office. The contract or permit may have stipulations on multiple land use. Disposals of salable minerals from BLM-administered lands are regulated by 43 CFR Part 3600, and from National Forest System lands by 36 CFR Subpart C 228.40. The salable minerals operation must be registered with the New Mexico Bureau of Mines Inspection.

NMBGMR reports that many inactive or intermittently operated aggregate pits are located in the Planning Area and can be re-opened for construction or local repairs at any time (Barker 2002). The Mine Safety and Health Administration (MSHA) reports one active and one intermittent aggregate pit in Socorro County, and two intermittent pits in Catron County (MSHA 2003).

3.3.3 Mineral Areas and Types

Salable mineral resources obtained from Quaternary alluvial sediments typically are found in active and former stream channels, floodplains, washes, and alluvial fans where they were deposited by streams and floods. Mineral types associated with Quaternary alluvial sediments include the following:

- very fine- to very coarse-grained sand
- well-graded sand and gravel aggregate
- rounded river rock
- cobbles and boulders

Eolian sand dunes are a mineralized area having a mineral type that consists of clean, fine-grained sand of uniform size. Some salable mineral resources may be obtained from talus slopes or rock falls. Mineral types associated with these mineral areas include small to large, angular cobbles and boulders of volcanic or intrusive rock that can be crushed to obtain construction materials of a specific size range, or that have a specific mineral composition needed for construction.

Specialty stone used for construction, such as flagstone, has a wide variety of sources, but usually is found in well-cemented, thin-bedded sandstone formations of Triassic to Permian age.

Travertine used for building stone has a wide variety of sources that are associated more with areas of calcium-rich water flow and calcite precipitation than with a specific geologic origin (Barker et al. 1996a). Travertine building stone comes in a range of mineral types having unusual colors, banding patterns, layers, cavities, and vugs that are too diverse to discuss in detail in this report. Travertine can be salable or locatable depending on its use and calcium carbonate content.

3.3.4 Mineral Economics

The demand for salable mineral resources is a function of construction activity and depends on where the construction activity is taking place. Transportation costs for sand and gravel aggregate can be minimized by using a salable mineral source close to a construction site. It is likely that construction projects will prefer using mineralized areas close to public roads. Development of salable mineral resources provides economic benefits to Federal, State, and local governments as well as to the public. Use of salable minerals under a sales contract at fair market value will generate revenue to the surface owner. Reclamation costs to reclaim public lands at the completion of salable mining activities also are necessary. The local economy may benefit through jobs and purchase of goods and services such as food, lodging, and supplies by mining companies and personnel. The State realizes additional revenue from taxes on those sales. The above benefits have a net positive impact on the State and local economy.

4.0 POTENTIAL FOR OCCURRENCE OF MINERAL RESOURCES

This section presents a narrative of the potential for occurrence of energy and mineral resources in Socorro and Catron Counties. The narrative references resource potential maps for each of the energy and mineral resources discussed above. The potential for occurrence of mineral resources are determined using guidance provided in Bureau of Land Management (BLM) Manual 3031 – Energy and Mineral Resource Assessment. The manual sets standards for assessing, classifying, and reporting the potential for occurrence of mineral resources on lands managed by the BLM.

4.1 DEFINITION OF MINERAL RESOURCE POTENTIAL

The potential occurrence of a mineral resource is a prediction of the likelihood that the mineral resource will occur in a given area. The potential occurrence of a mineral resource includes both exploitable and potentially exploitable occurrences, and does not evaluate whether the mineral resource can be developed economically. The four categories of mineral potential, as defined in BLM Manual 3031, are as follows:

- (no potential) – the geologic environment, inferred geologic processes, and lack of mineral occurrences do not indicate potential for accumulation of mineral resources

- L (low potential) – the geologic environment and inferred geologic processes indicate low potential for accumulation of mineral resources

- M (moderate potential) – the geologic environment, inferred geologic processes, and reported mineral occurrences or valid geochemical/geophysical anomaly indicate moderate potential for accumulation of mineral resources

- H (high potential) – the geologic environment, inferred geologic processes, and reported mineral occurrences or valid geochemical/geophysical anomaly, and known mines or deposits [within the same type of geologic environment] indicate high potential for accumulation of mineral resources

In addition to those four categories, within each mineral potential category the potential must be supported according to a level of certainty regarding the available data. The level of certainty is a measure of the report preparer's confidence in the data that were assessed. The four mineral potential categories are displayed on the mineral resource potential maps. The levels of certainty are annotated in the narrative of mineral resource potential using the letter designations described below, and are not displayed on the mineral resource potential maps:

- *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.

4.2 LEASABLE MINERAL POTENTIAL

As discussed in Section 3.0, a map showing the known occurrences, prospects, and resource potential in Socorro and Catron Counties was prepared for each leasable energy and mineral resource. Using those maps as a guide, the potential for each leasable energy and mineral resource is discussed below.

4.2.1 <u>Oil and Gas Potential</u>

Oil and gas potential is allocated to areas that have the following characteristics:

- Source for hydrocarbons – for example, an organic-rich shale or coalbed that has attained a level of thermal maturity through burial or other heating mechanism such that oil and/or gas could be generated. These data generally are obtained by testing core or drill cutting samples in a laboratory.

- Reservoir-quality rock – sandstone, limestone, or fractured rock having interconnected porosity and permeability into which oil and/or gas may migrate from the source rock and be trapped.

- Trapping mechanism that prevents oil and/or gas from migrating out of the reservoir-quality rock. Structural traps, stratigraphic traps, and faults are some common trapping mechanisms.

- Known deposits of oil and/or gas.

Areas having oil and gas potential are shown on Map 1. Using the criteria discussed above, no plays or basins in the Planning Area have high potential because there is no proven production from those areas.

The following basins or plays have moderate potential: Chupadera Mesa, Carrizozo Basin, Albuquerque-Belen Basin, Socorro Basin, Acoma Basin, Jornada del Muerto Basin, northern San Agustin Basin, Lucero Uplift, south-central Zuni Uplift, Zuni Basin, and the northern portion of the Los Pinos Uplift (refer to Map 1). The level of certainty for those plays is *C* because there is direct evidence through oil and gas shows, source rock, and geologic structures of the possible existence of oil and gas mineral resources. It is important to note that areas having moderate potential are not necessarily correlative with the basin boundaries shown on Map 1. For example, the depositional and tectonic history of the Planning Area has resulted in the uplift of reservoir-quality sedimentary rocks from Permian- and Pennsylvanian-age sedimentary basins to form the present-day Zuni and Lucero Uplifts shown on Map 1 (Broadhead et al. 2002b). There is potential for oil and gas accumulation in those reservoir-quality rocks even though they no longer occupy a structural basin.

Known occurrences and prospects for CBM mineral resources are shown on Map 4. Those areas are ranked as moderate potential for CBM mineral resources. Outcrops and drilling logs show that coal seams are present in those areas, and there are local shows of methane gas. However, there is no known methane production from those coalbeds, hence a level of certainty of *C* is assigned to the CBM potential. The coal seams are ranked as subbituminous to bituminous, and have the requisite thermal maturity to generate methane gas (Kaiser and Ayers 1994). In much of the potential area, the number and thickness of coal seams is low, and the structural regime may not have generated a large number of fractured reservoir-quality rocks. It also may not be economic to drill and extract coalbed methane from those areas because geologic conditions are not favorable for the generation and/or trapping of gas.

The southern San Agustin Basin, San Marcial Basin, La Jencia Basin, Mogollon-Datil Volcanic Field, Caballo Uplift, Los Pinos Uplift, and all but the south-central portion of the Zuni Uplift have low potential because there is no proven production, oil or gas shows, and no evidence for source rock (refer to Map 1). The level of certainty is *A* because there are insufficient data to evaluate those plays.

The areas with no potential occur where reservoir-quality rocks have been uplifted and exposed, or removed by erosion adjacent to the Precambrian basement outcrops (refer to Map 1). The level of certainty is *C* because oil and gas potentially could escape through the exposed surface of reservoir-quality rock or through extensive fractures in uplifted fault blocks or overthrusts. The presence of thermally mature petroleum source rock is uncertain in those areas for two reasons. First, the source rock may not have been buried deep enough to "cook" prior to uplift. Second, source rocks may have been thermally altered by high-temperature intrusive rocks during uplift.

4.2.2 Carbon Dioxide and Helium Potential

Carbon dioxide and helium (CO_2/He) potential is allocated to areas that have the following characteristics:

- A source for CO_2/He such as thick volcanic sequences that may have locally charged reservoir-quality sediments with CO_2. Helium also may be generated by radioactive decay of uranium and thorium from Precambrian basement rocks or sedimentary rocks enriched in uranium and thorium.

- Reservoir-quality rock – sandstone, limestone, or fractured rock having interconnected porosity and permeability into which CO_2/He may migrate from the source area and be trapped.

- Trapping mechanism that prevents CO_2/He from migrating out of the reservoir-quality rock. Structural traps, stratigraphic traps, and faults are some common trapping mechanisms.

- Known production of CO_2/He.

Areas having CO_2/He potential are shown on Map 5. The Zuni Basin area has high potential because drilling has proven that known occurrences of CO_2/He exist. The level of certainty is *D* for the Zuni Basin.

The Chupadera Mesa, Carrizozo Basin, Jornada del Muerto Basin, northern San Agustin Basin, and Zuni Uplift have moderate potential. These areas have had shows of CO_2/He or gas in well tests but no known production. The level of certainty for those areas is *C* because of direct evidence for the occurrence of CO_2/He.

The southern San Agustin Basin, Albuquerque-Belen Basin, Acoma Basin, San Marcial Basin, La Jencia Basin, Socorro Basin, Caballo Uplift, Los Pinos Uplift, Lucero Uplift, and Mogollon-Datil Volcanic Field have low potential because there are no known occurrences and no CO_2/He shows. However, the presence of volcanic activity and possible reservoir-quality rock in those areas provides some potential for CO_2/He resources. The level of certainty is *C* because in many of those areas drilling has not reported shows of CO_2/He.

Areas with no potential occur where reservoir-quality rocks have been uplifted and exposed, or removed by erosion adjacent to the Precambrian basement outcrops (refer to Map 5). The level of certainty for those areas is *D* because CO_2/He would likely escape from reservoir-quality rock through the exposed surface or through extensive fractures in uplifted fault blocks or overthrusts.

4.2.3 Coal and CBM Potential

Known occurrences and prospects for coal and coalbed methane (CBM) mineral resources are shown on Map 4. Those areas are ranked as high potential for coal mineral resources based on outcrops and drilling logs. However, some of the areas may have limited economic potential because of faults, fractures, and steeply dipping beds; thin, discontinuous coal seams; and limited subsurface data. A level of certainty of *D* is assigned to coal potential.

Moderate coal mineral potential exists in the area of CBM potential because coal seams are present. The level of certainty is *C* in the area of CBM potential because there is direct evidence that coalbeds are present in that area. However, it may not be economic to mine coal from some areas because the depth of burial and amount of overburden that would have to be removed to extract the coal would be prohibitively expensive under most economic conditions.

4.2.4 Geothermal Potential

he potential for geothermal energy resources ranges from high to none (refer to Map 6). High potential is located in areas of Known Geothermal Resource Area: two locations in southern Catron County and one location west of Socorro. Those locations are convective resource areas characterized by low-temperature geothermal energy resources suitable for heating buildings, swimming pools or spas, or for agriculture or aquaculture. Those locations have a level of certainty of *D*.

Most of the Planning Area has moderate potential because of crustal thinning that occurred during Basin and Range extension and formation of the Rio Grande Rift. Isolated known occurrences of low-temperature geothermal resources are located in the area of moderate potential (refer to Map 6). The level of certainty for moderate geothermal resources is *B* because for most of the area there are only isolated occurrences of geothermal resources. The areas east of the Rio Grande Rift and the northwestern corner of Catron County have low or no geothermal resource potential and no known occurrences. The level of certainty for low or no geothermal resources potential is *B* because the absence of occurrences provides limited indirect evidence for no or low potential.

4.2.5 Solar Energy

The map of solar energy resources shows that the Planning Area has generally uniform, high potential (refer to Maps 7 and 8). The relatively high elevation and arid climate are conducive to clear, sunny days with high solar radiation. The level of certainty is *D* because surveys have documented the known solar energy resources shown on Map 8.

4.2.6 Wind Energy

Wind energy potential ranges from high to low and is dependent on the difference in elevation. Hence, the higher mountain elevations have greater wind energy potential (refer to Map 9). High potential is found at the highest elevations, which include Socorro Peak and the Magdalena, Mogollon, and San Mateo Mountains. Moderate potential is found at the intermediate elevations on those same mountains. Low potential is found in areas having lesser elevation differences and the low elevations, such as the flat valleys east of the Rio Grande River. There are no areas of no-wind-energy potential because even areas having light winds can generate power using small-scale wind turbines. The level of certainty is *D* for all wind energy resources because surveys have documented the known wind energy resources shown in Map 9.

4.3 LOCATABLE MINERAL POTENTIAL

As discussed in Section 3.2, a map showing the known occurrences, prospects, and resource potential in Socorro and Catron Counties was prepared for locatable mineral resources. Using the map as a guide, the potential for locatable mineral resources is discussed below.

4.3.1 Metallic Minerals

High potential for metallic mineral resources is shown on Map 10 in mining districts with known occurrences of metallic minerals listed for each district. The level of certainty is *D* because available data provide abundant direct evidence that the metallic minerals occur in those districts.

There is low potential for metallic minerals in areas outside of the mining districts because mineral occurrences are not known. There is generally insufficient information on the geologic environment and geologic processes present outside the existing mineral districts to support other than a low potential for metallic mineral occurrence. The level of certainty is *B* because the areas designated as having low potential are areas that generally have only indirect evidence that metallic mineral resources exist (i.e., no mineral exploration has been conducted and/or no mining district has been established).

4.3.2 Nonmetallic Minerals

High potential for nonmetallic mineral resources is shown on Map 10 in mining districts with known occurrences of nonmetallic minerals listed for each district. The level of certainty is *D* because available data provide abundant direct evidence that the nonmetallic minerals occur in those districts.

There is low potential for nonmetallic minerals in areas outside the mining districts because mineral occurrences are not known. There is generally insufficient information on the geologic environment and geologic processes present outside of the existing mineral districts to support other than a low potential for nonmetallic mineral occurrence. The level of certainty is *B* because the areas designated as having low potential are areas that generally have only indirect evidence that nonmetallic mineral resources exist (i.e., no mineral exploration has been conducted and/or no mining district has been established).

4.4 SALABLE MINERAL POTENTIAL

The known occurrences, prospects, and potential of salable mineral resources in Socorro and Catron Counties are shown on Map 11. Most of the pits, quarries, and prospects are Quaternary alluvial deposits consisting of unconsolidated sand and gravel adjacent to public roads. Those resources were located and graded by the New Mexico Highway Department (NMHD). High potential salable mineral resources are deposits comparable to the deposits listed in the NMHD Manual, but are not necessarily adjacent to public roads. Quaternary geologic formations described as alluvial sand and gravel, colluvium, and eolian sand are shown on Map 11 as high potential prospects for salable minerals. The level of certainty is *D* for those resources because they are shown on the geologic map of the Planning Area, and have been evaluated for quality by the NMHD.

Quaternary-Tertiary sedimentary formations mentioned as prospect materials in the NMHD Manual are classified as moderate potential. The Quaternary-Tertiary deposits typically have more variable composition and are more indurated than Quaternary deposits. As such, certain outcrops of those deposits may be less suitable as salable mineral resources. For that reason, Quaternary-Tertiary deposits have moderate potential. The level of certainty is *C* because there is direct evidence for the occurrence of those resources, but the preferred salable mineral resource may not occur at all locations.

5.0 REASONABLE FORESEEABLE DEVELOPMENT

This section discusses the reasonable foreseeable development (RFD) for energy and mineral resources in Socorro and Catron Counties. The RFD is a reasonable projection of the most likely anticipated activity for development of energy and mineral resources supported by clearly stated assumptions. The RFD provides vital information to assist the resource specialist with making informed leasing decisions for proposed resource development projects. The baseline RFD is not constrained by management-imposed conditions on where, when, or how resource development might occur.

The RFD scenario is a professional opinion presented by the mineral resource preparer and is based primarily on the geologic potential for resource occurrence along with past and present energy and mineral resource activity and projected (15 years) demands and markets. Development of the RFD scenario also considers other factors that may significantly affect development of the resources such as technological changes, economics, access restrictions, existing or anticipated infrastructure, and transportation. The RFD also describes surface uses that may be necessary to implement the anticipated development of the energy and mineral resources, and the resulting impacts or disturbances to other resources (soil, water, air, wildlife, visual, cultural) and human communities.

5.1 LEASABLE MINERALS

5.1.1 <u>Oil and Gas</u>

5.1.1.1 Background Information and Assumptions

There has been extensive oil and gas exploration in Socorro and Catron Counties since the 1920s, with a total of 85 wells drilled (refer to Table 1). No oil and gas development has occurred in the Planning Area and there are no documented proven reserves. However, areas of high to moderate oil and gas potential exist in the Planning Area (refer to Map 1).

The price of crude oil was a significant driving force for increased oil and gas exploration activity in the 1970s when 21 wells were drilled in the Planning Area. The 1980s and 1990s saw active exploration in the Planning Area despite fluctuating crude oil prices. Eight wells were drilled in each of those decades, including three carbon dioxide ($CO_{2)}$ exploratory wells in the late 1990s. Drilling activity has continued from 2000 through 2002 with six wells drilled to date, including three CO_2 exploratory wells. A trend toward increasing exploration is occurring throughout the United States as the active rig count increases in conjunction with rising crude oil prices.

It is important here to separate the CO_2 exploration activity in northwestern Catron County from oil and gas (petroleum) exploration activity in the Planning Area. Although there is significant petroleum exploration activity in the Planning Area, the number of wells drilled is less than in the 1970s and 1980s. The CO_2 exploration activity is discussed in Section 5.1.2.

The Planning Area has moderate potential for coalbed methane (CBM), which is natural gas derived from coal deposits (refer to Map 4). CBM has not been targeted for exploration in the Planning Area, but some shows in oil and gas exploratory wells may have been derived from coalbeds. There is significant CBM development in the San Juan Basin of northern New Mexico and knowledge gained in that play may be applied to explore and develop CBM resources in the Planning Area.

The following assumptions were considered when evaluating the RFD for oil and gas in the Planning Area:

- Oil and gas drilling activity will increase in the next 15 years in response to increasing crude oil and gas prices, increasing domestic demand, and decreasing domestic production.

- CBM drilling activity will commence in the next 15 years in response to increasing gas prices, increasing domestic demand, and decreasing domestic production.

- Advances in 3-dimensional (3-D) seismic acquisition and processing technology will improve the resolution of subsurface structural and/or stratigraphic traps and delineate potential reservoir targets.

