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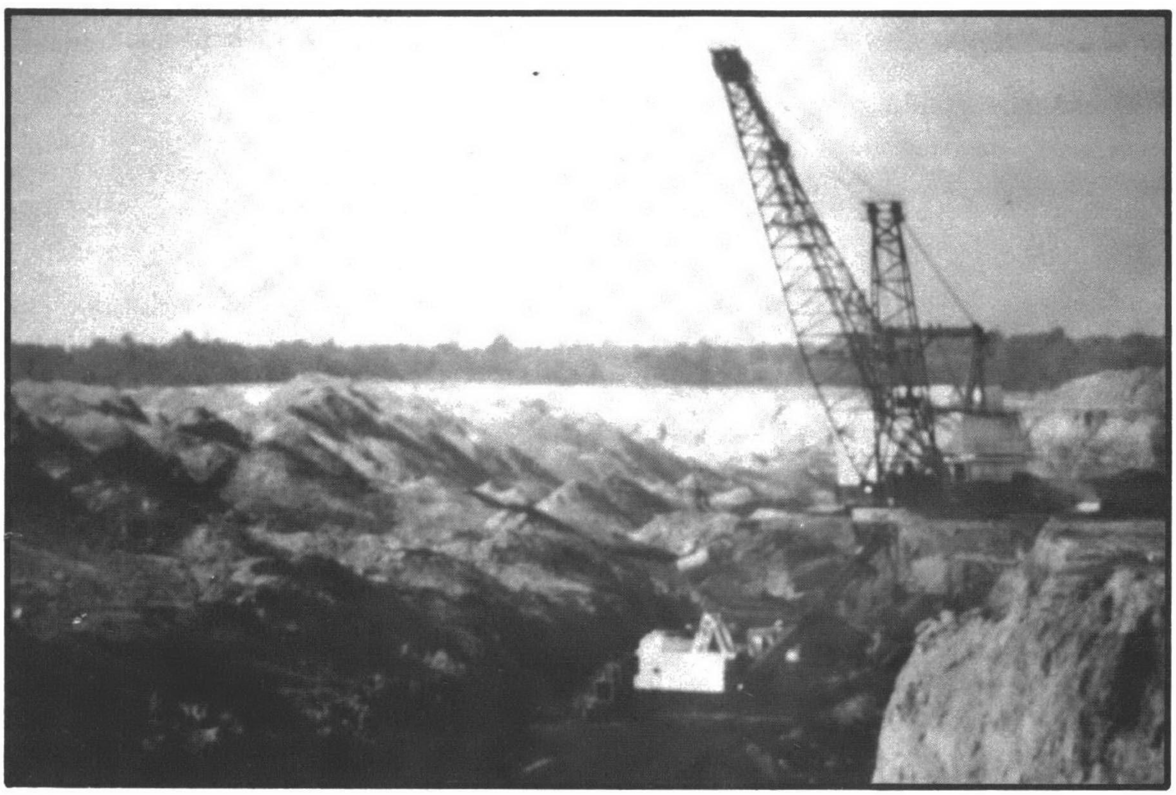
Environmental Inventory of 13 Counties With Known Coal Resources in New Mexico



WAPORA, Inc.

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ENVIRONMENTAL INVENTORY OF 13 COUNTIES WITH KNOWN COAL RESOURCES IN NEW MEXICO

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Directive of Work 21

Prepared by:

WAPORA, Inc.
8515 Greenville Avenue
Suite N-205
Dallas, Texas 75243

Federal Assistance Branch
Environmental Protection Agency
1201 Elm Street
Dallas, Texas 75270

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INTRODUCTION

Over the next two to three decades it appears clear that coal production will increase significantly as the United States strives for energy self-sufficiency. States in the middle south will likely, due to their large coal resources, play an important role in this production. Most coal production will come from surface mining, although underground mining will yield relatively large quantities of coal in some areas.

Accompanying increased coal production will be an alteration of vast natural and manmade resources. Public awareness for the need to protect and mitigate significant adverse effects to these resources has culminated in numerous Federal and State laws and regulations to guide coal development. The coal developer has the primary responsibility for adhering to these laws and regulations. The US Environmental Protection Agency (EPA) along with other State and Federal agencies presently maintains the role of working with and guiding coal developers in adhering to this responsibility.

This New Mexico Environmental Inventory Document was prepared by WAPORA, Inc., Dallas, Texas, to aid EPA, cooperating agencies, and industry in identifying potential environmental problems associated with future coal development and utilization. The development of coal is limited somewhat by distribution; the Study Area in New Mexico includes only the 13 counties underlain by potentially developable coal reserves (Figure 1).

This document is divided into nine chapters that provide an inventory of existing natural and manmade resource conditions. Information used to assemble this doucment was derived largely from nonproprietary sources and other readily available databases. Parts of the data base are unequal relative to depth of coverage, due to the absense of data for some areas. An effort was made to present a balanced presentation wherever possible. With the exception of Chapters 4 and 8, each chapter includes a fold out map(s) at

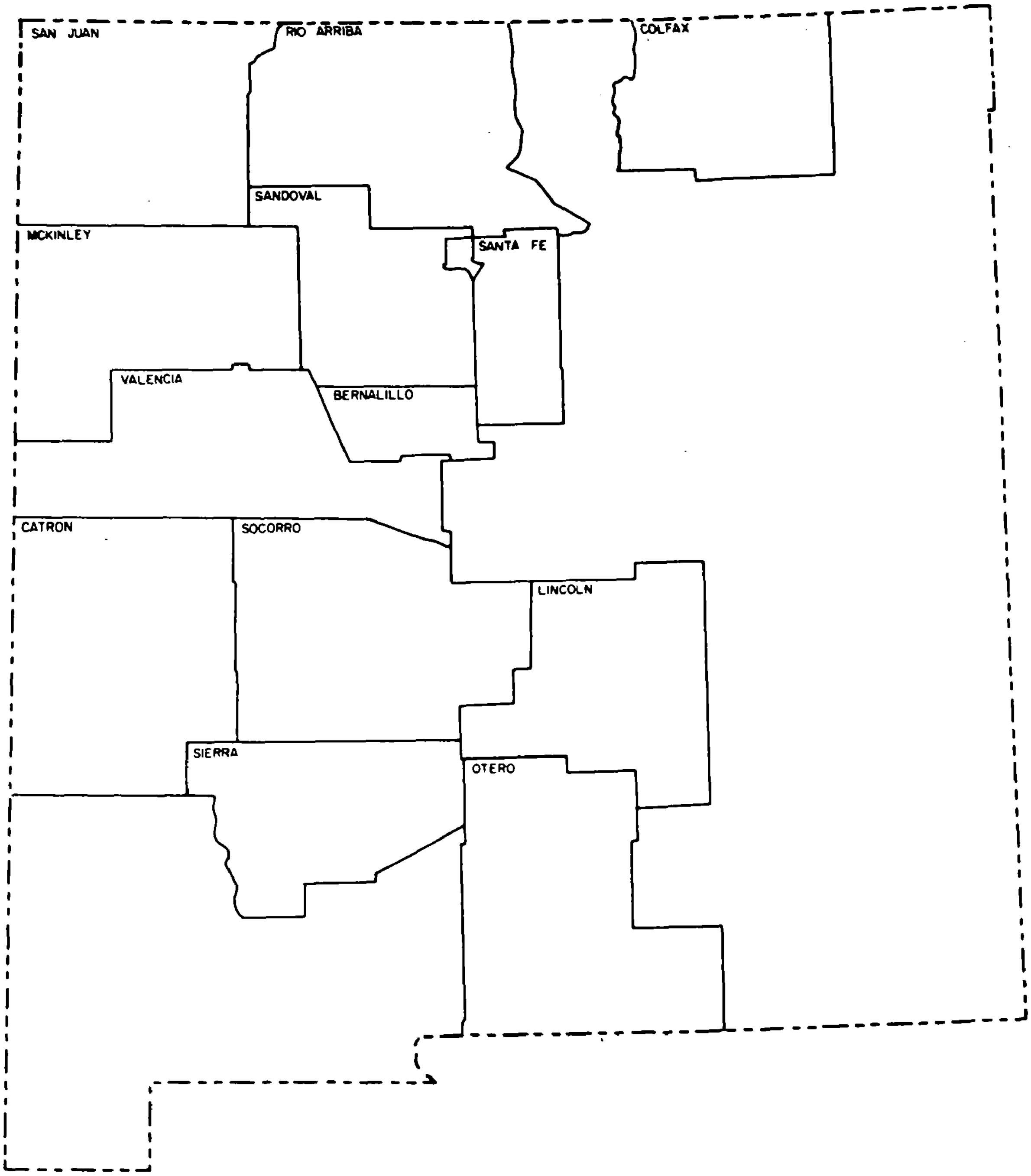

Figure 1. The 13 county New Mexico Study Area.

a scale of 1:1,000,000 depicting the major features of each resource. Additionally, there are page size graphics and tables containing specific information for each of the 13 counties in the Study Area. The narrative that accompanys each chapter is concise by design, and not intended to describe or analyze the variances associated with each resource. The user should refer to the tables, figures, and exhibits to obtain specific data primarily on the county level.

Chapter 1.0, "Coal Resources", contains a characterization of the coal/lignite resources of the Study Area. The origin, depth, as well as physical and chemical characteristics of the coal are presented.

Chapter 2.0, "Existing and Planned Coal Developments", describes the most probable types of coal development in the Study Area, and briefly discusses the primary technologies associated with coal development. Known existing and planned coal developments and associated characteristics also are presented.

Chapter 3.0, "Earth (Non-coal) Resources", is a summarization of the major earth resource conditions in the Study Area. Major elements discussed include physiography, soils, non-metals, metals, and petroleum and natural gas.

The social and economic conditions of the Study Area are presented in Chapter 4.0, "Socioeconomics". Major economic conditions considered are employment and income. Existing housing, education, and transportation are presented to describe the social environment.

Chapter 5.0, "Water Resources", contains a relatively detailed presentation of existing water resource conditions. Surface water and groundwater quantity and quality information is presented.

Chapter 6.0, "Land Use and Biological Resources", summarizes the biological data base for major vegetation cover (plants) and wildlife (game, furbearers, and endangered or threatened species). Additionally, major land uses (parks, forests, etc.) are dipicted and discussed.

Chapter 7.0, "Air Resources and Noise", is a consolidation of available information on climate, ambient air quality, and major point and area source emissions in the Study Area. Existing noise levels for typical coal machinery related activities are presented in a brief noise section.

Chapter 8.0, "Cultural Resources", contains an overview of known and potential prehistoric and historic resources. The information is presented utilizing a regional concept focusing on known sites and their orientation to physiographic features.

Chapter 9.0, is a resource-specific compendium of information sources utilized to assemble this document. Numerous other data sources were reviewed during the duration of this study, but were not included due to their marginal usefulness to the overall objective of the study.

CHAPTER 1.0 COAL RESOURCES

1.0 COAL RESOURCES

1.1 INTRODUCTION

New Mexico has extensive deposits of bituminous and subbituminous coal located in several major and minor districts. These deposits underlie about one-fifth of the State.

The Study Area consists of 13 counties containing known deposits of bituminous and subbituminous coal that have been mined or have the potential for future commercial development. Excluded are areas with minor outcrops of coal without potential for future development. Basic information on the coal deposits of New Mexico is summarized in Coal Resources Table 1-1 and depicted on the coal resources map (Exhibit 1).

New Mexico is divided into four major geological provinces as shown in Figure 1-1. Coal-bearing strata are found in the Great Plains Province, Interior Mountain Province, and Colorado Plateau Province. The Basin and Range Province is not in the Study Area. The rugged topography of most of the State makes is difficult to classify the characteristics for mining by individual area. In most cases it would be necessary to analyze the rock structure and topography of a specific locality to predict whether surface or underground mining would be appropriate. An exception is the San Juan River Basin where most of the deposits are suitable for surface mining. Areas known to be suitable for surface mining are outlined on Exhibit 1.

1.2 COAL PROVINCES

Coal deposits in New Mexico occur in two of the major coal provinces of the United States (Figure 1-1). The deposits in Colfax County are part of the Raton Basin which extends into New Mexico from Colorado as part of the Great Plains Coal Province. This province continues northward through Wyoming and Montana to Canada. Other deposits in New Mexico are part of the Rocky

Table 1-1. Coal resource data for 13 counties in New Mexico.

County	Province	Rank	% Moisture	% Ash	% Sulfur	Total No. Seams	Total Thickness	Depth*
Bernalillo	RM	Sub B	2	31	3.2	3	2.5	-
Catron	RM	Bit C	6	6	0.5	2	12.0	-
Colfax	GP	Bit B	2	15	0.5	6	13.0	-
Lincoln	RM	Bit C	2	13	0.6	3	7.0	-
McKinley	RM	Bit C	10	11	0.6	3	9.0	< 200
Otero	RM	Bit C	1	12	0.6	2	7.0	-
Rio Arriba	RM	Sub B	16	11	0.9	4	12.0	< 200
Sandoval	RM	Bit C	14	12	0.9	5	16.0	< 200
San Juan	RM	Bit C	15	13	0.7	7	21.0	< 200
Santa Fe	RM	Bit B	2	7	0.8	3	8.0	-
Sierra	RM	Bit	4	7	0.7	3	4.0	-
Socorro	RM	Bit C	3	11	0.7	2	7.0	-
Valencia	RM	Bit C	7	6	0.5	3	5.0	-

*Owing to the irregular topography and folding of coal seams, depth estimates are valid only in level deposits of the San Juan Basin.

Descriptions for Table 1-1.

- Province - indicates whether a county is in the Gulf Coast Lignite Province or the Oklahoma-Arkansas Coal Province.

- Rank - designation of the general characteristics of the coal as determined by the degree to which the coal has been altered from its original woody state. Rank is determined by the heating value of the coal (expressed in BTU per pound of naturally moist coal) or for the higher ranks of bituminous coal and anthracite, by the percentage of fixed carbon. Rank is defined in Table 1-2.

- Moisture - expression of the percentage of the coal that is moisture in the as-mined condition.

- Ash - incombustable as-mined coal remaining as a solid after the coal is burned.

- Sulfur - total of all forms of sulfur present in the coal.

- Number of Seams - subjective approximation of significant seams of coal that are known in the county.

- Total Thickness - the sum total thickness of all of the significant coal seams.

- Depth - general description of the distance below the ground surface at which the uppermost significant coal seam occurs.

Since the information for this table comes from very inconsistent sources, the following should be considered. For the developed mining districts, the data is for coal from the thickest seam and/or most productive mine in the county. Where coal data is based only on a sampling program, the data is for the sample from the thickest seam in the county. If there is only a mention of the presence of coal and its rank, only this information is tabulated. When only a range of composition is given for a county, the data in the table is the midpoint of the range.

Table 1-2. Rank of coal.

	Types of Coal	% Fixed Carbon	Heat Value BTU/lb
Ant 1	Meta-Anthracite	over 98%	**
Ant 2	Anthracite	92 - 97%	**
Ant 3	Semi-Anthracite	86 - 91%	**
Bit 1	Low Volatile Bituminous	78 - 85%	**
Bit 2	Medium Volatile Bituminous	69 - 77%	**
Bit A	High Volatile Bituminous A	less than 69%	over 14,000
Bit B	High Volatile Bituminous B	less than 69%	13,000-14,000
Bit C	High Volatile Bituminous C	less than 69%	11,000-13,000
Sub A	Subbituminous A *	less than 69%	11,000-13,000
Sub B	Subbituminous B	less than 69%	9,500-11,000
Sub C	Subbituminous C	less than 69%	8,300 9,500
Lig A	Lignite A	less than 69%	6,300 8,300
Lig B	Lignite B	less than 69%	below 6,300

* The distinction between Subbituminous A and Bituminous C is based on the weathering and aggolmerating characteristics of the coal.

**Coal containing over 69% fixed carbon is ranked by fixed carbon content instead of heat value.

† Coal of this rank is present in New Mexico.

Source: American Society for Testing and Materials 1978. Specification for class of coal by rank, D. 388, Philadelphia PA.

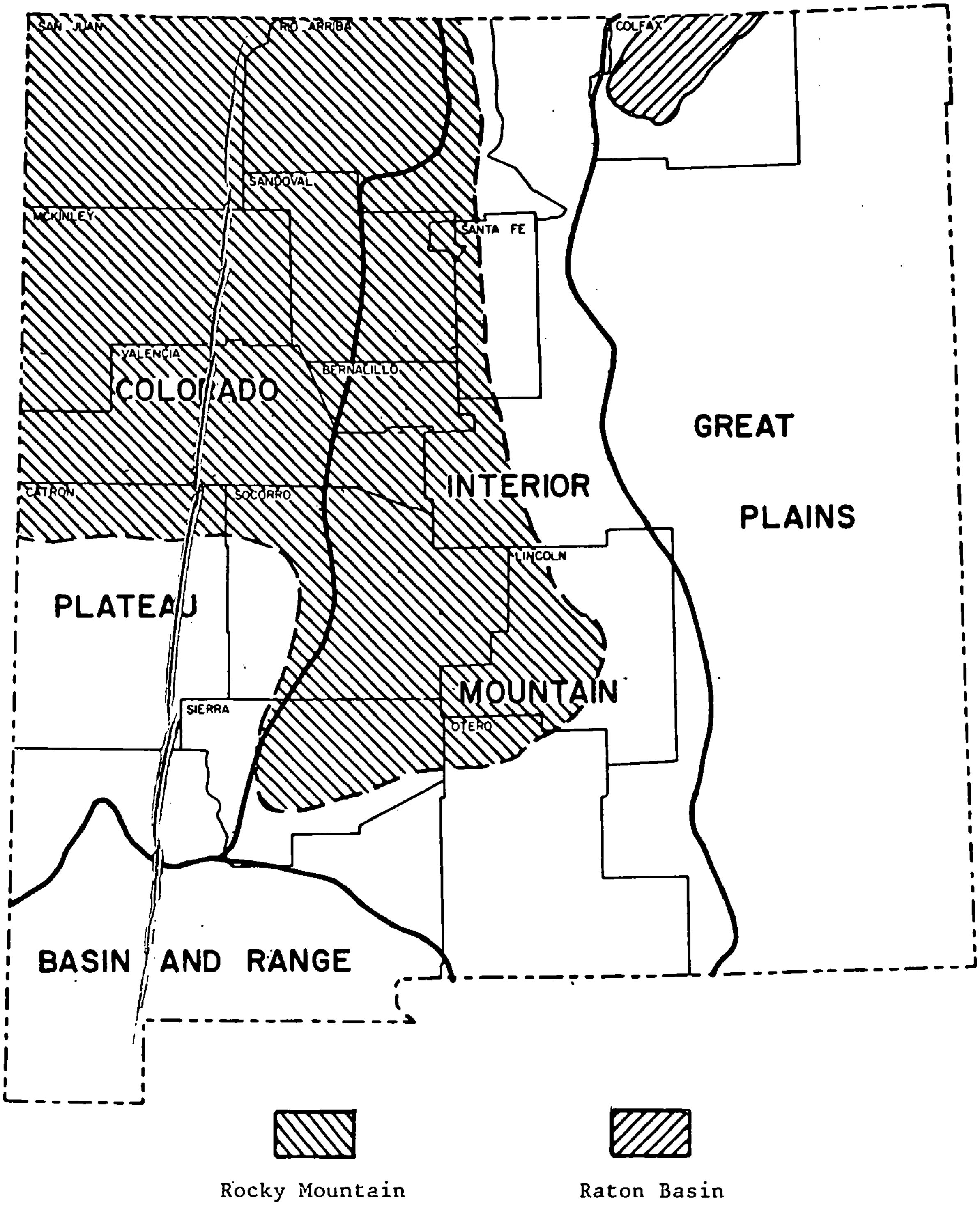

Figure 1-1. Geological provinces of New Mexico and coal provinces of Study Area.

Mountain Coal Province and are in both the Interior Mountain Province and the Colorado Plateau Province. The coal-bearing formations are similar in both provinces, however, more complicated structures typical of the Rocky Mountain Province produce more complex coal deposits in the central part of the State. Coal deposits of western and northwestern New Mexico are less complex and extend over a larger area.

1.2.1 Great Plains Coal Province

Eastern New Mexico is underlain by sedimentary rock of late Cretaceous and early Tertiary age (90-70 million years old). In the northern part of the State these strata are uplifted to form a plateau. The coal-bearing strata outcrop around the margin of this plateau to form the Raton Basin or Field (Exhibit 1).

The landforms of this area range from rolling plateaus to deep valleys and canyons. Owing to this rugged dissected terrain, some of the deposits must be mined by underground methods.

1.2.1.1 Extent and Nature of Deposits

The Raton Field occupies approximately the northwestern third of Colfax County. Coal-bearing beds are generally horizontal, or dip slightly to the west. Seams are nearest the surface in a zone northeast of Raton and along the southwest margin of the plateau. The general area of the coal field is shown in Figure 1-2. Coal is mined in two major seams, the Raton and the Vermejo, as well as several minor seams--the Tin Pan, Yankee, Left Fork, Cottonweed Canyon, Ancho Canyon, York Canyon, and Chimney Divide.

Raton coal is typically a high volatile bituminous A or B rank, with a moderate ash content and low sulfur content (Tabet and Frost 1978). Much of the Raton coal is suitable for metalurgical use and therefore of high value.

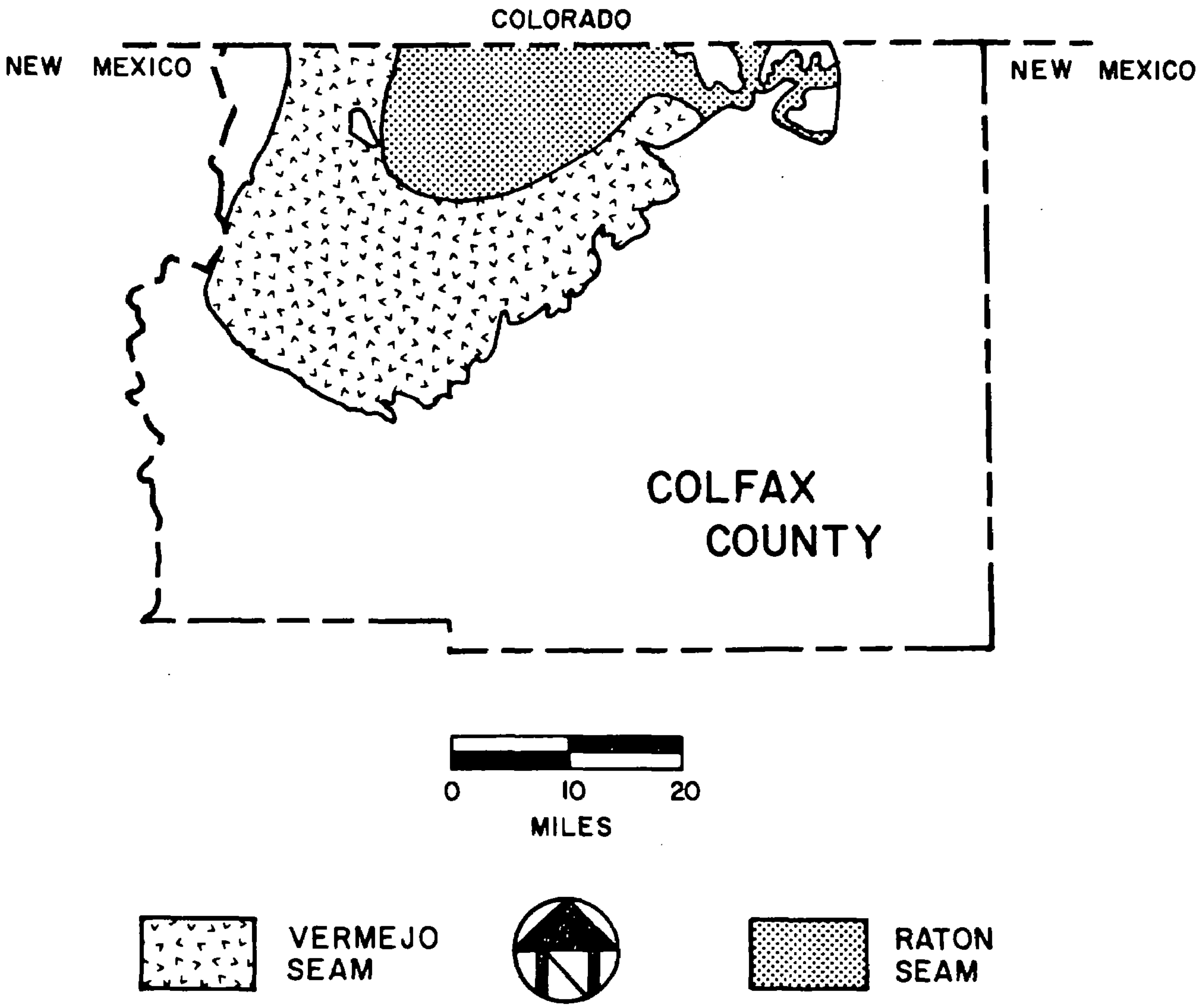

Figure 1-2. Areas of production in the major coal seams of the Raton District. (Tabet and Frost 1978)

1.2.1.2 Geologic Formations

The coal seams of the Raton Field occur in the sandstones and shales of the Vermejo Formation of late Cretaceous age (70 million years old) and in the overlying, younger conglomerate and sandy shale of the Raton Formation which is of early Eocene age. On the eastern side of the field the occurrence of mineable coal is affected by the presence of volcanic basalts which overlay the coal seams. These flows are related to the Mid-Tertiary age volcanos of northeastern New Mexico and southwestern Colorado. The coal-bearing formations correlate directly with the deposits of the Trinidad and Denver areas in Colorado.

1.2.1.3 Reserves

The current estimate of the Raton Field includes total reserves of 4.7 billion tons in seams 14 inches (.3m) or more in thickness (Tabet and Frost 1978). Reserve estimates are not available for separate districts in the field because current production is concentrated, and release of district reserves would compromise proprietary data.

1.2.2 Rocky Mountain Coal Province

The Rocky Mountain Coal Province includes deposits through central and western New Mexico. There are 12 named coal fields or districts in this province in addition to other unidentified minor coal outcrops (Exhibit 1).

These fields range in size and physical characteristics from the San Juan Basin with over 26,000 mi^2 (67,300 km^2) of coal-bearing formations in gently folded beds, to the Carthage Field with an area of less than 10 mi^2 (25.9 km^2) of highly folded seams. Deposits of this province are in the same geologic group with the exception of a few isolated outcrops of economically insignificant coal.

1.2.2.1 Extent and Nature of Deposits

The 12 fields that make up this province yield coal ranging in rank from subbituminous through semianthracite in beds intensely folded to beds relatively undisturbed. Some of the deposits are associated with igneous intrusions that have elevated the coal-bearing strata to near the surface, and in some instances heat from the intrusion has raised some of the bituminous coal to the rank of semianthracite.

The coal fields described in the following sequence are located on Exhibit 1.

Carthage Field - This district is located in east-central Soccorro County on the margin of an extensively faulted south plunging fold. There are two seams; the significant seam is up to 6 feet (1.8 meters) thick and occurs near the base of the Mesaverde Group. The deposits extend over an area of about 10 mi^2 (25.9 km^2). Coal in this field is generally high-volatile bituminous C.

Cerrillos Field - The Cerrillos Field is situated in the west-central part of Santa Fe County in the foothills of the Ortiz Mountains. Coal-bearing strata from 3 to 6 feet (0.9 to 1.8 meters) thick are found in the lower part of the Mesaverde Group. The seams are named (from lower to upper) Cook and White, Peacock, and White Ash. The field is in a complex area of downfolding and faulting intruded by dikes of igneous rock. Some of the bituminous coal near the igneous intrusions is altered to a semianthracite rank.

Datil Mountain Field - This field is located near the junction of Socorra, Catron, and Valencia counties in the west-central part of the State. The coal seams are from 3 to 5 feet (0.9 to 1.5 meters) thick and are located near the base of the Mesaverde Group. The geologic structure is complicated by extensive folding and faulting with associated igneous intrusions. The coal is subbituminous and bituminous rank.

Engle Field - The Engle Field is located in east-central Sierra County and contains thin seams, 1 to 2 feet (0.3 to 0.6 meter) thick, of bituminous coal. The seams dip rather steeply so that depth to the coal increases from west to east. The coal is from the lower part of the Mesaverde Group.

Hagen Field - The Hagan Field is located in southeastern Sandoval County just west of the Cerillos Field. Seams are of high-volatile bituminous C coal from 3 to 5 feet (0.9 to 1.5 meters) thick, and are located in the lower part of the Mesaverde Group. The geological structure is complex with numerous faults in coal-bearing beds.

Jornada del Muerto Field - This field is located in eastern Socorro County to the northwest of the Carthage Field. Lenticular seams of high-volatile bituminous C coal up to 3 feet (0.9 meter) in thickness occur in beds similar in composition and geology to those in the Carthage Field. The extent of the southern part of the deposit is not determined.

Rio Puerco Field - This field is located in western Bernalillo County and southwestern Sandoval County. Seams of bituminous coal from 2 to 3 feet (0.5 to 0.9 meter) thick occur in steeply dipping blocks in a complex faulted strata. The field is also considered an outlying member of fields of the San Juan Basin located to the west.

Salt Lake Field - The Salt Lake Field, located near the Arizona border in Catron and Valencia counties is less well known than other coal fields due to minimal development. Coal seams from 4 to 5 feet (1.2 to 1.5 meters) thick are reported in the area.

San Juan Basin Field - This large field of more than 26,000 mi^2 (67,300 km^2) is subdivided into 19 districts for purposes of mine designations. In this field, coal is mined from strata of both the Fruitland Group and the Mesaverde Group. Much of the coal is within a shallow depth zone suitable for surface mining (Exhibit 1).

Districts in the New Mexico portion of the field are shown in Figure 1-3 and listed as follows:

- Fruitland Group

  --Basti
  --Fruitland
  --Navaho
  --Star Lake

- Mesaverde Group

  --Barker Creek
  --Chaco Canyon
  --Chacon Mesa
  --Grown Point
  --Gallup
  --Hogback
  --Lavantera
  --New Comb
  --San Mateo
  --Standing Rock
  --Taylor Mountain
  --Tierra Amarilla
  --Toadlena
  --Zini

Sierra Blanca Field - This field is located in southwestern Lincoln County and northern Otero County. It contains high volatile bituminous C coal in seams of the Mesaverde Group that dip at angles of up to 15°. Numerous folds and faults make mining of the coal difficult. Although the seams are up to 7 feet (2.1 meters) thick in some areas, most contain large bodies of sand.

Tierra Amarilla Field - This field is located to the east of the San Juan Basin Field and is sometimes considered part of the San Juan Field. The deposits of subbituminous coal are in an outlying portion of the Mesaverde Group located in the Tierra Amarilla area of Rio Arriba County. The seam lies under a small mountain where deposits are exposed around the periphery. The individual coal seams vary in thickness over comparatively short distances, making mining somewhat unpredictable.

Tijeras Field - This small field is located in an isolated block of the Mesaverde Group in the Sandia Mountains of eastern Bernalillo County. Seams of bituminous coal from 1 to 3 feet (0.3 to 0.9 meter) thick are folded to high inclination. The coal-bearing beds are in the lower part of the Mesaverde Group.

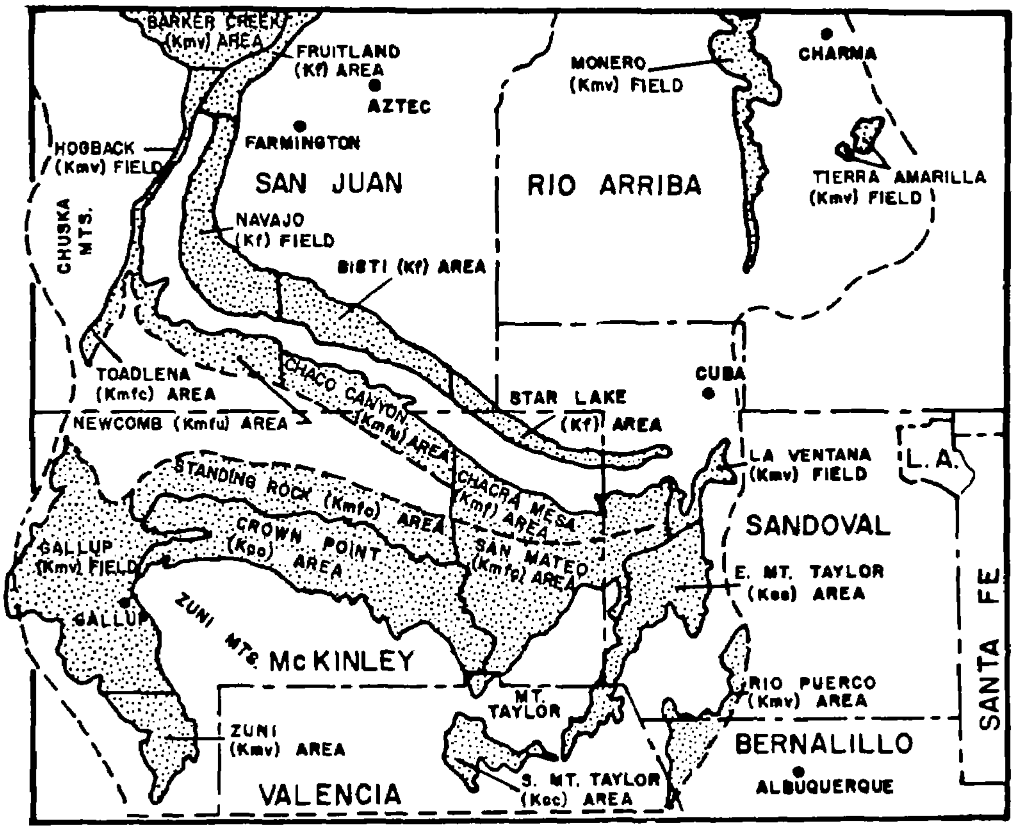

Figure 1-3. Mining Districts in the San Juan Basin Coal Field. (Shomaker and Whyte 1977)

1.2.2.2 Geological Formations

The coal deposits of the Rocky Mountain Province are present in two rock strata of late Cretaceous age (90 to 70 million years old). The Mesaverde Group is a sequence of sandstone, shale, and limestone, combined with seams of coal that occur throughout the State (Figure 1-1). Most coal in the San Juan Field, and virtually all of the coal in the other fields of this province, occur in these strata. The most important coal-bearing strata of the Mesaverde Group is the Crevasse Canyon Formation in the southern and southwestern fields, and the Menefee Formation in the northwestern field. In the central part of the San Juan Field there are major coal deposits of the Fruitland Formation which occur above the Mesaverde Group. The location of the coal formations and mining districts in the San Juan Basin are shown in Figure 1-3.

1.2.2.3 Reserves

The estimated coal reserves for New Mexico are presented in the following list of coal fields. Reserves are estimates of the coal present in seams more than 14 inches (0.3 meter) thick and within 3,000 feet (909 meters) of the surface. Sizeable areas with coal seam within 200 feet (60 meters) of the surface and suitable for surface mining are shown in Exhibit 1. The following data were derrived from Tabet and Frost (1978), Beaumont and Kottlowski (1971), and the US Geological Survey (PACER data 1980).

Coal Field	Reserves in Millions of Tons
Carthage	Not established
Cerrillos	53.2
Datil Mountain	More than 1,000
Engle Field	Not established
Hagan	17.3
Jornada del Muerto	Not established
Rio Puerco	Not established

Coal Field	Reserves in Millions of Tons
Salt Lake	320.0
San Juan Basin	
Fruitland Formation	248,810.0
Mesaverde Group	33,928.0
Total	282,738.0
Sierra Blanca	1,600.0
Tierra Amarilla	3.4
Tijeras	1.6

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CHAPTER 2.0 EXISTING AND PLANNED COAL DEVELOPMENT

2.0 COAL DEVELOPMENTS

2.1 INTRODUCTION

This chapter presents an overview of coal development as it exists and is expected to develop in the near future. The discussion examines the three most probable forms of lignite and bituminous coal development (coal mines, coal-fired electric generating facilities, and coal gasification and liquefaction facilities) in the Study Area. A brief description of each technology, including pertinent environmental considerations are presented. All known existing and planned coal developments are documented.

The primary limitations to the information presented in this chapter are:

- the necessity of timely response by industry to requests for information;
- the desire of industry to maintain confidentiality about existing and planned operations;
- the desire of State regulatory agencies to respect industry confidentiality; and
- the varying stages of development of planned facilities.

2.2 TECHNOLOGY OF COAL DEVELOPMENT

There are three predominant categories of coal development: coal mines, including surface and subsurface mines, coal-fired electric generating facilities, and coal gasification and liquefaction facilities. Section 2.2 contains a generalized outline of each development found in the Study Area, including associated environmental considerations. Typical environmental effects and mitigation measures are also included. The level of information presented is appropriate for drawing generalized conclusions about potential areas of environmental concern during preliminary project planning.

2.2.1 Coal Mines

In New Mexico, coal is either bituminous or subbituminous rather than lignite. Some bituminous mines, especially in the Raton Field, produce metallurgical grade coal. Both surface mining and sub-surface mining methods are utilized in New Mexico.

2.2.1.1 Surface Mining

Surface coal mines are classified as area mining, (a) conventional or (b) mountain top removal; contour mining, (a) box cut or (b) block cut; or open pit mining.

The following activities are generally uniform and common to all surface mining operations, differing only in procedural sequence among mining systems.

- clearing
- surface water diversion
- drilling and blasting
- overburden stripping & storage
- dewatering
- coal loading and transportation
- coal processing
- topsoil and overburden replacement
- revegetation
- reclamation and maintenance

Typical consumed resources, waste streams, environmental effects, and mitigation measures for each surface mining activity are included in Table 2-1. Revegetation, reclamation, nd maintenance are not included as separate operations because they are considered mitigation measures.

Table 2-1. Environmental considerations associated with surface mining.

Operation	Resources Consumed	Waste Streams	Effects	Mitigation
Clearing	Equipment, fuel, labor, timber, habitat	Fugitive dust, trees, brush, equipment exhaust, runoff	Decreased habitat, increased TSS in receiving stream, temporarily decreased air quality	Reclamation, incremental clearing
Surface water diversion	Equipment, fuel, labor, habitat	Stream sediment, equipment exhaust, fugitive dust	Habitat alteration, increased TSS in stream, temporarily decreased air quality	Reclamation, stream slope stablization
Drilling & blasting	Equipment, fuel, labor, land use	Noise, fugitive dust	Increased TSP, increased noise	Locate away from populated areas
Stripping and storage	Equipment, fuel, labor, water (minimal)	Runoff, fugitive dust, equipment exhaust, runoff treatment sludge	Erosion, increased TSS and altered pH in receiving streams, increased TSP	Runon diversion, runoff collection, runoff treatment, spraying water
Dewatering	Equipment, fuel, labor	Drainage, treatment sludge	Increased TSS and altered pH in receiving stream	Drainage treatment (sedimentation, neutralization), sludge dewatering and disposal
Coal loading & transportation	Equipment, fuel, labor	Vehicle emission, noise, fugitive dust	Increased TSP and vehicle emissions	Dust suppression, emission control, haul distance minimization
Coal processing	Equipment, fuel, labor	Solid waste, wastewater, storage pile runoff, noise, fugitive dust, air emissions	Increased TSS & altered pH in receiving stream, decreased air quality	Runoff interception & treatment, air pollution control equipment
Topsoil & overburden replacement	Equipment, fuel, labor	Fugitive dust, equipment emissions	Altered infiltration, altered runoff, increased TSS & altered pH in receiving stream	Segregate horizons, revegetation, water spraying

TSS - Total Suspended Solids
TSP - Total Suspended Particulate

2.2.1.2 Subsurface Mining

Subsurface coal mines are classified as:

1. Conventional Mining
   (a) Room and pillar
   (b) Longwall
   (c) Shortwall

2. Continuous Mining
   (a) Room and pillar
   (b) Longwall
   (c) Shortwall

There are five basic activities associated with subsurface mining:

- Cutting
- Drilling
- Blasting
- Loading and hauling
- Roof bolting

In conventional mining, all five activities are carried out separately. In continuous mining, the first four activities are carried out in one step.

Table 2-2 includes typical subsurface mining operations, resources consumed, waste streams, effects, and mitigation measures. Many of the operations occur underground and do not affect the environment to the extent of corresponding surface mining operations.

2.2.2 Coal-fired Electric Generating Facilities

Coal-fired electric generating facilities in New Mexico are bituminous coal burning. The qualities and proportions of constituents of waste streams may vary among facilities, but in general, waste streams and waste stream components are similar.

Table 2-2. Environmental consideration associated with sub-surface mining.

Operation	Resources Consumed	Waste Streams	Effects	Mitigation
Cutting	Equipment, fuel, labor	Fugitive dust, equipment emissions	Increased TSP & equipment emissions, increased noise	Locate away from populated areas, spray water
Above ground coal transportation	Equipment, fuel, labor	Fugitive dust, vehicle emissions, noise	Increased TSP & other vehicle emissions	Dust suppression, emission control, haul distance minimization
Coal storage	Equipment, fuel, labor	Runoff	Increased TSS & altered pH in receiving stream	Runon diversion, runoff collection, runoff treatment
Coal processing	Equipment, fuel, labor	Solid waste, wastewater, noise, storage pile runoff, fugitive dust	Increased TSS & altered pH in receiving stream, increased air emissions	Air pollution control runoff collection & treatment
Dewatering	Equipment, fuel, labor	Drainage, treatment sludge	Increased TSS & alter-pH in receiving stream	Wastewater treatment sludge dewatering & disposal
Post mining drainage		Drainage	Increased TSS & altered pH in receiving stream	Drainage collection & treatment, sealing abandoned mines
General			Subsidence of land surface	Adequate roof support

TSS - Total Suspended Solids
TSP - Total Suspended Particulate

Liquid Wastes

- sanitary waste
- boiler blowdown
- organic metal cleaning waste
- inorganic metal cleaning waste
- demineralizer waste
- cooling tower blowdown
- condensate polisher waste
- fuel storage pile runoff
- lime/limestone storage pile runoff
- process area runoff
- ash quench water
- laboratory wastes
- waste oils, hydraulic fluids
- preoperational boiler cleaning waste

Air Emissions

- fugitive dust
- total suspended particulate
- SO_x
- NO_x
- HC
- CO
- metals

Solid Wastes

- treatment sludges
- flue gas desulfurization sludge
- fly ash
- bottom ash
- economizer ash

Liquid waste treatment systems at electric generating facilities depend on the waste characteristics which are affected by raw intake water quality, fuel characteristics, water quality of the receiving water body, and process configuration at the facility. Typical air emission control equipment includes wet lime or limestone flue gas desulfurization scrubbers, or hot or cold side electrostatic precipitators for particulate removal. Solid wastes typically are landfilled when appropriate, or disposed of by contract waste disposers.

Condenser water cooling systems are environmentally significant. Common systems include impoundments (lakes or ponds) and cooling towers (wet or dry).

Materials consumed in significant quantities during construction and operation of an electric generating facility are listed below.

- Construction materials
- Labor
- Energy
- Water
- Land area
- Coal
- Lime or limestone
- Chemical substances
- Equipment

2.2.3 Coal Gasification and Liquefaction Facilities

There are dozens of coal gasification and liquefaction technologies currently under development. The processes can be categorized generically as (1) in-situ, where the coal is gasified or liquefied in-place underground without first being mined, and (2) above ground where the coal is mined, processed, and then gasified or liquefied.

2.2.3.1 Gasification

Some of the more common above ground gasification processes are the Lurgi Process, the Koppers-Totzek Process, the Winkler Process, and the Texaco Gasifier Process. All produce low/intermediate-Btu gas or high-Btu gas. The product gas contains varying concentrations of methane, hydrogen, and carbon monoxide. Gasifier reactors produce low-Btu gas from coal and steam. In a hydrogasifier, coal, steam, and hydrogen react to produce intermediate-Btu gas. A devolitization reactor is very similar to a hydrogasifier. Heat must be added to all three systems. A typical gasification operation would include the following process units:

- gasification
- shift conversion
- gas cooling
- gas purification
- methanation
- gas compression and drying
- byproduct recovery (organic, liquids, ammonia sulfur)

Table 2-3 includes the typical waste streams and treatment methods associated with non-in-situ gasification. Waste streams associated with coal processing prior to gasification are similar to those discussed in Section 2.2.1.1.

In-situ gasification takes place underground. Reaction gases are injected through an injection well into a coal deposit where gasification takes place. Product gas is removed from the ground through a production well in another part of the deposit.

A major environmental effect of in-situ gasification is potential groundwater pollution. Volatile organics vaporize, sweep through the gasification zone, and condense on coal, land, clay, and rock. Trace elements (e.g., Hg, Cd, Pb, and B) remain in ash or condense on surrounding materials. As groundwater levels are reestablished after gasification, these organics and trace elements can pollute groundwater.

Subsidence from in-situ gasification can seriously affect groundwater resources and modify area topography. Fractures created in overlying strata can decrease groundwater quality and quantity causing contamination and loss. Rock fracturing and subsidence may be prevented by designing the size, shape, and spacing of cavities to provide adequate natural support, or by providing additional support to cavities.

Less data are available on air pollution from in-situ gasification than on water pollution and land subsidence. It has been assumed that control technology for cleaning gas streams from in-situ gasification processes will be directly transferable from above-ground gasification technology (USEPA 1980f).

2.2.3.2 Liquefaction

All liquefaction processes produce liquids by yielding a material having higher hydrogen content than coal. Hydrogen content can be increased by either

Table 2-3. *Typical major waste streams, resources consumed, and mitigation methods associated with surface gasification operations.*

Operation	Resources Consumed	Waste Streams	Mitigation
Coal processing	Equipment, fuel, labor, water	Fugitive dust, rocks, debris, storage pile runoff	Cylones, spraying water, bag filters, runoff neutralization and sedimentation
Gasification	Equipment, fuel, labor, water, reaction gases	Wastewater (NH_3, phenols, cyanide), tar, char, ash, stack gases	Various wastewater treatment processes, reuse, utilization of tar and char by combustion or gasification, dewater and landfill ash, lime or limestone stack gas scrubbing
Shift conversion	Equipment, fuel, labor, catalysts, water	Acid gas, wastewater, spent catalysts	Sulfur recovery, various wastewater treatment processes, catalyst recovery
Gas cooling	Equipment, water	Blowdown, waste heat	Blowdown neutralization and sedimentation, waste heat recovery
Gas purification	Purifying media, equipment, fuel, labor	Spent media, sludge	Treatment, disposal
Methanation	Equipment, fuel, labor, catalyst, water, reaction gases	Wastewater	Reuse as boiler feed water
Gas compression and drying	Equipment, fuel, labor	Wastewater	Treatment and disposal or reuse
By-product recovery	Catalyst, equipment, labor, fuel	Spent catalyst, waste heat, tail gases	Oxidation and disposal of catalyst, waste heat recovery, air emission treatment

Table 2-3. Typical major waste streams, resources consumed, and mitigation methods associated with surface gasification operations (concluded).

Operation	Resources Consumed	Waste Streams	Mitigation
Auxiliary operations			
Oxygen generation	Equipment, fuel, labor	Stack gas (nitrogen)	
Waste treatment	Treatment chemicals, equipment, labor, fuel	Sludge, effluent	Sludge treatment and disposal, effluent discharge or reuse
Transportation	Equipment, labor, fuel	Fugitive dust, vehicle emissions	Roadway maintenance, emission control
Runoff	Soil	Wastewater (suspended sediments, organics, oil)	Neutralization, sedimentation, oxidation, oil separation
Other	Water	Sanitary waste	Biological oxidation, other treatment methods

Source: USEPA. 1978. Environmental review of synthetic fuels. Research Triangle Park NC, 3 (4): 15 p.

adding hydrogen to the coal or stripping the hydrogen-rich components from the coal, depending on the process. Typical unit processes include:

- coal preparation
- hydrogenation
- pyrolysis/hydrocarbonization
- hydrotreating
- catalytic synthesis
- supercritical gas extraction
- phase separation
- fractionation
- acid gas removal
- hydrogen-synthesis gas-generation (USEPA, Office of Research and Development 1978)

Not all liquefaction systems require all the above processes. Table 2-4 includes unit processes, typical resources consumed, typical waste streams, and typical environmental effects and mitigation measures associated with coal liquefaction.

Different liquefaction processes have unique waste streams which require individualized waste treatment techniques. In general, common air pollution control technologies are listed in Table 2-5. Common wastewater treatment systems are listed in Table 2-6.

In-situ liquefaction is a developing technology similar to in-situ gasification. It requires pumping a solvent into a fractured coal deposit. The liquid product is then removed through recovery wells. In most cases, a portion of the coal reserve is ignited to provide heat for the process. The environmental effects of in-situ liquefaction are similar to those of in-situ gasification. The potential for groundwater contamination is increased with liquefaction because solvents are introduced into the liquefaction zone.

2.3 EXISTING AND PLANNED COAL DEVELOPMENT

Facilities in operation, under construction, or issued new source National Pollutent Discharge Elimination System (NPDES) permits and/or State mining permits are categorized as existing facilities. Facilities in the planning stage and anticipated to be in operation by 1990 are categorized as planned facilities. All known facilities are shown in Exhibit 2.

Table 2-4. Typical major waste streams, resources consumed, and mitigation methods associated with surface coal liquefaction technologies.

Operation	Resources Consumed	Waste Streams	Mitigation
Coal processing	Equipment, fuel, labor	Fugitive dust, rocks, debris, storage pile runoff	Cyclones, bag filters, water spraying, runoff neutralization and sedimentation
Hydrogenation	Equipment, fuel, labor, catalyst	Stack emissions (CO, NO_x, H_2S, NH_3, hydrocarbons), waste heat, quench water (phenols, tars, NH_4, thiocyanates, sulfides, chlorides), spent catalyst	Equipment and operation control, scrubbers, waste heat recovery, wastewater treatment
Pyrolysis/hydrocarbonization	Equipment, fuel, water, reaction gases	Stack emissions (CO, NO_x, H_2S, NH_3, hydrocarbons), waste heat, quench water, spent catalyst, ash, slag, char	See hydrogenation
Hydrotreating	Equipment, fuel, labor, catalyst	Condensate (phenols, NH_4, sulfides), spent catalyst, stack emissions (CO, NO_x, H_2S, NH_3, hydrocarbons, particulate), waste heat	See hydrogenation
Catalytic synthesis	Equipment, fuel, labor, catalyst	Condensate (phenols, NH_4, sulfides), stack emissions (CO, NO_x, N_2S, NH_3, hydrocarbons), spent catalyst, spent absorbent	See hydrogenation

Table 2-4. Typical major waste streams, resources consumed, and mitigation methods associated with surface coal liquefaction technologies (continued).

Operation	Resources Consumed	Waste Streams	Mitigation
Supercritical gas extraction	Water, equipment, labor, solvent	Quench water (phenols, tars, ammonia, thiocyanates, sulfides, chlorides), ash, slag	Wastewater treatment, landfilling
Phase separation	Equipment, fuel, labor	Wastewater (oil, hydrocarbons, phenols, NH_4, sulfides), stack emissions (hydrocarbons, sulfides, SO_2, NH_4, particulate), fugitive dust, ash, slag, char	Wastewater treatment, scrubbers, particulate
Fractionation	Equipment, fuel, labor	Stack emissions (H_2S, CO_2), condensate (hydrocarbons, dissolved salts), ash, slag, char	Air emission control, wastewater treatment, landfilling
Acid gas removal	Aborbent, equipment, fuel, labor	Spent solvent, stack gases (CO_2, H_2S, CO, hydrocarbons, sulfides)	Solvent regeneration, air emission control
Hydrogen-synthesis gas-generation	Equipment, fuel, labor, catalyst	Quench water (phenols, tars, NH_4, thiocyanates, sulfides, chlorides), spent catalyst, ash, slag, char, waste heat, stack emissions (H_2S, CO, CO_2, NO_x, NH_3, hydrocarbons, sulfides)	Wastewater treatment, air emission control, waste heat recovery, landfilling

Table 2-4. Typical major waste streams, resources consumed, and mitigation methods associated with surface coal liquefaction technologies (concluded).

Operation	Resources Consumed	Waste Streams	Mitigation
Auxiliary operations			
Air emission control	Equipment, labor, fuel, water	Particulate, flue gas desulfurization sludge	Sludge dewatering, neutralization, landfilling
Wastewater treatment	Equipment, labor, fuel, chemicals	Sludge	Sludge dewatering and treatment, landfilling

Source: Office of Research and Development. 1978. Symposium proceedings: environmental aspects of fuel conversion technology, III. USEPA, Research Triangle Park NC, 544 p.

Table 2-5. Common air emission control technologies used in coal liquefaction systems.

<u>Particulate Controls</u>

Dry inertial separators
- cyclones
- multiclones
- baffle chambers
- settling chambers
- impingement separators
- gravity settling chambers

Electrostatic precipitators

Bag (fabric filters) houses

Wet scrubbers

<u>NO_x Control</u>

Reduction in excess air and temperature

<u>SO_2 Controls</u>

Wet limestone scrubbing

Limestone injection

<u>Sulfur Recovery</u>

Claus plants

Stretford plants

<u>Gaseous Pollutant Control</u>

Flares

Absorption

<u>Evaporation Controls (mainly hydrocarbons)</u>

Storage tank modifications

Inspections and maintenance

Vapor collection and recovery equipment

Source: Office of Research and Development. 1978. Symposium proceedings: environmental aspects of fuel conversion technology, III. USEPA, Research triangle Park NC, 544 p.

Table 2-6. Common wastewater treatment technologies used in coal liquefaction systems.

Physical	Chemical	Biological
Sedimentation	Neutralization	Activated sludge
Flotation	pH adjustment	Trickling filter
Oil Separation	Coagulation	Aerated lagoons
Stripping	Precipitation	Waste stabilization ponds
Solvent Extraction	Oxidation	
Adsorption	Ion exchange	
Combustion		
Filtration		

Source: Office of Research and Development. 1978. Symposium proceedings: environmental aspects of fuel conversion technology, III. USEPA, Research Triangle Park NC, 544 p.

2.3.1 Coal Mines

All mines identified as exploratory mines are not discussed in this study. However, not all mines could be classified as exploratory or producing due to the lack of available data.

2.3.1.1 Exisiting Coal Mines

Surface mining techniques are discussed in Section 2.2.1.1 and subsurface mining techniques are discussed in Section 2.2.1.2. A list of coal mines in New Mexico, and pertinent information about each is contained in Table 2-7.

2.3.1.2 Planned Coal Mines

A list of coal mines planned in New Mexico is presented in Table 2-8. The date of operation is dependent in part on the dates of permit issuances and the establishment of purchase agreements for the coal produced. State surface mining regulations require topsoil to be segregated during reclamation except in cases where the mine owner can demonstrate that the practice is unnecessary. It is therefore assumed that segregation will take place during reclamation at most planned mines.

2.3.2 Coal-Fired Electric Generating Facilities

The coal-fired electric generating facilities in New Mexico listed in this document include facilities supplying electricity for large areas. Coal-fired furnaces supplying energy other than electricity are excluded. Excluded facilities are generally small and insignificant compared to electric utility facilities.

2.3.2.1 Existing Coal-Fired Electric Generating Facilities

A list of existing coal-fired electric generating facilities in the Study Area and pertinent information about each facility is presented in Table 2-9.

Table 2-7. Existing coal mines in 13 counties in New Mexico.

Counties	Name	Mining Method	Area[1] [ha(ac)]	Production Rate[kkg/yr (t/yr)]	Dates of Operation	Coal Type[2]	Discharge To	Reclamation	Owner
Colfax	Westridge	Surface	1,170 (2,890)	700,000 (800,000)	1976	Bituminous	None	Grassland	Kaiser Steel Corp.
	York Canyon	Subsurface and Surface	2,970 (7,330)	0.4 to 0.9 million (0.5 to 1 million)	approx. 1955	Bituminous	None	Grassland and pines	Kaiser Steel Corp.
McKinley	Amcoal #1	Surface	57 (140)	NA	1976	Sub-bituminous	None	Grassland	Amcoal, Inc.
	McKinley	Surface	10,619 (26,219)	NA	1962	Sub-bituminous	None	Grassland	Pittsburgh and Midway Coal Co.
	Mentmore	Surface	2,730 (6,740)	NA	1979	NA	None	Grassland	Carbon Coal Co.
San Juan	Con Paso-Burnham	Surface	16,316 (40,286) Total Projected Lease	NA	1980	Sub-bituminous	None	Grassland	Consolidated Coal Co.
	Bisti	Surface	NA	NA	NA (inactive)	NA	None	Grassland	Western Coal Co.
	Black Diamond	Surface	NA	NA	NA (inactive)	NA	None	Grassland	Black Diamond Coal Co.
	De-Na-Zin	Surface	130 (320)	NA	NA (active)	NA	None	Grassland	Sunbelt Mining Co.
	Gamerco	Surface	NA	NA	NA	Bituminous	None	Grassland	Carbon Coal Co.

Table 2-7. Existing coal mines in 13 counties in New Mexico (concluded).

County	Name	Mining Method	Area[1] [ha(ac)]	Production Rate[kkg/yr (t/yr)]	Dates of Operation	Coal Type[2]	Discharge To	Reclamation	Owner
	Gallo Wash	Surface	NA	NA	1982	NA	None	Grassland, Segregate Horizons	Alamito Coal Co.
	La Plata	Surface	NA	NA	1981	NA	None	Grassland	Western Coal Co.
	Navajo	Surface	16,316 (40,286)	NA	1963	Sub-bituminous	None	Grassland	Utah International Coal Co.
	San Juan	Surface	1,453 (3,588)	NA	1973	Bituminous	None	Grassland	Utah International Coal Co.
Sandoval	Arroyo #1	Sub-Surface	98 (243)	NA	1980	Bituminous	None	-	Transcontinental Coal and Export
Socorro	Tres Hermanos	Sub-Surface	32 (80)	NA	1980	NA	None	-	Cactus Industries

\- - Not applicable
NA - Information not available
(inactive) - Mine permitted but not yet in operation
(-) - Not applicable
[1] - Areas for subsurface mines are mine areas projected upward to the surface plus areas of surface facilities. Areas for surface mines are permitted areas except where noted.
[2] - All coal is either Bituminous or Sub-bituminous.

Table 2-8. Planned coal mines in 13 counties in New Mexico.

County	Name	Mining Method	Area[1] [ha(ac)]	Production Rate [kkg/yr (t/yr)]	Dates of Operation	Coal Type	Discharge To	Reclamation	Owner
Lincoln	Old Abe	Surface	NA	NA	NA	NA	None	NA	Great American Coal Co.
McKinley	Carbon II	NA	NA	NA	NA	NA	None	NA	Carbon Coal Co.
	Lee Ranch	Surface	NA	NA	NA	NA	None	NA	S F Mining, Inc.
San Juan	West Area	Surface	6,100 (15,000)	NA	NA	NA	None	NA	El Paso Coal Co.
San Juan or McKinley	Black Lake	NA	NA	NA	NA	NA	None	NA	Western Associated Coal Corp.
Sandoval	La Ventana	Sub-Surface	4,252 (10,498)	1.3 million (1.4 million)	1982-2027	Bituminous	Rio Puerco	NA	Ideal Basic Industries
	Star Lake	Surface	NA	NA	NA	NA	None	NA	Chaco Energy Co.
Santa Fe	Carillos	Sub-Surface	NA	NA	NA	NA	None	NA	Horizon Mining Co.
NA	S. Hospah	NA	NA	3.1 million (3.4 million)	1981- NA	NA	None	NA	Chaco Energy Co.

NA - Information not available

[1] - Areas for subsurface mines are mine areas projected upward to the surface plus areas of surface facilities.

Table 2-9. Existing Coal-fired electric generating facilities in 13 counties in New Mexico.

County	Name	No. of Units	Generation Rate per Unit (MW)	Coal Type	Date On-Line	Cooling Method	Air Pol. Cont. Meth.	Owner
San Juan	Four Corners	5	190/190/252/ 818/818	Bituminous	1963/1963/ 1964/1969/ 1970	NA	NA	APSC
	San Juan	4	314/306/468/ 472	Bituminous	1976/1973/ 1979 1979/1982	Mechanical towers (1 wet/dry)	ESP, FGD NA	PSCNM

NA - Information not available
APSC - Arizona Public Service Company
ESP - Electrostatic precipator
FGO - Flue gas desulfurization
PSCNM - Public Service Company of New Mexico

Section 2.2.2 includes a discussion of the environmental considerations typically associated with coal-fired facilities.

2.3.2.2 Planned Coal-Fired Electric Generating Facilities

Table 2-10 contains a list of planned coal-fired electric generating facilities with background information about each.

2.3.3 Coal Gasification and Liquefaction Facilities

There are no coal gasification or liquefaction facilities in operation in New Mexico. All four planned facilities are presently preparing feasibility studies. The Energy Transition Corporation Project is in the most advanced stages of planning. A list of planned facilities and pertinent information about each are presented in Table 2-11.

Table 2-10. Planned coal-fired electric generating facilities in 13 counties in New Mexico.

County	Name	No. of Units	Generation Rate per Unit (MW)	Coal Type	Date On-Line	Cooling Method	Air. Pol. Cont. Meth.	Owner
San Juan	New Mexico	4	500	Bituminous	1990/1992/ NA	NA	NA	PSCNM
	Unnamed	1	330	Bituminous	1984	NA	NA	PEGTC

NA - Information nor available
PSCNM - Public Service Company of New Mexico
PEGTC - Plains Electric Generation and Transmission Co-op.

Table 2-11. Planned coal gasification and liquefaction facilities in 13 counties in New Mexico.

County	Name	Process	Coal Type	Coal Consumption per Year [kkg(t)]	Air. Pol. Cont. Meth.	Dates of Operation	Owner
McKinley	NA	Liquifaction (probably Lurgi)	NA	NA	NA	NA	Energy Transition Corp.
San Juan	NA	Gasification or Liquifaction	NA	NA	NA	NA	Public Service Co. of New Mexico
	NA	Gasification or Liquifaction	NA	NA	NA	NA	Texas Eastern Synfuels
McKinley or San Juan	NA	Liquefaction	NA	NA	NA	NA	Thermal Energy/ Peabody Coal

NA - Information not available

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DIGITALLY

CHAPTER 3.0 EARTH (NON-COAL) RESOURCES

3.0 EARTH (NON-COAL) RESOURCES

3.1 INTRODUCTION

Earth resources are a combination of the physical elements of the surface and subsurface of the earth from which most life forms derive their basic needs. The importance of these resources in a particular location varies depending on the nature in which various elements interact with other elements of the environment.

This chapter presents information (Table 3-1 and Exhibit 3) intended to aid in proper environmental planning to minimize adverse concerning effects of coal development on earth resources. Concerns for coal/lignite development include erosion, restoration, and reclamation (or enhancement) of the contour of the land and the soil conditions, and effects on other mineral resources.

3.2 PHYSIOGRAPHY

The processes of uplift, erosion, deposition, settling, faulting, and folding produced a highly diverse terrain in New Mexico. The results of these processes produced the major physiographic regions of the Study Area: the Great Plains, Southern Rocky Mountains, Colorado Plateau, and Basin and Range (Figure 3-1). The Great Plains occur only in Colfax County, while the Southern Rocky Mountains comprise only parts of Rio Arriba and Santa Fe counties. The remainder of the Study Area is comprised of the Colorado Plateau and Basin and Range provinces that cover the majority of the Study Area.

3.2.1 Great Plains

The Great Plains Province of the United States extends into eastern New Mexico and includes most of Colfax County. In the Study Area it is characterized by trenched and deeply eroded areas surmounted by dissected

Table 3-1. Earth resources of 13 New Mexico counties.

County	Physiography	Soils[1]				Minerals[2]
		Slope	Depth	Texture	Other	(Non-metals, metals, hydrocarbons)
Bernalillo	Plains with mountains in the east	Level to moderately steep	Mostly deep, shallow on steep slopes	Sandy to clay loam; alluvial parent material	Susceptible to wind and water erosion, limy below 20 inches	Pg, Fl, St, Gp, LA, L, G, S, Mo, Ba, C
Catron	Mountainous, hilly	Mostly hilly to very steep	Shallow	Gravelly, stony; igneous, conglomerate	Neutral to slightly acid	LA, Sa, U, Gu, L, G, S, As, Cp, Fl, Mo, Te, Bi
Colfax	Mountainous - West plains - East	Gently sloping to very steep	Moderately deep to deep	Loam to silty clay, sandy loam to loam and stony in steeper areas	Neutral to slightly acid, sandstone and shale parent material	As, C, St, Mo, U, Th, Tu, I, L, G, S, Cp, Te, Bi, Ch, He, CD
Lincoln	Plains with high mountains	Gently sloping to moderately steep	Mostly shallow	Gravelly loam	Occur over limestone and indurated caliche	S, L, I, Mo, RE, St, Sa, Gp, G, C, Cp, As, U, Ba, Tu, Fl, Z, G
McKinley	Plains with low mountains	Gently to strongly sloping	Shallow, locally deep	Rock outcrops and stony fine sandy loam to loam	Sandstone bedrock	U, Th, St, Gm, Mo, V, Se, C, P, AR
Otero	Plains with high mountains	Gently to strongly sloping, undulating, and very steep	Shallow to deep	Mostly sandy except loamy in mountains	Limy in subsoils; wind erodable	St, Gp, St, G, S, Cp, Mo, Sa, L, I, Fl, Th
Rio Arriba	Hilly, open high mountains in East	Nearly level to steep	Shallow to deep	Sandy loam to clay loam	Sandstone and shale parent rock	LA, C, I, Fl, A, Mo, L, G, S, Z, Cp, U, Th, T, Bi, Gm, Be, Tu, St, P, NG, AR, He, CD

Table 3-1. Earth resources of 13 Mexico counties (continued).

