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Sandia National Laboratories/New Mexico Environmental Baseline Update–Revision 1.0

IT Corporation
5301 Central Avenue, NE, Suite 700
Albuquerque, New Mexico 87108

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
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Prepared for:
Sandia National Laboratories/New Mexico
Risk Management and NEPA Department
Albuquerque, New Mexico 87185

Prepared by:
IT Corporation
5301 Central Avenue, NE, Suite 700
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Sandia Contract 120939-A

Abstract

The purpose of this Sandia National Laboratories/New Mexico (SNL/NM) Environmental Baseline Update is to provide the background information necessary for SNL/NM personnel and contractors to prepare clear and concise NEPA documentation. The scope of the Environmental Baseline Update is to provide comprehensive data needed to support a description of the affected environment at the SNL/NM facility. The "description of the affected environment," required by the CEQ regulations in 40 CFR §1502.15, is an essential prerequisite for assessing the environmental consequences (§1502.18) of a proposed action (project) to be implemented by SNL/NM.

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List of Abbreviations and Acronyms

%	percent
°C	degree(s) Celsius
°F	degree(s) Fahrenheit
μCi/MJ	microcurie(s) per megajoule
$\mu g/m^3$	microgram(s) per cubic meter
μ	micrometer(s)
ABQ	Albuquerque International Airport
ACF	Aerial Cable Facility
ACRR	Annular Core Research Reactor
AEHD	Albuquerque Environmental Health Department
AICUZ	Air Installation Compatible Use Zone
ANS	American Nuclear Society
APCD	Air Pollution Control Division
AQCR	Air Quality Control Regulations
BISONM	Biota Information Systems of New Mexico
BLM	Bureau of Land Management
CAA	Clean Air Act
CEC	Commission of the European Communities
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cm	centimeter(s)
CO	carbon monoxide
CWL	chemical waste landfill
dB	decibel(s)
dBA	A-weighted decibel(s)
DOE/AL	DOE-Albuquerque
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EA	environmental assessment
ECF	Explosive Components Facility
EIS	environmental impact statement
EO	executive order
EPA	U.S. Environmental Protection Agency

ft	foot
FY	fiscal year
GIS	Geographic Information System
HABS	Historic American Buildings Survey
HCF	Hot Cell Facility
HE	high explosives
HERMES-III	High Energy Radioactive Megavolt Electron Source-III
hr	hour(s)
HR1	Hydrogeologic Region I
HR2	Hydrogeologic Region II
HR3	Hydrogeologic Region III
HWMF	Hazardous Waste Management Facility
IAEA	International Atomic Energy Agency
in	inch(es)
IO	isolated occurrence
IP	instantaneous profile
IRP	Installation Restoration Program
ISCST	Industrial Source Complex Short-Term
ISCST2	ISC Short-Term
ISCLT2	ISC Long-Term
KAFB	Kirtland Air Force Base
kg	kilogram(s)
km	kilometer(s)
km^2	square kilometer(s)
KTF	Kauai Test Facility
L_{dn}	day-night average sound level
lb	pound(s)
LLW	low-level waste
LSF	Lower Santa Fe
m	meter(s)
m/s	meter(s) per second
m^3	cubic meter(s)
mb	millibars

List of Abbreviations and Acronyms *(Continued)*

MDL	Microelectronics Development Laboratory
MeV	million electron Volt
mi	mile(s)
mi^2	square mile(s)
MinNet	Minimization Network
MJ/yr	megajoule(s) per year
mm	millimeter(s)
mph	mile(s) per hour
mrem	milliroentgen equivalent man
MSA	Metropolitan Statistical Area
MSF	Middle Santa Fe
MSL	Melting and Solidification Laboratory
MWL	Mixed Waste Landfill
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NGTF	Neutron Generator Test Facility
NMDGF	New Mexico Department of Game and Fish
NMED	New Mexico Environment Department
NMFRCD	New Mexico Forestry and Resource Conservation Division
NMHU	New Mexico Highlands University
NMSA	New Mexico Statutes Annotated
NMSU	New Mexico State University
NOAA	National Oceanic Atmospheric Administration
NOX	nitrous oxide
NPDES	National Pollutant Discharge Elimination System
NRHP	National Register of Historic Places
PBFA-II	Particle Beam Fusion Accelerator II
PCB(s)	polychlorinated biphenyl(s)
ppb	part(s) per billion
PSL	Physical Science Laboratory
RCRA	Resource Conservation and Recovery Act
s	second(s)
SCB	Semiconductor Bridge

List of Abbreviations and Acronyms *(Continued)*

SHPO	State Historic Preservation Officer
SNL	Sandia National Laboratories
SNL/CA	Sandia National Laboratories/California
SNL/NM	Sandia National Laboratories/New Mexico
SPR	Sandia Pulsed Reactor
SURP	Sandia University Research Program
TASC	The Analytical Sciences Corporation
TAT	Transcontinental Air Transport
TOC	total organic carbon
TOX	total organic halogen
TSP	total suspended particulates
TTF	Thermal Treatment Facility
TTR	Tonopah Test Range
TWA	time-weighted average
UNM	University of New Mexico
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force
USDA	U.S. Department of Agriculture
USF	Upper Santa Fe
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VMS	Visual Management System
VOC	volatile organic compound
WAE	Western Air Express
yr	year(s)

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Preface

Section 102(2)(c) of the National Environmental Policy Act (NEPA) requires agencies to:

> (I)nclude in every recommendation or report on proposals for . . . major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on . . . the environmental impact of the proposed action . . . .

For this reason, the Council on Environmental Quality (CEQ) regulations contained in 40 Code of Federal Regulations (CFR) Parts 1500-1508 that implement NEPA focus almost exclusively on the preparation and review of environmental impact statements (EIS) and environmental assessments (EA).

The purpose of this Sandia National Laboratories/New Mexico (SNL/NM) Environmental Baseline Update is to provide the background information necessary for SNL/NM personnel and contractors to prepare clear and concise NEPA documentation. ***The scope of the Environmental Baseline Update is to provide the comprehensive data needed to support a description of the affected environment at the SNL/NM facility.*** The "description of the affected environment," required by the CEQ regulations in 40 CFR §1502.15, is an essential prerequisite for assessing the environmental consequences (§1502.16) of a proposed action (project) to be implemented by SNL/NM. Appendix A of the Environmental Baseline Update summarizes the CEQ requirements for the format and contents of a NEPA document (40 CFR Part 1502). Appendix A also summarizes the relationship of NEPA to other federal environmental laws, and how the requirements of other statutes, regulations, and executive orders (EO) are to be addressed in a NEPA document.

It is intended that this Environmental Baseline Update be used as a source document for preparing environmental descriptions in environmental checklists/action description memoranda, EAs, and EISs. The CEQ regulations specify that "descriptions shall be no longer than necessary to understand the effects of the alternatives" (§1502.15). Some of the environmental descriptions (e.g., noise and visual resources) will not be relevant to every proposed action.

Normally, a section in a NEPA document is devoted to a list of persons or organizations/ agencies contacted during the preparation of the document, as well as a list of preparers. In this Environmental Baseline Update, Chapter 14.0 includes the list of such organizations. SNL/NM personnel or contractors may find the list to be a useful reference in preparing future NEPA documentation. In addition, Department 7315, Risk Management and NEPA, at SNL/NM maintains a NEPA Compliance Guide (SAND95-1648) that provides direction on the preparation of NEPA documents (Hansen, 1995).

Additional information that may be helpful in the preparation of NEPA documents is provided in the Appendices. Appendix B contains example mitigation measures that can be recommended for minimizing adverse impacts to various resources. Appendix C provides species lists for SNL/NM and KAFB. Appendix D contains common models used by SNL/NM to estimate environmental impacts. Appendix E contains an annotated bibliography of selected references that are informative sources for the preparation of NEPA documents.

The narrative, tabular, and figure information provided in the Environmental Baseline Update can be used either as a "boilerplate" for future NEPA documentation or as a "springboard" for gathering more extensive project-specific data. A "baseline" is precisely as the term indicates: a summary of existing information that serves as a foundation on which to build needed documentation. SNL/NM intends to revise this baseline document periodically in order to provide SNL/NM personnel and contractors with current information. This iteration is Revision 1.0.

1.0 Background

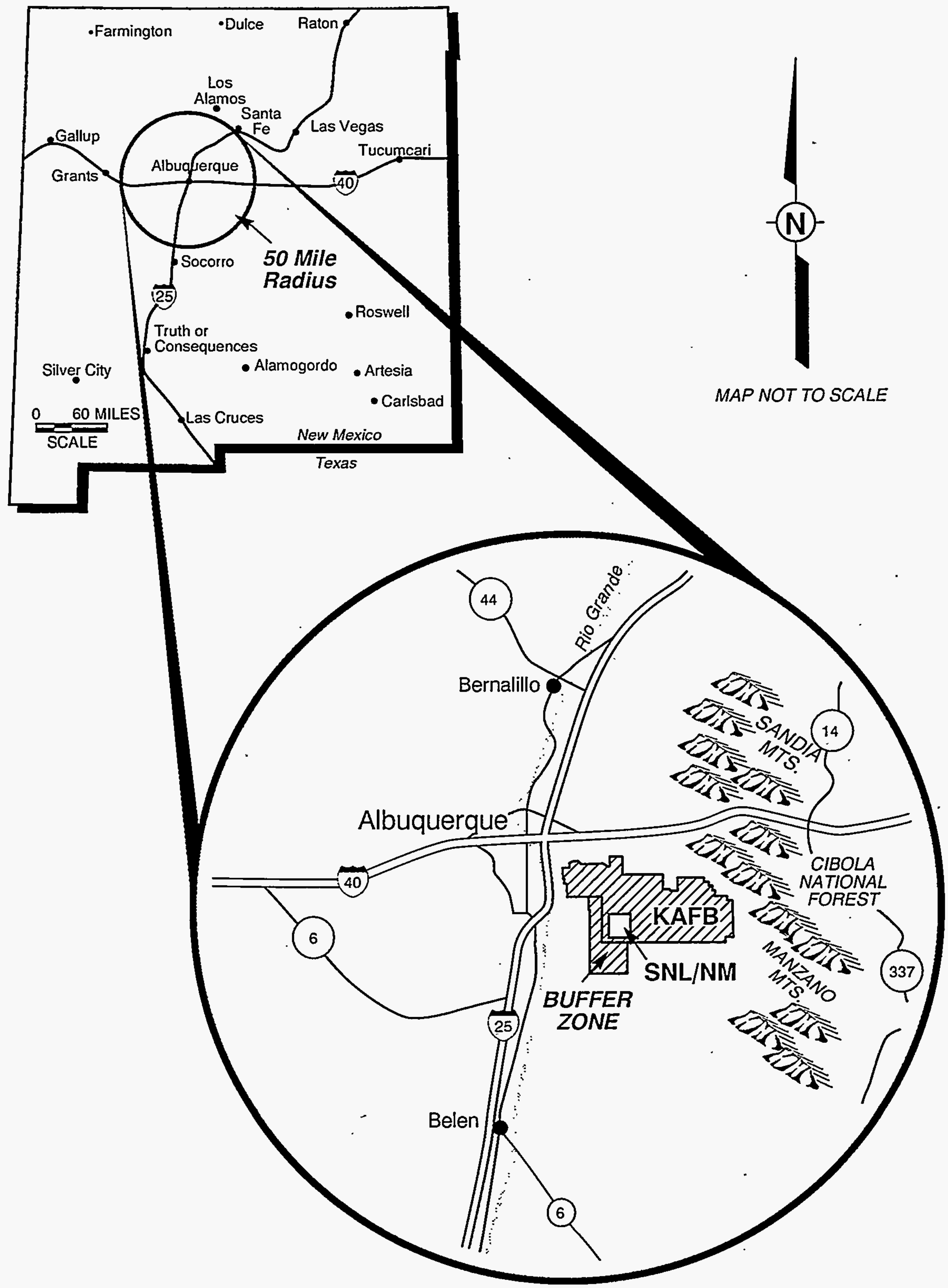
1.1 Early History

Sandia Laboratory was established in 1945 to support the United States weapons development program. Its purpose was to organize and direct engineering activities for development of nuclear and nonnuclear weapons; testing of new models; surveillance tests; and stockpiling of models. Sandia Laboratory was operated by the University of California until 1949, when President Truman asked American Telephone and Telegraph to assume the operation as an "opportunity to render an exceptional service in the national interest" (Furman, 1990). Sandia Laboratory's mission expanded as "more exotic nuclear designs" emerged on a global scale (Alexander, 1963). In the 1950s, weapons with variable yields were developed and refined. In order to meet the requirements for hardware and electronics to match the weapons development, Sandia Laboratory's emphasis began to shift from engineering for production to sophisticated design of new ordnance components and weapons (Alberts and Putnam, 1982). Full-scale testing of weapons and x-ray, gamma-ray, and particle-beam fusion accelerators was added to its programs.