- A discovered oil and gas field will be small (less than 500 acres). This assumes that the size of an oil and gas field is limited by the structural complexity present throughout much of the Planning Area, particularly within the Basin and Range physiographic province. It is assumed that there have been no discoveries in the Planning Area despite 80 years of exploration because no areally extensive (i.e., large) oil and gas deposits exist.

5.1.1.2 Reasonable Foreseeable Development

The RFD for oil and gas development in the Planning Area estimates that 22 exploratory wells will be drilled. Compared to the previous 15 years when 14 wells were drilled, an estimated 1.5 wells per year will be drilled in the next 15 years.

An estimated two exploratory wells (10 percent of the total drilled) will lead to the discovery and production of two small economic oil and gas (or CBM) fields in the next 15 years. The two discovered fields will be small (less than 500 acres).

An estimated 12 development or production wells will be drilled to delineate and exploit each oil and gas discovery field, approximately one per 40 acres.

5.1.1.3 Disturbance to the Planning Area

The extent of disturbance or impact to the land from development of a small oil and gas field is estimated using the mean generalized impact values presented by the Rocky Mountain Federal Leadership Forum (RMFLF 2002). Those assumptions are:

- Each small field discovery will require approximately 12 delineation and/or development well sites on a total development field area of 500 acres with roads and associated infrastructure.

- Each small field will impact or disturb an estimated 100 acres by installation of drill pads, roads, and infrastructure such as pipelines, compressor stations, storage tanks, and processing facilities.

- Each exploration well site will occupy 10 acres and each development or production well site will occupy 5 acres, including roads.

- Pad reclamation will reclaim approximately 50 percent of the exploration and production well drill pads for the long term.

- The average life of a small field will be 20 years.

Approximately 100 acres will be developed within the small oil and gas field and will generally not be accessible for other resource uses. Another 400 to 500 acres within the oil field leased area will probably not be developed. The gross surface disturbance (GSD) assumes impact to the field within the first five years and is calculated using the following guidance (BLM 2002; RMFLF 2002):

GSD = current disturbance + future disturbance

= (exploration wells)(acres/pad + road) + production wells (acres/pad + road).

The GSD for one small oil and gas field = (1 x 10) + (12 x 5) = 70 acres.

The net surface disturbance (NSD) is an estimate of the long-term surface disturbance and includes reclamation of 50 percent of the exploration and production drill pads during the remaining 15 years life of the field (BLM 2002):

NSD = current disturbance + future disturbance – reclamation

= (exploration wells)(acres/pad + road) + production wells (acres/pad + road) – exploration wells (acres reclaimed) **-** production wells (acres reclaimed).

The NSD for one small oil and gas field = (1 x 10) + (12 x 5) – (1 x 5) **-** (12 x 2.5) = 35 acres.

The potential impact to other resources, such as cultural, visual and wildlife resources, must be evaluated prior to making a leasing decision. It is common for grazing to continue in undeveloped portions of an existing oil and gas field, and disturbance of wildlife may likewise be minimal. The impact to human communities should also be examined as part of the leasing decision.

Soil, water, and air resources will be impacted by oil and gas field exploration and development. Soil and water will be impacted by waste products from the drilling process, including drilling muds and produced formation water that may have high salinity or petroleum contaminants. The volume and areal extent of such contaminants depends on the drilling method, depth of the well, geologic formation, and type of fluid resource encountered.

Air quality may be impacted by pollutants from gas flares and processing stacks.

5.1.2 Carbon Dioxide and Helium

5.1.2.1 Background Information and Assumptions

There has been significant CO_2/He exploration in the Planning Area since 1998. Areas having high and moderate CO_2/He potential are shown on Map 5. The Zuni Basin area has high potential because it is a known CO_2 producing area. Five wells testing producible CO_2/He have been completed in that area by Ridgeway. Leasing interest is high in and around the Zuni Basin.

The large proven reserves of CO_2 in western Catron County are well-suited for use in enhanced oil recovery programs at depleted oil fields in California and Texas. The limiting factor to development of CO_2 resources is the construction of pipelines to deliver CO_2 to the user. Ridgeway is negotiating delivery contracts that will support the construction of a CO_2/He processing plant in eastern Arizona and a CO_2 pipeline to California. The processing plant will extract and collect helium before the CO_2 enters the pipeline. This activity will stimulate exploration and development of CO_2/He resources in the Planning Area. Helium currently sells for $52.50 per mcf and CO_2 sells for $0.75 per mcf (Ridgeway 2003).

The following assumptions were considered when evaluating the RFD for CO_2/He in the Planning Area:

- Drilling activity will increase in the next 15 years to define the extent of CO_2 reserves in response to increasing helium prices and increasing domestic demand.
- A pipeline will be constructed to deliver CO_2 to out-of-state markets.
- A large CO_2/He field will be discovered (greater than 50,000 acres). This assumes that significant additional CO_2/He reserves will be delineated in the Zuni Basin area.
- State and BLM regional development strategy will authorize a 320-acre spacing for CO_2 development wells.

5.1.2.2 Reasonable Foreseeable Development

The RFD for CO_2/He development in the Planning Area estimates that 150 exploratory and development wells will be drilled. This assumes one 50,000-acre field will be discovered and developed with a well spacing of 320 acres.

5.1.2.3 Disturbance to the Planning Area

The extent of disturbance or impact to the land from development of a large CO_2/He field is estimated using the acres per well values presented by the RMFLF (2002). Those assumptions are:

- The large field discovery will require approximately 150 exploration and/or development well sites on a total development field area of 50,000 acres with roads and associated infrastructure.
- The large field will impact or disturb an estimated 1,000 acres by installation of drill pads, roads, and infrastructure such as pipelines, compressor stations, and processing facilities.
- Each exploration well site will occupy 10 acres and each development or production well site will occupy 5 acres, including roads.
- Pad reclamation will reclaim approximately 50 percent of the exploration and development well drill pads for the long term.
- The average life of the large field will be 40 years.

Approximately 1,000 acres will be developed within the large CO_2/He field and will generally not be accessible for other resource uses. Another 45,000 to 50,000 acres within the leased area will probably not be developed. The short-term GSD assumes impact to the field within the first 10 years and is calculated using the following guidance (BLM 2002; RMFLF 2002):

GSD = (exploration wells)(acres/pad + road) + production wells (acres/pad + road).

The GSD for one large CO_2/He field = (10 x 10) + (140 x 5) = 800 acres.

The GSD does not include reclamation of drill pads. The long-term NSD includes reclamation of 50 percent of the exploration and development well drill pads during the remaining 30-year life of the field.

The NSD = (exploration wells)(acres/pad + road) + production wells (acres/pad + road) – exploration wells (acres reclaimed) - production wells (acres reclaimed) = (10 x 10) + (140 x 5) – (10 x 5) - (140 x 2.5) = 400 acres.

The potential impact to other resources, such as cultural, visual, and wildlife resources, must be evaluated prior to making a leasing decision. For example, leasing in the Zuni Basin area will be affected by the presence of Special Management Areas (SMAs). The Fence Lake Watershed SMA, Cerro Pomo Recreation SMA, and Zuni Salt Lake Cultural SMA are in the Zuni Basin, as is the Agua Fria Rangeland Area of Critical Environmental Concern. It is possible for grazing to continue in undeveloped portions of an existing CO_2/He field and disturbance of wildlife may likewise be minimal. The impact to human communities also should be examined as part of the leasing decision.

Impact to soil, water, and air resources by CO_2/He field exploration and development should be limited by the general absence of contaminants such as hydrocarbons. Soil and water will be impacted by waste products from the drilling process, include drilling muds and produced formation water that may have high salinity. The volume and areal extent of such contaminants depends on the drilling method, depth of the well, geologic formation, and type of fluids encountered.

Air quality may be impacted by pollutants from processing plants.

5.1.3 Coal Potential

5.1.3.1 Background Information and Assumptions

In the past 10 years there has been limited development in the Salt Lake coal field, which is one of five coal fields in Catron and Socorro Counties. The Salt Lake and Datil Mountains coal fields contain large coal deposits having high to moderate coal potential (refer to Map 4). Coal resources in those fields may be developed to provide fuel for several coal-fired power plants in eastern Arizona and northern New Mexico.

It is anticipated that development of coal resources in the Planning Area will increase as the generating capacity of those power plants is increased, as existing sources of coal are depleted, as domestic sources of natural gas decrease, and if more coal-fired power plants are constructed in the region. For example, Tucson Electric Power plans to increase by 50 percent the generating capacity of its coal-fired plant near Springerville, Arizona.

The following assumptions were considered when evaluating the RFD for coal in the Planning Area:

- Coal development activity will increase in the next 15 years in response to increasing domestic demand for electricity, increasing demand for coal to fuel coal-fired power plants, and decreasing domestic production of natural gas.

- One new coal field will be permitted that will be comparable in size to the Fence Lake coal field (approximately 18,000 acres).

- Coal resources will be mined at the surface, which involves stripping away the surface overburden sediments prior to removing the coal.

- Transportation of coal to the power plant will be by railroad.

- The land surface will be reclaimed in part during the life of the coal field.

5.1.3.2 Reasonable Foreseeable Development

The RFD for coal development in the Planning Area estimates that one new coal field will be permitted and developed. A total of 80 million tons of coal will be mined during the 50-year life of the mine.

5.1.3.3 Disturbance to the Planning Area

Surface mining the coal will require stripping the overburden above the coalbeds, which will impact or destroy vegetation, wildlife habitat, watershed, and visual resources. Up to 18,000 acres will be affected by surface mining activities. Disturbance of the land surface will require reclamation at the end of the life of the mine.

Local air quality will be significantly impacted by particulate pollutants (dust and smoke) from the surface mine and the coal processing plant. Regional air quality and visual resources will be impacted by pollutants discharged from the coal-fired power plant. The impact on visual resources from the power plant can extend tens of miles downwind.

An abundant water supply will be required to process the coal for transportation. The mine will require approximately 100 gallons per minute of water. The water will probably come from groundwater aquifers because there is limited availability of surface water in the Planning Area. The impact to the aquifers should be evaluated as part of the mine permitting process.

A right-of-way will be required for a railroad to transport coal to the power plant. For a 100-foot-wide railroad right-of-way, approximately 12 acres will be disturbed per mile of track.

5.1.4 <u>Geothermal</u>

5.1.4.1 Background Information and Assumptions

There has been limited development of geothermal energy resources in Socorro and Catron Counties. Three known geothermal resource areas having high to moderate geothermal resource potential exist in the Planning Area (refer to Map 6). These low-temperature geothermal resources have been used for small-scale space heating and for resort spas. Two geothermal leases have expired in the Planning Area and there are no indications for future leasing activity. The absence of geothermal leasing activity in the Planning Area is probably due to the limited uses for those low-temperature resources and the considerable expense to explore and develop them.

The following assumptions were considered when evaluating the RFD for geothermal energy resources in the Planning Area:

- There will be no leasing interest in the next 15 years.

- Drilling costs to explore and develop subsurface geothermal resources are comparable to costs for oil and gas exploration, and are probably too expensive for the limited revenue that would be generated by a low-temperature geothermal resource.

5.1.4.2 Reasonable Foreseeable Development

The RFD for geothermal resource development in the Planning Area expects that no leasing, exploration, or development will occur in the next 15 years. Costs to develop low-temperature geothermal resources are prohibitive compared to the potential revenue generation and limited uses of those resources.

5.1.4.3 Disturbance to the Planning Area

There is no foreseeable disturbance to public lands in the Planning Area in the next 15 years.

5.1.5 Solar Energy

5.1.5.1 Background Information and Assumptions

There has been no commercial development of solar energy resources in Socorro and Catron Counties. The map of solar energy resources shows that the Planning Area has generally uniform, high potential (refer to Map 8). There are no indications for permitting activity in the near future. However, it is anticipated that interest in permitting public lands to develop solar energy resources will increase in the next 15 years as new technology and lower equipment costs make solar concentrators economically competitive as a renewable energy source. It is also anticipated that Federal and State governments will actively promote new programs, such as tax incentives and low-interest loans to businesses, designed to encourage development of renewable energy resources.

The following assumptions were considered when evaluating the RFD for solar energy resources in the Planning Area:

- There will be two right-of-way permits issued for solar testing and commercial development in the Planning Area in the next 15 years.
- Each right-of-way permit will allow development of one solar array facility on 10 acres of land. The solar array facility will include a series of solar collector arrays, access roads, battery storage facilities, and power transfer stations.
- Each solar array facility will require a right-of-way for transmission lines. It is anticipated that to remain cost-effective the solar array facility must be constructed within 10 miles of the electricity end-user such as a city or commercial development, or within 10 miles of existing regional transmission lines rated at greater than 115 kilovolts (kV).

5.1.5.2 Reasonable Foreseeable Development

The RFD for solar energy resources in the Planning Area is that two right-of-way permits will be issued in the next 15 years. Incentives to develop solar energy resources will include Federal and State programs designed to encourage use of renewable energy resources, such as tax incentives and low-interest business loans.

5.1.5.3 Disturbance to the Planning Area

The RFD anticipates permitting two rights-of-way totaling 20 acres for construction of solar array facilities. The solar array facilities will occupy most of the permitted acreage with solar concentrators, access roads, battery storage facilities, and power transfer stations.

The permits will also require rights-of-way for an estimated 20 miles of transmission lines to connect with the end user or regional transmission grid. The transmission lines could range in capacity from 69kV to 230kV depending upon the size of the solar array facilities. The right-of-way required for construction, operation, and maintenance of this line is approximately 75 to 150 feet wide. The transmission line would require minimal surface disturbance in relatively flat to rolling terrain; however, disturbance could increase in steep or rugged terrain to provide adequate construction access. Surface disturbance in relatively flat to rolling terrain would require minimal disturbance if overland construction methods (i.e., limited disturbance) are used. However, if overland construction access is not possible, construction of the transmission line could require establishing an access road 12 to 15 feet wide, structure pads up to 600 to 1,500 square feet, construction staging or assembly areas 1 to 2 acres per site, and 1 acre or less for conductor tensioning sites every 2 miles. Typical surface disturbance in this scenario would be approximately 2 to 3 acres per mile or approximately 40 to 60 acres total for the estimated 20 miles of transmission line.

The potential impact to other resources, such as cultural, visual, and wildlife resources, must be evaluated prior to making a leasing decision. Livestock grazing will be excluded from the solar array sites and habitat probably will be eliminated for most species of wildlife.

The impact to human communities should also be examined as part of the leasing decision. There will likely be a significant impact to visual resources from the transmission lines and the solar array facility.

Soil, water, and air resources will receive minimal impact from solar resource development. It is not expected that hazardous chemicals or substances potentially harmful to soil, wildlife, or water will be discharged to the ground. No discharges to the atmosphere will affect air quality.

5.1.6 Wind Energy

5.1.6.1 Background Information and Assumptions

There has been no commercial development of wind energy resources in Socorro and Catron Counties. Wind energy potential ranges from high to low and varies depending on differences in ground elevation. Hence, the higher mountain elevations have greater wind energy potential (refer to Map 9). There are no indications for permitting activity in the near future. However, it is anticipated that interest in permitting public lands to develop wind energy resources will increase in the next 15 years as new technology and lower equipment costs make wind turbines economically competitive as a renewable energy source. It is also anticipated that Federal and State governments will actively promote new programs, such as tax incentives and low-interest loans to businesses, designed to encourage development of renewable energy resources.

The following assumptions were considered when evaluating the RFD for wind energy resources in the Planning Area:

- There will be one right-of-way permit issued for wind energy testing and commercial development in the Planning Area in the next 15 years.
- The right-of-way permit will allow development of 40 acres of land, including wind turbine towers, access roads, battery storage facilities, and power transfer stations.
- Each wind farm facility will require a right-of-way for transmission lines. It is anticipated that to remain cost-effective the wind farm facility must be constructed within 50 miles of the electricity

end-user, such as a city or commercial development, or within 50 miles of existing regional transmission lines rated at greater than 115kV.

5.1.6.2 Reasonable Foreseeable Development

The RFD for wind energy resources in the Planning Area is that one right-of-way permit will be issued in the next 15 years. Incentives to develop wind energy resources will include Federal and State programs designed to encourage use of renewable energy resources, such as tax incentives and low-interest business loans.

5.1.6.3 Disturbance to the Planning Area

The RFD anticipates permitting one right-of-way totaling 40 acres for construction of a wind farm facility. The facility will occupy most of the permitted acreage with 40 wind turbines (approximately one per acre), access roads, battery storage facilities, and power transfer stations.

The wind farm will require a right-of-way permit for an estimated 50 total miles of transmission lines to the end-user or regional transmission lines. It is assumed that construction of the transmission lines will cause a moderate level of disturbance to the Planning Area. A moderate level of disturbance is based on the establishment of a new 150-foot-wide right-of-way on easily accessible flat terrain, and installation of a 69kV to 230kV transmission line on that right-of-way. The moderate level of impact of the transmission lines is estimated at 10 acres per mile, for a total disturbance of 500 acres.

The potential impact to other resources, such as cultural, visual, and wildlife resources, must be evaluated prior to making a leasing decision. In general, the effects of wind turbines on bird and bat populations must be evaluated prior to issuing a permit. It is likely that the land can be concurrently used for grazing in undeveloped portions of the wind farm. Disturbance of wildlife habitat will generally be limited to the pads supporting the wind turbines and access roads.

The impact to human communities should also be examined as part of the leasing decision. There will likely be significant impact to visual resources from the transmission lines and the wind turbine facility.

Soil, water, and air resources will receive minimal impact from wind energy resource development. It is not expected that hazardous chemicals or substances potentially harmful to soil, wildlife, or water will be discharged to the ground. No discharges to the atmosphere will affect air quality.

5.2 LOCATABLE MINERALS

5.2.1 Background Information and Assumptions

Mining districts are areas of known occurrences of locatable metallic and nonmetallic mineral resources (refer to Map 10). The year of discovery, years of production, commodities present, commodities mined, type of geologic deposit, cumulative tons, and cumulative value of mineral production for each district are listed in Table 6. The mining districts have high potential for metallic and nonmetallic mineral resources because the minerals are known to occur. However, most of the mines have been inactive for many years because the cost to mine the commodity exceeds the market value of the commodity. There are only two locatable mineral mines operating in the Planning Area.

The following assumptions were considered when evaluating the RFD for locatable mineral resources in the Planning Area:

- There will be two new small locatable mineral discoveries or mining districts discovered in the next 15 years.

- Each new locatable mineral discovery will occupy approximately 40 surface acres, and include tailings piles.

- The majority of the mining activity will be underground.

- Where applicable, milling of the commodity ore will be conducted offsite.

- Transportation of the commodity ore will be by surface road.

- The land surface will be not be reclaimed during the life of the mine.

5.2.2 Reasonable Foreseeable Development

The RFD for locatable mineral resources in the Planning Area expects that some exploration will occur in the next 15 years and two underground locatable mineral deposits will be developed.