County	Physiography	Soils: Slope	Soils: Depth	Soils: Texture	Soils: Other	Minerals (Non-metals, metals, hydrocarbons)
Sandoval	Variable, plains to mountains	Nearly level to very steep	Deep in valleys, shallow in uplands	Sand to clay loam, some gravelly	Eastern part - severe wind and water erosion potential	Mn, U, Cp, Su, Se, C, Th, Gp, Gm, G, S, CD, LA, L, Fl, Ba, Pg, P, NG, AR
San Juan	Plains with low mountains	Mostly rolling and undulating	Mostly deep	Sand to silty clay loam	Sand and shale parent material	P, NG, U, Th, V, C, St, Gm, AR, He, CD
Sante Fe	Plains with mountains in Northeast	Nearly level to very steep	Mostly deep	Stony and sandy to loamy	Lime accumulations below 20 inches, mixed parent material	U, Pg, Mo, Mn, C, G, S, L, Z, Th, I, Cp, St, T, A, As, Gp, Fl, Tu, Ba
Sierra	Plains with high mountians	Mostly rolling to very steep	Shallow to moderately deep	Mostly sandy with gravel, some loamy, much rock outcrop	Lime in subsoils, mixed parent material	T, C, Fl, Gm, I, Mo, U, L, G, S, Cp, Ba, Gp, V, A, Gu, Mn, Tu, Z, Pg, Th, St, As, Bi
Socorro	Plains with high mountains	Gently sloping to very steep	Deep in more level areas, shallow in rocky uplands	Much rockland, other areas sand to clay loam	Highly mixed parent material - limestone, sandstone, igneous, shale	LA, Ba, St, Mn, L, Z, U, Fl, C, Pg, V, Cp, I, Gp, Cp, S, Gm, Tu, Su, G, Mo, As, Bi, Cd, St, N, Gu
Valencia	Plains with low and high mountains	Gentle to very steep	Mostly shallow	Variable, rockland and loamy to clayey	Mostly sandstone or igneous parent material	U, V, Fl, St, G, S, Cp, Gp, C, Mo, As, LA, Gm, N

Table 3-1. Earth resources in 13 New Mexico counties (concluded).

[1] Information is summarized, being based on predominant features and considering all soil associations in the county. Key to <u>slope</u> designation: level or nearly level - 0 to 2%; gently sloping or undulating - 2 to 5%; strongly sloping, rolling, or hilly - 5 to 10%; moderately steep - 10 to 25%; steep - 25 to 75%; very steep - 75% plus. Key to <u>depth</u> designations: deep - greater than 100 centimeters (40 inches); moderately deep - 50 to 100 centimeters (20 to 40 inches); shallow - less than 50 centimeters (20 inches).

[2] Minerals:

A - Antimony	Fl - Fluorspar	Mo - Molybdenum	SG - Sand and Gravel
AR - Asphalt Rock	G - Gold	N - Nitrates	St - Stone
As - Arsenic	Gm - Gem Minerals	NG - Natural Gas	Su - Sulfur
Be - Beryllium	Gp - Gypsum	Nm - Niobium, Tantalum	T - Tin
Bi - Bismuth	Gu - Guano	P - Petroleum	Te - Tellurium
C - Clays	He - Helium	Pg - Pegmatites	Th - Thorium
Cd - Cadmium	I - Iron	RE - Rare Earths	Tu - Tungsten
CD - Carbon Dioxide	L - Lead	S - Silver	U - Uranium
Ch - Caliche	LA - Lightweight Aggregates	Sa - Salines, Salt	V - Vanadium
Cp - Copper	Mn - Manganese	Se - Selenium	Z - Zinc

Sources: USGS 1975; Bureau of Mines 1978; Maker et al. 1978; Anderson 1957; Talmadge and Weston 1937; USGS 1969; New Mexico Bureau of Mines and Mineral Resources (NMBMMR) 1969; NMBMMR 1979.

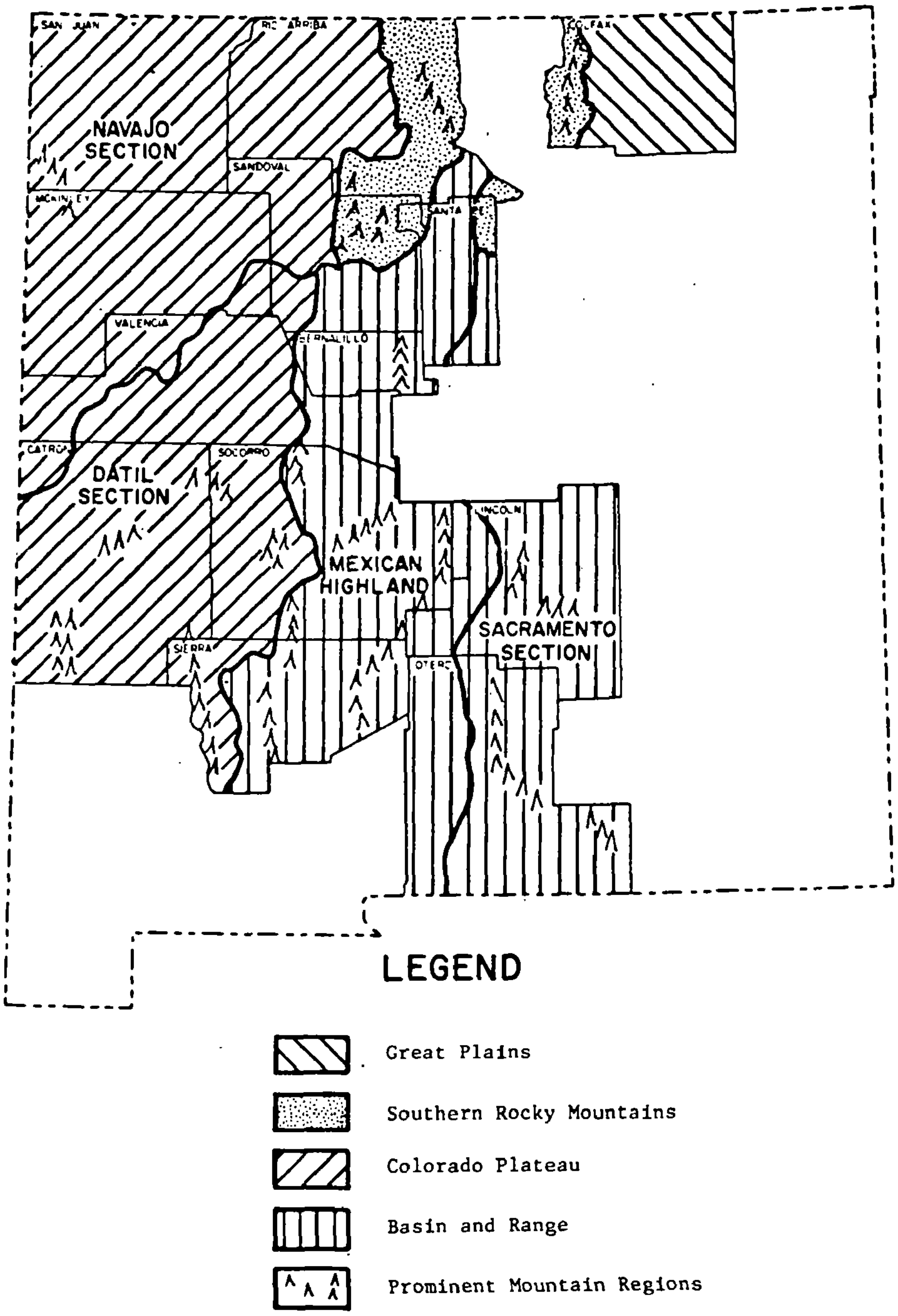


Figure 3-1. Physiographic provinces of 13 New Mexico counties.
Source: Adapted from US Geological Survey 1965.

lava-capped plateaus and buttes (New Mexico Bureau of Mines and Mineral Resources 1965). Elevations range from about 6,000 feet (1800 meters) above sea level in southeast Colfax County, to a high point of about 8800 feet (2643 meters) above sea level with local relief varying from approximately 500 to 1000 feet (150-300 meters).

Erosion is a major environmental problem in some of the areas west of Raton. Steep slopes and orientation of coal beds in major geologic formations will result in subsurface mining in most locals.

3.2.2 Southern Rocky Mountains

This province is small, comprising eastern Rio Arriba County, northeastern Santa Fe County, northeastern Sandoval County, and western Colfax County. Elevations in this mountainous region range from about 6,500 feet (1952 meters) to over 12,000 feet (3604 meters) above sea level, with local relief varying from 1000 feet (300 meters) to over 3000 feet (900 meters).

The Southern Rocky Mountain Province represents extremely rugged topography. However, coal deposits in the above mentioned counties lie primarily outside of the boundaries of the more rugged terrain and therefore should be affected less. Coal development has the greatest potential for causing problems in far western Colfax County, where the Raton Coal Field extends into this province.

3.2.3 Colorado Plateau

The northern reaches of the Colorado Plateau consist of a canyoned plateau known as the Navajo section. In the plateau's southern reaches it turns into a volcanic region known as the Datil section (Figure 3-1).

Elevations in the Colorado Plateau range from approximately 5,000 feet (1500 meters) to 10,000 feet (3000 meters) above sea level. The most rugged parts of the Study Area occur where local relief changes over 3,000 feet. southern Catron County and western sections of Socorro and Sierra counties contain areas of high relief. Less pronounced mountainous areas north and south of the above areas, as well as the southern edge of the San Juan River in the northwest, have local relief changes of 1,000 to 3,000 feet (300 to 900 meters). The remaining less eroded areas of the Colorado Plateau reflect local relief differences of 500 to 1000 feet (150 to 300 meters).

Major locations of environmental concern include the hilly and mountainous areas of San Juan, Rio Arriba, McKinley, Sandoval, and Valencia Counties. Much of this area is presently being mined or has planned coal development. However, many of the mountainous areas of the Colorado Plateau are outside coal deposit boundaries.

3.2.4 Basin and Range

The Basin and Range region is divided into the Mexican Highland, an area of isolated and dissected block mountains separated by desert plains, and the Sacramento Section, an area of mature block mountains with gently tilted strata forming plateaus and bolsons (Figure 3-1). Elevations range from approximately 4,000 feet to over 10,000 feet above sea level, while local relief changes generally exceed 3,000 feet (900 meters). Mountain chains contrast greatly with the expansive and level International Basin.

Much of the province is outside of major coal deposits, and thus will be unaffected by coal development. However, most of the localized deposits of coal in the province are associated with unlevel areas. In these high relief areas, the potential for erosion also is high.

3.3 SOILS

The productive quality of soil and its suitability for certain uses is largely determined by properties of slope, depth, texture, and levels of pH (Table 3-1 and 3-2). Soils in the same physiographic regions have similar soil characteristics and are classified by physical and chemical properties.

Table 3-2. Description of major soil associations depicted in Exhibit 3.

Region and Map Unit Number	Depth[1]	Slope (%)	Texture (Topsoil/ Subsoil	Present Use/[2] Suitability	Other
HIGH PLAINS					
11	(D)	2-5	Fine sandy loam or loamy sand/sandy clay loam	Mostly rangeland, some agricultural	Wind erosion in unvegetated areas
12	(S-D)	2-10	Loam/clay loam; often stony	Rangeland	Lime in much of the subsoil
13	(S-MD)	2-5	Loam or sandy loam /sandstone bedrock	Rangeland	
COOL DESERT					
25	(S-D)	2-5	Fine sandy loam to loam/loam to clayey to sandstone	Rangeland	Includes calcareous alluvium
26	(D)	0-5	Finely to coarsely loamy/stratified loam and clay	Agricultural (cropland)	Considerable urban use
27	(S)	0-75 plus	Loamy sand to silty clay loam/ bedrock	Rangeland	Barren outcrops of shale and sandstone
28	(S)	2-5	Silty clay loam/ shale	Rangeland	Prominent local uplands; highly erodable
29	(D)	2-5	Loamy fine sand/ loamy fine sand	Rangeland	Alluvial and wind deposits and some clay
30	(S)	75 plus	Rockland-sandstone outcrops	Rangeland	Canyonland

Table 3-2. Description of major soil associations depicted in Exhibit 3 (continued).

Region and Map Unit Number	Depth[1]	Slope (%)	Texture (Topsoil/ Subsoil	Present Use/[2] Suitability	Other
WARM DESERT					
31	(D)	0-25	Variable (sand to clay)/mostly sandy loam	Agricultural (cropland); rangeland	Mostly deep
32	(MD-D)	2-10	Sandy/sandy clay loam	Rangeland	Wind erodable; lime in subsoil
33	(MD-D)	2-10	Fine sandy loam/ sandy loam to clay loam	Rangeland	Water erosion in unvegetated areas
34	(S-MD)	0-5	Gravelly loam/ sandy clay loam	Rangeland	Cemented subsoil high in lime
35	(D)	0-5	Sandy clay loam/ clay loam	Rangeland	Gravelly at 4 to 6 feet
37	(S)	2-10	Sandy to loamy/ caliche	Rangeland	Caliche and cementation below 15 in.
39	(MD)	2-5	Sandy to sandy loam/ sandy clay loam	Rangeland (many sand dunes)	Wind erodable; calcareous subsurface
40	(D)	2-5	Sandy/sandy clay loam	Rangeland	Wind erodable with dunes
41	(D)	0-5	Loam/loamy with gypsum	Severely limited (little vegetation)	High in gypsum content; calcareous
43	(D)	0-5	Loam/clay loam	Rangeland	Contains gypsum and salt; water erodable
44	(D)	0-5	Silt loam/silty clay	Rangeland	20% strongly saline; includes gypsum strata

Table 3-2. Description of major soil associations depicted in Exhibit 3 (continued).

Region and Map Unit Number	Depth[1]	Slope (%)	Texture (Topsoil/ Subsoil	Present Use/[2] Suitability	Other
46	(S)	2-10	Stony, gravelly loam/basalt bedrock	Rangeland	Volcanic region with some steep areas
47	(S-MD)	2-75	Stony, gravelly loam/gravelly loam	Rangeland	Some cementation in subsurface
48	(S)	25-75	Cobbly to sandy loam/loamy over bedrock	Limited use - some rangeland	Much bedrock exposure
49	(S)	2-75	Stony loam/stony loam	Rangeland	Rock outcrops with deep soils interspersed
51	(D)	2-10	Gypsum sands	Recreation - limited for other uses	Dune surface
52	-	0-10	Rough, stony lava (very little soil)	Very limited use	Sharp, jagged surfaces; small soil pockets
EAST-CENTRAL PLAINS					
55	(MD-D)	0-5	Loam to silty clay loam/clay loam to clay	Rangeland	Some high time layers
56	(MD-D)	2-5	Loamy to clayey/ loamy to clayey	Rangeland	Soil derived from shale
57	(S)	2-25	Sandy loam to loam/ sandy clay loam	Rangeland	Sandstone bedrock
59	(MD-D)	0-10	Loam/limy clay loam	Rangeland	Potential wind and water erosion
60	(S-MD)	2-10	Loam to clay loam/ loam to clay loam	Rangeland	Underlain by strongly cemented caliche

Table 3-2. Description of major soil associations depicted in Exhibit 3 (continued).

Region and Map Unit Number	Depth[1]	Slope (%)	Texture (Topsoil/ Subsoil	Present Use/[2] Suitability	Other
61	(S-MD)	2-25	Fine sandy loam/ stony to clay loam	Rangeland	Some steep areas
64	(S-D)	2-25	Loam/loam to clay loam	Rangeland	Considerable lime in sub-soil
65	(S)	2-10	Sandy loam to loam/ loam or bedrock	Rangeland	Potential water erosion; calcareous
66	(S)	2-10	Stony loam/very stony loam to bedrock	Rangeland	Calcareous
67	(S-MD)	2-10	Loam/limy loam	Rangeland	Calcareous, some indurated caliche
68	(S)	2-25	Stony loam/very stony loam	Rangeland	Limestone bed-rock and outcrops
69	(MD-D)	2-10	Loam/clay loam	Rangeland	Calcareous
70	(S)	25-75	Thin stony material/ sandstone bedrock	Rangeland	Rough, broken topography
82	(S)	5-75	Stony loam/bedrock	Rangeland	Rocky lime-stone area
WESTERN PLATEAU					
84	(S-MD)	2-10	Fine sandy loam/ sandstone bedrock	Rangeland	Rough, broken top-ography, rock outcrops common
85	(S-D)	5-25	Silty clay loam/ stratified loam	Rangeland	Badlands common, poten-tial water erosion
86	(D)	0-5	Loam/clay loam	Rangeland	Well drained

Table 3-2. Description of major soil associations depicted in Exhibit 3 (continued).

Region and Map Unit Number	Depth[1]	Slope (%)	Texture (Topsoil/ Subsoil	Present Use/[2] Suitability	Other
87	(S)	0-75	Sandy to silty loam/ silty clay loam	Rangeland	Highly variable surface relief
88	(S-D)	2-10	Loam to silty clay/ silty clay loam	Rangeland	Shale and sand-stone rockland common
90	(S-MD)	2-10	Stony loam/stony loam	Rangeland	Volcanic soil; calcareous
91	(S-D)	2-10	Sandy loam/gravelly loam	Rangeland	Dissected steep areas
92	(S-MD)	2-10	Stony loam/cobbly clay	Rangeland	Volcanic origin Old lava flows
93	(MD-D)	2-10	Loam to sandy clay loam/loam to gravelly	Rangeland	Limy subsoil
94	(S)	0-5	Loam to clay loam/ loamy to clayey	Rangeland	Highly variable soil associa-tion
95	(D)	0-5	Sandy loam to clay loam throughout	Rangeland	Well drained
96	(S-D)	2-10	Loam to fine sandy loam/ sandy loam to clay	Rangeland	Variable topography
97	(S)	2-75	Stony loam/sandstone bedrock	Rangeland	Rough and broken topography
98	(MD-D)	1-20	Fine sandy loam to loam/loamy	Rangeland	High lime content 15 to 40 inches
99	(D)	0-5	Clayey/clayey	Rangeland	Calcareous and strongly alkaline
100	(D)	2-10	Gravelly loam/sandy clay loam	Rangeland	Valley fill parent material

Table 3-2. Description of major soil associations depicted in Exhibit 3 (continued).

Region and Map Unit Number	Depth[1]	Slope (%)	Texture (Topsoil/ Subsoil	Present Use/[2] Suitability	Other
101	(D)	2-75	Gravelly sandy loam/ gravelly clay loam	Rangeland	Variable topography
102	(S-D)	2-10	Loam to clay loam throughout	Rangeland	Limy between 15 and 40 in.
103	(MD-D)	2-25	Gravelly loam/ gravelly clay or loam	Rangeland	Rock outcrops common
104	(S-MD)	5-25	Stony to sandy loam/ gravelly clay loam	Limited rangeland	Rock outcrops common
105	(S-MD)	5-10	Stony, gravelly clay and loam	Rangeland	Rockland out-crops numerous
106		2-10	Lava rock	Limited use - sparse vegetation	Area of lava flows
MOUNTAIN					
107	(D)	10-25	Stony loam/stony clay	Forest, rangeland, recreation	Neutral to slightly acid
108	(MD-D)	10-25	Cobbly sandy loam/ sandy clay loam	Forest, recreation, rangeland	Mostly well drained
109	(S)	20-70	Thin organic layer/ gravel, stone	Forest, recreation, rangeland	Strongly acid
110	(S-MD)	25-75	Stony loam/cobbly loam	Forest, recreation, rangeland	Neutral to slightly acid
111	(S-D)	0-25	Stony clays and loams throughout	Forest, rangeland	Volcanic origin
114	(S-MD)	2-75	Sandy loam/sandy loam to clay	Forest, recreation, rangeland	Well drained, neutral to slightly acid

Table 3-2. Description of major soil associations depicted in Exhibit 3 (continued).

Region and Map Unit Number	Depth[1]	Slope (%)	Texture (Topsoil/ Subsoil	Present Use/[2] Suitability	Other
115	(D)	25-75	Cobbly clay loam/ clay	Rangeland, recreation	Steep rockland interspersed
116	(S-MD)	5-25	Clay loam to silty clay loam/clay	Rangeland	Shale parent material
117	(S)	75 plus	Rockland with some sandy loam to loam	Rangeland, forest	Rock outcrops dominate
118	(MD-D)	2-10 25-75	Loamy/clayey	Forest, rangeland, recreation	Includes extensive ridges and mesas
119	(S)	25-75	Loam/loam or clay loam	Forest, rangeland, recreation	Sandstone parent material
120	(S-MD)	0-25	Stony clay loam/ cobbly clay	Rangeland	Rockland common
121	(MD-D)	25-75	Stony loam to clay loam/clayey	Recreation, rangeland	Bedrock at 2 to 5 feet
122	(S-D)	2-10	Loam, clay loam/ loam, clay	Rangeland	Limy subsoil
123	(MD)	10-75	Cobbly clay loam throughout	Forest, rangeland, recreation	Mildly alkaline to slightly acid
124	(S)	2-25	Stony loam/limestone bedrock	Rangeland	Limestone parent material
125	(S-D)	2-75	Gravelly, stony loam/ gravelly, loam to clay	Rangeland	Neutral to slightly acid
126	(S)	2-75	Gravelly, loam to clay loam throughout	Recreation, rangeland	Extremely varied topography

Table 3-2. Description of major soil associations depicted in Exhibit 3 (concluded).

Footnotes:

[1] S = Shallow
D = Deep
MD = Moderately deep (e.g., S-MD is shallow to moderately deep)

[2] Agricultural refers to cropland. Forest includes timber, woodlands, and similar descriptions. Rangeland includes pasture, grazingland, grassland, and similar descriptions.

Source: Maker et al. 1978. Soils of New Mexico. Research Report 285. Agricultural Experiment Station, Las Cruces NM, 132 p.

Soils of the Study Area and their related physiographic classifications are shown in Exhibit 3. The six soil regions occurring in the Study Area are classified as follows: High Plains, Cool Desert, Warm Desert, East-Central Plains, Western Plateau, and Mountain. Each major region is divided into soil associations. The major regions correlate closely to physiographic regions described in Section 3.2. The High Plains and East-Central Plains soils are a part of the Great Plains Province, with some overlap with the Basin and Range Province. The Warm Desert soils and some Mountain soils occur in the Basin and Range Province of the Intermontane Plateaus, while the Cool Desert, Western Plateau, and much of the Mountain soils occur in the Colorado Plateau. The Southern Rocky Mountain Province is comprised of Mountain soils and Western Plateau soils.

3.3.1 High Plains

Soil associations of the High Plains occur in the southeast corner of Colfax County. Depths vary widely from shallow to deep, although the slope is fairly uniform ranging from 2 to 5 degrees. The soil basically consists of a sandy loam or loamy sand texture and is used primarily as rangeland. This region is generally outside of active coal development and will probably not be affected.

3.3.2 East-Central Plains

Soils of the East-Central Plains typically occur on gently undulating to rolling uplands interspersed with smooth valleys and basins. Isolated mountains, hills, mesas, and volcanic cinder cones are also present. Steeper areas occur along larger streams and around mesas and cones (Maker et al. 1978). Loamy to clay loam texture is characteristic, and a notable chemical feature of the soils of this type is the large quantity of calcareous material. Soils in steeper areas are for the most part stony. Rangeland represents the most substantial use, since the physical and chemical features discourage other uses.

Soils of this type in Socorro and Lincoln counties overlay developable coal. In areas with steeper slopes, soil erosion due to mining activities is a potential concern.

3.3.3 Warm Desert

Soils of this region occur on topography similar to that of the East-Central Plains except for the presence of several discontinuous mountain ranges trending from north to south. The texture of soil in this type varies, although typically a sandy loam predominates. Slopes range from 0 to 10% in more level areas, while the interspersed mountainous areas attain slopes as high as 75%. Soils of this type are typically calcareous and contain large amounts of gypsum. The above soil features, combined with the arid climate, limit the use to rangeland. In some areas the vegetation is too sparse for livestock production.

From an environmental viewpoint coal development must be concerned with the high wind and water erosion potential of these soils. Although, the only sizeable coal field is located southeast of Truth or Consequences in Sierra County.

3.3.4 Mountain

Mountain soils occur in the mountain and valley regions which dominate over a large section of the State. Mountain soils occur on the most rugged topography in the Study Area and have associated steep slopes of up to 75% over a majority of the area. The soils are similar texturally to mountain soils in the Warm Desert Region, except they tend to be somewhat coarser, with a high percent of stony, cobbly, and sandy loams. Many soils of this region have a tendency to be slightly acidic, a feature which sets them apart from the mostly basic soils of the rest of the Study Area. The shallow to deep soils of this region support all of the forest land in the Study Area. Additionally, soils of this region support some rangeland or are utilized for recreational purposes.

Some coal resource areas are located beneath these soils. Major environmental concerns include potential loss of forests and erosion of productive soils on unlevel areas.

3.3.5 Cool Desert

This region covers most of San Juan County. The general appearance is that of a moderately undulating plain of slopes less than 5%, although hogback ridges, canyons, and numerous small mesas account for some very steep slopes. Soil textures vary and range from loamy sand to silky clay loam topsoils. These soils are best suited for rangeland uses, although rich soils along the San Juan River support an important agroindustry.

The major environmental concern is the high potential for wind and water erosion on both level and unlevel surfaces. The risk is greatest in unvegetated areas. Because soils of this region are very productive, mining and especially reclamation will have to be carefully planned to mitigate losses.

3.3.6 Western Plateau

This region is noted for broad mesas and plateaus interspersed with numerous deep canyons. Solidified lava flows are a common feature. Soil texture ranges from stony loam to clay loam in the topsoil to a more clayey loam in the subsoil. Soil depths vary widely as do surface features. Rock outcrops, rough broken topography, or volcanic materials are common. A majority of the soils are on slopes of less than 10%, although steeper slopes occur in canyon areas. Much like the soil regions of the plains and desert, these soils are used primarily for rangeland.

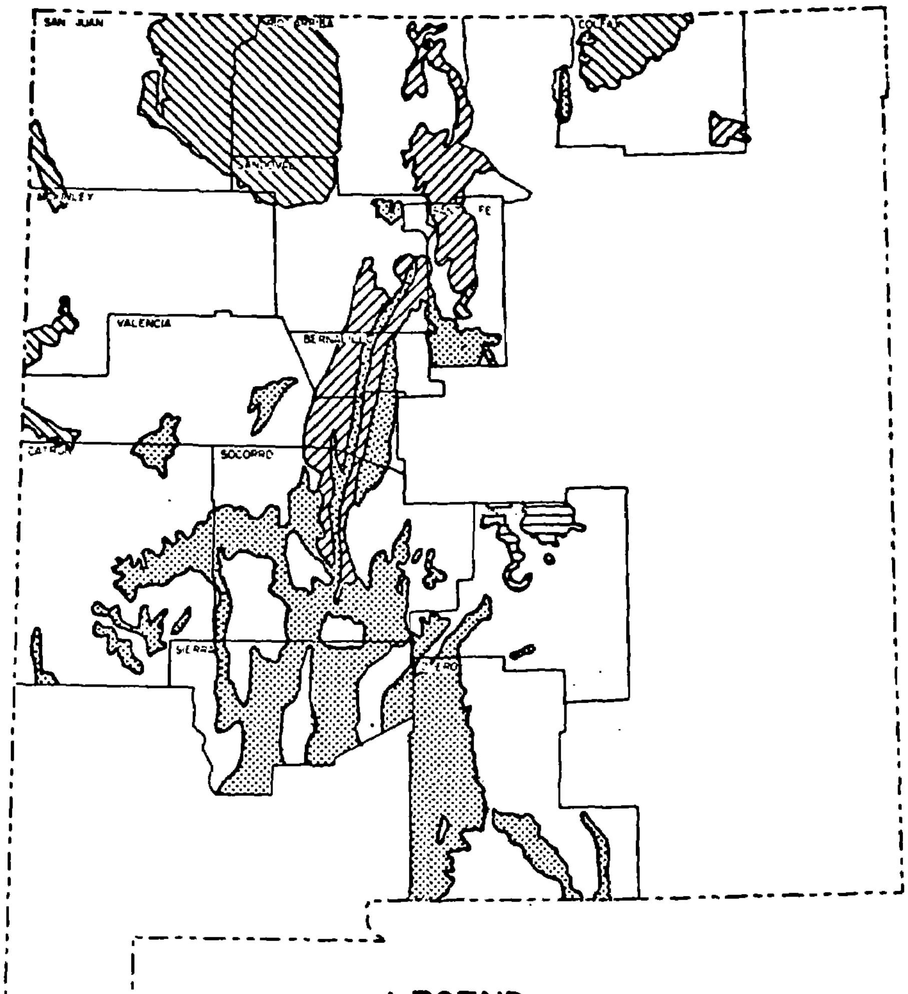
Some coal development has occurred and is planned in this region. Although soils are of minimal productivity, erosion associated with mining of steep slopes potentially will further reduce existing soil productivity.

3.4 NONMETALS

A wide variety of nonmetal resources occur in the Study Area (Exhibit 3). These include barite, flourspar, gem minerals, pegmatites, niobium and tantalum, salines, sulfur, clays, gypsum, anhydrite, lightweight aggregates, sand and gravel, and stone (Figure 3-2). Nonmetals that were or are presently mined and produced on a large scale include lightweight aggregates (mainly perlite), sand and gravel, and stone. Major mining areas exist in Rio Arriba County and Sierra County for perlite, and in Bernalillo and Valencia counties for sand and gravel, and stone. Potentially productive sand and gravel deposits lie above coal deposits in the San Juan Basin and in some localized parts of the Study Area. Mining for coal could potentially infringe on these deposits. The remaining nonmetals listed are also near the surface and should be of concern as coal development continues, although many are outside potential coal development areas and will not be disturbed directly by coal mining.

3.5 METALS

Deposits of many different metals occur in the Study Area. These include gold, silver, lead, zinc, copper, iron, manganese, beryllium, molybdenum, uranium, vanadium, selenium, tellurium, rare earths, tin, and tungsten. Principal commodities are uranium, molybdenum, copper, lead, zinc, silver, and gold. Major mining areas include McKinley and Valencia counties for uranium, Rio Arriba and Colfax counties for molybdenum, and Socorro and Sierra counties for copper, lead, zinc, silver, and gold. Uranium deposits occur almost entirely outside coal deposit boundaries and are generally deeper than coal deposits. However, small local areas could potentially have uranium overlying coal and would be of concern to coal development. Parts of Socorro and Sierra counties may have coal occurring near certain other metals, although most of the metal deposits lie away from coal deposit boundaries and will remain unaffected by coal development.



LEGEND

- Quaternary alluvium, bolson deposits, dune sand; includes Gila Conglomerate in southwestern part of State
- Middle and Late Tertiary deposits; includes Ogallala Formation in eastern part of State and Santa Fe Formation in north-central part
- Early Tertiary deposits, includes San Jose, Chuska, and Ojo Alamo Formations in western part of State; Raton and Galisteo Formations in eastern part
- Permian Glorieta Formation in central part of State has been suggested as source of silica sand

Figure 3-2. Sand and gravel deposits of New Mexico. (US Geological Survey et al. 1965)

3.6 PETROLEUM AND NATURAL GAS

Major petroleum and natural gas fields occur in the San Juan Basin in San Juan, Rio Arriba, McKinley, and Sandoval counties (Exhibit 3) in an area of major coal deposits. Although petroleum and natural gas deposits are much deeper than coal deposits, a concern does exist due to the potential conflict between petroleum or natural gas wells and coal mining. This conflict usually requires that coal mining activities be restricted to within a 100 feet (30 meters) radius of any oil or gas well.

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DIGITALLY

CHAPTER 4.0 SOCIOECONOMICS

4.0 SOCIOECONOMICS

Coal resource development involving large capital projects will affect the socioeconomic characteristics of both the locality and the region being developed. The area population is directly and indirectly affected by coal development, through changes in the existing environment and by the influx of new workers and their families. This assessment of the existing economic base and employment and income levels will focus on the key elements of the economy effected by coal development.

4.1 ECONOMICS

4.1.1 Introduction

This section describes the economic profile of the 13-county Study Area utilizing the major indicators which are affected by coal development--employment (labor), income, government revenue, and property values. The area economies will be stimulated by coal development leading to the expansion of existing economic activities. In addition, new economic ventures will be undertaken thereby diversifying the economic base and contributing to overall growth of the area economies. Existing economic conditions in the Study Area are summarized in Figure 4-1.

4.1.2 Employment

The discussion of employment is provided to describe the size, composition, and availability of the current labor force. Data relating civilian labor force, total employment, unemployment, and employment by sector are used to further describe employment.

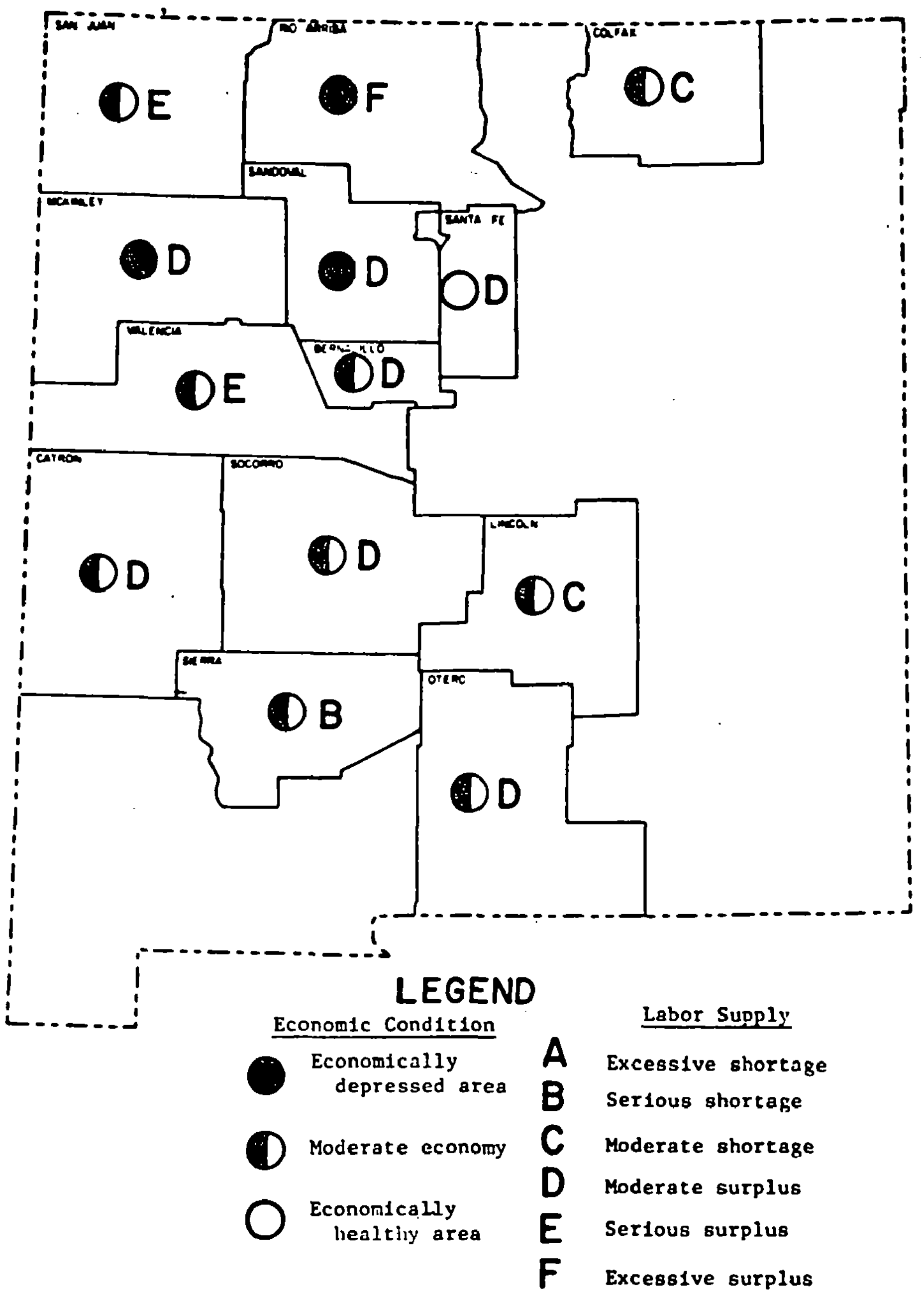


Figure 4-1. Economic indicators for 13 counties in New Mexico.

4.1.2.1 Civilian Labor Force

The civilian labor force represents a measure of the number of people 16 years of age and older available for work, excluding the military and institutional population. Labor force data, including the annual average of all people who are employed, unemployed, or involved in labor management disputes in 1980, are presented in Table 4-1. The labor force size varies directly with the population of the county and the demand for labor. Participation in the labor force increases with the demand for labor and new or additional development will increase the demand for certain types of labor.

4.1.2.2 Total Employment

Data for the number of persons actually employed, including full- and part-time employment and persons who are temporarily laid off, are presented in Table 4-1. The majority of the counties in the Study Area had a healthy increase in total employment between 1976 and 1980 (approximately 6%/year). Employment in 50% of the counties increased at a rate above the average overall increase for the State. A net decline in employment occurred only in Catron County between 1976 and 1980.

4.1.2.3 Unemployment

Unemployment data are shown in Table 4-1 and Figure 4-2. These data represent the number of people in the labor force who are not working, but who are available for work and are actively seeking employment. Unemployment data do not include workers who are underemployed or discouraged workers who have dropped out of the labor force.

The unemployment rates in the Study Area are relatively high, indicating an overall depressed economy. This trend is true for the entire State when compared to the rest of the US. Consistently high unemployment rates are an indication of structural unemployment problems, wherein there is a mismatch between the demand for labor and the type of skills available in the existing

Table 4-1. Labor force statistics for 13 counties in New Mexico (1976 and 1980).

	Civilian Labor Force 1980	Total Employment 1976	Total Employment 1980	% Change	Total Unemployment 1976	Total Unemployment 1980	Unemployment Rate 1976	Unemployment Rate 1980	Rank 1980 1 = Highest Unemployment	Labor Supply Classification
State	545,862	423,000	503,329	18.99	43,000	42,533	9.2	7.8	-	-
County										
Bernalillo[1]	205,977	154,981	188,653	24.66	16,804	17,324	9.8	8.4	5	D
Catron	994	962	930	- 3.32	128	64	9.8	6.4	8	D
Colfax	6,323	5,167	5,980	15.73	421	343	8.0	5.4	10	C
Lincoln	6,155	4,686	5,856	24.96	265	299	5.4	4.9	11	C
McKinley	18,906	15,359	17,254	12.33	1,272	1,652	7.6	8.7	4	D
Otero	12,875	10,885	11,913	9.44	1,098	1,926	9.2	7.5	6	D
Rio Arriba	9,985	7,830	8,283	5.78	2,456	1,702	23.9	17.0	1	F
Santoval[1]										
San Juan	34,288	23,225	31,200	34.33	2,654	3,088	10.3	9.0	3	E
Santa Fe	34,453	25,552	32,036	25.37	2,720	2,417	9.6	7.0	7	D
Sierra	2,693	2,500	2,617	4.68	178	76	6.6	2.8	12	B
Cocorro	4,287	3,232	4,017	24.28	288	270	8.2	6.3	9	D
Valencia	25,839	16,805	23,388	39.17	1,619	2,451	8.8	9.5	2	E

[1]Bernalillo and Santoval counties combined into Albuquerque SMSA.

Labor Supply Classification (D.O.L.) - to measure adequacy of labor supply.

Category	Description	Unemployment Rate
A	Excess labor shortage	Less than 1.5%
B	Serious labor shortage	1.5% - 2.9%
C	Moderate labor shortage	3.0% - 5.9%
D	Moderate labor surplus	6.0% - 8.9%
E	Serious labor surplus	9.0% - 11.9%
F	Excessive labor surplus	12% or more

Sources: New Mexico Employment Security Department. 1977. Table A - Civilian labor force, employment, unemployment and unemployment rate, 1976. Research and Statistics Section. Albuquerque NM, variously paged.

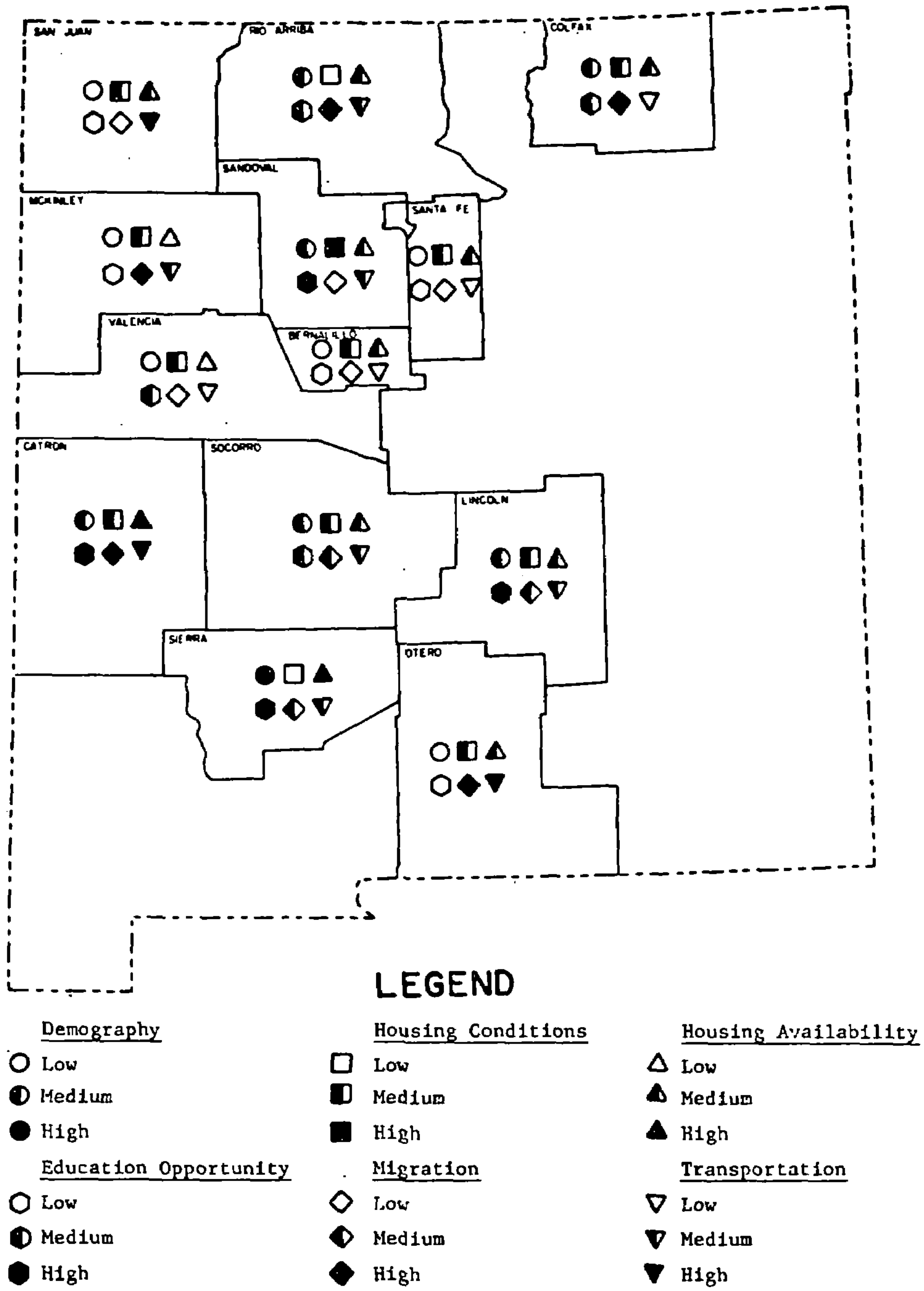


Figure 4-2. Existing social conditions for 13 counties in New Mexico.

Figure 4-2. Existing social conditions in 13 counties in New Mexico (concluded).

DEMOGRAPHY

Age Composition - Median Age	Value
Less than 30	3
30 - 40	2
Greater than 40	1

Education - Median Years Completed	Male	Female
12 or greater	1.5	1.5
10 - 11.9	1.0	1.0
Less than 10	0.5	0.5

Supplement Income Recipients	Value
Less than 20% of population	3
20% - 30% of population	2
Greater than 30% of population	1

If total value is:

Less than 5 - low demographic conditions
5 - 7 - medium demographic conditions
Greater than 7 - high demographic conditions

HOUSING CONDITIONS

Cost of Owner Housing	Value
Above State average	1
Below or equal to State average	2

Cost of Renter Housing	Value
Above State average	1
Below or equal to State average	2

Housing With Partial or No Plumbing	Value
Above State average	1
Below or equal to State average	2

Housing With 1.01 or More Persons/Room	Value
Above State average	1
Below or equal to State average	2

% Rent Housing	Value
Less than 20	1
20 - 40	2
Greater than 40	3

If total value is:

5 - 7 - low housing characteristics exists
8 - 9 - medium housing characteristics exists
10 - 11 - high housing characteristics exists

▲ HOUSING AVAILABILITY

% Population Change 1970 - 1980	Value
Less than 0	3
0 - 50	2
Greater than 50	1

% Housing Change 1970 - 1980	Value
Greater than 50	3
20 - 50	2
Less than 20	1

% Unoccupied Housing 1970	Value
Greater than 15	3
7.5 - 15	2
Less than 7.5	1

If 1980 population is:

Greater than 50,000 multiply subtotal by 2
10,000 - 50,000 multiply subtotal by 1.5
Less than 10,000 multiply subtotal by 1

If total value is:

Less than 8 - low housing availability
8 - 13 - medium housing availability
Greater than 13 - high housing availability

● EDUCATIONAL OPPORTUNITY

Public School Enrollment	Value
Less than 2,000	1
2,000 - 10,000	2
10,000 - 20,000	3
Greater than 20,000	4

Number of Colleges/Universities	Value
0 colleges/universities	0
1 college/university	1
2 or more colleges/universities	2

If total value is:

1 - 2 - low educational opportunity
3 - 4 - medium educational opportunity
5 - 6 - high educational opportunity

◆ MIGRATION

If in-migration between 1970 and 1980 is:

Less than 1,000 or out-migration occurs - low migration
1,000 - 10,000 - medium migration
Greater than 10,000 - high migration

▼ TRANSPORTATION DENSITY

Interstate Mileage Compared to Land Area	Value
Equal to or above State ratio	2
Below State ratio	1
None present	0

State Highway Mileage Compared to Land Area	Value
Equal to or above State ratio	2
Below State ratio	1

Railroad Mileage Compared to Land Area	Value
Equal to or above State ratio	2
Below State ratio	1
None present	0

If total value is:

1 - 2 - low transportation density
3 - 4 - medium transportation density
5 - 6 - high transportation density

labor force. A decline in unemployment between 1976 and 1980 occurred in all the counties in the Study Area with the exception of Valencia and McKinley, thereby beginning a reversal in the declining economic trend.

The Federal government designates certain areas as Labor Surplus Areas (unemployment rate at least 1.2 times the national unemployment rate for previous 2 years). These areas are eligible for bidding on Federal contracts in order to help guide a portion of the government's procurement dollars to these areas. San Juan and Rio Arriba counties qualified for eligibility in this category.

A ranking of unemployment by county is presented in Table 4-1. The lowest unemployment rate is indicated by a 1 (one). The labor supply classification developed by the US Department of Labor as a measure of the adequacy of the current labor supply in each county, is entered in the last column in Table 4-1.

The overall high unemployment and relatively low incomes found in the Study Area indicate a need for additional local jobs and income. Most forms of coal development will stimulate the economies of these areas. In addition, this unemployment trend indicates the existence of a reservoir of workers who would be available for seasonal and low-wage service jobs.

4.1.2.4 Employment by Sector

Information on employment by major industrial sector is given in Table 4-2. Government service including Federal, State, and local employees, is a significant source of employment for the Study Area, and accounts for 31% of the total employment. In New Mexico however, Government employment is 27% of the total State employment. Trade, including retail and wholesale trade, is a well developed economic activity that accounts for 20% and 22% of the total employment in the Study Area and State, respectively.

Table 4-2. Employment by industry for 13 New Mexico counties (1976 and 1980).

	State of New Mexico	Albuquerque Area[1]	Catron	Colfax	Lincoln
Total Employment 1980	462,300	193,200	452	4,501	3,396
Mining					
1976	21,500	N/A	-	-	-
1980	29,500	N/A	-	-	23
% County Labor Force 1980	6.38	-	-	-	0.67
Transp., Commun., and Public Utilities					
1976	23,400	8,600	12	244	150
1980	28,400	11,600	-	221	173
% County Labor Force 1980	6.14	6.00	-	4.91	5.09
Trade					
1976	90,400	40,300	38	865	729
1980	103,100	48,400	31	971	751
% County Labor Force 1980	22.30	25.05	6.85	21.57	22.11
Construction					
1976	26,100	10,300	-	157	306
1980	30,200	16,000	-	203	423
% County Labor Force 1980	6.53	8.28	-	4.51	12.45
Manufacturing					
1976	30,300	16,200	108	396	64
1980	34,300	17,600	95	387	107
% County Labor Force 1980	7.41	9.10	21.01	8.59	3.15
Finance, Insurance, and Real Estate					
1976	17,000	8,600	0	192	168
1980	21,000	11,500	-	207	291
% County Labor Force 1980	4.54	5.95	-	4.59	8.56
Service and Other					
1976	73,300	35,300	62	1,445	640
1980	91,300	45,200	61	1,474	644
% County Labor Force 1980	19.74	23.39	13.49	32.74	18.96
Government Service					
1976	108,000	36,400	314	919	856
1980	124,500	42,900	265	1,038	984
% County Labor Force 1980	26.93	22.20	58.62	23.06	28.97

Table 4-2. Employment by industry for 13 New Mexico counties (1976 and 1980)(continued).

	McKinley	Otero	Rio Arriba	San Juan	Sante Fe
Total Employment 1980	20,352	12,778	5,923	29,423	27,404
Mining					
1976	3,558	-	48	2,156	255
1980	5,238	-	21	3,941	354
% County Labor Force 1980	25.73	-	0.35	13.39	1.29
Transp., Commun., and Public Utilities					
1976	1,062	576	208	2,530	882
1980	958	602	279	3,541	931
% County Labor Force 1980	4.70	4.71	4.71	12.03	3.39
Trade					
1976	3,822	2,317	945	4,666	4,953
1980	3,937	2,816	962	5,565	5,739
% County Labor Force 1980	19.34	22.03	16.24	18.91	20.94
Construction					
1976	850	712	208	3,289	1,538
1980	481	545	433	4,554	1,772
% County Labor Force 1980	2.36	4.26	7.31	15.47	6.46
Manufacturing					
1976	1,222	1,258	386	925	1,000
1980	937	981	195	1,240	1,320
% County Labor Force 1980	4.60	7.67	3.29	4.21	4.81
Finance, Insurance, and Real Estate					
1976	328	398	184	667	1,082
1980	405	435	192	837	1,343
% County Labor Force 1980	1.98	3.40	3.24	2.84	4.90
Service and Other					
1976	2,084	2,383	1,173	4,159	5,457
1980	3,462	2,900	1,296	1,986	6,790
% County Labor Force 1980	17.01	22.69	21.88	16.94	24.77
Government Service					
1976	4,506	3,152	2,223	3,799	7,515
1980	4,934	4,499	2,545	4,759	9,155
% County Labor Force 1980	24.24	35.20	42.96	16.17	33.40

Table 4-2. Employment by industry for 13 New Mexico counties (1976 and 1980)(continued).

	Sierra	Socorro	Valencia
Total Employment 1980	1,589	3,664	13,958
Mining			
1976	69	-	1,895
1980	15	-	3,187
% County Labor Force 1980	0.94	-	22.83
Transp., Commun., and Public Utilities			
1976	92	95	907
1980	134	113	1,014
% County Labor Force 1980	8.43	3.08	7.26
Trade			
1976	379	572	2,064
1980	399	566	2,516
% County Labor Force 1980	25.11	15.44	18.02
Construction			
1976	68	127	525
1980	41	111	1,270
% County Labor Force 1980	2.58	3.02	9.09
Manufacturing			
1976	-	80	302
1980	-	54	294
% County Labor Force 1980	-	1.47	2.10
Finance, Insurance, and Real Estate			
1976	83	77	413
1980	77	104	460
% County Labor Force 1980	4.84	2.83	3.29
Service and Other			
1976	324	388	1,052
1980	284	723	1,811
% County Labor Force 1980	17.87	19.73	12.97
Government Service			
1976	592	1,548	2,483
1980	639	1,993	3,406
% County Labor Force 1980	40.21	54.39	24.40

[1]Albuquerque Area (SMSA) = Bernalillo and Santoval counties.

1976 data - annual average
1980 data - month of March
Agricultural wage employment not available
Dash (-) Disclosure - included in "Services and Other".

Table 4-2. Employment by industry for 13 New Mexico counties (1976 and 1980)(concluded).

Sources: New Mexico Employment Security Department. 1980a. Labor information series: nonagricultural wage and salary employment. Research and Statistics Section, Albuquerque NM, variously paged.

New Mexico Employment Security Department. 1980b. Nonagricultural wage and salary employment: Albuquerque area. Research and Statistics Section, Albuquerque NM, variously paged.

New Mexico Employment Security Department. 1980c. New Mexico labor market information review. Research and Statistics Section, Albuquerque NM, 11 p.

Manufacturing is a relatively undeveloped economic activity in both the Study Area and the State, accounting for 5% and 7% of total employment, respectively. The existing manufacturing activity is evenly distributed among the counties with only Sierra County having a total absence of this industry. The service sector accounts for 20% of total employment in both the Study Area and the State overall.

Mining was a significant activity in several counties (McKinley, San Juan and Valencia) and accounts for substantial employment. However, in 38% of the counties in the Study Area there was no mining activity. In the remaining counties, mining employment was minimal. It should be noted that in two of the three counties where mining was a significant economic activity, unemployment increase between 1976 and 1980, while the third qualified for bidding on Federal procurement grants due to high unemployment.

Construction activity and the finance, insurance, and real estate (F.I.R.E) sectors were all fairly evenly distributed across both the Study Area and the State. Construction accounts for 6% of total employment, while F.I.R.E. accounted for approximately 4% of the total employment.

4.1.3 Income

Income data are provided to assess the current standard of living. In general, the Study Area was characterized by low income, resulting from very low wages and a depressed economy. The low incomes were significantly less than the overall average income for the US. The following indicators are used to discuss income: per capita income; effective buying income; and average annual wages.

4.1.3.1 Per Capita Income (PCI)

Per capita income is measured by dividing the total personal income by the population to obtain a relative measure of the standard of living. Generally, the higher the PCI the more developed the economy. PCI data ranked by county from lowest to highest are presented in Table 4-3.

Table 4-3. Income statistics for 13 New Mexico counties.

	Per Capita Income $ 1978	Per Capita Income Ranking 1 = Lowest	Per Capita Income as % of US Average 1978	Median Household EBI[1] 1979	Average Annual Wages[2] $ 1977
State of New Mexico					
All Counties	6,599	NA	84	15,635	NA
Metro Counties	7,106	NA	91	16,189	NA
Non-metro Counties	6,249	NA	80	NA	NA
Counties					
Bernalillo	7,546	13	96	16,828	10,169
Catron	3,962	1	51	15,588	7,179
Colfax	6,385	10	81	13,577	8,632
Lincoln	5,647	7	72	12,643	6,714
McKinley	4,867	3	62	14,745	9,414
Otero	6,025	9	77	17,029	7,279
Rio Arriba	4,675	2	60	10,599	7,349
Santoval	5,206	5	66	10,048	6,811
San Juan	7,067	11	90	16,244	11,194
Santa Fe	7,247	12	92	15,836	8,167
Sierra	5,406	6	69	9,082	5,202
Socorro	4,986	4	64	12,784	6,756
Valencia	5,788	8	74	18,462	11,878

[1]EBI - Effective buying income is personal income less Federal, State and local taxes (equivalent to disposable income)

[2]Average annual wage is calculated by dividing total annual payroll by the number of employees.

Sources: US Department of Commerce. 1980. Survey of current business, Volume 60, No. 4. April 1980. Bureau of Economic Analysis, Washington DC, variously paged.

Sales and Marketing Management. 1980. Survey of buying power, July 28, 1980, variously paged.

US Department of Commerce. 1980. County business patterns 1977, United States. Bureau of the Census, Washington DC, variously paged.

The Study Area is characterized by low per capita incomes with no county having a PCI above the US average. The Study Area is typical of a depressed economy that has not diversified. Per capita incomes range from a low of $3,962 to a high of $7,546. Based on combined data on employment and PCI, the economy of the Study Area appears depressed and the standard of living low.

4.1.3.2 Effective Buying Income (EBI)

Effective buying income is the amount of personal income remaining after all Federal, State, and local taxes are paid. The median (or midpoint) EBI for households in each county in the Study Area is presented in Table 4-3. When PCI was low in a county median EBI was also low. The EBI range was wide among counties, from $9,082 to $18,462 per household. In 38% of the counties in the Study Area the EBI was higher than the average EBI ($15,635) for the State.

4.1.3.3 Average Annual Wages

Average annual wage data for 1977 are given in Table 4-3. These are computed by dividing total annual payroll by the average number of employees for that year. In general, where per capita income and median EBI was low, annual average wages were also low. Annual wages in the Study Area in 1977 ranged from $5,202 to $11,878.

4.2 SOCIAL

Social information describes people and the characteristics related to their environment. Coal and related developments require large work forces and often result in major changes in regional social (demographic) characteristics.

A large influx of people into underdeveloped or low populated areas can stress the capacity of local infrastructures, including: housing supply, public services, education services, and transportation. In addition, the introduction of people with ethnic, religious, and philosophic characteristics that are different than those of the original residents of the communities, can create social stresses. This section describes the existing demographic, housing, education, and transportation conditions for each county in the Study Area.

4.2.1 Demography

Demography is the statistical study of the human population. Demographic conditions examined in this section include population trends, projections, characteristics and settlement patterns.

4.2.1.1 Population Trends and Projections

The population in the Study Area increased moderately (less than 50%) for a majority of the counties (Table 4-4). The largest population increase, occurred in Sandoval and San Juan counties (98.9% and 53.9%, respectively). An increase in population occurred in all counties between 1970 and 1980.

Birth, death, and migration are the factors that determine population changes. Counties where the population experienced a natural increase and in-migration should continue to increase in population (Table 4-4). A population trend in counties with either a natural decrease and in-migration or a natural increase and out-migration cannot be predicted. A natural decrease in population or out-migration did not occur.

Population projections for 1990 (Table 4-4) were developed using the cohort-survival method. However, the 1990 projections were based on information that may not reflect changes that have occurred in the last 5 years.

4.2.1.2 Population Characteristics

Existing demographic conditions were described by combining data for age composition, education, and supplemental income recipients. (Figure 4-2).

Table 4-4. Population counts and projections for 13 counties in New Mexico.

	1970 Population	1980 Population	1970-1980 Change	% Change	Natural Increase or Decrease	Migration	1990 Population	1980-1990 Change	% Change
State	1,017,055	1,299,968	282,913	27.8	141,628	141,285	1,210,500	-89,468	-6.9
County									
Bernalillo*	315,774	419,700	103,926	32.9	40,126	63,800	411,300	-8,400	-2.0
Catron	2,198	2,720	522	23.7	172	350	1,300	-1,420	-52.2
Colfax	12,170	13,706	1,536	12.6	921	615	10,700	-3,006	-21.9
Lincoln	7,560	10,997	3,437	45.5	739	2,698	8,300	2,697	-24.5
McKinley	43,208	54,950	11,742	27.2	11,172	570	64,500	9,550	17.4
Otero	41,097	44,665	3,568	8.7	7,422	-3,854	50,600	5,935	13.3
Rio Arriba	25,170	29,282	4,112	16.3	4,140	-28	22,400	-6,882	-23.5
Sandoval*	17,492	34,799	17,307	98.9	3,212	14,095	28,800	-5,999	-17.2
San Juan	52,517	80,833	28,316	53.9	11,651	16,665	84,300	3,467	4.3
Santa Fe	54,774	75,306	20,532	37.5	6,930	13,602	67,500	-7,806	-10.4
Sierra	7,189	8,454	1,265	17.6	-532	1,797	9,400	946	11.2
Socorro	9,763	12,969	3,206	32.8	1,335	1,871	8,900	-4,069	-31.4
Valencia	40,756	60,853	20,097	50.0	6,537	13,560	59,500	-1,353	-2.2

*1980 Standard Metropolitan Statistical Area (SMSA) county

Sources: New Mexico Health and Environment Department 1981a; New Mexico Health and Environment Department 1981b; US Department of Commerce 1978a; US Department of Commerce 1981a; US Department of Commerce 1981b; US Department of Health, Education, and Welfare. 1970-1978. Volume 1 - Natality; US Department of Health Education, and Welfare. 1970-1978. Volume II - Mortality, part B; Wombold, Lynn 1979.

Age composition data provide an indication of the potential labor supply with respect to age. The median age in 9 of the 13 counties in the Study Area was under 30. The median age (50.6) was highest in Sierra County. A median age of between 30 and 40 was represented in other counties.

The median years of school completed indicates the level of educational achievement (Table 4-5). Depending on the types of skills required, education could restrict coal development. In Bernalillo, Lincoln, Otero, San Juan, and Santa Fe counties, over half the population 25 years and older graduated from high school.

Supplemental income recipients are people receiving aid either from the public assistance to families with dependent children program or the old age survivors, disability, and health insurance (OASDHI) program. Coal development and related activities in sparsely populated areas cause the cost of living to rise significantly. Consequently, counties with a high percent (30%) of people receiving supplemental income will be affected most by coal development and related activities (Table 4-5). Sierra County was the only county where more than 30% of the population receive supplemental income.

4.2.1.3 Settlement Patterns

Population density (number of people per square mile) and the percent of the population urban, rural non-farm, and farm are indicators of settlement and development data for counties where the urban population exceeds 50% and the population density is higher than the State population density are shown in Table 4-6 and Figure 4-3. The economy is considered more developed in counties where both of these qualities occur.

4.2.2 Housing Characteristics

A shortage of housing, especially in rural areas, is a major problem associated with coal development. Housing availability, renter/owner occupancy, and cost and quality are described in this section to characterize existing housing conditions in the Study Area.

Table 4-5. Population characteristics of 13 counties in New Mexico.

	Age Composition				Educational Achievement: Male - 25 Years and Over		Educational Achievement: Female - 25 Years and Over		Supplemental Income Recipients	
	% 0-17	% 18-49	% 50+	Median Age	Median Years Completed	% High School Graduates	Median Years Completed	% High School Graduated	1976 Recipients	% of 1975 • Population
State	32.5	45.5	22.0	27.5	12.2	55.6	12.1	54.9	212,211	18.6
County										
Bernalillo	30.3	48.8	20.9	28.0	12.6	67.4	12.4	65.1	61,834	17.1
Catron	26.3	38.8	34.9	35.3	10.5	39.7	11.4	46.7	503	21.5
Colfax	29.8	36.5	33.7	34.1	11.2	45.1	11.8	48.4	3,039	23.2
Lincoln	28.0	37.5	34.5	34.7	12.1	53.7	11.9	49.4	2,141	22.0
McKinley	42.1	42.6	15.3	22.5	10.3	40.4	9.9	39.1	9,340	18.3
Otero	66.0	51.2	14.8	25.0	12.5	68.1	12.3	61.8	5,202	12.2
Rio Arriba	37.4	40.9	21.7	25.4	9.8	36.6	9.6	33.8	7,011	25.1
Sandoval	38.2	40.1	21.7	24.8	9.9	37.8	10.7	41.4	4,926	21.8
San Juan	39.5	42.8	17.7	24.7	12.0	51.4	12.0	50.4	11,638	18.0
Santa Fe	31.3	44.9	23.8	28.8	12.4	59.9	12.3	61.0	11,509	18.4
Sierra	19.8	29.4	50.8	50.6	9.2	33.8	10.5	39.7	3,005	36.2
Socorro	32.7	44.9	22.4	25.6	11.3	46.6	10.8	43.8	2,297	23.2
Valencia	36.3	44.4	19.3	25.9	11.2	44.4	11.4	45.1	7,681	16.6

Sources: Sales and Marketing Management 1980; US Department of Commerce 1973; US Department of Commerce 1978a.

Table 4-6. Information on settlement patterns in 13 counties in New Mexico.

	Population Density (People/ Sq. Mile)	Urban Population %	Rural Non Farm Population %	Farm Population %
State	10.7	70.0	26.3	3.7
County				
Bernalillo	270.1	94.2	5.7	0.1
Catron	0.3	0	74.4	25.6
Colfax	3.6	59.5	35.3	5.2
Lincoln	2.3	0	95.0	5.0
McKinley	10.1	42.9	52.7	4.4
Otero	6.7	83.3	15.7	1.0
Rio Arriba	5.0	15.1	76.5	8.4

	Population Density (People/ Sq. Mile)	Urban Population %	Rural Non Farm Population %	Farm Population %
County				
Sandoval	9.4	0	96.1	3.9
San Juan	14.7	48.3	42.1	9.6
Santa Fe	39.6	77.5	21.9	0.6
Sierra	2.0	70.5	24.8	4.7
Socorro	2.0	48.6	47.5	3.9
Valencia	10.8	33.5	61.2	5.3

Note: Population density was determined by dividing the 1980 final census of population by the number of square miles in the State or county.

Sources: US Department of Commerce. 1978a. County and city data book, 1977. Bureau of Census, Washington DC, 956 p.

US Department of Commerce. 1981b. 1980 census of population and housing, advance reports - New mexico - final population and housing unit counts. Bureau of Census, Washington DC, 10 p.

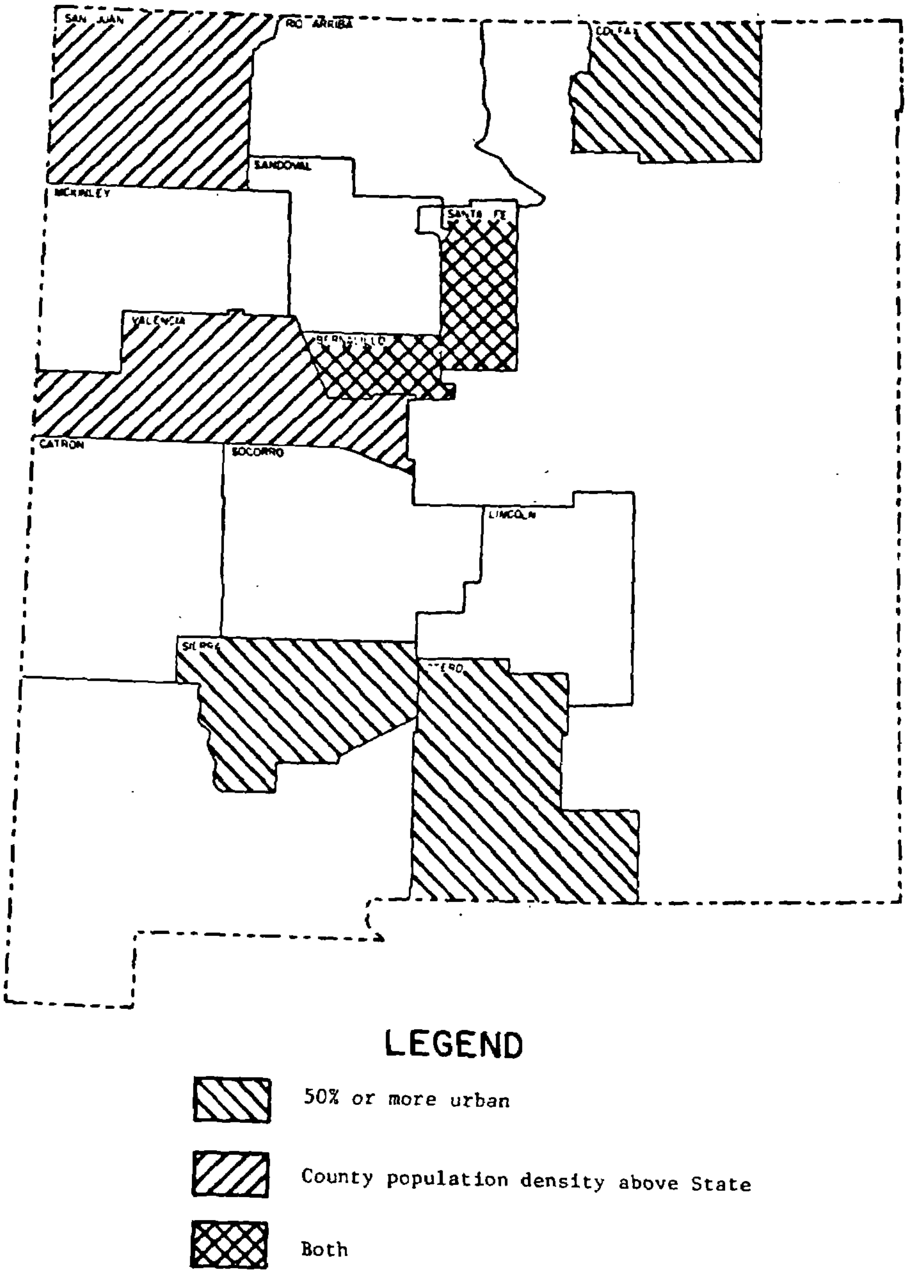


Figure 4-3. Settlement patterns for 13 counties in New Mexico.