Designated by Congress as a national laboratory in 1979, Sandia National Laboratories (SNL) is one of the U.S. Department of Energy's (DOE) most diverse laboratories and one of the nation's largest research and development facilities (Sandia Laboratories, 1980).

1.2 SNL/NM Today

Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, currently manages and operates SNL/NM for the DOE (Figure 1-1). SNL/NM's main responsibility is national security programs in defense and energy, with primary emphasis on nuclear weapons research and development. SNL/NM also does work for the Department of Defense and other federal agencies on a noninterference basis. The current mission of SNL/NM is to enhance the security, prosperity, and well-being of the nation by responding to the challenges and opportunities of an increasingly dynamic and demanding world. The response includes broad-based research and development programs that create solutions contributing to military security, energy security, environmental integrity, and economic competitiveness. The primary mission is to implement the nation's nuclear weapon policies through research, development, and testing related to nuclear ordnance, arms control, and weapon surety (SNL/NM, 1995a). Activities at SNL/NM include process development, environmental testing, radiation research, combustion



KAFB = Kirtland Air Force Base
SNL/NM = Sandia National Laboratories/New Mexico

Figure 1-1

Sandia National Laboratories/New Mexico and Kirtland Air Force Base Regional Location Map

research, computing, and microelectronics research and production. Over SNL/NM's four decades of operation, its mission has expanded from an original focus on nuclear weapons research and development to include research on other advanced military technologies, energy programs, arms verification, control technology, and applied research in numerous scientific fields, including an extensive program in materials research. Energy research activities include combustions research, integrated geosciences research, and solar and wind power programs. SNL/NM environmental projects include programs in waste reduction and research for increasing environmental concerns in commercial manufacturing. SNL/NM is a leader in scientific computing, especially in massive parallel processing, and it has an extensive semiconductor research and development program. SNL/NM is also working to strengthen the nation's economic security by transferring the commercially valuable technologies developed at SNL/NM to United States industry. SNL/NM has the responsibility of operating DOE facilities at Tonopah Test Range (TTR), Nevada; Sandia National Laboratories/California (SNL/CA); and Kauai Test Facility (KTF), Hawaii.

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2.0 Geology

This chapter provides a summary of SNL/NM-Kirtland Air Force Base (KAFB) regional geology and the area's role as a sediment deposition center and sediment source within the Albuquerque Basin. The discussion, ongoing Sitewide Hydrogeologic Characterization projects, and KAFB Installation Restoration Program (IRP) investigations. The geologic setting provides an overall framework for a better understanding of SNL/NM-KAFB hydrogeology. The following sections include discussions on geomorphology, stratigraphy, structural geology, seismology, and soils.

2.1 Geomorphology

SNL/NM is situated in the eastern portion of the Albuquerque Basin (Figure 2-1). This basin is one of the largest and deepest of a series of north-south-trending basins and is about 145 kilometers (km) [90 miles (mi)] long and 48 km (30 mi) wide. It is located along the Rio Grande Rift zone that lies within the northern portion of the Mexican Highlands section of the Basin and Range physiographic province (Fenneman, 1931). This basin is bounded by the Sandia and Manzano Mountains to the east, the Lucero Uplift and Puerco Plateau in the west, and the Nacimiento Uplift to the north. The southern boundary is defined by the Socorro Channel. The basin is widest in the Albuquerque area and is constricted to the south and north. Large-scale faulting, deepening of the basin, and tilting of the mountain areas occurred approximately 15 to 5.3 million years ago. Since then, basin deposits have been laid down in a complex sequence of sedimentary and volcanic rocks (ERDA, 1977). Landforms within the basin include mesas and structural benches, low hills and ridges, inset stream terraces, and graded alluvial slopes (Lozinsky et al., 1991; Kelley, 1977; Kelley and Northrup, 1975). The SNL/NM-KAFB site is located on a partially dissected coalescent alluvial-fan complex deposited by the Tijeras Arroyo, the Arroyo del Coyote, and smaller tributaries that drain the western margin of the Sandia and Manzanita Uplifts.

2.1.1 Geomorphic Provinces and Subprovinces in the SNL/NM-KAFB Region

Geomorphic features in the SNL/NM-KAFB region include a series of complex coalescent alluvial fans and piedmont alluvium between the eastern margin of the Rio Grande Valley and the western slopes of the Sandia and Manzanita Mountains (Hawley, 1978). The eastern piedmont areas are divided into the Llano de Sandia and Llano de Manzano geomorphic provinces (Machette, 1982). West of these piedmonts, the inner valley of the Rio Grande and its associated north-trending escarpments contain distinct geomorphic features and surficial deposits and are herein informally termed the Rio Grande geomorphic province. East of the Llano de Sandia and the Llano de Manzano are the Sandia and Manzanita Mountains, respectively,

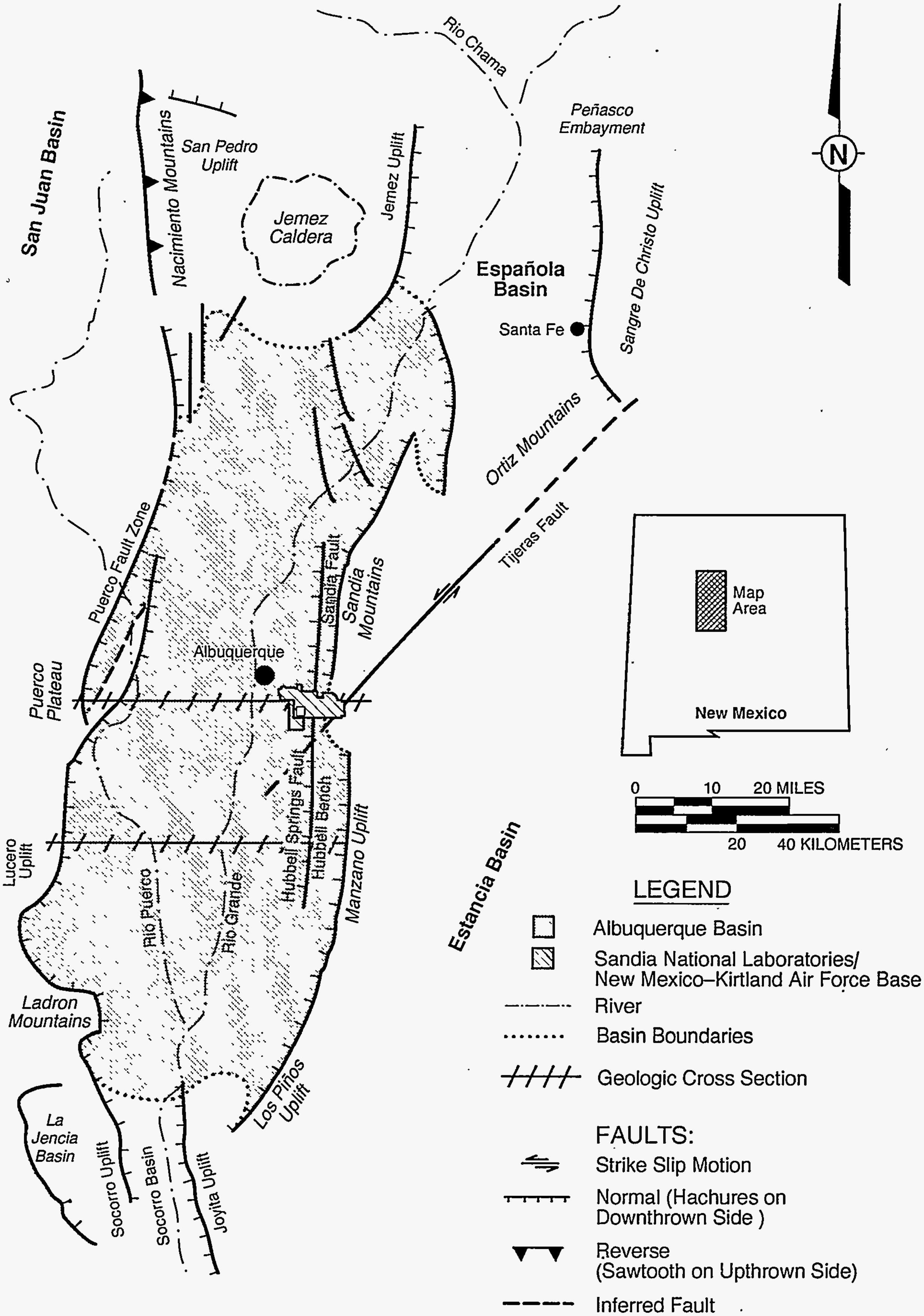


Figure 2 -1
Regional Tectonic Setting of the Albuquerque Basin,
North Central New Mexico,
Sandia National Laboratories/New Mexico and Kirtland Air Force Base Area

which have different landforms, relief, and surficial deposits than the piedmont provinces. The mountain areas are informally grouped as the Rift-Margin Ranges geomorphic province. Each of these four geomorphic provinces is subdivided into two or three subprovinces (Figure 2-2) on the basis of the number and types of landforms, the provenance for surficial deposits, and common surficial processes.

The nine geomorphic subprovinces in the SNL/NM-KAFB area (Figure 2-2) are differentiated based on landforms, relief, surficial deposits, and provenance. These subprovinces are named informally based on a distinguishing geographic or cultural feature within the subprovince. The subprovinces are characterized by multiple late Quaternary geomorphic surfaces and complex, laterally discontinuous surficial deposits. Although most physical and geochemical properties of these deposits (e.g., bed and deposit thickness, textural variations, clast lithology) are poorly documented at present, several generalizations can be made based on interpretation of aerial photography. First, deposits associated with alluvial fans, terraces, and possibly floodplains may be several meters to tens of meters thick. Textural and geochemical variations are probably substantial as a result of the laterally discontinuous nature of bedding and intermittent periods of weathering and soil formation. Second, deposits associated with pediments, colluvial slopes, channels, playas, and eolian sheets and dunes likely are less than tens of meters thick and may be less than a meter thick. These deposits probably contain substantial variations in texture and geochemistry as a result of heterogeneous depositional processes and weathering. Third, clast lithologies, and hence deposit geochemistry, vary among subprovinces.

The following subsections summarize these general characteristics of landforms and surficial deposits within each of the nine geomorphic subprovinces.

2.1.1.1 The Llano de Manzano Geomorphic Province

Four Hills Subprovince. The Four Hills subprovince includes a series of northeast-trending granite, quartzite, and metarhyolite bedrock hills surrounded by a moderately dissected piedmont (Figure 2-2). The subprovince is bordered on the north by the 50-meter (m) [165-foot (ft)]-deep Tijeras Arroyo, on the east by the Tijeras Fault, and on the south and west by the 15-m (50-ft)-deep Arroyo del Coyote. The subprovince is drained by several ephemeral channels that grade to the Tijeras Arroyo and the Arroyo del Coyote. Surficial deposits within the subprovince are derived principally from the Precambrian granite, quartzite, and metarhyolite of Four Hills and northeast of Four Hills (Myers and McKay, 1970; 1976).