5.2.3 Disturbance to the Planning Area

There is some foreseeable disturbance by mining activities on public lands in the Planning Area in the next 15 years. Surface activities associated with two new underground mines will impact or destroy vegetation, wildlife habitat, and watershed. Up to 80 acres will be affected by surface activities, including placement of tailings piles. Disturbance of the land surface will require reclamation at the end of the life of the mine.

A right-of-way will be required for a new road to transport commodity ore offsite. For a 40-foot-wide road right-of-way, approximately 5 acres will be disturbed per mile of road. Based on an estimate of 10 miles of road for each new mine, a total of 100 acres of land will be disturbed by new road construction.

5.3 SALABLE MINERALS

5.3.1 Background Information and Assumptions

There are many locations for salable mineral resources in Catron and Socorro Counties. Known occurrences (pits), prospects, and potential of salable mineral resources are shown on Map 11. The location, pit number, rock type, quality, thickness, and estimated quantity of salable minerals at each pit is presented in Table 7. Those locations have high potential for salable mineral resources because the minerals are known to occur. Most of the locations are inactive or are prospects that will be opened when salable minerals are needed for local construction operations. Mine Safety and Health Administration reports there is one active pit and three intermittently active pits operating in the Planning Area. Community pits on public lands are opened when the local community expresses an interest in those commodities.

The following assumptions were considered when evaluating the RFD for salable mineral resources in the Planning Area:

- The demand for salable minerals will increase during the next 15 years as population increases stimulate new construction of roads, buildings, and infrastructure.

- An estimated five new salable mineral pits or community pits will be permitted in the next 15 years.

- New pit access will not require new road construction because pits are usually sited for convenient access to existing paved roads.

5.3.2 Reasonable Foreseeable Development

An estimated five new salable mineral pits or community pits will be permitted or reactivated in the next 15 years. The type and volume of salable minerals disposed is uncertain and depends on the increase in community development. An estimated 50,000 cubic yards will be removed per year from each pit in the next 15 years, for a total disposal of 3,750,000 cubic yards.

5.3.3 Disturbance to the Planning Area

Each salable mineral pit or community pit will occupy approximately 30 acres. Approximately 150 total acres will be impacted by five pits. Disturbance of the land surface will require reclamation at the end of the life of the pits.

The potential impact to other resources, such as cultural, visual, and wildlife resources, must be evaluated prior to making a leasing decision. The impact to human communities should also be examined as part of the leasing decision.

Soil will locally be destroyed by removal of salable minerals from community pits. Surface water will be impacted by erosion and runoff of soil from those areas where ground cover has been removed.

Local air quality will be impacted by particulate pollutants (dust) from surface mining and the rock crushing plant, where applicable. Regional air quality will not be impacted by pit operations.

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TABLES

TABLE 1
OIL AND GAS EXPLORATION WELLS, SOCORRO AND CATRON COUNTIES, NEW MEXICO

Reference Number	Lease Name	Well No.	Operator Name	Location							Current Status	Driller TD	Formation At TD Name	Comp Date	Potential/ Shows
				Quad	Twp	Rge	Sec	160	40	10					
S-01	BELEN GRANT	1	JOINER OIL COMPANY	1	3	1	16	4	4	2	TA-O	600	UNKNOWN	19400821	oil show
S-02	SANCHEZ	2	LAING RICHARD B	1	2	4	23	3	1	3	D&A	400	PENNSYLVANIA	19530429	gas show
S-03	OIL AND GAS	2-A	KEELING DRLG CO	1	2	4	23				D&A	738	UNKNOWN	19541201	
S-04	FEDERAL	1	LAING RICHARD B	1	2	4	23	3	2	3	D&A-G	1182	UNKNOWN	19520401	gas show
S-05	SEIDLE ETAL		BELEN OIL & DEV CO	1	4	1	23	1	1		D&A-O	3545	UNKNOWN	19781231	oil show
S-06	AGUAYO JACK	1	AGUAYO JACK	1	3	3	28	3	1	1	D&A	1800	UNKNOWN	19850304	
S-07	ANGEL EYES	1	DAVIS PETROLEUM CORI	1	4	1	19	4	3		D&A	8074	BASALT	19960328	
S-08	SANCHEZ	2-A	KEELING DRLG CO	1	2	4	23	2	2		TA-OG	738	GRANITE	19550228	oil and gas show
S-09	BROWN	1	CENTRAL NEW MEXICO	1	3	1	16	2	2	2	D&A-O	2840	UNKNOWN	19391128	oil show
S-10	NFT	2	TWINING DRLG CORP	1	4	1	28	4	2	2	D&A	8400	BASALT	19990523	
S-11	NFT	3	TWINING DRLG CORP	1	4	1	27	4	2	1	D&A	6908	TERTIARY	20020404	
S-12	STATE	1	WHITE & MANGELS	2	4	3	32	1	3		D&A	201	UNKNOWN	19470718	
S-13	STATE	1	R B WHITE & E T MNGL	2	4	3	32				D&A	368	UNKNOWN	19470720	
S-14	MCDONALD-STATE	1	OHIO OIL CO THE	2	4	6	32	3			D&A	1997	UNKNOWN	19261121	
S-15	RED LAKE	1	MITCHELL L H & SONS	2	3	8	2	2	2		D&A	4012	UNKNOWN	19221231	
S-16	HENDERSON SFPRR	1	TRANS OCEAN OIL INC	2	1	6	35	1	3	4	D&A	9379	PRE CAMBRIAN	19770305	
S-17	MAJOR-SFPRR	1	TRANS OCCEAN OIL INC	2	4	6	27	2	3	4	D&A	4690	PRE CAMBRIAN	19770731	
S-18	SFP DAVIS PUEBLO	1	WHIGHAM INCORP	2	1	6	35	3	3	3	D&A	1163	DAKOTA	19790507	
S-19	SANTA FE PAC 9608	1-F	JTB OIL COMPANY	3	4	5	17	4	2		D&A-G	4784	PRE CAMBRIAN	19590820	gas show
S-20	APACHE	1-A	ARNOLD	3	6	1	13	4	4	1	D&A-O	2445	UNKNOWN	19271209	oil show
S-21	APACHE	2	ARNOLD	3	6	1	13	4	1		D&A-G	1973	UNKNOWN	19290509	gas show
S-22	FEDERAL-GODDARD	1	SKELLY OIL COMPANY	4	2	4	22	2	4		D&A	3385	PRE CAMBRIAN	19481207	
S-23	LOCKHART-FEDERAL	1	LOCKHART J R	4	4	6	28	4	2		D&A-O	2976	GRANITE	19531118	oil show
S-24	LOCKHART-FEDERAL	2	LOCKHART J R	4	4	6	33				D&A-OG	3037	UNKNOWN	19541108	oil and gas show
S-25	FEDERAL	3	LOCKHART J R	4	4	6	33	3	3	2	D&A-O	2666	PENNSYLVANIA	19551101	oil show
S-26	LACEY-HATTIE-FED	1	SPEED JACK	4	4	6	23	2	2		TA	1895	UNKNOWN	19710429	
S-27	HATTIE LACEY	1	SPEED JACK	4	4	6	23	2	2		D&A	1895	GRANITE	19711001	
S-28	PAN HANDLE	1	LANDRETH VIRGLE	4	4	6	23	2	2		D&A-G	3445	UNKNOWN	19720630	gas show
S-29	LACY-HATTIE-FED	1	SPEED JACK	4	4	6	23	2	2		D&A-OG	3445		19730201	oil and gas show
S-30	PANHANDLE A	1	LANDRETH VIRGLE	4	4	6	28				D&A-O	3240	UNKNOWN	19730810	oil show
S-31	MORRISON FEDERAL	1	REEVES BROTHERS PET	4	4	6	22	1	1		D&A	2928	PENNSYLVANIA	19760806	
S-32	MORRISON FEDERAL	2	REEVES BROTHERS PET	4	4	6	22	1	1	1	D&A	689	PERMIAN	19760621	
S-33	STACKHOUSE POWELL	1	LOCKHART OIL	4	3	6	14	1	4		D&A	2772	UNKNOWN	19300918	
S-34	BINGHAM-STATE	1	SUN OIL COMPANY	4	5	5	23	3	3		D&A	3141	GRANITE	19551021	
S-35	LOCKHART-FEDERAL	2	LOCKHART J R	4	4	6	33				D&A-G	3037		19601216	gas show
S-36	STONE	2	NEW MEXICO DEV	4	5	1	30	3	4		D&A-O	2370	UNKNOWN	19780101	oil show
S-37	C G STANLEY		CHUPADERA OIL	4	3	6	14	1	4		D&A	705	UNKNOWN	19780101	
S-38	GOVT PERMIT	1	ABO OIL COMPANY	4	3	6	14	3			D&A-G	584	UNKNOWN	19271209	gas show
S-39		1	LAJARA BASIN OIL CO	4	1	1	13	1			D&A	800	UNKNOWN	19230101	
S-40	WISHBONE	1	ANDERSON JAMES K INC	4	4	3	1	4	4	3	D&A	4997	GRANITE WASH	19890212	
S-41	LACY HATTIE	ST-1	MTN STATES PET CORP	4	4	6	11	2	2		D&A	3065	GRANITE	19910927	
S-42	CHUPADERA	1	MTN STATES PET CORP	4	3	6	23	4	4		D&A-G	4379	GRANITE	19930720	gas test

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Reference Number	Lease Name	Well No.	Operator Name	Location							Current Status	Driller TD	Formation At TD Name	Comp Date	Potential/ Shows
				Quad	Twp	Rge	Sec	160	40	10					
S-43	CATHEAD MESA	1	MANZANO OIL CORP	4	4	9	8	2	1	3	D&A-G	6190	PRE CAMBRIAN	19961103	gas show
S-44	DULCE DRAW STATE	1	PRIMERO OPER INC	4	4	9	2	3	2		D&A-G	4030	PRE CAMBRIAN	20010808	gas show
S-45	CATHEAD MESA UNIT	1	PRIMERO OPER INC	4	4	9	8	2	1	3	RE-ENTRY	6180	PRE CAMBRIAN	2002	gas test
C-01	GORMAN	1	GORMAN E J	2	3	9	34				D&A	166	UNKNOWN	19250508	
C-02	SMITH M P	1	RED FEATHER PETRO	2	4	9	30				D&A	510	MANCOS	19340103	
C-03	BAILEY R C	1	BOWSER & FENNER	2	2	16	35				D&A	300	CRETACEOUS	19280821	
C-04	BAILEY R C	1	FENNER A E	2	2	16	35				D&A	408	UNKNOWN	19290615	
C-05	BAILEY R C	2	FENNER OIL CO	2	2	16	35				D&AOG	670	UNKNOWN	19300415	oil and gas show
C-06	BACA H	1	BAILEY R C	2	1	16	3				D&A-O	505	UNKNOWN	19331014	
C-07	H BACA	2	BAILEY R C	2	1	16	3				W-INJ	505	UNKNOWN	19361127	
C-08	CLAUDE A TEEL	1	SKELLY OIL COMPANY	2	4	19	27	4	3		D&A	1140	SAN ANDRES	19520208	
C-09	TEEL CLAUDE A	1	SKELLY OIL COMPANY	2	4	19	27	4	3		D&A	1140	SAN ANDRES	19520208	
C-10	MARY NELL TEEL	1	SKELLY OIL COMPANY	2	2	19	7	4	4	3	D&A	2365	UNKNOWN	19520310	
C-11	STRAT TEST `SEC 27`	1	SKELLY OIL COMPANY	2	3	21	27	3			D&A	2597	PRE CAMBRIAN	19520401	
C-12	FEDERAL	1	HUCKELBERRY CLAUD	2	2	16	11				D&A	5642	UNKNOWN	19561225	
C-13	SANTA FE PAC UNIT H	1	JTB OIL COMPANY	2	4	11	27	4	1		D&A-OG	5397	PRE CAMBRIAN	19590923	oil and gas show
C-14	SANTA FE PACIFIC RR	1	SPANIEL & HEINZE	2	4	9	19				D&A-O	1200	CHINLE	19591128	
C-15	FEDERAL	1	CLEARY PETRO CORP	2	3	16	6	3	1		D&A	2595	GLORIETA	19631123	
C-16	COW SPRINGS	2	RED FEATHER	2	4	9	30	1			D&A-O	1330	UNKNOWN	19260501	
C-17	STATE-2111	1	TRANS OCEAN OIL INC	2	2	18	2	2	4	3	D&A	4275	PRE CAMBRIAN	19770601	
C-18	STATE-2094	1	TRANS OCEAN OIL INC	2	2	14	2	2	2	2	D&A	6030	PRE CAMBRIAN	19770701	
C-19		1	GORMAN S J	2	4	9	34	2	2		D&A	168	UNKNOWN	19780101	
C-20		2	GORMAN S J	2	3	9	34	2	2		D&A	510	UNKNOWN	19280119	
C-21	STATE-2095	1	TRANS OCEAN OIL INC	2	2	14	33	1	1	1	D&A	5542	PRE CAMBRIAN	19780303	
C-22	FEDERAL 23-6-88	1	TRANS OCEAN OIL INC	2	2	16	26	1	4	3	D&A	5810	UNKNOWN	19780203	
C-23	REEVES	2	REEVES BROTHERS PET	2	2	11	26	1	1	3	D&A	770	PERMIAN	19790826	
C-24	REEVES	1	REEVES BROTHERS PET	2	2	11	14	4	4	4	D&A-O	650	PERMIAN	19790826	
C-25	SFP	1	JONES MORRIS B	2	4	9	19	1	4	3	D&A	5106	PRE CAMBRIAN	19810908	
C-26	LAGUNA-FEDERAL	1	SAMEDAN OIL CORP	2	3	12	14	4	2	4	D&A	5915	GRANITE	19841112	
C-27	SFPRR	6	BLACK OIL COMPANY	2	3	9	21	2	4	2	D&A	680	MANCOS	19870620	
C-28	STATE 1-4	1	RIDGEWAY AZ OIL CORP	2	1	21	4	4	4		TA-G	2540	PRE CAMBRIAN	20000614	productive CO_2 test
C-29	STATE	1	RIDGEWAY AZ OIL CORP	2	2	21	13	4	3		D&A	2717	PRE CAMBRIAN	19980313	
C-30	NORTH STATE 16	1	RIDGEWAY AZ OIL CORP	2	1	20	16	4	4		TA-G	2959	PRE CAMBRIAN	20021022	productive CO_2 test
C-31	STATE NORTH 36	2	RIDGEWAY AZ OIL CORP	2	1	21	36	4	4		TA-G	3968	GRANITE WASH	20010326	productive CO_2 test
C-32	SAN AUGSTN PLNS U	1	SUN OIL COMPANY	3	3	9	29	3	3	3	D&A-G	12284	GRANITE	19660623	gas show
C-33	FEDERAL	1	TENNECO OIL CO	3	1	13	35	3	1		D&A	7900	GRANITE	19670713	
C-34	TURNER-SFPRR	1	TRANS OCEAN OIL INC	3	3	9	21	2	4	2	D&A	5220	PRE CAMBRIAN	19770506	
C-35	SWEPI ETAL STATE	1	SHELL WESTERN E&P IN	3	4	13	2	2	4	2	D&A-G	7000	PRE CAMBRIAN	19870904	gas show
C-36	SWEPI ET AL MANGUS	1	SHELL WESTERN E&P IN	3	3	15	21	2	2	3	D&A	7808	PRE CAMBRIAN	19871204	

TABLE 1
OIL AND GAS EXPLORATION WELLS, SOCORRO AND CATRON COUNTIES, NEW MEXICO

Reference Number	Lease Name	Well No.	Operator Name	Location Quad	Twp	Rge	Sec	160	40	10	Current Status	Driller TD	Formation At TD Name	Comp Date	Potential/ Shows
C-37	SWEPI ET AL ASPEN FE	1	SHELL WESTERN E&P IN	3	1	13	27	3	3	4	D&A	7961	PRE CAMBRIAN	19880304	
C-38	STATE	1	HUNT OIL CO	3	3	13	16	1	4	4	D&A-G	6900	ABO	19891108	gas show
C-39	SOUTH STATE 36	1	RIDGEWAY AZ OIL CORP	3	1	21	36	2	2		TA-G	3170	PRE CAMBRIAN	19990329	productive CO_2 test
C-40	STATE 1-16	1	RIDGEWAY AZ OIL CORP	3	1	21	16	3	2		TA-G	2861	SUPAI	19990825	productive CO_2 test

Petroleum Information/Dwights 2002; New Mexico Energy, Minerals and Natural Resources Department 2002; Broadhead and Black 1989; Broadhead 1983

NOTES:

Driller TD = total depth of well
D&A = drilled and abandoned
D&A-O = drilled and abandoned; oil show
D&A-G = drilled and abandoned; gas show
D&A-OG = drilled and abandoned; oil and gas show
W-INJ = water injection well
TA = temporarily abandoned
TA-G = temporarily abandoned; gas productive
TA-OG = temporarily abandoned; oil and gas shows

TWP = Township
RGE = Range
SEC = Section
QUAD = Quadrant relative to the intersection of the baseline and meridian (see diagram).
160 = The 160-acre quadrant within the designated Section.
40 = The 40-acre quadrant within the designated 160-acre portion of the Section.
10 = The 10-acre quadrant within the designated 40-acre portion of the Section.
1 = Northeast quadrant
2 = Northwest quadrant
3 = Southwest quadrant
4 = Southeast quadrant

2	1
3	4

TABLE 2
ESTIMATED COALBED METHANE MINERALIZED TYPE
SOCORRO AND CATRON COUNTIES, NEW MEXICO

		Coalbed Methane Prospects			
Characteristic	**Southern San Juan Basin** [1]	**West of Jornada del Muerto Coal Field** [2]	**West of Carthage Coal Field** [2,4]	**South of Salt Lake Coal Field** [2, 3]	**South of Datil Mountains Coal Field** [2]
Formation	**Fruitland**	**Mesaverde Group**	**Mesaverde Group**	**Moreno Hill**	**Tres Hermanos; Crevasse Canyon**
Tectonic Setting					
Regional tectonic controls	low	moderate	probably moderate	low	low
Burial depth (ft)	1,000 - 2,000	500 - 3,000+	unknown	500 - 3,000	500 - 3,000
Deformation	low	moderate	probably moderate	low	low
Coalbed attitude	low angle	moderate angle	unknown	low angle	low angle
Depositional Setting					
Stratigraphic traps	present	unknown	unknown	present	present
Net coal thickness (ft)	30-50	3-7 (est.)	8-14	6-22	6-12 (est.)
Average seam thickness (ft)	6-9	1-2 (est.)	4-7	5-15	3 (est.)
Number of coal seams	6-9	3-6 (est.)	2	11-13	3 (est.)
Fracture Patterns					
differential compaction	present	unknown	unknown	present	present
fractures, cleats	moderate	probably high	probably high	probably moderate	probably moderate
Hydrology	no data	no data	no data	no data	no data
Gas Composition / Thermal Maturity					
coal quality	subbitum B - A bitum	high-volatile C-bituminous	high-volatile C-bituminous	subbituminous A	subbituminous A
Est. Mineralized Type	moderate quality	high quality	high quality	moderate quality	moderate quality