Sources: US Department of Commerce 1978a; US Department of Commerce 1981b.

4.2.2.1 Availability of Housing

The availability of housing (Figure 4-2) was determined by considering housing and population changes between 1970 and 1980, unoccupied housing units in 1970, and the 1980 population. High housing availability occurred in McKinley and Valencia counties, while low housing availability occurred in Catron and Sierra counties.

4.2.2.2 Renter/Owner Occupancy

The short time period (2-5 years) associated with construction activities during coal development (i.e., power generating facility) necessitates that rent housing be available. McKinley County was the only county where renter housing in 1970 (Table 4-7) was over 40%.

4.2.2.3 Housing Cost and Quality

People associated with coal developments require adequate, affordable housing. High costs for housing and/or poor quality of housing are problematic to coal developments.

The median cost of housing for the county, compared to the median cost of housing for the State, was used to indicate housing costs. Bernalillo, Otero, and Santa Fe counties had housing costs equal to or above the State (Table 4-7).

The quality of housing was composed using data on housing units lacking some or all plumbing facilities and units with 1.01 or more persons per room. A higher percent of housing with 1.01 or more persons per room than the State average occurred in eight counties (Table 4-7). A higher percent of units lacking some or all plumbing facilities than the State average occurred in seven counties.

Table 4-7. Housing characteristics in 13 counties in New Mexico.

	1970 Housing Units	1970 Housing Units	1970–1980 Change	% Change	1970 Unoccupied Units (%)	1970 Occupied Percentage		Housing Quality Percentage (1970)		1970 County Median Housing Cost Compared to State	
						Owner	Renter	Lacking Some or All Plumbing Facilities	With 1.01 or More Persons Per Room	Owner %	Renter %
State	326,108	506,293	180,185	55.3	10.2	66.4	33.6	8.3	15.3	-	-
County											
Bernalillo	98,638	162,126	63,488	64.4	4.3	65.3	34.7	2.5	10.3	> 19.0	> 12.4
Catron	970	1,396	426	43.9	21.0	74.5	25.5	24.8	16.3	< 60.9	< 18.0
Colfax	4,804	6,923	2,119	44.1	20.7	70.3	31.7	6.4	15.6	< 36.6	< 19.1
Lincoln	4,950	9,739	4,789	96.7	33.4	73.6	26.4	8.4	12.7	< 24.0	< 5.6
McKinley	10,586	17,587	7,001	66.1	7.9	55.8	44.2	35.1	41.6	< 19.6	< 7.9
Otero	12,098	17,961	5,863	48.5	9.5	61.0	39.0	1.9	12.1	< 3.2	> 28.1
Rio Arriba	7,503	11,107	3,604	48.0	13.4	62.5	37.5	1.4	8.7	< 30.0	< 18.0
Sandoval	4,785	12,286	7,501	156.8	10.0	80.2	19.8	34.3	35.5	< 25.5	< 16.9
San Juan	14,960	29,552	14,592	97.5	10.0	67.9	32.1	17.2	27.0	< 1.1	< 10.1
Santa Fe	16,512	28,299	11,787	71.4	5.2	67.5	32.5	4.8	16.4	> 24.5	=
Sierra	3,743	5,392	1,649	44.1	22.5	66.9	33.1	7.8	10.9	< 40.7	< 31.5
Socorro	3,029	4,638	1,609	53.1	10.1	71.7	29.9	16.5	18.9	< 39.6	< 6.7
Valencia	11,563	22,252	10,689	92.4	9.0	73.3	26.7	17.1	25.3	< 15.2	< 9.0

Note: < Less than the State median

> Greater than the State median

Sources: US Department of Commerce. 1978a. County and city data book, 1977. Bureau of Census, Washington DC, 956 p.
US Department of Commerce. 1981b. 1980 census of population and housing, advance reports - New Mexico - final population and housing unit counts, Bureau of Census, Washington DC, 10 p.

4.2.3 Education

High numbers of school age children are often associated with the population influx that occurs with a coal development. Education was discussed using public school enrollment and number of higher education facilities to indicate the level and amount of educational services available.

4.2.3.1 Public Education

Larger school systems (systems with 10,000 plus students) can absorb increases in school enrollment more efficiently than smaller systems. Enrollment was more than 10,000 students in only six counties in the Study Area (Table 4-8). Therefore, large coal developments may strain the existing education systems in remaining counties.

4.2.3.2 Higher Education

Another indication of educational quality is the availability of higher education facilities. Only four counties did not have a college or university. Therefore, there was ample higher education opportunities in the Study Area.

4.2.4 Transportation

Existing transportation facilities are used extensively to mitigate costs incurred to move coal and materials used to extract coal. Existing highway, railroad, and commercial waterway systems are the main modes for transport of goods and services associated with coal development.

Table 4-8. Public school enrollment and number of colleges and universities in 13 counties in New Mexico.

	1975 Public School Enrollment	Number of Colleges and Universities
State	274,316	37
County		
Bernalillo	83,660	4
Catron	553	0
Colfax	3,055	1
Lincoln	2,130	0
McKinley	12,404	2
Otero	10,432	2
Rio Arriba	8,211	2
Sandoval	4,454	0
San Juan	16,204	2
Santa Fe	13,092	3
Sierra	1,484	0
Socorro	2,571	2
Valencia	12,014	1

Sources: Board of Educational Finance. No date. New Mexico post-secondary educational institutions and centers. Santa Fe NM, 1 sheet.

US Department of Commerce. 1978a. County and city data book, 1977. Bureau of Census, Washington DC, 956 p.

5.0 WATER RESOURCES

5.0 WATER RESOURCES

5.1 INTRODUCTION

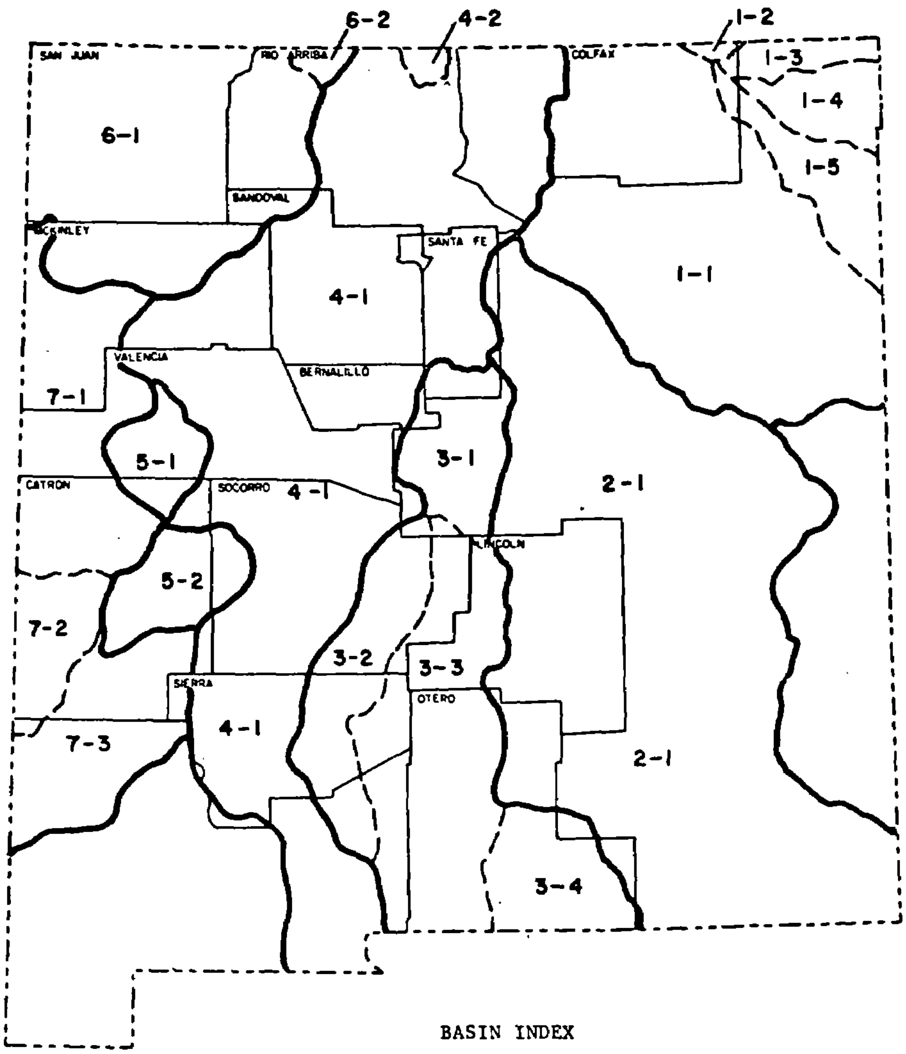
Adequate and reliable data on surface and groundwater quantity and quality are necessary as a basis for sound economic development. An inadequate water supply may limit the potential development of lignite/ coal resources. Industries using lignite as a fuel or a source for other products will use and consume water. In addition to needing adequate quantity, water must meet the requirements for quality. Water quantity and quality considerations cannot be evaluated unilaterally; they are closely related. The water supply becomes the used water to be returned as wastewater.

This chapter focuses on the existing quantity and quality of surface and groundwater in New Mexico where lignite/coal development is probable.

5.2 SURFACE WATER

The State is divided into 11 major river drainage basins--the San Juan, Upper Rio Grande, Middle Rio Grande, Lower Rio Grande, Lower Colorado, Western Closed, Central Closed, Pecos, Arkansas-White-Red, South Western Closed and Southern High Plain (Figure 5-1). The Study Area includes 9 of the 11 major basins, namely the Upper Rio Grande River, Middle Rio Grande River, Lower Rio Grande River, San Juan River, Lower Colorado River, Western Closed River, Central Closed River, Arkansas-White-Red River, and Pecos River.

This section addresses existing quantity and quality conditions. Continuously-recorded stream gauging stations, flow duration and low-flow magnitude and frequency are addressed, as well as total water usage by river basin (Exhibit 5a).



BASIN INDEX

Arkansas River Basin

1-1 Canadian River
1-2 Purgatoire River
1-3 Cimarron River
1-4 North Canadian River
1-5 Carrizo Creek

Pecos River Basin

2-1 Pecos River

Central Closed Basins

3-1 Estancia Basin
3-2 Jornada Del Muerto Basin
3-3 Tularosa Basin
3-4 Salt Basin

Rio Grande River Basin

4-1 Rio Grande River
4-2 Costilla Creek

Western Closed Basins

5-1 North Plains
5-2 San Augustin Plains

San Juan River Basin

6-1 San Juan River
6-2 Navajo River

Lower Colorado River Basin

7-1 Little Colorado River
7-2 San Francisco River
7-3 Gila River

Figure 5-1. Major drainage basins and segments in 13 counties in New Mexico (New Mexico State Engineer Office 1967).

Stream flow is important in design, construction, and operation of water related developments. Flow duration and low-flow magnitude and frequency are significant in addressing water supply characteristics of streams. Flow duration information is used to make preliminary estimates of water supply. Low-flow is used in estimating availability of water for dilution, transport of waste, and industrial cooling.

Water quality is accurately defined through the assessment of various biological, chemical, and physical parameters. Statistical data of selected water quality parameters along with the locations of significant dischargers are presented in Exhibit 5a.

To conform with other water management agencies (Federal and State) that define and collect surface water information, surface water quantity and quality data are presented by drainage basin. Each basin is further divided into smaller planning areas or "segments". Only segments located in the Study Area are discussed (Exhibit 5a).

5.2.1 Upper Rio Grande River Basin

The Upper Rio Grande River Basin is located in north central New Mexico, bordering Colorado to the north and extending below Cochiti Reservoir, near Bernallio to the south. The basin has a drainage area of 19,425 km^2 (7,500 mi^2). Principal tributaries are the Red River, Rio Taos River, Rio Hondo River, Embudo Creek, and Chana River (Exhibit 5a). Precipitation in the basin varies from 889 mm (35 inches) at upper elevations to about 152 mm (6 inches) in the south.

5.2.1.1 Quantity

All of the Upper Rio Grande River Basin is in the Study Area. The upper part of the basin is the major water-producing area in the Rio Grande River Basin. The drainage areas, discharges, and periods of record are presented in

Table 5-1. The percent of time daily discharges were equaled or exceeded for a given period of record is presented in Table 5-2. If a specified amount of water is needed for a given percent of time, the sites where stream flow is adequate to meet these requirements can be determined directly from Table 5-2. Annual low-flow frequency data for station's located in the Upper Rio Grande River Basin are presented in Table 5-3.

The average low-flow for 7 consecutive days that statistically will occur once during a recurrence interval is presented in Table 5-3. For example, during any given 10-year period, the average flow for 7 consecutive days at the gauging station on the Sante Fe River near Santa Fe will not exceed 0.1 m^3/sec (Table 5-3). Low-flow data are used to determine the dependable amount of water available for development. The application of data in Table 5-3 is illustrated by the following example. Assume a lignite-fired power plant has an average water demand of 50.0 m^3/sec. and could tolerate an insufficent supply of water for 7 consecutive days once every 10 years. The station on the Rio Grande River at Embudo (Station No. 2795) is the only station with adequate stream flow to meet this water demand. Data on the current and projected water withdrawals and depletions in the Upper Rio Grande River Basin are presented in Table 5-4.

5.2.2.1 Quality

Surface water quality in the Upper Rio Grande River Basin is generally good and suitable for most beneficial uses. The lower main streams of the Rio Grande River and Chama River are designated as marginal cold water fisheries; the remaining perennial water is designated as cold water or high quality cold water fisheries. Segments 7, 9, 10, 11, 12, 13, and 16 are classified as water quality limited by the New Mexico Water Quality Control Commission (Table 5-5).

Minimum levels (>5.0 mg/l) of dissolved oxygen (DO) are consistently recorded at key stations located along the Rio Grande River and its tributaries (Table 5-6). Levels of zinc, iron, copper, and manganese are within the recom-

Table 5-1. Drainage areas and discharges for continuous-record gauging stations in the Upper Rio Grande River Basin, New Mexico.

Number	Station Name	County	Period of Record (Water Years)	Drainage Area (km^2)	Minimum Discharge (m^3/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
2841	Rio Chama near La Puente	Rio Arriba	1955-1979	1,200.0	0.11	8.81	317.00
28416	Azotea Tunnel at outlet near Charma	Rio Arriba	1970-1979	NA	no flow	3.63	31.20
2842	Willow Creek above Heron Reservoir near Los Ojas	Rio Arriba	1962-1979	290.0	no flow	3.94	45.30
2843	Horse Lake Creek above Heron Reservoir near Las Ojas	Rio Arriba	1962-1979	120.0	no flow	0.03	112.00
2845	Willow Creek below Heron Dam	Rio Arriba	1971-1979	500.0	no flow	2.74	62.90
2855	Rio Chama below El Vado Dam	Rio Arriba	1913-1979	2,271.0	no flow	10.39	255.00
2865	Rio Chama above Abiquiu Reservoir	Rio Arriba	1961-1979	4,144.0	0.21	10.45	185.00
2870	Rio Chama below Abiquiu Dam	Rio Arriba	1961-1979	5,561.0	0.01	11.47	84.70
2890	Rio Ojo Calente at La Madera	Rio Arriba	1932-1979	1,085.0	0.01	1.88	88.90
2910	Santa Cruz River at Cundiyo	Santa Fe	1930-1979	220.0	0.01	0.82	68.50
2943	Rio Nambe at Nambe Falls	Santa Fe	1963-1979	88.6	0.01	0.30	30.90
3126	Pojoaque River at at San Ildefonso Pueblo	Santa Fe	1972-1979	477.0	no flow	-	173.00

Table 5-1. Drainage areas and discharges for continuous-record gauging station in the Upper Rio Grande River Basin, New Mexico (concluded).

Number	Station Name	County	Period of Record (Water Years)	Drainage Area (km^2)	Minimum Discharge (m^3/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
3130	Rio Grande at Otowi Bridge near San Ildefonso McClure Reservoir	Santa Fe	1895-1905 1909-1979	37,040.0	1.70	ND	692.00
3160	Santa Fe River near Santa Fe	Santa Fe	1913-1979	47.1	0.002	0.23	42.50
3172	Santa Fe River above Cochita Lake	Santa Fe	1970-1979	598.0	no flow	0.25	323.00
31795	Galisteo Creek below Galisteo Dam	Santa Fe	1970-1979	1,546.0	no flow	0.19	56.60
3174	Rio Grande below Cochita Dam	Santa Fe	1970-1979	38,590.0	0.014	ND	292.00

ND - Not determined
(-) - No flow most of the time

Source: USGS. 1979. Water Resources Data for New Mexico. Albuquerque NM, 747 p.

Table 5-2. Duration of daily flow (m^3/sec.) from gauging stations on streams in the Upper Rio Grande River.

Station Number	Station Name	County	Area (km^2)	Flow in m^3/sec, Equaled or Exceeded for Percent of Time Indicated					Period of Record
				99	50	25	10	1	
3160	Sante Fe River near Santa Fe	Santa Fe	47	0.01	0.11	0.23	0.49	1.88	1914-1978
2795	Rio Grande at Embudo	Rio Arriba	26,940	5.13	14.62	22.12	49.64	165.20	1900-1978
2865	Rio Chama Above Abiqui Reservoir	Rio Arriba	260	0.59	3.47	13.52	28.63	72.80	1962-1978
2870	Rio Chama Below Abiquiu Dam	Rio Arriba	5,561	0.64	4.18	15.78	29.98	56.00	1963-1978
2890	Rio ojo caliente a la Madera	Rio Arriba	8,143	0.07	0.47	0.93	4.17	25.20	1933-1978
2841	Rio Chama near La Puente	Rio Arriba	1,200	0.22	1.96	5.76	23.67	86.49	1956-1978
28416	Azotea Tunnel at Outlet near Chama	Rio Arriba	N/A	0.00	0.29	3.47	13.44	N/A	1971-1979
2842	Willow Creek above Heron Reservoir near Los Ojos	Rio Arriba	290	0.00	0.08	1.18	7.10	N/A	1964-1979
2843	Horse Lake Creek above Heron Reservoir near Los Ojos	Rio Arriba	120	N/A	N/A	0.00	0.03	0.78	1963-1973
2855	Rio Chama below El Vado Dam	Rio Arriba	2,271	0.02	2.61	14.75	31.20	70.93	1937-1977
3172	Sante Fe River above Cochiti Lake	Santa Fe	598	0.02	0.18	0.24	0.33	1.57	1971-1978

Table 5-2. Duration of daily flow (m^3/sec.) from gauging stations on streams in the Upper Rio Grande River (concluded).

Station Number	Station Name	County	Area (km^2)	Flow in m^3/sec, Equaled or Exceeded for Percent of Time Indicated: 99	50	25	10	1	Period of Record
3174	Rio Grande below Cochiti Dam	Sandoval	38,590	1.44	19.29	29.52	51.10	145.82	1971-1978
31795	Galisteo Creek below Galisteo Dam	Santa Fe	1,546	N/A	0.01	0.04	0.19	4.41	1971-1978
2811	Rio Grande above San Juan Pueblo	Rio Arriba	27,320	4.08	14.0	22.88	33.08	92.40	1964-1978
2900	Rio Chama near Chamita	Rio Arriba	8,143	0.05	4.89	18.07	38.51	113.40	1913-1978
2910	Santa Cruz River near Cundiyo	Santa Fe	220	0.11	0.39	0.84	1.86	6.16	1933-1978
2943	Rio Nambe at Nambe Falls, near Nambe	Santa Fe	89	0.03	0.18	0.33	0.58	1.79	1964-1978
3130	Otowi Bridge	Santa Fe	37,040	4.68	21.95	40.56	92.40	292.00	1901-1978

N/A - Not available

Source: US Geological Survey. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas TX.

Table 5-3. Seven day low flow for various recurrence intervals in streams in the Upper Rio Grande River Basin, New Mexico.

Station Number	Station Name	County	Area (km^2)	Annual Low Flow in m^3/sec. for 7 Consecutive Days for Indicated Recurrence Interval in Years: 1	2	5	10	20	Period of Record
3160	Sante Fe River near Santa Fe	Santa Fe	47	0.95	0.290	0.15	0.100	0.069	1914-1978
2795	Rio Grande at Embudo	Rio Arriba	26,940	168.12	72.210	56.84	50.810	46.620	1901-1978
2865	Rio Chama above Abiqui Dam	Rio Arriba	260	28.40	7.740	5.01	4.030	3.370	1963-1978
2870	Rio Chama below Abiquiu Dam	Rio Arriba	5,561	23.87	7.730	5.59	4.790	4.250	1963-1978
2890	Rio ojo caliente a la Madera	Rio Arriba	8.143	2.43	1.010	0.68	0.540	0.440	1933-1978
2841	Rio Chama near La Puente	Rio Arriba	1,200	27.89	5.530	2.97	2.130	1.610	1956-1978
2842	Willow Creek above Heron Reservoir near Los Ojos	Rio Arriba	290	0.16	0.038	0.13	0.006	0.003	1964-1979
2855	Rio Chama below El Vado Dam	Rio Arriba	2,271	34.01	1.790	0.49	0.240	0.130	1937-1977
2811	Rio Grande above San Juan Pueblo	Rio Arriba	27,320	220.30	61.450	42.03	35.040	3.390	1964-1978
2900	Rio Chama near Chamita	Rio Arriba	8,143	30.47	4.670	1.13	0.440	0.180	1914-1978
2910	Santa Cruz River near Cundiyo	Santa Fe	220	3.10	1.870	1.41	1.190	0.102	1933-1978
2943	Rio Nambe at Nambe Falls, near Nambe	Santa Fe	89	1.29	0.610	0.43	0.290	0.200	1964-1978

Table 5-3. Seven day low flow for various recurrence intervals in streams in the Upper Rio Grande River Basin, New Mexico (concluded).

Station Number	Station Name	County	Area (km^2)	Annual Low Flow in m^3/sec. for 7 Consecutive Days for Indicated Recurrence Interval in Years					Period of Record
				1	2	5	10	20	
3130	Otowi Bridge	Santa Fe	37,040	246.52	87.600	54.23	41.210	32.430	1901-1978

Source: US Geological Survey. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas TX.

Table 5-4. Current and projected water withdrawals and depletions (thousands of acre feet) in the Upper Rio Grande River Basin, New Mexico.

Use	1970 Wd.	1970 Depl.	1980 Wd.	1980 Depl.	1990 Wd.	1990 Depl.	2020 Wd.	2020 Depl.
Urban	11.6	5.2	11.5	7.9	21.8	13.0	28.7	19.9
Rural	3.2	1.4	3.6	2.3	5.5	4.1	8.3	6.2
Manufacturing	.4	.3	.7	.3	1.1	.6	1.7	1.0
Minerals	6.4	1.1	12.7	6.1	23.3	13.0	48.1	30.5
Fish and Wildlife	5.7	5.7	11.5	11.5	15.6	15.6	17.8	17.8
Recreation	.2	.1	.4	.2	.9	.6	.9	.5
Indian Irrigation	52.2	26.1	60.2	29.7	58.1	29.4	56.0	29.1
Non-Indian Irrigation	206.5	102.7	216.8	109.5	210.8	108.0	199.3	106.9
Livestock	1.0	1.0	1.2	1.2	1.2	1.2	1.3	1.3
TOTALS	287.2	143.6	322.6	168.7	338.3	185.5	362.1	213.2

Source: Water Quality Control Commission. 1979. New Mexico statewide water quality management plan, appendix. Santa Fe NM, variously paged.

Table 5-5. Water quality inventory summary for the Upper Rio Grande River Basin, New Mexico.

Segment No.	Location	Classification EL/WQL	Designated Uses	Known Water Quality Problems
7	The main stem of the Rio Grande from Angostura Diversion Works upstream to Cochiti Dam	WQL	Irrigation; livestock and wildlife watering; secondary contact recreation; cold water fishery	Poor wastewater treatment causes DO depletion bacteria and suspended solid
8	Cochiti Reservoir	EL	Irrigation, livestock and wildlife watering; warm water fishery; cold water fishery; secondary contact recreation	
9	The main stem of the Rio Grande from the headwaters of Cochiti Reservoir upstream to Taos Junction Bridge including the main stem of Embudo Creek from its confluence with the Rio Grande upstream to Dixon and the Santa Fe River upsteam to Siler Rd.	WQL	Irrigation; livestock and wildlife watering; marginal cold water fishery; secondary contact recreation; warm water fishery	Municipal wastewater and low flow cause algal booms
10	El Rito Creek above the Town of El Rito and Vallecitos Creek above Ojo Caliente Creek and all tributaries	WQL	Domestic water supply; irrigation high quality cold water fishery; livestock and wildlife watering; secondary contact recreation	Municipal wastewater and low flow cause DO depletion and bacteria
11, 12, 13	The Rio Chama from its confluence with the Rio Grande upstream to El Vado and any flow below the perennial reaches of El Rito Creek and Rio Ojo Caliente which enters the main stem of the Rio Chama	WQL	Irrigation; livestock and wildlife watering; marginal cold water fishery; secondary contact recreation; warmwater fishery; domestic water supply; high quality coldwater fishery	Municipal wastewater causes bacteria

Table 5-5. Water quality inventory summary for the Upper Rio Grande River Basin, New Mexico (continued).

Segment No.	Location	Classification EL/WQL	Designated Uses	Known Water Quality Problems
14, 15	All perennial reaches of tributaries to the Rio Chama above Abiquiu Reservoir and the main stem of the Rio Chama from El Vado upstream to the New Mexico-Colo. line, including El Vado Reservoir	EL	Water fishery; irrigation; livestock and wildlife watering; secondary contact recreation; irrigation storage; primary contact recreation; warmwater fishery	No signigicant problems
16	All perennial reaches of tributaries to the Rio Grande in Santa Fe County except the Santa Fe River below Siler Rd.	WQL	Domestic water supply; high quality cold water fishery; irrigation; livestock and wildlife water; municipal and industrial water supply; secondary contact recreation; fish culture	NA
17	The main stem of the Rio Grande from Taos Junction Bridge upstream to the Colorado-New Mexico line and the Red River from its confluence with the Rio Grande upstream to a point 1½ miles above the bridge at the Red River Fish Hatchery	EL	Cold water fishery; livestock and wildlife watering; irrigation storage; primary contact recreation	No significant problems
18	The Red River from a point 1½ miles above the bridge at the Red River Fish Hatchery upstream to its headwaters including all tributaries thereto and all other perennial reaches	EL	Domestic water supply; fish culture; high quality cold water fishery; irrigation; livestock and wildlife watering	No significant problems

Table 5-5. Water quality inventory summary for the Upper Rio Grande River Basin, New Mexico (concluded).

Segment No.	Location	Classification EL/WQL	Designated Uses	Known Water Quality Problems
(continued)	(continued) of tributaries to the Rio Grande in Taos County, including Embudo Creek above Dixon	(continued)	(continued)	(continued)

NA - Information not available

WQL - Water Quality Limited - A segment where water quality does not meet applicable water quality standards, and is not expected to meet standards after the application of the effluent limitations required by Section 301 (b) (1) (B) of the 1972 Federal Water Pollution Control Act Amendments.

EL - Effluent Limited - A segment where water quality is meeting and will continue to meet applicable water quality standards or where there is an adequate demonstration that water quality will meet applicable water quality standards after the application of the effluent limitations required by Section 201 (b) (1) (A) and 301 (b) (1) (B) of the 1972 Federal Water Pollution Control Act Amendments.

Source: New Mexico Water Quality Commission. 1980. Water Quality Status Summary. Santa Fe, NM. Variously paged.

Table 5-6. Water quality statistical summary for stations located in Upper Rio Grande River Basin, NM.

Parameters	Sta. No: 3172 Location: Santa Fe R. County: Santa Fe Segment:			Sta. No. 3174 Location: Rio Grande R. County: Sandoval Segment:		
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	12.25	1.50	26.00	12.14	5.00	21.00
Turbidity (JTU)	-	-	-	-	-	-
Dissolved oxygen (Mg/L)	9.20	7.90	11.40	8.29	8.29	8.29
BOD 5 Day (Mg/L)	-	-	-	-	-	-
pH (SU)	7.84	6.90	8.20	8.29	8.29	8.29
Total Alkalinity $CaCO_3$ (Mg/L)	206.00	83.00	281.00	-	-	-
Total Residue (Mg/L)	0.73	0.73	0.73	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-	201.33	16.00	720.00
Total Phosphorus P (Mg/L)	-	-	-	-	-	-
Dissolved Phosphorus P (Mg/L)	-	-	-	-	-	-
Total Hardness $CaCO_3$ (Mg/L)	156.33	79.00	200.00	-	-	-
Dissolved Calcium Ca (Mg/L)	49.00	25.00	62.00	-	-	-
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	8.10	3.90	11.00	-	-	-
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	22.33	11.00	29.00	-	-	-
Total Iron Fe (ug/L)	-	-	-	-	-	-
Dissolved Iron Fe (ug/L)	43.33	30.00	60.00	-	-	-
Dissolved Lead Pb (ug/L)	1.00	1.00	1.00	-	-	-
Total Lead Pb (ug/L)	100.00	100.00	100.00	-	-	-
Manganese Mn (ug/L)	-	-	-	-	-	-
Dissolved Manganese Mn (ug/L)	155.00	150.00	160.00	-	-	-
Dissolved Nickel Ni (ug/L)	-	-	-	-	-	-
Total Nickel Ni (ug/L)	-	-	-	-	-	-
Dissolved Silver Ag (ug/L)	0.00	0.00	0.00	-	-	-
Total Silver Ag (ug/L)	-	-	-	-	-	-
Dissolved Zinc Zn (ug/L)	25.00	20.00	30.00	-	-	-
Total Zinc Zn (ug/L)	-	-	-	-	-	-
Dissolved Selenium Se (ug/L)	0.00	0.00	0.00	-	-	-
Total Selenium Se (ug/L)	-	-	-	-	-	-
Total Ammonia NH_4 (Mg/L)	4.00	4.00	4.00	-	-	-
Dissolved Ammonia NH_4 (Mg/L)	-	-	-	-	-	-
Total Coliform /100 ml	-	-	-	-	-	-

Table 5-6. Water quality statistical summary for stations located in Upper Rio Grande River Basin, NM. (continued).

Parameters	Sta. No: 2795 Location: Rio Grande County: Rio Arriba Segment:			Sta. No. 2865 Location: Rio Chama County: Rio Arriba Segment:		
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	5.57	1.00	16.00	8.81	0.00	25.60
Turbidity (JTU)	-	-	-	-	-	-
Dissolved oxygen (Mg/L)	10.27	8.30	12.00	10.11	8.30	11.40
BOD 5 Day (Mg/L)	1.11	0.40	2.70	0.86	0.60	1.40
pH (SU)	7.82	7.60	8.10	-	-	-
Total Alkalinity $CaCO_3$ (Mg/L)	-	-	-	-	-	-
Total Residue (Mg/L)	-	-	-	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-	-	-	-
Total Phosphorus P (Mg/L)	-	-	-	-	-	-
Dissolved Phosphorus P (Mg/L)	-	-	-	-	-	-
Total Hardness $CaCO_3$ (Mg/L)	115.50	104.00	128.00	-	-	-
Dissolved Calcium Ca (Mg/L)	-	-	-	-	-	-
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	-	-	-	-	-	-
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	6.35	4.90	7.00	-	-	-
Total Iron Fe (ug/L)	-	-	-	-	-	-
Dissolved Iron Fe (ug/L)	-	-	-	-	-	-
Dissolved Lead Pb (ug/L)	-	-	-	-	-	-
Total Lead Pb (ug/L)	-	-	-	-	-	-
Manganese Mn (ug/L)	-	-	-	-	-	-
Dissolved Manganese Mn (ug/L)	-	-	-	-	-	-
Dissolved Nickel Ni (ug/L)	-	-	-	-	-	-
Total Nickel Ni (ug/L)	-	-	-	-	-	-
Dissolved Silver Ag (ug/L)	-	-	-	-	-	-
Total Silver Ag (ug/L)	-	-	-	-	-	-
Dissolved Zinc Zn (ug/L)	-	-	-	-	-	-
Total Zinc Zn (ug/L)	-	-	-	-	-	-
Dissolved Selenium Se (ug/L)	-	-	-	-	-	-
Total Selenium Se (ug/L)	-	-	-	-	-	-
Total Ammonia NH_4 (Mg/L)	-	-	-	-	-	-
Dissolved Ammonia NH_4 (Mg/L)	-	-	-	-	-	-
Total Coliform /100 ml	108.40	1.00	200.00	244.80	30.00	540.00

Table 5-6. Water quality statistical summary for stations located in Upper Rio Grande River Basin, NM. (concluded).

Parameters	Sta. No: 2900 Location: Rio Chama County: Rio Arriba Segment:			Sta. No. 3130 Location: Rio Grande County: Santa Fe Segment:		
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	11.97	0.00	37.19	13.39	0.00	38.88
Turbidity (JTU)	82.63	0.00	380.00	72.58	7.00	1300.00
Dissolved oxygen (Mg/L)	10.11	8.20	11.4	9.64	6.50	29.00
BOD 5 Day (Mg/L)	1.37	0.50	2.60	1.65	0.60	4.90
pH (SU)	7.63	6.90	8.50	7.93	6.60	8.90
Total Alkalinity $CaCO_3$ (Mg/L)	127.66	63.00	222.00	111.55	45.00	202.00
Total Residue (Mg/L)	-	-	-	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-	214.00	11.00	3440.00
Total Phosphorus P (Mg/L)	-	-	-	0.19	0.01	4.00
Dissolved Phosphorus P (Mg/L)	-	-	-	0.05	0.00	0.61
Total Hardness $CaCO_3$ (Mg/L)	196.06	72.00	391.00	148.19	67.00	702.00
Dissolved Calcium Ca (Mg/L)	58.57	24.00	130.00	46.72	9.80	258.00
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	11.26	2.40	27.00	7.55	2.20	23.00
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	9.94	1.26	35.00	7.00	0.00	44.00
Total Iron Fe (ug/L)	-	-	-	4856.00	400.00	51,000.00
Dissolved Iron Fe (ug/L)	36.62	$4.99x10^5$	180.00	56.75	0.00	889.99
Dissolved Lead Pb (ug/L)	4.49	3.00	5.99	5.08	0.00	80.00
Total Lead Pb (ug/L)	47.62	4.00	200.00	61.43	3.00	100.00
Manganese Mn (ug/L)	-	-	-	228.21	40.00	1040.00
Dissolved Manganese Mn (ug/L)	5.33	0.99	15.00	14.24	0.00	120.00
Dissolved Nickel Ni (ug/L)	6.16	2.00	22.00	1.50	0.00	9.00
Total Nickel Ni (ug/L)	-	-	-	5.83	3.00	9.00
Dissolved Silver Ag (ug/L)	0.72	0.00	2.00	0.08	0.00	1.00
Total Silver Ag (ug/L)	-	-	-	0.06	0.00	1.00
Dissolved Zinc Zn (ug/L)	225.67	3.00	579.99	7.21	0.00	20.00
Total Zinc Zn (ug/L)	-	-	-	45.11	8.00	210.00
Dissolved Selenium Se (ug/L)	2.59	0.00	10.00	0.73	0.00	13.00
Total Selenium Se (ug/L)	-	-	-	0.29	0.00	1.00
Total Ammonia NH_4 (Mg/L)	-	-	-	-	-	-
Dissolved Ammonia NH_4 (Mg/L)	-	-	-	-	-	-
Total Coliform /100 ml	41.42	50.00	20,000.00	3290.47	42.00	32,000.00

Source: USGS. 1981. WATer Data STOrage and REtrieval (WATSTORE). Dallas, Texas.

mended standards (Table 5-7). According to the data available to the New Mexico Water Quality Control Commission there is some indication that phosphorus and nitrogen levels increase in the lower reaches. Mean total phosphorus measured at Lobatus, Colorado was 0.124 mg/l and mean total nitrogen was 0.488 mg/l at Otowi Bridge. Average chloride and sulfate concentrations were generally low throughout the Upper Rio Grande River Basin.

Sources of surface water pollution include municipal dischargers (Sante Fe treatment plants, Espanola sewage treatment plant, and Taos sewage treatment plant) and industrial dischargers (Exhibit 5a). There is only one industrial discharger of significance in the basin, Molycorp, Inc. (not in Study Area). Non-point sources of potential problem include run-off from winter pastures adjoining cold water fisheries and sediment loads resulting from poor range and timber mamagement.

5.2.2 Middle Rio Grande River Basin

The Middle Rio Grande River Basin is located in the central part of New Mexico and contains over 30,769 km^2 (11,880 mi^2). The principal tributaries are the Jemez River, Rio Puerco River, Rio San Jose River, and Rio Saldo River.

5.2.2.1 Quantity

The current and projected water withdrawal and depletion in the Middle Rio Grande River Basin are presented in Table 5-8. Data for the drainage areas, discharges, flow duration and 7 day low-flows are presented in Table 5-9 through Table 5-11.

5.2.2.2 Quality

The Middle Rio Grande River has historically been severely limited in recreational and fisheries potential due to an extremely wide variation in flow. The fecal coliform standard is the only water quality standard which fre-

Table 5-7. Water quality standards and recommended water quality limits.

Water Quality Parameter	New Mexico Standard	EPA Quality Criteria for Domestic Water*	National Academy of Science and National Academy of Engineering, 1974, Recommended Limits	
			Public Water Supply	Livestock
Arsenic	a	50 ug/L	100 ug/L	200 ug/L
Cadmium	a	10 ug/L	10 ug/L	50 ug/L
Chloride	b	250 mg/L[d]	250 mg/L	---
Chromium	a,c	50 ug/L	50 ug/L[c]	1,000 ug/L
Copper	a	1,000 ug/L	100 ug/L	500 ug/L
Dissolved solids	b	250 mg/L[e]	---	---
Dissolved oxygen	b	5.0 mg/L	---	---
Iron	a	300 ug/L	300 ug/L	---
Lead	a	50 ug/L	50 ug/L	100 ug/L
Manganese	a	50 ug/L	50 ug/L	---
Mercury	a	2.0 ug/L	2 ug/L	1,000 ug/L
pH	b	5.0-9.0	5.0-9.0	---
Phosphorus	b	100 ug/L	---	---
Sulfate	b	250 mg/L	250 mg/L	---
Zinc	a	5,000 mg/L	500 mg/L	---

*Also Public Health Service Limit.

[a]Standards are based on 96-hour Median Tolerance Limit. See "Water Quality Standards for Interstate and Interstate Streams in New Mexico", August 28, 1980.

[b]Standards are set for individual segments. See "Water Quality Standards for Interstate and Interstate Streams in New Mexico", August 28, 1980.

[c]Hexavalent (Cr^{+6}).

[d]Applicable only to Public Health Service Limit.

[e]Not applicable to Public Health Service Limit.

Source: Water Quality Control Commission. 1980. "Water Quality Standards for Interstate and Interstate Streams in New Mexico", August 28, 1980. Sante Fe NM, 40 p.

Table 5-8. Current and projected water withdrawals and depletions (thousands of acre-feet) in the Middle Rio Grande River Basin, New Mexico.

Use	1970 Wd.	1970 Depl.	1980 Wd.	1980 Depl.	2000 Wd.	2000 Depl.	2020 Wd.	2020 Depl.
Urban	66.7	30.1	83.0	41.7	134.6	79.5	202.5	141.2
Rural Domestic	5.8	2.7	4.4	2.9	5.1	3.6	5.1	3.7
Manufacturing	2.2	1.3	3.3	1.9	5.0	3.0	10.8	6.1
Minerals[1]	9.1	4.5	19.8	12.6	34.0	24.2	54.1	40.9
Power[2]	4.9	3.4	8.5	5.9	6.0	4.1	12.2	8.6
Military	7.7	4.2	7.7	4.2	7.7	4.2	7.7	4.2
Livestock	2.5	2.5	3.1	3.1	3.6	3.6	4.3	4.3
Fish and Wildlife	9.2	5.8	21.9	18.5	30.3	24.4	30.8	24.9
Recreation[3]	0.8	0.5	1.4	0.9	2.4	1.6	4.8	3.1
Irrigation (Tot.)[4]	331.8	154.7	324.4	154.9	309.0	153.4	290.3	151.8
Indian	32.6	15.4	32.0	15.4	30.5	15.2	28.7	15.0
Non-Indian	299.2	139.3	292.4	139.5	278.5	138.2	261.6	136.8
TOTALS	440.7	209.7	477.5	246.6	537.7	301.6	622.6	388.8

[1]County totals for Bernalillo, Sandoval, Valencia and Socorro counties.

[2]Includes projected installation of fossil fuel electric generating plant before 2020 between Bernalillo and Albuquerque (Sandoval County).

[3]Land based only.

[4]Not considering transfer to other areas.

Source: Water Quality Control Commission. 1979. New Mexico statewide water quality management plan, appendix. Santa Fe NM, variously paged.

Table 5-9. Drainage areas and discharges for continuous-record gauging stations in the Middle Rio Grande River Basin, New Mexico.

Number	Station Name	County	Period of Record (Water Years)	Drainage Area (km^2)	Minimum Discharge (m^3/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
3190	Rio Grande at San Felipe	Sandoval	1925-1978	41670	0.906	27.950	773
3240	Jemez River near Jemez	Sandoval	1936-1941 1949-1952 1953-1978	1220	0.120	1.883	167
3290	Jemez River below Jemez Canyon Dam	Sandoval	1936-1938 1943-1978	2628	no flow	1.495	462
33201	Rio Grande Floodway near Bernardo	Socorro	1936-1939 1943-1978	48810	no flow	25.430	595
3340	Rio Puerro above Arroyo Chico near Guadalupe	Sandoval	1951-1978	1090	no flow	0.365	197
3343	Papers Wash near Star Lake Trading Post	McKinley	1977-1978	52.5	no flow	-	0.68
3405	Aroyyo Chico near Guadalupe	Sandoval	1943-1978	3600	no flow	0.603	430
3426	San Mateo Creek near San Mateo	Socorro	1977-1978	199.8	no flow	-	17.80
3430	Rio San Jose at Grants	Valencia	1912-1978	2640	no flow	0.092	49.80
3431	Grants Canyon at Grants	Valencia	1961-1978	33.7	no flow	0.005	43.90
3435	Rio San Jose near Grants	Valencia	1936-1978	5960	0.054	0.184	39.60
2398	Rio Paguate below Jackpile Mine near Laguna	Valencia	1976-1978	277	0.002	NA	2.80

Table 5-9. Drainage areas and discharges for continuous-record gauging stations in the Middle Rio Grande River Basin, New Mexico (concluded).

Number	Station Name	County	Period of Record (Water Years)	Drainage Area (km^2)	Minimum Discharge (m^3/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
3515	Rio San Juan at Carreo	Valencia	1943-1978	9480	no flow	0.323	202
3530	Rio Puerro near Bernardo	Socorro	1939-1978	19040	no flow	1.345	532
3540	Rio Salada near San Acacia	Socorro	1947-1978	3570	no flow	0.436	1030
3549	Rio Grande Floodway at San Acacia	Socorro	1936-1978	69330	no flow	25.090	776
3584	Rio Grange Floodway at San Marcial	Socorro	1964-1978	71740	no flow	34.690	1420

(-) - No flow most of the time
NA - Not applicable

Source: USGS. 1979. Water Resources Data for New Mexico. Albuquerque NM, 747 p.

Table 5-10. Duration of daily flow (m^3/sec.) from gauging stations on streams in the Middle Rio Grande River Basin, New Mexico.

Station Number	Station Name	County	Area (km^2)	Flow in m^3/sec, Equaled or Exceeded for Percent of Time Indicated: 99	50	25	10	1	Period of Record
3306	Tijeras Arroyo near Albuquerque	Bernalillo	344	N/A	N/A	N/A	N/A	0.42	1975-1977
3308	Tijeras Arroyo BL. S. Div. Inlet near Albuquerque	Bernalillo	-	N/A	N/A	N/A	N/A	0.50	1975-1977
33199	Rio Grande Conveyance Channel near Bernardo	Socorro	-	0.00	6.94	21.18	33.91	N/A	1953-1978
33201	Rio Grande floodway near Bernardo	Socorro	49,810	N/A	N/A	6.09	30.92	132.44	1958-1978
33205	Bernardo Interior Drain near Bernardo	Socorro	N/A	0.34	1.25	1.85	2.62	4.03	1965-1978
3530	Rio Puerco near Bernardo	Socorro	19,040	N/A	N/A	0.06	1.71	28.00	1941-1978
3548	Rio Grande Conveyance Channel at San Acacia	Socorro	-	0.00	11.21	24.04	N/A	N/A	1959-1978
3549	Rio Grande Floodway at San Acacia	Socorro		0.00	0.24	1.52	23.98	112.40	1959-1978
3515	Rio San Jose at Correo	Valencia	9,480	N/A	N/A	0.09	0.75	7.11	1944-1978
3540	Rio Salado near San Acacia	Socorro	3,570	N/A	N/A	N/A	0.03	11.62	1948-1979
3190	Rio Grande at San Felipe	Socorro	69,330	3.30	21.48	38.05	76.70	252.80	1928-1978
3300	Rio Grande at Albuquerque	Bernalillo	7,610	0.00	16.59	30.21	66.51	197.94	1943-1978
3405	Arroyo Chico near Guadalupe	Sandoval	3,600	N/A	N/A	0.02	0.46	15.05	1944-1979

Table 5-10. Duration of daily flow (m^3/sec.) from gauging stations on streams in the Middle Rio Grande River Basin, New Mexico (concluded).

Station Number	Station Name	County	Area (km^2)	Flow in m^3/sec, Equaled or Exceeded for Percent of Time Indicated					Period of Record
				99	50	25	10	1	
3431	Grants Canyon at Grants	Valencia	33	N/A	N/A	N/A	N/A	0.11	1963-1979
3430	Rio San Jose at Grants	Valencia	2,640	N/A	N/A	N/A	0.03	2.44	1913-1979
3498	Rio Paguate below Jackpile Mine near Laguna	Valencia	277	0.00	0.03	0.04	0.06	0.29	1977-1978

- - Not applicable

NA - Not available

Source: US Geological Survey. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas TX.

Table 5-11. Seven day low flow for various recurrence intervals in streams in the Middle Rio Grande River Basin, New Mexico.

Station Number	Station Name	County	Area (km^2)	Annual Low Flow in m^3/sec. for 7 Consecutive Days for Indicated Recurrence Interval in Years: 1	2	5	10	20	Period of Record
33199	Rio Grande Conveyance Channel near Bernardo	Socorro	-	223.71	2.43	0.270	0.080	0.030	1954-1978
33205	Bernardo Interior Drain near Bernardo	Socorro	N/A	8.89	6.66	4.640	3.530	2.700	1965-1978
3548	Rio Grande Conveyance Channel at San Acacia	Socorro	-	133.71	0.17	0.040	0.020	0.013	1959-1978
3549	Rio Grande Floodway at San Acacia	Socorro	-	5.07	0.14	0.023	0.008	0.003	1959-1978
3190	Rio Grande at San Felipe	Socorro	69,330	262.39	74.09	42.810	31.490	24.170	1928-1978
3300	Rio Grande at Albuquerque	Bernalillo	7,610	257.26	10.92	2.580	1.130	0.550	1943-1978
3430	Rio San Jose at Grants	Valencia	2,640	1.38	1.17	1.060	0.990	0.930	1913-1979

- = Not applicable

NA = Not available

Source: USGS. 1981. WATer Data STOrage and REtrieval (WATSTORE). Dallas, Texas.

quently is exceeded in this segment. In general, surface water quality deteriorates downstream as the river gains soluble constituents from surface runoff, irrigation, and municipal treatment plant discharges. Dissolved solids loadings varied with the tributaries from which most of the flow at a given time is derived. Mean values overall are well below (<5.0 mg/l) applicable standards. The mean total dissolved solids levels are higher than the standard (Table 5-7) only in the Rio Puerco River near Bernardo. Chloride levels at all flows are in excess of the standard level between 2 and 18% of the time.

The major point sources of surface water pollution included the Albuquerque, Bernalillo, Los Lunas, and Belen sewage treatment plants. The significant industrial dischargers in the basin is New Mexico Public Service Company's Reeves Generating Station near Albuquerque (Exhibit 5a). Data for the industrial discharges located in the Middle Rio Grande River Basin are presented in Exhibit 5a. The water quality inventory summary and statistical data for the stations located in this basin are presented in Tables 5-12 and 5-13.

5.2.3 Lower Rio Grande River Basin

The Lower Rio Grande River covers an area of 15,462 km^2 (5,970 mi^2) in the south central portion of the State. The Rio Grande River is the only perennial stream in the basin. Rainfall varies with elevation, from 76 to 483 mm (3 to 19 inches); annual evapo-transpiration exceeds precipitation.

5.2.3.1 Quantity

Information on recent and projected withdrawals and depletion of water use in Ike Dona Ana and Sierro counties is presented in Table 5-14. Data for the drainage area and discharges (Table 5-15), flow duration (Table 5-16), and 7-day, low-flow (Table 5-17) are also presented.

Table 5-12. Water quality statistical summary for stations located in Middle Rio Grande River Basin, NM.

Parameters	Sta. No: 3300 Location: Rio Grande R. County: Bernalillo Segment:			Sta. No. 3190 Location: Rio Grande County: Sandoval Segment:		
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	14.43	0.00	33.00	11.41	0.99	25.00
Turbidity (JTU)	-	-	-	105.55	2.00	2800.00
Dissolved oxygen (Mg/L)	8.80	8.80	8.80	9.74	6.90	13.40
BOD 5 Day (Mg/L)	-	-	-	-	-	-
pH (SU)	8.03	7.70	8.40	8.07	7.40	8.80
Total Alkalinity $CaCO_3$ (Mg/L)	132.00	130.00	134.00	105.98	57.00	142.00
Total Residue (Mg/L)	-	-	-	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-	311.00	0.00	9470.00
Total Phosphorus P (Mg/L)	0.22	0.22	0.22	0.23	0.01	6.60
Dissolved Phosphorus P (Mg/L)	-	-	-	0.40	0.01	0.10
Total Hardness $CaCO_3$ (Mg/L)	173.00	140.00	210.00	132.99	70.00	190.00
Dissolved Calcium Ca (Mg/L)	57.75	42.00	70.00	41.19	22.00	59.99
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	8.45	7.80	9.09	7.22	3.50	10.00
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	18.70	8.10	37.00	6.22	2.30	13.00
Total Iron Fe (ug/L)	-	-	-	670.00	670.00	670.00
Dissolved Iron Fe (ug/L)	10.00	10.00	10.00	20.91	0.00	110.00
Dissolved Lead Pb (ug/L)	-	-	-	0.33	0.00	1.00
Total Lead Pb (ug/L)	-	-	-	47.15	0.00	400.00
Manganese Mn (ug/L)	-	-	-	50.00	50.00	50.00
Dissolved Manganese Mn (ug/L)	-	-	-	10.00	10.00	10.00
Dissolved Nickel Ni (ug/L)	-	-	-	-	-	-
Total Nickel Ni (ug/L)	-	-	-	-	-	-
Dissolved Silver Ag (ug/L)	-	-	-	-	-	-
Total Silver Ag (ug/L)	-	-	-	-	-	-
Dissolved Zinc Zn (ug/L)	-	-	-	1.50	0.00	3.00
Total Zinc Zn (ug/L)	-	-	-	148.00	10.00	550.00
Dissolved Selenium Se (ug/L)	-	-	-	0.00	0.00	0.00
Total Selenium Se (ug/L)	-	-	-	0.60	0.00	3.00
Total Ammonia NH_4 (Mg/L)	0.12	0.12	0.12	0.34	0.00	0.15
Dissolved Ammonia NH_4 (Mg/L)	-	-	-	0.02	0.00	0.08
Total Coliform /100 ml	-	-	-	-	-	-

Table 5-12. Water quality statistical summary for stations located in Middle Rio Grande River Basin, NM. (continued).

Parameters	Sta. No: 3310 Location: Rio Grande R. County: Valencia Segment:			Sta. No. 3548 Location: Rio Grande County: Socorro Segment:		
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	15.45	1.00	27.00	15.72	0.00	31.10
Turbidity (JTU)	245.75	15.00	2600.00	2029.92	15.00	40000.00
Dissolved oxygen (Mg/L)	7.90	3.90	13.00	8.99	6.00	12.60
BOD 5 Day (Mg/L)	-	-	-	-	-	-
pH (SU)	7.76	6.70	8.40	7.93	7.80	8.10
Total Alkalinity $CaCO_3$ (Mg/L)	129.59	62.00	183.00	177.00	177.00	177.00
Total Residue (Mg/L)	-	-	-	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	325.92	6.00	3960.00	1513.32	20.00	16500.00
Total Phosphorus P (Mg/L)	0.89	0.15	4.40	1.50	0.14	36.00
Dissolved Phosphorus P (Mg/L)	0.48	0.08	1.50	0.18	0.18	0.18
Total Hardness $CaCO_3$ (Mg/L)	150.98	74.00	230.00	479.49	170.00	1230.00
Dissolved Calcium Ca (Mg/L)	47.67	23.00	74.00	152.75	53.00	391.99
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	7.75	4.00	11.00	24.10	8.90	60.99
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	17.02	3.10	34.00	24.00	19.00	29.00
Total Iron Fe (ug/L)	4571.00	20.00	20000.00	10000.00	10000.00	10000.00
Dissolved Iron Fe (ug/L)	53.98	0.00	2000.00	15.00	10.00	20.00
Dissolved Lead Pb (ug/L)	3.50	0.00	18.00	4.00	3.00	5.00
Total Lead Pb (ug/L)	52.00	6.00	100.00	33.30	13.00	100.00
Manganese Mn (ug/L)	222.00	90.00	500.00	-	-	-
Dissolved Manganese Mn (ug/L)	33.04	5.00	100.00	-	-	-
Dissolved Nickel Ni (ug/L)	4.00	4.00	4.00	-	-	-
Total Nickel Ni (ug/L)	-	-	-	-	-	-
Dissolved Silver Ag (ug/L)	0.00	0.00	0.00	-	-	-
Total Silver Ag (ug/L)	0.25	0.00	1.00	-	-	-
Dissolved Zinc Zn (ug/L)	7.69	0.00	20.00	3.00	3.00	3.00
Total Zinc Zn (ug/L)	33.33	0.00	100.00	120.00	120.00	120.00
Dissolved Selenium Se (ug/L)	0.31	0.00	4.00	0.00	0.00	0.00
Total Selenium Se (ug/L)	0.19	0.00	1.00	0.00	0.00	0.00
Total Ammonia NH_4 (Mg/L)	0.76	0.11	1.90	0.09	0.01	0.22
Dissolved Ammonia NH_4 (Mg/L)	1.39	0.17	3.90	-	-	-
Total Coliform /100 ml	-	-	-	-	-	-

Table 5-12 Water quality statistical summary for stations located in Middle Rio Grande River Basin, NM. (concluded).

Parameters	Sta. No: 3549 Location: Rio Grande County: Socorro Segment:		
	Mean	Min.	Max.
Water temperature (Deg.C)	17.25	1.10	30.00
Turbidity (JTU)	3498.40	40.00	17,000.00
Dissolved oxygen (Mg/L)	8.82	7.50	9.80
BOD 5 Day (Mg/L)	-	-	-
pH (SU)	8.14	7.90	8.70
Total Alkalinity $CaCO_3$ (Mg/L)	180.00	102.00	258.00
Total Residue (Mg/L)	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-
Total Phosphorus P (Mg/L)	0.85	0.45	1.40
Dissolved Phosphorus P (Mg/L)	-	-	-
Total Hardness $CaCO_3$ (Mg/L)	486.33	124.00	955.00
Dissolved Calcium Ca (Mg/L)	149.33	36.00	292.00
Total Calcium Ca (Mg/L)	-	-	-
Dissolved Magnesium Mg (Mg/L)	27.77	8.30	55.00
Total Magnesium Mg (Mg/L)	-	-	-
Chloride Cl (Mg/L)	28.00	28.00	28.00
Total Iron Fe (ug/L)	-	-	-
Dissolved Iron Fe (ug/L)	-	-	-
Dissolved Lead Pb (ug/L)	-	-	-
Total Lead Pb (ug/L)	-	-	-
Manganese Mn (ug/L)	-	-	-
Dissolved Manganese Mn (ug/L)	-	-	-
Dissolved Nickel Ni (ug/L)	-	-	-
Total Nickel Ni (ug/L)	-	-	-
Dissolved Silver Ag (ug/L)	-	-	-
Total Silver Ag (ug/L)	-	-	-
Dissolved Zinc Zn (ug/L)	-	-	-
Total Zinc Zn (ug/L)	-	-	-
Dissolved Selenium Se (ug/L)	-	-	-
Total Selenium Se (ug/L)	-	-	-
Total Ammonia NH_4 (Mg/L)	-	-	-
Dissolved Ammonia NH_4 (Mg/L)	-	-	-
Total Coliform /100 ml	-	-	-

Source: USGS. 1981. WATer Data STOrage and REtrieval (WATSTORE). Dallas, Texas.

Table 5-13. Water quality inventory summary for the Middle Rio Grande River Basin, New Mexico.

Segment No.	Location	Classification EL/WQL	Designated Uses	Known Water Quality Problems
5	The main stem of the Rio Grande from the headwaters of Elephant Butte upstream to the Angostura Diversion Works, including any flow below the perennial reaches of the Rio Puerco and Jemez River which enters the main stem of the Rio Grande.	WQL	Irrigation; limited warm-water fishery; livestock and wildlife watering; secondary contact recreation.	Urban runoff causes high coliform
6	The Jemez River and all tributaries above the town of Jemez Springs and the Guadalupe River and all its tributaries and all perennial reaches of tributaries to the Rio Puerco.	WQL/EL	Domestic water supply; fish culture; high quality cold water fishery; irrigation; livestock and wildlife watering; secondary contact recreation.	NA

NA - Information not available

WQL - Water Quality Limited - A segment where water quality does not meet applicable water quality standards, and is not expected to meet standards after the application of the effluent limitations required by Section 301 (b) (1) (B) of the 1972 Federal Water Pollution Control Act Amendments.

EL - Effluent Limited - A segment where water quality is meeting and will continue to meet applicable water quality standards or where there is an adequate demonstration that water quality will meet applicable water quality standards after the application of the effluent limitations required by Section 201 (b) (1) (A) and 301 (b) (1) (B) of the 1972 Federal Water Pollution Control Act Amendments.

Source: New Mexico Water Quality Commission. 1980. Water Quality Status Summary. Santa Fe, NM. Variously paged.

Table 5-14. Recent and projected withdrawals and depletions (thousands of acre-feet) in Dona Ana and Sierra counties, New Mexico.

Use	1970		1980		2000	
	Wd.	Depl.	Wd.	Depl.	Wd.	Depl.
Urban	11.1	5.6	14.9	8.9	25.0	14.9
Rural	1.9	0.9	1.5	1.0	1.8	1.3
Manufacturing	0.3	0.2	0.3	0.2	0.4	0.2
Irrigation	476.6	219.2	436.2	216.3	424.3	211.3
Minerals	4.1	0.1	1.8	0.7	5.7	3.0
Military	2.8	1.7	3.0	1.9	3.0	1.9
Livestock	0.9	0.9	1.1	1.1	1.2	1.2
Stockpond Evaporation	0.8	0.8	1.0	1.0	1.2	1.2
Reservoir Evaporation	99.7	99.7	99.7	99.7	99.7	99.7
Fish and Wildlife	0.3	0.3	0.3	0.3	0.3	0.3
Power	3.4	3.4	5.1	3.6	34.2	24.3
Recreation	0.2	0.1	0.3	0.2	0.5	0.2
TOTALS	602.1	332.9	565.2	334.9	597.3	360.0

Source: Water Quality Control Commission. 1979. New Mexico statewide management plan, appendix. Santa Fe NM, variously paged.

Table 5-15. Drainage areas and discharges for continuous-record gauging stations in the Lower Rio Grande River Basin, New Mexico.

Number	Station Name	County	Period of Record (Water Years)	Drainage Area (km^2)	Minimum Discharge (m^3/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
8361	Rio Grande below Elephant Butte	Sierra	1915-1978	76,280	no flow	27.96	233
83625	Rio Grande below Caballo Reservoir	Sierra	1938-1978	79,510	0.003	24.02	217

Source: USGS. 1979. Water Resources Data for New Mexico. Albuquerque NM, 747 p.

Table 5-16. Duration of daily flow (m^3/sec.) from gauging stations on streams in the Lower Rio Grande River Basin, New Mexico.

Station Number	Station Name	County	Area (km^2)	Flow in m^3/sec, Equaled or Exceeded for Percent of Time Indicated					Period of Record
				99	50	25	10	1	
3515	Rio San Jose at Correo	Valencia	9,480	N/A	N/A	0.09	0.75	7.11	1944-1978
3610	Rio Grande below Elephant Butte Dam	Sierra	76,280	0.03	27.54	44.84	61.20	75.760	1917-1978
3625	Rio Grande below Caballo Dam	Sierra	79,510	0.02	16.18	38.95	56.73	N/A	1961-1980

N/A - Not available

Source: US Geological Survey. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas, Texas.

Table 5-17. Seven day low flow for various recurrence intervals in streams in the Lower Rio Grande River Basin, New Mexico.

Station Number	Station Name	County	Area (km^2)	Annual Low Flow in m^3/sec. for 7 Consecutive Days for Indicated Recurrence Interval in Years: 1	2	5	10	20	Period of Record
3610	Rio Grande below Elephant Butte Dam	Sierra	76,280	2,408.31	1.74	0.480	0.31	0.24	1917-1978
3625	Rio Grande below Caballo Dam	Sierra	79,510	1.10	0.27	0.214	0.20	0.19	1961-1980

Source: US Geological Survey. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas TX.

5.2.3.2 Quality

In the Lower Rio Grande River Basin, fecal coliform bacteria is the only water quality standard frequently exceeded. The source of this problem appears to be the Las Cruces sewage treatment plant. Standards governing concentrations of total dissolved solids (TDS) (filterable residue), chloride, and sulfate, are exceeded in this basin. Average levels of TDS increase from about 500 mg/l at Caballo Dam to over 80 mg/l at El Paso. Segments 1, 3, and 4 were water quality limited segments (Table 5-18). A point source of surface water pollution includes the Las Cruces sewage treatment plant. There were no significant industrial dischargers in the Lower Rio Grande River Basin. The major problem attributable to nonpoint sources in the basin was high salinity levels resulting from reservoir evaporation, runoff from ephemeral tributaries, and irrigated agriculture return flows. The statistical water quality summary of stations located on the Lower Rio Grande River Basin is presented in Table 5-19.

5.2.4 San Juan River Basin

The San Juan River is located in the northwest corner of New Mexico and includes parts of San Juan, McKinley, Rio Arriba, and Sandoval counties. It has a drainage area of 25,330 km^2 (9780 mi^2). The climate is dry, with an average annual rainfall of 203 to 254 mm (8 to 10 inches). The major perennial tributaries to the San Juan River are the Navajo River, Los Rinos River, Animas River, La Plata River, and Marcos River.

5.2.4.1 Quantity

Water usage in the San Juan River Basin from 1970 through 2000 is presented in Table 5-20. Data for the drainage areas and discharges, flow duration, and 7 day, low-flow frequency are presented in Tables 5-21, 5-22, and 5-23.

Table 5-18. Water quality inventory summary for the Lower Rio Grande River Basin, New Mexico.

Segment No.	Location	Classification EL/WQL	Designated Uses	Known Water Quality Problems
1	From: International boundary and water sampling station above American Dam at El Paso upstream to one mile below Percha Dam	WQL	Irrigation; limited warmwater fishery; livestock and wildlife watering; secondary contact recreation	High coliform caused by urban stormwater runoff
2	From: One mile below Percha Dam upstream to the headwaters of Caballo Reservoir including Caballo Reservoir	EL	Irrigation; livestock and wildlife watering; primary contact recreation; warmwater fishery	No significant problems
3	From: The headwater of Caballo Lake upstream to Elephant Butte Dam	WQL	Fish culture; irrigation; livestock and wildlife watering; marginal coldwater fishery; secondary contact recreation; warmwater fishery	Flow dependent on release from Elephant Butte Reservoir
4	Elephant Butte Reservoir and the Rio Grande River upstream to the Lower Rio Grande Basin Boundary	WQL	Irrigation storage; livestock and wildlife watering; primary contact recreation; warmwater fishery	Decomposition of organic matter causes occasional DO depletion

WQL - Water Quality Limited - A segment where water quality does not meet applicable water quality standards, and is not expected to meet standards after the application of the effluent limitations required by Section 301 (b) (1) (B) of the 1972 Federal Water Pollution Control Act Amendments.

EL - Effluent Limited - A segment where water quality is meeting and will continue to meet applicable water quality standards or where there is an adequate demonstration that water quality will meet applicable water quality standards after the application of the effluent limitations required by Section 201 (b) (1) (A) and 301 (b) (1) (B) of the 1972 Federal Water Pollution Control Act Amendments.

Source: New Mexico Water Quality Commission. 1980. Water Quality Status Summary. Santa Fe, NM. Variously paged.

Table 5-19. Water quality statistical summary for stations located in Lower Rio Grande River Basin, NM.