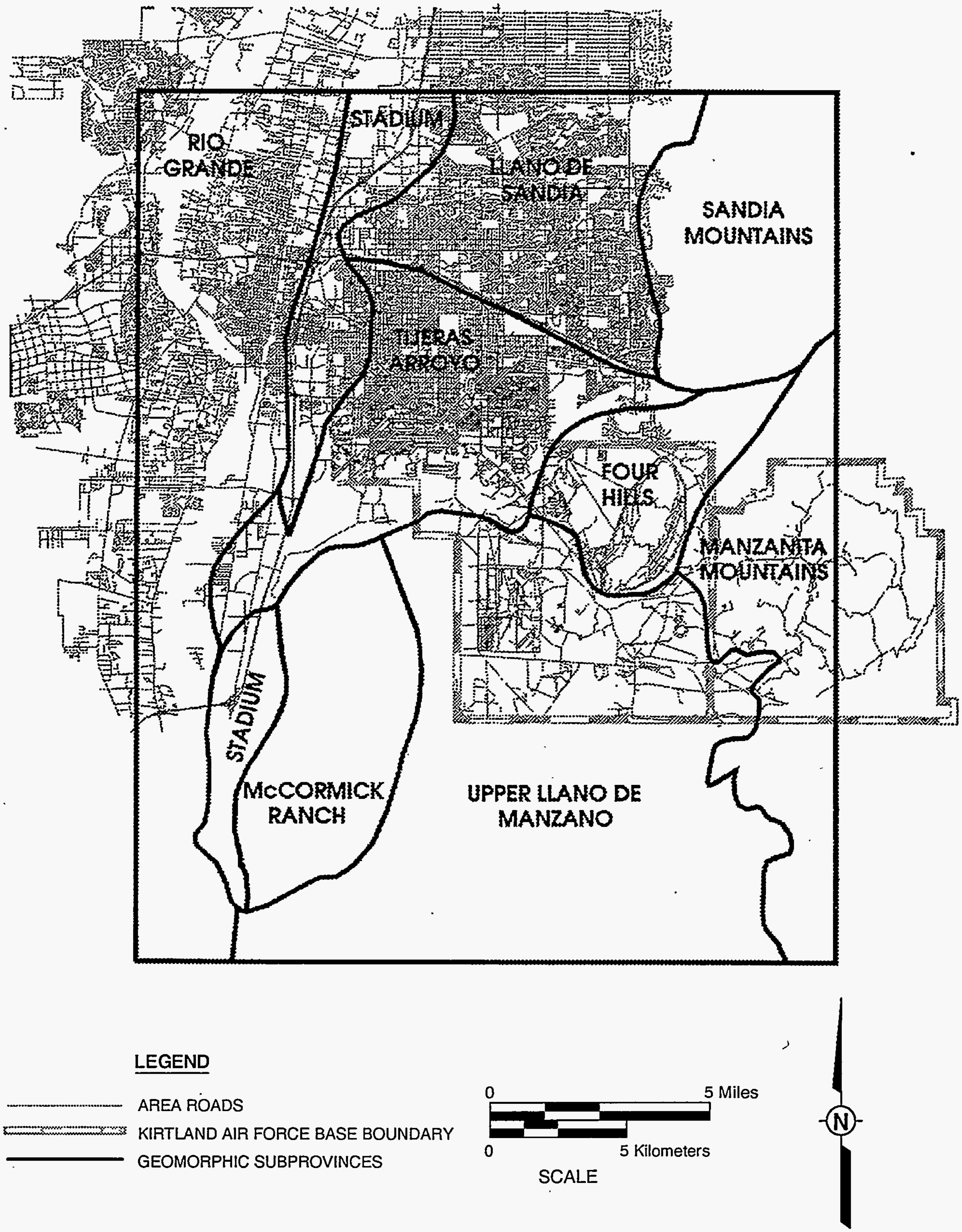


Figure 2-2

Geomorphic Subprovinces in the Area of Sandia National Laboratories/New Mexico and Kirtland Air Force Base

Upper Llano de Manzano Subprovince. The Upper Llano de Manzano subprovince encompasses the broad, west-sloping piedmont flanking the western margin of the Manzanita Mountains south of and including the Arroyo del Coyote (Figure 2-2). This subprovince makes up the higher, eastern part of the Llano de Manzano geomorphic province defined by Bryan and McCann (1938); it is moderately dissected by the Arroyo del Coyote, the Hells Canyon Wash, and associated piedmont tributaries. Surficial deposits are derived primarily from Paleozoic clastics and carbonates exposed in the Manzanita Mountains and minor granites and metarhyolite at the southern end of the Four Hills (Myers and McKay, 1970).

McCormick Ranch Subprovince. The McCormick Ranch subprovince is bordered on the north by the Tijeras Arroyo, on the east by the piedmont of Four Hills and the Manzanita Mountains, and on the west by the Rio Grande Valley (Figure 2-2). The subprovince, which makes up the western half of the Llano de Manzano geomorphic province of Bryan and McCann (1938), is flat or slopes gently to the east. Piedmont drainages within the Upper Llano de Manzano subprovince flow into closed depressions in the eastern part of the McCormick Ranch subprovince. Surficial deposits in the McCormick Ranch subprovince are derived principally from local fluvial and eolian erosion of the underlying Santa Fe Group, small arroyos in the Upper Llano de Manzano subprovince, and eolian deposits derived from the west and southwest. These surficial deposits consist primarily of sand, silt and clay derived from fine-grained, quartz- and feldspar-rich sediments.

2.1.1.2 The Llano de Sandia Geomorphic Province

Tijeras Arroyo Subprovince. The Tijeras Arroyo subprovince extends from the mouth of Tijeras Canyon on the east to the Rio Grande Valley on the west and from Embudo Arroyo (approximately along Interstate Highway 40) to the southern rim of the Tijeras Arroyo (Figure 2-2). The Tijeras Arroyo, Embudo Arroyo, and minor tributaries to the Rio Grande drain the subprovince, and surficial deposits originated principally from the Tijeras Arroyo headwaters in the eastern Sandia Mountains and western Manzanita Mountains. These drainages are underlain by Precambrian granitic rocks of the Sandia Mountains, Precambrian schist, greenstone, and quartzite of the Manzanita Mountains, and Paleozoic clastics and carbonates of both ranges (Myers and McKay, 1970, 1976; Kelley and Northrop, 1975). The Tijeras Arroyo subprovince is characterized by broad, west-sloping alluvial surfaces and the 50-m (165-ft)-deep Tijeras Arroyo. Lambert (1968) mapped the Santa Fe Group and "alluvium of Tijeras Arroyo" within this subprovince.

Llano de Sandia Subprovince. The Llano de Sandia subprovince includes the western piedmont of the Sandia Mountains in the northern Albuquerque Basin (Figure 2-2) and makes up most of the Llano de Sandia geomorphic province of Bryan and McCann (1938). The piedmont is a partially dissected plain 10 to 11 km (6 to 6.6 mi) wide that slopes westward from the front of the Sandia Mountains to the rim of the inner valley of the Rio Grande. The surface is extensively dissected by small, subparallel streams that create small-scale ridge and swale topography. Lambert (1968) used the term Sandia piedmont plain for the portion of the subprovince north of the Tijeras Arroyo. Most of the subprovince is underlain by sand and gravel with local sedimentation of Precambrian granite along the range front. Surficial deposits in the subprovince are derived from granites and minor limestone of the western escarpment of the Sandia Mountains.

2.1.1.3 The Rio Grande Geomorphic Province

Stadium Subprovince. The Stadium subprovince is bordered on the north by the Embudo Arroyo, on the east by the Sandia Mountains, on the south by Hells Canyon, and on the west by the Rio Grande Valley (Figure 2-2). The subprovince lies along the western margins of the Llano de Sandia and Llano de Manzano provinces defined by Bryan and McCann (1938) and encompasses the irregular eastern escarpment of the Rio Grande Valley. Small, west-facing basins drain the escarpment and provide sediment to the Rio Grande Valley margin. Surficial deposits in the subprovince are derived from the Santa Fe Group and eolian and alluvial deposits exposed along the rim of the escarpment. Lambert (1968) mapped deposits within the subprovince as piedmont alluvial fans and terraces and alluvial terraces of the Rio Grande (the late Pleistocene Menaul and Edith Formations).

Rio Grande Subprovince. The Rio Grande subprovince includes the Rio Grande Valley floor directly west of the eastern valley escarpment (Figure 2-2). The wide valley floor slopes gently to the south and is underlain by the "alluvium of the Rio Grande" of Lambert (1968). The alluvium of the Rio Grande Valley is distinct from deposits in other subprovinces in the SNL/NM-KAFB area because it is derived from many volcanic, igneous, metamorphic, and sedimentary rock sources throughout northern New Mexico and southern Colorado.

2.1.1.4 The Rift-Margin Ranges Geomorphic Province

Manzanita Mountains Subprovince. The Manzanita Mountains subprovince, which includes the uplands and valleys of the Manzanita Mountains, is bordered on the north by the Tijeras Arroyo and on the west by the Upper Llano de Manzano subprovince (Figure 2-2). The subprovince is drained by ephemeral streams within the mountains that are graded to the Arroyo del Coyote and to piedmont drainages in the Upper Llano de Manzano subprovince. Surficial deposits in the subprovince are derived from Paleozoic clastics and carbonates exposed in the Manzanita Mountains (Myers and McKay, 1970; 1976).

Sandia Mountains Subprovince. The Sandia Mountains subprovince, which includes the uplands and valleys of the Sandia Mountains, is bordered on the south by the Tijeras Arroyo and on the west by the piedmont of the Llano de Sandia subprovince (Figure 2-2). The subprovince is drained by ephemeral drainages within the mountains that are graded to the Tijeras Arroyo or to piedmont drainages in the Llano de Sandia subprovince. Surficial deposits are derived from Precambrian granite and minor Paleozoic limestone exposed in the western escarpment of the Sandia Mountains.

2.2 Stratigraphy

The majority of the Albuquerque Basin is composed of poorly consolidated sediments eroded from the surrounding mountain areas, following the faulting and structural changes that occurred 15 to 5.3 million years ago, during the interval of most active uplift of the Sandia-Manzanita-Manzano range (Hawley and Haase, 1992). Specifically, the upper part of the basin fill is comprised of a complex sequence of gravel, sand, silt, clay, and caliche deposits known as the Santa Fe Group and post-Santa Fe deposits (Figure 2-3). Underlying these deposits are Mesozoic and Paleozoic deposits of unknown total thickness, although gravity and aeromagnetic mapping indicate that these rocks extend about 4,600 m (15,000 ft) below ground level in the deepest portions of the basin (ERDA, 1977). These sedimentary rocks overlie the Precambrian (570 million years ago) rocks that underlie the entire basin and are then uplifted to form the western plateaus and caprock of the eastern mountains. The Sandia Mountains are about 1,500 m (5,000 ft) above the basin, giving a total difference in elevation between bedrock in the basin and the mountains of about 6,000 m (20,000 ft) (ERDA, 1977). Discussion of stratigraphic units is limited to those exposed on the surface and/or that occur in the subsurface on and in the vicinity of SNL/NM-KAFB (Figure 2-3). For this report, they are grouped into six major categories, and described from oldest to youngest: (1) Precambrian basement complex, (2) Upper Paleozoic strata, (3) Upper Cretaceous strata, (4) Paleogene strata, (5) Neogene/ Quaternary Santa Fe Group strata (late Oligocene through lower Pleistocene), and (6) Quaternary Post-Santa Fe Group sediments (upper Pleistocene to Recent). For a more detailed description of the various formations and lithologies, refer to the 1992 Sitewide Hydrogeologic Characterization Annual Report (McCord et al., 1993).

Erathem/System/Series			Time (Millions of Years)	Unit/Formation/Group		Strat. Column	Description
CENOZOIC	NEOGENE	Holocene to Middle Pleistocene		Post Santa Fe Basin and Valley Fill			Cross-bedded, fine to medium eolian sand Poorly sorted silty sandy cobble to boulder gravel Local unconformity Poorly sorted silty sandy cobble to boulder gravel with relict and buried soils
			0.79				← Unconformity
CENOZOIC	NEOGENE	Early Pleistocene to late (Oligocene)		Santa Fe Group	Upper Santa Fe Unit		Basinal: coarse-to-fine grained sandstones: common buried soils Marginal: pebbles, cobbles in fine-grained matrix
			5				
CENOZOIC	NEOGENE	Early Pleistocene to late (Oligocene)		Santa Fe Group	Middle Santa Fe Unit		Basinal: medium-to fine-grained sandstone and mudstone; common buried soils Marginal: conglomeratic sandstone to pebbles and cobbles; common buried soils
			15				
CENOZOIC	NEOGENE	Early Pleistocene to late (Oligocene)		Santa Fe Group	Lower Santa Fe Unit		Basinal: medium-to-fine sandstones, sandy mudstones Marginal: conglomeratic sandstone and mudstone
			23.5[a]				← Unconformity
CENOZOIC	PALEOGENE	Oligocene	30[b]	Unit of Isleta #2 Well			Fine-to-coarse-grained sandstone with claystones and silty interbeds
			35.5				← Unconformity
CENOZOIC	PALEOGENE	Eocene to Paleocene		Baca/ Galisteo/ Nacimiento Formations			Sandstone, variegated mudstone, and conglomerate
			65				← Unconformity
UPPER MESOZOIC		Upper Cretaceous		Mancos Equivalent			Claystone w/calcareous lenses, carbonaceous beds
			97 256				← Unconformity
UPPER PALEOZOIC		Lower Permian		Yeso Formation			Upper: gypsiferous sand, siltstone, limestone Lower: fine-grained sandstone and siltstone
UPPER PALEOZOIC		Lower Permian		Abo Formation			Fine-to-coarse-grained sandstone and conglomerate with interbedded siltstone
			290				
UPPER PALEOZOIC		Upper to Middle Pennsylvanian		Madera Group	Wild Cow Formation		Rhythmically bedded sequence: conglomerate, sandstone, siltstone, shale, limestone
UPPER PALEOZOIC		Upper to Middle Pennsylvanian		Madera Group	Los Mayos Limestone		Gray calcarenite with chert
UPPER PALEOZOIC		Middle Pennsylvanian		Sandia Formation			Fining-upwards clastic sequence: conglomerate to calcareous siltstone
			310 320				← Unconformity
UPPER PALEOZOIC		Mississippian		Arroyo Penasco Group			Dense, gray, fine-grained to oolitic limestone
			360 570				← Unconformity
PRE-CAMBRIAN				Sandia Granite Tijeras Greenstone Coyote Canyon Sequence Sevillita Rhyolite			Microcline and biotite granite; metarhyolite; quartzite; greenstone

[a] Paleogene–Neogene Boundary
[b] Lower Contact of Lower Santa Fe Unit

Figure 2-3
Generalized Stratigraphic Column and Time Scale for the Sandia National Laboratories/New Mexico and Kirtland Air Force Base Area

2.2.1 Precambrian Basement Complex

The surface exposures of basement complex on SNL/NM-KAFB consists of Precambrian igneous, metasedimentary, metaigneous, and minor metamorphic rocks (Figure 2-3). The basement bedrock is exposed in the uplifted Four Hills and Manzanita Mountains, which are located in the eastern part of SNL/NM-KAFB. The west-facing mountain fronts, which are coincident with north-and northwest-trending faults, expose Precambrian granite, metarhyolite, greenstone, quartzite, and minor gneiss and schist. These same rock types unconformably underlie late Paleozoic sediments throughout the western Manzanita Mountains, as well as middle to late Cenozoic Albuquerque Basin fill immediately west of the uplifts. All Precambrian rocks in the SNL/NM-KAFB area have experienced at least one major episode of deformation, thus displaying a multitude of fractures, faults and other deformation features and fabrics.