SOURCES:

[1] Ayers, Walter B., Jr., and William R. Kaiser, eds. 1994

[2] Hoffman, Gretchen K. 1996

[3] Campbell, Frank 1989

[4] Tabet, David E. 1979

NOTE:

est. = estimated for this report

TABLE 3
WELLS WITH GAS SHOWS AND CARBON DIOXIDE (CO_2)/HELIUM (He) POTENTIAL
SOCORRO AND CATRON COUNTIES, NEW MEXICO

Reference Number	Lease Name	Well No.	Operator Name	Location							County Name	Current Statis	Driller TD	Formation At TD Name	Comp Date	Potential/ Shows
				Quad	Twp	Rge	Sec	160	40	10						
S-02	SANCHEZ	2	LAING RICHARD B	1	2	4	23	3	1	3	SOCORRO	D&A-G	400	PENNSYLVANIAN	19530429	gas show
S-04	FEDERAL	1	LAING RICHARD B	1	2	4	23	3	2	3	SOCORRO	D&A-G	1182	UNKNOWN	19520401	gas show
S-08	SANCHEZ	2-A	KEELING DRLG CO	1	2	4	23	2	2		SOCORRO	TA-OG	738	GRANITE	19550228	oil and gas show
S-19	SANTA FE PAC 9608	1-F	JTB OIL COMPANY	3	4	5	17	4	2		SOCORRO	D&A-G	4784	PRECAMBRIAN	19590820	gas show
S-21	APACHE	2	ARNOLD	3	6	1	13	4	1		SOCORRO	D&A-G	1973	UNKNOWN	19290509	gas show
S-24	LOCKHART-FEDERAL	2	LOCKHART J R	4	4	6	33				SOCORRO	D&A-OG	3037	UNKNOWN	19541108	oil and gas show
S-28	PAN HANDLE	1	LANDRETH VIRGLE	4	4	6	23	2	2		SOCORRO	D&A-OG	3445	UNKNOWN	19720630	oil and gas show
S-29	LACY-HATTIE-FED	1	SPEED JACK	4	4	6	23	2	2		SOCORRO	D&A-OG	3445		19730201	oil and gas show
S-35	LOCKHART-FEDERAL	2	LOCKHART J R	4	4	6	33				SOCORRO	D&A-G	3037		19601216	gas show
S-38	GOVT PERMIT	1	ABO OIL COMPANY	4	3	6	14	3			SOCORRO	D&A-G	584	UNKNOWN	19271209	gas show
S-42	CHUPADERA	1	MTN STATES PET CORP	4	3	6	23	4	4		SOCORRO	D&A-G	4379	GRANITE	19930720	gas test
S-43	CATHEAD MESA	1	MANZANO OIL CORP	4	4	9	8	2	1	3	SOCORRO	D&A-G	6190	PRE CAMBRIAN	19961103	gas show
S-44	DULCE DRAW STATE	1	PRIMERO OPER INC	4	4	9	2	3	2		SOCORRO	D&A-G	4030	PRE CAMBRIAN	20010808	gas show
S-45	CATHEAD MESA UNIT	1	PRIMERO OPER INC	4	4	9	8	2	1	3	SOCORRO	RE-ENTRY	6180	PRE CAMBRIAN	2002	gas test
C-05	BAILEY R C	2	FENNER OIL CO	2	2	16	35				CATRON	D&A-OG	670	UNKNOWN	19300415	oil and gas show
C-13	SANTA FE PAC UNIT H	1	JTB OIL COMPANY	2	4	11	27	4	1		CATRON	D&A-OG	5397	PRE CAMBRIAN	19590923	oil and gas show
C-28	STATE 1-4	1	RIDGEWAY AZ OIL CORP	2	1	21	4	4	4		CATRON	TA-G	2540	PRE CAMBRIAN	20000614	productive CO_2 test
C-30	NORTH STATE 16	1	RIDGEWAY AZ OIL CORP	2	1	20	16	4	4		CATRON	TA-G	2959	PRE CAMBRIAN	20021022	productive CO_2 test
C-31	STATE NORTH 36	2	RIDGEWAY AZ OIL CORP	2	1	21	36	4	4		CATRON	TA-G	3968	GRANITE WASH	20010326	productive CO_2 test
C-32	SAN AUGUSTN PLNS	1	SUN OIL COMPANY	3	3	9	29	3	3	2	CATRON	D&A-G	12284	GRANITE WASH	19660623	gas show
C-35	SWEPI ETAL STATE	1	SHELL WESTERN E&P IN	3	4	13	2	2	4	2	CATRON	D&A-G	7000	PRE CAMBRIAN	19870904	gas show
C-38	STATE	1	HUNT OIL CO	3	3	13	16	1	4	4	CATRON	D&A-G	6900	ABO	19891108	gas show
C-39	SOUTH STATE 36	1	RIDGEWAY AZ OIL CORP	3	1	21	36	2	2		CATRON	TA-G	3170	PRE CAMBRIAN	19990329	productive CO_2 test
C-40	STATE 1-16	1	RIDGEWAY AZ OIL CORP	3	1	21	16	3	2		CATRON	TA-G	2861	SUPAI	19990825	productive CO_2 test

SOURCE:
Petroleum Information/Dwights 2002; New Mexico Energy, Minerals and Natural Resources Department 2002; Johnson, Roy E. 2002

NOTE: For purposes of this report all "gas" shows are considered potential CO_2/He shows even though many tests did not analyze for and/or report CO_2 or helium composition in gas.

TWP = Township
RGE = Range
SEC = Section
D&A = drilled and abandoned
D&A-O = drilled and abandoned; oil show
D&A-G = drilled and abandoned; gas show
D&A-OG = drilled and abandoned; oil and gas show
W-INJ = water injection well
TA-G = temporarily abandoned; gas productive
TA-OG = temporarily abandoned; oil and gas shows
DRILLER TD = Total depth of well

QUAD = Quadrant relative to the intersection of the baseline and meridian (see diagram).
160 = The 160-acre quadrant within the designated Section.
40 = The 40-acre quadrant within the designated 160-acre portion of the Section.
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2	1
3	4

TABLE 4
ANALYSES OF COAL SAMPLES FROM FOUR COAL FIELDS
SOCORRO AND CATRON COUNTIES, NEW MEXICO

	Coal Field			
Analysis (Average)	**Jornada del Muerto**	**Carthage**	**Salt Lake**	**Datil Mountains**
Coal Rank	**high-volatile C-bituminous**	**high-volatile C-bituminous**	**subbituminous A**	**subbituminous A**
Moisture (%)	2.7	3.58	14.71	6.24
Ash (%)	8.3	10.86	17.07	12.84
Volatile matter (%)	42.6	36.53	31.67	38.28
Fixed carbon (%)	46.5	49.04	36.19	42.69
Sulfur (%)	0.8	0.84	0.69	0.72
Calorific value (Btu/lb)	13,140	12,531 [1]	9,166	11,465
Lbs of Sulfur/MBtu	NR	0.67 [1]	0.77	0.66
Number of Samples	2	8	58	10

SOURCE:

Hoffman, Gretchen K. 1996

NOTES:

Btu = British thermal unit

lb = pound

MBtu = Thousand Btu

1 Average of 7 samples

NR = Not reported

TABLE 5
GEOTHERMAL ENERGY RESOURCES
SOCORRO AND CATRON COUNTIES, NEW MEXICO

Reference Number	Name	Well/ Spring	County	Depth m	Temp °C	Latitude	Longitude	Location							Geothermal Energy Mineral Type [1]		
								Quad	Twn	Rng	Sec	160	40	10	Temp	Geology	Fluid
S-01	Core Hole	w	Socorro	205.7	42.2	34.0800	106.9500	3	3	1	4	4	3	3	L	Gv	W
S-02	Warm Well	w	Socorro	66.5	36.0	34.1006	107.5419	3	2	7	27	4	4	4	L	Gv	W
S-03	Welty Salty Well	w	Socorro	234.7	35.0	33.7997	107.6389	3	6	8	8	4	3	2	L	Gc	W
S-04	Blue Canyon Well	w	Socorro	91.4	32.4	34.0467	106.9508	3	3	1	16	3	2	3	L	Gc	W
S-05	Socorro Gallery Spring	s	Socorro		32.0	34.0403	106.9383	3	3	1	22	1	1	3	L	Gv	W
S-06	Socorro/Sedilla Gallery Spring	s	Socorro		30.0	34.0378	106.9386	3	3	1	22	1	1	3	L	Gv	W
S-07	Well	w	Socorro		30.0	33.7633	107.3500	3	6	5	27	3	2		L	U	W
S-08	Monticello Box Warm Spring	s	Socorro		29.0	33.3933	107.5817	3	8	7	31	2	4		L	Gv	W
S-09	Monticello Box Warm Spring	s	Socorro		28.0	33.5733	107.6017	3	8	7	31	4	1		L	Gv	W
S-10	Cook Spring	s	Socorro			34.0467	106.9367	3	3	1	17	3	1		L	U	W
S-11	Bosque del Apache Well #13	w	Socorro		33.0	33.7900	106.8600	4	6	1	17	2	1	3	L	U	W
S-12	Warm Well	w	Socorro	30.5	33.0	33.8058	106.8761	4	6	1	7	2	1	3	L	Gv	W
S-13	Well	w	Socorro		30.0	34.1706	106.7522	4	2	2	5	2	2	3	L	Gv	W
S-14	Artesian Well	w	Socorro		26.0	34.5700	107.4400	2	4	6	14	3	1		L	Gv	W
S-15	Field Artesian Well	w	Socorro		25.0	34.5300	107.4700	2	4	6	33	3	4		L	Gv	W
S-16	Ojo Saladito Spring	s	Socorro		24.0	34.5100	107.1300	2	3	3	4	2	4		L	Gv	W
C-01	Hot Spring	s	Catron		64.8	33.2333	108.2367	3	12	14	24	4	4		L	Gv	W
C-02	Hot Spring	s	Catron		60.6	33.2333	108.2417	3	12	14	24	4	1	1	L	Gv	W
C-03	Well	w	Catron	182.9	32.0	33.2250	108.2417	3	12	14	25	2	3	1	L	Gc	W
C-04	Gila Middle Fork Hot Spring	s	Catron		34.0	33.2666	108.2500	3	12	14	1	3	3		L	Gv	W
C-05	Hot Spring	s	Catron		32.8	33.2600	108.2300	3	12	13	7	3	4		L	Gv	W
C-06	Test Well	w	Catron	182.9	32.2	33.2200	108.2200	3	12	13	30	2	3	1	L	Gc	W
C-07	Gila Middle Fork Pool HS	s	Catron			33.2333	108.2333	3	12	13	31	1			L	Gv	W
C-08	Gila Middle Fork Hot Spring	s	Catron		36.0	33.2900	108.2650	3	11	14	34	2	4		L	Gv	W
C-09	Gila Middle Fork Hot Spring	s	Catron		31.0	33.2833	108.2633	3	11	14	35	3	4		L	Gv	W
C-10	Gila Middle Fork Meadows HS	s	Catron		27.5	33.3100	108.3300	3	11	14	30	2			L	Gv	W
C-11	Warm Seep	s	Catron		27.2	33.2900	108.2600	3	11	14	35	4			L	Gv	W
C-12	Gila Middle Fork Hot Spring	s	Catron		37.0	33.2833	108.2666	3	11	14	35	3	2		L	Gv	W
C-13	Lower Frisco Hot Spring	s	Catron		46.1	33.2450	108.8817	3	12	20	23	1	2		L	Gv	W
C-14	Lower Frisco Hot Spring	s	Catron		43.3	33.2450	108.8817	3	12	20	23	3	2		L	Gv	W
C-15	Lower Frisco Hot Spring	s	Catron		43.0	33.2447	108.8811	3	12	20	23	3	2	1	L	Gv	W
C-16	Lower Frisco Hot Spring	s	Catron		40.0	33.2467	108.8783	3	12	20	23	1	4		L	Gv	W
C-17	Lower Frisco Hot Spring	s	Catron		35.0	33.2447	108.8811	3	12	20	23	3	2	1	L	Gv	W
C-18	Upper Frisco Hot Spring	s	Catron		36.5	33.8314	108.7994	3	5	19	35	1	3	2	L	Gv	W
C-19	Frieborn Canyon Hot Spring	s	Catron		33.3	33.7100	109.0100	3	7	21	9	4	4	2	L	Gv	W
C-20	Well	w	Catron		32.0	33.9575	107.8014	3	4	9	17	3	1	1	L	U	W
C-21	Pueblo Windmill	w	Catron	320.0	33.8	34.5389	108.7772	1	4	19	25	4	1	4	L	Gc	W
C-22	Well	w	Catron	411.5	28.0	34.5400	108.8300	1	4	19	28	2	3	4	L	Gc	W
C-23	Zuni Salt Lake Warm Spring	s	Catron		26.0	34.4500	108.7667	1	3	18	30	3	1		L	Gv	W

SOURCES:
Rural Economic Development Through Tourism 2002; Witcher, James C. 1995

NOTES:
Resource Type: Well (w) or Spring (s) — w = well; s = spring
1 See text for discussion of mineral types.

Temperature Type	Geologic Setting Type	Fluid Type
L = low	Gm = magmatic	W = liquid-dominated
M = moderate	Gv = convective	V = vapor-dominated
H = high	Gd = conductive	HDR = hot dry rock dominated
	Gg = geopressured	
	U = unknown	

QUAD = Quadrant relative to the intersection of the baseline and meridian (see diagram).

160 = The 160-acre quadrant within the designated Section.
40 = The 40-acre quadrant within the designated 160-acre portion of the Section.
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1 = Northeast quadrant
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2	1
3	4

October 2003

TABLE 6
MINING DISTRICTS AND MINERAL RESOURCE POTENTIAL
SOCORRO AND CATRON COUNTIES, NEW MEXICO

NMBGMR Mining District Name and ID Number [1]	General Land Office-BLM Mining District Name and Plat Number (and aliases)	Year of Discovery	Years of Production	Commodities Mined	Commodities Present	Estimated Cumulative Value of Production ($)	Type of Deposit	Estimated and Reported Base and Precious Metals Production by District*							
								Years Recorded	Ore Short Tons	Copper (lbs)	Gold (oz)	Silver (oz)	Lead (lbs)	Zinc (lbs)	Manganese (lbs)
SOCORRO COUNTY															
Abbe Spring - 206	(Abbe)	1870	1904	Ag, Cu, Pb	Ba, Zn	<1,000	volcanic-epithermal	Unknown	0	NA	0	NA	0	0	NA
ABBEY, Bear Mountains - 207	Abbey - 21A, (Bear Spring)	1983	None	None	Ag, Cu, Sb, Zn	0	volcanic-epithermal	NA	NA	NA	NA	NA	NA	NA	NA
CARTHAGE - 208	None	NA	NA	NA	Cu, Pb coal, clay, ls	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CAT MOUNTAIN Cat Mountain - 209	Cat Mountain - 9	1870	Unknown	Au, Ag, Cu	F, Ba, U, W	<1,000	volcanic-epithermal	Unknown	0	NA	<100	1,302	0	0	NA
Chupadera Mountains - 210	(Coyote Hill)	1900	None	None	Au, Ag, Cu, Pb, Zn, F, Ba, U, Th, Ti, Nb	0	Precambrian vein/replacement, carbonatite, REE-Th-U veins	NA	NA	NA	NA	NA	NA	NA	NA
CHUPADERO Chupadero - 211	(Minas de Chupadero, Chupadera, La Parida)	1800	Unknown	Ag, Cu	F, Ba, Pb, U	<1,000	sedimentary-Cu	1959-1960	2,000	80,000	0	NA	0	0	NA
CUCHILLO - 192	Iron Mountain No. 2														NA
COUNCIL ROCK Council Rock - 212	Iron Mountain - 34 (Iron Mountain No. 1, Ten Mile, Galena)	1881	Unknown	Ag, Fe, Pb	Cu, F, Ba, Mn, Zn, U	<1,000	volcanic-epithermal	Unknown	0	0	0	NA	NA	0	NA
Goldsboro [a] - 194	None	1900	None	None	Au, Ag, Cu, Sb, Mo, Mn	0	volcanic-epithermal	NA	NA	NA	NA	NA	NA	NA	NA
HANSONBURG Hansonburg - 213	Mound Springs - 46A-B, Oscura 14A-B	1872	1872-1957	Au, Ag, Cu, Pb, F, Ba	F, Mo, V	1,700,000	RGR	1937-1957	228,396	12,600	17	18,156	11,047,400	33,000	NA
Hook Ranch-Riley - 214	None	1950's	1954-1961	U, V	coal	40,000	sedimentary-U	NA	NA	NA	NA	NA	NA	NA	NA
HOP CANYON Hop Canyon - 215	Silver Mountain - 74A-C (Hope Canyon)	1880	1913-1941	Au, Ag, Cu, Pb	Ba, Zn, U	<1,000	volcanic-epithermal	1913-1941	(500)	(7,000)	(<100)	(1200)	(200)	0	NA
IRON MOUNTAIN NO. 2	(Limestone, Iron Mountain, Sierra Cuchillo)	NA	NA	Be, F, Fe, U, W	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
JONES Jones Camp - 216	(Estey, Chupadera Mesa)	1900	1942-1943	Fe	none	1,000	GPM	NA	NA	NA	NA	NA	NA	NA	NA
JOYITA HILLS Joyita Hills - 217	(Canyoncito, Dewey, La Joya)	1880	1915	Ag, F, Pb	Cu, Ba	<1,000	RGR	Unknown	0	0	0	(50)	NA	0	NA
LADRON Ladron Mountains - 218	Hanson - 29	1868	Unknown	Ag, Cu, F, Mn, Pb, U, V	Ba, Mo, Zn, W	<3,500	Precambrian vein/replacement, Ag-Cu (U) veins	Unknown	0	NA	0	NA	NA	0	NA
LEMITAR MOUNTAINS Lemitar Mountains - 219	(Box Canyon, Lemitar, Polvadero)	1880	Unknown	Ag, Cu, Ba, Pb, Mn, U	F, Zn, Th, Nb, Ti, REE	<1,000	Precambrian vein/replacement, carbonatite, REE-Th-U veins	Unknown	0	NA	0	NA	NA	0	NA
LUIS LOPEZ Luis Lopez - 220	(Genaros, Iron Horse, Red Hills, San Antonio)	1910	1942-1958	Mn, Fe	Au, Ag, Co, Mn, Pb, Zn, Ni, W	276,000	volcanic-epithermal	NA	NA	NA	NA	NA	NA	NA	30,000,000
MAGDALENA Magdalena - 221	Magdalena & Pueblo - 42A-X (East Magdalena, Kelley, Kelly, Pueblo)	1866	1866-1968	Au, Ag, Cu, Pb, Mn, Zn	F, Ba, Mo, V, W	<56,000,000	carbonate-hosted Pb-Zn	1904-1957	1,503,552	11,281,051	3,104	1,560,404	82,862,484	324,290,000	NA
								1866-1957	NA	(12,000,000)	(3,500)	(4,000,000)	(125,000,000)	(350,000,000)	NA
MILL CANYON	None	NA	NA	Au, Cu	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MOCKINGBIRD GAP Mockingbird Gap [a] - 222	Mocking Bird - 92A, Dripping Spring - 79A, Little Burro - 41A	1900	1934-1941	Ag, Ba, F, Pb	Cu, Zn	4,000	Precambrian vein/replacement, Ag-Cu (U) veins	1934-1941	833	0	0	117	71,200	0	NA