Parameters	Sta. No: 3583 Location: Rio Grande County: Socorro Segment:			Sta. No. 3584 Location: Rio Grande Floodway County: Socorro Segment:		
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	13.82	0.00	38.88	15.08	0.00	34.50
Turbidity (JTU)	2454.47	2.00	38000.00	3054.94	2.00	80000.00
Dissolved oxygen (Mg/L)	8.81	3.20	15.60	8.67	4.40	12.50
BOD 5 Day (Mg/L)	4.00	0.60	20.00	2.00	1.00	3.40
pH (SU)	7.84	6.90	8.70	7.88	6.79	8.90
Total Alkalinity $CaCO_3$ (Mg/L)	169.18	103.00	340.00	158.29	79.56	344.00
Total Residue (Mg/L)	-	-	-	1.26	0.00	23.00
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	4209.33	73.00	23000.00	755.40	357.00	1100.00
Total Phosphorus P (Mg/L)	0.80	0.02	15.00	0.38	0.06	4.40
Dissolved Phosphorus P (Mg/L)	0.11	0.05	0.19	-	-	-
Total Hardness $CaCO_3$ (Mg/L)	282.61	108.00	930.00	260.24	0.00	855.00
Dissolved Calcium Ca (Mg/L)	88.26	38.00	278.00	81.50	0.00	270.00
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	15.29	3.20	58.00	13.81	0.00	51.00
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	49.38	14.00	350.00	37.34	5.70	175.00
Total Iron Fe (ug/L)	16110.00	550.00	25000.00	44688.00	5300.00	480000.00
Dissolved Iron Fe (ug/L)	36.86	0.00	1100.00	23.06	0.00	290.00
Dissolved Lead Pb (ug/L)	14.58	0.00	102.00	2.45	0.00	19.00
Total Lead Pb (ug/L)	74.46	14.00	100.00	138.14	8.00	1000.00
Manganese Mn (ug/L)	625.00	380.00	820.00	2143.18	290.00	22000.00
Dissolved Manganese Mn (ug/L)	26.27	0.00	280.00	4.08	0.00	10.00
Dissolved Nickel Ni (ug/L)	20.00	5.99	34.00	2.17	0.00	4.00
Total Nickel Ni (ug/L)	-	-	-	20.83	7.00	43.00
Dissolved Silver Ag (ug/L)	3.36	0.00	34.00	0.00	0.00	0.00
Total Silver Ag (ug/L)	0.00	0.00	0.00	0.21	0.00	1.00
Dissolved Zinc Zn (ug/L)	60.68	0.00	389.99	7.04	0.00	20.00
Total Zinc Zn (ug/L)	68.00	10.00	90.00	292.27	30.00	2200.00
Dissolved Selenium Se (ug/L)	2.56	0.00	13.80	0.39	0.00	6.00
Total Selenium Se (ug/L)	0.40	0.00	1.00	0.47	0.00	1.00
Total Ammonia NH_4 (Mg/L)	0.11	0.05	0.18	0.09	0.00	0.36
Dissolved Ammonia NH_4 (Mg/L)	0.20	0.00	0.71	0.08	0.00	0.23
Total Coliform /100 ml	35759.00	1.00	277000.00	131000.00	110000.00	152000.00

Table 5-19. Water quality statistical summary for stations located in Lower Rio Grande River Basin, NM. (concluded).

Parameters	Sta. No: 3610 Location: Rio Grande County: Sierra Segment:		
	Mean	Min.	Max.
Water temperature (Deg.C)	19.69	3.5	37.50
Turbidity (JTU)	16.08	1.00	600.00
Dissolved oxygen (Mg/L)	8.21	1.00	20.00
BOD 5 Day (Mg/L)	-	-	-
pH (SU)	8.11	6.80	9.70
Total Alkalinity $CaCO_3$ (Mg/L)	121.05	100.00	150.00
Total Residue (Mg/L)	-	-	-
Tol. Filterable Residue (Mg/L)	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-
Total Phosphorus P (Mg/L)	0.09	0.00	1.30
Dissolved Phosphorus P (Mg/L)	0.13	0.60	0.32
Total Hardness $CaCO_3$ (Mg/L)	151.50	140.00	200.00
Dissolved Calcium Ca (Mg/L)	47.00	42.00	62.00
Total Calcium Ca (Mg/L)	-	-	-
Dissolved Magnesium Mg (Mg/L)	8.38	31.00	70.00
Total Magnesium Mg (Mg/L)	-	-	-
Chloride Cl (Mg/L)	22.60	17.00	43.00
Total Iron Fe (ug/L)	644.29	120.00	2300.00
Dissolved Iron Fe (ug/L)	16.25	10.00	40.00
Dissolved Lead Pb (ug/L)	0.57	0.00	2.00
Total Lead Pb (ug/L)	3.29	0.00	10.00
Manganese Mn (ug/L)	130.00	10.00	440.00
Dissolved Manganese Mn (ug/L)	74.71	1.00	330.00
Dissolved Nickel Ni (ug/L)	1.80	0.00	4.00
Total Nickel Ni (ug/L)	6.80	0.00	22.00
Dissolved Silver Ag (ug/L)	0.00	0.00	0.00
Total Silver Ag (ug/L)	0.00	0.00	0.00
Dissolved Zinc Zn (ug/L)	4.71	3.00	10.00
Total Zinc Zn (ug/L)	15.71	0.00	30.00
Dissolved Selenium Se (ug/L)	0.00	0.00	0.00
Total Selenium Se (ug/L)	0.00	0.00	0.00
Total Ammonia NH_4 (Mg/L)	0.11	0.00	0.48
Dissolved Ammonia NH_4 (Mg/L)	0.09	0.00	0.28
Total Coliform /100 ml	-	-	-

Source: USGS. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas, Texas.

Table 5-20. Water use (thousands of acre-feet) in the San Juan River Basin, New Mexico. (1970 - 2000)

Use	1970 Wd.	1970 Depl.	1975 Wd.	1975 Depl.	1980 Wd.	1980 Depl.	2000 Wd.	2000 Depl.
Urban (municipal)	8.8	3.9	12.8	5.8	6.3	3.1	9.7	5.8
Rural domestic	3.1	1.4	2.2	1.0	2.4	1.6	2.9	2.1
Irrigated Agriculture	209.8	80.4	222.3	97.6	335.8	179.3	545.1	330.0
Manufacturing	0.4	0.2	0.2	0.1	0.3	0.2	0.4	0.2
Minerals	6.1	2.3	6.6	2.8	53.2	45.6	87.1	78.2
Military	0	0	0	0	0	0	0	0
Livestock	0.8	0.8	0.9	0.9	0.8	0.8	1.0	1.0
Stockpond Evaporation	3.5	3.5	3.3	3.3	4.2	4.2	4.9	4.9
Power	24.7	16.4	56.8	22.7	49.8	49.0	71.9	71.9
Fish and Wildlife	2.8	1.0	2.0	0.8	21.3	6.6	33.0	18.3
Recreation	0	0	0	0	0	0	0.1	0.1
Reservoir Evaporation	24.2	24.2	24.2	24.2	31.1	31.1	32.7	32.7
Playa Lakes Evaporation	0	0	0	0	0	0	0	0
TOTALS	284.2	134.1	331.3	159.2	505.2	321.5	788.8	545.2

Source: Water Quality Control Commission. 1979. New Mexico statewide water quality management plan, appendix. Santa Fe NM, variously paged.

Table 5-21. Drainage areas and discharges for continuous-record gauging stations in the San Juan River Basin, New Mexico.

Number	Station Name	County	Period of Record (Water Years)	Drainage Area (km^2)	Minimum Discharge (m^3/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
3464	San Juan River near Corracas	Archuleta	1961-1979	3,190.0	0.10	17.90	276.00
3498	Piedra River near Arboles	Archuleta	1962-1979	1,629.0	0.03	10.34	237.00
3545	Los Pinos River at La Boca	La Plata	1950-1979	1,320.0	0.16	5.61	181.0
3550	Spring Creek at La Boca	La Plata	1950-1979	150.0	0.02	0.84	56.10
3555	San Juan River near Archuleta	San Juan	1963-1979	8,440.0	0.23	30.67	535.00
3565 65	Canon Largo near Blanco	San Juan	1977-1979	4,440.0	no flow	-	141.00
3571	San Juan River at Hammond Bridge near Bloomfield	San Juan	1910-1979	14,350.0	1.42	ND	580.00
35725	Gallegos Canyon Wash near Farmington	San Juan	1977-1979	751.0	no flow	-	25.50
3635	Animas River near Cedar Hill	La Plata	1933-1979	2,820.0	1.78	25.23	371.00
3645	Animas River at Farmington	San Juan	1912-1979	3,520.0	0.028	25.91	710.00
3650	San Juan River at Farmington	San Juan	1912-1979	18,750.0	0.40	67.18	1,930.00
3665	La Plata River at Colorado/New Mexico state line	La Plata	1920-1979	857.0	no flow	0.94	135.00

Table 5-21. Drainage areas and discharges for continuous-record gauging stations in the San Juan River Basin, New Mexico (continued).

Number	Station Name	County	Period of Record (Water Years)	Drainage Area (km^2)	Minimum Discharge (m^3/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
3675	La Plata River near Farmington	San Juan	1938-1979	1,510.0	no flow	0.716	ND
36754	San Juan River near Fruitland	San Juan	1977-1979	20,750.0	9.06	ND	402.00
367555	Shumway Arroyo near Fruitland	San Juan	1975-1979	163.0	no flow	-	142.00
367561	Shumway Arroyo near Waterflow	San Juan	1974-1979	191.0	no flow	0.500	182.00
36766	Chaco Wash near Star Lake Indian Post	McKinley	1977-1978	153.0	0.00	-	2.75
37101	San Juan River at Four Corners	Montezuma	1977-1979	37,800.0	3.11	ND	479.00
36768	Chaco Wash at Chaco Canyon National Monument	San Juan	1976-1979	1,497.0	no flow	-	35.70
367682	Gallo Wash near Chaco Canyon National Monument	San Juan	1977-1979	93.8	no flow	-	7.19
367685	Ah-Shi-Sle-Sah Wash near Kimboto	San Juan	1976-1979	21.2	no flow	-	33.10
36771	De-Na-Zin Wash near Bisti Trading Post	San Juan	1975-1979	477.0	no flow	-	273.00
36793	Hunter Wash at Bisti Trading Post	San Juan	1975-1979	118.0	no flow	-	44.50
367934	Tea-Ni-Di-Tso Wash near Burnham Trading Post	San Juan	1977-1979	18.6	no flow	-	7.59
367936	Burnham Wash near Burnham	San Juan	1977-1979	22.3	no flow	-	14.70

Table 5-21. Drainage areas and discharges for continuous-record gauging stations in the San Juan River Basin, New Mexico (concluded).

Number	Station Name	County	Period of Record (Water Years)	Drainage Area (km^2)	Minimum Discharge (m^3/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
367938	Chaco River near Burnham	San Juan	1977-1979	9,430.0	no flow	-	191.00
36795	Chaco River near Waterflow	San Juan	1975-1979	11,300.0	ND	ND	207.00
3680	San Juan River	San Juan	1927-1979	33,400.0	0.23	61.86	2,270.00

ND - Not determined
(-) - No flow most of the time

Source: USGS. 1979. Water Resources Data for New Mexico. Albuquerque NM, 747 p.

Table 5-22. Duration of daily flow (m^3/sec.) from gauging stations on streams in the San Juan River Basin, New Mexico.

Station Number	Station Name	County	Area (km^2)	Flow in m^3/sec, Equaled or Exceeded for Percent of Time Indicated: 99	50	25	10	1	Period of Record
3650	San Juan River at Farmington	San Juan	18,750	3.99	27.02	64.04	139.81	372.00	1931-1978
367561	Shumway Arroyo near waterflow	San Juan	191	0.00	0.02	0.04	0.07	0.25	1975-1978
36795	Chaco River near waterflow	San Juan	11,300	0.12	0.48	0.64	0.88	14.93	1977-1978
3555	San Juan River near Archuleta	San Juan	8,440	8.37	15.22	42.68	67.92	179.20	1956-1978
3645	Animas River at Farmington	San Juan	3,520	0.57	10.05	24.73	63.62	175.0	1914-1978
3675	LaPlata River near Farmington	San Juan	1,510	0.00	0.08	0.43	1.49	10.83	1939-1979
367555	Shumway Arroyo near fruitland	San Juan	163	N/A	N/A	N/A	N/A	0.34	1976-1980
367680	Canyon Natl. Monument	San Juan	1,497	N/A	N/A	N/A	0.01	2.82	1977-1978

N/A - Not available

Source: US Geological Survey. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas, Texas.

Table 5-23. Seven day low flow for various recurrence intervals in streams in the San Juan River Basin, New Mexico.

Station Number	Station Name	County	Area (km^2)	Annual Low Flow in m^3/sec. for 7 Consecutive Days for Indicated Recurrence Interval in Years					Period of Record
				1	2	5	10	20	
3650	San Juan River at Farmington	San Juan	18,750	319.75	93.060	45.440	29.26	19.63	1932-1978
367561	Shumway Arroyo near waterflow	San Juan	191	212.85	76.210	48.320	37.37	29.93	1975-1978
3645	Animas River at Farmington	San Juan	3,520	148.60	23.250	8.520	4.66	2.72	1921-1978
3675	LaPlata River near Farmington	San Juan	1,510	1.79	0.051	0.012	0.005	0.003	1939-1979

Source: US Geological Survey. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas TX.

5.2.4.2 Quality

Except for Segments 1 and 3, all stream segments in the basin were effluent limited (Table 5-24). The quality of water in the San Juan River Basin presents no major problems for existing uses.

Stream Segment 1 meets or exceed existing standards, although there are no specific standards for parameters such as turbidity, sulfate, chloride and total dissolved solids. This stretch of the San Juan River receives ephemeral flows from Canyon Largo, Gallups Canyon, and Chaco Canyon, and is high in sediment and TDS content. No significant water quality problems occurred in Segment 2-7 (Table 5-24). The statistical water quality summary for the basin is presented in Table 5-25.

5.2.5 Lower Colorado River Basin

The Lower Colorado River Basin extends along much of the western New Mexico border to the extreme southwest and has an area of 34,447 km^2 (13,30 mi^2). The major tributaries are the Little Colorado River, San Francisco River, Gila River, San Simon Creek, Rio Yaqui River, and Animal Closed River (Exhibit 5a). The climate is dry, with potential evaporation exceeding precipitation except at higher elevations.

5.2.5.1 Quantity

Table 5-26 presents the water use in the Lower Colorado River Basin is presented in Table 5-26. Data on drainage areas and discharges are presented in Table 5-27. Duration of daily flow data and 7-day low-flow information are presented in Table 5-28 and Table 5-29.

Table 5-24. Water quality inventory summary for the San Juan River Basin, New Mexico.

Segment No.	Location	Classification EL/WQL	Designated Uses	Known Water Quality Problems
1	The main stem of the San Juan River from the point where the San Juan leaves New Mexico and enters Colorado upstream to New Mexico Highway 17 at Blanco, and any flow which enters the San Juan River from the Mancos and Chaco Rivers	WQL	Industrial water supply; irrigation; livestock and wildlife watering; secondary contact recreation; warm-water fishery; marginal coldwater fishery	NA
2	La Plata River from its confluence with the San Juan River upstream to the New Mexico-Colorado line	EL	Irrigation; limited warm-water fishery; livestock and wildlife watering; secondary contact recreation	No significant problems
3	The Animas River from its confluence with the San Juan upstream to US Highway 550 to Aztec	WQL	Industrial water supply; irrigation; livestock and wildlife watering; marginal coldwater fishery; secondary contact recreation; warm water fishery	NA
4	The Animas River from US Highway 550 upstream to the New Mexico-Colorado line	EL	Coldwater fishery; irrigation; livestock and wildlife watering; municipal and industrial water supply; secondary contact recreation	No significant problems
5	The main stem of the San Juan River from New Mexico Highway 17 at Blanco upstream to the Navajo Dam	EL	High quality coldwater fishery; irrigation; livestock and wildlife watering; municipal and industrial water supply; secondary contact recreation	No significant problems
6	Navajo Reservoir in New Mexico	EL	Coldwater fishery; irrigation storage; livestock and wildlife watering; municipal and industrial water storage; primary contact recreation; warmwater fishery	No significant problems

Table 5-24. Water quality inventory summary for the San Juan River Basin, New Mexico (concluded).

Segment No.	Location	Classification EL/WQL	Designated Uses	Known Water Quality Problems
7	The Navajo and Los Pinos Rivers in New Mexico	EL	Coldwater fishery; irrigation; livestock and wildlife watering; secondary contact recreation	No significant problems

NA - Information not available

WQL - Water Quality Limited - A segment where water quality does not meet applicable water quality standards, and is not expected to meet standards after the application of the effluent limitations required by Section 301 (b) (1) (B) of the 1972 Federal Water Pollution Control Act Amendments.

EL - Effluent Limited - A segment where water quality is meeting and will continue to meet applicable water quality standards or where there is an adequate demonstration that water quality will meet applicable water quality standards after the application of the effluent limitations required by Section 201 (b) (1) (A) and 301 (b) (1) (B) of the 1972 Federal Water Pollution Control Act Amendments.

Source: New Mexico Water Quality Commission. 1980. Water Quality Status Summary. Sante Fe, NM. Variously paged.

Table 5-25. Water quality statistical summary for stations located in San Juan River River Basin, NM.

	Mean	Min.	Max.
Sta. No:	3680		
Location:	San Juan R.		
County:	San Juan		
Segment:			
Water temperature (Deg.C)	12.56	0.00	30.00
Turbidity (JTU)	455.83	1.00	13,000.00
Dissolved oxygen (Mg/L)	9.80	4.60	14.50
BOD 5 Day (Mg/L)	1.64	0.60	6.60
pH (SU)	7.84	6.80	9.10
Total Alkalinity $CaCO_3$ (Mg/L)	128.86	21.00	250.00
Total Residue (Mg/L)	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-
Total Nonfilterable Residue (Mg/L)	1005.30	36.00	9700.00
Total Phosphorus P (Mg/L)	0.69	0.00	33.00
Dissolved Phosphorus P (Mg/L)	0.05	0.00	0.25
Total Hardness $CaCO_3$ (Mg/L)	247.88	76.00	920.00
Dissolved Calcium Ca (Mg/L)	76.07	1.00	240.00
Total Calcium Ca (Mg/L)	-	-	-
Dissolved Magnesium Mg (Mg/L)	14.02	1.10	77.00
Total Magnesium Mg (Mg/L)	-	-	-
Chloride Cl (Mg/L)	17.93	1.60	196.00
Total Iron Fe (ug/L)	32,054.40	760.00	350,000.00
Dissolved Iron Fe (ug/L)	33.64	0.00	1700.00
Dissolved Lead Pb (ug/L)	4.53	0.00	40.00
Total Lead Pb (ug/L)	82.78	2.00	300.00
Manganese Mn (ug/L)	1256.30	40.00	12,000.00
Dissolved Manganese Mn (ug/L)	113.39	0.00	2100.00
Dissolved Nickel Ni (ug/L)	6.64	0.00	20.00
Total Nickel Ni (ug/L)	7.5	1.00	15.00
Dissolved Silver Ag (ug/L)	0.13	0.00	0.99
Total Silver Ag (ug/L)	0.55	0.00	4.00
Dissolved Zinc Zn (ug/L)	38.99	0.00	489.99
Total Zinc Zn (ug/L)	208.46	10.00	1300.00
Dissolved Selenium Se (ug/L)	3.63	0.00	50.00
Total Selenium Se (ug/L)	2.78	0.00	10.00
Total Ammonia NH_4 (Mg/L)	0.07	0.00	0.18
Dissolved Ammonia NH_4 (Mg/L)	0.08	0.00	0.24
Total Coliform /100 ml	8696.92	50.00	40,000.00

Table 5-25. Water quality statistical summary for stations located in San Juan River Basin, NM. (continued).

Parameters	Sta. No: 367938 Location: Chaco R. County: San Juan Segment:			Sta. No. 367950 Location: Chaco R. County: San Juan Segment:		
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	12.48	1.50	14.22	14.22	0.00	35.00
Turbidity (JTU)	-	-	-	1108.18	230.00	7200.00
Dissolved oxygen (Mg/L)	8.67	6.50	11.20	9.74	6.30	14.20
BOD 5 Day (Mg/L)	-	-	-	-	-	-
pH (SU)	8.05	6.70	8.90	7.69	6.80	8.89
Total Alkalinity $CaCO_3$ (Mg/L)	230.56	75.00	440.00	137.36	26.00	468.00
Total Residue (Mg/L)	-	-	-	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-	450.00	450.00	450.00
Total Phosphorus P (Mg/L)	2.85	0.92	7.10	0.74	0.01	4.80
Dissolved Phosphorus P (Mg/L)	0.11	0.04	0.48	0.03	0.00	0.09
Total Hardness $CaCO_3$ (Mg/L)	49.53	18.00	80.00	735.96	74.00	1900.00
Dissolved Calcium Ca (Mg/L)	17.06	6.50	27.00	200.73	26.00	300.00
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	1.71	0.50	3.10	56.87	2.30	210.00
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	7.90	2.50	13.00	116.31	14.00	300.00
Total Iron Fe (ug/L)	200000.00	200000.00	200000.00	115224.00	230.00	790000.00
Dissolved Iron Fe (ug/L)	350.00	10.00	2100.00	34.46	0.00	340.00
Dissolved Lead Pb (ug/L)	12.67	0.00	44.00	1.44	0.00	9.00
Total Lead Pb (ug/L)	606.50	56.00	1200.00	276.63	0.00	1400.00
Manganese Mn (ug/L)	7152.50	610.00	180000.00	4749.84	40.00	30000.00
Dissolved Manganese Mn (ug/L)	9.00	0.00	20.00	12.37	0.00	90.00
Dissolved Nickel Ni (ug/L)	2.75	0.00	4.00	0.00	0.00	0.00
Total Nickel Ni (ug/L)	66.00	31.00	100.00	7.00	7.00	7.00
Dissolved Silver Ag (ug/L)	-	-	-	0.00	0.00	0.00
Total Silver Ag (ug/L)	-	-	-	1.91	0.00	10.00
Dissolved Zinc Zn (ug/L)	9.75	4.00	20.00	12.88	3.00	40.00
Total Zinc Zn (ug/L)	743.33	130.00	1800.00	258.33	30.00	1100.00
Dissolved Selenium Se (ug/L)	2.75	0.00	6.00	11.84	1.00	47.00
Total Selenium Se (ug/L)	5.87	0.00	21.00	10.29	0.00	51.00
Total Ammonia NH_4 (Mg/L)	1.05	0.04	6.80	0.09	0.02	0.29
Dissolved Ammonia NH_4 (Mg/L)	-	-	-	0.92	0.01	0.30
Total Coliform /100 ml	-	-	-	-	-	-

Table 5-25. Water quality statistical summary for stations located in San Juan River Basin, NM, (continued).

Parameters	Sta. No: 367934 Location: Teec-Ni-Di-TSO Wash. County: San Juan Segment:			Sta. No. 367936 Location: Burnham Wash. County: San Juan Segment:		
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	12.00	0.00	19.50	9.74	0.00	176.00
Turbidity (JTU)	-	-	-	-	-	-
Dissolved oxygen (Mg/L)	9.40	7.10	11.70	9.39	8.50	11.60
BOD 5 Day (Mg/L)	-	-	-	-	-	-
pH (SU)	9.30	9.30	9.30	8.32	7.60	9.30
Total Alkalinity $CaCO_3$ (Mg/L)	161.00	64.00	258.00	271.00	200.00	342.00
Total Residue (Mg/L)	-	-	-	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-	-	-	-
Total Phosphorus P (Mg/L)	1.75	1.50	2.00	3.68	3.10	4.70
Dissolved Phosphorus P (Mg/L)	0.10	0.03	0.17	0.07	0.03	0.13
Total Hardness $CaCO_3$ (Mg/L)	12.50	10.00	15.00	42.75	14.00	79.00
Dissolved Calcium Ca (Mg/L)	3.80	3.10	4.50	10.73	5.10	18.00
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	0.65	0.50	0.81	3.92	0.27	12.00
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	7.50	4.30	11.00	8.05	4.50	10.00
Total Iron Fe (ug/L)	-	-	-	-	-	-
Dissolved Iron Fe (ug/L)	225.00	190.00	260.00	552.50	100.00	1700.00
Dissolved Lead Pb (ug/L)	10.00	10.00	10.00	20.50	10.00	31.00
Total Lead Pb (ug/L)	180.00	180.00	18.00	655.00	560.00	750.00
Manganese Mn (ug/L)	2200.00	2200.00	2200.00	11400.00	7800.00	15000.00
Dissolved Manganese Mn (ug/L)	6.00	6.00	6.00	61.00	2.00	120.00
Dissolved Nickel Ni (ug/L)	2.00	2.00	2.00	2.50	1.00	4.00
Total Nickel Ni (ug/L)	64.00	64.00	64.00	99.00	78.00	120.00
Dissolved Silver Ag (ug/L)	-	-	-	-	-	-
Total Silver Ag (ug/L)	-	-	-	-	-	-
Dissolved Zinc Zn (ug/L)	35.00	35.00	35.00	137.00	24.00	250.00
Total Zinc Zn (ug/L)	430.00	430.00	430.00	1700.00	1600.00	1800.00
Dissolved Selenium Se (ug/L)	2.00	2.00	2.00	4.00	2.00	6.00
Total Selenium Se (ug/L)	6.00	6.00	6.00	3.86	0.00	13.00
Total Ammonia NH_4 (Mg/L)	0.16	0.16	0.16	6.79	0.57	13.00
Dissolved Ammonia NH_4 (Mg/L)	-	-	-	-	-	-
Total Coliform /100 ml	-	-	-	-	-	-

Table 5-25. Water quality statistical summary for stations located in San Juan River Basin. NM. (continued).

Parameters	Sta. No: 367561 Location: Shumuay Arroyo County: San Juan Segment:			Sta. No. 367682 Location: Gallo Wash. County: San Juan Segment:		
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	15.41	0.00	40.00	2.00	0.00	4.00
Turbidity (JTU)	54.82	2.00	420.00	-	-	-
Dissolved oxygen (Mg/L)	7.29	0.00	12.60	11.60	11.60	11.60
BOD 5 Day (Mg/L)	-	-	-	-	-	-
pH (SU)	7.47	2.40	71.99	7.82	7.10	8.50
Total Alkalinity $CaCO_3$ (Mg/L)	163.01	0.08	1430.00	75.00	75.00	75.00
Total Residue (Mg/L)	-	-	-	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	68.00	68.00	68.00	-	-	-
Total Phosphorus P (Mg/L)	0.73	0.05	6.50	0.63	0.63	0.63
Dissolved Phosphorus P (Mg/L)	0.16	0.04	0.29	0.21	0.21	0.21
Total Hardness $CaCO_3$ (Mg/L)	1738.81	250.00	4400.00	47.00	47.00	47.00
Dissolved Calcium Ca (Mg/L)	351.74	71.00	680.00	16.00	16.00	16.00
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	208.67	16.00	810.00	1.70	1.70	1.70
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	361.12	28.00	1900.00	7.80	7.80	7.80
Total Iron Fe (ug/L)	86,064.70	460.00	580000.00	2700.00	2700.00	2700.00
Dissolved Iron Fe (ug/L)	718.13	0.00	16000.00	40.00	40.00	40.00
Dissolved Lead Pb (ug/L)	5.31	0.00	22.00	0.00	0.00	0.00
Total Lead Pb (ug/L)	186.63	0.00	1500.00	-	-	-
Manganese Mn (ug/L)	3556.09	40.00	38000.00	500.00	500.00	500.00
Dissolved Manganese Mn (ug/L)	474.83	0.00	2800.00	-	-	-
Dissolved Nickel Ni (ug/L)	58.00	58.00	58.00	-	-	-
Total Nickel Ni (ug/L)	73.00	73.00	73.00	-	-	-
Dissolved Silver Ag (ug/L)	0.00	0.00	0.00	-	-	-
Total Silver Ag (ug/L)	0.00	0.00	0.00	-	-	-
Dissolved Zinc Zn (ug/L)	83.04	0.00	280.00	-	-	-
Total Zinc Zn (ug/L)	155.91	20.00	400.00	-	-	-
Dissolved Selenium Se (ug/L)	137.83	1.00	720.00	-	-	-
Total Selenium Se (ug/L)	147.22	2.00	710.00	1.14	1.00	2.00
Total Ammonia NH_4 (Mg/L)	0.79	0.00	1.70	-	-	-
Dissolved Ammonia NH_4 (Mg/L)	0.81	0.49	1.30	-	-	-
Total Coliform /100 ml	-	-	-	-	-	-

Table 5-25. Water quality statistical summary for stations located in San Juan River Basin, NM. (continued).

Parameters	Sta. No: 3675 Location: La Plata R. County: San Juan Segment:			Sta. No. 367540 Location: San Juan R. County: San Juan Segment:		
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	14.12	0.00	34.00	11.84	0.00	25.00
Turbidity (JTU)	381.48	0.99	8500.00	-	-	-
Dissolved oxygen (Mg/L)	9.17	5.50	13.00	9.92	7.60	12.00
BOD 5 Day (Mg/L)	-	-	-	-	-	-
pH (SU)	8.18	7.10	8.60	8.24	7.90	8.60
Total Alkalinity $CaCO_3$ (Mg/L)	208.25	75.00	450.00	109.32	51.00	154.00
Total Residue (Mg/L)	-	-	-	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-	98.00	98.00	98.00
Total Phosphorus P (Mg/L)	0.57	0.00	5.40	0.35	0.02	2.00
Dissolved Phosphorus P (Mg/L)	0.01	0.00	0.05	-	-	-
Total Hardness $CaCO_3$ (Mg/L)	859.53	150.00	1600.00	179.53	86.00	380.00
Dissolved Calcium Ca (Mg/L)	215.27	46.00	410.00	55.86	27.00	100.00
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	80.69	8.60	270.00	9.93	4.60	31.00
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	106.44	7.70	420.00	10.44	1.00	31.00
Total Iron Fe (ug/L)	460.00	370.00	610.00	2775.00	1300.00	4100.00
Dissolved Iron Fe (ug/L)	41.31	0.00	340.00	37.03	10.00	320.00
Dissolved Lead Pb (ug/L)	4.90	0.00	25.00	4.77	0.00	23.00
Total Lead Pb (ug/L)	23.00	5.00	96.00	23.00	0.00	83.00
Manganese Mn (ug/L)	1142.00	80.00	4000.00	200.90	50.00	920.00
Dissolved Manganese Mn (ug/L)	245.64	0.00	960.00	17.31	0.00	90.00
Dissolved Nickel Ni (ug/L)	1.45	0.00	5.00	0.84	0.00	3.00
Total Nickel Ni (ug/L)	33.00	3.00	140.00	6.13	3.00	14.00
Dissolved Silver Ag (ug/L)	-	-	-	-	-	-
Total Silver Ag (ug/L)	-	-	-	-	-	-
Dissolved Zinc Zn (ug/L)	19.09	0.00	50.00	21.14	3.00	120.00
Total Zinc Zn (ug/L)	204.29	0.00	940.00	77.50	20.00	270.00
Dissolved Selenium Se (ug/L)	1.27	0.00	6.00	1.08	0.00	5.00
Total Selenium Se (ug/L)	1.29	0.00	5.00	0.88	0.00	1.00
Total Ammonia NH_4 (Mg/L)	0.07	0.00	0.22	0.06	0.00	0.42
Dissolved Ammonia NH_4 (Mg/L)	-	-	-	-	-	-
Total Coliform /100 ml	14.04	10.00	10000.00	-	-	-

Table 5-25. Water quality statistical summary for stations located in San Juan River Basin, NM. (continued).

Parameters	Sta. No: 3645 Location: Animas R. County: San Juan Segment:			Sta. No. 3650 Location: San Juan R. County: San Juan Segment:		
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	12.36	0.00	72.00	18.78	0.00	N/A
Turbidity (JTU)	136.00	0.00	3400.00	195.15	9.99	4600.00
Dissolved oxygen (Mg/L)	9.70	5.99	14.20	9.58	5.40	14.60
BOD 5 Day (Mg/L)	1.41	0.59	2.80	1.58	0.20	5.60
pH (SU)	7.82	7.00	9.04	7.83	6.90	8.90
Total Alkalinity $CaCO_3$ (Mg/L)	134.41	50.00	1560.00	113.32	49.00	302.00
Total Residue (Mg/L)	-	-	-	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	311.43	10.00	1100.00	-	-	-
Total Phosphorus P (Mg/L)	0.18	0.00	2.80	0.29	0.03	4.00
Dissolved Phosphorus P (Mg/L)	0.03	0.00	0.06	0.07	0.01	0.17
Total Hardness $CaCO_3$ (Mg/L)	242.78	80.00	608.00	188.49	65.00	820.00
Dissolved Calcium Ca (Mg/L)	79.01	24.00	211.00	61.58	5.10	276.00
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	11.15	1.70	55.00	8.39	0.30	32.00
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	19.06	1.80	52.00	9.68	1.30	160.00
Total Iron Fe (ug/L)	8686.84	20.00	100000.00	28289.2	760.00	310000.00
Dissolved Iron Fe (ug/L)	30.51	0.00	600.00	44.73	0.00	1700.00
Dissolved Lead Pb (ug/L)	5.00	0.00	39.00	1.00	0.00	4.00
Total Lead Pb (ug/L)	101.38	1.00	700.00	94.24	5.00	400.00
Manganese Mn (ug/L)	426.32	30.00	3300.00	1149.23	50.00	12000.00
Dissolved Manganese Mn (ug/L)	74.25	0.00	620.00	20.33	0.00	70.00
Dissolved Nickel Ni (ug/L)	3.00	0.00	6.00	-	-	-
Total Nickel Ni (ug/L)	4.33	1.00	7.00	-	-	-
Dissolved Silver Ag (ug/L)	0.31	0.00	2.00	0.12	0.00	1.00
Total Silver Ag (ug/L)	2.35	0.00	10.00	0.00	0.00	0.00
Dissolved Zinc Zn (ug/L)	28.54	0.00	340.00	14.66	0.00	70.00
Total Zinc Zn (ug/L)	208.26	10.00	270.00	220.76	20.00	1900.00
Dissolved Selenium Se (ug/L)	19.15	0.00	540.00	0.93	0.00	2.00
Total Selenium Se (ug/L)	1.50	0.00	7.00	1.31	0.00	5.00
Total Ammonia NH_4 (Mg/L)	0.07	0.01	0.18	0.22	0.02	0.80
Dissolved Ammonia NH_4 (Mg/L)	0.06	0.00	0.18	0.17	0.00	0.80
Total Coliform /100 ml	339.99	9.99	1520.00	162439.00	2849999.00	100.00

Table 5-25. Water quality statistical summary for stations located in San Juan River Basin, NM. (continued).

Parameters	Sta. No: 357250	Location: Gallegos Canyon	County: San Juan Segment:	Sta. No. 3573	Location: San Juan R.	County: San Juan Segment:
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	9.50	0.00	26.00	11.87	0.00	28.00
Turbidity (JTU)	-	-	-	59.99	59.99	59.99
Dissolved oxygen (Mg/L)	9.97	5.50	14.00	10.04	5.50	13.70
BOD 5 Day (Mg/L)	-	-	-	1.40	1.40	1.40
pH (SU)	8.63	8.20	9.10	7.90	6.80	9.00
Total Alkalinity $CaCO_3$ (Mg/L)	281.64	104.00	591.00	100.97	69.00	226.00
Total Residue (Mg/L)	-	-	-	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-	-	-	-
Total Phosphorus P (Mg/L)	1.17	0.03	3.80	-	-	-
Dissolved Phosphorus P (Mg/L)	0.05	0.01	0.09	-	-	-
Total Hardness $CaCO_3$ (Mg/L)	114.00	19.00	230.00	158.44	76.00	350.00
Dissolved Calcium Ca (Mg/L)	39.32	6.90	79.00	49.35	29.00	120.00
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	3.47	0.40	7.30	7.63	2.40	15.00
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	24.43	6.10	49.00	4.91	1.30	18.00
Total Iron Fe (ug/L)	460.00	460.00	460.00	-	-	-
Dissolved Iron Fe (ug/L)	175.83	10.00	780.00	56.42	0.00	1700.00
Dissolved Lead Pb (ug/L)	8.00	8.00	8.00	-	-	-
Total Lead Pb (ug/L)	-	-	-	100.00	100.00	100.00
Manganese Mn (ug/L)	40.00	40.00	40.00	-	-	-
Dissolved Manganese Mn (ug/L)	15.00	10.00	20.00	87.49	0.00	350.00
Dissolved Nickel Ni (ug/L)	6.00	6.00	6.00	-	-	-
Total Nickel Ni (ug/L)	-	-	-	-	-	-
Dissolved Silver Ag (ug/L)	-	-	-	-	-	-
Total Silver Ag (ug/L)	-	-	-	-	-	-
Dissolved Zinc Zn (ug/L)	20.00	20.00	20.00	-	-	-
Total Zinc Zn (ug/L)	-	-	-	-	-	-
Dissolved Selenium Se (ug/L)	7.00	7.00	7.00	47.75	0.00	180.00
Total Selenium Se (ug/L)	-	-	-	1.00	1.00	1.00
Total Ammonia NH_4 (Mg/L)	0.37	0.00	1.30	-	-	-
Dissolved Ammonia NH_4 (Mg/L)	-	-	-	-	-	-
Total Coliform /100 ml	-	-	-	1882.85	99.99	4299.99

Table 5-25. Water quality statistical summary for stations located in San Juan River Basin, NM. (continued).

Parameters	Sta. No: 356565 Location: Canon Largo County: San Juan Segment:			Sta. No. 3571 Location: San Juan 2 County: San Juan Segment:		
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	8.16	0.00	24.00	11.29	1.00	25.00
Turbidity (JTU)	-	-	-	-	-	-
Dissolved oxygen (Mg/L)	9.36	6.40	11.60	10.07	7.40	12.60
BOD 5 Day (Mg/L)	-	-	-	-	-	-
pH (SU)	7.96	7.10	8.50	8.31	7.90	8.90
Total Alkalinity $CaCO_3$ (Mg/L)	301.00	131.00	648.00	96.95	66.00	213.00
Total Residue (Mg/L)	-	-	-	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-	-	-	-
Total Phosphorus P (Mg/L)	1.58	0.01	9.50	0.23	0.01	3.80
Dissolved Phosphorus P (Mg/L)	0.03	0.01	0.07	0.02	0.00	0.06
Total Hardness $CaCO_3$ (Mg/L)	606.66	110.00	1300.00	132.71	91.00	200.00
Dissolved Calcium Ca (Mg/L)	171.05	40.00	410.00	41.55	28.00	65.00
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	43.55	3.10	110.00	33.21	14.00	73.00
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	27.03	5.00	83.00	3.77	2.20	6.60
Total Iron Fe (ug/L)	300.00	300.00	300.00	1748.00	540.00	3300.00
Dissolved Iron Fe (ug/L)	43.33	0.00	140.00	33.50	0.00	280.00
Dissolved Lead Pb (ug/L)	2.00	1.00	3.00	3.61	0.00	18.00
Total Lead Pb (ug/L)	56.00	56.00	56.00	11.75	7.00	38.00
Manganese Mn (ug/L)	1940.00	180.00	3700.00	100.00	40.00	300.00
Dissolved Manganese Mn (ug/L)	42.00	0.00	180.00	15.06	4.00	40.00
Dissolved Nickel Ni (ug/L)	1.33	0.00	3.00	0.54	0.00	3.00
Total Nickel Ni (ug/L)	75.00	75.00	75.00	6.13	2.00	16.00
Dissolved Silver Ag (ug/L)	-	-	-	-	-	-
Total Silver Ag (ug/L)	-	-	-	-	-	-
Dissolved Zinc Zn (ug/L)	36.67	20.00	50.00	49.92	5.00	440.00
Total Zinc Zn (ug/L)	510.00	510.00	510.00	40.00	20.00	80.00
Dissolved Selenium Se (ug/L)	2.25	0.00	5.00	0.69	0.00	1.00
Total Selenium Se (ug/L)	11.31	1.00	35.00	0.88	0.00	1.00
Total Ammonia NH_4 (Mg/L)	0.42	0.07	3.10	0.05	0.00	0.33
Dissolved Ammonia NH_4 (Mg/L)	-	-	-	-	-	-
Total Coliform /100 ml	-	-	-	-	-	-

Table 5-25. Water quality statistical summary for stations located in San Juan River Basin, NM. (concluded).

Parameters	Sta. No: 36766 Location: Chaco Wash. County: McKinley Segment:			Sta. No. 3550 Location: San Juan R. County: San Juan Segment:		
	Mean	Min.	Max.	Mean	Min.	Max.
Water temperature (Deg.C)	13.94	1.00	22.00	9.61	0.50	25.6
Turbidity (JTU)	-	-	-	6.35	0.99	15.00
Dissolved oxygen (Mg/L)	8.50	6.30	10.80	11.44	6.60	15.33
BOD 5 Day (Mg/L)	-	-	-	0.78	0.10	1.80
pH (SU)	7.60	7.00	8.80	7.80	6.90	9.49
Total Alkalinity $CaCO_3$ (Mg/L)	87.00	71.00	110.00	93.33	49.00	185.00
Total Residue (Mg/L)	-	-	-	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-	-	-	-
Total Phosphorus P (Mg/L)	1.00	0.12	1.70	0.04	0.00	0.24
Dissolved Phosphorus P (Mg/L)	0.07	0.03	0.12	0.06	0.00	0.23
Total Hardness $CaCO_3$ (Mg/L)	16.60	11.00	21.00	113.78	40.00	250.00
Dissolved Calcium Ca (Mg/L)	6.08	4.40	7.80	35.37	10.00	79.00
Total Calcium Ca (Mg/L)	-	-	-	-	-	-
Dissolved Magnesium Mg (Mg/L)	0.38	0.10	0.50	6.16	0.60	21.00
Total Magnesium Mg (Mg/L)	-	-	-	-	-	-
Chloride Cl (Mg/L)	-	-	-	3.57	0.70	14.00
Total Iron Fe (ug/L)	-	-	-	525.00	0.00	19000.00
Dissolved Iron Fe (ug/L)	378.00	120.00	1000.00	18.55	0.00	120.00
Dissolved Lead Pb (ug/L)	20.50	3.00	38.00	1.79	0.00	8.00
Total Lead Pb (ug/L)	137.50	95.00	180.00	41.14	0.00	100.00
Manganese Mn (ug/L)	1550.00	1100.00	2000.00	31.58	0.00	270.00
Dissolved Manganese Mn (ug/L)	3.00	0.00	5.00	9.32	0.00	40.00
Dissolved Nickel Ni (ug/L)	5.00	4.00	7.00	3.00	3.00	3.00
Total Nickel Ni (ug/L)	58.00	26.00	90.00	-	-	-
Dissolved Silver Ag (ug/L)	-	-	-	0.28	0.00	3.00
Total Silver Ag (ug/L)	-	-	-	0.16	0.00	8.00
Dissolved Zinc Zn (ug/L)	59.67	8.00	140.00	18.77	0.00	150.00
Total Zinc Zn (ug/L)	560.00	360.00	760.00	21.58	0.00	80.00
Dissolved Selenium Se (ug/L)	2.00	1.00	4.00	1.70	0.00	8.00
Total Selenium Se (ug/L)	3.18	0.00	12.00	0.90	0.00	2.00
Total Ammonia NH_4 (Mg/L)	1.24	0.67	2.30	0.12	0.00	0.41
Dissolved Ammonia NH_4 (Mg/L)	-	-	-	0.07	0.00	0.26
Total Coliform /100 ml	-	-	-	152.68	5.00	1160.00

Source: USGS. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas, Texas.

Table 5-26. Water use (thousands of acre-feet) in the Lower Colorado River Basin, New Mexico. (1970 - 2000)

Use	1970 Wd.	1970 Depl.	1975 Wd.	1975 Depl.	1980 Wd.	1980 Depl.	2000 Wd.	2000 Depl.
Urban (municipal)	3.5	1.4	4.2	1.9	6.1	2.9	9.7	5.5
Rural domestic	1.3	0.6	1.4	0.6	1.1	0.7	0.9	0.7
Irrigated Agriculture	99.3	55.3	78.3	43.5	145.5	81.2	150.1	86.8
Manufacturing	0.3	0.2	0.3	0.2	0.3	0.2	0.5	0.3
Minerals	8.8	4.6	13.0	8.4	16.6	11.1	23.8	16.2
Military	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Livestock	1.7	1.7	1.8	1.8	1.3	1.3	1.4	1.4
Stockpond Evaporation	2.7	2.7	2.3	2.3	3.3	3.3	3.8	3.8
Power	0.9	0.7	0.3	0.3	1.0	0.9	16.7	16.7
Fish and Wildlife	1.0	1.0	1.3	1.3	3.2	3.2	9.0	9.0
Recreation	0	0	0	0	0	0	0	0
Reservoir Evaporation	4.6	4.6	4.6	4.6	14.0	14.0	23.2	23.2
Playa Lakes Evaporation	9.4	9.4	9.4	9.4				
TOTALS	133.6	82.3	117.0	74.4	192.5	118.9	239.1	163.7

Source: Water Quality Control Commission. 1979. New Mexico statewide water quality management plan, appendix. Santa Fe NM, variously paged.

Table 5-27. Drainage areas and discharges for continuous-record gauging stations in the Lower Colorado River Basin, New Mexico.

Number	Station Name	County	Period of Record (Water Years)	Drainage Area (km^2)	Minimum Discharge (m^3/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
3869	Rio Nutria near Ramah	McKinley	1969-1978	185	no flow	0.105	22.1
38695	Zuni River above Black Rock Reservoir	McKinley	1969-1978	2,100	no flow	0.228	147.0
4426	San Francisco River near Reserve	Catron	1959-1978	907	0.028	0.649	337.0
442692	Tularosa River above Aragon	Catron	1966-1978	244	0.031	0.095	11.1
4430	San Francisco River Near Alma	Catron	1904-1914 1964-1978	4,004	no flow	1.829	867.0
4440	San Francisco River	Catron	1927-1978	4,281	0.042	1.974	966.0

Source: USGS. 1979. Water Resources Data for New Mexico. Albuquerque NM, 747 p.

Table 5-28. Duration of daily flow (m^3/sec.) from gauging stations on streams in the Lower Colorado River Basin, New Mexico.

Station Number	Station Name	County	Area (km^2)	Flow in m^3/sec, Equaled or Exceeded for Percent of Time Indicated					Period of Record
				99	50	25	10	1	
442692	Tularosa River above Aragon	Catron	244	0.07	N/A	N/A	0.09	0.45	1967-1978
4430	San Francisco River near Alma	Catron	4,004	0.00	0.29	0.99	4.60	27.90	1965-1979
4440	San Francisco River near Glenwood	Catron	4,281	0.21	0.82	1.43	3.59	20.78	1966-1978
3869	Rio Nutria near Ramah	McKinley	185	0.00	0.00	0.01	0.07	2.36	1970-1978
44268	San Francisco River near Reserve	Catron	907	0.05	0.20	0.43	1.20	8.40	1960-1978

N/A - Not available

Source: US Geological Survey. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas, Texas.

Table 5-29. Seven day low flow for various recurrence intervals in streams in the Lower Colorado River Basin, New Mexico.

Station Number	Station Name	County	Area (km^2)	Annual Low Flow in m^3/sec. for 7 Consecutive Days for Indicated Recurrence Interval in Years					Period of Record
				1	2	5	10	20	
442692	Tularosa River above Aragon	Catron	244	0.82	0.70	0.66	0.64	0.62	1967-1978
3869	Rio Nutria near Ramah	McKinley	185	8.18	3.16	2.23	1.85	1.59	1966-1978
44268	San Francisco River near Reserve	Catron	907	2.20	0.69	0.51	0.44	0.40	1960-1978

Source: US Geological Survey. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas TX.

5.2.5.2 Quality

In general the quality of water in the Lower Colorado River Basin presents no significant problems and is suitable for most beneficial uses. The upper reaches of the Gila River Sub-basin and the San Francisco River Sub-basin are acceptable sources of domestic water supply. Segment 1 of the San Francisco River Sub-basin is water quality limited (Table 5-30).

The quality of water in the upper reaches of the basin is high, with turbidity and color degrading downstream. Suspended sediment levels in the Gila River and San Francisco River are notably low, with an average of 389,200 metric ton per year (429,000 tons per year) passing Glenwood on the San Francisco River (Station 4440, Table 5-31 and Exhibit 5a) and 107,000 metric ton per year (118,000 tons per year) passing Gila on the Gila River.

Total dissolved solids concentrations are also low, ranging between 90 mg/l and 234 mg/l on the Gila River and between 139 mg/l and 275 mg/l on the San Francisco River. Dissolved oxygen levels in the basin are above standards (Table 5-31). There are no significant municipal or industrial dischargers in the basin.

5.2.6 Western Closed Basins

The Western Closed Basins consist of the North Plains Basin and the San Augustin Plains Basin. The total drainage area of the basin is 6,993 km^2 (2,700 mi^2). The basin receives about 381 mm (15 inches) of precipitation annually. There are no perennial streams in the Western Closed Basins. The only surface water is an occasional spring, or stock tank, and an ephemeral playa at the western edge of the San Augustin Plains.

5.2.7 Arkansas-White-Red River Basin

The Arkansas-White-Red River Basin is located in the northeast corner of New Mexico. It has a drainage area of 45,325 km^2 (17,500 mi^2). Most of

Table 5-30. Water quality inventory summary for the Lower Colorado River Basin, New Mexico.

Segment No.	Location	Classification EL/WQL	Designated Uses	Known Water Quality Problems
		Gila River Sub-Basin		
1	Gila River from Arizona boundary upstream to Redrock	EL	Irrigation; limited warm-water fishery; livestock and wildlife watering; secondary contact recreation	No significant problems
2	Main stem of the Gila River from Redrock to confluence of West Fork and East Fork	EL	Industrial water supply; irrigation; livestock and wildlife watering; marginal coldwater fishery; secondary contact recreation; warm-water fishery.	No significant problems
3	All tributaries of the Gila River above Cliff, excluding Segment No. 2	EL	Domestic water supply, high quality coldwater fishery; irrigation; livestock and wildlife watering; secondary contact recreation	No significant problems
		San Francisco River Sub-Basin		
1	San Francisco River from Arizona boundary upstream to Tularosa confluence	WQL	Irrigation; limited warmwater and marginal coldwater fishery; livestock and wildlife watering; secondary contact recreation	NA
2	San Francisco River from Tularosa confluence up-stream to Arizona boundary	EL	Coldwater fishery; irrigation; livestock and wildlife watering; secondary contact recreation	No significant problems

Table 5-30. Water quality inventory summary for the Lower Colorado River Basin, New Mexico (concluded).

NA - Information not available

WQL - Water Quality Limited - A segment where water quality does not meet applicable water quality standards, and is not expected to meet standards after the application of the effluent limitations required by Section 301(b)(1)(B) of the 1972 Federal Water Pollution Control Act Amendments.

EL - Effluent Limited - A segment where water quality is meeting and will continue to meet applicable water quality standards or where there is an adequate demonstration that water quality will meet applicable water quality standards after the application of the effluent limitations required by Section 201(b)(1)(A) and 301(b)(1)(B) of the 1972 Federal Water Pollution Control Act Amendments.

Source: New Mexico Water Quality Commission. 1980. Water Quality Status Summary, Santa Fe NM, variously paged.

Table 5-31. Water quality statistical summary for stations located in Lower Colorado River Basin. NM.

Parameters	Sta. No: 4440 Location: San Francisco County: Catran Segment:		
	Mean	Min.	Max.
Water temperature (Deg.C)	16.75	0.00	29.00
Turbidity (JTU)	119.13	2.00	2200.00
Dissolved oxygen (Mg/L)	8.40	1.20	12.00
BOD 5 Day (Mg/L)	1.17	0.00	5.00
pH (SU)	7.96	6.99	9.10
Total Alkalinity $CaCO_3$ (Mg/L)	148.02	75.00	202.00
Total Residue (Mg/L)	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-
Total Phosphorus P (Mg/L)	0.42	0.03	4.40
Dissolved Phosphorus P (Mg/L)	-	-	-
Total Hardness $CaCO_3$ (Mg/L)	129.71	74.00	300.00
Dissolved Calcium Ca (Mg/L)	36.66	22.00	77.00
Total Calcium Ca (Mg/L)	-	-	-
Dissolved Magnesium Mg (Mg/L)	9.09	5.40	26.00
Total Magnesium Mg (Mg/L)	-	-	-
Chloride Cl (Mg/L)	13.03	2.20	67.00
Total Iron Fe (ug/L)	2792.50	260.00	6400.00
Dissolved Iron Fe (ug/L)	25.21	0.00	320.00
Dissolved Lead Pb (ug/L)	20.33	0.00	40.00
Total Lead Pb (ug/L)	100.00	100.00	100.00
Manganese Mn (ug/L)	143.33	30.00	220.00
Dissolved Manganese Mn (ug/L)	13.64	0.00	25.00
Dissolved Nickel Ni (ug/L)	27.00	20.00	35.00
Total Nickel Ni (ug/L)	-	-	-
Dissolved Silver Ag (ug/L)	-	-	-
Total Silver Ag (ug/L)	-	-	-
Dissolved Zinc Zn (ug/L)	13.82	0.00	32.00
Total Zinc Zn (ug/L)	252.50	20.00	900.00
Dissolved Selenium Se (ug/L)	0.00	0.00	0.00
Total Selenium Se (ug/L)	0.00	0.00	0.00
Total Ammonia NH_4 (Mg/L)	-	-	-
Dissolved Ammonia NH_4 (Mg/L)	0.12	0.00	0.43
Total Coliform /100 ml	917.94	5.00	13000.00

Source: USGS. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas, Texas.

the basin is semi-arid with over half of the precipitation falling between May and September. Major tributaries include the Canadian River, Purgatory River, Dry Cimmarron River, Carrizozo River, North Canadian River, Carizo Creek, and Red River.

5.2.7.1 Quantity

Water use data in the Arkansas-White-Red River Basin are presented in Table 5-32. Data on drainage areas and discharges are presented in Table 5-33.

5.2.7.2 Quality

In general, there are no major water quality problems in the Arkansas-White-Red River Basin. Segment 3 and Segment 5 are suitable for a limited warm water fishery. Segment 6 is suitable for a high quality warm water fishery as well as a drinking water supply. All of the segments in the basin are classified as effluent limited by the New Mexico Water Quality Control Commission (Table 5-34).

Dissolved solids and suspended sediments are the significant water quality parameters in the basin. Suspended sediment concentrations in the Canadian River increase from 400 mg/l near Taylor Springs (Station No. 2115) to 16,00 mg/l, at the State line. Total dissolved solids concentrations increase similarly between the same two stations, from 500 mg/l to 1,500 mg/l, respectively. The increase in salinity is due primarily to concentration by surface water evaporation. Increases in sediment loads potentially result from erosion. The municipal discharges from Tucumcari and Raton are in violation of NPDES permit limitations. Discharges from the York Canyon Mine do not present significant problems. The Raton Public Service Co. discharge is also affecting receiving streams, as are the two feed lots in the basin. A water quality statistical summary for stations located in the Arkansas-White-Red River Basins is presented in Table 5-35.

Table 5-32. Water use (thousands of acre-feet) in the Arkansas-White-Red River Basin, New Mexico (1970 - 2000).

Use	1970 Wd.	1970 Depl.	1975 Wd.	1975 Depl.	1980 Wd.	1980 Depl.	2000 Wd.	2000 Depl.
Urban (municipal)	4.0	1.8	3.9	1.7	4.2	2.2	8.3	4.8
Rural domestic	1.2	0.5	2.0	0.9	1.5	0.9	1.8	1.2
Irrigated Agriculture	223.0	176.1	326.0	159.9	424.3	229.5	415.6	235.3
Manufacturing	0.2	0.1	0.1	0.1	0.3	0.2	0.5	0.3
Minerals	0.4	0.2	0.4	0.2	1.9	1.2	5.8	4.0
Military	0	0	0	0	0	0	0	0
Livestock	3.6	3.6	5.4	5.4	3.8	3.8	4.1	4.1
Stockpond Evaporation	10.8	0.8	10.3	10.3	11.5	11.5	12.6	12.6
Power	0.1	0.1	0.2	0.2	0.3	0.2	14.6	14.6
Fish and Wildlife	18.5	18.5	18.5	18.5	13.3	10.5	14.0	11.2
Recreation	0.1	0.1	0.1	0.1	0	0	0	0
Reservoir Evaporation	52.7	52.7	32.7	32.7	74.5	74.5	76.8	76.8
Playa Lakes Evaporation	0	0	0	0				
TOTALS	426.1	265.3	399.6	230.0	535.6	334.5	554.1	364.9

Source: Water Quality Control Commission. 1979. New Mexico statewide water quality management plan, appendix. Santa Fe NM, variously paged.

Table 5-33. Drainage areas and discharges for continuous-record gauging stations in the Arkansas River Basin, New Mexico.

Number	Station Name	County	Period of Record (Water Years)	Drainage Area (km^2)	Minimum Discharge (m^3/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
1990	Canadian River near Hebron	Colfax	1946-1978	593.0	no flow	0.204	1,770.000
1996	Chicorica Creek near Yankee	Colfax	1975-1978	84.2	no flow	ND	0.142
20142	Una De Gato Creek below Throttle Dam near Raton	Colfax	1975-1978	128.2	no flow	ND	14.900
2030	Vermijo River near Dragon	Colfax	1915-1978	780.0	no flow	0.507	357.000
2040	Moreno Creek at Eagle Nest	Colfax	1928-1955 1964-1978	191.0	no flow	ND	6.800
2045	Cieneguilla Creek near Eagle Nest	Colfax	1928-1955 1964-1978	145.0	no flow	ND	14.300
2050	Sixmile Creek near Eagle Nest	Colfax	1928-1955 1958-1978	27.2	no flow	0.071	3.620
2060	Cimarron River below Eagle Nest Dam	Colfax	1950-1978	433.0	no flow	0.385	5.810
2070	Cimarron River near Cimarron	Colfax	1950-1978	761.0	no flow	0.572	439.000
2075	Ponil Creek near Cimarron	Colfax	1915-1929 1950-1978	443.0	no flow	0.306	159.000
2085	Rayado Creek at Sauble Ranch near Cimarron	Colfax	1909-1978	168.0	0.001	0.388	250.000

Table 5-33. Drainage areas and discharges for continuous-record gauging stations in the Arkansas River Basin, New Mexico (concluded).

Number	Station Name	County	Period of Record (Water Years)	Drainage Area (km^2)	Minimum Discharge (m^3/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
2110	Cimarron River at Springer	Colfax	1907-1909 1921-1978	2,673.0	no flow	0.464	835.00
2115	Canadian River near Taylor Springs	Colfax	1940-1978	7,380.0	no flow	2.325	4,590.00

ND - Not determined

Source: USGS. 1979. Water Resources Data for New Mexico. Albuquerque NM, 747 p.

Table 5-34. Water quality inventory summary for the Arkansas River Basin, New Mexico.

Segment No.	Location	Classification EL/WQL	Designated Uses	Known Water Quality Problems
3	The main stem of the Canadian River from the headwaters of the reservoir upstream to Concha Dam and all of the Ute Creek	EL	Irrigation; limited warmwater fishery; livestock and wildlife watering; secondary contact recreation	No significant problems
5	The main stem of the Canadian River from the headwaters of Conchas Reservoir upstream to N.M. Highway 56, and Conchas River and any flow from below the perennial reaches of the Mora River, and Chiconas Creek which enters the main stem of the Canadian River	EL	Irrigation; limited warmwater fishery; livestock and wildlife watering; secondary contact recreation	No significant problems
6.	All tributaries to the Mora River above the town of Mora Coyote Creek all tributaries to the Cimarron River above the town of Cimarron, Rayado Creek above Miami Lake division and all other tributaries to Canadian River northwest of U.S. Highway 64 in Colfax County, and perennial reaches of the main stem of the Canadian River upstream from NM Highway 56	EL	Domestic water supply; irrigation; high quality wildwater fishery; wildlife watering and livestock; municipal and industrial water supply; secondary contact recreation	No significant problems

EL - Effluent Limited - A segment where water quality is meeting and will continue to meet applicable water quality standards or where there is an adequate demonstration that water quality will meet applicable water quality standards after the application of the effluent limitations required by Section 201(b)(1)(A) and 301(b)(1)(B) of the 1972 Federal Water Pollution Control Act Amendments.

Source: New Mexico Water Quality Commission. 1980. Water Quality Status Summary, Santa Fe NM, variously paged.

Table 5-35. Water quality statistical summary for stations located in Arkansas-White-Red River Basin, NM.

Parameters	Sta. No: 2030 Location: Vermejo R. County: Colfax Segment:		
	Mean	Min.	Max.
Water temperature (Deg.C)	11.71	0.00	26.00
Turbidity (JTU)	2.00	2.00	2.00
Dissolved oxygen (Mg/L)	6.79	6.79	6.79
BOD 5 Day (Mg/L)	-	-	-
pH (SU)	7.87	6.80	9.30
Total Alkalinity $CaCO_3$ (Mg/L)	157.15	62.00	236.22
Total Residue (Mg/L)	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-
Total Phosphorus P (Mg/L)	-	-	-
Dissolved Phosphorus P (Mg/L)	-	-	-
Total Hardness $CaCO_3$ (Mg/L)	201.74	86.00	625.00
Dissolved Calcium Ca (Mg/L)	57.28	20.00	130.00
Total Calcium Ca (Mg/L)	-	-	-
Dissolved Magnesium Mg (Mg/L)	14.35	5.50	36.00
Total Magnesium Mg (Mg/L)	-	-	-
Chloride Cl (Mg/L)	5.34	1.70	12.00
Total Iron Fe (ug/L)	-	-	-
Dissolved Iron Fe (ug/L)	28.34	0.00	220.00
Dissolved Lead Pb (ug/L)	6.64	4.00	14.00
Total Lead Pb (ug/L)	63.64	3.00	170.00
Manganese Mn (ug/L)	-	-	-
Dissolved Manganese Mn (ug/L)	38.73	2.00	350.00
Dissolved Nickel Ni (ug/L)	6.91	2.00	16.00
Total Nickel Ni (ug/L)	-	-	-
Dissolved Silver Ag (ug/L)	0.90	0.00	2.00
Total Silver Ag (ug/L)	-	-	-
Dissolved Zinc Zn (ug/L)	315.20	3.00	939.99
Total Zinc Zn (ug/L)	-	-	-
Dissolved Selenium Se (ug/L)	0.88	0.00	5.00
Total Selenium Se (ug/L)	-	-	-
Total Ammonia NH_4 (Mg/L)	-	-	-
Dissolved Ammonia NH_4 (Mg/L)	-	-	-
Total Coliform /100 ml	-	-	-

Source: USGS. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas, Texas.

5.2.8 Pecos River Basin

The Pecos River Basin is the largest water quality basin in New Mexico. It stretches for 700 km (435 miles) from its headwaters in the Sangre de Cristos Mountains in the north central part of the State to the extreme southeastern corner at the Texas River. The basin has a drainage area of 67,300 km^2 (25, 985 mi^2). The major tributaries of the Pecos River Basin are Eagle Creek, Gallinas River, and Cow Creek (Exhibit 5a).

5.2.8.1 Quantity

The drainage areas and discharges, duration of daily flow, and 7-day low-flow frequency information are presented in Table 5-36, Table 5-37 and Table 5-38. Data on water use in the Pecos River Basin are presented are Table 5-39.

5.2.8.2 Quality

The general surface water quality in the basin is acceptable for designated uses. The waters of Segment 8 are designated acceptable for a marginal coldwater fishery. Segment 9 contains water suitable for a domestic water supply and high quality cold water fishery. Segment 9 waters are classified as water quality limited by the New Mexico Water Quality Control Commission (Table 5-40). Dissolved solids concentrations are of primary concern in the basin, especially down stream. Greatly reduced flow, caused by irrigation, compounds water quality problems.

Dissolved solids are contributed to the Pecos River from springs and groundwater seepage, and possibly from irrigation return flows, oilfield brines, and discharges from potash industries. Average dissolved solids concentrations on the Pecos River between 1974 and 1979 were 2,500 mg/l at Artesia and 8,500 mg/l at Red Bluff. Dissolved oxygen levels in the lower Pecos River can fluctuate diurnally between 0.0 and 18 mg/l during the summer.

Table 5-36. Drainage areas and discharges for continuous-record gauging stations in the Pecos River Basin, New Mexico.

Number	Station Name	County	Period of Record (Water Years)	Drainage Area (km^2)	Minimum Discharge (m^3/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
3869	F. Herrera Ditch S. at Hollywood	Lincoln	1960-1978	NA	no flow	0.014	0.19
3870	Rio Ruidosa at Hollywood	Lincoln	1953-1979	310.00	0.008	0.388	37.90
3876	Eagle Creek below South Fork near Alto	Lincoln	1969-1978	21.08	0.001	0.075	3.03
3878	Eagle Creek near Alto	Lincoln	1969-1978	40.07	no flow	0.037	2.04

NA - Not available

Source: USGS. 1979. Water Resources Data for New Mexico. Albuquerque NM, 747 p.

Table 5-37. Duration of daily flow (m^3/sec.) from gauging stations on streams in the Pecos River Basin.

Station Number	Station Name	County	Area (km^2)	Flow in m^3/sec, Equaled or Exceeded for Percent of Time Indicated: 99	50	25	10	1	Period of Record
3869	F. Herrera ditch S. at Hollywood	Lincoln	-	N/A	0.00	0.02	0.04	0.10	1961-1979
3870	Rio Ruidoso at Hollywood	Lincoln	310.00	0.03	0.22	0.44	0.92	2.56	1954-1978
3876	Eagle Creek below South Fork near Alto	Lincoln	21.08	0.00	0.03	0.08	0.19	0.60	1970-1978
3878	Eagle Creek near Alto	Lincoln	40.70	N/A	N/A	0.03	0.20	0.71	1971-1979

N/A - Not available
\- - Not applicable

Source: US Geological Survey. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas, Texas.

Table 5-38. Seven day low flow for various recurrence intervals in streams in the Pecos River Basin, New Mexico.

Station Number	Station Name	County	Area (km^2)	Annual Low Flow in m^3/sec. for 7 Consecutive Days for Indicated Recurrence Interval in Years					Period of Record
				1	2	5	10	20	
3869	F. Herrera ditch S. at Hollywood	Lincoln	-	3.28	0.61	0.34	0.25	0.20	1955-1978

- = Not applicable

Source: US Geological Survey. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas TX.