2.2.2 Upper Paleozoic Strata

Upper Paleozoic formations within the Albuquerque Basin, which are Mississippian to Permian in age, include marine to nonmarine interstratified carbonates and clastics (Figure 2-3). Rare exposures of the marine Mississippian Arroyo Peñasco Group are present in the Tijeras Canyon (Kues et al., 1982); the strata consist of dense gray, fine-grained to oolitic, massive to medium-bedded limestone. Marine and marginal marine Pennsylvanian Age rocks, which are prominently exposed in the Sandia and Manzanita Mountains, are subdivided into the Sandia Formation and overlying Madera Group (Figure 2-3). The Sandia Formation is a sequence of olive-drab micaceous siltstone, sandstone, and conglomerate, capped by a shaley limestone (Myers and McKay, 1970). The Madera Group is subdivided (Myers, 1973) into the Los Moyos Limestone (cliff-forming gray limestones) and the overlying Wild Cow Formation (rhythmically bedded arkosic conglomerate, sandstone, siltstone, shale, and limestone). Permian strata include isolated Abo Formation outcrops on SNL/NM-KAFB (Myers and McKay, 1970) and Yeso Formation outcrops south of the base (Myers and McKay, 1971); they consist of shallow marine and nonmarine, massive to thinly bedded red sandstones, siltstones, and shales. Locally, the strata are gypsum-bearing, especially the Yeso Formation.

2.2.3 Upper Cretaceous Strata

Near and possibly on SNL/NM-KAFB, Upper Cretaceous sediments, equivalent to the Mancos Shale (Figure 2-3) are preserved only in the subsurface. Lozinsky (1988) identified age-equivalent strata in the Transocean, Isleta No. 1 exploratory well, drilled on the Isleta Pueblo south of SNL/NM-KAFB; lithologies in this well consist of gray to dark gray shale, minor fine- to medium-grained sandstone beds, and coaly interbeds. These sediments were deposited in a low-energy environment within a very broad, low-relief basin.

2.2.4 Paleogene Strata

Although no Paleogene Age outcrops are present on SNL/NM-KAFB, the Eocene Baca Formation is exposed south of SNL/NM-KAFB on the eastern part of the Hubbell Bench structural feature (Lozinsky, 1988). The strata consist of sandstones, siltstones, shales, and fanglomerates (Figure 2-3). Paleogene strata, consisting of sandstone, siltstone, shale, and coaly shale, were encountered in a down-faulted structural block in South Fence Road wells. It is uncertain whether this section is age-equivalent to the Baca Formation or to carbonaceous shale of the Paleocene Nacimiento Formation; the Nacimiento is not known to occur outside of the San Juan Basin.

Lozinsky (1988) described an ash-dated Oligocene sequence of pinkish-red to brown, weakly consolidated fine- to coarse-grained sand with clay and silt interbeds from the Shell, Isleta No. 2 exploratory well southwest of SNL/NM-KAFB. An equivalent-aged unit may be present in down-faulted structural blocks on SNL/NM-KAFB. The Paleogene sediments were deposited within a nonmarine alluvial system within a broad shallow basin.

2.2.5 Neogene/Quaternary Santa Fe Group Strata

Santa Fe Group strata comprise the principal portion of the Albuquerque Basin. The Santa Fe Group consists of complexly interstratified gravels, sands, silts, and clays. These sediments were deposited either as alluvial fans sourced from the nearby mountains, as fluvial deposits transported by rivers from source areas outside the basin, or as locally thick playa-lake and eolian deposits (Lozinsky, 1988; Hawley and Haase, 1992). Buried soil horizons are common within this group. The Santa Fe Group is over 4,420 m (14,500 ft) thick in the center of the rift, which is located near the western margin of SNL/NM-KAFB (Hawley and Haase, 1992). Hawley and Haase (1992) subdivided the group into lower, middle, and upper hydrostratigraphic units (Section 2.2.5.1) based on depositional environments and age (Figure 2-3).

The Lower Santa Fe (LSF) unit (Hawley and Haase, 1992) is dominated by intertonguing piedmont-slope alluvial fan deposits, eolian deposits, and fine-grained basin-floor deposits. The deposits range in age from about 30 to 15 million years and represent deposition in an internally drained basin prior to deep subsidence and uplift of rift-margin ranges.

The Middle Santa Fe (MSF) unit (Hawley and Haase, 1992) was deposited between about 15 and 5 million years ago, when tectonism was most active in the rift. Piedmont-slope sediments continued at the margins of the Albuquerque Basin, but major fluvial systems from the north, northeast, and southwest also were transporting sediments into the basin. These fluvial systems probably terminated in playa lakes in the southern part of the basin (Lozinsky and Tedford, 1991). This is the thickest of the three Santa Fe Group units resulting from rapid sedimentation related to active tectonism.

About 5 million years ago, a through-flowing ancestral Rio Grande system developed (Lozinsky et al., 1991), forming a large aggradational plain in the central basin area. The Upper Santa Fe (USF) Group (Hawley and Haase, 1992) was deposited from about 5 to 1 million years ago. It is characterized by intertonguing piedmont-slope deposits (alluvial and debris-flow) and cross-stratified ancestral river basin-floor deposits (thick clean sand and pebble gravel). Fine- to medium-grained overbank sediments were deposited in areas where major river systems merged and in basin-floor and piedmont-slope transition zones.

2.2.5.1 Hydrostratigraphic Units

Brief discussions of hydrogeologic mapping units and lithofacies are contained in this subsection because of their relationship to the local stratigraphy. Because of differences in underlying bedrock and/or sediment source lithologies among the various geomorphic subprovinces, deposits differ in lithologic, soil, and geochemical properties. Although there is an interrelationship between geology and groundwater hydrology, the groundwater hydrology of the SNL/NM-KAFB area is addressed separately in Chapter 3.0.

The basic hydrogeologic mapping unit used by Hawley and Haase (1992) is the hydrostratigraphic unit. It is defined in terms of (1) environment of deposition of sedimentary strata, (2) distinctive combinations of lithologic features (lithofacies) such as grain-size distribution, mineralogy, and sedimentary structures, and (3) general time interval of deposition.

The ten lithofacies subdivisions of the Santa Fe Group and Post-Santa Fe deposits (Hawley and Haase, 1992) are defined primarily on the basis of sediment texture (gravel, sand, silt, clay, or mixtures thereof), degree of cementation, and geometry of bodies of a given textural class and their relative distribution patterns. Lithofacies I, II, III, V, and VI are unconsolidated or have zones of induration (strong cementation) that are not continuous. Clean sand and gravel bodies are major constituents of facies I, II, V, and VI; while clay or cemented sand zones form a significant part of facies III and IV. Subdivision IV is characterized by thick eolian sand deposits of the LSF unit that are partly cemented with calcite. Coarse-grained channel deposits of the modern and ancestral Rio Grande (lithofacies I and II) are the major components of USF and river-alluvium hydrostratigraphic units. They form the most important aquifers and potential enhanced-recharge zones in the basin. Buried arroyo-channel deposits of a large alluvial fan that spread out from the mouth of the Tijeras Canyon (facies Vd) form another major hydrogeologic unit (MSF-1 and USF-1) that has greater than average aquifer potential. This ancient complex of fan distributaries is now partly dissected by valleys of the present Embudo, Campus and Tijeras arroyo systems. Lithofacies VII and VIII are partly to well-indurated piedmont-slope deposits; while facies IX and X comprise thick sequences of fine-grained basin-floor sediments that include playa-lake beds.

2.2.6 Quaternary Post-Santa Fe Group Sediments

Post-Santa Fe Group units include fan, pediment, inset-terrace, eolian, playa, colluvial, and floodplain deposits (Lambert, 1968; Hawley and Haase, 1992). Rock pediment and graded alluvial slopes generally occur on piedmont surfaces that extend from the bases of the Sandia and Manzanita uplifts along the eastern part of SNL/NM-KAFB. Multiple alluvial fans are present throughout much of SNL/NM-KAFB and are derived from the Four Hills and Manzanita Mountain range fronts and drainages. Several fluvial terraces are inset into older alluvial fans along major drainages and interfinger with younger alluvial fans. Eolian deposits include active and stabilized dunes as well as sheets that cover and modify alluvial deposits. Colluvium is present within the steep terrain of the range block, and playa deposits are present in topographic and structural depressions in western-most SNL/NM-KAFB. Buried soils are common within many, if not all, of these surficial deposits. Santa Fe Group sediments are overlain in places by the Ortiz Gravel (5.3 to 1.6 million years ago) which was deposited after subsidence of the Santa Fe Group. Subsequent uplift caused the Ortiz Gravel to be extensively eroded leaving a discontinuous gravel unit of 0 to 46 m (0 to 150 ft) in the area of SNL/NM south of the Tijeras Arroyo. Overlying the Ortiz Gravel in this area are recent fan deposits eroded from the eastern mountains that contain sediments from the Tijeras Arroyo. The exact thickness of the Tijeras Arroyo sediments is unknown (Kelly, 1977). Recent work indicates the sediments vary from 30 to 90 m (100 to 300 ft) near SNL/NM-KAFB (Goodrich, 1991).

2.3 Structural Geology

This section discusses the tectonic settings and fault systems of the Albuquerque Basin.