TABLE 6
MINING DISTRICTS AND MINERAL RESOURCE POTENTIAL
SOCORRO AND CATRON COUNTIES, NEW MEXICO

NMBGMR Mining District Name and ID Number [1]	General Land Office-BLM Mining District Name and Plat Number (and aliases)	Year of Discovery	Years of Production	Commodities Mined	Commodities Present	Estimated Cumulative Value of Production ($)	Type of Deposit	Estimated and Reported Base and Precious Metals Production by District*: Years Recorded	Ore Short Tons	Copper (lbs)	Gold (oz)	Silver (oz)	Lead (lbs)	Zinc (lbs)	Manganese (lbs)
NORTH MAGDALENA North Magdalena - 223	Magdalena & Pueblo - 42A-X (Silver Hill, Pueblo Springs, San Viciente)	1863	prior to 1957	Au, Ag, Cu, Ba, Pb	V, Zn	<1,000	volcanic-epithermal, carbonate-hosted Pb-Zn	1863-1957	0	NA	35	(<200)	1,400	0	NA
RAYO Rayo - 224	(Joya Mountains, La Joya, Manzanares)	1900's	1900's	Ag, Cu	none	<1,000	sedimentary-Cu	Unknown	0	NA	0	0	0	0	NA
None	Red Hill - 55A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ROSEDALE Rosedale - 225	Rosedale - 73A-C (San Mateo Mountains)	1882	1882-1981	Au, Ag	Cu, F, Mn, U	500,000	volcanic-epithermal, placer Au	1896-1941	81,828	0	13,276	5,363	0	0	NA
								1882-1981		0	(27,750)	(10,000)	0	0	NA
SAN JOSE San Jose - 226	San Jose - 118 (Nogal, San Mateo, Rhyolite, Nigger Diggings, Quartz Hill)	prior to 1900	prior to 1946	Au, Ag, Cu, Pb, Zn	Mo	40,000	volcanic-epithermal	1900-1946	4,706	250	842 (900)	12,920 (13,000)	100	0	NA
SAN LORENZO San Lorenzo 227	(Alamillo, Jerome, San Acacia)	1901	1900's	Ag, Cu	Au, U	<1,000	volcanic-epithermal	NA	NA	NA	NA	NA	NA	NA	NA
SCHOLLE Scholle [d] - 246	(Carocito, Abo, Avo)	1900's	1915-1961	Au, Ag, Cu, Pb, Ra	U, V	300,000	sedimentary-Cu	NA	NA	NA	NA	NA	NA	NA	NA
Socorro - 228	None	1950's	1955-1963	U, V	Cu	70,000	sandstone U, Ag-Cu (U) veins	NA	NA	NA	NA	NA	NA	NA	NA
SOCORRO PEAK Socorro Peak - 229	Socorro - 84A, La Encarnacion - 81A, Encarnacion La - 81 (Socorro Mountain)	1867	1867-1900 (Ag); 1949-present (perlite)	Ag, Pb, kaolin, perlite	Au, As, F, Ba, Br, Mn, Mo, V, W	11,000,000 (?)	volcanic-epithermal	1867-1900	0	0	0	(750,000)	NA	0	NA
SPRING HILL	Amy	NA	Cu	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
OJO CALIENTE NO. 2 Taylor - 230	None	1900's	Unknown	Ag, Cu, Pb	Au, Be, Mn	<1,000	volcanic-epithermal	Unknown	0	NA	0	NA	NA	0	NA
WATER CANYON Water Canyon - 231	Magdalena & Pueblo - 42A-X (Silver Mountain)	1868	1904-1956	Au, Ag, Cu, Pb	Zn, Mn	10,000	carbonate-hosted Pb-Zn	1905-1956	1,161	15,377	196	2,064	125,884	0	NA
UNNAMED (T.6S,R.8E)	None	1993	None	Gypsum	NA	NA	sedimentary	NA	NA	NA	NA	NA	NA	NA	NA
CHLORIDE Chloride [a,c] - 191	Black Range No. 1 - 2A-D (Apache, Fluorine)	1879	1879-1988	Au, Ag, Cu, Pb, Zn, Sn, zeolite	F, Ba, Mo, gem	20,000,000	volcanic-epithermal, placer Au, Laramide skarn	1934-1988	NA	(10,127,097)	(25,253)	(3,647,763)	(1,300,000)	(1,500)	NA
MOGOLLON Mogollon - 007	Cooney - 11 (Alma, Glenwood, Mogollon Mountains)	1875	1875-1969	Au, Ag, Cu, Pb, Zn, U	F, Ba, Mn, Mo	>25,000,000	volcanic-epithermal	1875-1969	1,967,656	(1,500,000)	(365,000)	(>20,000,000)	(1,200,000)	NA	NA
								1904-1957	NA	969,401	345,404	(16,890,929)	0	0	NA
QUEMADO SALT Zuni Salt Lake - 011	(Crater Salt Lake)	NA	NA	Salt	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Red Basin-Pie Town - 008	(Datil, McPhaul Ranch)	1954	1954-1957	U		13,000	sandstone U	NA	NA	NA	NA	NA	NA	NA	NA
San Francisco [b] - 064	None	1960	None	None	Au, Ag, Cu, Sb, Mn, Mo	0	volcanic-epithermal	NA	NA	NA	NA	NA	NA	NA	NA
TAYLOR CREEK Taylor Creek [a] - 204	(Black Range, Taylor Creek Tin)	1918	1919-1943	Sn, Mn	kaolin	7,000-8,000	tin veins and placer gold	NA	NA	NA	NA	NA	NA	NA	174,000
WILCOX Wilcox [b] - 010	Wilcox - 99A-E, (Seventy-four, Sacton Mesa, Tellurium)	1879	1941	Au, Ag, Cu, F, Te, Mn	Pb, Zn, Cd, Mo	100,000-500,000	volcanic-epithermal	1941	2	NA	1	17	0	0	174,000

[1] CAPITALIZED Mining District name from New Mexico Bureau of Mines and Mineral Resources (NMBMMR 1966); BLM Mining Districts from General Land Office-BLM (Sitzler 2003); Mining Districts with IDs from NMBGMR (McLemore 2002).

* = Data from USGS, 1902-1927; U.S. Bureau of Mines, 1927-1993; Lasky, 1932; Anderson, 1957; Thompson, 1965a, b; North, 1983; McLemore, 1994, 2002b, 2003; General Land Office-Bureau of Land Management; NMBGMR files; NMBMMR (1966).

Au = gold; Ag = silver; As = arsenic; Ba = barium; Be = beryllium; Bi = bismuth; Br = bromine; Cd = cadmium; Co = cobalt; Cu = copper; F = fluorine; Fe = iron; Ga = gallium; Ge = germanium; Mn = manganese; Mo = molybdenum;

Nb = niobium; Ni = nickel; Pb = lead; Ra = radium; Te = tellurium; REE = rare-earth elements; Sb = antimony; Sn = tin; V = vanadium; Th = thorium; Ti = titanium; U = uranium; W = tungsten; Zn = zinc; ls = limestone

a = A portion of this district extends into Sierra County. b = A portion of this district extends into Grant County. c = Most of the reported production in the Chloride District is from Sierra County. d = A portion of this district extends into Torrance County.

TABLE 7
SALABLE MINERALS
SOCORRO AND CATRON COUNTIES, NEW MEXICO

Pit Name or Number	Location								Pit Name and Rock Type	BLM Commodity Number		Quantity Produced		Prospect Pit or Quarry
	Quad	Twp	Rge	Sec	160	40	10	County				cu. Yds	tons	
BLM Pit														
067607	4	4	1	27	4	4	4	Socorro	M&M Rock;pumice, pumicite	491		40		
067617	3	4	1	22	1,2	3,4	1,4	Socorro	MCA Gravel-sand and gravel	523		220		P
067618	3	3	1	26,27				Socorro	Hwy 60-sand and gravel	523		875		P
067619	4	2	2	4	3			Socorro	Mesa del Yeso-flagstone	565			33.5	
077488	3	2	1	26				Socorro	Escondida-soil, fill	891		3552		P
094677	3	7	3	20;34	1;4	2;4		Socorro	NMHD-sand and gravel	525		327,000		P
095114	3;4	4	1	12;18	2;2	-;4		Socorro	sand and gravel	525		0		
096497	3	2	8	33	4	3		Socorro	sand and gravel	521		500		P
097799	4	2	1	21	3	4	2,3	Socorro	flagstone	565			500	P
097800	4	5	1	13	4			Socorro	sand and gravel	525		300		
097802	3	4	1	15;22	3;4	1;4	1,2	Socorro	MCA Pit-sand and gravel	523		15,088	25	P
101702	4	4	1	27;34	1,4;1	4;1		Socorro	pumice, volcanic ash	492		4,000		
101703	4	2	1	23	3	2-4		Socorro	flagstone	565		319	252	
103664	4	2	2	14	2	4	3	Socorro	stone	560			12.5	
103674	3	3	2	8	4;4	1;4	1,4;1	Socorro	sand and gravel	525		18,120		
103678	4	2	1	21	3	4	2,3	Socorro	flagstone	565		477		
103680	3	5	1	13	4	2	3	Socorro	soil, fill	891		0		
104141	4	2	1	16,17	20,2	multiple		Socorro	Pueblito Rock Area-flagstone	565			21.5	
106164	4	2	1	16	3	3		Socorro	Pueblito Rock Area-flagstone	565		31		
106165	4	2	1	16	3	3		Socorro	Pueblito Rock Area-flagstone	565		556		
106166	3	4	1	15	1,2;3	1,2;3,4		Socorro	sand and gravel	523		20		
106583	3	4	1	17	3;4	4;3		Socorro	sand and gravel	524		250,000		
097796	2	4	11	18				Catron	sand and gravel	525		0		
097803	3	1	19	10	1,2	2,3;1,4		Catron	Red Hill-cinders	525		9,865	3,699	P
101694	3	1	19	10	1,2	1,2		Catron	Red Hill-sand and gravel	523		53,000	40	P
104137	3	1	19	10				Catron	Red Hill-sand and gravel	525		410		P
104140	3	4	1	15;22	3,4;1,2			Catron	MCA Pit-sand and gravel	523		72		P

TABLE 7
SALABLE MINERALS
SOCORRO AND CATRON COUNTIES, NEW MEXICO

Pit Name or Number	Location								Rock Type	Quality of Material	Thickness of Material ft	Thickness of Overburden ft	Estimated Quantity cu. yds	Prospect Pit or Quarry
	Quad	Twp	Rge	Sec	160	40	10	County						
NMHD Pit														
5243	4	4	1	18				Socorro	NA	NA	NA	NA	NA	
5244	4	4	1	19	2			Socorro	sand and gravel	good	6+	0-2	400,000	
5245	4	4	1	31				Socorro	sand and gravel	good	10	0-2	150,000	
5308	3	3	8	25	4			Socorro	sand and gravel	good	6+	0-2	250,000	
5673	3	2	1	10	1			Socorro	sand and gravel	excellent	4-12	1.6-2.5	200,000+	
5703	3	2	4	6	2			Socorro	sand and gravel	good	16	0-6	500,000+	
5711	3	2	4	35	3			Socorro	mill tailings	fair	12	0-2	16,000	
5717	2	1	1	13				Socorro	sand and gravel	good	2-8	3-5	100,000+	
5786	1	2	4	10			*	Socorro	sand and gravel	good	4-12	0-1.7	250,000	
5912	4	4	1	6	1, 2			Socorro	sand	good	7-12	3-4	10,000	
5964	3	2	1	26	3			Socorro	sand and gravel	good	10	2	250,000	
6008	4	5	2	23				Socorro	rhyolite	good	25+	NA	135,000	
6019	3	4	1	7				Socorro	sand and gravel	excellent	9-13	0-4	200,000+	
6140	3	5	1	12	3			Socorro	sand and gravel	excellent	10	0-2	250,000	
6141	3	5	1	13				Socorro	sand and gravel	excellent	10	0-2	200,000	
6142	3	5	1	35			**	Socorro	sand and gravel	excellent	12	0-3	250,000	
6143	3	5	1	23			**	Socorro	sand and gravel	excellent	7-10	3-6	300,000+	
6536	3	9	4	35	4			Socorro	sand and gravel	excellent	10-13	0-2	200,000+	
6537	3	8	3	28				Socorro	sand and gravel	good	10	0-2	300,000	
6538	3	7	3	36				Socorro	sand and gravel	excellent	12	0-2	400,000	
6540	3	9	3	18	2			Socorro	sand and gravel	excellent	10	0-3	600,000	
6540	3	9	3	18	4			Socorro	sand and gravel	excellent	10	0-3	600,000	
6720	3	8	3	29	1			Socorro	sand and gravel	excellent	10-13	0-1	400,000	
6721	3	9	3	5				Socorro	sand and gravel	good	6+	0-2	350,000	
6721	3	9	3	4				Socorro	sand and gravel	good	6+	0-2	350,000	
6757	3	7	3	36				Socorro	NA	NA	NA	NA	NA	

TABLE 7
SALABLE MINERALS
SOCORRO AND CATRON COUNTIES, NEW MEXICO

Pit Name or Number	Location								Rock Type	Quality of Material	Thickness of Material ft	Thickness of Overburden ft	Estimated Quantity cu. yds	Prospect Pit or Quarry
	Quad	Twp	Rge	Sec	160	40	10	County						
6810	3	2	1	14	3, 4			Socorro	silty sand and gravel	excellent	10	1-2	400,000+	
6811	3	2	1	26				Socorro	silt, rock, gravel	good	8-12	2-3	500,000+	
7201	4	4	1	31	1, 4			Socorro	sand and gravel	excellent	12+	0-3	230,000+	
7309	3	5	1	13	1, 4			Socorro	sand and gravel	excellent	8-12	1-3	300,000+	
7317	3	9	4	35	3, 4			Socorro	sand and gravel	excellent	12-14	0-2	200,000+	
55127	3	2	1	23				Socorro	sand and gravel	good	6-12	1-6	500,000+	
55127	3	2	1	26				Socorro	sand and gravel	good	6-12	1-6	500,000+	
57114	2	2	1	3	4			Socorro	sand and gravel	good	2-14	2-4	150,000+	
57119	1	2	2	13				Socorro	NA	good	20+	NA	250,000+	
57121	1	2	2	24				Socorro	NA	good	50+		500,000	
57131	2	1	1	14			*	Socorro	sand and gravel	good	12-16	1-3	300,000+	
57132	2	1	1	11			*	Socorro	sand and gravel	good	12-14	2-4	300,000+	
0518	4	5	4	14	1			Socorro	filler sand	fair	8+	1	100,000	P
0519	4	5	6	6	3			Socorro	sand and gravel	excellent	10	1	100,000	P
0520	4	4	6	11	4			Socorro	limestone	good	8	1	100,000	P
0522	4	4	8	29	3			Socorro	limestone	fair	4	0-2	75,000	P
0523	4	5	7	24	1			Socorro	metamorphics	fair	10	0-1	75,000	P
0524	4	5	7	33	2			Socorro	limestone and sandstone	good	4	1	100,000	P
0525	4	6	7	9	3			Socorro	diabase	fair	5+	0-20	100,000	P
0526	4	6	8	1	1			Socorro	cinders	good	150	0	1,475,000	P
0527	4	6	8	29	1			Socorro	gravel	excellent	5+	0	100,000	P
0609	4	8	5	31	1, 2			Socorro	cemented sand and gravel	excellent	12	1	unlimited	P
Puertecito	2	3	4	30-31				Socorro	travertine	NA	50	NA	NA	
Puertecito	2	3	5	25				Socorro	travertine	NA	50	NA	NA	
Riley North	2	2, 3	3					Socorro	travertine	NA	50	NA	NA	
Riley North	2	2, 3	3					Socorro	travertine	NA	5 - 85	NA	NA	
Riley South	2, 3	1, 1	2, 3					Socorro	travertine	NA	5 - 85	NA	NA	

TABLE 7
SALABLE MINERALS
SOCORRO AND CATRON COUNTIES, NEW MEXICO

Pit Name or Number	Location								Rock Type	Quality of Material	Thickness of Material ft	Thickness of Overburden ft	Estimated Quantity cu. yds	Prospect Pit or Quarry
	Quad	Twp	Rge	Sec	160	40	10	County						
4705	2	1	17	13	3			Catron	sand and gravel	good	5	0-2	75,000	
4706	2	1	17	24	2			Catron	sand and gravel	fair	5+	0-2	100,000	
4707	2	1	17	20	3, 4			Catron	basalt and cinders	good	10	NA	200,00	
4708	3	1	19	8	4			Catron	sand and gravel	good	6+	0-2	100,000	
4710	2	1	15	9				Catron	sand and gravel	good	10+	3-7	30,000	
4711	2	1	16	1	2, 3			Catron	sand and gravel	fair	8	1-3	200,000	
4713	2	1	11	35				Catron	volcanics	fair	12+	NA	250,000+	
4714	2	1	11	34				Catron	volcanics	poor	10+	NA	300,000+	
4715	2	1	11	33				Catron	volcanics	poor	10+	NA	200,000+	
4716	2	1	13	9				Catron	sand, gravel, cql.	good	10	NA	300,000	
5404	3	7	19	8	1			Catron	sand and gravel	good	3-6	0-3	30,000+	
5494	3	12	20	14	1, 4			Catron	sand and gravel	NA	5-15	0	NA	
5494	3	12	20	13	2, 3			Catron	sand and gravel	NA	5-15	0	NA	
5566	3	7	19	23	4			Catron	sand and gravel	good	9	0-3	30,000+	
5582	3	7	19	27	3, 4			Catron	sand and gravel	good	8	0-2	150,000	
5679	3	8	20	10	2			Catron	sand and gravel	good	4-6	0-2	20,000	
5680	3	7	20	24	2			Catron	soil and gravel	good	4-10	0-2	50,000+	
5887	2	2	15	9	3			Catron	sand and gravel	good	15	1-3.5	100,000+	
6224	3	12	14	36	4			Catron	sand and gravel	good	3-12	0-2	200,000+	
6512	3	10	12	7	1			Catron	basalt	good	20+	0-1	300,000	
6513	3	10	12	13	4			Catron	sand and gravel	fair	10	0-2	unlimited	
6514	3	10	12	24				Catron	gravel	poor	6+	0-2	100,000+	
6532	3	1	20	14	1			Catron	sand and gravel	fair	12+	2-5	250,000	
6533	3	1	20	13	2			Catron	sand and gravel	good	12+	3-6	250,000	
6566	3	5	17	27	2			Catron	sand and gravel	good	3-11	1-4	50,000+	
6607	3	1	21	3				Catron	sand and gravel	good	6+	0-2	250,000	

TABLE 7
SALABLE MINERALS
SOCORRO AND CATRON COUNTIES, NEW MEXICO

Pit Name or Number	Location								Rock Type	Quality of Material	Thickness of Material ft	Thickness of Overburden ft	Estimated Quantity cu. yds	Prospect Pit or Quarry
	Quad	Twp	Rge	Sec	160	40	10	County						
6622	3	1	21	25	4			Catron	basalt	good	12+	1-2	300,000+	
6809	3	3	18	36	4			Catron	andesite	good	12+	3	100,000+	
6812	3	1	18	6	1			Catron	basalt	good	12+	1	200,000+	
6824	3	1	16	8	3			Catron	basalt	poor	5	0-1	150,000+	
6825	3	2	17	14	3			Catron	andesite	good	12+	NA	350,000	
6921	3	2	17	13	2			Catron	sand	good	12	0-1	100,000	
7007	3	3	17	18	2			Catron	sand	good	6+	0-1	200,000	
54108	3	11	20	2	2			Catron	sand and gravel	NA	5-10	1.5-2	60,000	
54109	3	10	20	8	3			Catron	sand and gravel	NA	NA	0	80,000	
54110	3	11	20	4	4			Catron	sand	NA	2-11	NA	12,000	
Cimarron	3	1	19	10	1			Catron	scoria	good	NA	NA	NA	
Red Butte	3	4	20	34	1			Catron	scoria	good	NA	NA	NA	
Red Hill	3	1	19	10	2			Catron	scoria	good	NA	NA	NA	
Armstrong	2	1, 2	17					Catron	travertine	NA	NA	NA	NA	
Zuni Salt Lake	2	3	18	31				Catron	travertine	NA	NA	NA	NA	

Sources: Bureau of Land Management LR 2000 Database 2003;
New Mexico Highway Department/New Mexico Bureau of Geology and Mineral Resources 2002

In the case of discrepency between the location of a pit or quarry by township/range/section on the tables in the New Mexico State Highway Department Geology and Aggregate Resources (NMSHDGAR) and the location on the quadrangle map in the NMSHDGAR, the location on the quadrangle map was used.