Table 5-39. Water use (thousands of acre-feet) in the Pecos River Basin, New Mexico. (1970 - 2000)

Use	1970 Wd.	1970 Depl.	1975 Wd.	1975 Depl.	1980 Wd.	1980 Depl.	2000 Wd.	2000 Depl.
Urban (municipal)	24.5	12.6	28.1	13.8	33.1	20.2	51.0	33.5
Rural domestic	3.7	1.8	3.7	1.9	4.1	2.7	4.4	3.1
Irrigated Agriculture	676.2	402.5	688.0	408.1	692.6	416.3	661.4	404.2
Manufacturing	0.8	0.5	0.6	0.4	1.3	0.8	2.1	1.3
Minerals	9.4	6.5	33.7	12.2	18.6	11.8	40.2	31.0
Military	0	0	0	0	0	0	0	0
Livestock	5.5	2.8	5.5	5.5	6.0	6.0	6.5	6.5
Stockpond Evaporation	7.0	7.0	7.3	7.3	8.1	8.1	9.2	9.2
Power	24.4	0.9	14.1	0.6	0.6	0.4	1.1	1.1
Fish and Wildlife	7.6	6.4	6.2	5.9	29.9	19.3	35.3	22.8
Recreation	0	0	0	0	0.1	0.1	0.2	0.2
Reservoir Evaporation	49.6	49.6	42.6	42.6	65.5	65.5	88.3	88.3
Playa Lakes Evaporation	7.4	7.4	7.4	7.4				
TOTALS	816.1	500.7	837.2	605.7	859.9	551.2	899.7	601.2

Source: Water Quality Control Commission. 1979. New Mexico statewide water quality management plan, appendix. Santa Fe NM, variously paged.

Table 5-40. Water quality inventory summary for the Pecos River Basin, New Mexico.

Segment No.	Location	Classification EL/WQL	Designated Uses	Known Water Quality Problems
8	Perennial reaches of the Rio Penasco and its tributaries above Dunken, and Perennial reaches of Boniot Creek below Angus, the Rio Ruidoso below Sleeping Springs Lakes and Aqua Chiquita	EL	Fish culture; irrigation; livestock and wildlife watering; marginal cold-water fishery; secondary contact recreation	No significant problems
9	Eagle Creek above upstream of Angus and Rio Ruidoso and its tributaries above Sleeping Springs Lakes	WQL/EL	Domestic water supply; fish culture; high quality cold-water fishery; irrigation; livestock and wildlife watering; municipal and industrial water supply; secondary contact recreation	Municipal waste-water causes high phosphorus

WQL - Water Quality Limited - A segment where water quality does not meet applicable water quality standards, and is not expected to meet standards after the application of the effluent limitations required by Section 301 (b) (1) (B) of the 1972 Federal Water Pollution Control Act Amendments.

EL - Effluent Limited - A segment where water quality is meeting and will continue to meet applicable water quality standards or where there is an adequate demonstration that water quality will meet applicable water quality standards after the application of the effluent limitations required by Section 201 (b) (1) (A) and 301 (b) (1) (B) of the 1972 Federal Water Pollution Control Act Amendments.

Source: New Mexico Water Quality Commission. 1980. Water Quality Status Summary. Sante Fe, NM. Variously paged.

There are no major industrial dischargers, although there are three large feedlots in the basin. Most municipalities discharge poor quality effluent in the Pecos River Basin, but upgraded treatment levels are anticipated.

5.2.9 Central Closed Basins

The Central Closed Basins consist of the Estancia, Tularaso, Salt and Jorando del Muerto Basins. The basin has a drainage area of 37,736 km^2 (14,570 mi^2) and extends from the center of the State to the Texas border.

The Estancia Basin has no perennial streams. The Tularnso Basin has several perennial streams, including Three Rivers and the Rio Tulayosa River; both have significant flows. The Tornado del Muerto Basin has no perennial streams.

5.2.9.1 Quantity

A summary of the estimated annual water use in the Central Closed Basin is presented in Table 5-41. Drainage areas and discharges (Table 5-42), data on duration of daily flow (Table 5-43), and low-flow frequency data (Table 5-44), are presented in table form.

5.2.9.2 Quality

Surface water in the basins is generally acceptable for all designated uses including municipal water supply (Table 5-45). Total dissolved solids, sulfates, and chlorides are high in some streams, and occasionally exceed standards (Table 5-46).

Total dissolved solids averaged 1,242 mg/l in the water in the Tularosa Basin in 1976, while sulfates averaged 617.6 mg/l. During 1975 and 1976, total dissolved solids in LaLuz Creek were also high.

Table 5-41. Summary of estimated average annual water uses (thousands of acre-feet) in the Central Closed Basins, New Mexico.

Item	Total Diversion	Total Depletion
Irrigation	81·59	53·04
(Sewage used for irrigation)		(0·82)
Urban	5·12	2·56
Self-supplied		
Industrial	0·20	10
Minerals	0·70	30
Sub-total, Self-supplied	(0·90)	(0·40)
Military	3·83	1·91
Rural Domestic	1·22	0·56
Livestock		1·10
Fish, recreation and wildlife		0·14
Evaporation		
Reservoirs		0·06
Stock ponds		1·36
Playa lakes*		50·00
	TOTAL	110·77

* - In Estancia basin only

Source: New Mexico Water Quality Control Commission. 1975. Central closed basin plan. Santa Fe NM, variously paged.

Table 5-42. Drainage areas and discharges for continuous-record gauging stations in the Central Closed Basins, New Mexico.

Number	Station Name	County	Period of Record (Water Years)	Drainage Area (km^2)	Minimum Discharge (m^3/s)	Average Discharge (m^3/s)	Maximum Discharge (m^3/s)
4815	Rio Turlarosa near Bent	Otero	1947-1978	310	0	0.274	121

Source: USGS. 1979. Water Resources Data for New Mexico. Albuquerque NM, 747 p.

Table 5-43. Duration of daily flow (m^3/sec.) from gauging stations on streams in the Central Closed Basin, New Mexico.

Station Number	Station Name	County	Area (km^2)	Flow in m^3/sec, Equaled or Exceeded for Percent of Time Indicated					Period of Record
				99	50	25	10	1	
4815	Rio Tularosa near Bent	Otero	310	0.09	0.27	0.33	0.38	0.55	1949-1978

Source: US Geological Survey. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas, Texas.

Table 5-44. Seven day low flow for various recurrence intervals in streams in the Central Closed Basins, New Mexico.

Station Number	Station Name	County	Area (km^2)	Annual Low Flow in m^3/sec. for 7 Consecutive Days for Indicated Recurrence Interval in Years					Period of Record
				1	2	5	10	20	
4815	Rio Tularosa near Bent	Otero	310	2.21	1.22	0.93	0.79	0.69	1969-1978

Source: US Geological Survey. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas TX.

Table 5-45. Water quality inventory summary for the Closed Central Basins, New Mexico.

Segment No.	Location	Classification EL/WQL	Designated Uses	Known Water Quality Problems
1	Rio Tularosa lying east of New Mexico Highway 70 bridge crossing east of Tularosa, and perennial tributaries to the Tularosa Basin	EL	Coldwater fishery; fish culture; irrigation; livestock and wildlife watering; municipal and industrial water supply; secondary contact recreation	No significant problems

EL - Effluent Limited - A segment where water quality is meeting and will continue to meet applicable water quality standards or where there is an adequate demonstration that water quality will meet applicable water quality standards after the application of the effluent limitations required by Section 201(b)(1)(A) and 301(b)(1)(B) of the 1972 Federal Water Pollution Control Act Amendments.

Source: New Mexico Water Quality Commission. 1980. Water Quality Status Summary, Santa Fe NM, variously paged.

Table 5-46. Water quality statistical summary for stations located in Central Closed River Basin, NM.

Parameters	Sta. No: 4815 Location: Rio Tularosa County: Otero Segment:		
	Mean	Min.	Max.
Water temperature (Deg.C)	14.19	0.50	28.00
Turbidity (JTU)	238.76	3.00	7500.00
Dissolved oxygen (Mg/L)	8.85	6.99	11.50
BOD 5 Day (Mg/L)	-	-	-
pH (SU)	7.79	7.00	8.50
Total Alkalinity $CaCO_3$ (Mg/L)	189.58	57.00	247.00
Total Residue (Mg/L)	-	-	-
Vol. Filterable Residue (Mg/L)	-	-	-
Total Nonfilterable Residue (Mg/L)	-	-	-
Total Phosphorus P (Mg/L)	0.17	0.00	5.90
Dissolved Phosphorus P (Mg/L)	0.01	0.00	0.08
Total Hardness $CaCO_3$ (Mg/L)	814.63	490.00	1500.00
Dissolved Calcium Ca (Mg/L)	223.79	97.00	560.00
Total Calcium Ca (Mg/L)	-	-	-
Dissolved Magnesium Mg (Mg/L)	59.84	6.30	87.00
Total Magnesium Mg (Mg/L)	-	-	-
Chloride Cl (Mg/L)	62.99	31:00	110.00
Total Iron Fe (ug/L)	1909.20	150.00	25000.00
Dissolved Iron Fe (ug/L)	32.23	0.00	1200.00
Dissolved Lead Pb (ug/L)	1.76	0.00	15.00
Total Lead Pb (ug/L)	42.96	0.00	100.00
Manganese Mn (ug/L)	94.80	20.00	950.00
Dissolved Manganese Mn (ug/L)	27.60	0.00	50.00
Dissolved Nickel Ni (ug/L)	0.80	0.00	3.00
Total Nickel Ni (ug/L)	3.80	2.00	6.00
Dissolved Silver Ag (ug/L)	0.00	0.00	0.00
Total Silver Ag (ug/L)	0.88	0.00	10.00
Dissolved Zinc Zn (ug/L)	11.24	0.00	90.00
Total Zinc Zn (ug/L)	20.80	0.00	110.00
Dissolved Selenium Se (ug/L)	1.04	0.00	3.00
Total Selenium Se (ug/L)	1.24	0.00	3.00
Total Ammonia NH_4 (Mg/L)	0.05	0.00	0.41
Dissolved Ammonia NH_4 (Mg/L)	0.04	0.00	0.31
Total Coliform /100 ml	-	-	-

Source: USGS. 1981. WATer data STOrage and REtrieval (WATSTORE). Dallas, Texas.

There are no industrial discharges to surface water in the basins and Cloudcraft is the only municipal discharger.

5.3 GROUNDWATER

Groundwater data for New Mexico are reported by major surface water drainage basins (Figure 5-1). These basins were introduced in Section 5.2.

The amount of groundwater available to wells depends on saturated thickness, areal extent, and specific yield. The amount of groundwater in storage depends on the amount of recharge from precipitation. The mean annual precipitation in New Mexico ranges from 203 mm (8 inches) along the Lower San Juan River Valley and the Rio Grande River Valley, to 762 mm (30 inches) in the Rocky Mountains. Most of the precipitation at lower altitudes falls during summer as heavy downpours. The annual runoff across the Study Area ranges from 12.7 to 127 mm (0.5 to 5.0 inches) (Exhibit 5b).

The geologic structure and hydrologic properties of aquifers, as well as water quantity and quality are addressed in this chapter. These aspects are essential in an evaluation of the effects of proposed coal development on groundwater resources.

5.3.1 Arkansas River Basin

The central and eastern parts of the Arkansas River Basin are in the Great Plains physiographic province; the western edge is in the southern Rocky Mountain physiographic province. Colfax is the only county in the Study Area located in the Arkansas River Basin. Generally for most areas in this basin, groundwater is difficult to obtain and at present not extensively developed. Only 5% of the water used in the Arkansas River Basin is groundwater.

5.3.1.1 Quantity

The principal aquifers in Colfax County are in sandstone (Figure 5-2), and range in age from Pennsylvanian to Cretaceous (Table 5-47). Aquifers underlying Colfax County generally yield water quantities of less than 0.4 m^3/m (10 gpm). One USGS observation well is located in the county (Table 5-48 and Exhibit 5b). Most of the groundwter in Colfax County is used for watering livestock and/or irrigation. Recharge is primarily local and largely limited to precipitation falling in the basin. In areas where groundwater is used for irrigation, information regarding extent and general condition of the aquifers is not available. Information on the depth to groundwater in Colfax County is presented in Figure 5-3.

5.3.1.2 Quality

Because groundwater in New Mexico originates primarily from precipitation, mineralization results when the water passes through rocks and soil to the zone of saturation. The quality of water is directly related to the solubility of the minerals in the enclosing rock and the length of time the water is in contact with the minerals.

Water quality standards are established for water used for municipal, industrial, and irrigation supplies. Sulfate and chloride concentrations in drinking water should not exceed 250 mg/l, the nitrate level should not exceed 45 mg/l, and dissolved soilds content should not exceed 500 mg/l. Chemical parameters applicable to irrigation uses include specific electrical conductance, sodium absorption ratio, residual sodium carbonate, and boron concentration.

The general areal extent of groundwater in New Mexico is depicted in Figures 5-4, 5-5, and 5-6. Water quality data obtained from wells in Colfax County are presented in Table 5-49.

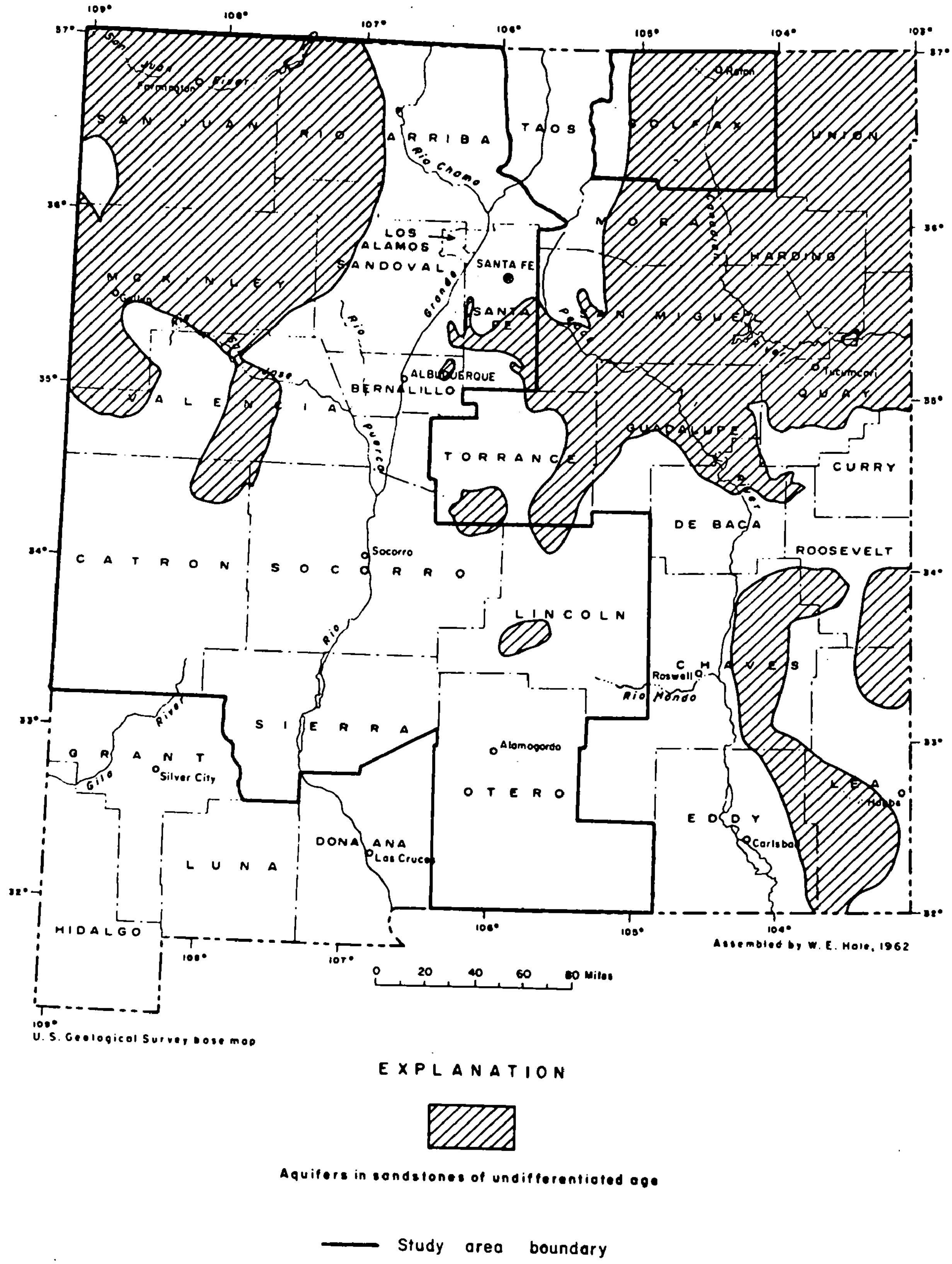


Figure 5-2. Principal sandstone aquifers in New Mexico.

Table 5-47. Generalized stratigraphic section in the Arkansas River basin, New Mexico.

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Quaternary	*Alluvium	Generally less than 100	Tributaries to Arkansas River, Tucumcari area.	Silt, sand, and gravel.	Yields small to moderate quantities of water to wells. Generally yields fresh water in most areas.
	*Pediment and terrace deposits	0 to 100	Cap flat-top mesas near Canadian River and large tributaries. Terraces are prominent along the large stream valleys.	Silt, sand, gravel, and boulders.	Recharge by precipitation or surface flow; may yield small to moderate quantities of water to wells. Generally yields fresh water.
Quaternary and Tertiary	*Volcanic complex	0 to 1,000	Cap many high mesas, occur as channel deposits, dikes, sills, and interbedded with sedimentary rocks.	Basalt, cinders, and fine to coarse basaltic alluvium, scoria, pumice.	May yield small to large quantities of water to wells depending on fractures and saturated thickness. Generally is not a principal aquifer. Generally yields fresh water.
Tertiary	*Ogallala Formation	0 to 400	Mostly in south-central and eastern parts of Canadian River basin.	Irregularly bedded sand, grit, and local conglomerate cemented by caliche and local beds of shale, clay, and limestone.	Recharged by precipitation, varies in permeability; may yield small to medium quantities of water to wells. Generally yields fresh water.
	Poison Canyon Formation	-	Underlies high mesas.	Conglomerate, arkose, sandstone, siltstone, and shale; intertongues with the Raton Formation.	Not known to yield water to wells.
	*Raton Formation	1,000	Underlies high mesas generally.	Conglomerate and sandstone; black shale with coal beds; intertongues with Poison Canyon Formation.	Recharged from rainfall and snow melt; spring discharge in many places; yields small quantities of water to wells at some places. Generally yields fresh water.
Cretaceous	Vermejo Formation and Trinidad Sandstone	100±	North and east of Raton. Coal mined in this formation in Colfax County.	Interbedded sandstone and shale with coal beds.	Not known to yield water to wells.
	*Pierre Shale and upper part of Niobrara Formation	1,650	Outcrops in large areas in southern Colfax County and Mora County.	Compact shale with thin calcareous beds and nodules.	Yields small amounts of water to wells in the weathered zone of the formation. Generally yields slightly saline water.
	*Fort Hays Limestone Member of Niobrara Formation	900+	Exposed on gentle soil-covered slopes in Colfax County.	Thin-bedded marine limestone with some thin shale interbeds.	Permeability depends on interconnected fractures and bedding-plane openings. Yields small quantities of water to wells in some areas. Generally yields fresh water.
	*Carlile Shale	220±	San Miguel and Colfax Counties.	Sandy shale with some beds of sandstone.	Yields small quantities of water to wells. Generally yields slightly saline water.
	*Greenhorn Limestone	35+	Exposed along streams and ridges in Union and Colfax Counties.	Marine limestone with thin interbeds of shale.	Yields water to some stock and domestic wells; water is hard but fair quality.
	*Graneros Shale	215	do.	Dark fissile shale with sandy shale and some thin sandstone beds at base.	Yields small quantities of water to wells; quality of water is generally slightly saline but suitable for livestock.
	*Dakota Sandstone (Also Purgatoire Formation in Union County)	200±	Exposed on hillsides and streams in reach of the Arkansas River basin.	Conglomeratic sandstone, sandstone, and shale.	Best source of stock and domestic water in many areas. Generally yields fresh water.
Jurassic	*Morrison Formation	100 to 370	Colfax, San Miguel, Union, and Harding Counties.	Fine-grained shale and sandstone.	Poor source of water; yields small quantities of water to some wells. Generally yields fresh water.
	*Entrada Sandstone	175	Union, Harding, and Quay Counties.	Fine-grained massive sandstone.	Principal aquifer in Tucumcari area; of little importance as aquifer elsewhere; has small recharge area; yields small quantities of water to wells locally. Generally yields fresh water.
Triassic	*Chinle Formation and Santa Rosa Sandstone	1,000+	Exposed over small area in Colfax County and large area on plains of San Miguel County.	Interbedded red shale, siltstone, sandstone.	Santa Rosa Sandstone is an important aquifer for stock and domestic wells in San Miguel County. Chinle Formation is less important but supplies small quantities of water to some wells. Generally yields slightly to moderately saline water.
Permian	*San Andres Limestone	50 to 400	Union and San Miguel Counties.	Dolomite, anhydrite, and fine-grained sandstone.	Varies in permeability; yields small quantities of water to stock and domestic wells in San Miguel County. Generally yields fresh water.
	Yeso Formation	100 to 500	Southwest Union County.	Fine- to coarse-grained sandstone and mudstone.	Not known to yield water to wells.
	*Glorieta Sandstone	-	San Miguel County.	Quartzitic sandstone.	Yields small quantities of water to some wells. Generally yields fresh to slightly saline water.
Pennsylvanian	Sangre de Cristo Formation (locally also Magdalena Limestone)	600 to 1,000	Probably underlies all of the northern part of the Arkansas River basin.	Shale and feldspathic sandstone.	Yields small quantities to stock wells in western Colfax and San Miguel Counties.
	Sedimentary rocks	3,500 to 4,000	Western Colfax County and Cimarron Range.	Limestone, shale, arkose, and sandstone.	Not known to yield water to wells.
Precambrian	Metamorphic and igneous rocks	-	Exposed in the Cimarron Range and several places along the western boundary of Colfax County.	Granite, gneiss, schist, and quartzite.	do.

*Known or probable aquifer, regardless of areal extent or production potential.

Source: New Mexico State Engineer Office. 1967.

Table 5-48. Records of wells in selected New Mexico counties.

Exhibit Designation	Well Number	Owner	County	Well Characteristics			Water-Bearing Unit	Period of Record	Water Level Extremes For Period of Record*	
				Type of Well	Depth (m)	Diameter (m)			High (m)	Low (m)
101	345730106431001	Denison	Bernalillio	Drilled	Unknown	0.30	Santa Fe Group	1958-1979	3.42	4.97
102	350655106395001	City of Albuquerque	Bernalillio	Drilled	290.0	0.15	Alluvium & Santa Fe Group	1953; 1957-1979	3.69	10.59
103	350415106403001	City of Albuquerque	Bernalillio	Drilled	NA	0.15	Alluvium & Santa Fe Group	1956-1979	4.39	8.24
104	364500104031501	John King	Colfax	Drilled	37.0	0.20	Alluvium	1957-1969; 1971-1979	1.42	2.86
105	333015105382201	M. W. Coll	Lincoln	Drilled	27.4	0.20	Alluvium	1955-1979	5.05	13.52
106	333242105340701	Village of Capitan	Lincoln	Drilled	98.8	0.20	Mancos Shale of Getaceous Age	1955-1979	11.38	21.27
107	332145105333001	E. H. Fuchs	Lincoln	Drilled	27.4	0.20	Alluvium	1955-1979	17.42	19.43
108	332157105094101	Lincoln Co. Cimestock Co.	Lincoln	Drilled	38.1	0.30	Yeso Formation of Permian Age	1955-1979	13.68	18.34
109	330324106011201	Luther Watson	Otero	Drilled	70.1	0.43	Bolson Deposits	1952-1979	22.48	40.79
110	324853105582501	US Air Force	Otero	Drilled	71.9	0.25	Bolson Deposits	1955-1979	18.72	25.65
111	320650105034801	Frank Gentry	Otero	Drilled	165.0	0.46	Bolson Deposits	1971-1979	15.57	25.21
113	352235106282401	John Bowers	Sandoval	Drilled	15.2	0.31	Valley Fill	1976 only	6.70	7.89
114	350525106025001	W. R. Irby	Santa Fe	Drilled	156.0	NA	Valley Fill	1950-1979	26.44	43.76
115	350340106005001	Glen Terry	Santa Fe	Drilled	61.0	0.36	Glorieta Sandstone of Permian Age	1951-1979	17.67	32.48
116	353810106025501	Santa Fe Country Club	Santa Fe	Drilled	122.0	0.13	Ancha Formation	1951; 1953-1979	75.56	82.92
117	330715107171901	City of Truth or Consequences	Sierra	Drilled	134.0	0.31	Santa Fe Group of Quaternary Age	1976	2.81	9.48
118	325550107184001	William M. Dawson	Sierra	Drilled	NA	0.41	Valley Fill	1974-1979	7.66	12.42
119	325350107175501	US Govt.	Sierra	Drilled	9.8	0.25	Valley Fill	1957-1979	3.97	8.47
120	35040010107510501	Monico Mirabal	Valencia	Drilled	65.8	0.41	Glorieta Sandstone of Permian Age	1952-1979	6.76	11.57
121	350925107523001	City of Grants	Valencia	Drilled	48.2	41.0-30.0	San Andras Limestone of Permian Age	1953-1979	6.05	11.91

Table 5-48. Records of wells in selected New Mexico counties (concluded).

Exhibit Designation	Well Number	Owner	County	Well Characteristics: Type of Well	Well Characteristics: Depth (m)	Well Characteristics: Diameter (m)	Water-Bearing Unit	Period of Record	Water Level Extremes For Period of Record*: High (m)	Water Level Extremes For Period of Record*: Low (m)
122	351400107524201	A. R. Card	Valencia	Drilled	62.5	0.46	San Andras Limestone of Permian Age	1944; 1946-1979	19.95	32.80
123	351650107535001	Tom Yager	Valencia	Drilled	154.0	0.41	San Andras Limestone of Permian Age	1946-1979	28.58	42.38
124	351610107514501	Duane Berryhill	Valencia	Drilled	39.6	0.10	Alluvium of Quaternary Age	1949-1979	26.16	30.90

*Below Land-surface Datum (LSD)

Source: USGS. 1979. Water Resources Data for New Mexico. Albuquerque NM, 747 p.

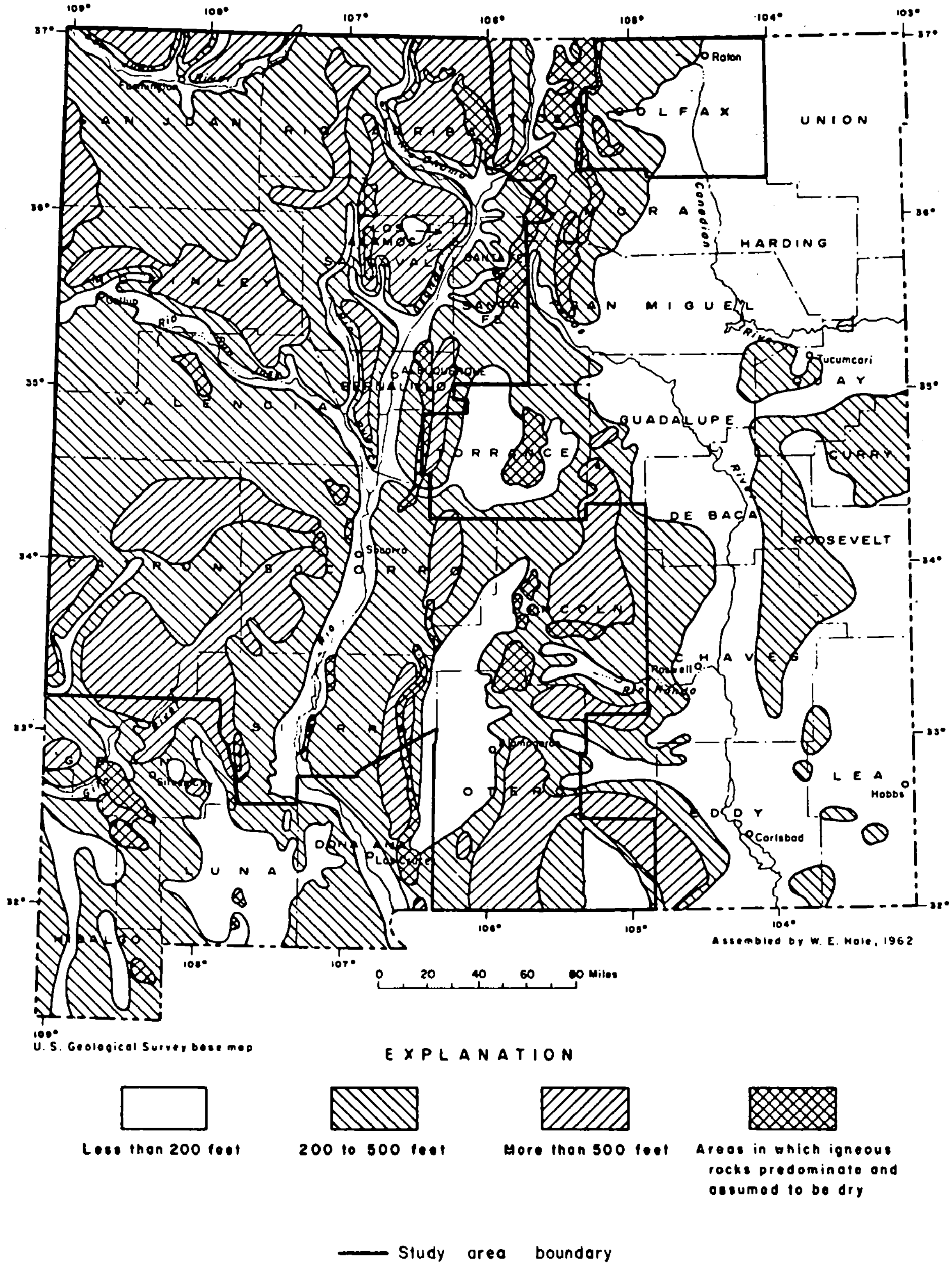


Figure 5-3. Depth to ground water in New Mexico.

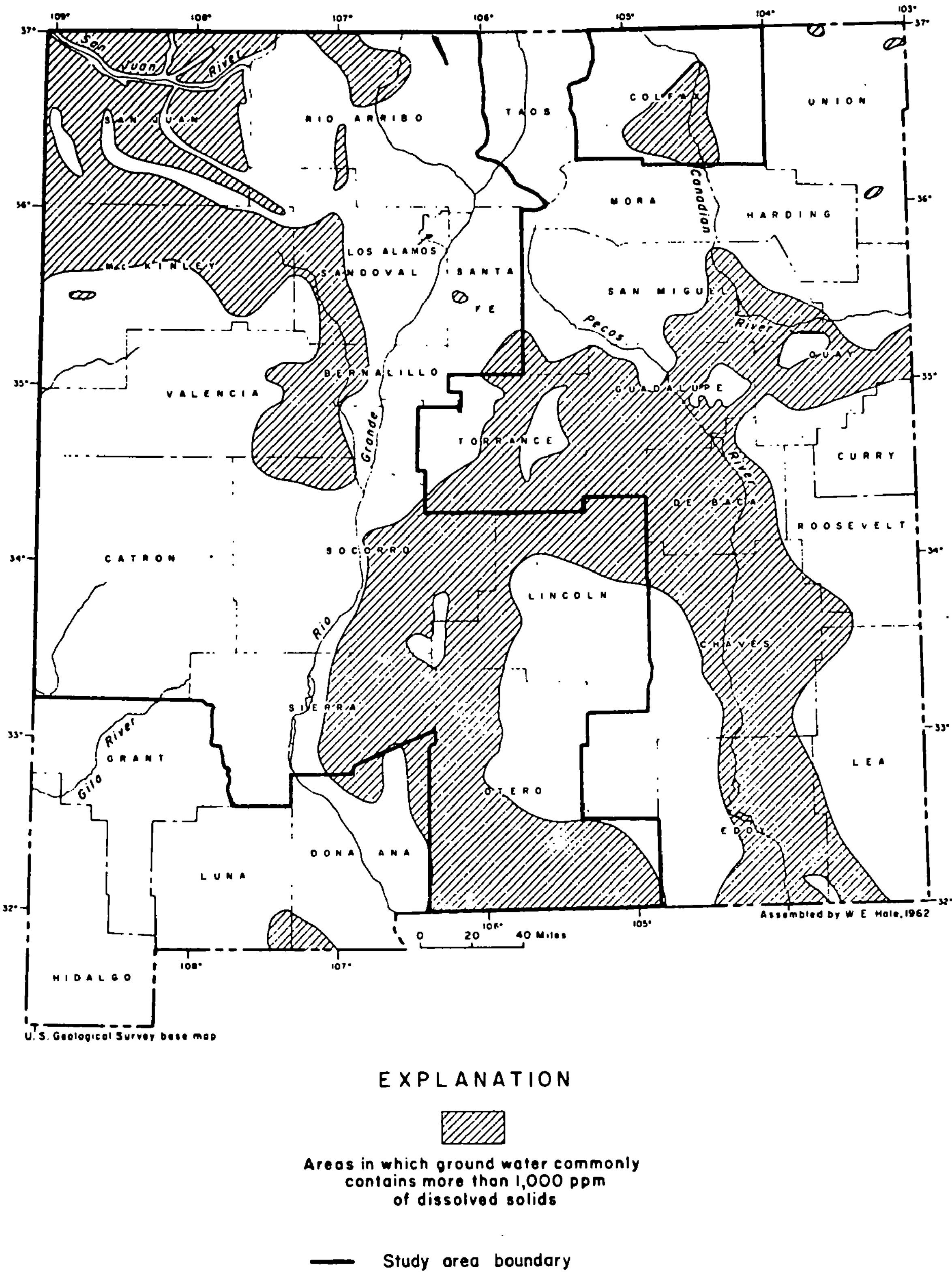


Figure 5-4. General quality of shallow ground water in New Mexico.

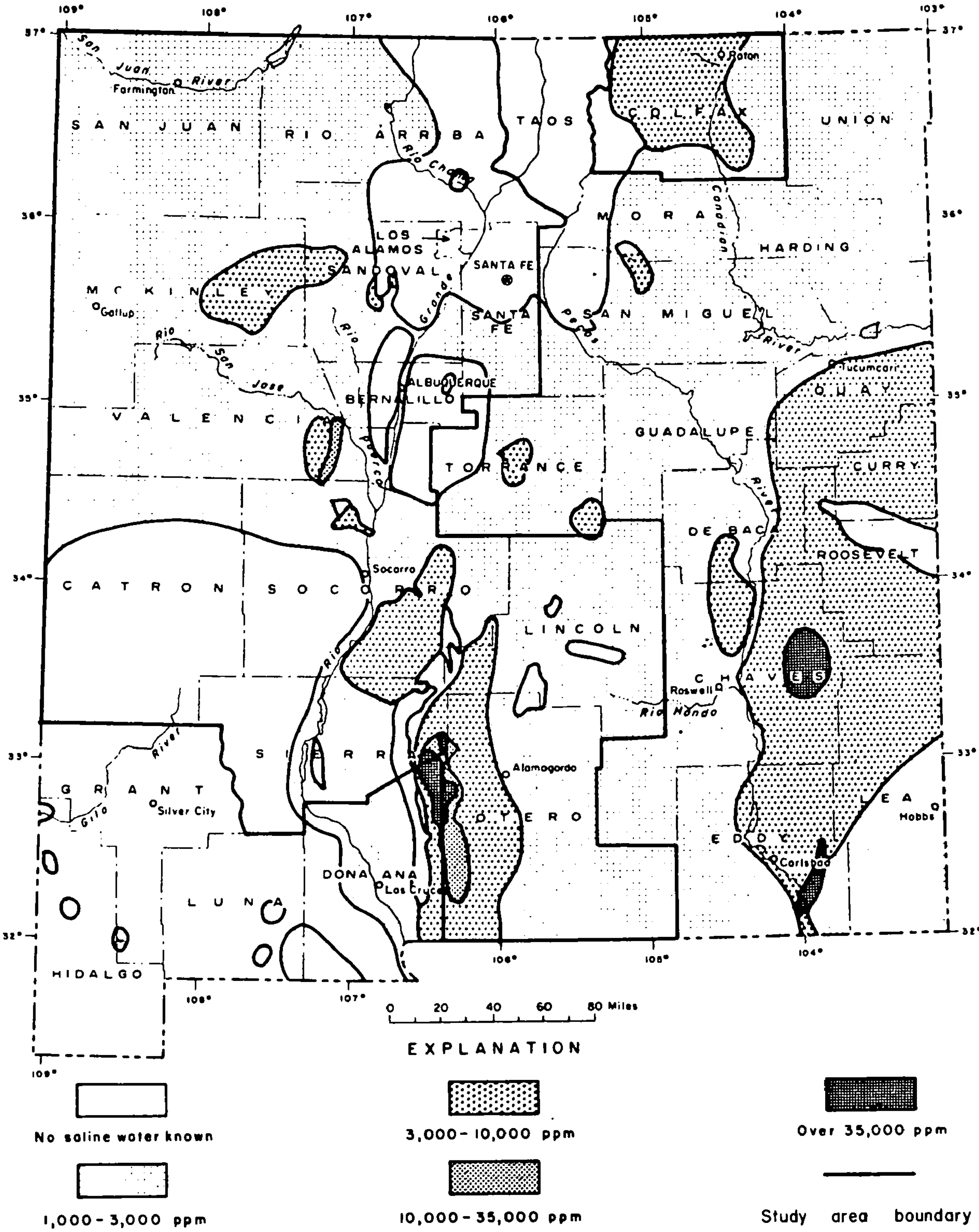


Figure 5-5. General occurrence of saline groundwater in New Mexico.

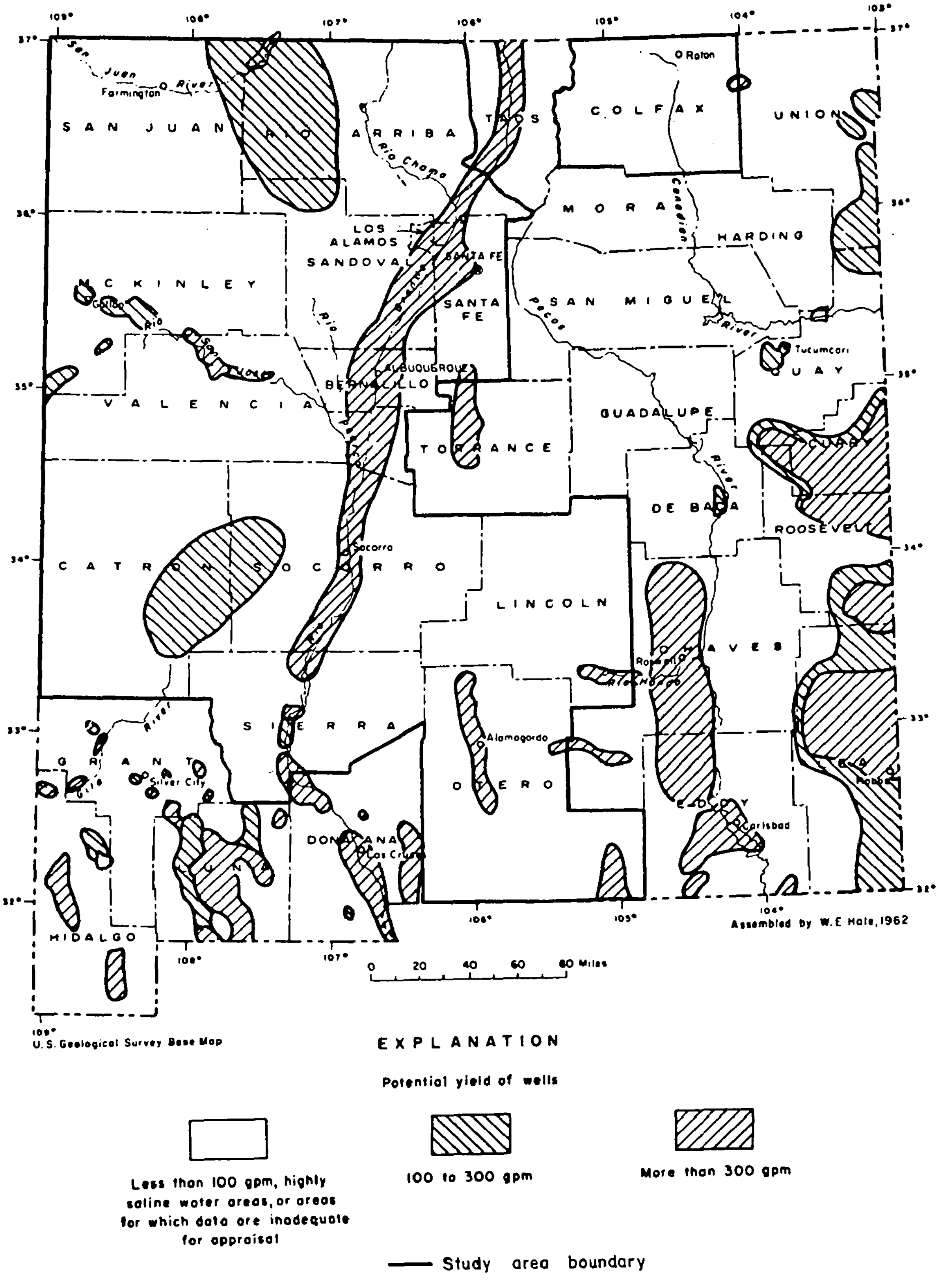


Figure 5-6. General availability of relatively fresh ground water in New Mexico.

Table 5-49. Chemical analysis of water in selected New Mexico counties.

Well Number	County	Date of Collection	Depth (meters)	Specific Conductance Micro mhos	Temperature (°C)	pH	Carbonate (mg/l)	Bicarbonate (mg/l)	Dissolved Solids (mg/l)	Dissolved Sulfate (mg/l)	Dissolved Chloride (mg/l)	Nitrogen $NO_2 + NO_3$ (mg/l)	Dissolved Iron (mg/l)	Dissolved Manganese (mg/l)	Hardness as $CaCO_3$ Total (mg/l)	Hardness as $CaCO_3$ Non Carbonate (mg/l)
350612106440901	Bernalillo	78-12-01	480.06	440	30.0	8.5	NA	NA	299	62.0	6.9	2.40	30	5	7	0
350851106322101	Bernalillo	79-04-25	512.06	700	28.0	7.7	NA	NA	-	-	-	-	-	-	-	-
350422106312601	Bernalillo	79-02-05	510.54	350	26.5	7.6	NA	NA	206	34.0	7.5	0.42	0	10	80	0
350410106310001	Bernalillo	79-03-21	518.16	400	25.0	7.6	NA	NA	249	53.0	9.6	0.61	20	10	120	0
350931106315501	Bernalillo	79-06-20	-	422	26.0	7.7	NA	NA	270	31.0	61.0	0.17	0	0	120	28
350835106314601	Bernalillo	79-06-01	469.39	280	26.0	7.6	NA	NA	184	17.0	7.1	0.22	10	20	76	0
342545108252001	Catron	79-08-03	-	1040	24.0	8.2	-	630	631	12.0	33.0	0.02	270	170	110	0
342200108571001	Catron	79-08-05	-	1020	20.0	7.9	-	660	664	8.4	34.0	0.02	130	110	110	0
340946109021601	Catron	79-06-26	3.96	-	19.8	-	-	0	315	40.0	5.8	0.08	100	50	150	0
342830108423001	Catron	79-07-17	-	460	16.0	7.8	-	240	262	19.0	10.0	1.20	10	3	130	0
340326107481801	Catron	79-08-30	-	312	-	8.1	-	-	225	15.0	14.0	1.60	10	2	140	0
340218107462201	Catron	79-08-30	-	-	12.6	-	-	-	280	17.0	16.0	1.30	10	6	140	0
340115107461701	Catron	79-08-02	-	-	12.6	-	-	-	299	49.0	9.6	0.20	50	1	120	0
343220108470001	Catron	79-08-04	-	487	14.0	7.7	-	200	284	22.0	33.0	3.00	0	5	120	0
335937107483301	Catron	79-08-21	-	-	-	-	-	-	498	51.0	18.0	0.13	60	2	3	0
335835107475001	Catron	79-08-13	-	420	18.0	7.8	0	140	250	53.0	14.0	0.52	670	10	31	0
335727107480501	Catron	79-07-13	-	310	18.0	7.9	0	-	185	13.0	19.0	3.70	60	10	75	0
33859107542401	Catron	79-08-29	-	240	26.0	8.3	0	140	180	14.0	8.9	0.77	120	1	42	0
335617108065501	Catron	79-07-11	-	-	33.8	-	-	-	1020	310.0	68.0	0.00	1600	100	440	0
335321107523901	Catron	79-08-29	-	310	25.0	9.2	18	100	215	14.0	19.0	0.58	200	0	8	0
335248108052901	Catron	79-08-30	-	400	17.0	8.6	4	170	286	37.0	27.0	2.40	10	3	24	0
334925108043201	Catron	79-07-12	-	330	32.0	9.0	24	120	246	23.0	13.0	0.90	50	< 1	3	0
335416108114201	Catron	79-08-30	-	360	15.0	7.9	0	160	232	14.0	18.0	4.00	40	10	130	0
335320108114001	Catron	79-08-30	-	610	14.0	8.7	16	294	469	17.0	32.0	23.00	320	8	11	0
335155108112101	Catron	79-08-30	-	2000	14.5	8.4	0	280	1180	190.0	380.0	.02	50	8	38	0
335037108102901	Catron	79-08-30	-	1620	15.0	9.7	120	340	< 996	140.0	150.0	.07	40	2	2	0
334927108133301	Catron	79-06-13	335.28	40800	14.5	6.7	-	-	-	100.0	16000.0	-	-	-	-	-
335311108180801	Catron	79-08-23	-	250	19.0	8.1	0	130	< 163	7.3	4.2	.51	10	5	83	0
335407108295801	Catron	78-11-29	-	240	20.0	8.0	-	-	170	4.3	4.4	.84	0	1	78	0
334819108084701	Catron	79-08-30	-	800	19.0	8.0	-	-	514	96.0	81.0	.84	150	30	130	0
334819108084501	Catron	79-08-30	-	550	15.0	8.0	-	-	345	59.0	32.0	6.30	50	20	63	0
335144108131301	Catron	79-08-30	-	1200	20.0	-	-	-	757	150.0	160.0	1.80	250	20	100	0
334748108193801	Catron	79-08-22	-	330	15.0	7.8	0	160	< 206	11.0	7.7	1.40	20	3	120	0
334746108184801	Catron	79-08-22	-	1180	21.0	-	-	-	757	32.0	120.0	.04	340	20	19	0
334602108171201	Catron	79-08-30	-	380	19.0	8.1	0	130	245	13.0	50.0	.35	20	0	63	0
334649108343301	Catron	79-08-22	-	200	10.0	7.4	0	66	< 145	34.0	2.3	.10	380	50	89	35
334347108032601	Catron	79-07-11	228.60	280	26.0	8.0	0	180	212	10.0	4.8	.29	40	2	96	0
334210108175101	Catron	79-08-22	-	180	15.0	7.5	0	52	< 153	45.0	4.2	.59	10	0	82	39
333946108222301	Catron	79-08-22	-	220	18.0	8.1	0	110	159	6.9	3.6	.31	670	0	66	0
333718108110201	Catron	79-08-23	471.48	210	28.0	8.5	6	86	< 157	7.9	4.5	.95	80	0	75	0
333403108134501	Catron	79-08-23	329.18	510	19.5	7.6	0	100	304	23.0	86.0	.53	20	0	160	79
364454104040401	Colfax	79-09-17	94.00	368	14.0	7.6	NA	NA	< 246	19.0	3.5	1.10	10	0	160	0
345751108380801	McKinley	79-06-20	12.19	2900	14.0	6.8	-	-	2940	1900.0	50.0	0.86	3200	-	1900	1600
350040108435801	McKinley	79-04-06	-	362	17.0	-	-	-	218	56.0	28.0	1.40	20	3	140	72
345931108461201	McKinley	79-08-21	374.90	2650	14.0	8.9	-	-	1980	900.0	350.0	0.02	40	40	39	0
35022818474201	McKinley	79-04-05	-	500	16.5	-	-	-	246	14.0	22.0	0.21	< 10	< 1	120	0
350626108345201	McKinley	79-06-18	-	420	14.0	7.6	-	-	319	39.0	19.0	0.80	10	-	160	0
350626108342901	McKinley	79-06-18	-	410	14.5	7.7	-	-	300	35.0	10.0	0.82	10	-	160	0
350538108593601	McKinley	79-09-05	62.18	360	17.5	8.4	-	-	263	23.0	34.0	7.30	20	5	150	43
350309108575201	McKinley	79-09-04	175.26	1540	28.5	8.3	-	-	969	320.0	51.0	0.11	40	20	17	0
351022108560401	McKinley	79-09-05	152.4	304	19.5	8.1	-	-	189	11.0	7.2	1.40	60	20	110	0
355446107204801	McKinley	79-07-24	16.46	6800	14.0	12.4	197	-	2500	24.0	69.0	0.05	90	0	10	0

Table 5-49. Chemical analysis of water in selected New Mexico counties (continued).

Well Number	County	Date of Collection	Depth (meters)	Specific Conductance Micro mhos	Temperature (°C)	pH	Carbonate (mg/l)	Bicarbonate (mg/l)	Dissolved Solids (mg/l)	Dissolved Sulfate (mg/l)	Dissolved Chloride (mg/l)	Nitrogen $NO_2 + NO_3$ (mg/l)	Dissolved Iron (mg/l)	Dissolved Manganese (mg/l)	Hardness as $CaCO_3$ Total (mg/l)	Hardness as $CaCO_3$ Non Carbonate (mg/l)
355437107220101	McKinley	79-08-02	41.76	2370	21.5	8.7	35	996	1700	490.0	40.0	-	20	10	12	0
355400107224201	McKinley	79-07-25	71.02	4000	16.0	8.8	-	840	2450	380.0	700.0	0.01	20	0	28	0
355447107224301	McKinley	79-07-25	55.47	1900	16.0	9.0	39	860	1350	290.0	31.0	0.05	0	1	7	0
355353107244501	McKinley	79-07-24	18.29	4600	15.5	8.1	24	1500	-	-	-	0.00	110	170	86	0
355811107534701	McKinley	79-08-20	1356.36	1580	23.5	8.4	-	-	1190	670.0	17.0	0.01	350	40	38	0
352306106275701	Sandoval	79-09-14	167.64	850	26.0	7.1	NA	520	632	34.0	44.0	0.14	< 10	< 1	280	0
355217106545701	Sandoval	78-11-27	847.34	3780	16.3	6.6	NA	-	2140	160.0	1200.0	-	16000	-	1500	1500
363113108333501	San Juan	79-09-24	3.35	2790	34.0	7.4	0	320	2070	1200.0	33.0	-	1500	54	280	17
363503108342101	San Juan	79-09-24	2.29	1730	34.0	0.0	0	340	1440	620.0	11.0	-	1900	1500	230	0
364325108353001	San Juan	79-03-17	2.90	3090	10.0	8.3	0	222	2060	1100.0	160.0	-	720	120	100	0
361503108243801	San Juan	79-09-21	2.44	7150	26.0	7.6	0	500	5970	4000.0	20.0	-	170	26	560	150
362145108310901	San Juan	79-09-21	2.47	2000	25.0	7.6	0	340	1710	770.0	10.0	-	30	210	210	0
361554108333201	San Juan	79-09-24	3.66	910	25.0	7.5	0	310	697	250.0	7.8	-	2600	640	97	0
362217108335701	San Juan	79-08-21	2.90	3490	-	7.2	-	-	2950	2100.0	32.0	2.1	30	0	1000	-
362213108340501	San Juan	79-09-21	2.29	1160	26.0	7.5	0	380	600	310.0	7.9	-	8300	1100	120	0
362212108340701	San Juan	79-09-21	11.58	1440	24.0	7.3	0	460	739	360.0	10.0	-	12000	820	110	0
362208108341201	San Juan	79-08-20	2.44	6250	-	7.7	-	-	5280	3500.0	85.0	1.5	40	2400	730	-
361142108220401	San Juan	79-09-21	-	1190	25.5	7.4	0	430	828	300.0	7.7	-	370	1500	66	0
360415108022201	San Juan	79-09-20	-	986	30.0	7.9	0	360	852	220.0	6.7	-	80	600	56	0
360621107582301	San Juan	79-09-20	-	1200	25.0	7.7	0	370	469	360.0	8.4	-	30	30	76	0
360733108103201	San Juan	79-09-21	2.29	1250	20.0	7.7	0	420	1170	330.0	10.0	-	40	40	150	0
361318108151401	San Juan	79-09-21	2.44	1940	22.5	7.6	0	380	1370	690.0	16.0	-	20	20	180	0
353257105492801	Santa Fe	79-09-12	18.90	460	14.5	7.1	NA	240	283	40.0	7.8	0.58	10	< 1	210	16
355006106093001	Santa Fe	79-09-12	333.15	355	23.5	8.3	NA	230	268	18.0	2.6	0.83	< 10	< 1	27	0
332727107410301	Sierra	79-04-04	133.81	220	17.5	8.5	-	120	156	6.6	3.6	1.40	10	2	20	0
332723107434501	Sierra	79-04-05	38.1	480	14.5	7.4	0	223	333	80.0	7.1	0.38	30	6	240	57
341520107375601	Socorro	79-07-10	-	520	-	7.8	0	150	396	150.0	7.8	0.90	10	< 1	180	57
341014106450810	Socorro	79-07-10	-	4000	40.0	8.3	-	-	3840	2600.0	68.0	0.97	40	290	2600	2400
340602107323101	Socorro	79-05-07	-	430	-	8.3	0	124	293	50.0	24.0	1.60	200	0	27	0
340656107401401	Socorro	79-08-30	-	210	-	8.4	0	120	145	9.5	0.4	1.20	10	0	28	0
340424107372701	Socorro	79-08-21	-	310	-	7.9	0	140	207	22.0	7.7	1.20	10	0	74	0
340238107402301	Socorro	79-08-31	-	270	-	-	-	-	-	14.0	9.1	10.00	-	-	-	-
335840107434001	Socorro	79-05-08	-	460	-	8.0	0	190	292	27.0	15.0	4.50	50	10	80	0
335112107430801	Socorro	79-08-23	-	310	-	8.0	0	130	221	16.0	5.1	0.98	10	0	86	0
334908106390801	Socorro	79-02-15	-	3470	-	7.6	-	-	-	-	-	-	-	-	-	-
334759107410201	Socorro	79-08-24	234.70	2100	-	7.5	0	120	< 1440	580.0	280.0	0.02	180	200	440	350
334347107470001	Socorro	79-03-30	176.79	250	-	7.9	0	142	183	5.5	4.0	0.48	10	0	100	0
334038107402201	Socorro	79-08-31	-	200	-	7.8	-	-	145	11.0	3.0	0.84	80	0	84	9
334032107431801	Socorro	79-08-24	-	310	-	9.0	4	110	186	18.0	4.8	0.62	40	0	19	0
323155107353501	Socorro	79-12-13	-	870	-	7.7	-	-	537	100.0	150.0	0.24	< 0	< 1	110	10
333322107353501	Socorro	79-04-18	-	900	-	7.9	-	-	-	270.0	9.2	-	-	-	-	-
333354107384901	Socorro	79-04-12	36.58	700	-	8.0	0	120	-	39.0	130.0	-	-	-	-	-
333257107404601	Socorro	79-04-11	-	290	-	7.5	0	150	201	19.0	5.5	1.8	40	2	120	0
343010108390001	Valencia	79-07-19	-	-	-	-	NA	NA	731	180.0	19.0	0.02	10	< 1	42	0
343756107523301	Valencia	78-10-30	-	1990	12.0	7.2	NA	NA	-	620.0	56.0	0.61	1200	120	390	4
343957108151601	Valencia	78-11-28	68.09	2130	12.0	8.5	NA	NA	1450	560.0	35.0	0.09	130	30	45	0
343905108182001	Valencia	79-08-10	-	-	-	-	NA	NA	260	22.0	12.0	0.00	10	60	120	0
344852108061901	Valencia	79-11-30	139.42	259	16.0	8.5	NA	NA	156	18.0	10.0	0.04	290	10	37	0
345217109020701	Valencia	79-06-19	-	1250	16.0	-	NA	NA	1010	480.0	45.0	0.01	3200	-	460	210
345619107505001	Valencia	78-11-30	62.79	893	13.0	7.6	NA	NA	634	250.0	10.0	1.70	20	10	390	130
345333107513401	Valencia	78-11-13	78.03	727	13.0	7.8	NA	NA	-	170.0	9.4	1.80	1300	90	320	100

Table 5-49. Chemical analyses of water in selected New Mexico counties (concluded).

Well Number	County	Date of Collection	Depth (meters)	Specific Conductance Micro mhos	Temperature (°C)	pH	Carbonate (mg/l)	Bicarbonate (mg/l)	Dissolved Solids (mg/l)	Dissolved Sulfate (mg/l)	Dissolved Chloride (mg/l)	Nitrogen $NO_2 + NO_3$ (mg/l)	Dissolved Iron (mg/l)	Dissolved Manganese (mg/l)	Hardness as $CaCO_3$ Total (mg/l)	Hardness as $CaCO_3$ Non Carbonate (mg/l)
345706108015701	Valencia	78-11-02	-	342	12.0	7.9	NA	NA	-	16.0	6.5	1.40	0	6	140	0
345450108404601	Valencia	79-08-31	-	700	-	8.3	NA	NA	532	210.0	5.9	0.14	50	20	18	0
345455108575401	Valencia	79-06-19	-	1370	28.0	8.1	NA	NA	966	450.0	43.0	0.25	20	-	470	250
345438108570201	Valencia	79-06-19	-	1050	22.0	7.0	NA	NA	761	310.0	32.0	0.01	10	-	520	250
345245108591901	Valencia	79-08-21	-	1060	18.0	7.6	NA	NA	725	370.0	21.0	0.02	< 10	110	210	56

- = Unknown

Source: USGS. 1979. Water Resources Data for New Mexico. Albuquerque NM, 747 p.

5.3.2 Pecos River Basin

The Pecos River Basin occurs in several physiographic provinces. The headwaters of the Pecos River are in the southern Rocky Mountain Province of the Rocky Mountain System. The headwaters of tributary streams from the west are in the Sacramento section of the Basin and Range Province of the Intermontane Plateaus. The remainder of the basin, or the Pecos River Valley Section, is in the Great Plains Province of the Interior Plains. Portions of Lincoln and Otero counties in the Study Area are located in the Pecos River Basin.

5.3.2.1 Quantity

In the northern half of the Pecos River Basin groundwater development is primarily for public supply, rural, domestic, and livestock uses. In the southern half of the basin groundwater is used extensively for irrigation.

Important aquifers in the Pecos River Basin occur in sedimentary rocks (Figure 5-7). The generalized stratigraphic section presented in Table 5-50, reveals the geologic formations and water-bearing characteristics. Most of the water-bearing rock formations in the Pecos River Basin are found in the plains areas. Large scale withdrawal of groundwater in the south-central part of the basin has resulted in a long-term net loss of groundwater storage. The alluvial aquifers are generally stream connected and usually are recharged by local precipitation and floods. Yields of over 300 gallons per minute are derived from alluvial or limestone aquifers. Data on well characteristics and extreme high and low water levels of wells located in Lincoln County and Otero County are presented in Table 5-48.

5.3.2.2 Quality

The groundwater quality in the Pecos River Basin generally is acceptable for domestic uses with no treatment other than disinfection. The quality of groundwater presents few problems in the northern part of the basin. However,

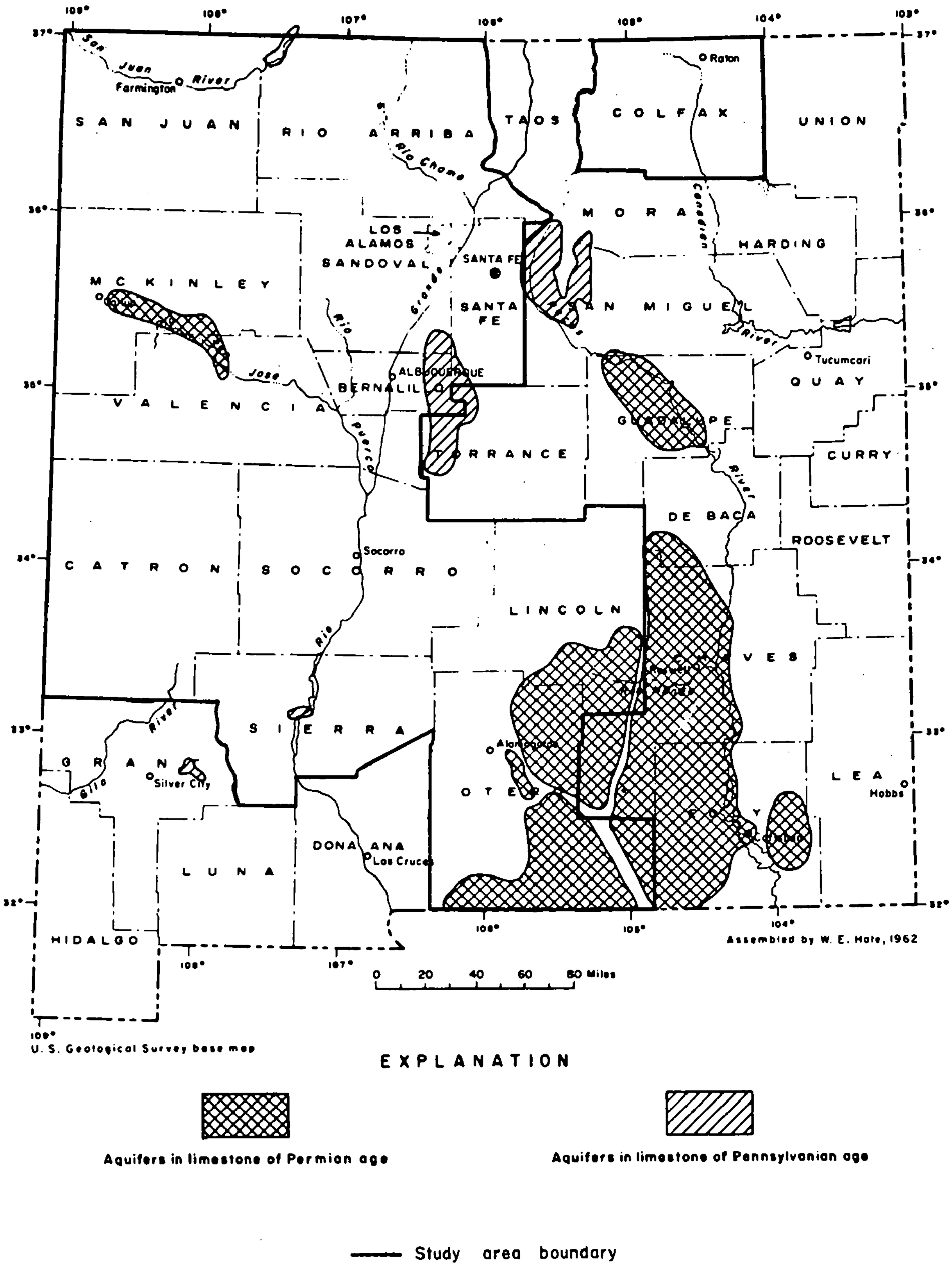


Figure 5-7. Principal limestone aquifers in New Mexico.

Table 5-50. Generalized stratigraphic section in the Pecos River basin, New Mexico.