2.3.1 Regional Tectonic Setting

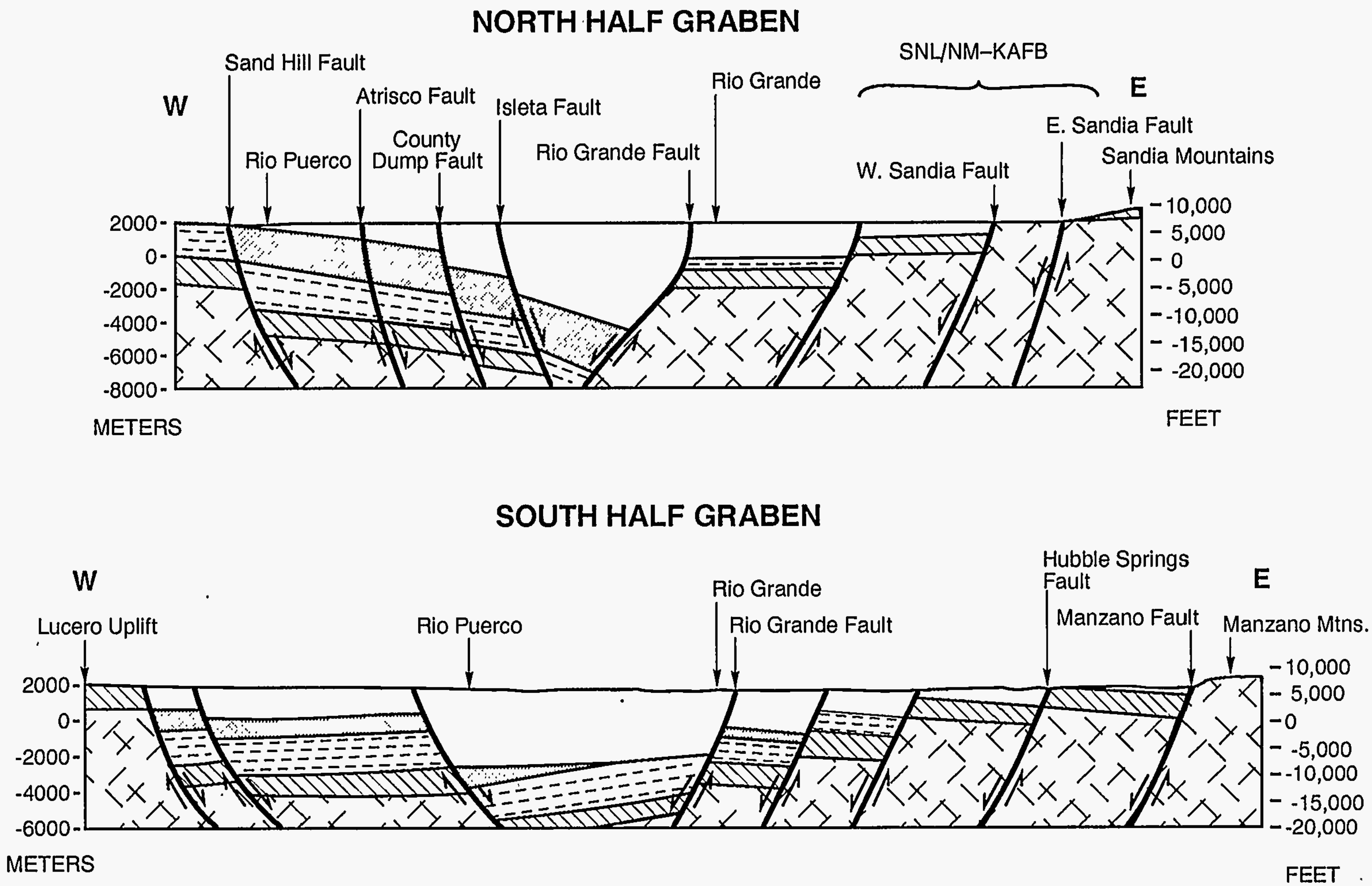
SNL/NM-KAFB is located in the east-central part of the Albuquerque Basin, which is an elongated structural depression within the Rio Grande Rift (Figure 2-1). The north-trending Albuquerque Basin, which has undergone several kilometers of east-west extension over the past 30 to 40 million years, is bordered by basement uplifts including the Sandia-Manzanita-Manzano-Los Pinos uplifts on the eastern margin. The basin is bordered by major Neogene faults and bisected by the northeast-trending Tijeras Fault zone, forming two half-grabens (Figure 2-4). The Tijeras Fault acts as a zone of strain accommodation between differential extension rates of the northern and southern subbasins (Russell and Snelson, 1990; Lozinsky et al., 1991). These half-grabens are characterized by a deep, sediment-filled inner depression flanked by a series of faulted ramps along the basin margin. Neogene faults with the largest displacements border the inner structural trough, although faults within and bordering the basin exhibit evidence of late Pleistocene and possibly Holocene displacement. Overall structural relief between Precambrian strata within the inner trough to the top of the eastern margin uplift is about 10 km (6 mi).

2.3.2 Local Faults

Several major rift-bounding faults are present on SNL/NM-KAFB (Figure 2-5). These include north- and northwest-trending faults along the base of the Manzanita and Sandia Mountains such as the Sandia, Coyote, Colorado, and Manzano Faults, and faults located west of the range front such as the Hubbell Springs Fault and unnamed faults west of the Hubbell Springs Fault. These faults generally are west-dipping normal faults that exhibit down-to-the-west displacement. In addition, the northeast-trending Tijeras Fault zone traverses SNL/NM-KAFB and intersects or merges with the Sandia and Hubbell Springs Faults in the south-central part of the site (Figure 2-5). The following sections briefly describe the major faults on SNL/NM-KAFB; a more detailed discussion of these faults is provided in the 1992 Sitewide Hydrogeologic Characterization Annual Report (McCord et al., 1993).

The Sandia Fault is a north-trending, west-dipping normal fault along the eastern margin of the Albuquerque Basin (Kelley and Northrop, 1975). The location and lateral continuity of the fault are poorly constrained, although an exposure in the Tijeras Arroyo shows Precambrian granitic rocks faulted against upper Santa Fe Group sediments (Lambert et al., 1982). Kelley (1977) suggests that there has been late Quaternary displacement on the fault based on a topographic scarp along the Rincon Fault, which is a northern extension of the Sandia Fault (Cordell, 1978). Substantial increases in the thicknesses of units of the Santa Fe Group occur across the fault (Hawley and Haase, 1992).

The Hubbell Springs Fault is a series of north-trending, west-dipping normal fault strands along the western margin of the Hubbell Bench, which extends to the south from the southeastern part of SNL/NM-KAFB (Figure 2-5). The fault intersects or merges with the Tijeras and Sandia Faults in the south-central part of SNL/NM-KAFB. The fault displays prominent geomorphic



Source: *Hawley, J.W., and C.S. Haase, 1992. Hydrogeologic Framework of the Northern Albuquerque Basin, "New Mexico Bureau of Mines and Mineral Resources Open-File Report 387."*

No vertical exaggeration
See Figure 3-1 for fault locations.

Figure 2-4
Diagrammatic Geologic Cross-Sections of the Central Albuquerque Basin North and South of the Tijeras Fault Zone

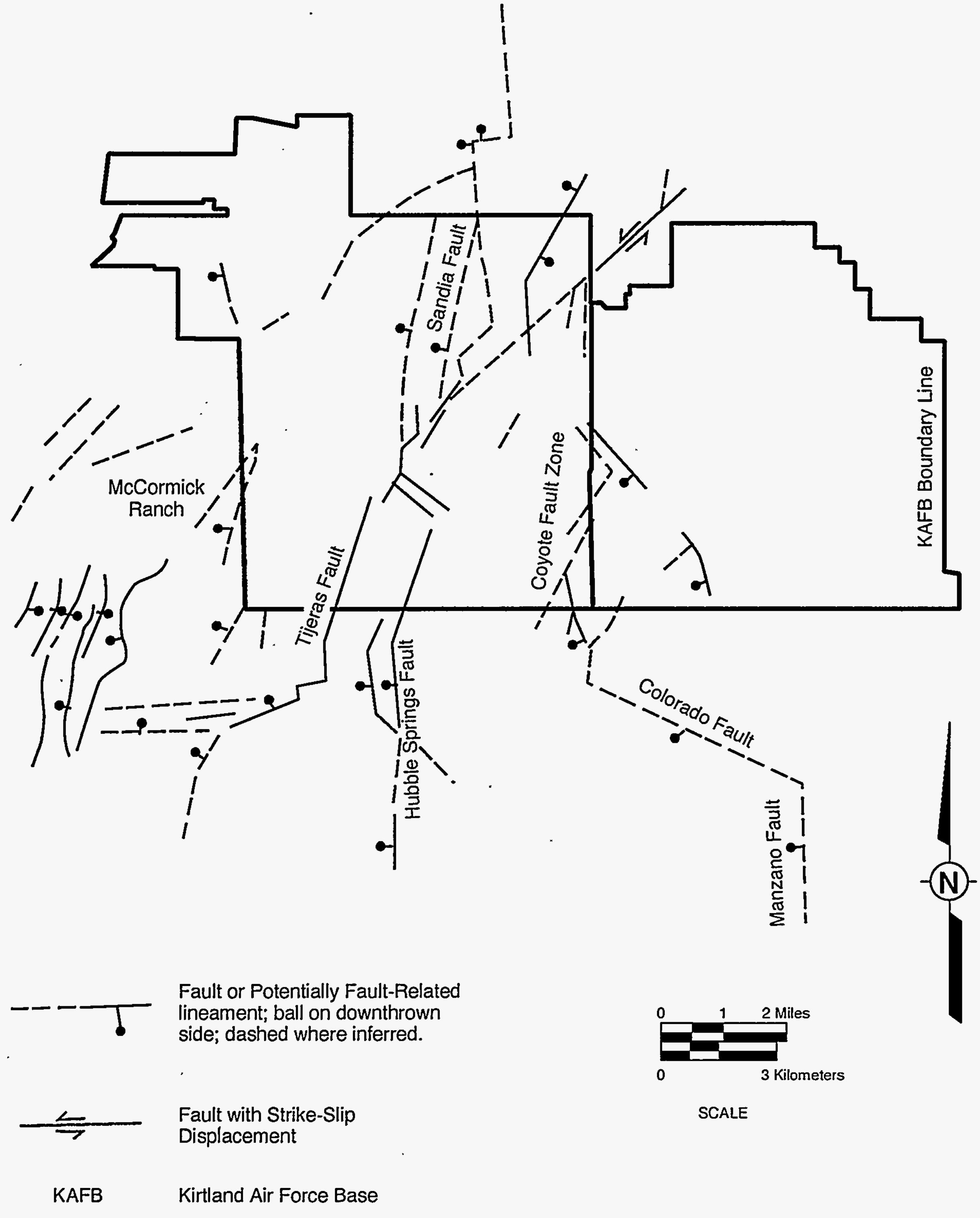


Figure 2-5
Map of Local Structural Features in the
Sandia National Laboratories/New Mexico and Kirtland Air Force Base Area

evidence of late Quaternary displacement and is a major potentially active fault along the eastern side of the Albuquerque Basin.

The northeast-trending Tijeras Fault zone extends from SNL/NM-KAFB to the north-northeast through Tijeras Canyon, where it separates the Sandia and Manzanita Mountains, and to the south-southwest across the Rio Grande Rift, where it separates the northern and southern subbasins of the Albuquerque Basin (Figure 2-5). The Tijeras Fault is evidenced by a 50-km (31-mi) fault scarp extending from Manzano Base to Golden, New Mexico. The fault zone consists of several faults that have near-vertical dips and exhibit evidence of normal and left-lateral displacement (Lisenbee et al., 1979; Maynard et al., 1991). There is geologic evidence of multiple episodes of movement along the fault during the Precambrian, Paleozoic, and Quaternary, with each episode having a different sense of displacement (Lisenbee et al., 1979). However, displacement of Quaternary colluvium in Tijeras Canyon (Lisenbee et al., 1979) shows that the fault is a potentially active structure.

The Coyote and Colorado Faults are located along the base of the Manzanita Mountains in the southeastern part of SNL/NM-KAFB (Figure 2-5). These faults form the eastern margin of the Hubbell Bench and exhibit down-to-the-west or -southwest displacement. The northwest-trending Colorado Fault extends from the northern end of the Manzano Fault (Machette, 1982) to the southern end of the Coyote Fault and thus may be a relay fault between these two range-bounding structures. Both faults are expressed geomorphically as linear range-front facets, and, as evidenced by the coincidence of Coyote Springs with the Coyote Fault, both probably influence groundwater pathways from the range block to the rift-fill sediments. There are no available data addressing possible late Quaternary activity on either of these structures.

The area between the Hubbell Springs Fault and the eastern escarpment of the Rio Grande Valley contains several prominent north-trending air-photo lineaments and topographic scarps that coincide with an unnamed fault mapped by Hawley and Haase (1992). These potentially fault-related lineaments occur in a zone about 7 km (4.2 mi) wide that extends from the Hells Canyon Wash to near McCormick Ranch, directly west of the western SNL/NM-KAFB boundary (Figure 2-5). The overall pattern of the lineaments suggests a broad, complex graben containing several smaller-scale internal horsts and grabens.

2.4 Seismology

It is likely that earthquakes have occurred in the Albuquerque Basin since the basin stabilized in its present form, approximately 11.2 to 5.3 million years ago (ERDA, 1977). The Albuquerque area is located in Seismic Risk Zone 2 (ERDA, 1977), which, by definition, is a region that can be expected to receive moderate damage from earthquakes (corresponding to Intensity VII of the Modified Mercalli Intensity Scale of 1931). The scale measures the amount of ground shaking with respect to damage to cultural features. An example is Intensity VII: "Everybody runs outdoors, damage to buildings varies depending on quality of construction; noticed by drivers of automobiles." The records for this region show fairly high activity but low magnitude and intensity, especially compared to west coast earthquakes. There have been only ten earthquakes of Intensity VII in New Mexico in the last century (ERDA, 1977).

New Mexico earthquakes with a Mercalli Intensity of VII or greater, since records were first kept in 1869, are shown in Tables 2-1 and 2-2. However, the records are poor and incomplete, with 1869 being the earliest recorded date. Many of the earthquakes have occurred in sparsely populated regions, where there is little to no interest in keeping earthquake records. The earlier records (newspapers articles, diaries, and letters) are inadequate to determine the origin of the earthquakes. In 1935, the Richter method, which records earthquake magnitude on a scale in terms of energy released, replaced the Mercalli scale. The earthquake locations in New Mexico with a modified Richter magnitude of 3.5 or greater are shown in Figure 2-6.

The earthquakes that have most affected New Mexico in the past century are those of 1906, 1966, and 1971. A series of shocks occurred at Socorro almost daily from July 2, 1906, until well into 1907. On July 12, 1906, some adobe walls were cracked and others thrown down. Wave-like ground motion was seen, and there were fissures in the ground. A more severe shock on July 16, 1906, was felt at Raton, New Mexico, and in Douglas, Arizona, each over 320 km (200 mi) distant from the origin, and a train was nearly derailed 16 km (10 mi) west of Socorro. A November 15, 1906, shock at Socorro was felt over a region of about 260,000 square km (km^2) (100,000 square mi [mi^2]). The history of the Socorro region shows frequent earthquakes of some intensity.