TWP = Township
RGE = Range
SEC = Section

QUAD = Quadrant relative to the intersection of the baseline and meridian (see diagram).
160 = The 160-acre quadrant within the designated Section.
40 = The 40-acre quadrant within the designated 160-acre portion of the Section.
10 = The 10-acre quadrant within the designated 40-acre portion of the Section.

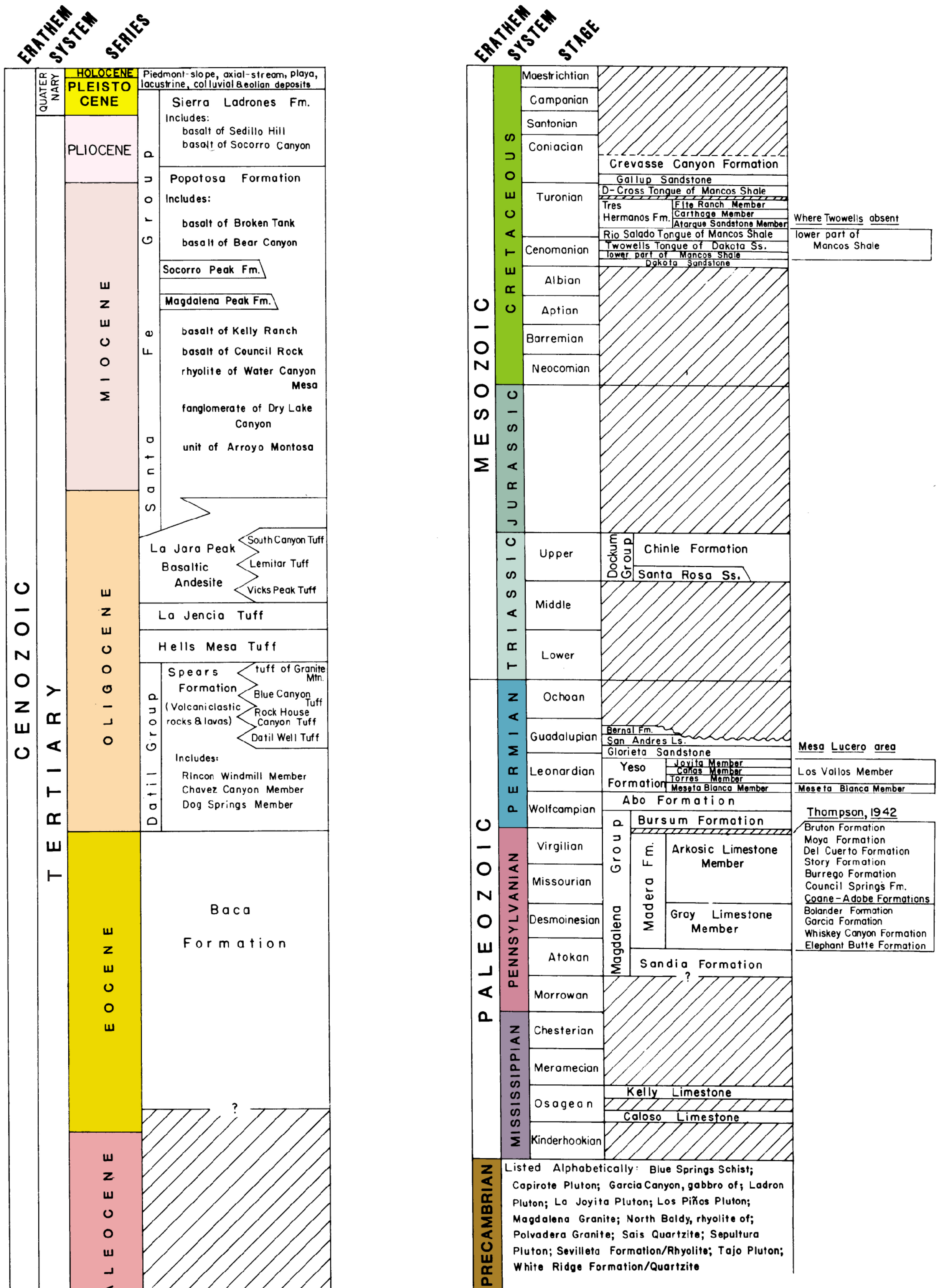
1 = Northeast quadrant
2 = Northwest quadrant
3 = Southwest quadrant
4 = Southeast quadrant

2	1
3	4

NA = Not available
* Sevilleta Grant
** Bosque Del Apache National Wildlife Refuge

ft = feet
cu. yds = cubic yards
P - Prospect pit or quarry

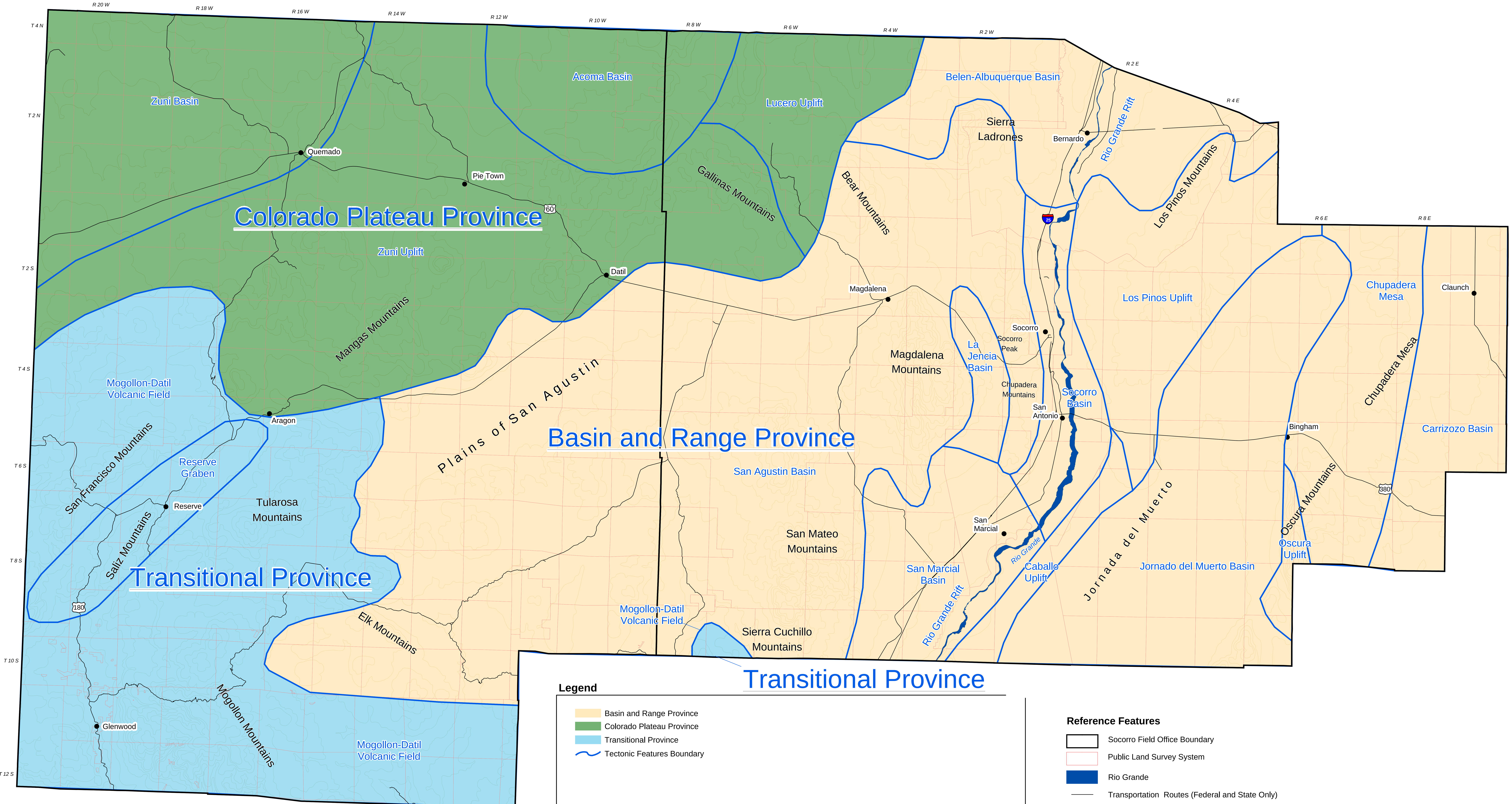
FIGURES



STRATIGRAPHIC NOMENCLATURE CHART, G. R. Osburn and Christina Lochman-Balk.

Figure 1

MAPS



Legend

- Basin and Range Province
- Colorado Plateau Province
- Transitional Province
- Tectonic Features Boundary

Reference Features

- Socorro Field Office Boundary
- Public Land Survey System
- Rio Grande
- Transportation Routes (Federal and State Only)
- 500-Meter Topographic Contours
- City, Town, or Village

Physiographic Provinces, Topographic, and Tectonic Features

Socorro Field Office RMPR/EIS

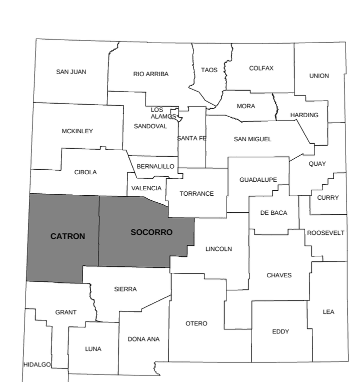
July 23, 2003

Universal Transverse Mercator
Zone 13, Units Meters
GRS 1980 Spheroid
NAD83 Datum

0 2.5 5 10 15 20 Miles

0 2.5 5 10 15 20 Kilometers

N
W E
S



Location in New Mexico

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Source:
Base Map Information: BLM, Socorro Field Office 2003
Grant and Foster 1989
Petroleum Information / Dwights 2002
New Mexico Energy Minerals and Natural Resources Department 2002
Broadhead and Black 1989
Broadhead 1983

URS

Map 1

Legend

Geology (Geologic Formation Names are Provided in Appendix A)

Quaternary
- Qa
- Qa/QTs
- Qa/QTsf
- Ql
- Qe
- Qe/QTsf
- Qe/Qp
- Qpl
- Qp
- Qp/QTsf
- Qb
- Qv
- Qbo
- Qoa

Quaternary-Tertiary
- QTp
- QTs
- QTsf
- QTg
- QTb
- QTt

Tertiary
- Tus
- Tfl
- Tsf
- Tos
- Tnb
- Tpb
- Tmb
- Tnr
- Tv
- Tuv
- Tlv
- Tuau
- Tual
- Turp
- Tlrp
- Turf
- Tlrf
- Ti
- Tui
- Tuim
- Tli
- Tla
- Tps

Cretaceous
- K
- Kmc
- Kmv
- Kcc
- Kmg
- Kmr
- Kth
- Kma
- Kdr
- Kdm
- Kd
- Kdg

Triassic
- TR

Permian
- P
- Pat
- Psa
- Pg
- Pa
- Psg
- Pb
- Py
- Pys

Pennsylvanian
- ℙ
- ℙm
- ℙme
- ℙs

Mississippian-Cambrian
- M
- Mississippian-Cambrian
- Ordorician-Cambrian

Precambrian
- Xm
- Xp
- Yp

- Water

Reference Features

- Socorro Field Office Boundary
- Public Land Survey System
- Rio Grande
- Transportation Routes (Federal and State Only)
- 500-Meter Topographic Contours
- City, Town, or Village

Geologic Map

Socorro Field Office RMPR/EIS

May 12, 2003

Universal Transverse Mercator
Zone 13, Units Meters
GRS 1980 Spheroid
NAD83 Datum

Miles: 0, 2.5, 5, 10, 15, 20

Kilometers: 0, 2.5, 5, 10, 15, 20

N W E S

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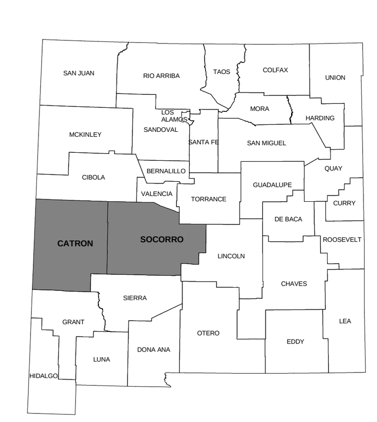
Location in New Mexico



Source:
Base Map Information: BLM, Socorro Field Office 2003
U.S. Geologic Survey 1997, Digital Geologic Map of New Mexico in Arc/Info Format
USGS Open-File Report OF-97-52.

URS

Map 2

Oil and Gas Potential

Socorro Field Office RMPR/EIS

May 12, 2003

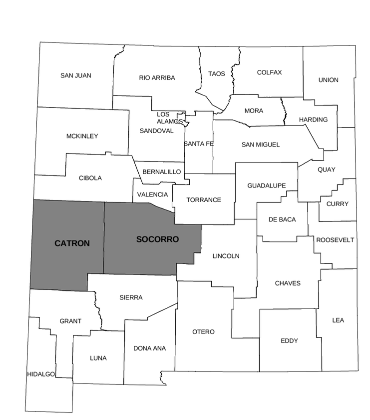
Universal Transverse Mercator
Zone 13, Units Meters
GRS 1980 Spheroid
NAD83 Datum

Miles: 0 2.5 5 10 15 20

Kilometers: 0 2.5 5 10 15 20

N W E S

Location in New Mexico



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Legend

Oil and Gas Potential

- Moderate Potential
- Low Potential
- No Potential
- Tectonic Features Boundary
- S-1 Exploration Well Location and Reference Number
  - S = Socorro County (S-1 through S-45)
  - C = Catron County (C-1 through C-40)
- Dry Hole
- Gas Show
- Gas Well
- Oil Show
- Oil and Gas Show
- Oil Well

Reference Features

- Socorro Field Office Boundary
- Public Land Survey System
- Rio Grande
- Transportation Routes (Federal and State Only)
- 500-Meter Topographic Contours
- City, Town, or Village

Source:
Base Map Information: BLM, Socorro Field Office 2003
New Mexico Bureau of Geology and Mineral Resources 2002
New Mexico Energy, Minerals, and Natural Resources Department 2002
Broadhead et al. 2002a; 2002b
Johnson 2002

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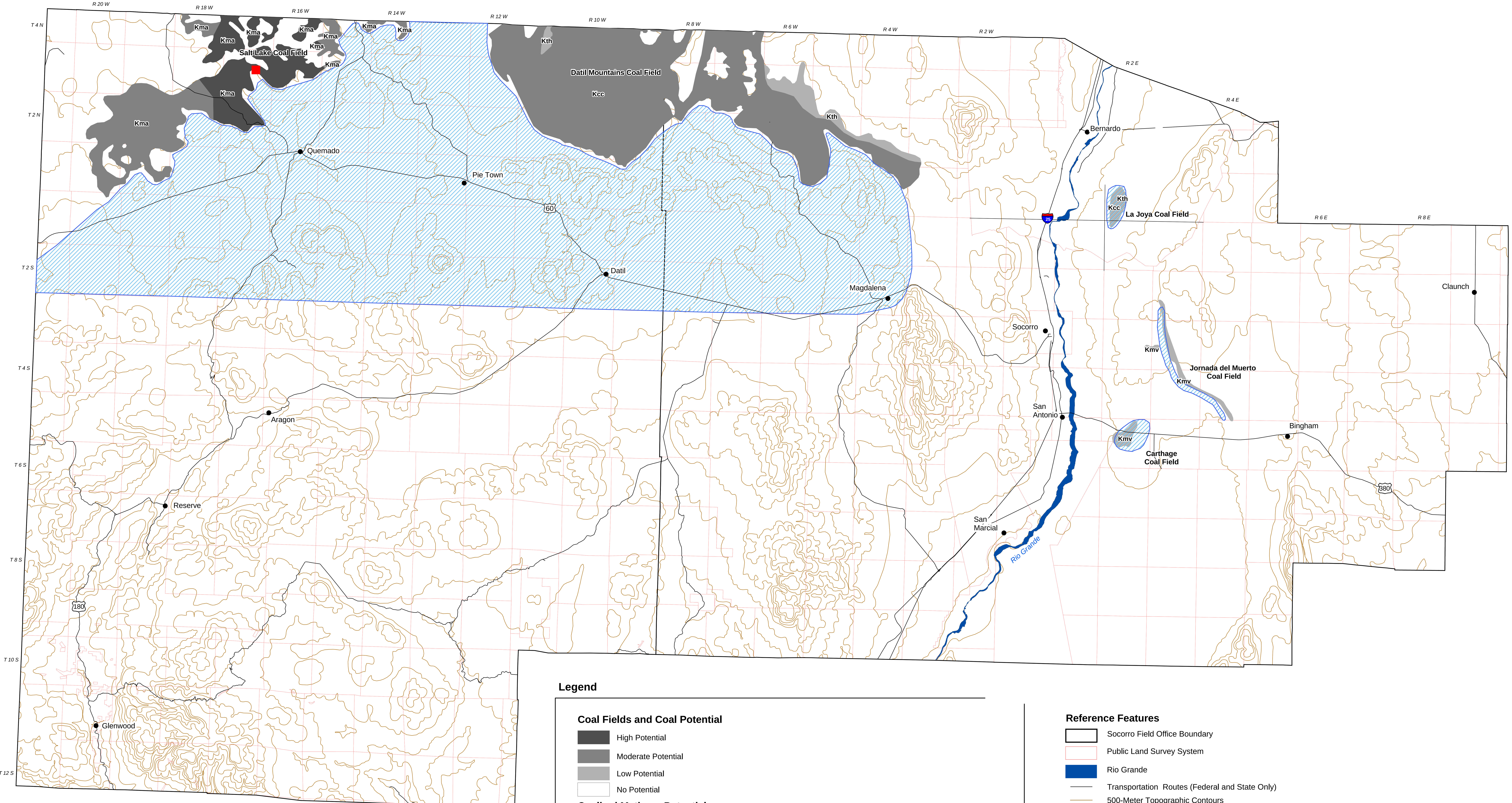
Map 3