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Quaternary	*Alluvium	0 to 350±	Thick in lowland areas, thin in upland areas, in all parts of basin.	Gravel, sand, and silt; caliche, lime-cemented conglomerate.	Yields 2 to 3,500 gpm. Large yields are in Pecos Valley, Hondo Valley, and near Carlsbad. Generally usable for domestic supply, satisfactory for irrigation and stock use. Yields fresh to highly saline water.
	Bolson deposits, dune sand, alluvial fans.	-	Scattered distribution in most areas of basin.	Boulders, sand, unsorted rock debris.	Not generally utilized as a source of water.
Quaternary(?) and Tertiary(?)	*Alluvium	0 to 500±	Southeast of Carlsbad.	Fluvial gravel, sand, and silt.	Yields small quantity of saline to moderately saline water.
	Pediment gravel	0 to 50±	Mostly in central part of basin.	Gravel, sand, caliche.	Not utilized as a source of water.
Tertiary	*Ogallala Formation	0 to 300±	Mostly in northern part of basin.	Silt, sand, gravel, sandstone, conglomerate, and caliche.	Yields 0.2 to 1,600 gpm. Generally fresh water. Large yields in Quay, Curry, and Roosevelt Counties.
Tertiary(?)	*Intrusive and extrusive igneous rocks	-	Scattered distribution in most areas of basin.	Andesite, diorite, microgranite, and rhyolite dikes, sills, and stocks.	Yields a few gpm to wells; generally fresh water.
Cretaceous(?)	*Cub Mountain Formation of Bodine (1956)	0 to 500±	Western part of Rio Hondo drainage basin.	Sandstone, pebble, conglomerate, shale.	Yields 5 to 50 gpm. Generally yields fresh water.
Cretaceous	*Mesaverde Formation	0 to 540±	Western part of Lincoln County.	Sandstone, shale, coal, and carbonaceous shale.	Yields 5 to 20 gpm. Generally yields slightly to moderately saline water.
	*Mancos Shale	0 to 400±	Western part of Lincoln County.	Shale, limestone, sandstone.	Yields 6 to 75 gpm. Generally yields moderately saline water.
	*Greenhorn Limestone and Graneros Shale	0 to 260±	San Miguel County.	Limestone, shale, sandstone.	Yield about 5 gpm of slightly to moderately saline water.
	*Dakota Sandstone	0 to 130±	Western part of Lincoln County, Quay and San Miguel Counties.	Sandstone, shale, and conglomerate.	Yields 5 to 125 gpm of fresh water to wells.
Jurassic	*Morrison Formation	0 to 400±	San Miguel and Guadalupe Counties.	Clay, shale, sandstone.	Yields about 2 gpm of fresh to slightly saline water to wells.
	*Entrada Sandstone	0 to 240±	do.	Sandstone, limestone, and siltstone.	Yields about 5 gpm of fresh to slightly saline water to wells.
Triassic	*Chinle Formation	0 to 1,000±	Most parts of basin except Roswell artesian basin west of Pecos River.	Shale, clay, siltstone, sandstone, and limestone.	Yields 0.1 to 50 gpm of fresh to slightly saline water to wells.
	*Santa Rosa Sandstone	0 to 380±	Most parts of basin except Roswell artesian basin.	Sandstone, limestone, shale, and pebble conglomerate.	Yields 1 to 750 gpm of fresh to slightly saline water.
Permian	Dewey Lake Redbeds	0 to 350±	Eddy and Lea Counties.	Siltstone; sandy shale, shale, and sandstone.	Not known to yield water to wells in basin.
	*Rustler Formation	0 to 500±	do.	Gypsum, siltstone, claystone, sandstone, halite, and dolomite.	Yields about 10 gpm of slightly to moderately saline water.
	Salado Formation	0 to 1,000	do.	Halite interbedded with anhydrite, thin clastic rocks, and beds of potash ore.	Yields no water to wells as the formation is relatively impermeable.
	*Castile Formation	0 to 2,500	Subsurface in Eddy and Lea Counties.	Anhydrite, banded layers of anhydrite and bituminous calcite; local beds of salt.	Yields small quantities of slightly saline water to stock wells mostly in the Black River valley and adjacent areas.
	Artesia Group				
	*Tansill Formation	125	West of Carlsbad.	Dolomite, limestone, siltstone, and gypsum.	Yields large quantities of fair to slightly saline water to wells at Carlsbad.
	*Yates Formation	250 to 300	do.	Dolomite, limestone, sandstone, siltstone, gypsum, and clastic rocks.	Yields small quantities of fresh water to wells.
	*Seven Rivers Formation	270 to 400	Chaves and Eddy Counties	Dolomite, limestone, sandstone, and siltstone.	Yields small quantities of fresh water to many wells; yields of 2,000 gpm or more in the area from Lake McMillan to just below Major Johnson Springs.
	*Queen Formation	325 to 400	do.	Dolomite, sandstone, and siltstone.	Yields small quantities of fresh to slightly saline water.
	*Grayburg Formation	475	do.	do.	Yields moderate to large quantities of fresh water.
	*Artesia Formation (Same age as Artesia Group)	0 to 1,000±	Underlies most parts of the basin.	Gypsum, anhydrite, dolomite, impure limestone, siltstone, shale, and sandstone.	Yields as much as 200 gpm of slightly saline water in many parts of basin. Slightly to highly saline quality in eastern part of Rio Hondo Drainage Basin.
	*Capitan Limestone (Same age as Artesia Group)	1,000 to 1,500	Eddy County.	Limestone.	Yields large quantities of fresh water to wells. Yields saline water east of Carlsbad.
	Goat Seep Limestone	-	do.	do.	Not developed by wells because of great depth.
	Bell Canyon, Cherry Canyon, and Brushy Canyon Formations (Same age as Artesia Group)	-	do.	Sandstone, shaly sandstone, carbonate rocks.	Yield no water to wells or springs in the basin. Sandstones contain salt water.
	*San Andres Limestone	0 to 1,500	Underlies most parts of basin.	Limestone, dolomite, sandstone, siltstone, shale, gypsum, and anhydrite.	Yields 8 to 2,000 gpm of fresh water to wells. Very saline water east of Pecos River and in extreme eastern part of Rio Hondo Drainage Basin.
	*Glorieta Sandstone (Also Hondo Sandstone Member of San Andres Limestone)	0 to 160	do.	Sandstone, silty limestone, siltstone, gypsum, and anhydrite.	Yields to 700 gpm of fresh water.
	*Yeso Formation	1,000± to 2,000±	do.	Siltstone, limestone, sandstone, shale, gypsum, anhydrite, and salt.	Yields 1 to 125 gpm of slightly to moderately saline water.
Pennsylvanian	*Sangre de Cristo Formation	600 to 1,000	San Miguel County.	Shale and sandstone.	Yields small quantities of fresh water.
	*Magdalena Group	0 to 2,000	do.	Sandstone, shale, and limestone.	Yields small to large quantities of fresh water.
Precambrian	*Metamorphic and igneous rocks	-	Outcrops in San Miguel and Torrance Counties, underlies most of basin.	Gneiss, schist, quartzite, granitic rocks, and pegmatite.	Yields small quantities of fresh to slightly saline water.

*Known or probable aquifer, regardless of areal extent or production potential.

Source: New Mexico State Engineer Office. 1967.

in the southern part of the basin, the encroachment of saline water in fresh artesian aquifers is threatening irrigation and municipal supplies. Approximately 361 hm^3 (280,580 acre-feet) of groundwater is depleted from the Pecos River Basin annually by beneficial uses (State Planning Office 1967). The largest single depletion is for irrigation.

5.3.3 Central Closed Basins

The Central Closed Basins are all in the Basin and Range Physiographic Province. They consist of the Entancia Basin, Tularosa Jornada del Mueto Basin, and Salt Basin (Figure 5-1). In general, there is considerable relief between the central part of each basin and the higher mountainous ridges. Portions of Socorro, Lincoln, Sierra, and Otero counties are included in the basin.

5.3.3.1 Quantity

The major source of water in the Estancia Basin is the alluvium (Figures 5-7 and 5-8). The Maclera Limestone in the west, Glorieta Sandstone in the north, and Yeso Formation in the southern and northeastern parts of the valley also yield considerable quantites of water (Table 5-51). The total volume of stored groundwater is roughly estimated at 2,500 hm^3 (2 million acre-feet); all of this amount is not readily available. Between 1948 and 1960, the level of groundwater in the Estancia Basin near Moriarty dropped as much as 7.6 m (25 feet).

Groundwater in the Tularosa Basin is located in a large alluvial deposit. The only sources of fresh groundwater in this basin occur in a long narrow band around Tularosa and Alamogordo, and in the southwestern part of the basin. An estimated 9,000 hm^3 (7.3 million acre-feet) of fresh groundwater occurs in the aquifers in this basin.

In the Jornada del Muerto Basin, groundwater in sufficent quantities for watering stock is found at depths ranging from 9 m to about 120 m (30 to about

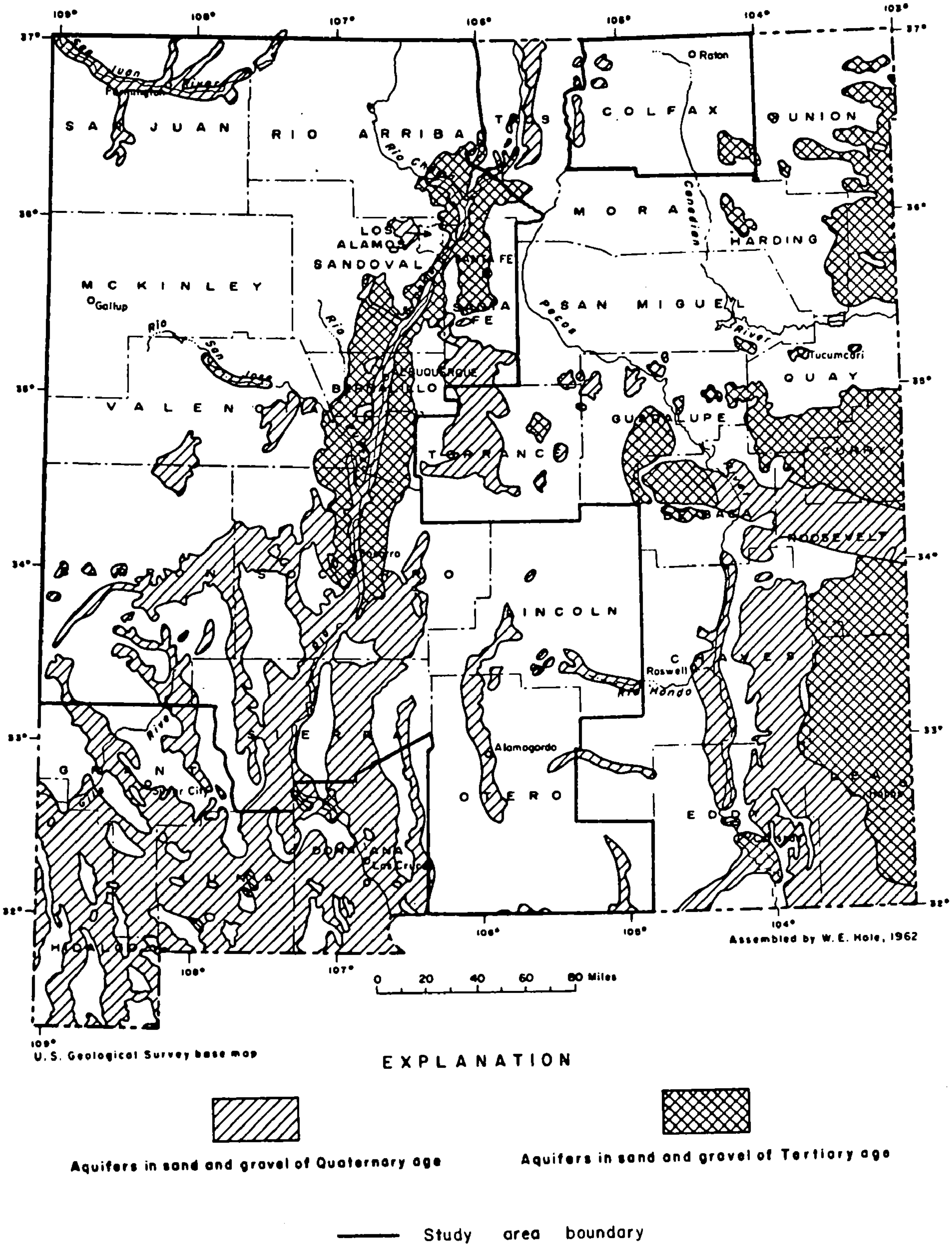


Figure 5-8. Principal sand and gravel aquifers in New Mexico.

Table 5-51. Generalized stratigraphic section in the Central closed basin, N.M.

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Quaternary	Pediment, terrace, dune, playa, and other surficial deposits	Generally thin, but dunes may reach 40	Pediment and terrace deposits on bajadas. Dunes on valley flats and bajadas.	Gravel, sand, and silt; generally unconsolidated, but terrace deposits may be cemented by caliche.	Only playa deposits known to contain water, this water highly saline.
	*Alluvium in present stream channels	Generally thin; probably less than 10	Perennial and intermittent stream channels.	Unconsolidated sand and gravel.	Probably will yield small quantities of water to shallow wells where locally recharged by perennial streams; otherwise usually above zone of saturation.
	Surficial volcanic rocks	0 to 300(?)	Large flows in northern parts of Jornada del Muerto and Tularosa basin.	Massive to vesicular basalt with local breccia and scoria.	Not generally a water-yielding unit, but is recharge area for underlying aquifers.
	Lacustrine sediments	Probably 300 in Estancia and Salt basins, unknown in Tularosa basin	Central valley floors of Estancia, Tularosa, and Salt basins.	Unconsolidated silt and clay, thin-bedded to minutely laminated; may contain few thin sand and gravel beds.	Yields small to large volumes of very highly saline water to wells.
Quaternary and Tertiary(?)	*Alluvial bolson sediments	0 to 300 in Estancia basin; 0 to 1,000+ in Jornada del Muerto; 0 to 4,900 in Tularosa basin; 0 to 500 in Salt basin	Basin-filling sediments, interfinger with lacustrine sediments in centers of all but Jornada del Muerto.	Unconsolidated to compacted and moderately consolidated silt, clay, sand and gravel. Generally coarse near upland sources at basin sides, finer and better sorted toward basin centers.	Yields small to large volumes of potable to saline water to wells. Largest yields obtained from wells on bajadas penetrating thick sections of moderately well-sorted sand and gravel, maximum yields: Estancia basin, 2,380 gpm; Jornada del Muerto, 1,000+ gpm; Tularosa basin, 1,000+ gpm; Salt basin, 840 gpm. Potable water mostly from wells on bajadas near sides of basin, grades to saline water toward basin centers and commonly at depth.
Quaternary(?) and Tertiary(?)	*Santa Fe Group	Maximum probably about 2,000 on west side of area	Southern and northwestern parts of Jornada del Muerto.	Poorly consolidated, thin-bedded silt, clay, sand, and gravel.	Yields large quantities of water to deep wells in Rio Grande trough and probably would also where thick in Jornada del Muerto.
Tertiary	Rhyolitic to andesitic volcanic rocks (includes Datil Formation)	Maximum probably 2,000	Crops out locally on both sides of Jornada del Muerto and Tularosa basin; presumed to underlie parts of both basins.	Massive, to thin-bedded flows, locally interbedded sandstone, conglomerate, tuff.	Usually will yield no water. Locally, small quantities might be developed from interbedded clastic rocks.
	Clastic sedimentary units including Love Ranch, Palm Park**, Baca, and Thurman** Formations	Maximum probably 2,000 to 3,000	do.	Interbedded sandstone, siltstone, shale, conglomerate, tuff.	Water-bearing characteristics mostly unknown. Probably will yield small quantities of water to wells in much of area of occurrence.
Tertiary(?) and Cretaceous(?)	*Cub Mountain Formation of Bodine (1956)	500 to 1,000	East side of Tularosa basin in vicinity of Three Rivers and Carrizozo.	Sandstone, siltstone, and shale.	May yield small quantities of potable water to a few wells.
	*McRae Formation**	About 3,000	Central and northwestern Jornada del Muerto.	Conglomerate, siltstone, and shale with locally interbedded andesitic tuff and breccia.	Do.
Cretaceous	*Mesaverde Group	500 to more than 2,000	Northern parts of Estancia basin, Jornada del Muerto, and Tularosa basin.	Shale, siltstone, and sandstone with interbedded local coal.	Sandstone beds may yield small amounts of water, generally of saline to slightly saline quality.
	*Mancos Shale	Maximum thickness more than 1,000	do.	Dark-gray, marine shale, locally with thin interbedded sandstone and limestone.	Do.
	*Dakota Sandstone	50 to 300	do.	Fine-grained, quartzitic sandstone with interbedded carbonaceous shale.	Do.
Triassic	*Dockum Group	0 to about 1,000	Northern parts of Estancia basin, Jornada del Muerto, and Tularosa basin. Depositional wedge-out to south. Wedge edge crosses centers of Jornada and Tularosa basin	Red, purple shale and siltstone with interbedded sandstone.	Sandstone will yield small to moderate quantities of water to wells. Water generally of poor quality.
Permian	*San Andres Limestone	250 to 700	Crops out on east and south and underlies center of Estancia basin; crops out and underlies central and northern Jornada del Muerto and Tularosa basin.	Limestone, dolomite, sandstone, gypsum.	Yields generally nonpotable water to some wells on southern Chupadera Mesa. Not known to yield water in Estancia basin.
	*Glorieta Sandstone	50 to 300	Crops out on east and south and underlies center of Estancia basin, crops out around and underlies northern Jornada del Muerto and Tularosa basin.	Sandstone, usually well cemented.	Yields up to 3,000 gpm to wells where intensely fractured as in north-central Estancia basin; elsewhere, where saturated, may yield small to moderate quantities.
	*Yeso Formation	Few Hundred to about 4,000	Widespread; crops out in or underlies much of Central closed basins area.	Sandstone, shale, gypsum, limestone.	Commonly yields small to moderate quantities of generally nonpotable water to wells; locally in Estancia Valley up to 3,000 gpm is probably derived from fractured and cavernous limestone of the Yeso.
	*Bone Spring Limestone	1,600 where cropping out in Guadalupe Mountains	Crops out around and underlies most of Salt basin. Interfingers with Yeso and lower part of San Andres to north.	Cherty, cavernous limestone, and siliceous shale.	Yields up to 3,600 gpm (with 10 feet of drawdown) to irrigation wells in Crow Flats area of Salt basin.
	*Abo Formation	300 to 1,400	Crops out around and underlies Estancia basin, and most of Jornada del Muerto and Tularosa basin. Interfingers with Hueco Limestone to south.	Shale with interbedded sandstone, and arkose.	Yields small quantities of water southwest of Estancia basin; elsewhere not important as aquifer.
	*Bursum Formation	300 to 400	do.	Arkose, limestone, and shale.	Where saturated may yield small quantities of water to wells.
	Hueco Limestone	300 to 1,500	Crops out in Hueco Mountains between Salt basin and Tularosa basin, in Sacramento Mountains, and in San Andres Mountains. Thins northward.	Mostly limestone.	Not important as an aquifer.
Pennsylvanian	*Magdalena Group	1,000 to 3,100	Crops out around all but Salt basin; underlies all basins, usually at great depth.	Limestone with interbedded shale, sandstone, and arkose.	Yields small quantities of generally potable water in and near outcrop areas.
Mississippian	Sedimentary rocks	Variable but 1,400 maximum	Crop out around and underlie centers of all basins.	Sandstone, shale, and limestone.	Not important as aquifers.
Devonian	Sedimentary rocks	80 to 100	Crop out in Sacramento and San Andres Mountains and elsewhere around basins.	Thin units of shale, siltstone, and limestone.	Do.
Silurian	Fusselman Dolomite	0 to 1,000	Crops out in Sacramento Mountains and southern part of San Andres Mountains. Thins northward.	Massive, relatively pure dolomite.	Do.
Ordovician	Montoya Dolomite	0 to 400	do.	Massive dolomite and limestone.	Do.
	and El Paso Limestone	0 to 1,600	do.	Massive limestone and dolomite.	Do.
Ordovician and Cambrian	Bliss Sandstone	0 to 225	Crops out in Sacramento and San Andres Mountains. Thins northward.	Sandstone, quartzite, and shale.	Not important as aquifers.
Precambrian	*Metamorphic and igneous rocks	-	-	Igneous and metamorphic rocks.	Yields small quantities of water to a few springs in outcrop areas.

*Known or probable aquifer, regardless of areal extent or production potential.

Source: New Mexico State Engineer Office. 1967.

400 feet). An estimated 2,100 hm^3 (1.7 million acre-feet) of freshwater is stored in this basin, of which 1,850 hm^3 (1.5 million acre-feet) is in the southern area (Herrick and Davis 1965).

The Bolson Alluvium in the Salt Basin yields about 3.2 m^3/m (840 gpm) of water. The Bone Spring Limestone is a prolific bedrock aquifer penetrated by many irrigation wells, and yields as much as 13.7 m^3/m (3,620 gpm) with only .3 meters (10 feet) of draw down. A rough estimate of the freshwater storage capacity in the Salt Basin is 620 hm^3 (500,000 acre-feet).

5.3.3.2 *Quality*

Limited monitoring of the quality of groundwater is conducted in the Central Closed Basins. The chemical characteristics of groundwater in the Central Closed Basin are presented in Table 5-49. Areas of high quality water usually occur around the edge of each basin, whereas the center of each closed basin contains highly saline water.

Information from groundwater samples from wells in Estancia, Mountairian, Manzano, Moriarty and Tajique indicate available water of suitable quality for all beneficial uses. The water supply system in Moriarty pumps water of about 1,300 ppm total dissolved soilds (TDS), which exceeds the recommended 1,000 ppm concentration.

Most of the freshwater in Tularosa Basin is in the extreme southwest and to the east in the vicinity of Alamogordo. Groundwater of good to inferior quality can be obtained north of Alamogordo along the east side of the basin. Small areas of potable water occur elsewhere in the basin in areas such as Mockingbird Gap. Good quality groundwater is present in the western and southern ends of the Jornada del Muerto Basin. Water of good to inferior quality can be obtained in all but the northern part of the basin. Groundwater in large quantities suitable for irrigation is obtained west of the alkali flat, an area that occupies the central part of the basin.

5.3.4 Rio Grande River Basin

The Rio Grande River Basin in New Mexico includes parts of several physiographic provinces: Southern Rocky Mountains Province, Navajo and Datil sections of the Colorado Plateaus Province, and the Mexican Highland Section of the Basin and Range Province. Most of the Rio Grande River Basin is in the Study Area.

5.3.4.1 Quantity

Aquifers in the Rio Grande River Basin are generally separated into two groups: the valley fill, and bedrock. Valley fill aquifers usually are stream connected and recharged primarily from streamflow. Valley fill aquifers are the most reliable aquifer for large quantities of water in the basin. Yields of water in the Albuquerque area range from 0.91 to 7.6 m^3/m (240 to 2,000 gpm) and average 3.3 m^3/m (860 gpm). The valley fill aquifer along tributary streams is a less reliable aquifer. Wells in Rio San Jose yield about 0.04 to 0.4 m^3/m (10 to 100 gpm), and wells in the valley fill along the Pojoque River in Santa Fe County yield from less than 0.04 to more than 1.1 m^3/m (10 to 275 gpm).

Bedrock aquifers in the Rio Grande River Basin consist of sandstone, conglomerate, or limestone. Generally, beds of shale, mudstone, siltstone, or clay yield little or no water directly to wells. Generalized physical properties and water-bearing characteristics of formations are presented in Table 5-52. Known and probable aquifers are designated by an asterisk in the stratigraphic-unit column. Depth to groundwater in this basin is presented in Figure 5-3.

5.3.4.2 Quality

The quality of groundwater in the upper Rio Grande River Basin is generally good. Near the confluence of Rio Chama Creek and El Rito Creek, slightly saline groundwater containing 1,000 to 3,000 ppm total dissolved

Table 5-52. Generalized stratigraphic section in the Rio Grande basin, New Mexico.

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Quaternary	*Alluvium	Generally thin; less than 100	Perennial stream channels, flood plains, and locally in dry arroyos.	Unconsolidated silt, sand, and gravel.	Recharged from streamflow; generally yields small to moderate quantities of water to wells; may yield large quantities locally.
	*Pediment, terrace, and bajada deposits	May be as much as 200	Along streams and adjacent to mountains. Terraces are prominent along the Santa Fe River.	Generally unconsolidated silt, sand, gravel, and boulders. Gravel and boulder deposits may be lenticular.	Recharged by surface flow and by direct precipitation. Water generally is less abundant than in stream alluvium; may yield small to large quantities of water to wells.
Quaternary and Tertiary	*Volcanic complex	0 to 2,600+	Caps many mesas and occurs as channel deposits, dikes, sills, and interbedded with sedimentary rocks in most of the Rio Grande basin.	Basalt, andesite, rhyolite, latite, pumice, and tuff.	May yield small to large quantities of water to wells; yield depends primarily on fracture permeability and saturated thickness. Generally is not a principal or reliable aquifer.
Quaternary(?) and Tertiary	*Santa Fe Group	0 to 9,000±	Fills the Rio Grande trough.	Clay, silt, sand, and gravel conglomerate; mostly unconsolidated. Contains volcanic material locally.	Yields large quantities of water (as much as 2,500 gpm, locally) to deep wells. This is the most extensive and reliable aquifer in the Rio Grande basin.
Tertiary	Galisteo Formation	900 to 4,500	Exposed in valleys near Cienega in Santa Fe County; probably underlies Albuquerque area at great depth.	Sandstone, sand, clay, and shale; also may contain some conglomerate.	Low permeability where tested south of Santa Fe. Formation lies at great depth elsewhere in the basin and uneconomical to tap.
	Sedimentary rocks	0 to 6,000+	Sedimentary rocks are present throughout the Rio Grande basin; however, abundant nomenclature prohibits extensive treatment here.	Sandstone, siltstone, shale, and some conglomerate.	Generally yield small quantities of water to wells; locally, beds of sandstone might yield moderate quantities; and cumulative yield from many beds of sandstone could be large.
Cretaceous	*Ojo Alamo Sandstone	70 to 200	San Juan (structural) basin.	Coarse-grained, conglomeratic sandstone.	Known to yield 2 to 30 gpm.
	Kirtland Shale and Fruitland Formation	100± to 600±	do.	Shale, sandy shale, siltstone and interbedded sandstone.	Beds of sandstone of low permeability might yield small quantity of water. Generally not considered as an aquifer.
	*Pictured Cliffs Sandstone	35 to 75	do.	Thin- to thick-bedded sandstone with interbedded siltstone and shale.	Low porosity and low permeability. Generally not considered as an aquifer; however, may yield small quantities of water locally.
	Lewis Shale	600 to 1,400	do.	Fissile clay shale with interbedded siltstone, sandstone, and limestone.	Generally does not yield water; thin beds of sandstone in lower part might yield small amount of water, but it probably is saline.
	*Mesaverde Group	250 to 2,500±	Primarily in the San Juan (structural) basin; underlies most of the Rio Grande basin at great depth.	Shale with interbedded sandstone and coal.	Sandstone may yield small to moderate quantities of water; not tapped in many areas because of great depth.
	*Mancos Shale	350 to 2,500	Crops out at edge of San Juan (structural) basin and underlies most of the Rio Grande basin at great depth.	Dark-gray, marine shale, sandstone interbedded near the base locally.	Beds of sandstone might yield small quantities of water.
	*Dakota Sandstone	25 to 245	San Juan (structural) basin and most of Rio Grande basin.	Sandstone with interbedded carbonaceous shale.	Yields small to moderate quantities of water to wells; not tapped at many places because of great depth. Water quality probably best near outcrops.
Jurassic	*Morrison Formation	210 to 910	San Juan (structural) basin; may underlie other parts of the Rio Grande basin, but probably at great depth.	Variegated shale, claystone, and siltstone with interbedded sandstone.	Yields small to moderate quantities of water to wells; depends on saturated thickness of sandstone.
	*Bluff Sandstone	75 to 150	San Juan (structural) basin; this formation or its equivalent may underlie other parts of the Rio Grande basin.	Sandstone.	May yield small quantities of water to wells where saturated. Generally has low permeability.
	Summerville Formation	60 to 120	do.	Sandstone, siltstone, and sandy shale.	Not known to yield water to wells.
	Todilto Limestone	0 to 100	do.	Gypsum and fissile limestone.	Yields very little water to wells. Water generally has high sulfate content.
	*Entrada Sandstone	150 to 250	do.	Cross-bedded sandstone.	May yield small quantities of poor quality water to wells.
Triassic	*Chinle Formation	600 to 1,600	do.	Mudstone and siltstone with interbedded sandstone.	Sandstone may yield small to moderate quantities of generally poor quality water; quality is best close to the outcrops.
Permian	*San Andres Limestone	50 to 1,000	Probably widespread and crops out in or underlies most of Rio Grande basin.	Limestone, sandstone, siltstone, and gypsum.	Fracture or solution-channel permeability. May yield large quantities of water to wells. (Yields as much as 3,000 gpm near Grants.) Water quality is variable and is best close to the outcrops.
	*Glorieta Sandstone	70 to 300	San Juan (structural) basin. This formation or its equivalent may underlie other parts of the Rio Grande basin.	Thick-bedded to massive sandstone.	May yield moderate quantities of water to wells.
	*Yeso Formation	200 to 1,100	Widespread; crops out in or underlies most of Rio Grande basin.	Siltstone, sandstone, and shale.	May yield small to moderate quantities of water to wells.
	*Abo Formation	300 to 1,100	do.	Arkosic sandstone, siltstone, and shale.	Generally low permeability, but yield of water to wells may range from small to large.
Permian and Pennsylvanian	*Sangre de Cristo Formation	250 to 1,800	Sangre de Cristo Mountains; may underlie Santa Fe area.	Arkosic shale, sandstone, and conglomerate.	Generally not an aquifer in the basin because depth to water is too great.
	*Magdalena Group	0 to 2,500	Widespread; crops out in or underlies most of the basin.	Limestone, sandstone, and interbedded shale.	May yield small quantities of water to wells.
Mississippian	Lake Valley Limestone	0 to 60	Mountains in southern part of the basin.	Limestone and some shale.	Unknown.
Devonian	Percha Shale	20 to 105	do.	Shale, claystone, and some sandstone and siltstone.	Do.
Silurian	Fusselman Dolomite	Less than 20 to about 50	do.	Cherty dolomite	Do.
Ordovician	Montoya Dolomite	200 to 450±	do.	Massive dolomite, chert limestone, claystone, and a basal sandstone.	Do.
	El Paso Limestone	350 to 450±	do.	Thin-bedded limestone; basal unit is laminated, cherty limestone.	Do.
Cambrian	Bliss Formation	0 to 400	do.	Thin- to thick-bedded sandstone with some conglomerate and limestone.	Do.
Precambrian	*Metamorphic and igneous rocks	-	Underlie all of the Rio Grande basin.	Granite, schist, gneiss, and other metamorphic rocks.	Yield small quantities of water to wells, generally near the outcrops.

*Known or probable aquifer, regardless of areal extent or production potential.

Source: New Mexico State Engineer Office. 1967.

solids occurs. Groundwater in the upper basin is moderately hard, but generally adequate for irrigation, stock, and domestic consumption. Data from chemical analyses of USGS observation wells are presented in Table 5-49.

Groundwater quality is normally acceptable for domestic and industrial uses in the middle Rio Grande River Basin, although localized groundwater contamination problems do exist, particularly in the shallow aquifers in the floodplain of the middle Rio Grande River and Grants Mineral Belt. Water with a total dissolved solids content of less than 1,000 mg/l is often found in the Santa Fe Group. Sulfates and dissolved solids often are high in aquifers along tributaries to the Rio Grande River in the middle section. Sulfate concentrations in wells along the Rio San Jose River range between 112 and 410 mg/l for the communities of Bluewater, Milan, Grants, and Cuba.

The surface waters in the lower Rio Grande River Basin are generally of better mineral quality than groundwater, especially in the lower Mesilla Valley. In general the mineral quality of groundwater decreases as one proceeds down the valley. The quality of groundwater in the lower Rio Grande River Basin is generally acceptable for domestic use with no treatment necessary other than disinfection.

5.3.5 Western Closed River Basin

The Western Closed River Basin is in the Datil section of the Colorado Plateaus Province (Fenneman 1933). Portions of Valencia, Catron, and Socorro counties are included in the Study Area.

5.3.5.1 Quantity

Known and probable aquifers in the Western Closed River Basins are designated by an asterisk on the stratigraphic section in Table 5-53. The principal aquifer in the North Plains region is the thick basalt of Quaternary age rock that underlies the North Plains and extends over half the total area of the basin. The principal aquifer in the San Agustin Plains is formed by

Table 5-53. Generalized stratigraphic section in the Western closed basins, New Mexico.

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Quaternary	*Alluvium	0 to 100±	About 100 sq. miles in south part of North Plains. Small scattered patches in San Agustin Plains.	Valley fill and flood plain deposits of unconsolidated silt, clay, sand, and gravel.	Ground-water possibilities not known. May contain water where below regional water table. Quality of water uncertain.
	*Bolson deposits	0 to 2,000+	San Agustin Plains.	Unconsolidated clay, silt, sand, and gravel composed of debris from enclosing uplands.	Yield moderate to large quantities of water to wells. Yield fresh to moderately fresh water.
	*Basalt	0 to 600+	North Plains.	Dense to vesicular black basalt, extruded as lava flows of varying thickness and extent.	Yields small quantities of water to wells. Generally yields fresh to slightly saline water.
Quaternary(?) and Tertiary	Basalt	-	South and southwestern sides of San Agustin Plains.	Flows of basalt and basaltic andesite. Scoriaceous in upper part. Some latite and rhyolite flows and tuff.	Ground-water possibilities not known.
Quaternary and Tertiary	*Gila Conglomerate	Variable to 2,000+	Small outcrops in San Agustin Plains.	Variable, commonly well-cemented, locally unconsolidated clay, silt, sand, and gravel.	Yields small to moderate quantities of water to wells. Yields fresh to slightly saline water.
Tertiary	Basalt	-	Cebolleta Mesa and south end of North Plains basin.	Flows of basalt. Includes small amounts of latite, andesite and tuff.	Yields small to moderate quantities of water to wells. Yields fresh to slightly saline water.
	*Datil Formation	Variable to 5,000	Highlands around perimeter of San Agustin Plains. Sedimentary facies present in southwestern end of North Plains.	Intertonguing volcanic flows, pyroclastic rocks, and sedimentary rocks that consist largely of volcanic detritus. Sedimentary facies in lower part. Andesite and rhyolite facies in upper part. Latite facies in middle or lower part.	Yields small quantities of water locally and moderate quantities where below regional water table. Generally yields fresh to slightly saline water.
	*Rubio Peak Formation	Variable to 5,000	Small outcrops in San Agustin Plains.	Andesite, basalt, and latite flows and pyroclastic rocks.	Yields small quantities of water to wells. Generally yields slightly saline water.
	Baca Formation	0 to 700	South end of North Plains.	Maroon to brick-red and variegated shale, siltstone, graywacke, sandstone, and conglomerate.	Ground-water possibilities not known.
Cretaceous	*Mesaverde Group	1,000 to 1,500	East side of North Plains.	Gray to yellowish-buff silty shale and thin- to thick-bedded fine-grained sandstone, with some local coal beds.	Sandstone formations yield small quantities of water to wells in adjacent areas. Generally yields fresh to moderately saline water.
	*Mancos Shale	700 to 800	East side of North Plains.	Platy, calcareous dark-gray marine shale, with some thick-bedded sandstone in lower part.	Sandstone beds, where present within the formation, yield small quantities of water to wells in adjacent areas. Generally yields slightly to moderately saline water.
	*Dakota Sandstone	50 to 100	East side of North Plains.	Massive, medium- to coarse-grained yellowish-buff sandstone, locally with interbedded siltstone.	Yields small quantities of water to wells in adjacent areas. Generally yields fresh water near outcrop.
Jurassic	*Zuni Sandstone	175 to 325	East side of North Plains.	Gray, tan, brown, or pink, thin-bedded to massive sandstone.	Yields small quantities of water to wells in adjacent areas.
Triassic	*Chinle Formation	1,400 to 1,600	North end of North Plains in Zuni Mountains.	Variegated siltstone and mudstone, with interbedded silty sandstone and some conglomeratic sandstone.	Sandstone beds, where present within the formation, yield small quantities of water to wells in adjacent areas.
Permian	*San Andres Limestone	80 to 150	North end of North Plains in Zuni Mountains.	Thick-bedded to massive light-gray limestone and sandy limestone.	Yields small to moderate quantities of water to wells. Generally yields fresh to slightly saline water.
	*Glorieta Sandstone	125 to 300	North end of North Plains in Zuni Mountains.	Thick-bedded to massive white- to yellowish-gray sandstone.	Yields small to moderate quantities of water to wells. Generally yields fresh to slightly saline water.
	*Yeso Formation	350 to 500	North end of North Plains in Zuni Mountains.	Orange to red siltstone and fine-grained silty sandstone. In part gypsiferous.	Yields small quantities of water to wells in adjacent areas. Generally yields fresh to slightly saline water.
	Abo Formation	500 to 800	North end of North Plains in Zuni Mountains.	Dark brick-red to reddish-brown arkosic sandstone and conglomerate.	Ground-water possibilities not known.
Pennsylvanian (?)	Sedimentary rocks	0 to 480	Assumed to be present in subsurface beneath entire area.	Arkose and conglomerate, and a few limestone lenses and shale beds.	Ground-water possibilities not known.
Precambrian	Metamorphic and igneous rocks	-	Crop out in Zuni Mountains at north end of North Plains.	Granite, gneiss, schist, and greenstone.	Assumed to be non-water-bearing.

*Known or probable aquifer, regardless of areal extent or production potential.

Source: New Mexico State Engineer Office. 1967.

the bolson deposits of the Quaternary age that underlie the mid-section of the basin. The only known use of groundwater in the North Plains is for domestic use and livestock. Similar conditions apply in the San Agustin Plains, with the exception of the additional use of groundwater for irrigation. Yields of wells located in the Western Closed River Basin are presented in Table 5-53.

5.3.5.2 Quality

Much of the North Plains section (the San Agustine Plains) is underlain by slightly saline water (McGuinness 1963). Analyses of water are available for a few wells in the northeastern part of the North Plains and the southwestern part of the San Agustine Plains. No data are available for other localities in the Western Closed Basin. Water quality data are presented in Table 5-49.

5.3.6 San Juan River Basin

The San Juan River Basin in New Mexico is in the Canyon Lands and Navajo sections of the Colorado Plateaus Province (Femmem 1931). Portions of San Juan, Rio Arribia, McKinley, and Sandoral counties lie in the San Juan River Basin.

5.3.6.1 Quantity

A minimal amount of information is available for groundwater in the San Juan River Basin. Groundwater occurs in limited supply and only a few of the rock formations are capable of yielding significant quantities of water with the exception of the San Jose and Nacimiento Formations (Table 5-54). The estimated amount of recoverable fresh (0-1,000 mg/l TDS) groundwater in the San Juan River Basin is only 2,500 hm^3 (2 million acre-feet). Two of the formations, the San Jose and Nacimiento, outcrop over a considerable area in the eastern section of the basin and yield up to 0.75 m^3/m (200 gpm), with predicted yields calculated at 4.5 m^3/m (1,200 gpm). The alluvium of stream valleys comprises a known and significant aquifer of limited capacity that yields minimal volumes of water to wells. During prolonged droughts alluvial

Table 5-54. Generalized stratigraphic section in the San Juan River basin, New Mexico.

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Quaternary	*Alluvium	0-50	Stream deposits in all major valleys and local in most minor tributaries; wind-blown sand on inter-stream areas; terrace gravels.	Mostly unconsolidated clay, silt, sand, and gravel; generally poorly sorted; well-sorted dune sands.	Poor to excellent depending on the coarseness and degree of sorting; high yields uncommon because of generally thin deposits in the stream valleys; terrace gravels generally not water bearing. Generally yields fresh to slightly saline water.
Tertiary	Chuska Sandstone	1,000±	West side of the Chuska Mountains, western San Juan County.	Gray to grayish-white, cross-bedded sandstone with some interbedded shale and siltstone.	Unknown, but probably ranging from poor to good, depending on thickness of interbeds of shale and siltstone.
	*San Jose Formation	250± to 1,000±	Eastern part of San Juan basin.	Gray to brown conglomeratic sandstone interbedded with variegated shale; locally well-sorted sand beds.	Generally fair to excellent, depending on thickness of well-sorted beds of sand; potentially good to excellent aquifer; yields up to 200 gpm reported, yields up to 1,000 gpm predicted. Generally yields fresh to slightly saline water.
	*Nacimiento Formation	1,140±	Central and eastern part of San Juan basin; underlies the San Jose Formation.	Lenticular yellow, to soft white, and conglomeratic sandstone with interbedded variegated shale in northern part of basin; gray and red shale, soft sandstone and gray to black shale in southern part.	Poor, yields generally less than 10 gpm. Generally yields slightly to moderately saline water.
Cretaceous	*Ojo Alamo Sandstone	400±	Central and eastern part of San Juan basin; underlies the Nacimiento Formation.	Gray to brown coarse sandstone, with lenses of pebbles and variegated shale.	Poor to locally fair--a potential aquifer in the eastern half of the San Juan basin to supply water to stock and domestic wells. Generally yields fresh water.
	*Kirtland Shale, Fruitland Formation, Pictured Cliffs Sandstone and Lewis shale.	1,000± to 4,500±	Underlie all rocks of Tertiary age in the central and eastern part of the basin.	Mostly light-gray to blue-gray and brown shales; locally carbonaceous; and light-colored, soft, fine-grained sandstone, locally crossbedded.	Generally poor; sandstone units comprise important oil and gas reservoirs of the basin; most water saline except in immediate vicinity of outcrops, where it may be fresh to slightly saline.
	Mesa Verde Group	600± to 3,500±	Underlies all the San Juan basin in New Mexico except for a narrow strip along the NW side of San Juan County.	Yellow to reddish-brown and gray sandstone, massive to thin-bedded, some concretionary, sandy shale, and gray to dark gray carbonaceous shale.	Mostly poor everywhere, except for the Gallup Sandstone at the base, which, in the southwest part of the basin, yields fair to moderate amounts of fresh water. Sandstone units toward base of the group act as reservoir rock for oil and gas. Water in most rocks of the group is saline.
	*Mancos Shale and Dakota Sandstone	800±	Underlie all the San Juan basin in New Mexico except for a narrow strip along the NW side of San Juan County.	Dark gray to olive green, commonly fissile shale, and brown sandstone with thin shale and coal; cherty conglomerate locally at base.	Mostly poor everywhere in the shale beds; locally fair to good in the Dakota Sandstone near areas of outcrop; yields seldom more than 10-15 gpm from the Dakota. Generally yields fresh to moderately saline water.
Jurassic ____?____	*Morrison Formation, San Rafael Group, and Glen Canyon Group	400± to 1,600±	Probably underlie all of the San Juan basin.	Variegated shale and silty sandstone, orange-red to gray cross-bedded sandstone, red to gray shale, sandy shale, and red cross-bedded sandstone.	Generally poor everywhere; yields seldom more than 5-10 gpm of water. Generally yields slightly saline water near outcrop and very saline water away from outcrop.
Triassic	*Chinle Formation	800± to 1,600	Probably underlies all of the San Juan basin.	Red to variegated and white shale and sandstone; some thin beds of limestone.	Generally poor everywhere; yields generally less than 5 gpm, commonly less than 1 gpm. Generally yields slightly to moderately saline water.
Permian to Cambrian	*Sedimentary rocks	5,000±	Rocks of Paleozoic age are believed to underlie much of the northern and eastern part of the San Juan basin. Oil test holes in the central part of the basin, in San Juan County, generally are bottomed at depths not greater than 7,000 ft. and at that depth commonly find the Morrison Formation of Jurassic age. Rocks of Pennsylvanian age yield oil and gas from depths of about 8,000 to 9,000 ft. in the Barker Creek area, north-central San Juan County.	Massive to thin-bedded limestone, local beds of evaporites, and widespread thick deposits of reddish and variegated shale, siltstone, sandstone, and conglomerate.	Generally yield moderately to very saline water.

*Known or probable aquifer, regardless of areal extent or production potential.

Source: New Mexico State Engineer Office. 1967.

reservoirs may dry up, however, their proximity to streams results in rapid recharge during periods of stream flow. Only the alluvium in valleys of the main stream of the San Juan River and the perennial northern tributaries of the San Juan River are recharged.

5.3.6.2 Quality

In general, groundwater from stream valley alluvium and bolson deposits is of good quality, suitable for domestic, livestock, irrigation, and most industrial uses. Total dissolved solids average about 250 ppm, but range as high as 1,000 to 3,000 ppm. Also, water in the bolson normally contains more dissolved solids than water in the stream-valley alluvium.

The Gila River and San Francisco River recharge extensive groundwater supplies in shallow, alluvial deposits. No problems are noted with water quality in these shallow aquifers or in the deeper deposits that are used for livestock and domestic uses near these rivers.

Highly mineralized groundwater is found in the Little Colorado River Sub-basin in sedimentary rocks of Cambrian to Cretaceous age (Table 5-54). Data on groundwater quality in these aquifers are presented in Table 5-49.

5.3.7 Lower Colorado River Basin

This basin covers parts of three physiographic sections of two physiographic provinces - the Navajo and Datil sections of the Colorado Plateaus Province, and the Mexican Highland section of the Basin and Range Province. The Study Area in this basin includes portions of McKinley, Valencia, and Catron counties.

5.3.7.1 Quantity

Groundwater in the lower Colorado River Basin is locally available for domestic and livestock uses. Approximately 1.3 million hm^3 (355 million acre-feet) of recoverable fresh (0 to 1,000 mg/l TDS) groundwater exists in the basin. The alluvial aquifers in the channels and valleys of the Little Colorado Sub-basin are stream connected, because recharge occurs infrequently during periods of flow. These aquifers are thin and undeveloped for other than domestic and livestock uses. In areas where groundwater is used in the San Francisco and Gila Sub-basins pumping occurs in highly permeable floodplain material where groundwater withdrawal is primarly replaced from surface flows. A generalized stratigraphic section of the Lower Colorado River Basin is presented in Table 5-55.

5.3.7.2 Quality

In general, groundwater from stream valley alluvium and from bolsom deposits is of good quality and suitable for domestic, stock, irrigation, and most industrial uses. Total dissolved solids average about 250 ppm, but range as high as 1,000 ppm. Generally, water in the bolsom fill has a higher concentration of dissolved solids than water in the stream-valley alluvium. Water in intrusive and volcanic rocks in the basin also is generally of good quality, although it tends to be somewhat more mineralized than water in alluvium and bolsom fill. Water in volcanic rocks may be highly mineralized locally and unsuitable for domestic use. Fluoride in concentrations up to 12 ppm occurs in thermal spring waters originating in volcanic rocks at several places in the Gila drainage.

Groundwater in the sedimentary rocks of Cambrian to Cretaceous age in the drainage of the Little Colorado River commonly is mineralized, except in the immediate vicinity of outcrops where recharge tends to freshen the water. As the water moves away from the area of recharge it rapidly mineralizes from contact with the thick sequences of carboniferous shales, limestones, and locally interbedded evaporites. Many wells in the vicinity of Gallup produce water with total dissolved solids in excess of 1,000 ppm. Data on water quality in the Colorado River Basin are included in Table 5-49.

Table 5-55. Generalized stratigraphic section in the Lower Colorado River basin, New Mexico.

System	Strati-graphic Unit	Thickness (feet)	Distribution	Physical Properties	Water-bearing characteristics
Quaternary	*Stream channel alluvium	0 to 100±	In all major valleys and in most minor tributaries.	Unconsolidated clay, silt, sand, and gravel, generally poorly sorted, of varied composition.	Poor to excellent depending on the coarseness and degree of sorting; yields up to 2,000 gpm in the Gila River valley. Generally yields fresh, locally slightly saline water.
	Landslide blocks	Highly variable	Along southeastern front of Chuska Mountains, San Juan County.	Unsorted and highly disturbed debris composed of sandstone, siltstone, and shale.	Unknown, but likely to be poor.
	*Basalt	0 to 100	In stream valleys east of Zuni and on the plains near Fence Lake, Valencia County.	Dense to highly scoriaceous and broken flows of basalt	Unknown, but could produce large quantities of water locally, under favorable circumstances, as near Grants and Bluewater. Quality of water likely to be fresh.
	*Bolson fill	Variable to 1,000 or more	In San Simon Valley, Hidalgo County, and the area immediately south of the Gila River, Grant and Hidalgo Counties.	Poorly to well-sorted clay, silt, sand, and gravel; locally well indurated.	Yields up to 1,000 gpm in the San Simon valley; stock well, only adjacent to the Gila River because of greater depth of water. Generally yields fresh water.
	*Terrace gravel	Thin, seldom over 50	Along main drainage-ways in all areas.	Generally poorly sorted, unconsolidated silt, sand, and gravel.	Generally poor to non-water bearing because of location above the general water table. Generally yields fresh water.
Quaternary and Tertiary	*Gila Conglomerate	Variable to 2,000 or more	Underlies the bolson fill and the slopes up to the higher ground bordering the Gila and San Francisco Rivers, Grant and Catron Counties.	Highly variable; commonly well cemented but locally unconsolidated clay, silt, sand, and gravel, locally derived; includes several members locally separated by angular unconformities.	Yields from less than 1 gpm up to 500 gpm depending upon the degree of consolidation and the locality. Generally yields fresh water
	*Basalt and rhyolite flows	Variable to 1,000	Upper part locally interbedded with Gila Conglomerate. In the high country of the Gila-San Francisco drainage area.	Mostly dense, locally vesicular and jointed. Some andesite flows and breccias.	Locally water-bearing; yields range from ½ to 10 gpm. Generally yield fresh water, but may have high concentration of fluoride.
Tertiary	*Chuska Sandstone, Bidahochi Formation, alluvium and lake deposits	1,000±	On the west flank of the Chuska Mountains, and in SW McKinley County and western Valencia County.	Gray to pink cross-bedded tuffaceous sandstone; reddish sand and clay, soft white sandstone, gray shale, and white tuff.	Unknown, but probably ranging from poor--where lake sediments prevail, to good where the Chuska Sandstone and Bidahochi Formation are saturated. Generally yield fresh water.
	*Datil Formation	Variable to 5,000+	Underlies most of the high country of the Gila and San Francisco River drainage area.	Rhyolite, latite, and andesite flows, tuffs, welded tuffs, and associated interbedded tuffaceous sand and gravel deposits.	Yields ½ to 10 gpm locally from the flow rocks, and up to 400 gpm where flows and interbedded sand and gravel occur below the regional water table. Generally yields fresh water.
	Baca Formation	0 to 700	Northwestern Catron County.	Variegated shale, siltstone, graywacke, sandstone, and conglomerate.	Generally unknown, but probably poor; reports from vicinity of Pietown indicate the formation there is mostly red clay and siltstone, and non-water-bearing to depths of 700 ft.
Tertiary and Cretaceous	*Volcanic intrusive, and associated sedimentary rocks	Variable to 10,000±	Western Grant County, and in Chuska Mountains, northwestern McKinley County.	Intrusive diorites and monzonites; andesite and dacite flows, associated pyroclastics, and interbedded sandstone conglomerate, and fanglomerates.	Intrusive rocks locally water-bearing; yield 1/5 to 20 gpm from joints, fractures, and weathered zones. Occurrence in flow rocks erratic; yield generally less than ½ gpm. Sediments locally water-bearing; yield generally less than 10 gpm. Generally yields fresh water.
Cretaceous	*Colorado Shale and Beartooth Quartzite	0 to 1,500	In central Grant County.	Shaly sandstone, shale, and quartzite.	Generally poor; unlikely to yield more than 5 gpm, commonly no more than 1 gpm. Generally yield fresh water.
	*Mesaverde Group	2,000±	Widespread in northwestern Catron County, western Valencia and McKinley Counties, and southwestern San Juan County.	Quartzose sandstone, shale, carbonaceous shale, and coal.	Poor, yields generally less than 10 gpm; the Gallup Sandstone, where it occurs below the regional water table, is a relatively reliable aquifer for small amounts of water. Generally yield slightly to moderately saline water.
	*Mancos Shale and Dakota Sandstone	500± to 800±	Widespread in northwestern Catron County, and western Valencia and McKinley Counties.	Marine shale, sandy shale, thin-bedded limestone; quartzose sandstone, conglomerate, and carbonaceous shale.	Generally poor in the shale, sandy shale, conglomerate, and limestone beds; somewhat better in the sandstone units; yield seldom more than 10-15 gpm. Generally yield slightly to moderately saline water.
Jurassic	*Morrison Formation Zuni Sandstone and San Rafael Group	1,000±	The Morrison in SW San Juan County, the Zuni in SW McKinley County, and the San Rafael in W Valencia and McKinley Counties.	Variegated clay and shale, interbedded with sandstone and conglomerate, thin-bedded to massive sandstone, and limestone.	In general poor, especially where shale and shaly sandstones predominate; yield generally less than 10 gpm. Generally yield fresh to slightly saline water.
Jurassic and Triassic	*Glen Canyon Group	1,800±	In SW San Juan County, and western Valencia and McKinley Counties.	Shale, siltstone, and sandstone.	In general very poor where shale and siltstone predominate, slightly better where sandy; yields commonly less than 5 gpm. Generally fresh to slightly saline water.
Permian	*San Andres Limestone, Glorieta Sandstone, and Chiricahua Limestone of Stoyanow (1936)	1,000±	Crop out along the crest of the Zuni Mountains in western McKinley County, but probably underlie all younger rocks to the west; Chiricahua Limestone in the Peloncillo Mountains.	Thick- to thin-bedded limestone, locally includes shale and evaporite rocks; friable to well-indurated quartzose sandstone.	Not well known in this basin; elsewhere, as near Grants-Bluewater, up to 3,000 gpm. Deep wells near Zuni, believed drilled into the Glorieta, produced saline water.
	*Yeso Formation, Abo Sandstone, and undivided sedimentary rocks of Early Permian age.	1,500±	Crop out along the crest of the Zuni Mountains in western McKinley Co., but probably underlie all younger rocks to the west; Lower Permian rocks, undivided, in the Peloncillo Mts., Hidalgo County.	Fine-grained silty sandstone, gypsum, limestone, and dolomitic limestone. Mudstone and sandstone; locally may be arkosic and conglomeratic.	Generally poor, yield commonly less than 10 gpm. Generally yield fresh to very saline water.
Permian, Pennsylvanian, and Mississippian	*Magdalena Group, Lake Valley Limestone, Escabrosa and Horquilla Limestones, Madera and Sandia Formations	1,300±	Magdalena and Lake Valley exposed only in the Silver City Range, but probably underlie much of the Datil Formation; Escabrosa Limestone in the Peloncillo Mts., Hidalgo Co., Madera and Sandia Formations on crest of Zuni Mts., and probably in subsurface to the west.	Limestone and cherty limestone with interbedded shale; siltstone, sandstone, and conglomerate.	Generally poor because of their situation at higher elevations; yield commonly less than 5 gpm from factures and joints, but local yields up to 150 gpm from springs in Silver City Range; yields up to 500 gpm may be possible in basin areas. Generally yield fresh water.
Devonian	Percha Shale	300±	Exposed in the Silver City Range but probably underlies much of Datil Formation.	Black and grey fissile shale.	Poor; yields generally less than 1 gpm.
Silurian, Ordovician, and Cambrian	*Fusselman Dolomite, Montoya Dolomite, El Paso Limestone and Bliss Sandstone.	1,150	Exposed in the Silver City Range but probably underlie much of Datil Formation.	Cherty dolomite, dolomite, dolomitic limestone, massive to thin-bedded limestone, glauconitic and hematitic sandstone.	Generally poor, yield commonly less than 5 gpm from fractures and joints; yields up to 500 gpm may be possible in basin areas. Generally yield fresh water.
Precambrian	*Metamorphic and igneous rocks		Exposed in the Zuni and Burro Mts., and along base of the Silver City Range.	Granite, gneiss, schist, and greenstone. Mostly crystalline, hard, and dense, especially at depth; locally deeply weathered, jointed, and fractured.	Poor, yield generally less than 5 gpm from deeply weathered zones, fractures, and joints; commonly no measurable yield from unweathered, unbroken rock. Generally yield fresh water.

*Known or probable aquifer, regardless of areal extent or production potential.
Source: New Mexico State Engineer Office. 1967.

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CHAPTER 6.0 LAND USE AND BIOLOGICAL RESOURCES

6.0 LAND USE AND BIOLOGICAL RESOURCES

6.1 LAND USE

6.1.1 Introduction

In the United States agricultural land alone is converted to other uses at a rate of 3 million acres (5 million ha) each year (US Department of Agriculture 1981). Similar acreages of forest land, as well as other natural vegetation, are likewise being developed. Although some land use values can be mitigated by reclamation or through the development of parks, lakes, and associated recreational facilities, many of the land uses will be converted indefinitely.

Major concerns associated with land use result from conversion, loss of prime or unique farmlands, changes in land values, and degradation of recreational and natural areas. Major land modifying developments, such as coal/lignite mining, must incorporate in the initial planning stages adequate mitigation measures to insure that the values of existing land use will be maintained.

6.1.2 Land Use/Land Cover

Eight major land use/land cover types (urban, agriculture, rangeland, coniferous forest, deciduous forest, water, barren land, and tundra) are delineated for the 13-county Study Area in Exhibit 6a. The classifications used in Exhibit 6a, "Vegetation and Land Use in New Mexico", correspond to the New Mexico vegetation and land use classifications as follows:

Exhibit 6a Classification	Vegetation and Land Use in New Mexico Classification
Urban	Urban Areas
Agricultural Land	Irrigated agriculture Dryland agriculture Orchard crops
Rangeland	Grama/galleta steppe Grama/buffalo grass "shortgrass prairie" Intermontane meadows Great Basin sagebrush Saltbush/greasewood Creosote bush/tarbush Scrub oak Grama/tobosa/mesquite shrub steppe Yucca/cholla
Coniferous Forest	Spruce/fir Pine/fir Pinon/juniper
Deciduous Forest	Cottonwood/willow/tamarisk
Water	Major lakes and reservoirs
Barren Land	Playa Sand dunes
Tundra	Alpine meadows

The acreages in Table 6-1 are from the "New Mexico Water Resource Assessment For Planning Purposes," and correspond in the following manner:

Table 6-1. Number of acres and percent of total acres of land use/land cover classifications in 13 counties in New Mexico.

	Urban	%	Agricultural Land	%	Rangeland	%	Forest	%	Other Land	%	Land	%	Water	%	Total
State	738,798	1.0	2,678,160	3.4	50,049,892	64.3	19,947,221	25.6	4,300,669	5.5	77,714,740	99.8	151,500	0.2	77,866,240
County															
Bernalillo	86,180	11.5	17,040	2.3	358,589	47.9	223,730	29.9	62,621	8.4	748,160	100.0	0	0	748,160
Catron	9,434	0.2	3,000	0.1	1,937,625	43.9	2,448,773	55.5	15,482	0.3	4,414,314	100.0	406	0.0	4,414,720
Colfax	26,000	1.1	50,220	2.1	1,449,577	60.1	826,039	34.2	54,356	2.2	2,406,192	99.7	7,248	0.3	2,413,440
Lincoln	20,837	0.7	5,240	0.2	2,144,561	68.9	729,735	23.5	209,214	6.7	3,109,587	100.0	173	0.0	3,109,760
McKinley	18,703	0.5	17,640	0.5	1,493,155	42.7	1,910,171	54.7	51,850	1.5	3,491,519	99.9	3,521	0.1	3,495,040
Otero	33,623	0.8	16,000	0.4	1,863,808	43.8	853,372	20.1	1,481,517	34.9	4,248,320	100.0	0	0	4,248,320
Rio Arriba	22,101	0.6	51,160	1.4	1,223,898	32.5	2,408,956	64.0	42,509	1.1	3,748,624	99.6	16,496	0.4	3,765,120
Sandoval	22,960	1.0	18,850	0.8	1,090,742	45.8	1,211,103	50.9	35,225	1.5	2,378,880	100.0	0	0	2,378,880
San Juan	18,607	0.5	61,000	1.7	2,983,432	84.5	409,145	11.6	48,408	1.4	3,520,592	99.7	9,648	0.3	3,530,240
Santa Fe	27,102	2.2	37,010	3.0	498,018	40.8	647,697	53.0	11,758	1.0	1,221,585	100.0	175	0.0	1,221,760
Sierra	10,652	0.4	8,840	0.3	1,714,397	63.5	353,540	13.1	573,254	21.3	2,660,683	98.5	39,477	1.5	2,700,160
Socorro	23,281	0.6	36,800	0.9	2,240,786	52.8	1,412,942	33.3	516,310	12.2	4,230,119	99.8	10,521	0.2	4,240,640
Valencia	73,000	2.0	67,280	1.9	1,902,014	52.5	1,554,702	42.9	22,178	0.6	3,619,174	99.9	1,946	0.1	3,621,120

Sources: Adapted from US Department of the Interior. 1976. New Mexico water resource assessment for planning purposes. Published by Bureau of Reclamation in cooperation with the State of New Mexico, Amarillo TX, 218 p.

Table 6-1 Classification	New Mexico Water Resource Assessment For Planning Purposes Classification
Urban	Urban and built-up
Agriculture Land	Cropland - Total
Rangeland	Rangelands
Forest	Commercial Timber Non commercial timber and woodland
Other Land	Roads Defense Park F&WL
Water	Inland Waters

Since it was necessary to obtain data from different sources, the information in Table 6-1 and Exhibit 6a does not correspond in all instances.

Two land use/land cover types, forest and rangeland, are the predominant cover in the the Study Area. In counties where coal development is proposed, the predominant land use is forest (McKinley 54.7%, Sandoval 50.9%, and Santa Fe 53.0%) and rangeland (Lincoln 68.9% and San Juan 84.5%). If present reclamation trends continue, it is likely that large acreages of forest will be converted to other land uses (probably rangeland). A change in land use may result in alterations in plant and wildlife species diversity as well as aesthetic qualities.

6.1.3 Recreation Lands

Recreation areas are established not only for recreation purposes, but also for scenic, historic, and conservation purposes. Five of the 17 State parks in the Study Area are underlain by coal (Exhibit 6b and Table 6-2). Coal development generally will be restricted in and near the boundaries of State parks and other recreational lands due to their associated recreational and aesthetic values.

Coal development would also be limited on Federal recreation areas. The coal deposits under the Aztec Ruins National Monument and Chaco Canyon National Monument (Exhibit 6b) would be prohibited from development. In addition, the coal deposits in Sevilleta National Wildlife Refuge (Exhibit 6b) would be excluded from development.

6.1.4 Select Natural Areas

Natural areas are valued for their aesthetic, scientific, wild, and essentially undisturbed natural qualities. National Natural Landmarks, National Forests, and Wild and Scenic Rivers are Federal natural areas virtually excluded from changes in land use. The 6,651,395 acres (2,691,820 ha) of National Forests represent 16.7% of the land area in the Study Area. The location of the National Natural Landmarks in Exhibit 6b are approximations because the specific location for some landmarks is not provided due to an owner's request for minimum publicity and/or the fragility of the landmark's natural features. There are no Wild and Scenic Rivers in the Study Area.

6.1.5 Selected Federal and Indian Land Ownership

Over half the land in the Study Area is owned by a Federal agency or Indian tribe. The Bureau of Land Management, Forest Service, and Indian tribes are the major landowners with 16.4%, 16.7%, and 17.6% of the land area, respectively.

Surface mining is forbidden on land where the National Forest Service owns both surface and mineral rights (By phone, Harry Switzer, USFS, August 1981). In instances where the National Forest Service does not control both surface and mineral rights, surface mining is decided through litigation. Coal development can occur on Bureau of Land Management lands provided all regulations are satisfied (By phone, Gil Esquerdo, BLM, August 1981). The Indian land acreages listed in Table 6-3 represent the Bureau of Indian Affairs classification of Tribal and Government-owned lands.

Table 6-3. Number of acres and percent of total land area of select Federal and Indian land ownership in 13 counties in New Mexico.

	BLM	%	FS	%	W&P	%	NPS	%	Army	%	COE	%	F&W	%	Indian	%	Total	%	Total Land Area
State	12,860,922	16.6	8,996,958	11.6	178,018	0.2	236,876	0.3	0	0	27,305	0.0	15,767	0.0	13,603,496	17.5	35,919,342	46.2	77,703,680
County																			
Bernalillo	16,009	2.1	73,828	9.9	0	0	0	0	0	0	0	0	0	0	217,264	29.0	307,101	41.0	748,160
Catron	593,742	13.5	2,149,492	48.7	0	0	533	0.0	0	0	0	0	0	0	0	0	2,743,767	62.2	4,414,080
Colfax	1,215	0.1	11,505	0.5	1,690	0.1	0	0	0	0	0	0	0	0	0	0	14,410	0.6	2,408,960
Lincoln	517,259	16.6	398,775	12.8	0	0	0	0	0	0	0	0	0	0	0	0	916,034	29.5	3,109,120
McKinley	249,992	7.2	170,246	4.9	0	0	640	0.0	0	0	0	0	0	0	1,772,158	50.8	2,193,036	62.8	3,490,560
Otero	929,578	21.9	469,700	11.1	0	0	84,906	2.0	0	0	0	0	0	0	460,402	10.8	1,944,586	45.8	4,248,320
Rio Arriba	560,720	15.0	1,411,629	37.7	25,317	0.7	0	0	0	0	3,368	0.1	0	0	646,146	17.3	2,647,180	70.8	3,739,520
Sandoval	547,416	23.0	399,655	16.8	0	0	25,428	1.1	0	0	2,289	0.1	0	0	645,085	27.1	1,592,873	66.9	2,379,520
San Juan	843,361	24.0	0	0	17,095	0.5	20,536	0.6	0	0	0	0	0	0	2,130,886	60.5	3,011,878	85.6	3,520,000
Santa Fe	72,155	5.9	250,577	20.6	0	0	826	0.1	0	0	2,689	0.2	0	0	79,420	6.5	405,667	33.3	1,217,280
Sierra	824,687	30.9	384,274	14.4	62,353	2.3	0	0	0	0	0	0	0	0	0	0	1,271,314	47.7	2,666,240
Socorro	947,016	22.4	630,652	14.9	15,990	0.4	371	0.0	0	0	0	0	140	0.0	43,344	1.0	1,637,513	38.7	4,225,920
Valencia	408,967	11.3	301,062	8.3	0	0	1,040	0.0	0	0	0	0	0	0	1,025,006	28.3	1,736,075	48.0	3,619,840

LEGEND

BLM - Bureau of Land Management
FS - Forest Service
W&P - Water and Power Resources Service
NPS - National Park Service
COE - Corps of Engineers
F&W - Fish and Wildlife Service

Sources: US Department of Commerce 1978; US Department of the Interior 1979; US Department of the Interior 1980b.

6.1.6 Farmland

Farmland, as described in this section, uses the Bureau of Census 1969 definition of farmland. Farmland is a part of the agricultural land listed in Section 6.1.2, but the two terms are not synonymous.

Farmland in New Mexico increased by 5.0% between 1969 and 1978 (Table 6-4). In comparison, the acres in farmland in the Study Area increased by 606,862 acres (245,597 ha) during the same time period, a 2.9% increase. Every county that has a proposed coal development project had an increase in farmland between 1969 and 1978. The value of farmland and buildings more than doubled between 1969 and 1978 in every county in the Study Area, due primarily to inflation. However, as coal is developed, there could be a decrease in farmland.

Prime farmland has the best combination of physical and chemical characteristics for producing food, feed forage, fiber, and oil seed crops, of lands available for these uses. County data on prime farmland in the Study Area is limited (By phone, Jim Hosack, SCS, August 1981). However, site-specific information can be obtained through contact with the Soil Conservation Service (SCS).

6.2 BIOLOGICAL RESOURCES

6.2.1 Introduction

Biological resources are the product of the interactions between species of vegetation and wildlife. These resources are linked to climate, physiography, and man's activities. The major vegetation and wildlife occurring in the Study Area are discussed in this section. The section is organized by Biological Provinces (Bailey 1978), thus allowing a concise, systematic, and geographic evaluation of the resources. Similar organization is being utilized in various other Federal studies (e.g., USFWS habitat evaluations).

Table 6-4. Acreages and values per acre of farmland in 13 counties in New Mexico.

	Acres in Farmland				Value of Farmland and Buildings				Prime Farmland	
	1969	1978[a]	Change	% Change	1969[b]	1978[b]	Change	% Change	Acres	% County
State	46,792,302	49,117,462	2,325,160	5.0	42	143	101	240	N.A.	N.A.
County										
Bernalillo	392,213	431,117	38,904	9.9	164	351	187	114	6,436	0.9
Catron	1,669,248	1,524,704	-144,544	-8.7	21	92	71	338	N.A.	N.A.
Colfax	2,329,287	2,433,658	104,371	4.5	32	115	83	259	N.A.	N.A.
Lincoln	1,982,738	2,008,792	26,054	1.3	27	99	72	267	N.A.	N.A.
McKinley	3,185,818	3,275,983	90,165	2.8	22	73	51	232	N.A.	N.A.
Otero	999,136	1,183,824	184,688	18.5	57	262	205	360	N.A.	N.A.
Rio Arriba	1,639,666	1,594,852	-44,814	-2.7	41	193	152	371	N.A.	N.A.
Sandoval	706,269	811,277	105,008	14.9	42	247	205	488	N.A.	N.A.
San Juan	1,895,854	1,917,319	21,465	1.1	21	144	123	586	N.A.	N.A.
Santa Fe	766,748	843,893	77,145	10.1	53	134	81	153	N.A.	N.A.
Sierra	1,245,839	1,412,643	166,804	13.4	26	97	71	273	N.A.	N.A.
Socorro	1,957,639	1,898,235	-59,404	-3.0	28	118	90	321	N.A.	N.A.
Valencia	2,481,124	2,522,144	41,020	16.5	34	141	107	315	19,605	0.5

[a]Using 1969 definition of farmland

[b]Average per acre

N.A. - Not Available

Sources: US Department of Agriculture 1978; US Department of Agriculture 1980; US Department of Commerce 1977; US Department of Commerce 1978; US Department of Commerce 1980.