The January 1966 earthquake and its aftershocks were centered near Dulce, New Mexico, near the Colorado border. Nearly every house in Dulce was affected; damage was estimated at $200,000. Porches were displaced from houses; walls and foundations cracked; water pipes were broken; fireplaces were cracked in half; a church roof partially collapsed; and people in houses were knocked down. This shock, which registered 5.5 on the modified Richter scale, was the largest in

Table 2-1
Noninstrumentally Located Earthquakes in New Mexico

Month/Day/Year	Origin Time MST	Approximate Location	Modified Mercalli Intensity
04/18/1869		Socorro	VII
09/07/1893		Los Lunas and Sabinal	VII
07/16/06		Socorro	VIII
11/15/06		Socorro	VII to VIII
05/23/18	04:30	Cerrillos	VII to VIII
12/20/35	03:30	Belen	VII
12/21/35	18:56	Belen	VII
12/28/35	12:05	Belen	VII
12/28/35	15:15	Belen	VII+
12/30/35	22:10	Belen	VII+

MST = Mountain Standard Time

Sources: Energy Research and Development Administration (ERDA), 1977; "Environmental Impact Statement," EIA/MA 77-1, Sandia Laboratories, Albuquerque, New Mexico.

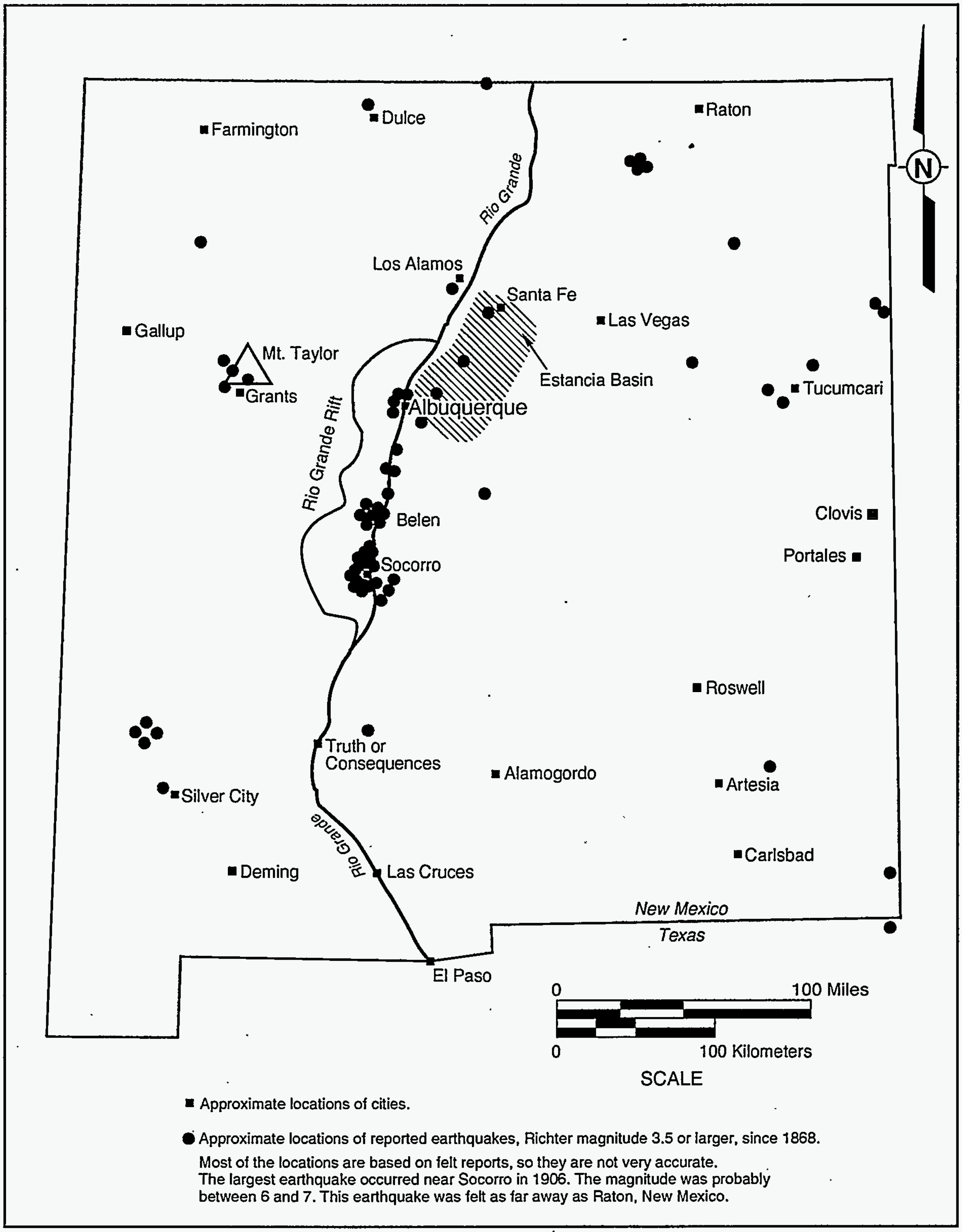
Gibson, D., 1991, Personal Communication, Sandia National Laboratories, Albuquerque, New Mexico.

Table 2-2
Instrumentally Located Earthquakes in New Mexico

Month/Day/Year	MST Time	Approximate Location	Richter Magnitude	Modified Mercalli Intensity
01/23/66	01:56	Dulce	5.5	VII
01/04/71	07:39	Albuquerque	4.7	V
01/05/76	06:23	Gallup	5.0	VI
01/04/76	23:23	Grants	4.6	V
06/24/76	09:27	Nara Visa	3.5	V
03/04/77	20:00	Grants	4.2	V
03/04/77	20:00	Grants	4.2	V
09/19/82	20:55	Socorro	3.5	V
03/02/83	16:22	Socorro	4.1	V
04/30/83	00:34	Truth or Consequences	3.5	V
08/16/85	07:56	Socorro	4.1	V
12/15/85	00:14	Garita	3.6	V
11/28/89	23:54	Belen	4.7	V
01/29/90	06:16	Belen	4.8	V
01/30/90	18:08	Belen	4.0	V
02/21/90	05:02	Socorro	3.6	V
02/27/90	06:23	Socorro	3.9	V
05/05/90	09:26	Belen	3.6	V
07/22/90	14:27	McIntosh	3.7	V
11/08/90	03:46	Belen	4.3	V
11/15/90	00:25	Belen	3.6	V
06/20/91	09:05	Socorro	3.5	V
01/02/92	05:45	Eunice	5.0	VI

MST = Mountain Standard Time

Sources: Energy Research and Development Administration (ERDA), 1977. U.S. Geological Survey National Earthquake Information Center (USGS/NEIC), 1995.



Source: IT Corporation (IT), 1992. "Sandia National Laboratories, Albuquerque Environmental Baseline Update," prepared for Sandia National Laboratories, Albuquerque, New Mexico.

Figure 2-6

Reported Earthquakes in New Mexico of Richter Magnitude 3.5 or Larger (Since 1868)

New Mexico since 1906. Between January 23 and 28, 119 aftershocks were recorded at the Coast and Geodetic Survey's Albuquerque observatory 225 km (140 mi) to the south (Lander, 1966).

Perhaps the strongest shock of the century in the Albuquerque area was that of January 4, 1971, even though it was only of magnitude 4.7 on the Richter scale. The Bernalillo County jail, the University of New Mexico, and the West Mesa High School reported cracked walls, window breakage, and damage from fallen items. The records indicate no appreciable or serious damage to SNL/NM or Energy Research and Development Administration buildings; although cracks were observed in some buildings, there was no evidence that these cracks did not predate the earthquake. The cracks were noticed only after the event, when a search for possible damage was made.

As noted, the Albuquerque area has been classified as being located in Seismic Risk Zone 2, a zone subject to moderate seismic damage, which corresponds to Intensity VII of the Modified Mercalli Intensity Scale. Analysis of one thousand earthquakes revealed that most seismic activity falls into three areas: (1) The Socorro and Albuquerque areas of the Rio Grande Rift, (2) the Mount Taylor area, and (3) the Estancia Basin (Jaksha and Sanford, 1986). This analysis indicates that moderate damage is a reasonable expectation, if an earthquake occurs, but earthquakes are of rare incidence. The largest shock predicted in New Mexico in a 100-year period is of magnitude 6.0 on the Richter scale (Sanford et al., 1972). All buildings used by SNL/NM are built to the specifications of the Seismic Risk Zone, as specified in the Uniform Building Code (ERDA, 1977).

2.5 Soils

Information with respect to surface soils present at SNL/NM-KAFB is presented in the following subsections.

2.5.1 Geomorphic Relations

Surface soils within SNL/NM-KAFB are developed in fluvial, alluvial fan deposits, colluvium, and several different bedrock types. Generally, variations in soil properties reflect differences in deposit or bedrock characteristics, in length of exposure to surficial weathering, and in local climate. (See Section 2.1 for a discussion of the geomorphology of the SNL/NM-KAFB area.) Soils within the Llano de Manzano geomorphic province are developed primarily in alluvium derived from schist, greenstone, sandstone, siltstone, and limestone in the Manzanita Mountains; in granitic alluvium derived from the Four Hills; and in eolian deposits in the McCormick Ranch subprovince. In general, soils developed on middle to late Pleistocene alluvial fans in the Upper Llano de Manzano and Four Hills subprovinces and on thin pediment deposits in the Tijeras Arroyo subprovince contain well-developed argillic (clay-rich) and calcic (calcium carbonate-rich) horizons. These horizons probably influence rates of infiltration and the geochemistry of percolating water. There is a moderate hazard of surface erosion of these soils, which include primarily the Tijeras gravelly fine sandy loam, the Wink fine sandy loam, the Madurez loamy fine sand, and the Latene sandy loam (Hacker, 1977).

In the Upper Llano de Manzano and Four Hills subprovinces, soils developed in Holocene deposits are less developed than those on older surfaces. For example, soils developed on younger fans derived from the western side of Four Hills include the Embudo gravelly fine sandy loam and the Tome very fine sandy loam (Hacker, 1977). Moderately developed calcic horizons in these soils influence rates of infiltration and the geochemistry of percolating water. Areas underlain by the Embudo-Tijeras complex in this area contain Embudo soils in drainages and Tijeras soils on ridges, which is a result of erosion of the Tijeras soils. The heterogeneity of this complex shows that the locations and rates of infiltration, potential for surface erosion, and geochemical interactions between soils and percolating water may vary substantially in this part of SNL/NM-KAFB.

Soils associated with the Tijeras Arroyo and Arroyo del Coyote valley floors generally are well-drained, have moderate permeability, and have high potential for surface erosion. The Gila fine sandy loam is associated with the floors of large, active arroyos, such as the Tijeras Arroyo (Hacker, 1977). This poorly developed soil lacks evidence of substantial clay or salt accumulation and likely allows for rapid percolation of surface water. Escarpments flanking the large arroyos in the western SNL/NM-KAFB also are associated with poorly developed soils, such as the Bluepoint-Kokan association (Hacker, 1977). Areas underlain by this soil series, however, locally contain well-developed calcic horizons, which are remnants of the Tijeras, Wink, and Madurez soils originally developed on older surficial deposits. The Bluepoint-Kokan soils reflect erosion of older soils and therefore are characterized by discontinuous soil horizons. This heterogeneity strongly influences the location and rates of infiltration and geochemical interactions between surface soils and percolating water.

Soils developed in the bedrock uplands and small valleys in the eastern part of SNL/NM-KAFB (i.e., the Manzanita Mountains subprovince) are heterogeneous, consisting of poorly developed soils of the Rock Outcrop-Orthids complex, the moderately developed Salas complex, and the moderately developed Tesajo-Millet series. The Rock Outcrop-Orthid soils are formed in limestone, sandstone, and schist bedrock and are characterized by substantial variation in carbonate content (Hacker, 1977). The Salas complex contains well-drained soils developed in residuum derived from schist bedrock and characterized by moderate amounts of clay and carbonate accumulation. The Tesajo-Millet soils are formed in alluvium on valley floors and low terraces. These three soil complexes differ substantially in properties that likely influence interactions between surface and vadose water.

Soils are developed in silty, sandy surficial deposits in the McCormick Ranch subprovince, in contrast to the coarse-grained deposits of the Upper Llano de Manzano subprovince. In particular, eolian influx into surficial deposits, and thus soil horizons, is probably substantial in this subprovince. It is likely that the eolian dunes and eolian-modified alluvium are a substantially different parent material than that for limestone- and sandstone-rich alluvium in the Upper Llano de Manzano subprovince. At present, these possible differences are poorly characterized.