Coal Fields, Coal, and Coalbed Methane Resources Potential

Socorro Field Office RMPR/EIS

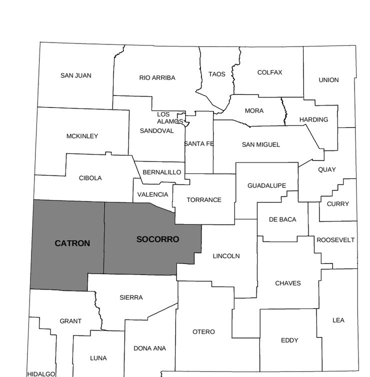
May 12, 2003

Universal Transverse Mercator
Zone 13, Units Meters
Clarke 1866 Spheroid
NAD83 Datum

Miles: 0 2.5 5 10 15 20

Kilometers: 0 2.5 5 10 15 20

N, E, S, W



Location in New Mexico

P:\BLM\Socorro RMPR_EIS\GIS\mxds\Energy-Report\CoalResources.mxd

Legend

Coal Fields and Coal Potential

- High Potential
- Moderate Potential
- Low Potential
- No Potential

Coalbed Methane Potential

- Moderate Potential
- No Potential

Coal Bearing Formations

- **Kmv** Mesaverde Group
- **Kcc** Crevasse Canyon Formation
- **Kth** Tres Hermanos Formation
- **Kma** Moreno Hill Formation
- Fence Lake Coal Mine

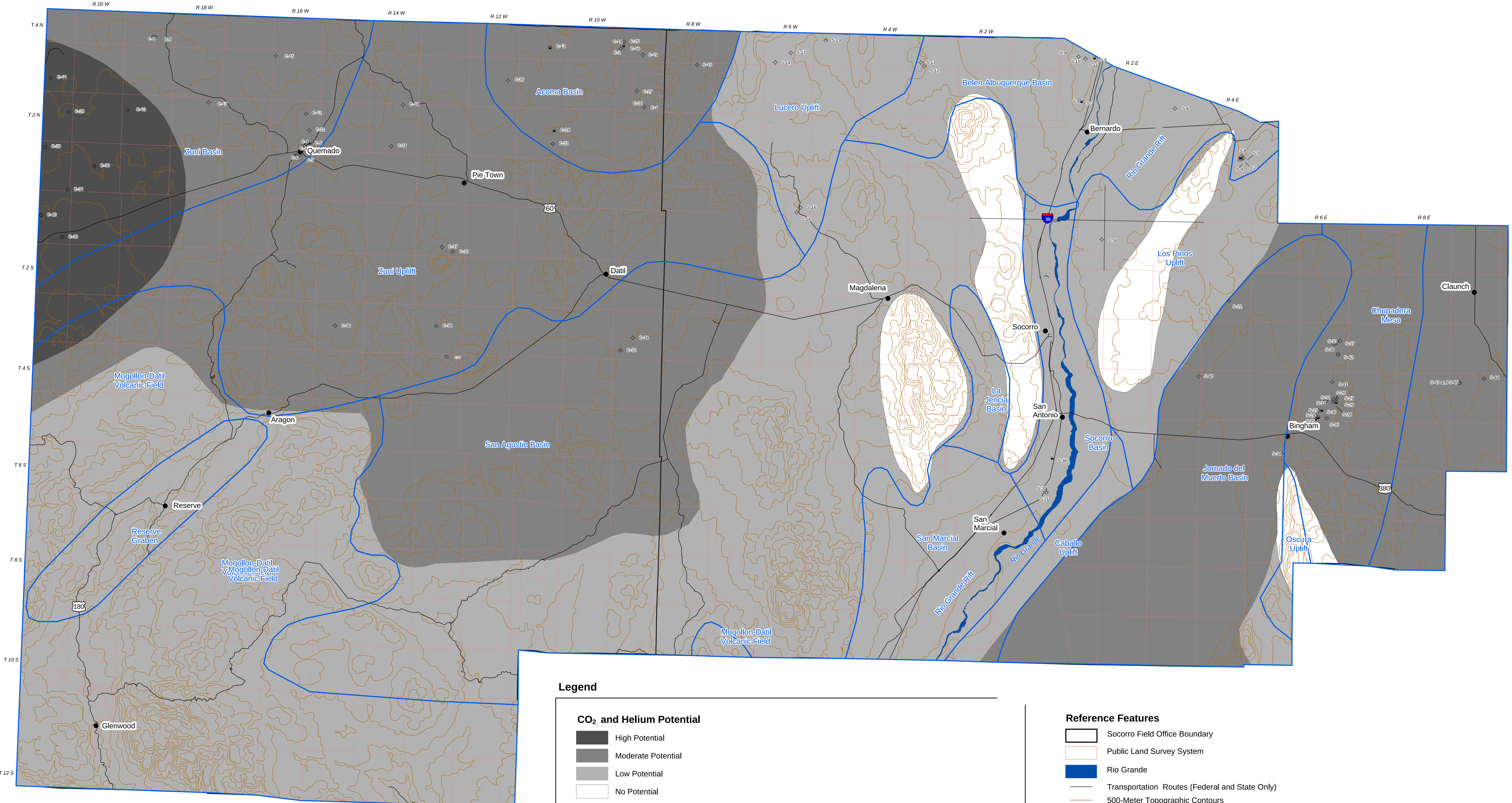
Reference Features

- Socorro Field Office Boundary
- Public Land Survey System
- Rio Grande
- Transportation Routes (Federal and State Only)
- 500-Meter Topographic Contours
- City, Town, or Village

Source:
Base Map Information: BLM, Socorro Field Office 2003
Coal Fields: Hoffman 2002.
Coalbed Methane: Broadhead and others 2002

URS

Map 4



Legend

CO_2 and Helium Potential

- High Potential
- Moderate Potential
- Low Potential
- No Potential
- Tectonic Features Boundary
- S-1 Exploration Well Location and Reference Number
  - S = Socorro County (S-1 through S-45)
  - C = Catron County (C-1 through C-40)
- Dry Hole
- Gas Show
- Gas Well
- Oil Show
- Oil and Gas Show
- Oil Well

Reference Features

- Socorro Field Office Boundary
- Public Land Survey System
- Rio Grande
- Transportation Routes (Federal and State Only)
- 500-Meter Topographic Contours
- City, Town, or Village

CO_2 and Helium Potential

Socorro Field Office RMPR/EIS

May 12, 2003

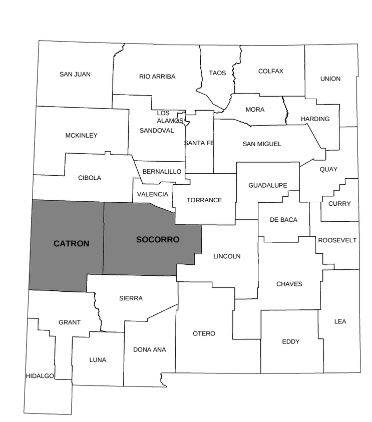
Universal Transverse Mercator
Zone 13, Units Meters
GRS 1980 Spheroid
NAD83 Datum

N
W E
S

Miles: 0 2.5 5 10 15 20

Kilometers: 0 2.5 5 10 15 20

Location in New Mexico



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Source:
Base Map Information: BLM, Socorro Field Office 2003
New Mexico Bureau of Geology and Mineral Resources 2002
New Mexico Energy, Minerals, and Natural Resources Department 2002
Broahead and Black 1989
Broahead 1983

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Map 5

Legend

Geothermal Resource Area Potential

All Geothermal Resources in the Planning Area are Low-Temperature Resources < 90° C

Well or Spring	Temperature
(green dot)	< 30° C
(yellow dot)	30° C - 60° C
(red dot)	>60° C

S-1 Geothermal Spring or Well Reference Number (See Table 2-8)
C = Catron County (23 Sites)
S = Socorro County (16 Sites)

Area with Geothermal Potential

Geothermal Potential

High Potential
Moderate Potential
Low Potential
No Potential

Known Geothermal Resource Areas (KGRA)

Socorro: S-1, S-4 to S-6, S-10

Gila: C-1 to C-12

San Francisco: C-13 to C-17

Reference Features

Socorro Field Office Boundary
Public Land Survey System
Rio Grande
Transportation Routes (Federal and State Only)
500-Meter Topographic Contours
City, Town, or Village

Geothermal Resources Potential

Socorro Field Office RMPR/EIS

May 12, 2003

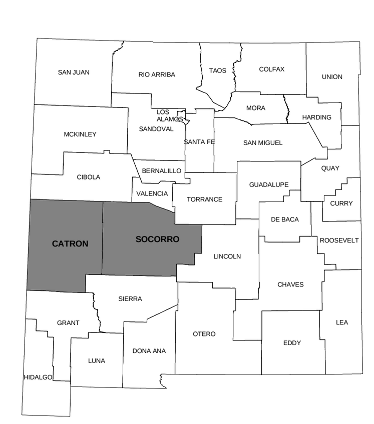
Universal Transverse Mercator
Zone 13, Units Meters
GRS 1980 Spheroid
NAD83 Datum

N
W E
S

Miles
0 2.5 5 10 15 20

Kilometers
0 2.5 5 10 15 20

Location in New Mexico



P:\BLM\Socorro RMPR_EIS\GIS\mxds\Energy-Report\GeoThermal.mxd

Source:
Base Information: BLM, Socorro Field Office 2003
Southwest Technology Development Institute 1995

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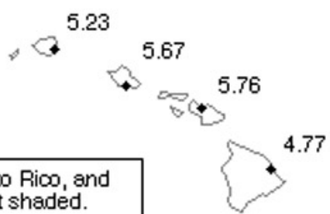
Map 6

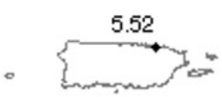
Alaska

Hawaii



Hawaii, Puerto Rico, and Guam are not shaded.

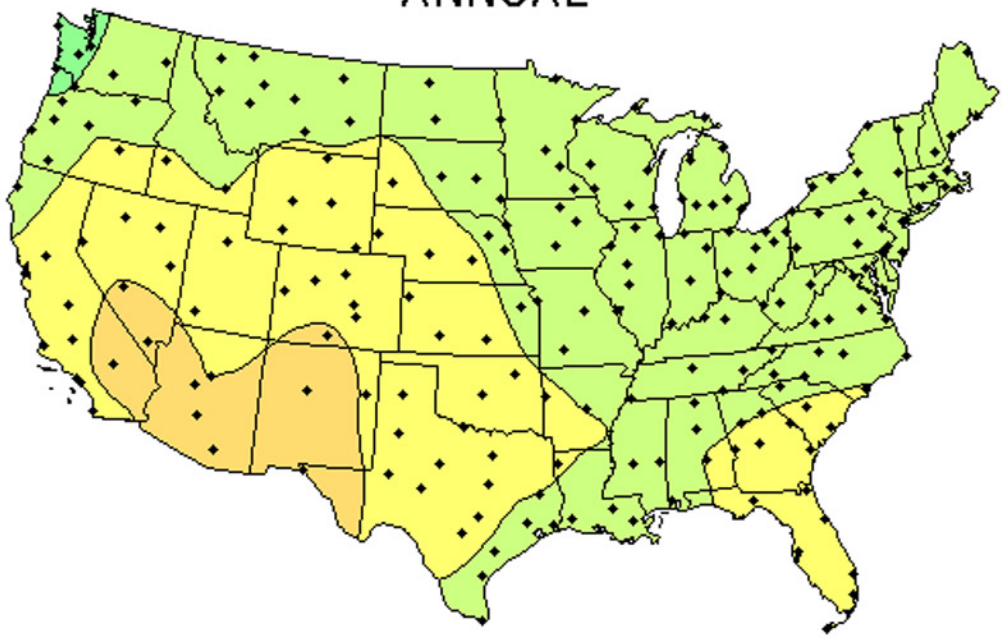
San Juan, PR



Guam, PI

Average Daily Solar Radiation Per Month

ANNUAL



Flat Plate Tilted South at Latitude

Collector Orientation

Flat-plate collector facing south at fixed tilt equal to the latitude of the site: Capturing the maximum amount of solar radiation throughout the year can be achieved using a tilt angle approximately equal to the site's latitude.

This map shows the general trends in the amount of solar radiation received in the United States and its territories. It is a spatial interpolation of solar radiation values derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). The dots on the map represent the 239 sites of the NSRDB.

Maps of average values are produced by averaging all 30 years of data for each site. Maps of maximum and minimum values are composites of specific months and years for which each site achieved its maximum or minimum amounts of solar radiation.

Though useful for identifying general trends, this map should be used with caution for site-specific resource evaluations because variations in solar radiation not reflected in the maps can exist, introducing uncertainty into resource estimates.

Maps are not drawn to scale.