This discussion includes only characteristic vegetation and selected wildlife species (game, furbearers, and State or Federally endangered or threatened species) of each Biological Province.

New Mexico vegetation and wildlife differ widely throughout the Study Area due to vast changes in altitude and water availability. Vegetative cover ranges from softwood forest at the highest elevations to sparce xeric grasses and shrubs in lowlying areas. Wildlife species dependent on water are restricted primarily to the larger river drainages and associated wetlands. There exists a distinct separation of wildlife forms as one move farther away from permanent water.

6.2.2 Biological Provinces (Ecoregions)

Biological Provinces are regions that contain similar vegetation and wildlife throughout a specific geographic area. The Study Area is composed of portions of three Biological Provinces (Figure 6-1): the Upper Gila Mountains Forest Province, the Grama-Galleta Steppe and Juniper-Pinyon Woodland Mosaic Section of the Colorado Plateau Province, and the Ponderosa-Pine-Douglas-Fir Forest Sections of the Rocky Mountain Forest Province. Although these biological regions differ, many species of vegetation and wildlife are common to all.

6.2.2.1 Upper Gila Mountains Forest Province

The Upper Gila Mountains Forest Province is located in the central portion of western New Mexico. This region includes approximately 28% of the Study Area and covers approximately 17,750 mi^2 (45,950 km^2). The province remains largely (77%+) in natural vegetation and contains moderate numbers of Federally listed (3 to 4) and State listed (4 to 5) endangered or threatened species (Figure 6-2 and Table 6-5).

Land Cover - The major land cover types are rangeland and forest, with small acreages of urban, agricultural, and water (Table 6-1 and Exhibit 6a).

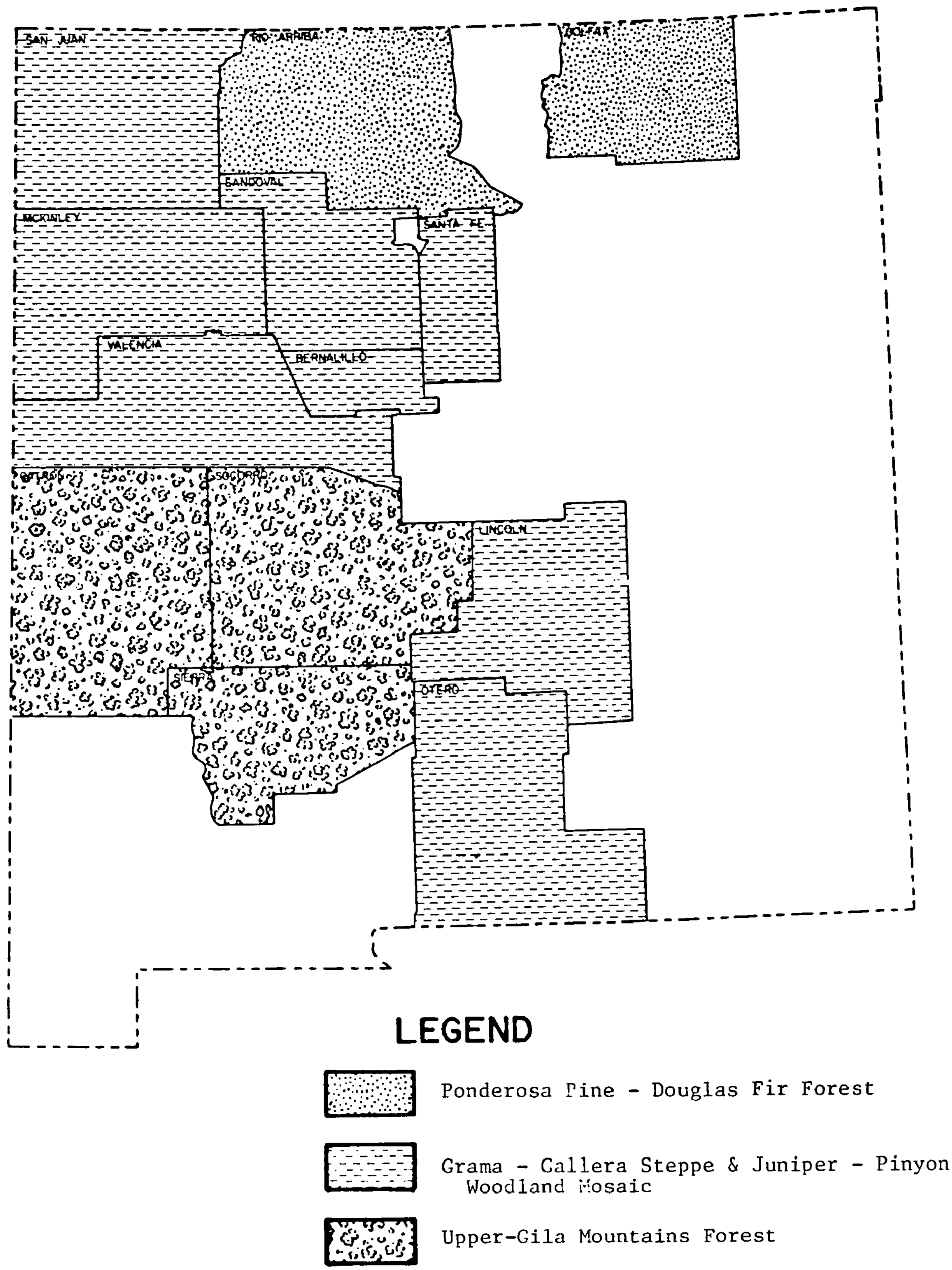

Figure 6-1. Biological provinces of the 13 county Study Area in New Mexico.

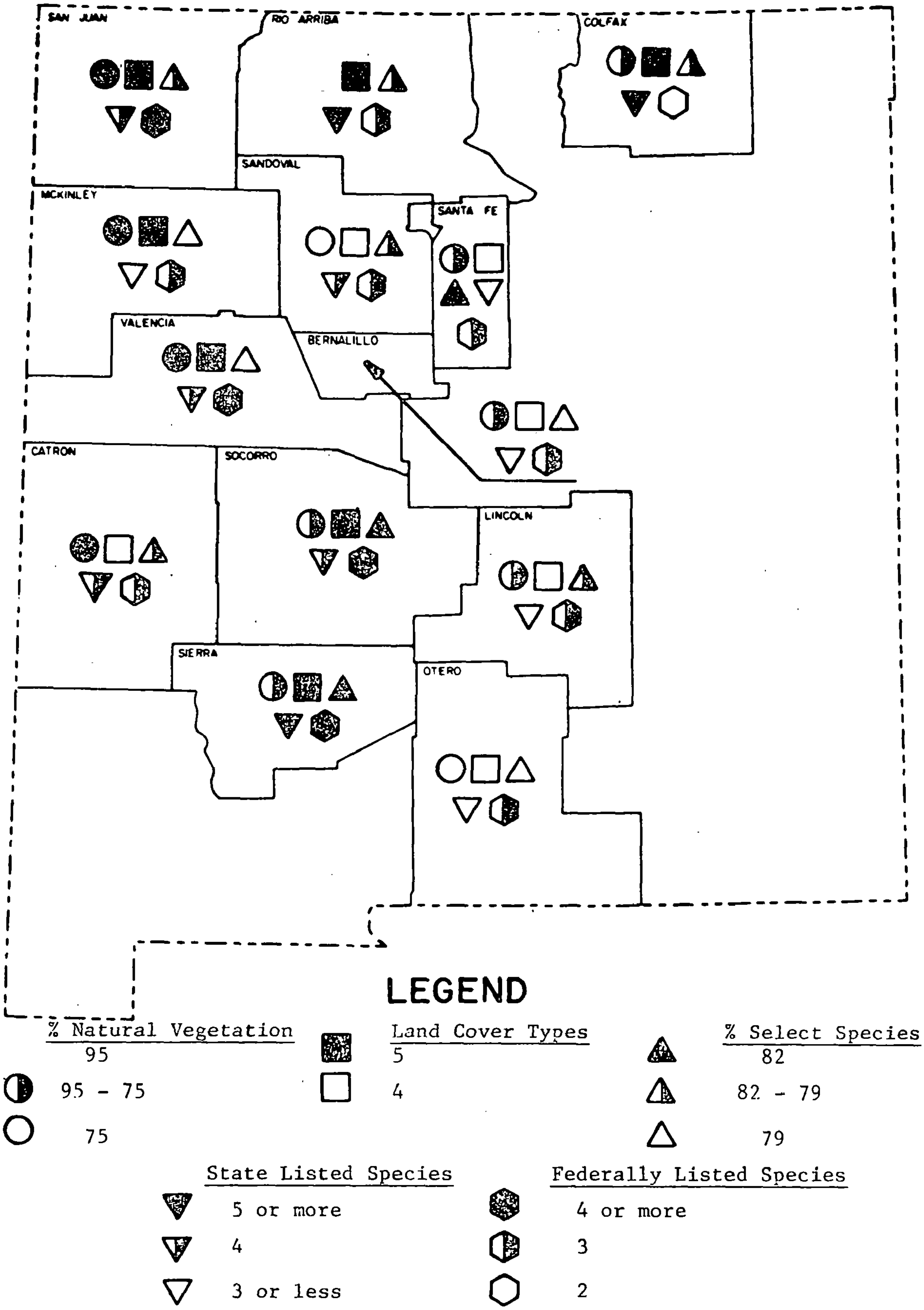

Figure 6-2. Biological resources of 13 counties in New Mexico.

Table 6-5 . Numbers of select wildlife species in 13 counties in New Mexico.

Province/ County	Wildlife: Federally Listed Species (#)	State Listed Species (#)	Game Species (#)	Furbearers (#)	Flora: Federally Listed Species
Ponderosa Pine-Douglas fir Forest					
Colfax	2	8	44	11	0
Rio Arriba	3	7	47	12	0
Upper Gila Mountains Forest					
Catron	3	4	43	11	0
Sierra	3	5	48	12	1
Socorro	4	4	46	12	0
Grama-Galleta Steppe + Juniper-Pinyon Woodland Mosaic					
Bernalillo	3	3	41	12	0
Lincoln	2	1	43	11	1
McKinley	3	3	39	11	0
Otero	2	3	42	11	1
Sandoval	3	4	43	12	0
San Juan	4	4	43	12	2
Santa Fe	3	3	43	13	0
Valencia	4	4	40	13	0

Fifty two percent of this province is covered by rangeland. Common species of vegetation include grama, galleta, tobosa, and mesquite. At higher elevations, forests dominate (37%) the province. At approximately 7,000 feet above sea level, open forest of ponderosa pine occur, with pinyon-juniper common on southern slopes. This zone extends to about 8,000 feet above sea level and is replaced by Douglas fir and aspen (Bailey 1978).

Todsen's pennyroyal is the only species of endangered plant occurring in the Upper Gila Mountains Forest Province (USFWS 1980). This species is found on steep, gravelly gypsum limestones in Sierra County (Figure 6-3).

Wildlife - The distribution of wildlife in the Upper Gila Mountains Forest Province varies with respect to altitude, land cover type, and water availability.

Most game fish are distributed throughout the province. Sunfish are dominant in larger bodies of water (e.g., lakes), while trout are abundant in streams. Largemouth and smallmouth bass are abundant in large reservoirs and their tributary streams. Catfish are common in most streams and reservoirs throughout the State (Table 6-6).

All upland and waterfowl species are present throughout the region. Most upland game species are residents while other species migrate and are common only during specific seasons (primarily fall and winter) of the year (Table 6-6).

The most common and economically important large mammal is the mule deer. Other game mammals include the black bear, mountain lion, whitetail deer, and blacktail jackrabbit. Oryx were stocked in Catron and Sierra counties and offer restricted hunting opportunities. Important furbearers are the gray fox, raccoon, coyote, and beaver.

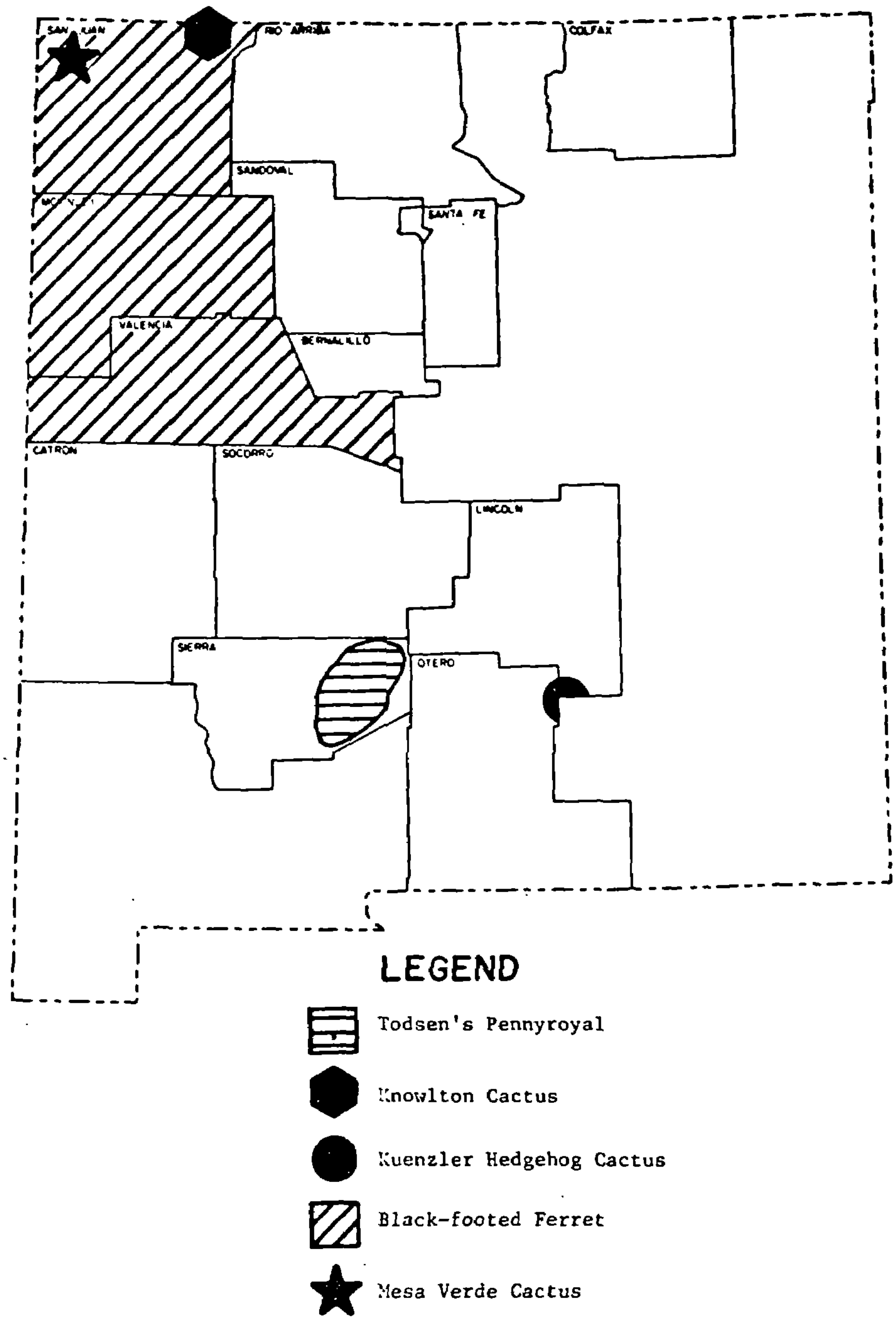

Figure 6-3. Ranges of five Federally listed endangered species.

Table 6-6. Occurrence of selected wildlife species in 13 counties in New Mexico.

	Ponderosa Pine-Douglas-fir Forest		Upper Gila Mountains Forest			Grama-Galleta Steppe + Juniper-Pinyon Woodland Mosaic								Habitat					
	Colfax	Rio Arriba	Catron	Sierra	Socorro	Bernalillo	Lincoln	McKinley	Otero	Sandoval	San Juan	Santa Fe	Valencia	Brush edge	Rangeland	Forest	Wetlands	Agriculture	Water
Amphibian																			
Bullfrog			Distributed Throughout Study Area														X		X
Fish																			
Coho Salmon		X									X								X
Kokanee Salmon		X									X								X
Cutthroat Trout	X	X	X	X	X	X	X	X		X	X	X	X						X
Rainbow Trout			Distributed Throughout Study Area																X
Brown Trout			Distributed Throughout Study Area																X
Brook Trout	X	X	X	X			X		X	X		X							X
Arctic Grayling		X																	X
Northern Pike	X			X	X														X
Channel Catfish			Distributed Throughout Study Area																X
Flathead Catfish				X	X		X		X										X
White Bass				X	X														X
Striped Bass				X	X														X
Green Sunfish			Distributed Throughout Study Area																X
Bluegill			Distributed Throughout Study Area																X
Smallmouth Bass		X	X	X	X	X				X	X	X	X						X
Largemouth Bass			Distributed Throughout Study Area																X
White Crappie			Distributed Throughout Study Area																X
Black Crappie			Distributed Throughout Study Area																X
Walleye				X								X							X
Birds																			
Canada Goose			Migrant/Winter Resident														X	X	X
Mallard			Migrant/Winter Resident														X	X	X
Pintail			Migrant/Winter Resident														X		X
Gadwall			Migrant/Winter Resident														X		X
American Wigeon			Migrant/Winter Resident														X		X

Table 6-6. Occurrence of selected wildlife species in 13 counties in New Mexico (continued).

	Ponderosa Pine-Douglas-fir Forest		Upper Gila Mountains Forest			Grama-Galleta Steppe + Juniper-Pinyon Woodland Mosaic								Habitat					
	Colfax	Rio Arriba	Catron	Sierra	Socorro	Bernalillo	Lincoln	McKinley	Otero	Sandoval	San Juan	Santa Fe	Valencia	Brush edge	Rangeland	Forest	Wetlands	Agriculture	Water
Birds (continued)																			
Northern Shoveler			Migrant/Winter Resident														X		X
Blue-Winged Teal			Migrant														X		X
Green-Winged Teal			Migrant/Winter Resident														X		X
Redhead			Migrant														X		X
Canvasback			Migrant														X		X
Ring-necked Duck			Migrant/Winter Resident														X		X
Lesser Scaup			Migrant/Winter Resident														X		X
Common Merganser			Migrant/Winter Resident														X		X
Turkey			Resident											X	X	X			
Scaled Quail			Resident											X	X				
Gambel's Quail			Resident											X	X				
Ring-necked Pheasant			Resident											X	X	X		X	
Sandhill Crane			Migrant											X	X	X	X		
Virginia Rail			Migrant														X		
American Coot			Migrant/Summer Resident														X		X
Common Snipe			Migrant/Winter Resident														X		
Band-tailed Pigeon			Migrant/Summer Resident											X	X	X			
Mourning Dove			Migrant/Winter Resident											X	X	X		X	
Mammals																			
Black Bear[1]			Distributed Throughout Study Area													X			
Raccoon[2]		X	X	X	X	X		X		X	X	X	X			X	X		
Ringtail[2]			Distributed Throughout Study Area											X	X				
Longtail Weasel[2]			Distributed Throughout Study Area											X	X	X	X		
Badger[2]			Distributed Throughout Study Area											X	X				
Spotted Skunk[2]			Distributed Throughout Study Area											X	X				
Striped Skunk[2]			Distributed Throughout Study Area											X	X				
Coyote[2]			Distributed Throughout Study Area											X	X	X			

Table 6-6. Occurrence of selected wildlife species in 13 counties in New Mexico (concluded).

	Ponderosa Pine-Douglas-fir Forest		Upper Gila Mountains Forest			Grama-Galleta Steppe + Juniper-Pinyon Woodland Mosaic								Habitat					
	Colfax	Rio Arriba	Catron	Sierra	Socorro	Bernalillo	Lincoln	McKinley	Otero	Sandoval	San Juan	Santa Fe	Valencia	Brush edge	Rangeland	Forest	Wetlands	Agriculture	Water
Mammals (continued)																			
Red Fox[2]	X	X		X	X	X	X		X	X	X	X	X	X	X	X			
Gray Fox[2]			Distributed Throughout Study Area											X	X	X			
Mountain Lion[1]			Distributed Throughout Study Area												X	X	X		
Bobcat[2]			Distributed Throughout Study Area											X	X	X			
Beaver[2]			Distributed Throughout Study Area														X		X
Muskrat[2]			Distributed Throughout Study Area														X		X
Whitetail Jackrabbit[1]	X	X												X	X				
Blacktail Jackrabbit[1]			Distributed Throughout Study Area											X	X				
Eastern Cottontail[1]			X	X	X	X	X		X			X	X	X	X	X	X		
Mountain Cottontail[1]	X	X						X		X	X	X		X	X	X			
Desert Cottontail[1]			Distributed Throughout Study Area											X	X				
Elk[1]	X	X													X	X			
Muledeer[1]			Distributed Throughout Study Area											X	X	X			
Whitetail Deer[1]	X		X	X	X	X	X		X	X		X	X	X	X	X	X	X	
Pronghorn Antelope[1]			Distributed Throughout Study Area												X				
Oryx[1] (Exotic)				X	X		X		X						X				
Rocky Mountain Bighorn[1,3]			X																
Barbary Sheep[1,3]		X								X	X								

[1]Game

[2]Furbearer

[3]Occurs in mountainous areas

Sources: Lee et al. 1980; New Mexico Department of Game & Fish undated; Bellrose 1976; Robbins, Brun, and Zim 1966; Burt and Grossenheider 1976; and Hall and Kelson 1959.

Many of the Federal and State* listed endangered or threatened species that occur in this province are associated with water or wetlands (Table 6-7). Several listed species are restricted in range to a few counties in the Study Area, whereas other species such as the Bald Eagle and Peregrine Falcon, occur throughout the State. The ranges of Federally listed endangered species not occurring throughout the Study Area are presented in Figures 6-3 and 6-4.

Coal development occurring in forests, wetlands, or in or near permanent water in this and other provinces will be required to consider mitigation for potentially displacing or altering critical habitats of endangered and threatened species as required by the Endangered Species Act of 1973 and its amendments. Mitigation, as required by the Fish and Wildlife Coordination Act, may also be necesary when large acreages of habitat supporting other select species are destroyed.

6.2.2.2 Grama-Galleta Steppe and Juniper-Pinyon Woodland Mosaic Section

The Grama-Galleta Steppe and Juniper-Pinyon Woodland Mosaic Section covers the northwestern and southcentral portions of the State and approximately 56%, or 34,925 mi^2 (90,465 km^2) of the Study Area. This area has 4 to 5 land cover types, is largely rangeland and forest, and contains high to moderate numbers of Federally listed endangered species (Figure 6-2 and Table 6-5).

Land Cover - Major land cover types in this region are identical to other regions. Vegetation zones are conspicuous, but are not uniform over this section. Fifty-five percent of the land in this section is rangeland. Xeric shrubs grow in open stands among grasses, and sagebrush is dominant over large areas. The woodland zone (34% of the section) is dominated by open stands of pinyon pine and several species of juniper. Ground cover is sparse and consists mainly of grama, other grasses, herbs, and various shrubs (Bailey 1968).

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*State listed endangered species are those species classified as Group No. 1 in the State Game Commissions Regulation No. 599 as amended 4 May 1980.

Table 6-7. Occurrence of State and Federally listed threatend (T) and endangered (E) species in 13 counties in New Mexico.

	Ponderosa Pine-Douglas-fir Forest		Upper Gila Mountains Forest			Grama-Galleta Steppe + Juniper-Pinyon Woodland Mosaic							
	Colfax	Rio Arriba	Catron	Sierra	Socorro	Bernalillo	Lincoln	McKinley	Otero	Sandoval	San Juan	Santa Fe	Valencia
Mesa Verde Cactus[1]											T		
Kuenzler Hedgehog Cactus[1]							E		E				
Knowlton Cactus[1]											E		
Todsens Pennyroyal[1]				E									
Socorro Isopod[1]					E								
Gila Trout[1]			E										
Arkansas River Shiner[2]	E												
Bluntnose Shiner[2]		E		E	E	E				E		E	E
Southern Redbelly Dace[2]	E												
Colorado Squawfish[1,2]											E		
Gray Hawk[2]									E				
Bald Eagle[1]				Statewide Migrant									
Caracara[2]													
Peregrine Falcon[1,2]				Statewide Migrant									
Aplomado Falcon[2]			E	E									
Whooping Crane[1]		E		E	E	E				E		E	
White-tailed Ptarmigan[2]	E	E											
Sharp-tailed Grouse[2]	E	E											
Sage Grouse[2]	E	E											
Black-footed Ferret[1]								E			E		E
River Otter[2]	E	E	E	E	E	E		E		E	E	E	E
Desert Bighorn Sheep[2]	E	E	E	E	E			E	E	E	E		E

[1]Federally Listed Species

[2]State Listed Species (Group No. 1)

Source: USFWS 1980; (New Mexico) State Game Commission 1980; Burt and Grossenheider 1976; Stebbins 1966; American Ornithologists' Union 1957.

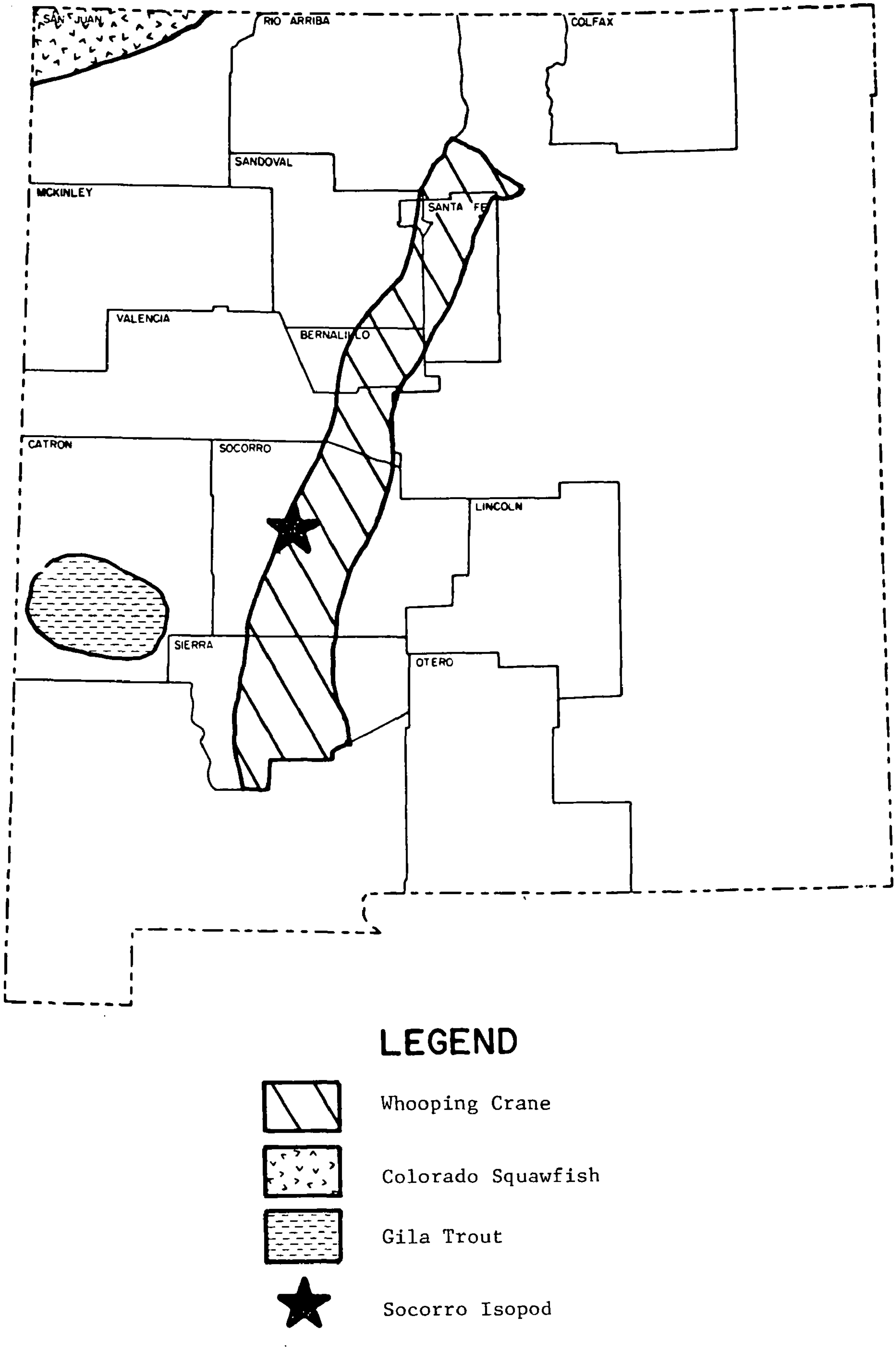

Figure 6-4. Ranges of four Federally listed endangered species.

The Federally threatened Mesa Verde cactus, and the Federally endangered Knowlton cactus and Kuenzler hedgehog cactus are found in this section (Table 6-7 and Figure 6-3).

Wildlife - Sunfish and trout are the important game fish of this region. Salmon are present due to stocking in San Juan County. Other fish are distributed as described in the previous section.

Ducks, geese, and other waterfowl are present in abundance along the Rio Grande River and other large bodies of water. All upland game birds are present throughout the section and are important locally.

Major game mammals include the mule deer, black bear, mountain lion, pronghorn, and whitetail deer. The exotic Barbary sheep is present in Sandoval and San Juan counties. Important furbearers are the gray and red fox, bobcat, beaver, and raccoon. (Table 6-6).

The Federally listed black-footed ferret may still exist in McKinley, San Juan, and Valencia counties (USFWS 1980). Moderate to low numbers of State listed species are found in this area (Table 6-7). Ranges of Federally listed species that are not distributed throughout the State are presented in Figures 6-3 and 6-4.

6.2.2.3 Ponderosa Pine-Douglas-Fir Forest Section

The Ponderosa Pine-Douglas Fir Forest Section (Figure 6-1) covers the extreme north central portion of the State and approximately 16%, or 9655 mi^2 (25,005 km^2) of the Study Area. There are high numbers (5) of land cover types and State listed species in this province. Moderate percentages of select wildlife species are present (Figure 6-2), and the amount of land in natural vegetation ranges from 94 to 96%.

Land Cover - The major land cover types are forest and rangeland (Table 6-1). Other land cover types occupy less than 5% of the total area. A large portion of this section lies in the Sangre de Christo Mountains and the vegetation reflects the montane conditions. Ponderosa pine and Douglas fir are the dominant tree species at higher elevations; the understory is extremely sparce. Treeless areas in this mountainous region support sparce stands of grass mixed with sagebrush.

Rangeland areas of this section contain various grass, brush, and shrub species characteristics of a semidesert environment.

No endangered or threatened plant species occur in the Ponderosa Pine-Douglas Fir Forest Section (USFWS 1980).

Wildlife - As in most of New Mexico, the distribution of wildlife is dependent on altitude, cover type, and the presence of water.

Sunfish and trout are both important game fish in this area. In some streams and lakes, salmon, northern pike, and grayling have been stocked (Table 6-6).

Upland game birds are the most economically important fowl in this area. Common species include Scaled Quail, Gambel's Quail, and Ring-necked Pheasant. Waterfowl are not as abundant as in other portions of the Study Area.

Important large game mammals include the American elk, mule deer, black bear, mountain lion, and whitetail deer. The whitetail jackrabbit and mountain cottontail also are present (Table 6-6). Important furbearers include the raccoon, coyote, red fox, beaver, and muskrat.

The White-tailed Ptarmigan, Sharp-tailed Grouse, and Sage Grouse are State listed endangered species which are unique to this portion of the Study Area (Table 6-7). Ranges of Federally listed species not distributed throughout the State are presented in Figures 6-3 and 6-4.

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CHAPTER 7.0 AIR RESOURCES AND NOISE

7.0 AIR RESOURCES AND NOISE

7.1 INTRODUCTION

Air and noise pollution can be major environmental concerns associated with coal development. Regulations promulgated to protect and improve air quality may limit coal development and noise associated with coal development that may affect people in the surrounding environs.

7.2 AIR RESOURCES

7.2.1 Climate

Climatological factors affect the emission and dispersion of air pollutants associated with coal development. The climatic conditions (precipitation, mixing heights, and wind) that have the greatest effect on air emissions from coal development are presented in this section.

7.2.1.1 Precipitation

Fugitive dust emissions, the major air pollutant associated with coal mining and transport, are inversely proportional to precipitation. As moisture increases, the fine particles in the coal or overburden, which would otherwise become airborne, adhere to larger particles due to the increased surface tension created by the water.

The precipitation in New Mexico (Table 7-1) is about evenly distributed through the year with peak precipitation falling in the months of July and August. From 60 to 90 days each year, the majority of the Study Area receives 0.01 inches (0.03 cm) or more precipitation; most precipitation falls as rain (Baldwin 1973).

Table 7-1. Climatological data for the Study Area in New Mexico (1941-1970).

Climatological Station[1]	Mean Annual Precipitation (inches)	Mean Annual Wind Speed (mph)
Bernalillo County, Albuquerque	7.77	9.0
Union County, Clayton	15.91	no data available
Chaves County, Roswell	10.61	8.9
El Paso County, El Paso, Texas	7.77	9.5

[1] These climatological stations were selected as representative of the Study Area although some of the stations are not located within the Study Area.

Source: NOAA/National Climatic Center. 1978. Local climatological data, annual summary with comparative data. USDOC, Asheville, North Carolina, variously paged.

Precipitation in certain areas of the US has become acidic as a result of the mixing of emissions from the combustion of fossil fuels (such as coal) with moisture. The primary pollutants associated with acid precipitation are sulfur and nitrogen dioxide which convert to acids through a series of complex chemical reactions in the atmosphere. Acid precipitation, commonly known as acid rain, can result in severe ecological effects on the environment. Due to the soils, climatic patterns, and types of vegetation, certain areas are more sensitive to acid precipitation. The majority of the Study Area is highly sensitive to acid precipitation, while the remaining areas have a low sensitivity (Figure 7-1) (USEPA 1979d).

7.2.1.2 Precipitation-Evaporation Index

Precipitation and evaporation, expressed by the (P-E) index developed by C. Warren Thornthwaite, has an effect on fugitive emissions from coal storage piles as well as other cleared or exposed surfaces (USEPA 1978b). The greatest effect is on coal storage piles since they are usually exposed for a longer period of time. Humidity, precipitation, and temperature are considered in developing a numerical value (index), which describes the moisture entering (precipitation) and leaving (evaporation) an area. Lower fugitive emissions are associated with higher P-E index values. This results because higher P-E index values are indicative of higher precipitation and lower evaporation (i.e., higher moisture).

The P-E index values in New Mexico range from 18 to 46 (Figure 7-2). These values are less than the national average of 91 (USEPA 1978b). Therefore, emissions from coal storage piles in New Mexico are generally higher than the national averages for this factor.

7.2.1.3 Morning and Afternoon Mixing Heights

The mixing height is the height above the surface through which relatively vigorous vertical mixing occurs. The dispersion of emissions is directly proportional to the mixing height because this layer produces the volume

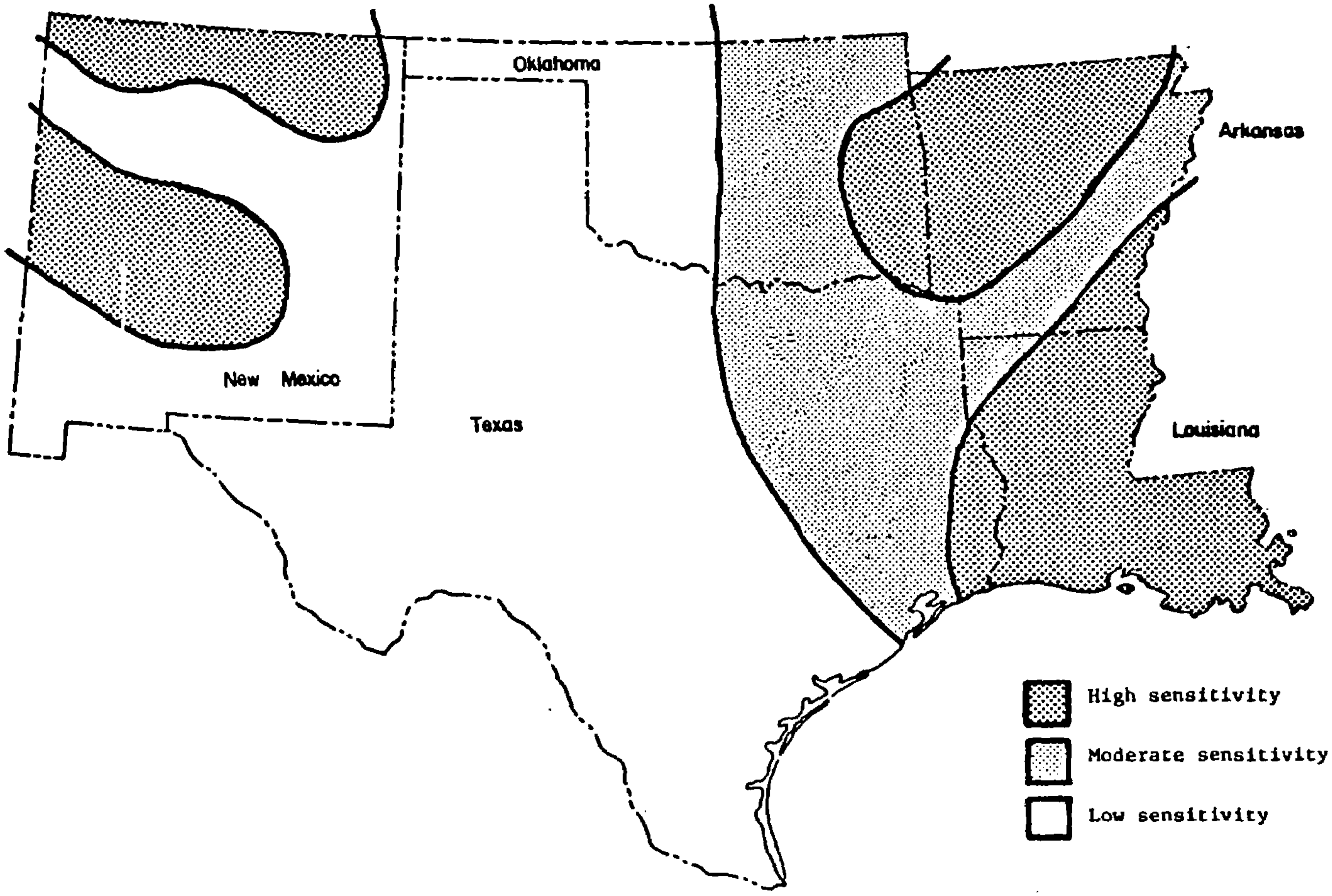


Figure 7-1. Areas sensitive to acid precipitation based on soils, climatic patterns, and vegetation (USEPA 1979).

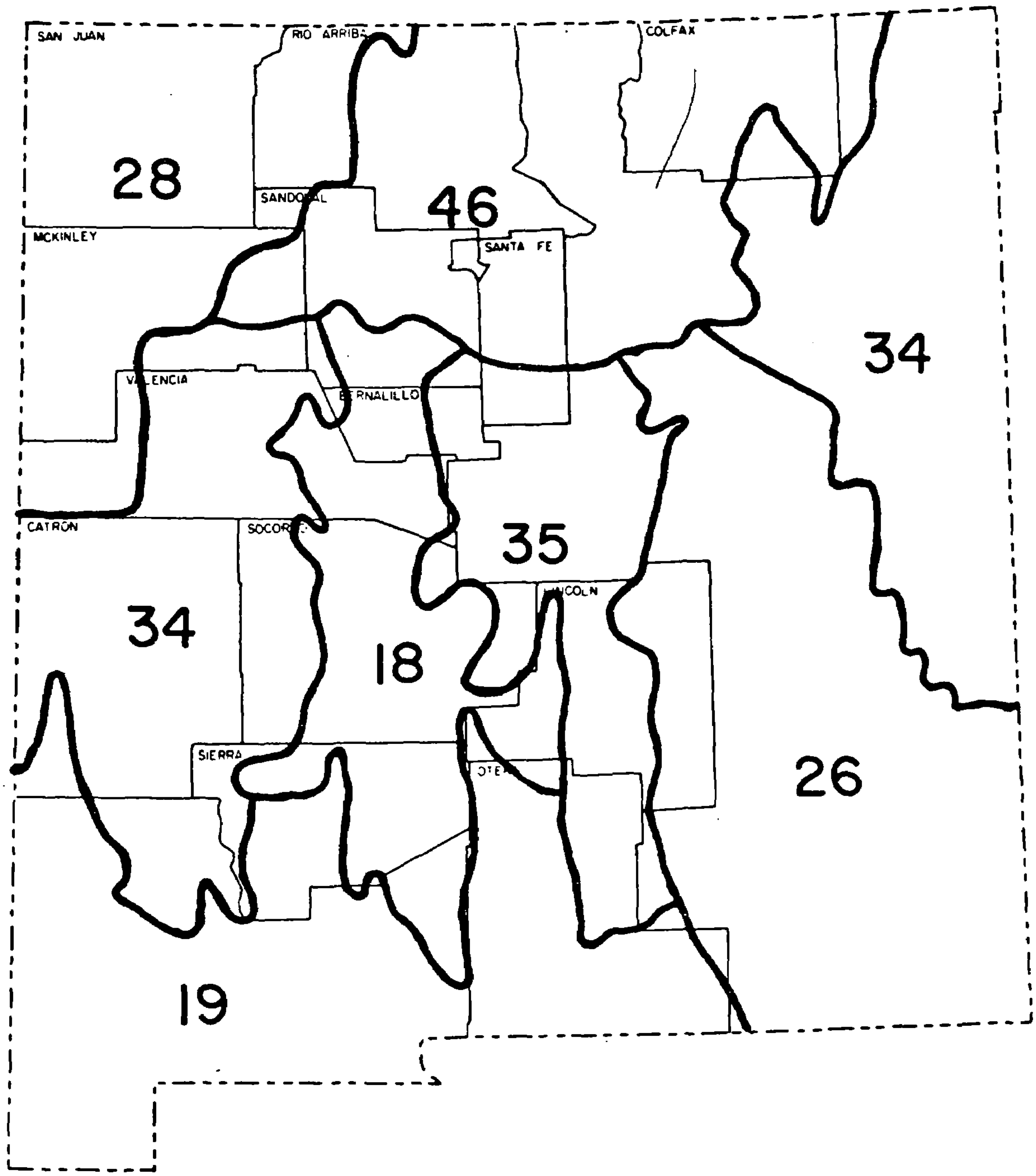


Figure 7-2. Precipitation-evaporation indexes for New Mexico (USEPA 1978b).

through which the pollutant can disperse. The morning mixing heights for New Mexico are about average for this region, while the afternoon mixing heights are greater than the eastern sections of the region (Figure 7-3).

7.2.1.4 Wind Speed

Fugitive dust emissions and dispersion of air pollutant emissions are directly related to wind speed. Fugitive dust emissions increase with wind speed due to the increase in wind energy which is capable of lifting larger particles and making them airborne. Conversely, downwind concentrations of pollutants decrease with increased wind speed due to the greater distances traveled per unit of time (larger dispersion volume). The wind speeds for New Mexico (Table 7-1, Figure 7-3) are fairly consistent through the morning and afternoon mixing layer.

7.2.1.5 Wind Direction

The direction of the prevailing wind aids in determining the primary area of effects from the emission of air pollutants. Receptors downwind from the source, in the predominant wind direction, receive a greater time of pollutant exposure.

When analyzed for the year, wind direction is about evenly distributed between the 16 points on the compass with a slight predominance of winds from the north and southeast (Figure 7-4).

7.2.2 Ambient Air Quality

The discussion and presentation in this section will be limited to the baseline information on the major pollutants associated with coal and coal related developments [particulates, sulfur dioxide (SO_2), and nitrogen

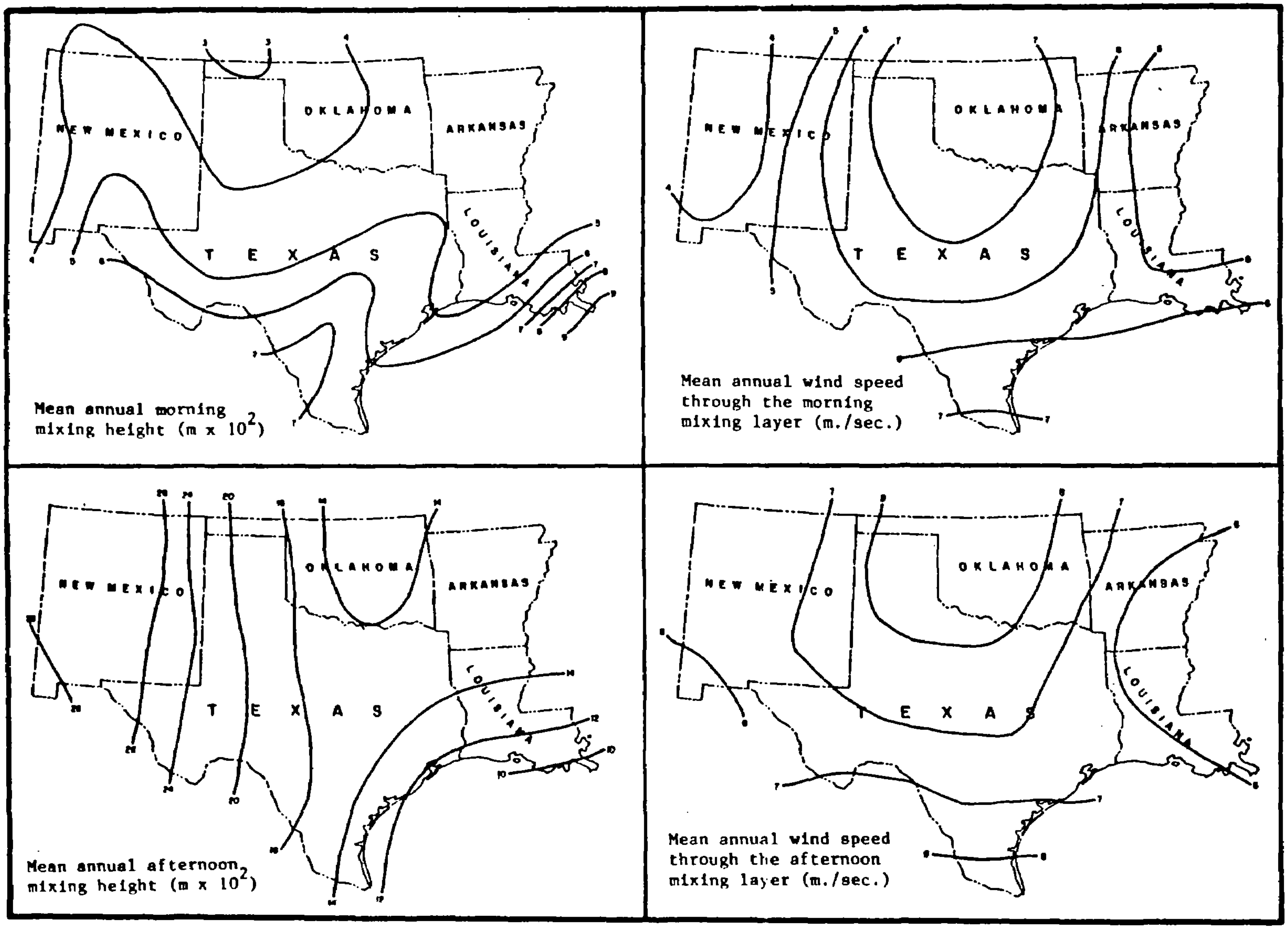
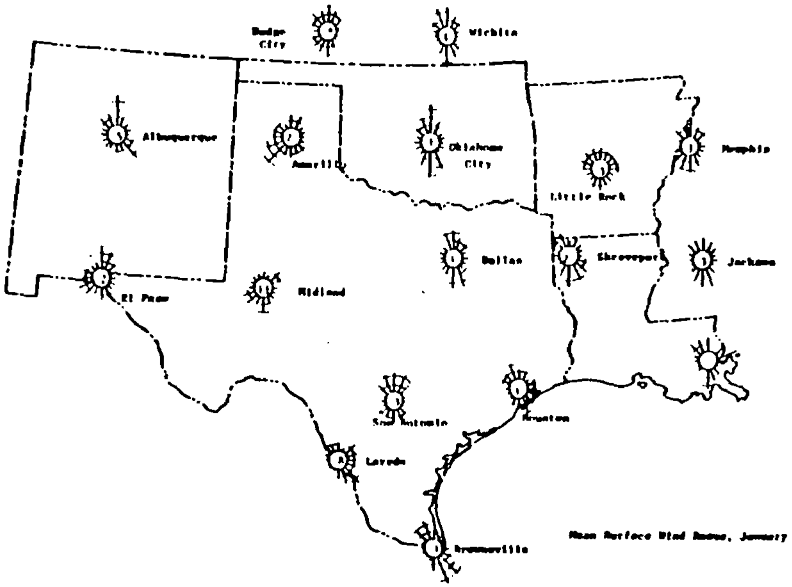
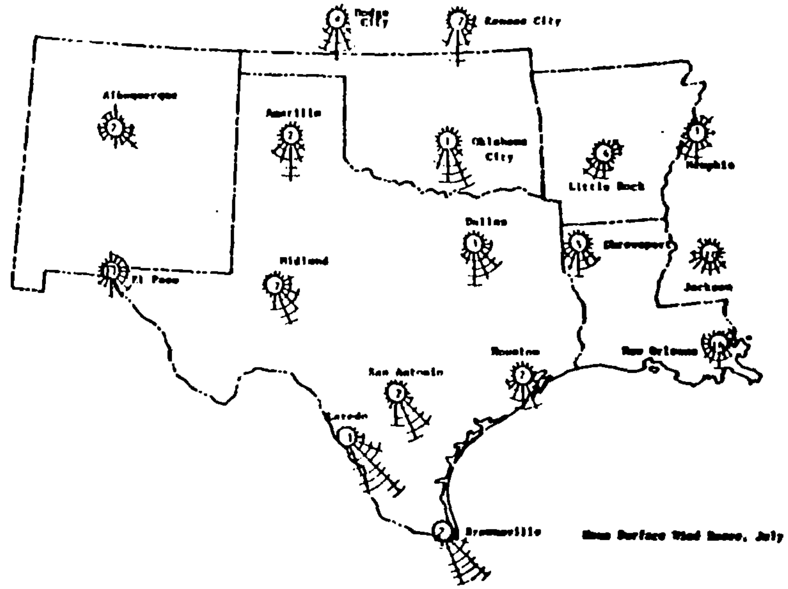
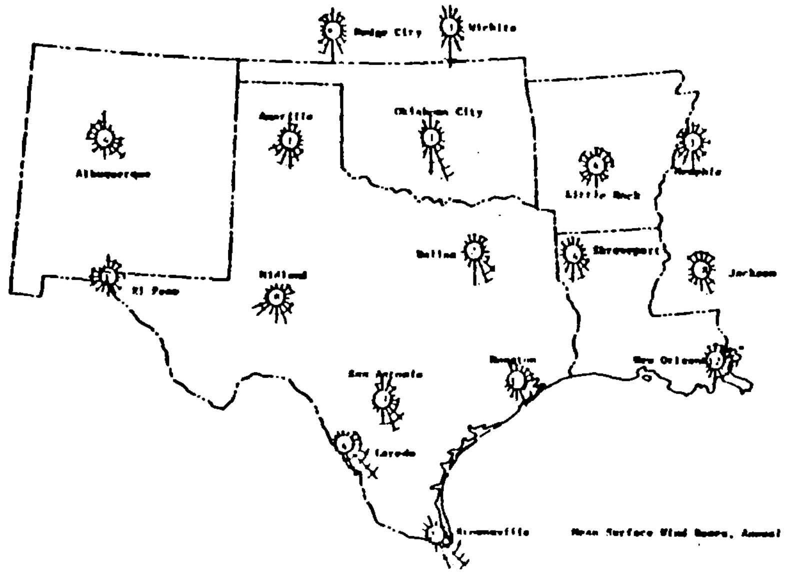


Figure 7-3. Mean annual mixing heights and wind speeds for the Region 6 Study Area (Holzworth 1972).







Legend

Wind roses show percentage of time wind blew from the 16 compass points or was calm.

* Indicates less than 0.5% calm.

Hourly Percentage

25 — calm — 25

Note: Based on hourly observations 1951-60

Figure 7-4. Prevailing mean surface wind directions in the Region 6 Study Area (Baldwin 1973) dioxide (NO_2))][1]. Nonattainment areas for ozone, total suspended particulates (TSP), carbon monoxide, and sulfur dioxide are shown because coal and coal related development (i.e., power plants) could be limited in these areas.

7.2.2.1 Air Quality Control Region (AQCR)

The 1967 Air Quality Act designated that the nation be divided into air quality control regions (AQCR). Organization by AQCRs reduces the State to a more manageable size; AQCRs are included in this document to allow for cross-referencing with other USEPA documents (Exhibit 7).

7.2.2.2 Nonattainment Areas

Under the Clean Air Act Amendments of 1977, the States are required to identify, for each AQCR, the attainment status of each criteria pollutant. All of Bernalillo County is nonattainment for carbon monoxide, while part of the county is nonattainment for TSP and ozone. Other nonattainment areas in the Study Area include parts of San Juan County that are nonattainment for SO_2 (Exhibit 7). Sources locating in a nonattainment area must comply with Section 74-2-7 of the New Mexico Air Quality Control Act as well as Air Quality Control Regulation 702 or 703. The air quality control regulations for coal-burning equipment, coal mining and preparation plants, and gasification facilities would apply in attainment and nonattainment areas and include Regulations 504, 602, 603, and 670-682. In Bernalillo County, the Albuquerque-Bernalillo County Air Quality Control Board has permitting authority for the New Mexico Air Quality Control Act.

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[1]The USEPA National Aerometric Data Bank - SAROAD System (ambient data) monitors for NO_2, while the USEPA NEDS (point and area sources) monitors for NO_x.

7.2.2.3 Prevention of Significant Deterioration (PSD) Areas

PSD regulations apply to areas where the existing air quality is cleaner than the NAAQS. Congress has determined that additional pollutant growth in these areas will be limited to a certain quantity (increment). In addition, three classes of areas were identified with different increments assigned to each class. Class I areas are pristine areas where any effects from air pollutants may be adverse. Class II areas are regions of nominal air quality sensitivity. Class III areas have little air quality sensitivity and the air quality increment for these areas is the most lenient. At present, only two pollutants (particulate matter and sulfur dioxide) are assigned PSD increments. Table 7-2 shows the increments allowed for each of the PSD classes. The Class I areas in New Mexico are shown in Exhibit 7. The name of the Class I areas and their acreage are as follows: Wheeler Peak Wilderness Area - 6,027 acres (2440 ha); San Pedro Parks Wilderness Areas - 41,132 acres (16,653 ha); Bandelier Wilderness Area - 23,267 acres (9,420 ha); Pecos Wilderness Area - 167,416 acres (67,780 ha); Gila Wilderness Area - 433,690 acres (175,583 ha); Bosque del Apache Wilderness Area - 30,850 (12,490 ha); White Mountain Wilderness Area - 31,171 acres (12,620 ha); Salt Creek Wilderness Area - 8,500 acres (3,441 ha); and Carlsbad Caverns National Park - 46,435 acres (18,800 ha). Salt Creek Wilderness Area and Carlsbad Caverns National Park are not located in the Study Area. However, both areas are included due to the potential limiting effect they could exert on coal development in the Study Area as a result of long range transport. The remaining areas of the State are designated as Class II, or unclassified. As yet, there are no Class III areas designated in the United States.

The requirements for obtaining a PSD permit are applicable to most major stationary sources or modifications and are included in 40 CFR Parts 51.24 and 52.21. The requirements associated with effects on a Class I area also are included in these regulations.

Table 7-2. Regulatory standards affecting air quality.

National Ambient Air Quality Standards (NAAQS)

Pollutant	Type of Standard	Averaging Time	Frequency Parameter	Concentration ug/m^3	Concentration ppm
Nitrogen dioxide	Primary & Secondary	1 yr	Arithmetic mean	100	0.05
Particulate matter	Primary	24 hr	Annual maximum	260	-
		24 hr	Annual geometric mean	75	-
	Secondary	24 hr	Annual maximum	150	-
		24 hr	Annual geometric mean	60	
Sulfur dioxide	Primary	24 hr	Annual maximum	365	0.14
		1 yr	Arithmetic mean	80	0.03
	Secondary	3 hr	Annual maximum	1,300	0.5
Carbon monoxide	Primary & Secondary	1 hr	Annual maximum	40,000	35
		8 hr	Annual maximum	10,000	9
Ozone	Primary & Secondary	1 hr		235	0.12

Prevention of Significant Deterioration (PSD) increments:

maximum allowable increase by class

Pollutant	Class I (ug/m^3)	Class II (ug/m^3)	Class III (ug/m^3)
Particulate Matter:			
Annual geometric mean	5	19	37
24-hour maximum	10	37	75
Sulfur Dioxide:			
Annual arithmetic mean	2	20	40
24-hour maximum	5*	91	182
3-hour maximum	25*	512	700

* A variance may be allowed to exceed each of these increments on 18 days per year, subject to limiting 24-hour increments of 36 ug/m^3 for low terrain and 62 ug/m^3 for high terrain and 3-hour increments of 130 ug/m^3 for low terrain and 221 ug/m^3 for high terrain. To obtain such a variance both state and Federal approval is required.

Section 169A of the Clean Air Act requires visibility protection for mandatory Class I areas where it has been determined that visibility is an important value. On 30 November 1979, USEPA promulgated a list of the mandatory Class I areas where visibility is an important value. This list includes all the Class I areas in New Mexico (USEPA 1979b). One integral vista (a view perceived from within a mandatory Class I Federal area of a specific landmark or panorama located outside the boundary of the mandatory Class I area) is identified for Carlsbad Caverns National Park (National Park Service 1981). As yet no integral vistas are identified for the wilderness areas.

7.2.2.4 Ambient Monitoring Data for Total Suspended Particulates (TSP)

Sources that are potential major emitters of particulate matter (i.e., coal developments) are required to conduct an air quality analysis to determine if the NAAQS and PSD increments will be violated.

Ambient monitoring data (24-hour second high and annual geometric mean) from the USEPA National Aerometric Data Bank-SAROAD System for those counties in New Mexico that monitor for TSP are presented in Table 7-3. The ambient TSP levels in the Study Area were rated high, medium, or low for the most recent year available (Figure 7-5). The arbitrary ratings were based on the upper third (high), middle third (medium), and lower third (low), of the NAAQS for the 24-hour annual geometric mean. TSP is the only criteria pollutant that occurs at levels in the top third (high rating) of the NAAQS. The ranking is applicable only to the location of the monitoring station. When there is more than one station per county, the highest level was rated.

7.2.2.5 Ambient Monitoring Data for Sulfur Dioxide (SO_2)

Sources that are potential major emitters of SO_2 (i.e., coal related developments) are required to conduct an air quality analysis to determine if NAAQS and PSD increments will be violated.

Table 7-3. Ambient monitoring data for those counties in the Study Area that monitor for TSP, SO_2 and NO_2.

		TSP Level				SO_2 Level				NO_2 Level	
County	City	Most Recent Year / Year w/ Highest Level	24-Hr 2nd High	Most Recent Year / Year w/ Highest Level	Geometric Mean	Most Recent Year / Year w/ Highest Level	24-Hr 2nd High	Most Recent Year / Year w/ Highest Level	Arithmetic Mean	Most Recent Year / Year w/ Highest Level	Arithmetic Mean
Bernalillo	Albuquerque	1980	190[b]	1979	54	1979	5	c	c	1978	34
		1977	318	1977	99	1977	50	c	c	a	a
Bernalillo	Albuquerque	1980	215[b]	1979	95	1979	73	1976	15	1978	6
		1979	400	1976	142	same	same	a	a	1976	34
Bernalillo	Albuquerque	1980	146[b]	1979	57	1976	26	c	c	c	c
		1979	179	1976	80	a	a	c	c	c	c
Bernalillo	Albuquerque	1979	110	1978	27	-	-	-	-	-	-
		1976	207	1976	74	-	-	-	-	-	-
Bernalillo	Albuquerque	1979	40	1978	29	-	-	-	-	-	-
		1977	106	1976	45	-	-	-	-	-	-
Bernalillo	Albuquerque	1980	116[b]	1979	41	-	-	-	-	-	-
		1978	167	1976	67	-	-	-	-	-	-
Bernalillo	Albuquerque	1980	219[b]	1979	72	-	-	-	-	-	-
		same	same	1976	103	-	-	-	-	-	-
Bernalillo	Albuquerque	1979	227	1979	72	-	-	-	-	-	-
		same	same	1977	96	-	-	-	-	-	-
Bernalillo	Albuquerque	1980	145[b]	-	-	-	-	-	-	-	-
		a	a	-	-	-	-	-	-	-	-
Bernalillo	Albuquerque	1980	143[b]	-	-	1980	17[b]	c	c	c	c
		a	a	-	-	a	a	c	c	c	c
Bernalillo	Albuquerque	1979	188	1978	76	-	-	-	-	-	-
		1977	258	1976	99	-	-	-	-	-	-
Bernalillo		1979	232	1979	65	1976	3	c	c	c	c
		1977	289	1976	97	a	a	c	c	c	c
Bernalillo		1980	300[b]	-	-	-	-	-	-	-	-
		a	a	-	-	-	-	-	-	-	-
Bernalillo		1980	171[b]	1979	75	-	-	-	-	-	-
		1977	332	1976	114	-	-	-	-	-	-
Bernalillo		1980	118	-	-	-	-	-	-	-	-
		a	a	-	-	-	-	-	-	-	-

Table 7-3. Ambient monitoring data for those counties in the Study Area that monitor for TSP, SO_2 and NO_2 (continued).

		TSP Level				SO_2 Level				NO_2 Level	
County	City	Most Recent Year / Year w/ Highest Level	24-Hr 2nd High	Most Recent Year / Year w/ Highest Level	Geometric Mean	Most Recent Year / Year w/ Highest Level	24-Hr 2nd High	Most Recent Year / Year w/ Highest Level	Arithmetic Mean	Most Recent Year / Year w/ Highest Level	Arithmetic Mean
Bernalillo	Albuquerque	1980	75[b]	1979	24	1976	3	c	c	c	c
		1976	236	1976	37	a	a	c	c	c	c
Bernalillo		1980	108[b]	1978	50	-	-	-	-	-	-
		1977	172	same	same	-	-	-	-	-	-
Colfax	Raton	1980	118[b]	1979	56	1978	5	1977	11	1979	27
		1977	410	1977	67	1977	37	1976	13	1976	30
Lincoln	Ruidoso Downs	1977	208	c	c	-	-	-	-	-	-
		same	same	c	c	-	-	-	-	-	-
McKinley	Gallup	1980	315[b]	1979	128	-	-	-	-	-	-
		1979	373	a	a	-	-	-	-	-	-
McKinley		1980	86[b]	1979	59	-	-	-	-	-	-
		1977	298	1976	70	-	-	-	-	-	-
McKinley	Zuni Pueblo	1980	86[b]	1979	29	-	-	-	-	-	-
		1977	119	1978	33	-	-	-	-	-	-
Otero	Alamagordo	1980	146[b]	1979	71	-	-	-	-	-	-
		1977	294	1977	93	-	-	-	-	-	-
Otero	Tularosa	1980	146[b]	1979	77	-	-	-	-	-	-
		1977	355	1977	84	-	-	-	-	-	-
Rio Arriba	Espanola	1980	231[b]	1979	55	-	-	-	-	-	-
		same	same	same	same	-	-	-	-	-	-
Rio Arriba	Dulce	1979	33	1978	13	-	-	-	-	-	-
		1977	171	1977	14	-	-	-	-	-	-
Sandoval	Bernalillo	1980	135[b]	1979	77	-	-	-	-	-	-
		1977	234	1977	109	-	-	-	-	-	-
San Juan	Aztec	1980	150	1977	58	1978	13	c	c	c	c
		1977	198	same	same	1977	50	c	c	c	c
San Juan	Farmington	1979	119	1978	112	1978	3	c	c	c	c
		1976	323	1976	137	1977	50	c	c	c	c
San Juan	Farmington	1980	501	c	c	-	-	-	-	c	c
		same	same	c	c	-	-	-	-	c	c

Table 7-3. Ambient monitoring data for those counties in the Study Area that monitor for TSP, SO_2 and NO_2 (continued).

		TSP Level				SO_2 Level				NO_2 Level	
County	City	Most Recent Year / Year w/ Highest Level	24-Hr 2nd High	Most Recent Year / Year w/ Highest	Geometric Mean	Most Recent Year / Year w/ Highest Level	24 Hr. 2nd High	Most Recent Year / Year w/ Highest Level	Arithmetic Mean	Most Recent Year / Year w/ Highest Level	Arithmetic Mean
San Juan	Farmington	1980	85[b]	1978	29	1980	89	1979	20	1977	10
		1976	346	1976	52	1979	95	same	same	a	a
San Juan	Farmington	1980	113[b]	1978	47	-	-	-	-	-	-
		1976	357	1976	77	-	-	-	-	-	-
San Juan		1980	79[b]	1978	46	1978	3	1977	14	1977	19
		1977	348	1977	64	1977	39	a	a	a	a
San Juan	Kirtland	1980	254[b]	1978	45	-	-	-	-	-	-
		same	same	1976	59	-	-	-	-	-	-
San Juan	Huerfano	1979	99	1978	29	-	-	-	-	-	-
		1977	502	1977	42	-	-	-	-	-	-
San Juan	Chaco Canyon	1979	57	1978	24	-	-	-	-	-	-
		1977	274	1977	31	-	-	-	-	-	-
San Juan	Burnham	1979	26	c	c	-	-	-	-	-	-
		1977	324	c	c	-	-	-	-	-	-
San Juan	Navajo Indian Reservation	1980	109[b]	1978	47	1980	123	1979	19	1978	17
		1977	229	same	same	1979	185	same	same	same	same
San Juan	Shiprock	1980	73[b]	1978	32	1980	136	1977	6	-	-
		1977	158	a	a	same	same	a	a	-	-
Santa Fe	Santa Fe	1980	104[b]	1979	41	1978	8	1977	8	1979	16
		1977	110	1976 & 77	47	1976	47	1976	20	same	same
Santa Fe	Santa Fe	1980	201	1979	83	-	-	-	-	-	-
		1979	223	same	same	-	-	-	-	-	-
Santa Fe	Santa Fe	1980	131[b]	1979	55	-	-	-	-	-	-
		1979	157	same	same	-	-	-	-	-	-
Sierra	Truth or Consequences	1980	214[b]	1979	61	-	-	-	-	-	-
		1978	246	1976	85	-	-	-	-	-	-
Socorro	Socorro	1980	119[b]	1979	62	1978	5	1977	9	1979	21
		1978	194	same	same	1976	60	a	a	same	same
Valencia	Belen	1980	165[b]	1979	91	-	-	-	-	-	-
		1976	287	same	same	-	-	-	-	-	-

Table 7-3. Ambient monitoring data for those counties in the Study Area that monitor for TSP, SO_2 and NO_2 (concluded).