2.5.2 Soil Series

Table 2-3 presents general soils information. Figure 2-7 shows the dominant soils within a geomorphic subprovince of SNL/NM-KAFB for a geographic area. Minor amounts (less than 30 percent) of other soils are present within each dominant map unit on Figure 2-7. The Bluepoint Series consists of deep, somewhat excessively drained loamy fine sand on alluvial fans and terraces. Elevations range from 1,478 to 1,824 m (4,850 to 6,000 ft) with 1 to 15 percent slopes. Bluepoint soils are associated with Kokan, Latene, Madurez, and Wink Soils (USDA, 1977).

The Embudo Series consists of deep, well-drained gravelly fine sandy loam that formed from weathered granitic rocks on old fan-shaped deposits. Elevations range from 1,525 to 1,980 m (5,000 to 6,500 ft) with 0 to 5 percent slopes. Tijeras and Wink soils are associated with the Embudo Series (USDA, 1977). The Gila Series consists of deep, well-drained loamy soils that formed in and at the mouth of the Tijeras Arroyo. Elevations range from 1,478 to 1,829 m (4,850 to 6,000 ft) with 0 to 2 percent slopes. Small areas of Embudo, Bluepoint, and Glendale soils are mapped with this unit (USDA, 1977).

The Ildefonso Series consists of gravelly sandy loam that is found in areas near the Hells Canyon Wash and west of the Manzano Mountains. Elevations range from 1,829 to 2,133 m (6,000 to 7,000 ft) with 1 to 9 percent slopes. A small percent of Latene soils are mapped with this unit (USDA, 1977).

Table 2-3
General Soils Classification for Sandia National Laboratories/New Mexico

Series	Type	Subprovince*	Percent Slope	Runoff	Soil and Water Erosion Hazard	Use
Bluepoint	BCC-Bluepoint loamy fine sand	1	1-9	Slow	Severe	Range, watershed, wildlife habitat, recreation, and community development
	BKD-Bluepoint-Kokan association	1,3	5-40	Slow	Water erosion-moderate to severe	Range, watershed, wildlife habitat, recreation, and community development
Cut & Fill	Cu-Cut and fill land	1	1-25	Slow to Rapid	Slight to severe	Community development and watershed
Embudo	EmB-Embudo-gravelly fine sandy loam	1,2	0-5	Medium	Water erosion-moderate	Watershed, wildlife habitat, and community development
	EtC-Embudo Tijeras complex	1	0-9	Medium	Water erosion-moderate	Community development, watershed, wildlife habitat, and range
Gila	GA-Gila fine sandy loam	1,2,3,4	0-0.5	Slow	Water erosion and soil blowing-moderate	Wildlife habitat, watershed, and community development
Ildefonso	ILC-Ildefonso gravelly sandy loam	3	1-9	Medium	Water erosion-moderate	Range, watershed, and wildlife habitat
Laporte	LRD-Laporte-Rock outcrop Escabosa Complex	3	5-20	Moderate	Moderate	Watershed, wildlife habitat, community development, and recreation
Latene	LtB-Latene sandy loam	1,3	1-5	Medium	Water erosion and soil blowing-moderate	Range, watershed, wildlife habitat, and community development
Madurez	MaB-Madurez loamy fine sand	1,3	1-5	Slow	Soil blowing-severe	Range, wildlife habitat, watershed, and community development
	MWA-Madurez-Wink association	1,2,3.	1-5	Slow	Soil blowing-moderate to severe	Range, wildlife habitat, watershed, and community development
Nickel	NL-Nickel Latene association	3	5-30	Rapid	Water erosion-moderate to severe	Range, watershed, and wildlife habitat
Pino	PR-Pino-Rock outcrop association	4	3-15	Medium	Water erosion-moderate	Range, timber, recreation, wildlife habitat, and watershed
Rock Outcrop	RLF-Rock outcrop-Laporte complex	4	30-80	Rapid	Water erosion-slight	Watershed, wildlife habitat, and range
	ROF-Rock outcrop-Orthids complex	2,3,4	40-80	Rapid	Water erosion-moderate	Watershed, recreation, and wildlife habitat
	RUF-Rock outcrop-Ustolls complex	3	15-70	Rapid	Water erosion-moderate	Range, wildlife habitat, recreation, and watershed
Salas	SAF-Salas Complex	2,3,4	20-80	Rapid	Water erosion-moderate	Wildlife habitat, watershed, and recreation
Seis	SEC-Seis very cobbly loam	4	0-15	Medium	Water erosion-moderate	Range, recreation, wildlife habitat, watershed, and limestone quarrying
	SGE-Seis-Silver Complex	4	10-40	Medium-rapid	Water erosion-moderate-severe	Range, wildlife habitat, and watershed
	SHF-Seis complex	4	30-80	Rapid	Water erosion-severe	Wildlife, habitat, watershed, recreation, and range
Silver	Sw C-Silver and Witt soils	4	5-9	Rapid	Water erosion-moderate-severe	Range, watershed, wildlife habitat, and community development

Refer to footnotes at end of table.

Table 2-3 *(Continued)*

General Soils Classification for Sandia National Laboratories/New Mexico

Series	Type	Subprovince*	Percent Slope	Runoff	Soil and Water Erosion Hazard	Use
Tesajo	Te-Tesajo-Millet stony sandy loams	2,3,4	3-20	Medium	Water erosion-moderate	Watershed, wildlife habitat, community development, and range
Tijeras	TgB-Tijeras gravelly fine sandy loam	1,2,3	1-5	Moderate	Water erosion-moderate	Community development, range, watershed, and wildlife habitat
Tome	To-Tome very fine sandy loam	2,3	0-2	Medium	Water erosion-moderate	Range, watershed, and wildlife habitat
Wink	WaB-Wink fine sandy loam	1,2,3	0-5	Medium	Water erosion-slight to moderate soil blowing-moderate	Range, watershed, wildlife habitat, and community development
	Web-Wink-Embudo Complex	1,3	0-5	Medium	Water erosion-moderate	Community development, watershed, and wildlife habitat
	WM-Wink-Madurez association	3	1-7	Medium	Soil blowing-severe	Range, watershed, and wildlife habitat

*Subprovinces: 1—Tijeras Arroyo; 2—Four Hills; 3—Upper Llano de Manzano; 4—Manzanita Mountains

Source: U.S. Department of Agriculture (USDA), 1977, "Soil Survey of Bernalillo County and Parts of Sandoval and Valencia Counties, New Mexico," Soil Conservation Service, U.S. Department of the Interior, Bureau of Indian Affairs and Bureau of Land Management.

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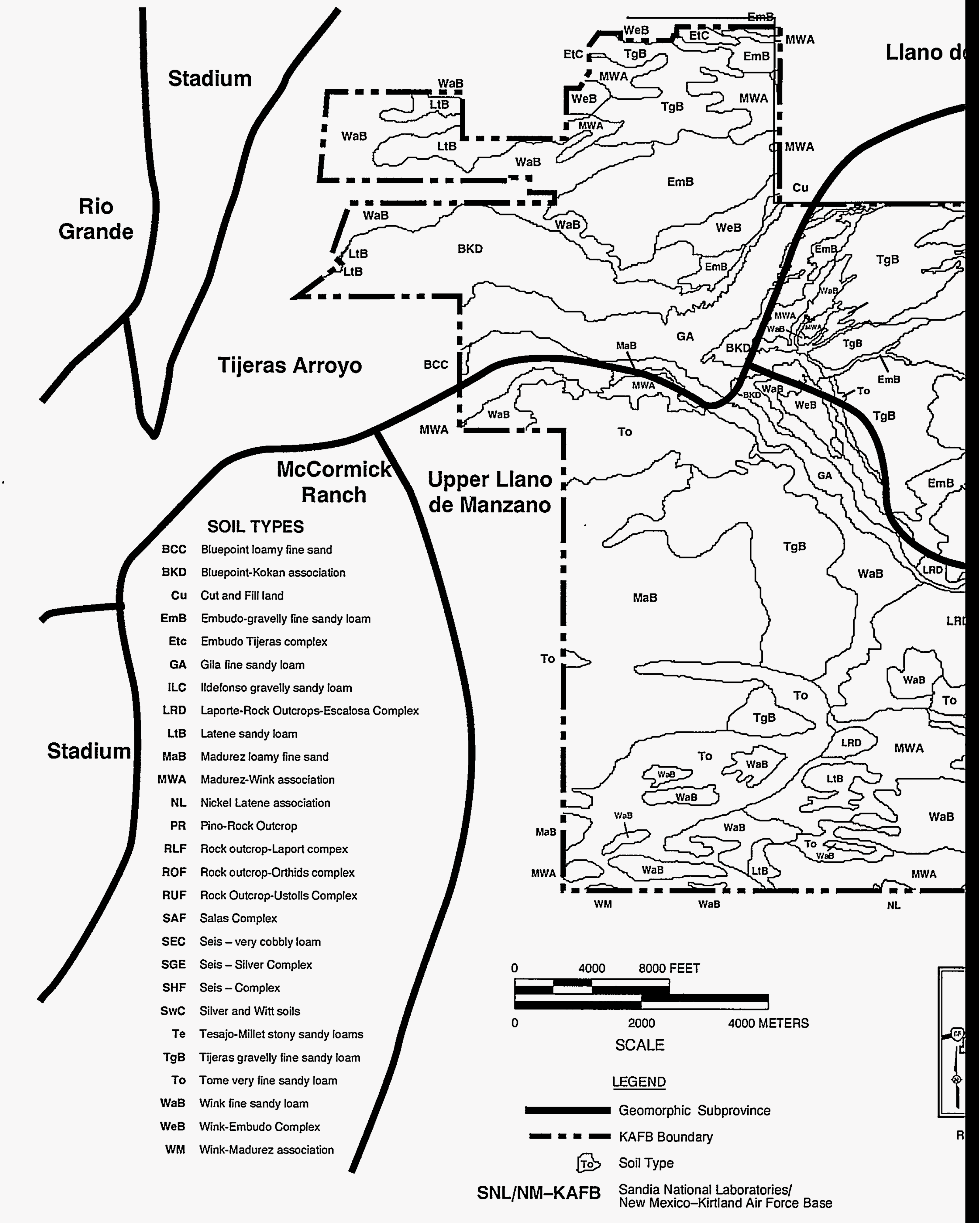
Figure 2-7
Generalized Soils Classification with Geomorphic Subprovinces for Sandia National Laboratories/New Mexico and Kirtland Air Force Base


Stadium
Rio Grande
Tijeras Arroyo
McCormick Ranch
Upper Llano de Manzano
Llano de
Stadium
SOIL TYPES
BCC Bluepoint loamy fine sand
BKD Bluepoint-Kokan association
Cu Cut and Fill land
EmB Embudo-gravelly fine sandy loam
Etc Embudo Tijeras complex
GA Gila fine sandy loam
ILC Ildefonso gravelly sandy loam
LRD Laporte-Rock Outcrops-Escalosa Complex
LtB Latene sandy loam
MaB Madurez loamy fine sand
MWA Madurez-Wink association
NL Nickel Latene association
PR Pino-Rock Outcrop
RLF Rock outcrop-Laport compex
ROF Rock outcrop-Orthids complex
RUF Rock Outcrop-Ustolls Complex
SAF Salas Complex
SEC Seis – very cobbly loam
SGE Seis – Silver Complex
SHF Seis – Complex
SwC Silver and Witt soils
Te Tesajo-Millet stony sandy loams
TgB Tijeras gravelly fine sandy loam
To Tome very fine sandy loam
WaB Wink fine sandy loam
WeB Wink-Embudo Complex
WM Wink-Madurez association
0 4000 8000 FEET
0 2000 4000 METERS
SCALE
LEGEND
Geomorphic Subprovince
KAFB Boundary
Soil Type
SNL/NM-KAFB Sandia National Laboratories/ New Mexico–Kirtland Air Force Base

The Laporte Rock outcrop Escabosa Complex contains 35 percent Laporte loam with 20 percent rock outcrop and 15 percent Escabosa loam. The Laporte loam is a very shallow to shallow soil derived from weathered limestone from the mountain foothills. The rock outcrop is limestone while the Escabosa loam is a moderately deep, weathered soil that formed from the weathered limestone of the rock outcrop. The elevations range from 1,980 to 2,286 m (6,500 to 7,500 ft) with 5 to 20 percent slopes. Approximately 20 percent of Ildefonso, Manzano, Silver, and Witt soils are included in this mapping unit (USDA, 1977).

The Latene Series consists of deep, well-drained loamy to fine sandy soils. Elevations range from 1,500 to 1,929 m (5,000 to 6,000 ft) with 1 to 5 percent slopes. Wink and Madurez soils make up about 15 percent of the unit (USDA, 1977).