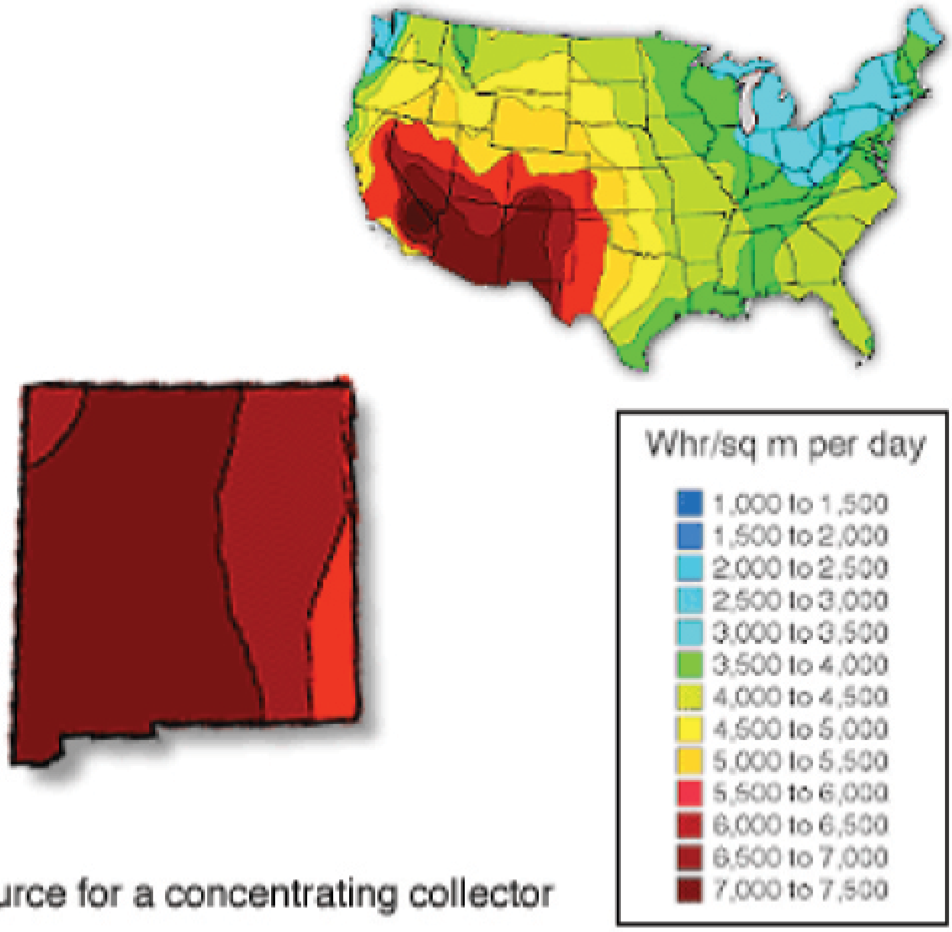
NREL

National Renewable Energy Laboratory
Resource Assessment Program

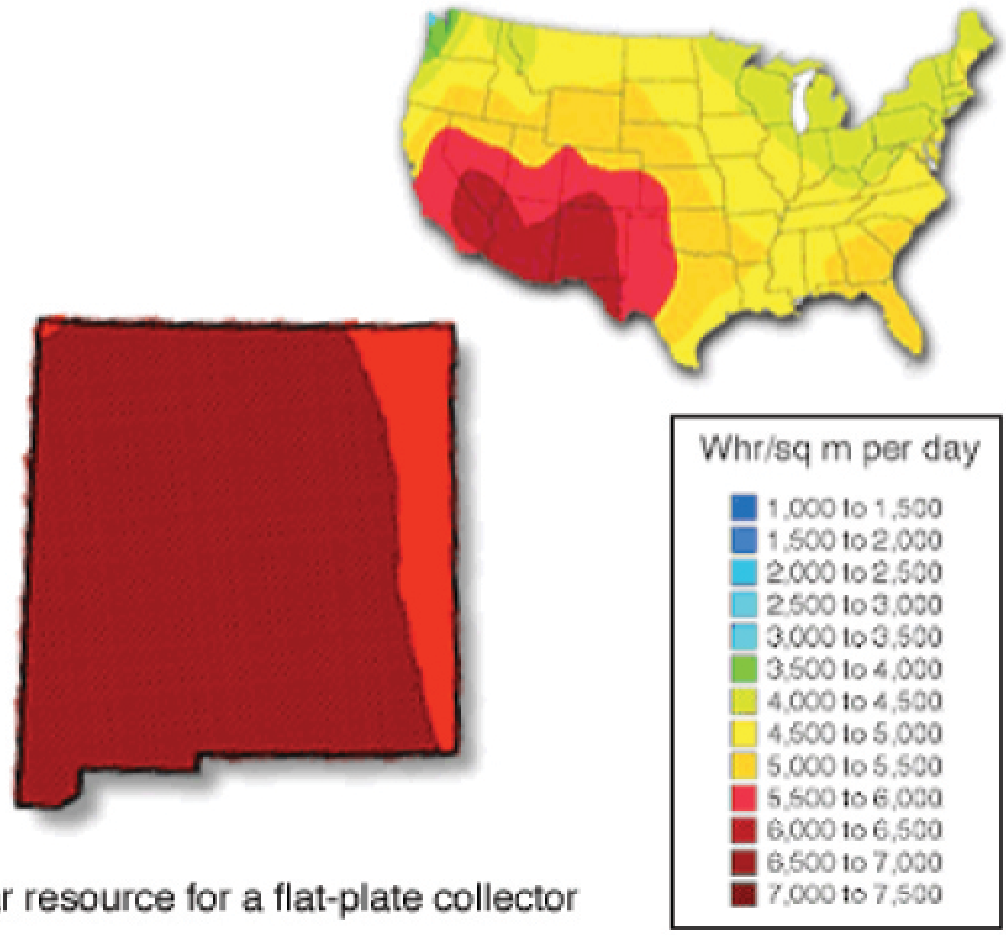
$kWh/m^2/day$

10 to 14
8 to 10
7 to 8
6 to 7
5 to 6
4 to 5
3 to 4
2 to 3
0 to 2
none

FLATA13-208

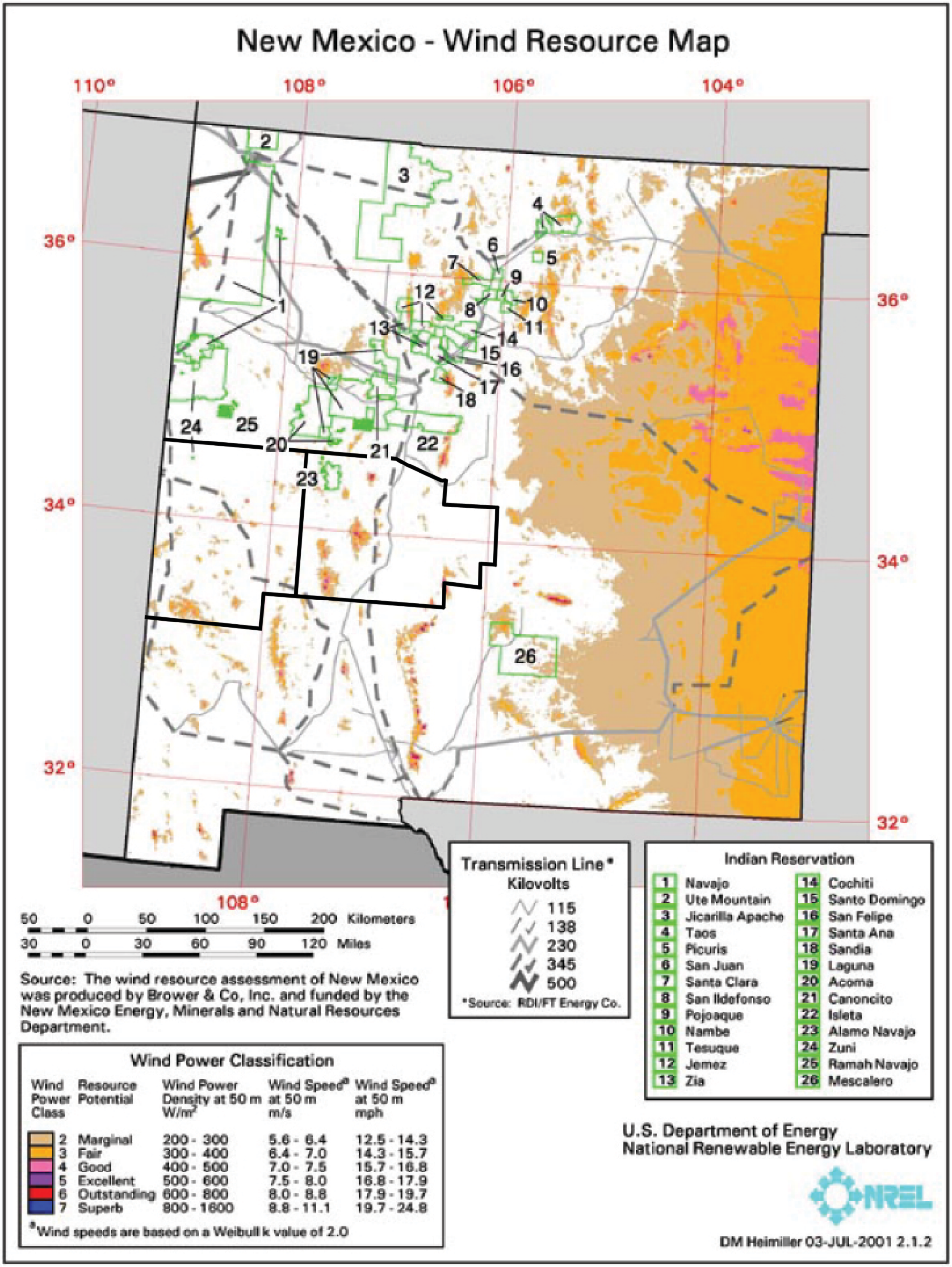


Solar resource for a concentrating collector



Solar resource for a flat-plate collector

Solar Collector Comparison
Map 8


New Mexico - Wind Resource Map
110°
108°
106°
104°
36°
34°
32°
Transmission Line*
Kilovolts
115
138
230
345
500
*Source: RDI/FT Energy Co.
Indian Reservation
1 Navajo
2 Ute Mountain
3 Jicarilla Apache
4 Taos
5 Picuris
6 San Juan
7 Santa Clara
8 San Ildefonso
9 Pojoaque
10 Nambe
11 Tesuque
12 Jemez
13 Zia
14 Cochiti
15 Santo Domingo
16 San Felipe
17 Santa Ana
18 Sandia
19 Laguna
20 Acoma
21 Canoncito
22 Isleta
23 Alamo Navajo
24 Zuni
25 Ramah Navajo
26 Mescalero
50 0 50 100 150 200 Kilometers
30 0 30 60 90 120 Miles
Source: The wind resource assessment of New Mexico was produced by Brower & Co, Inc. and funded by the New Mexico Energy, Minerals and Natural Resources Department.
Wind Power Classification
Wind Power Class | Resource Potential | Wind Power Density at 50 m W/m² | Wind Speed^a at 50 m m/s | Wind Speed^a at 50 m mph
2 Marginal 200 - 300 5.6 - 6.4 12.5 - 14.3
3 Fair 300 - 400 6.4 - 7.0 14.3 - 15.7
4 Good 400 - 500 7.0 - 7.5 15.7 - 16.8
5 Excellent 500 - 600 7.5 - 8.0 16.8 - 17.9
6 Outstanding 600 - 800 8.0 - 8.8 17.9 - 19.7
7 Superb 800 - 1600 8.8 - 11.1 19.7 - 24.8
^a Wind speeds are based on a Weibull k value of 2.0
U.S. Department of Energy
National Renewable Energy Laboratory
DM Heimiller 03-JUL-2001 2.1.2

Map 9

Mining Districts and Locatable Minerals Potential

Socorro Field Office RMPR/EIS

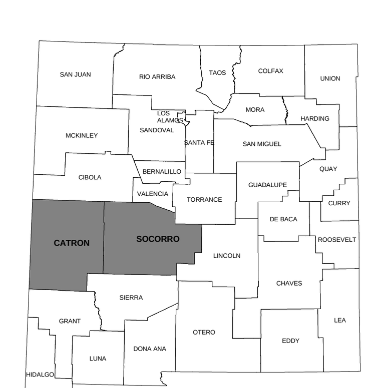
July 31, 2003

Universal Transverse Mercator
Zone 13, Units Meters
GRS 1980 Spheroid
NAD83 Datum

Miles: 0, 2.5, 5, 10, 15, 20

Kilometers: 0, 2.5, 5, 10, 15, 20

P:\BLM\Socorro RMPR_EIS\GIS\mxds\Energy-Report\miningdistricts.mxd



Location in New Mexico

Legend

Mining Districts

NMBMMR 1966 Potential
- High to Moderate Potential
- Low Potential

BLM Potential
- High to Moderate Potential
- Low Potential

NMBGMR 2002 Potential
- Metals (High to Moderate Potential)
- Uranium (High to Moderate Potential)
- Low Potential

( ) Commodities present, but not mined

X[1] Volcanic Stone Company, Hiawatha and Little Jim Claims Sn, surface mine

X[2] Socorro Perlite Mine/Mill surface mine

Minerals Potential Shown by Symbol

Au = gold
Ag = silver
As = arsenic
Ba = barium
Be = beryllium
Bi = bismuth
Br = bromine
Cd = cadmium
Co = cobalt
Cu = copper
F = fluorine
Fe = iron
Ga = gallium
Ge = germanium
Mn = manganese
Mo = molybdenum
Nb = niobium
Ni = nickel
Pb = lead
Ra = radium
Te = tellurium
REE = rare-earth minerals
Sb = antimony
Sn = tin
V = vanadium
Th = thorium
Ti = titanium
U = uranium
W = tungsten
Zn = zinc

Reference Features

- Socorro Field Office Boundary
- Public Land Survey System
- Rio Grande
- Transportation Routes (Federal and State Only)
- 500-Meter Topographic Contours
- City, Town, or Village

Source:
Base Map Information: BLM, Socorro Field Office 2003
Mining Districts: New Mexico Bureau of Geology and Mineral Resources (NMBGMR) 2002
File and Northrop 1966
General Land Office, BLM

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Map 10

Salable Mineral Resources Potential

Socorro Field Office RMPR/EIS

July 31, 2003

Universal Transverse Mercator
Zone 13, Units Meters
GRS 1980 Spheroid
NAD83 Datum

Miles: 0, 2.5, 5, 10, 15, 20

Kilometers: 0, 2.5, 5, 10, 15, 20

N, S, E, W

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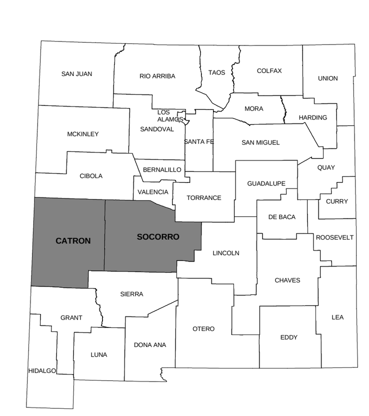
Location in New Mexico



Legend

Salable Mineral Potential

- High Potential
- Moderate Potential
- Low Potential
- 5144 New Mexico Highway Department Existing Pit or Quarry with Reference Number
- 619 BLM Existing Pit or Quarry with Reference Number (last 3 digits)
- Travertine Quarry or Deposit

* Partial Inventory within the Socorro Field Office. Data provided by New Mexico Highway Department.

Geology (Geologic Formation Names are Provided in Appendix A)

Quaternary: Qa, Qa/QTs, Qa/QTsf, Ql, Qe, Qe/QTsf, Qe/Qp, Qpl, Qp, Qp/QTsf, Qb, Qv, Qbo, Qoa

Quaternary-Tertiary: QTp, QTs, QTsf, QTg, QTb, QTt

Tertiary: Tus, Tfl, Tsf, Tos, Tnb, Tpb, Tmb, Tnr, Tv, Tuv, Tlv, Tuau, Tual, Turp, Tlrp, Turf, Tlrf, Ti, Tui, Tuim, Tli, Tla, Tps

Cretaceous: K, Kmc, Kmv, Kcc, Kmg, Kmr, Kth, Kma, Kdr, Kdm, Kd, Kdg

Triassic: ꞅ

Permian: P, Pat, Psa, Pg, Pa, Psg, Pb, Py, Pys

Pennsylvanian: ꟼ, ꟼm, ꟼsw, ꟼs

Mississippian-Cambrian: M, Mississippian-Cambrian, Ordorician-Cambrian

Precambrian: Xm, Xp, Yp

Water

Reference Features

- Socorro Field Office Boundary
- Public Land Survey System
- Rio Grande
- Transportation Routes (Federal and State Only)
- City, Town, or Village

Source:
Base Map Information: BLM, Socorro Field Office 2003
Geology: U.S. Geologic Survey 1997, Digital Geologic Map of New Mexico in Arc/Info Format, USGS Open-File Report OF-97-52

Pit or Quarry: BLM LR2000 Database
New Mexico Highway Department 2002

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Map 11

APPENDIX A

GEOLOGIC FORMATION SYMBOLS

APPENDIX A
GEOLOGIC FORMATION SYMBOLS
SOCORRO AND CATRON COUNTIES, NEW MEXICO

Qa	Alluvium; upper and middle Quaternary
Ql	Landslide deposits and colluvium
Qe	Eolian deposits
Qpl	Lacustrine and playa-lake deposits
Qp	Piedmont alluvial deposits: upper and middle Quaternary
Qb	Basalt and andesite flows and locally vent deposits
Qv	Basaltic volcanics; tuff rings, cinders, and proximal lavas
Qbo	Basalt or basaltic andesite; middle and lower Pleistocene
Qoa	Older alluvial deposits of upland plains and piedmont areas, and calcic soils and eolian cover sediments of High Plains region
QTp	Older piedmont alluvial deposits and shallow basin fill
QTb	Basaltic and andesitic volcanics interbedded with Pleistocene and Pliocene sedimentary units
QTt	Travertine
QTg	Gila Group
QTsf	Santa Fe Group, undivided. Basin fill of Rio Grande rift region
QTs	Upper Santa Fe Group
Tus	Upper Tertiary sedimentary units
Tfl	Fence Lake Formation;
Tsf	Lower and Middle Santa Fe Group
Tos	Mostly Oligocene and upper Eocene sedimentary and volcaniclastic sedimentary rocks with local andesitic to intermediate volcanics
Tnb	Basalt and andesite flows; Neogene. Includes flows interbedded with Santa Fe and Gila Groups
Tpb	Basalt and andesite flows; Pliocene
Tmb	Basalt and andesite flows; Miocene
Tnr	Silicic to intermediate volcanic rocks; mainly quartz latite and rhyolite Neogene
Tnv	Neogene volcanic rocks; primarily in Jemez Mountains
Tv	Middle Tertiary volcanic rocks, undifferentiated
Tuv	Volcanic and some volcaniclastic rocks, undifferentiated; lower Miocene and Upper Oligocene (younger than 29 Ma)
Tlv	Lower Oligocene and Eocene volcanic rocks, undifferentiated; dominantly intermediate composition, with interbedded volcaniclastic rocks
Tuau	Lower Miocene and uppermost Oligocene basaltic andesites (22-26 Ma)
Tual	Upper Oligocene andesites and basaltic andesites (26-29 Ma)
Turp	Upper Oligocene rhyolitic pyroclastic rocks (ash-flow tuffs) (24-29 Ma)
Tlrp	Lower Oligocene silicic pyroclastic rocks (ash-flow tuffs) (31-36.5 Ma)
Turf	Upper Oligocene silicic (or felsic) flows and masses and associated pyroclastic rocks
Tlrf	Lower Oligocene silicic (or felsic) flows, domes, and associated pyroclastic rocks and intrusions
Ti	Tertiary intrusive rocks; undifferentiated
Tui	Miocene to Oligocene silicic to intermediate intrusive rocks; dikes, stocks, plugs, and diatremes
Tuim	Upper and Middle Tertiary mafic intrusive rocks
Tli	Quartz monzonites (Eocene) in the Silver City and Los Pinos Range, intermediate intrusives of the Cooke's Range (Oligocene)
Tla	Lower Tertiary, (Lower Oligocene and Eocene) andesite and basaltic andesite flows, and associated volcaniclastic units
Tps	Paleogene sedimentary units; includes Baca, Galisteo, El Rito, Blanco Basin
K	Cretaceous rocks, undivided
Kmc	McRae Formation; Engle basin - Cutter sag area; Maastrichtian
Kmv	Mesaverde Group includes the Gallup Sandstone, Crevasse Canyon Formation
Kcc	Crevasse Canyon Formation; coal-bearing units are Dilco and Gibson Coal Members
Kmg	Gallup Sandstone and underlying D-Cross Tongue of the Mancos Shale; Turonian
Kmr	Rio Salado Tongue of the Mancos Shale. Overlies Twowells Tongue of Dakota Sandstone
Kth	Tres Hermanos Formation; formerly designated as Lower Gallup Sandstone in the Zuni Basin; Turonian
Kma	Moreno Hill Formation and Atarque Sandstone; in Salt Lake coal field and extreme southern Zuni basin
Kdr	Dakota Sandstone and Rio Salado Tongue of the Mancos Shale
Kdm	Intertongued Dakota-Mancos sequence of west-central New Mexico
Kd	Dakota Sandstone; includes Oak Canyon, Cubero, and Paguate Tongues plus Clay Mesa Tongue of Mancos Shale
Kdg	Dakota Group of east-central and northeast New Mexico
₮R	Triassic rocks, undivided; continental red beds
P	Permian rocks, undivided
Pat	Artesia Group; shelf facies forming broad south-southeast trending outcrop
Psa	San Andres Formation; limestone and dolomite with minor shale; Guadalupian in south, in part Leonardian to north
Pg	Glorieta Sandstone; texturally and mineralogically mature, high-silica quartz sandstone
Psg	San Andres Limestone and Glorieta Sandstone; Guadalupian and Leonardian
Py	Yeso Formation; sandstones, siltstones, anhydrite, gypsum, halite, and dolomite; Leonardian
Pa	Abo Formation; red beds, arkosic at base, finer and more mature above

APPENDIX A
GEOLOGIC FORMATION SYMBOLS
SOCORRO AND CATRON COUNTIES, NEW MEXICO

Pys	Yeso, Glorieta and San Andres Formations, undivided
Pb	Bursum Formation; shale, arkose, and limestone; earliest Permian
₱	Pennsylvanian rocks, undivided; in Sangre de Cristo Mountains
₱ m	Madera Formation (Limestone or Group); in Manzano Mountains includes Los Moyos Limestone
₱me	Madera Limestone, exotic blocks; present only in the Chloride area of Sierra County
₱s	Sandia Formation; predominately clastic unit (commonly arkosic) with minor black shales
M_	Mississippian rocks, undivided; Arroyo Penasco Group in Sangre de Cristo
M_	Mississippian through Cambrian rocks, undivided; includes Lake Valley Limestone
O_	Ordovician and Cambrian rocks, undivided; includes Bliss Sandstone, El Paso Formation
Yp	Middle Proterozoic plutonic rocks (younger than 1600 Ma)
Xm	Lower Proterozoic metamorphic rocks, dominantly felsic volcanic, volcaniclastic
Xp	Lower Proterozoic plutonic rocks (older than 1600 Ma)

NOTE:

T̶R = Triassic symbol

₱ = Pennsylvanian symbol