County	City	TSP Level: Most Recent Year / Year w/ Highest Level	TSP Level: 24-Hr 2nd High	TSP Level: Most Recent Year / Year w/ Highest Level	TSP Level: Geometric Mean	SO_2 Level: Most Recent Year / Year w/ Highest Level	SO_2 Level: 24-Hr 2nd High	SO_2 Level: Most Recent Year / Year w/ Highest Level	SO_2 Level: Arithmetic Mean	NO_2 Level: Most Recent Year / Year w/ Highest Level	NO_2 Level: Arithmetic Mean
Valencia	Milam	1980	407[b]	1979	164	-	-	-	-	-	-
		1977	677	a	a	-	-	-	-	-	-
Valencia	Grants	1979	498	1979	100	-	-	-	-	-	-
		1978	574	1978	130	-	-	-	-	-	-
Valencia	Paquate	1980	234[b]	1979	79	-	-	-	-	-	-
		1976	326	same	same	-	-	-	-	-	-
Valencia	San Mateo	1980	128[b]	1979	40	-	-	-	-	-	-
		1978	242	same	same	-	-	-	-	-	-
Valencia	Anaconda	1980	140[b]	1979	20	-	-	-	-	-	-
		1978	183	1977	32	-	-	-	-	-	-
Valencia	Bluewater	1980	249[b]	1979	73	-	-	-	-	-	-
		1978	365	same	same	-	-	-	-	-	-
Valencia		1980	255[b]	1979	128	-	-	-	-	-	-
		1979	596	same	same	-	-	-	-	-	-
Valencia		1980	341[b]	1979	73	-	-	-	-	-	-
		same	same	a	a	-	-	-	-	-	-

\- No data available

[a]Only year for which data is available or only year that data meets EPA summary criteria

[b]1980 4th quarter data is not included

[c]No data available that meets EPA's summary criteria

Source: USEPA. 1981. Natioanl aerometric data bank/quick look report. Computer printout, January 1981. 123p.

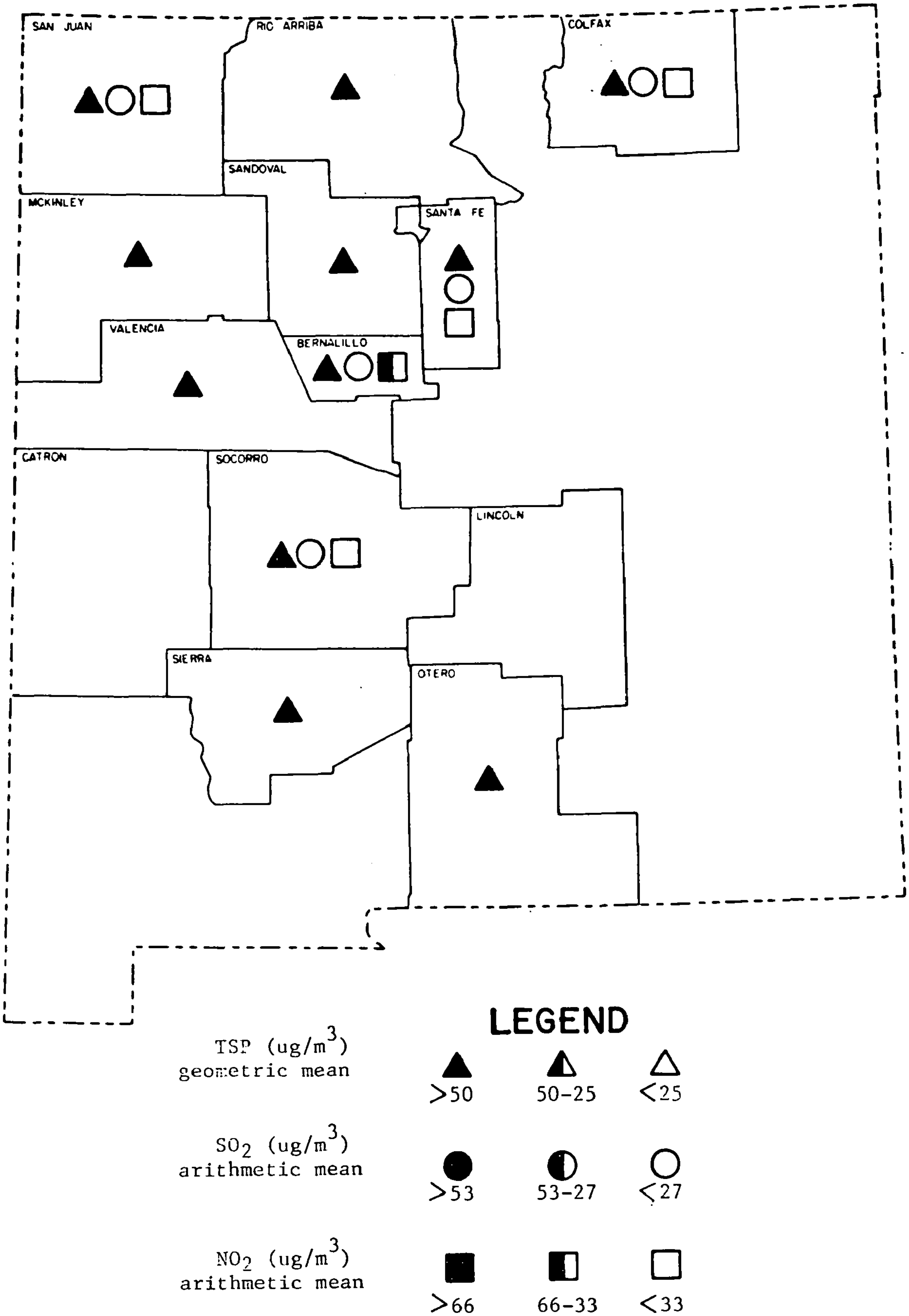

Figure 7-5. Ranking of ambient monitoring data for those counties in the Study Area that monitor for TSP, SO_2, and NO_2.

Ambient monitoring data from the USEPA National Aerometric Data Bank-SAROAD System for counties in New Mexico that monitor for SO_2 are presented in Table 7-3. The 24-hour second high value and the arithmetic mean are presented to aid in the planning of coal developments. The arithmetic mean was rated high, medium, or low for the most recent year available (Figure 7-5). The ratings were arbitrarily based on the upper third (high), middle third (medium), and lower third (low) of the NAAQS for the arithmetic mean. SO_2 was rated above low in all counties where SO_2 monitoring occurred. The ranking is applicable only to the location of the monitoring station. When there was more than one station per county, the highest level was included in the rating.

7.2.2.6 Ambient Monitoring Data for Nitrogen Dioxide (NO_2)

Sources that are potential major emitters of NO_2 (i.e., coal related developments) are required to conduct an air quality analysis to determine if NAAQS will be violated.

Ambient monitoring data (arithmetic mean) from the USEPA National Aerometric Data Bank-SAROAD System for those counties in New Mexico that monitor for NO_2 are presented in Table 7-3. The ambient NO_2 levels in the Study Area were rated high, medium, or low for the most recent year available (Figure 7-5). The ratings were arbitrarily based on the upper third (high), middle third (medium), and lower third (low) of the NAAQS for the arithmetic mean. A rating above low occurred only in Bernalillo County. The ranking is applicable only to the location of the monitoring station. When there was more than one station per county, the highest level was used.

7.2.3 Major Emission

The quantity and location of the major point source emissions[1] in New Mexico are helpful in planning the location of coal development. The potential for a violation of either the NAAQS or the PSD increments (for SO_2 and particulates) increases where there is a cluster of major point source emitters or where there are higher levels of point and area source emissions.

7.2.3.1 Point Source Emissions

Major point sources are clustered around larger cities such as Albuquerque, Santa Fe, and Farmington (Exhibit 7 and Table 7-4). Point source emissions of particulates were greater than 15,000 tons/year in Bernalillo and San Juan counties. SO_2 emissions greater than 25,000 tons/year were also reported from Bernalillo and San Juan counties. SO_2 emissions in excess of 100,000 tons/year occurred in San Juan County. NO_x emissions greater than 5,000 tons/year were reported from Bernalillo, McKinley, and San Juan counties (Table 7-4).

7.2.3.2 Area Source Emissions

Area source emissions are defined as sources reported collectively because they are too difficult to be surveyed individually. These sources can affect the ambient air quality of the county relative to the NAAQS and the PSD increments (for SO_2 and particulate matter), and therefore could affect the amount of additional emissions allowed in the area.

Data for the total 1978 area sources particulates (SO_2, and NO_x) for each county are presented in Table 7-5. Data for the total 1978 point and area sources for each county are presented in Table 7-6. The total point and area source emissions for particulates range from 16,667 tons/year in Sierra County to 1,313,758 tons/year in McKinley County. Point and area source particulate emissions greater than 100,000 tons/year were reported for Bernalillo, McKinley, and San Juan counties. The SO_2 area and point source emissions range fdrom 35 tons/year in Catron County to 131,979 tons/year in San Juan County. Point and area source SO_2 emissions greater than 20,000 tons/year were reported from Bernalillo and San Juan counties, with the

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[1]The USEPA National Aerometric Data Bank - SAROAD System (ambient data) monitors for NO_2, while the USEPA NEDS (point and area sources) monitors for NO_x.

Table 7-4. Total 1978 county emissions (tons/year) from point sources for 13 New Mexico counties.

County	Total Point Source Emissions			Number of Plants > 100 Tons Per Year		
	Particulates	SO_2	NO_x	Particulates	SO_2	NO_x
Bernilillo	23,126	23,618	11,010	7	3	4
Catron	42	1	6	0	0	0
Colfax	515	144	149	2	1	1
Lincoln	22	0	2,626	0	0	2
McKinley	783	2,466	6,330	3	3	7
Otero	758	2	18	1	0	0
Rio Arriba	238	36	2,332	0	0	6
Sandoval	538	42	1,029	1	0	2
San Juan	16,983	130,747	122,527	4	4	20
Santa Fe	510	0	0	1	0	0
Sierra	1,821	0	0	1	0	0
Socorro	17	0	0	0	0	0
Valencia	639	41	3,270	1	0	5

Source: USEPA. 1981. National emissions data system. Computer printout, January 1981, variously paged.

Table 7-5. Total 1978 county emissions (tons/year) from area sources for 13 New Mexico counties.

County	Particulates	SO_2	NO_x
Bernalillo	111,602	3,223	16,460
Catron	34,267	34	414
Colfax	26,368	140	1,127
Lincoln	43,685	135	1,104
McKinley	1,312,975	974	6,816
Otero	56,507	426	2,778
Rio Arriba	76,595	196	1,797
Sandoval	42,372	235	2,673
San Juan	142,443	1,232	6,894
Santa Fe	44,162	497	3,289
Sierra	14,846	58	515
Socorro	44,294	91	997
Valencia	93,041	352	3,308

Source: USEPA. 1981. National emissions data system. Computer printout, January 1981, variously paged.

Table 7-6. Total 1978 emissions (tons/year) from point and area sources for 13 New Mexico counties.

County	Particulates	SO_2	NO_x
Bernalillo	134,728	26,841	27,470
Catron	34,309	35	420
Colfax	26,883	284	1,276
Lincoln	43,707	135	3,730
McKinley	1,313,758	3,440	13,146
Otero	57,265	428	2,796
Rio Arriba	76,833	232	4,129
Sandoval	42,910	277	3,702
San Juan	159,426	131,979	129,421
Santa Fe	44,672	497	3,289
Sierra	16,667	58	515
Socorro	44,311	91	997
Valencia	93,680	393	6,578

Source: USEPA. 1981. National emissions data system. Computer printout, January 1981, variously paged.

emissions in San Juan County in excess of 100,000 tons/year. The total point and areas sources for NO_x range from 420 tons/year in Catron County to 129,421 tons/year in San Juan County. Point and area source NO_x emissions greater than 25,000 tons/year were reported from Bernalillo and San Juan counties. NO_x emissions in excess of 100,000 tons/year were reported from San Juan County.

7.3 NOISE

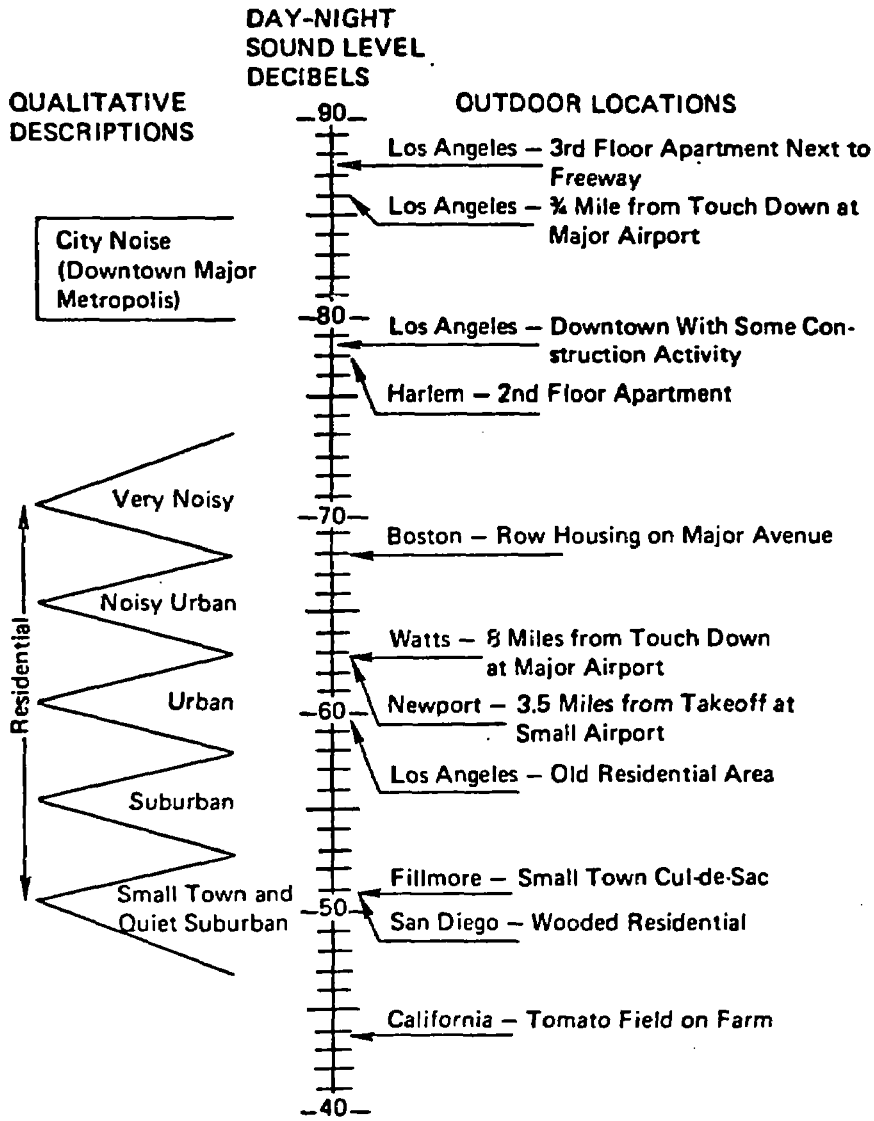
7.3.1 Existing Environment

Specific information concerning the existing noise environment of New Mexico cannot be presented because noise levels differ dramatically from one area to another. Since noise attenuates rapidly with distance, it is best defined on a site-specific basis (i.e., a noise survey should be performed at each location of interest to determine the actual noise environment). "Typical" noise values for urban and rural environments are established (Figure 7-6). However, even in the noise categories presented, the noise level can vary significantly depending on location.

7.3.2 Noise Levels from Typical Mining Operations

The major noise producing equipment associated with mining operations are the dragline, front loaders, tractors, haul trucks, scrapers, backhoes, water trucks, and mine vent fans (Table 7-7). Whereas noise levels attenuate rapidly with distance (6 dBA per doubling of distance), the effects of noise sensitive receptors will be confined to those areas immediately outside of the mine area. Noise sensitive receptors may include private residences, schools, hospitals, and parks. Commercial and industrial activities are not generally considered sensitive to noise (USEPA 1978a).

Figure 7-6. Typical urban and rural L_{dn}[1] noise levels (NRC 1977).



[1]The L_{dn} is the 24-hour equivalent noise level with a 10 dBA penalty applied to the hours between 10:00 p.m. and 7:00 a.m.

Table 7-7. Noise levels (dBA) produced by coal mining equipment at 100 feet (30 meters).

Equipment	Sound Level
Dragline[1]	74
100 ton truck (loaded) at 12 MPH[1]	70
Tractor[1]	72
Water truck (10-12 MPH)[1]	65
Scraper[1]	67
Front loader[2]	73
Backhoe[2]	71
Mine vent fan[3]	77

Sources: [1]Adapted from USGS 1976.

[2]Adapted from USEPA 1971.

[3]Adapted from Watkins and Associates 1979.

7.3.3 Noise Criteria and Standards

There are no Federal, State, or local regulations at this time defining the noise level effects associated with industrial or mining operations. The USEPA has published values below which there is no reason to suspect that the general public will be at risk from any effects of noise (EPA 1978). These values are not considered guidelines or regulations and were derived without concern for technical or economic feasibility, these values contain a margin of safety to ensure their protective benefit. These values are presented in Table 7-8.

Table 7-8. Yearly L_{dn} values established to protect public health and welfare with a margin of safety.

Effect	Level	Area
Hearing	$L_{eq}(24)$ 70 dB	All areas (at the ear)
Outdoor activity interference and annoyance	$L_{eq}(24)$ 70 dB	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	$L_{eq}(24)$ 55 dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity interference and annoyance	L_{dn} 45 dB	Indoor residential areas.
	$L_{eq}(24)$ 45 dB	Other indoor areas with human activities such as schools, etc.

Source: USEPA 1978a. Protective noise levels. EPA 550/9-79-100, Washington DC.

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CHAPTER 8.0 CULTURAL RESOURCES

8.0 CULTURAL RESOURCES

8.1 INTRODUCTION

Cultural resources are archaeological data "embodied in material remains (artifacts, structures, refuse, etc.), utilized purposefully or accidentally by human beings, and in the spatial relationships among such remains (36 CFR 1210.4[1b])". Cultural resources may be historic, prehistoric, or scientific data.

This discussion is based on a review of relative literature and will briefly define the major (prehistoric and historic) cultural traditions and identify the different types of sites for each and their known distribution. The major traditions represent similar trends in technology, settlement patterns, and site types over a wide geographic area. Although all major traditions are present throughout New Mexico, there are regional variations in specific manifestations. Figure 8-1 is a graphical outline of the two major cultural regions in the Study Area. The major traditions and the regional sequences, with each sequence being defined by specific artifact types, are identified in Table 8-1.

All observations concerning site distributions are tentative, given the present state of knowledge. Although New Mexico is among the most intensively investigated areas in the United States, the data base is neither complete nor accurate enough to predict exactly where sites occur except in certain select areas. Although approximately 11,000 sites from the 13 counties are on file with the Archeological Records Management Program at the Laboratory of Anthropology, New Mexico Museum, and the New Mexico State Historic Preservation Bureau (Table 8-2, Figure 8-2), these do not represent the total number of sites present, since no county is has been inventoried completely. The National Park Service has developed a computerized data base using records of known sites to develop a predictive model of site location based on exist-

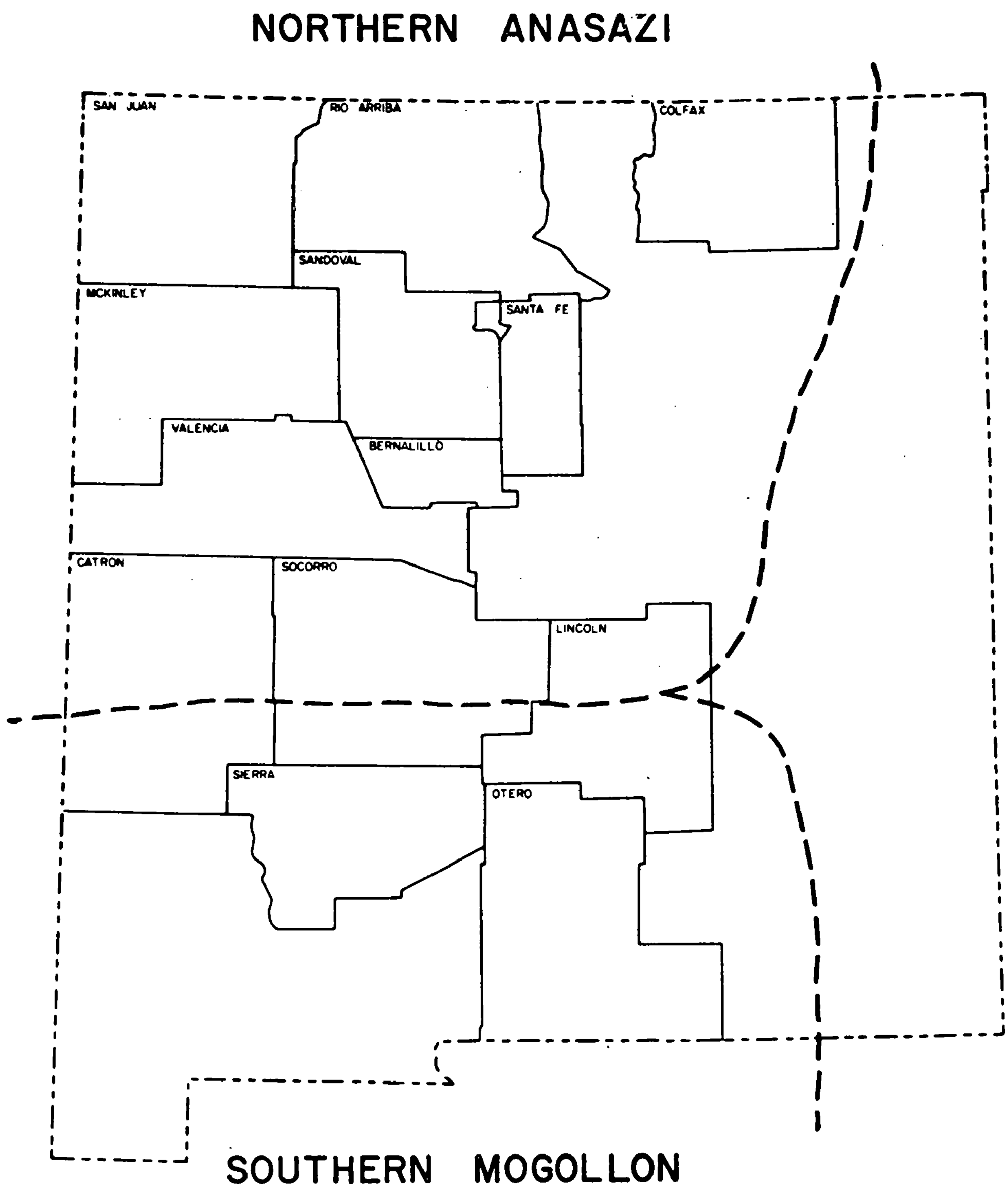


Figure 8-1. Major cultural regions of New Mexico.

Table 8-1. Major cultural traditions and regional sequences in New Mexico.

Years BP[1]	Major Traditions	Regional Sequences: Northern (Anasazi)		Regional Sequences: Southern (Mogollon)	
0–400	Historic	Historic		Historic	
400–2000	Ceramic	Anasazi	Pueblo V Pueblo IV Pueblo III Pueblo II Pueblo I	Mogollon	Pueblo IV Pueblo III
			Basketmaker III		5 4 3 2 1
			Basketmaker II		
2000–7000	Archaic	Oshara Tradition		Cochise Tradition	
7000–12000	Paleo-Indian	P A L E O - I N D I A N			

[1]BP = "Before Present"

Table 8-2. Number of prehistoric and historic sites in the Study Area.

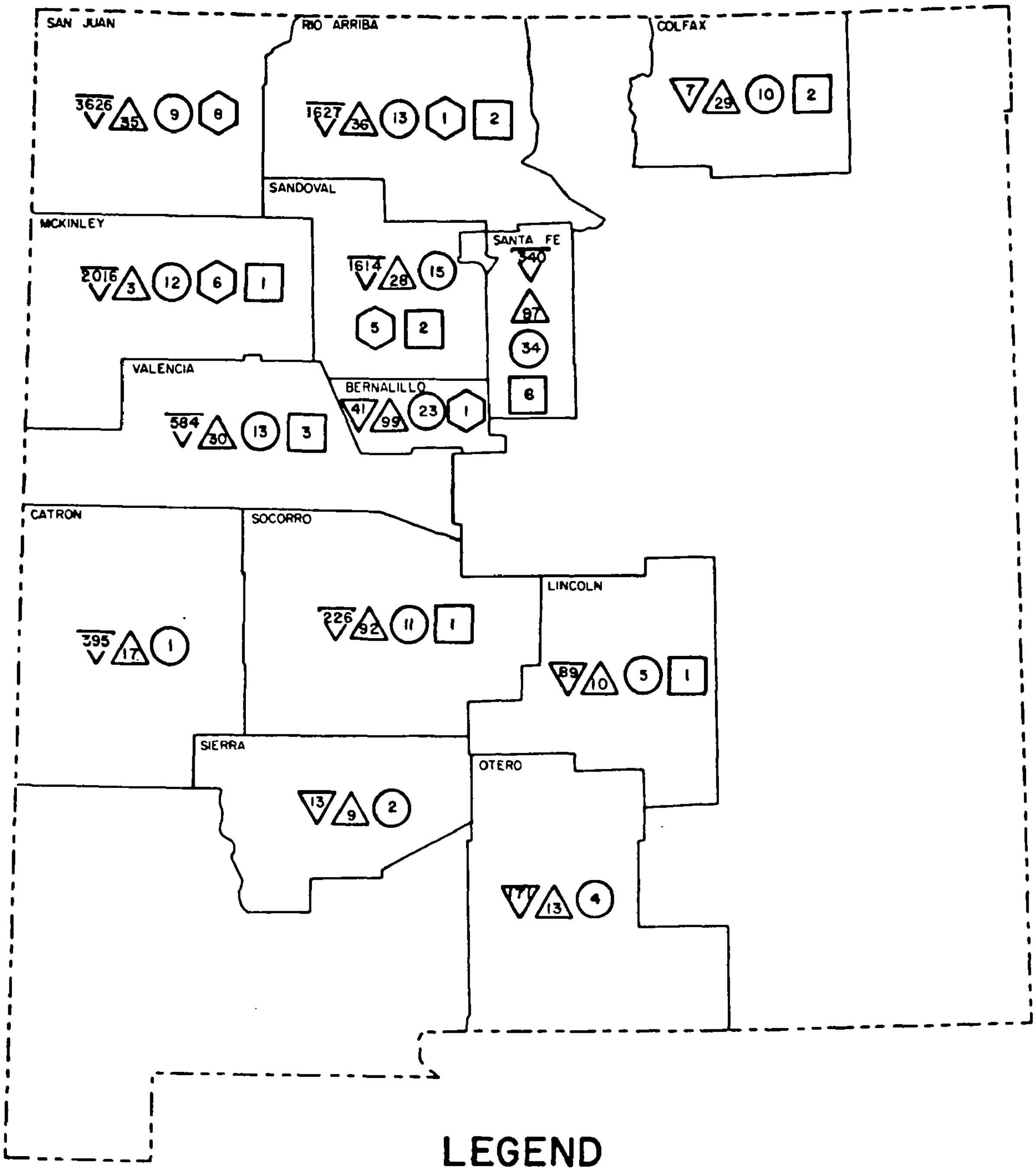
County	Laboratory of Anthropology, Museum of New Mexico	New Mexico State Historic Preservation Program	National Register of Historic Places	National Historic Landmarks
Bernalillo	41	99	23 (1 district)	
Catron	395	17	4	
Colfax	7	29	10 (2 districts)	2
Lincoln	89	10	5 (2 districts)	1
McKinley	2,016	33	12 (3 districts) [6-4 districts]	1
Otero	171	13	4 (2 districts)[3]	
Rio Arriba	1,627	36	13 (1 district) [1 district]	2
Sandoval	1,614	28	15 [5-1 district]	2
San Juan	3,626	35	9 (2 districts) [8-4 districts]	
Santa Fe	340	97	34 (4 districts)	7
Sierra	13	9	2	
Socorro	226	92	11	1
Valencia	584	30	13	3
	10,749	528	155 (17 districts)[23]	19

[ ] = Eligible sites

Sources: Federal Register. Volume 44, No. 26, pt. 2, 1979, Volume 45, No. 54, pt. 2, 1980; Volume 46, No. 22, pt. 2, 1981.

Laboratory of Anthropology, Museum of New Mexico. Archeological Records Management Program. February, 1981.

State of New Mexico, State Historic Preservation Program. Property Inventory By County, Revised August, 1980.



LEGEND

▽ Museum of New Mexico, Laboratory of Anthropology

△ State Historic Sites Inventory

○ National Register

⬡ Eligible Sites

□ National Historic Landmarks

Figure 8-2. Recorded prehistoric and historic sites in the Study Area.

ing data in the San Juan Basin. This program was instituted, in part, to aid energy development projects in fulfilling obligations with regards to cultural resources.

Although the following discussion on site distributions is based on an incomplete data base, two main axioms generally are accepted: (1) prehistoric occupations tend to be oriented toward major drainages and associated tributaries, and (2) historic occupations tend to be more randomly scattered about the landscape.

The following discussion is not necessarily meant to emphasize prehistoric sites. Because historic sites are more visible and more variabile than prehistoric sites, those sites in the Study Area included in or eligible to the National Register of Historic Places (Tables 8-3 and 8-4) are presented to show the variety of historic resources. The National Register has traditionally emphasized historic resources; by referring to Tables 8-3 and 8-4, a better description of the types of historic resources in New Mexico can be obtained.

8.2 TEMPORAL UNITS

The major cultural traditions in New Mexico are identified in Table 8-1. These are pan-regional constructs that extend beyond New Mexico and have temporal significance because of similarities in types and distributions of artifacts and sites. The specific manifestations of these traditions vary throughout the State and are thought of as individual archaeological cultures identified by a specific artifact assemblage (Table 8-1).

8.2.1 Paleo-Indian (12000 - 7000 BP[1])

Importance: Earliest widely accepted evidence for human occupation in North America.

Settlement-subsistence: Exploitation of large Late Pleistocene animals by highly mobile human groups.

[1]BP - "Before Present, "i.e., before 1950.

Table 8-3. Sites in the Study Area presently on the National Register of Historic Places.

<u>Bernalillo County</u>

Albuquerque. Armijo, Salvador, House, 618 Rio Grande Blvd., NW., (10-8-76)
Albuquerque. Barela-Bledsoe House, 7017 Edith Blvd., NE., (3-12-79)
Albuquerque. DeGracia, Tomasa Griego, House, 6939 Edith Blvd., NE (6-19-79)
Albuquerque. First Methodist Episcopal Church, 3rd St. and Lead Ave., (11-7-76)
Albuquerque. First National Bank Building, 217-233 Central Ave., NW., (2-2-79)
Albuquerque. Hodgin Hall, University of New Mexico campus, (1-30-78)
Albuquerque. Hope Building, 220 Gold St., SW. (8-29-80)
Albuquerque. Huning Highlands Historic District, Bounded by Grand Ave., I-25 Hazeldine and AT&SF RR, (11-17-78)
Albuquerque. Kimo Theater, 421 Central Ave., (5-2-77)
Albuquerque. Lewis, Charles W. Building, 1405-1407 2nd St., SW., (7-3-79)
Albuquerque. Occidental Life Building, 119 3rd Avd., SW., (1-30-78)
Albuquerque. O'Reilly, J.H., House, 220 9th St., NW., (1-29-79)
Albuquerque. Pacific Desk Building, 213-215 Gold Ave., SW. (9-30-80)
Albuquerque. Rancho De Carnue Site, Off US 66, (5-4-77)
Albuquerque. Rosenwald Building, 320 Central Ave., SW., (6-29-78)
Albuquerque. San Felipe De Neri Church, Old Town Plaza, NW., (10-1-69)
Albuquerque. San Ignacio Church, 1300 Walter St., NE, (8-21-79)
Albuquerque. Southwestern Brewery and Ice Company, 601 Commercial St., NE., (3-30-78)
Albuquerque. Spitz, Berthold, House, 323 N. 10th St., (12-22-77)
Albuquerque. Superintendent's House, Atlantic & Pacific Railroad, 1023 S. 2nd St., (1-20-78)
Albuquerque. Vigil, Antonio, House, 413 Romero St., (5-5-78)
Isleta. Isleta Pueblo (Tuei), US 85, (9-5-75)
Tijeras. Holy Child Church, Off I-40/US 66, (3-8-78)

<u>Catron County</u>

Datil vicinity. AKE Site, SE of Datil, (4-2-76)
Horse Springs vicinity. Bat Cave, S of Horse Springs, (4-23-76)
Red Hill vicinity. Mogollon Pueblo, N of Red Hill, (5-5-78)
Silver City vicinity. Gila Cliff Dwellings National Monument, 47 mi. N of Silver City on NM 25 and 527, (10-15-66)

<u>Colfax County</u>

Abbott vicinity. Dorsey Mansion, about 12 mi. NE of Abbott off US 56, (9-4-70)
Cimmaron. Cimmaron Historic District, S edge of city along NM 21, (4-3-73)
Eagle Nest vicinty. Eagle Nest Dam, 3 mi. SE of Eagle Nest off US 64, (4-18-79)
Folsom vicinity. Folsom Site, 8 mi. W of Folsom, (10-15-66) NHL
Raton. Raton Downtown Historic District, Roughly bounded by Rio Grande, Clark, 1st and 3rd Sts., (10-21-77)
Raton vicinity. Catskill Charcoal Ovens, 35 mi. (56 km) W of Raton, (1-30-78)
Raton vicinity. Raton Pass, US 85-87, Co/NM border, (10-15-66)(also in Las Animas County, Co) NHL
Raton vicinity. St. John's Methodist Episcopal Church, 17 mi. (27 km) E of Raton on NM 72, (1-18-78)
Springer. Cowan, R.H., Livery Stable, 220 Maxwell Ave., (8-3-79)
Springer. Mills House, 509 1st St., (10-6-70)

Table 8-3. Sites in the Study Area presently on the National Register of Historic Places (continued).

<u>Lincoln County</u>

Capitan vicinity. Fort Stanton, 7 mi. SE of Capitan near US 380, (4-13-73)
Lincoln. Lincoln Historic District, US 380, (10-15-66) NHL
Lincoln vicinity. Feather Cave, (11-20-74)
Nogal vicinity. El Paso and Southwestern Railway Water Supply System, S of Nogal, (11-21-79)
White Oaks. White Oaks Historic Distric, 12 mi. NE of Carrizozo on NM 349, (9-4-70)

<u>McKinley County</u>

Crownpoint vicinity. Case De Estrella Archeological Site (Anasazi Sites within the Chacoan Interaction Sphere Thematic Resources)(10-10-80)
Crownpoint vicinity. Dalton Pass Archeological Site (Anasazi Sites within the Chacoan Interaction Sphere Thematic Resources)(10-10-80)
Crownpoint vicinity. Greenlee Archeological Site (Anasazi Sites within the Chacoan Interaction Sphere Thematic Resources)(10-10-80)
Crownpoint vicinity. Haystack Archeological District (Anasazi Sites within the Chacoan Interaction Sphere Thematic Resources)(10-10-80)
Crownpoint vicinity. Upper Kin Klizhin Archeological Site (Anasazi Sites within the Chacoan Interaction Sphere Thematic Resources)(10-10-80)
Fort Wingate. Fort Wingate Historic District, NM 400, (5-26-78)
Fort Wingate vicinity. Fort Wingate Archeological Site (Anasazi Sites within the Chacoca Interaction Sphere Thematic Resources)(10-10-80)
Gallup. Cotton, C.N., House, 406 W. Aztec Ave., (7-10-79)
Gallup vicinity. Halona Pueblo (Zuni Pueblo), 36 mi. S of Gallup on NM 2 and NM 3, (2-10-75)
Manuelito vicinity. Manuelito Complex, S of Manuelito, (10-15-66) NHL
Prewitt vicinity. Andrews Archeological District, NE of Prewitt, (5-17-79)
Thoreau vicinity. Chaco Canyon National Monument, 64 mi. N of Thoreau on NM 56, (10-15-66)

<u>Otero County</u>

Cloudcroft vicinity. Mexican Canyon Trestle, NW of Cloudcroft off NM 83, (5-7-79)
La Luz Townsite Multiple Resource Area. This area includes: La Luz, La Luz Historic District, off NM 83; Garcia, Juan House, Tulurosa St.; Queen Anne House, Kearny St.; Sutherland, D. H., House, Main St., (10-23-80)
La Luz vicinity. La Luz Pottery Factory, 2 mi. (3.2 km) E of La Luz, (5-29-79)
Tularosa. Tularosa Original Townsite District, US 54/70, (2-14-79)

<u>Rio Arriba County</u>

Cumbres and Toltec Scenic Railroad (Denver and Rio Grande Western Railroad), Between Chama, New Mexico and Antonito, Colorado (1-2-74)
Abiquiu vicinity. Santa Rosa De Lima De Abiquiu, E of Abiquiu on US 84, (4-14-78)
Blanco vicinity. Frances Canyon Ruin, 17 mi. NE of Blanco, (9-4-70)
Canones vicinity. Tsiping, 7 mi W of Abiquiu in Santa Fe National Forest, (9-4-70)
Cordova. San Antonio De Padua Del Quemado Chapel, off NM 76, (11-2-78)
Dulce vicinity. Vicenti Site, (5-14-79)
Embudo. Embudo Historic District, US 64, (3-12-79)

Table 8-3. Sites in the Study Area presently on the National Register of Historic Places (continued).

Rio Arriba County (cont'd)

Espanola. Bond, Frank, House, Bond St. (3-6-80)
Espanola vicinity. Puye Ruins, 14 mi. W of Espanola, (10-15-66) NHL
Espanola vicinity. San Gabriel De Yungue-Quinge, 4 mi. N of Espanola, (10-15-66) NHL
Espanola vicinity. Santa Clara Pueblo (Kapo'onwi), S of Espanola off NM 30, (11-5-74)
Farmington vicinity. Crow Canyon Archeological Site, E of Farmington, (also in San Juan County) (7-15-74)
Santa Fe vicinity. San Juan Pueblo (Oke'onwi), N of Santa Fe, (7-30-74)

Sandoval County

Albuquerque vicinity. Pueblo of Santo Domingo (Kiua), 35 mi. NE of Albuquerque, off I-25, (12-12-73)
Bernalillo. Abenicio Salazar Historic District, US 85 (6-8-80)
Bernalillo. Our Lady of Sorrows Church, US 85, (4-29-77)
Bernalillo vicinity. Jemez Pueblo, 28 mi. N of Bernalillo on NM 4, (5-2-77)
Bernalillo vicinity. Kuaua Ruin, N of Bernalillo off NM 44, (1-1-76)
Bernalillo vicinity. Sandia Cave, 11 mi. E of Bernalillo in Cibola National Forest, (10-15-66) NHL
Bernalillo vicinity. Tamaya (Santa Ana Pueblo), N of Bernalillo, (11-1-74)
Bernalillo vicinity. Zia Pueblo, 18 mi. W of Bernalillo on NM 44, (4-3-73)
Casa Salazar vicinity. Big Bead Mesa, W of Casa Salazar in Cibola National Forest, (10-15-64) NHL
Corrales. San Ysidro Church, Church Rd., (7-30-80)
Guadalupe vicinity. Guadalupe Ruin, SE of Guadalupe (3-24-80)
Jemez Spring vicinity. San Juan Mesa Ruin, 4 mi. E of Jemez Springs in Santa Fe National Forest, (7-9-70)
Jemez Springs. Jemez State Monument (San Jose De Los Jemez Mission and Giusewa Pueblo), NM 4, (3-14-73)
Los Alamos vicinity. Bandelier National Monument, 12 mi. S of Los Alamos on NM 4, (10-15-66)
Santa Fe vicinity. Cochiti Pueblo, 27 mi. SW of Santa Fe on the Rio Grande, (11-20-74)

San Juan County

Crow Canyon Archeological Site, Reference-see Rio Arriba County (1-2-74)
Aztec vicinity. Aztec Ruins National Monument, 1 mi. N of Aztec, (10-15-66)
Bloomfield vicinity. Halfway House Archeological Site (Anasazi Sites within the Chacoan Interaction Sphere Thematic Resources)(10-10-80)
Bloomfield vicinity. Twin Angels Archeological Site (Anasazi Sites within the Chacoan Interaction Sphere Thematic Resources)(10-10-80)
Farmington vicinity. Gallegos Wash Archeological District, SE of Farmington, (11-20-75)
Farmington vicinity. Salmon Ruin, 9 mi. E of Farmington off NM 17, (9-4-70)
Fruitland vicinity. Archeological Site OCA-CGP-56, SW of Fruitland, (2-23-78)
Fruitland vicinity. Site No. OCA-CGP-54-1, SW of Fruitland, (4-19-78)
La Plata vicinity. Morris' No. 41 Archeological District, (5-17-79)

Table 8-3. Sites in the Study Area presently on the National Register of Historic Places (continued).

Santa Fe County

Glorieta Pass Battlefield. 10 mi. SE of Santa Fe on US 84-85, (also in San Miguel County) (10-15-66) NHL

Chimayo vicinity. Plaza Del Cerro (Plaza Del San Buenaventura), SW of jct. of Rtes. 76 and 4, (7-17-72)

Espanola vicinity. San Ildefonso Pueblo, SW of Espanola off NM 4, (6-20-74)

Lamy vicinity. Apache Canyon Railroad Bridge, 3 mi. (4.8 km) NE of Lamy over Galisteo Creek, (4-27-79)

Madrid. Madrid Historic District, 25 mi SW of Santa Fe on MN 14, (11-9-77)

Santa Cruz. La Iglesia De Santa Cruz and Site of the Plaza of Santa Cruz De La Canada, (8-17-73)

Santa Fe. Barrio De Analco Historic District, roughly bounded by E. De Vargas and College Sts. and the Santa Fe River, (11-24-68) NHL

Santa Fe. Bergere, Alfred M., House, 135 Grant Ave., (10-1-75)

Santa Fe. Crespin, Gregorio, House, 132 E. De Vargas St., (5-29-75)

Santa Fe. Davey, Randall, House, Upper Canyon Rd., (7-9-70)

Santa Fe. Digneo-Valdes House, 1231 Paseo de Peralta, (11-21-78)

Santa Fe. Federal Building, Cathedral Pl. at Palace St., (8-15-74)

Santa Fe. Fort Marcy Officer's Residence, 116 Lincoln Ave., (6-20-75)

Santa Fe. Fort Marcy Ruins, off NM 475, (4-14-75)

Santa Fe. Hayt-Wientge House, 620 Paseo de la Cuma, (5-6-77)

Santa Fe. National Park Service Southwest Regional Office, Old Santa Fe Trail, (10-6-70)

Santa Fe. Palace of the Governors, The Plaza, (10-15-66) NHL

Santa Fe. Reredos of Our Lady of Light, Christo Rey Church, Canyon Rd. and Cristo Rey St., (9-4-70)

Santa Fe. Santa Fe Historic District, (7-23-73)

Santa Fe. Santa Fe Plaza, (10-15-66) NHL

Santa Fe. Second Ward School, 312 Sandoval St., (3-30-78)

Santa Fe. Shonnard, Eugenie, House, 226 Hickox St., (9-5-75)

Santa Fe. Spiegelberg House (Spitz House), 237 E. Palace St., (5-25-73)

Santa Fe. Tully, Pinckney R., House, 136 Grant Ave., (11-5-74)

Santa Fe. US Courthouse, Federal Pl., (5-25-73)

Santa Fe. Vierra, Carlos, House, 1002 Old Pecos Trail, (8-3-79)

Santa Fe. Vigil, Donaciano, House, 518 Alto St., (6-28-72)

Santa Fe vicinity. Acequia System of El Rancho de las Golondrinas, 12 mi. SE of Santa Fe (2-1-80)

Santa Fe vicinity. Otowi Historic District, 25 mi. N of Santa Fe on NM 4 in Rio Grande Valley, (12-4-75)

Santa Fe vicinity. Pueblo of Nambe, about 16 mi. off NM 4, (1-21-74)

Santa Fe vicinity. Pueblo of Tesuque (Tatunge), about 8 mi. N of Santa Fe on W bank of Tesuque River, (7-16-73)

Santa Fe vicinity. San Lazaro, 25 mi. S of Santa Fe, (10-15-66) NHL

Santa Fe vicinity. Seton Village, 6 mi. S of Santa Fe off US 84/85, (10-15-66) NHL

Truchas vicinity. El Santuario De Chimayo, S of Truchas in Chimayo, (4-15-70) NHL

Sierra County

Arrey vicinity. Percha Diversion Dam, 2 mi. (3.2 km) NE of Arrey, (4-6-79)

Elephant Butte vicinity. Elephant Butte Dam and Reservoir, NW of Elephant Butte off NM 51, (4-9-79)

Table 8-3. Sites in the Study Area presently on the National Register of Historic Places (concluded).

Socorro County
Bingham vicinity. Trinity Site, 25 mi. S of US 380 on White Sands Missile Range, (10-15-66) NHL
Gran Quivira vicinity. Gran Quivira National Monument, 1 mi. E of Gran Quivira on NM 10, (10-15-66)(also in Torrance County)
Magdalena. Atchison, Topeka and Santa Fe Railway Depot, off US 60 (12-29-78)
Magdalena. MacDonald Merchandise Building, US 60 (9-25-80)
Magdalena vicinity. Clemens Ranchhouse, S of Magdalena, (4-18-79)
Magdalena vicinity. Gallinas Springs Ruin, 25 mi. S of Santa Fe in Cibola National Forest, (9-4-70)
Socorro. Bursum House, 326 Church St., (6-18-75)
Socorro. Garcia Opera House, Terry Ave and California St., (8-13-74)
Socorro. Illinois Brewery, Neal Ave and 6th St., (9-2-75)
Socorro. Val Verde Hotel, 203 Manzanares St., (9-13-77)
Socorro vicinity. Fort Craig, 37 mi. S of Socorro, (10-15-70)

Valencia County
Acoma. San Estevan Del Rey Mission Church; on NM 23, (4-15-70) NHL
Adelino. Baca, Miguel E., House, NM 47, (12-11-78)
Albuquerque vicinity. Laguna Pueblo, 45 mi. W of Albuquerque off US 66, (6-19-73)
Casa Blanca vicinity. Acoma, 13 mi. S of Casa Blanca on NM 23, (10-15-66) NHL
El Morro vicinity. El Morro National Monument, 2 mi. W of El Morro via NM 53, (10-15-66)
Encinal. Village of Encinal Day School (8-8-80)
Granta vicinity. Dittert Site, S of Grants, (8-22-77)
Laguna Pueblo. San Jose De La Laguna Mission and Convento, (1-29-73)
Los Lunas. Atchison, Topeka, and Santa Fe Railroad Depot, US 85, (8-1-79)
Los Lunas vicinity. Luna, Tranquilino, House, SW of Los Lunas at jct. of US 85 and NM 6, (4-16-75)
San Mateo vicinity. San Mateo Archeological Site, NW of San Mateo, (5-17-79)
Tome. Tome Jail, Tome Plaza, (10-5-77)
Zuni vicinity. Hawikuh, 12 mi. SW of Zuni, Zuni Indian Reservation, (10-15-66) NHL

NHL - National Historic Landmark

Table 8-4. Sites in the Study Area that are eligible for inclusion in the National Register.

McKinley County

51 Sites in the Bisti-Star Lake Region
Crownpoint vicinity. Archeological Site SJC-479
Gallup vicinity. McKinley Mine Archeological District
Navajo New Mexico High School Site
Zuni. Oak Wash Sites N.M.G.:13:19-NMG:13-37. Zuni Pueblo Watershed
Zuni Pueblo Multiple Resource Area, Yellowhouse Dam Project. This area includes sites: 2-4, 6-9, 11, 12, 14-20, 22, 23, 25-45, 49-69, 71-73, 75-85, 87-133, 135-151, 153-156, 158-165, 170-172, 174-182, 184-192, 195-200, 202-223, 225-227, 229-235, 238-240, 244-257, 259-294, 296-306, 308-313, 315, 318, and localities numbered: 404, 405-407, 411, 413, 414, 417, 418, 422-425, 431, 435, 440, 441, 445-449, 451-457, 459-61, 463, 472-475, 481, 483, 484, 488, 490, 491, 498, 504, 507, 508, 515.

Otero County

Dog Canyon Archeological Site (LA 15839), Oliver Lee Memorial State Park
Three Rivers Petroglyphs
La Luz vicinity. La Luz Pottery Factory, 2 mi. (3.2 km) E of La Luz (5-29-79)

Rio Arriba County

Ghost Ranch vicinity. Cerrito Recreation Site Archeological District, (11-14-78)

Sandoval County

Bandelier National Monument. Archeological Sites LA 13659 and LA 12117
Boca Geothermal Lease Archeological District
Corrales vicinity. Archeological Site OCA:SCS:3, (63.3)
Tetilla Peak Recreation Area. Tetilla Peak Site

San Juan County

Archeological Site DCA-79-364
Bolack Land Exchange Multiple Resource Area. This area includes 53 sites in Stewart Canyon
Burnham. Lower Chaco River Multiple Resource Area. This area includes 152 archeological sites along the Chaco River
Burnham. Navajo Tribal Lands Multiple Resource Area. This area includes 8 archeological sites situated on tribal lands leased to Consolidated Coal
Farmington. Archeological Site DCA-80-19
Little Water vicinity. Archeological Site LA 7371, near US 666
Shiprock vicinity. Archeological Site LA 8970, off US 550
Squaw Springs vicinity. Squaw Springs Archeological Sites 1, 8-23, 25-51, 53-61

Diagonistic artifacts: Distinctive, lanceolate-shaped projectile points.

Site types:

Kill sites - locations where Late Pleistocene animals were killed and butchered.

Camp sites - Occupational locations.

Comments: Some of the most well-known Paleo-Indian sites, such as Folsom Site and Sandia Cave (both are on the National Register of Historic Places and list of National Historic Landmarks), are in the Study Area. New Mexico has long been important for the study of Paleo-Indians. Both site types have been identified in New Mexico. Paleo-Indian sites are often associated with Pleistocene playa deposits in central and northwestern New Mexico but are occasionally found at higher elevations. Paleo-Indian occupations are known from both open-air and camp sites. In general, sites are in close proximity to water, in areas that potentially served as game traps and at points that provided overviews of the surrounding plains. There exists a possibility of buried Paleo-Indian sites along valleys of major rivers such as the Rio Grande River. Paleo-Indian sites are known from areas around Albuquerque.

8.2.2 Archaic (7000 - 2000 BP)

Importance: Represents increasing regionalism and a change in settlement-subsistence and technology.

Settlement-subsistence: Seasonal movement between sites to exploit locally available flora and fauna.

Diagonistic artifacts: Includes projectile points called "dart points, and food grinding implements.

Site types:

Base camps - Major site types where a variety of activities took place and identified by a wide variety of artifact types, depth and extent of cultural material, and features such as hearths, burials, and storage pits and pit houses late in this period.

Campsites/specialized activity sites - locations where specific activities took place that lack the variety and density of artifacts at base camps. Specialized activity sites include:

- Quarry sites - where raw material for stone tools were procured.
- Hunting-butchering sites - where animals were killed and butchered.
- Plant processing sites - where plant foods were secured.

Comments. Base camps are generally located near drainages or other permanent water or along upland edges. Dunefields, rockshelters and overhangs were used when available. Specialized activity sites were randomly distributed and generally associated with the desired resources. Two major Archaic traditions are present: the Oshara Tradition to the north and the Cochise tradition to the south. The former developed into the succeeding Anasazi Tradition, while the latter became the Mogollon Tradition.

8.2.3 Ceramic (3000 - 300 BP)

Importance: Represents the zenith and culmination of prehistoric occupation marked by the appearance of domesticates, sedentism, and increased social organization and ceremonialism.

Settlement - subsistence: Semi-sedentary occupations based on domesticates.

Diagonistic artifacts: Ceramics, small projectile points called "arrow-points" and occasional ceremonial objects.

Site types:

Habitation sites:

- Surface structures contain above-ground structures constructed with masonary, adobe or jackal, and include pueblos, pueblitos and field houses.
- Sub-surface structures contain semi-subterranean structures and include pithouses, pithouse villages and kivas (usually associated with pueblos and publitos).
- Undefined surface sites include lithica and ceramic scatters, (with or without refuse areas), isolated hearths or hearth clusters, tepee rings and campsites, and specialized activity sites.
- Rockshelters and overhangs

Non-habitation sites include petroglyph-pictograph sites, quarries, roads, trails, irrigation canals, diversion dams, terraced fields, stone enclosures, shrines, and ritual structures.

Comments: Two general traditions are identified for the Ceramic period. To the north was the Anasaizi (Basketmaker-Pueblo) Tradition; to the south the Mogollon Tradition. The former developed out of the Oshara Tradition, while the latter grew out of the Cochise Tradition. In general, the differences between the Anasazi and Mogollon represent different adaptive strategies to differing environments; the Anasazi were desert-oriented while the Mogollons adapted to more mountainous environments. The major differences in cultural traits include the emphasis in black-on-white pottery among the Anasazi, and Red-on-Brown pottery among the Mogollon, the relative late appearances of villages and greater emphasis on hunting in the former compared with the later, and the greater use of elaborate water erosion control devices and the presence of complex communication and trade among the Anasazi. Further, throughout much of this period, the Anasazi tended towards more dense and larger population aggregates, such as at Chaco Canyon and Pajarito Plateau. Both traditions encompass several distinct subareas. Both the Mogollon and Anasazi cultures emphasized population centers characterized by above-ground pueblos resembling apartment-block structures. In addition, the Mogollon utilized semi-subterranean pithouse villages. The larger population centers of both centers are found along major drainages.

8.2.4 Historic (300 BP - Present)

Importance: Represents the period of Euro-American occupation.

Settlement-subsistence: Sedentism based on agro-economy.

Diagnostic artifacts: Glass, metal, and other nonaboriginal items along with historic Navaho, Comanche, Apache, and Ute items.

Site types: The number of site types is extremely varied; a partial list includes: early trading posts, military posts, farmsteads, missions, churches, cemeteries, courthouses, communities, roadways, lumbering camps, mines and mining camps, and ranches, land grants, haciendas, ranches; sites associated with the oil industry, the uranium industry, the railroad industry, along with historic Navaho, Apache, Comanche, and Ute sites, hogans, shrines, corrals, sheepherder sites, trails, tepee rings, and historic pueblos.

Comments. The historic tradition is probably the most archaeologically visible of all traditions. The period began with the advent of the first Spanish explorers, principally Fray Marcos Niza in 1539 and Coronado in 1540. However, European colonization really did not begin until the late 1500's and early 1600's with the appearance of Spanish and Mexican colonists. Early colonists tried to convert the Indians and established missions, trading posts, and haciendas near the pueblos. During this period many of the major pueblos such as Pecos, Acoma, and Santo Domingo were occupied by Spanish missionaries.

The Spanish colonial period extended to the late 1700's and was characteristized by the establishment of Spanish land grants and haciendas along with early communities. These were concentrated along the Rio Grande River north of Santa Fe and from Santa Domingo south to Belem. During this period there was much strife between the Spanish and the Pueblo Indians, which culminated in 1680 with the Pueblo Revolt. This revolt resulted in internal problems among the Pueblos and the breakdown of the various Pueblo provinces.

The Eighteenth Century saw the breakdown of the haciendas into smaller rancho settlements and increasing in-roads by Apache, Comanche, Ute, and Navaho groups. In 1821, the Republic of Mexico was established and was accompanied by increased trade and settlements by Americans. The Santa Fe Trail was a popular route of travel during this period. In 1848, New Mexico became a territory of the United States. Numerous battles were fought in New Mexico during the Mexican-American War and the Civil War. During these wars an influx of American military personnel entered New Mexico. This was further augmented by the Homestead Act of 1862 and the Indian Wars of the 1870's and 1880's. The containment of the area by the military and the confinement of the Indians to reservations was accompanied by the development of ranching, sheep raising, timbering, mining, stage and railroad industries, that in turn induced greater numbers of American settlers and the establishment of most of the major modern communities in New Mexico. These various historic periods are characterized by specific site types and distributions. The inclusion of all sites included in or eligible to the National Register of Historic Places (Tables 8-3 and 8-4) provides an idea of the types and varieties of historic (and, to a lesser extent, prehistoric) sites in the Study Area.

8.3 REGIONS

The remainder of this chapter will focus on the archaeology of the two major regions as defined in Figure 8-1. These regions roughly correspond to the Mogollon/Anasazi culture areas, although the differences between these two groups is not as much in kind as in type.

8.3.1 Northern-Anasazi Area

The Northern-Anasazi area is especially well known owing to numerous Pueblo ruins, such as Chaco Canyon, Salmon River, Pecos Pueblo, and Acoma. Many of these are now National Parks or are still occupied. Chaco Canyon, with its concentration of Pueblos, is perhaps one of the most spectacular and well known of the Puebloan sites. It has long attracted archaeological attention and Anasazi sites in the Chacoan interaction sphere are considered a thermatic resource on the National Register of Historic Places (Table 8-3). The region sequence is outlined in Table 8-1.

8.3.1.1 Paleo-Indian

A number of Palo-Indian sites are known from this region, including the National Register Sites of Sandia Cave above Albuquerque, and the Folsom Site in Colfax County. A majority of the finds consist of isolated occurrences of projectile points; however, a number of areas possibly, such as the Central Rio Grande River Valley, were densely populated. In the Middle Rio Grande River Valley, three types of Paleo-Indian sites are known: base camps, armament sites, and processing sites. Sites generally are near water, a relatively short distance from a hunting area, and at or near an overview area. The critical factor in site location was apparently the presence of water. This same pattern was followed farther north in the Four Corners-San

Juan River Basin area where Paleo-Indian sites were found in upland areas in association with sand dunes. Paleo-Indian points also are found at high elevations in the Sangre de Cristo Mountains and in buried Pleistocene gravel deposits along the Middle Rio Grande River Valley near Albuquerque.

8.3.1.2 Archaic

In this region, the Archaic occupation is associated with the Oshara Tradition and occurs in a variety of areas. When available, rockshelters and overhangs were used in more mountainous situations. In the northwest, between the Puerco River and Jemez River, sites occur in six well-defined locations: canyon head clifftop dunes, canyon head cliffbase springs, canyon rivers, ephemeral ponds, low mesaland, and upland arroyo-edge dune ridges. Over 500 archaeologic sites were found in this area. Base camps were located at Canyon head, while scattered special-use sites were found on sloping mesas and along canyon rims. Rare isolated hunting camps were situated near ephemeral ponds, and quarry sites were located near outcrops of the desired raw materials, such as in the Jemez Mountains. Seasonal sites were located along cliff bases and in small rockshelters. In the Four Corners area the majority of Archaic sites occur in upland areas, particularly around sand dunes. In the West Mesa of Albuquerque, sites were found on the south faces of dunes and on dune covered ridges overlooking present-day arroyos. Late phase sites often contained pit houses and were located on escarpments that form the borders of the West Mesa. Pithouses also appear late in the sequence elsewhere in northern New Mexico. Around Abiquiu Reservoir, Archaic populations utilized river terraces, while in more mountainous areas sites are located near grassland-woodland and pinion-juniper ecotones. Late Archaic sites occur at higher elevations in the southern Sangre de Cristo Mountains. In general, Archaic population selected areas with the highest vegetation diversity, in terrain where a variety of different resources could be exploited easily.

8.3.1.3 Ceramic-Anasazi

The Ceramic-Anasazi period gradually grew out of the Archaic-Oshara Tradition. There is no well defined cutoff point where Anasazi appeared and Oshara disappeared; rather it was a gradual transition. During the earlier phases (Basketmaker II-III) sites were situated in locations suitable for floodplain agriculture, although sites such as rockshelters used by archaic groups, were still employed. Population growth occurred during the early Puebloan period and resulted in population aggregates, such as Chaco Canyon, and the appearance of sites in areas not formerly extensively utilized. Major population centers during the Anasazi period were along the San Juan River and Chaco River, and in the Middle Rio Grande River Valley. The larger Pueblos were situated along these drainages or associated major tributaries.

8.3.1.4 Historic

The Historic Period began with the advent of Spanish explorations. A majority of the early routes into the region paralleled the Rio Grande River. Other routes went eastward along the Pecos River. Between 1540 and 1821, a number of Spanish settlements were established, primarily along major drainages. In addition, the Spanish partitioned the State into a number of administrative units called alcaldias. Each alcaldia had an administrative center: Albuquerque was one such center. There were a number of large land holdings called haciendas, and smaller settlements called ranchos such as the National Register site of Rancho de Carnue east of Albuquerque. The Mexican period from 1820 to 1848 saw a continuation of the older Spanish pattern. During this same period Navajo, Apache, and Ute Indians began to appear. Because these groups were highly mobile, their early sites tend to be ephemeral, although some early Navajo villages indicate some degree of sedentism. During the 17th century these groups lived in the middle and northern Rio Grande River Valley.

Starting in the early 1800's, Anglo settlements began to appear with increasing frequency especially after the opening of the Santa Fe Trail. Several additional events such as the exploration of the Rio Grande River Valley in 1806-1807 by Zebulon Pike and the subsequent Mexican-American and Civil Wars resulted in increased Anglo occupation and settlements. Following the Civil War, Anglo communities were common along the major drainages. During the late 1860's and the 1870's many of the Indians were placed on reservations. A number of U.S. Army forts were built and stage routes were established in northern New Mexico, further aiding Anglo settlement. Between 1866 and 1913, the silver boom occurred and a number of mining districts were created. In addition, other semi-precious metals were discovered. During this period the railroad and lumbering industries were established. The Historic period encompasses a wide variety of site types. To obtain an indication of site variety, refer to Tables 8-3 and 8-4 for a list of all sites presently included in or eligible to the National Register of Historic Places.

8.3.2 Southern-Mogollon

Southern New Mexico is more mountainous and offers a more varied resource base. However, trends in this area closely paralled those in the northern half of the State. Again the occupational emphasis was along the major drainages. The regional sequence is presented in Table 8-1.

8.3.2.1 Paleo-Indian

Paleo-Indian occupations occur in the same general topographic situations as farther north. Paleo-Indian points were found around the edges of Pleistocene playas in Otero County and in deflated and eroded sand dunes on the plains of San Augustin. Points also were found on mesas overlooking drainages, on open plains, and in the foothills of mountains. Most evidence consists of isolated finds of projectile points, although campsites and possibly killsites, such as the National Register site of AKE in Catron County, are present. Other areas where Paleo-Indian materials were found include the Jornada del Muerto in Socorro County, the lower reaches of the eastern Ladron Mountains, and the Rio Grande River Valley. In general, the nature of Paleo-Indian occupation in this region is not as well known as areas in the northern part of the State. However, the presence of Paleo-Indian projectile points indicates the area was utilized during this period. Additionally, the evidence indicates a preference for playa edges, ridges, and sand dunes as occupational loci.

8.3.2.2 Archaic

The cultural manifestations in this area comparable to the Oshara Tradition is the Cochise Tradition. Perhaps the most famous Cochise site is the National Register Site of Bat Cave in Catron County. The cave contained a well-defined deposit containing primitive corn, to date the earlisest known in the southwest. Cochise occupations were identifed in open air sites, caves, and rockshelters. Sites were concentrated above the margins of former lake terraces or playas, such as on the Plains of San Augustin. In mountainous areas, sites were frequently found adjacent to springs and along the banks of arroyos. Sites were reported along west Leggett arroyo, Largo Creek Valley, Harris Creek Valley, Aqua Fria Creek, and in Gila and Cibola National Forests. Major cave sites include Tularosa and Cordova Caves, in the Gila National Forest, and the Lenutar and Hackberry rockshelters in Socorro County. Near the end of this period, as agriculture became more important, sites often contained semi-subterranean pithouses with the trend toward terrace occupations.

8.3.2.3 Ceramic

The Mogollon Tradition developed from the Cochise Tradition. Earliest Mogollon occupations featured pithouse villages, replaced in future years by surface pueblos. Mogollon population centers in New Mexico were not as numerous as the Anasazi, but included the Pine Lawn Valley, Reserve-Apache Creek, and Mimbres. Further south and east, Mogollon sites are known in the Jounada area around El Paso and in the Guadalupe Mountains on the Texas-New

Mexico border. Early period villages were generally built on high mesas, cliffs, or ridges, well back from the mainstream of travel. In later years, sites were located in more topographically accessible areas such as in valleys near streams or rivers; irrigation was practiced in some areas. Limited activity sites were widely scattered and were located on mesa tops, in valley bottoms, and in rockshelters and overhangs.

8.3.2.4 Historic

The Spanish influence in this region was not as extensive as it was farther north. Most of the Mogollon villages were abandoned by the time the Spanish entered. Also, few were located in the Rio Grande River Valley. The major access route of the early explorers was the Camino Road which paralleled the river. Few Spanish explorers ventured into the Mogollon heartland. The Spanish established villages, such as Piros, in the Rio Grande Valley. From the late 1700's through the late 1800's, Apaches and Navajos were active in the area. Both groups were highly nomadic and fought continously, first with the Spanish and later the U.S. Calvery. The major foci of their occupation were in the Datil Mountains and the Zuni Salt Lake. The American period was marked by the establishment of military posts such as Fort Conrad on the Rio Grande River in Socorro County. During the Civil War a number of skirmishes took place in the area, such as the battle of Valverde. Military posts, as well as Apache and Navajo reservations like the Warm Springs Apache Agency, were established in the 1870's. The military posts became focal points of Euro-American occupations. These posts include Fort Tularosa in Catron County, and the Ojo Caliente Post near the Alamosa River.

Ranching developed out of the old Spanish Land Grants and included raising sheep and cattle. Other industries affecting this area included the railroad and mining interests. Although several small towns resulted from the development of these industries, few have been examined in any detail. The historic resources of southern New Mexico are extremely varied. Sites presently included in or considered eligible to the National Register of Historic Places are listed in Tables 8-3 and 8-4. These lists provide examples of the diversity of historic resources.

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