The Madurez Series consists of deep, well-drained fine sandy loam that formed on piedmonts in old unconsolidated alluvium modified by wind. Elevations range from 1,500 to 1,800 m (4,900 to 5,900 ft) with 1 to 5 percent slopes. Limited amounts of Bluepoint, Latene, and Wink soils are associated with the Madurez Series (USDA, 1977).

The Nickel-Latene association is approximately 50 percent gravelly fine sandy loam (Nickel) with 40 percent sandy loam (Latene). The remaining 10 percent is composed of rock outcrop. Elevations range from 1,600 to 1,800 m (5,200 to 5,800 ft), with 1 to 30 percent slopes. These soils are associated with Latene, Tome, and Wink soils (USDA, 1977).

The Pino-Rock outcrop association is about 40 percent silt loam. The Rock outcrop (30 percent) is limestone with minor amounts of sandstone outcrops. Elevations range from 2,250 to 2,440 m (7,400 to 8,000 ft) with 3 to 15 percent slopes. Escabosa and Laporte soils are included in this mapping unit (USDA, 1977). Sandstone, limestone, or basalt exposed through faulting or stream channel erosion compose 90 percent of the Rock outcrop. Elevations range from 1,829 to 3,050 m (6,000 to 10,000 ft) with 25 to 80 percent slopes. The remaining 10 percent of the unit is composed of gravelly, stony debris found at the base of the moderately to very steep slopes (USDA, 1977).

The Salas complex is composed of very gravelly loam with the remaining 30 percent stony soils. Elevations range from 1,829 to 2,150 m (6,000 to 7,000 ft) with 20 to 80 percent slopes. Laporte soils and Rock outcrop make up the remaining 15 percent of the mapping unit (USDA, 1977).

The Seis Series formed moderately deep, well-drained very cobbly loam, very stony clay loam, and very stony light clay loam composed of weathered limestone from the mountains. Elevations range from 1,829 to 2,400 m (6,000 to 7,800 ft) with 0 to 60 percent slopes. These soils are mapped with minor amounts of Ildefonso and Silver soils (USDA, 1977).

Fifty-five percent of the Silver and Witt soils are deep, well-drained very fine sandy loam derived from sedimentary rocks, and 25 percent is the very fine sandy loam of the Witt soils derived from mixed rocks. Silver soils are dominant south of Interstate 40 and Witt soils dominate north of Interstate 40. Elevations range from 1,950 to 2,286 m (6,400 to 7,500 ft), with 0 to 15 percent slopes. Manzano and Laporte soils are found within this mapping unit (USDA, 1977).

Tesajo-Millet is a stony sandy loam. Elevations range from 1,829 to 2,133 m (6,000 to 7,000 ft), with 3 to 20 percent slopes. Rock outcrop composes 20 percent of this unit where the surface is covered with boulders (USDA, 1977).

The Tijeras Series are yellowish-brown gravelly fine sandy loam. Elevations range from 1,524 to 1,980 m (5,000 to 6,500 ft), with 1 to 5 percent slopes. Embudo, Madurez, and Latene soils comprise 20 percent of this unit (USDA, 1977).

The Tome Series are very fine sandy and silt loam derived from limestone and shale. Elevations range from 1,460 to 1,705 m (4,800 to 5,600 ft), with slopes of 0 to 2 percent. Madurez and Wink soils make up 15 percent of this mappable unit (USDA, 1977).

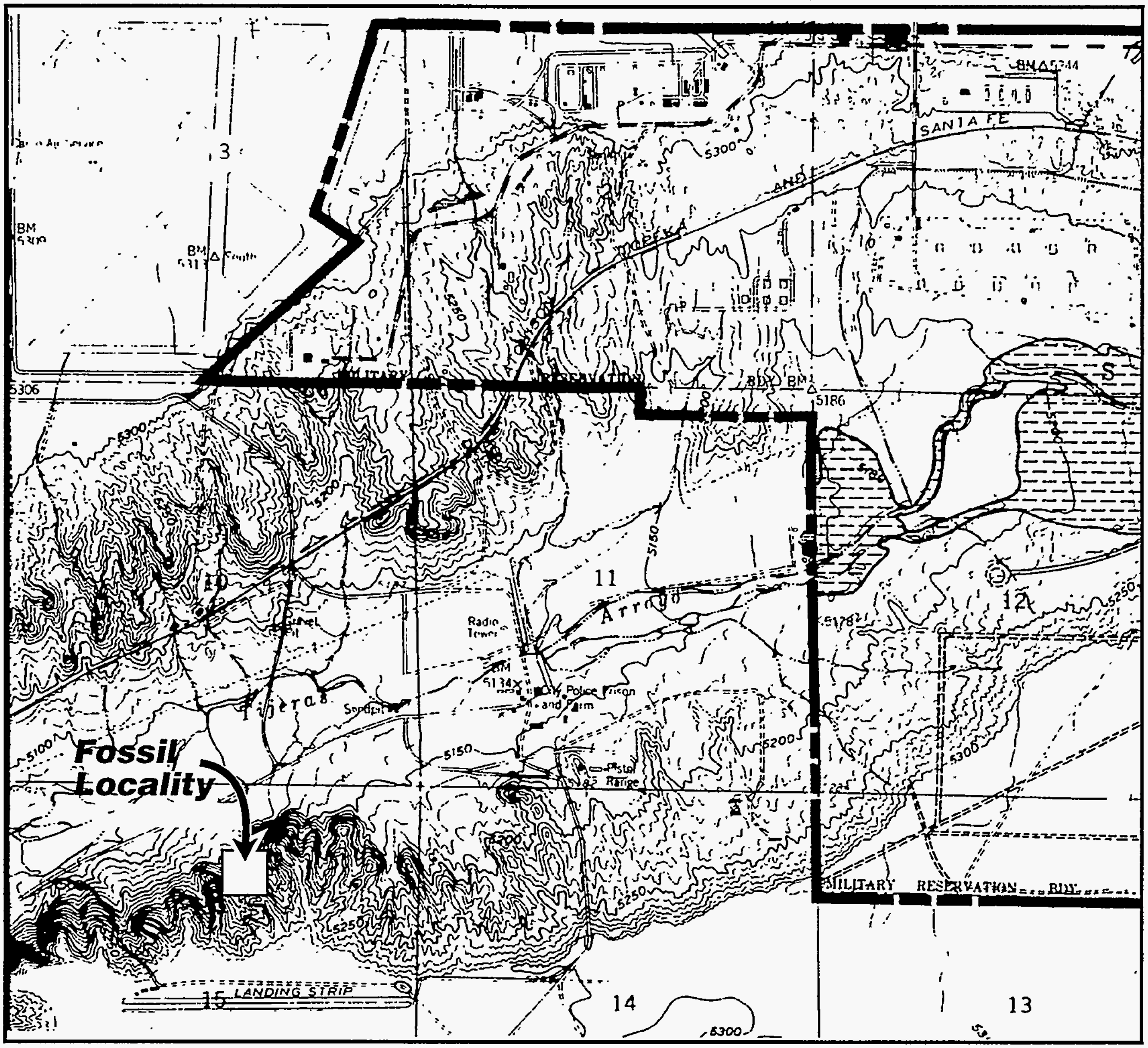
The Wink Series consists of brown, well-drained fine sandy and sandy loam. Elevations range from 1,524 to 1,829 m (5,000 to 6,000 ft) with slopes of 0 to 7 percent. Wink soils are associated with Madurez, Latene, Bluepoint, and Embudo soils (USDA, 1977).

Cut and fill land consists of sandy loam and very gravelly sand that has been mixed for residential, industrial, and business developments. It is on high terrace breaks of the Rio Grande Valley, primarily within Albuquerque. Elevations range from 1,494 to 1,829 m (4,900 to 6,000 ft) with 1 to 25 percent slopes. Minor pockets of Bluepoint, Kokan, and Wink soils are associated with cut and fill land (USDA, 1977).

2.6 Paleontology

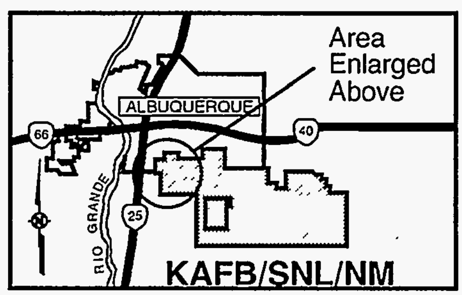
Few fossils have been discovered in the vicinity of SNL/NM. Lambert (1968) describes fossil vertebrate remains approximately 2.4 km (1.5 mi) west of the KAFB boundary ("Fossil Locality" on Figure 2-8). An ankle bone of the extinct Pleistocene camel *Camelops* (on the basis of size) was excavated from a lenticular deposit of silt and fine sand, interbedded with sandy gravel on the southern side of the Tijeras Arroyo approximately 5 to 8 km (3 to 5 mi) west-northwest of Technical Area III. In the same area, two horse teeth identified as being from *Equus* cf. *plesippus* or *E. bautistensis* were found loose near the bottom of a small arroyo. The headwaters of the arroyo drain a lense 3 to 4.5 m (10 to 15 ft) thick of interbedded clay, silt, fine sand, and tuff. The teeth were found about 15 m (50 ft) downstream from the lense and undoubtedly weathered from it (Lambert, 1968). Near the mouth of the Tijeras Arroyo, vertebrate fossils were collected in a quarry (locality outside of Figure 2-8). They included most of a horse skull identified as cf. *Equus* and hare teeth identified as cf. *Lepus*.

According to Lambert (1968), the formation containing the fossils consists of stream deposits, interbedded with sediments that were deposited on the basin floor and arroyo bottoms. The high-energy environments associated with the formation suggest that, although the formation may not extend beneath SNL/NM, the fossils may have been transported varying distances from their original source. It is possible that fossils are present at SNL/NM but are buried by the alluvial fan deposits from the Sandia Mountains.

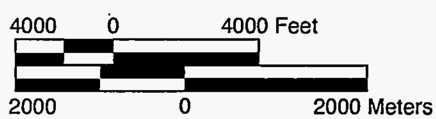


LEGEND

▬ ▬ ▬	Kirtland Air Force Base
– – – – – –	DOE Land Use Permit Area
———	Improved Roads
=========	Unimproved Roads
KAFB/SNL/NM	Kirtland Air Force Base/ Sandia National Laboratories/ New Mexico



Regional Locator Map



SCALE

Figure 2-8

**Fossil Locality,
Sandia National Laboratories/New Mexico**

3.0 Hydrology

The following sections describe the surface-water, vadose zone, and groundwater hydrology of the SNL/NM area and monitoring programs at SNL/NM, KAFB, and vicinity.

3.1 Surface-Water Hydrology

The major surface hydrologic feature in central New Mexico is the Rio Grande, which flows north to south through Albuquerque and lies approximately 8 km (5 mi) west of KAFB (SNL, 1991a). Average flow in the Rio Grande from 1967 to 1977 was about 1.01×10^9 cubic meters (m^3)/year (yr) (816,000 acre ft/yr) (U.S. Army Corps of Engineers [USACE], 1979a). The East Mesa, on which SNL/NM is located (SNL/NM, 1992a), has a generally west-southwestward ground-surface slope, ranging from about 75 m/km (250 ft/mi) near the mountains to 6 m/km (20 ft/mi) near the Rio Grande. The distance from the foot of the mountains to the river varies from 4.8 km (3 mi) in the northern part of the mesa to 14.5 km (9 mi) in the southern part. There are minor surface water bodies, as wetlands, on the East Mesa (SNL/NM, 1992a). (See Chapter 5.0 for a description of canyon wetlands, including Coyote Springs and Sol se Mete Spring).

Surface water on the East Mesa is in the form of sheet flow that drains into small gullies during precipitation events. The water is carried by natural and artificial flow paths into the two primary surface channels at SNL/NM, the Tijeras Arroyo, and the smaller Arroyo del Coyote, and an unnamed drainage south of the Arroyo del Coyote. Except for two very short reaches of channel, these drainages are all ephemeral within SNL/NM-KAFB (Figure 3-1). Arroyo del Coyote adjoins the Tijeras Arroyo about 1.6 km (1 mi) west of the Tijeras Arroyo Golf Course. Both flow intermittently during heavy summer thunderstorms (July through September) and during spring snowmelt (USACE, 1979b). However, most of the water does not reach the Rio Grande (U.S. Geological Survey [USGS], 1977) because of evapotranspiration and percolation into permeable alluvial deposits. The Tijeras Arroyo (above the confluence with the Arroyo del Coyote) drains about 210 km^2 (81 mi^2), while the Arroyo del Coyote (above the confluence with the Tijeras Arroyo) drains about 70 km^2 (27 mi^2) (USACE, 1979a). The upper reaches of the arroyos cut through mountainous terrain at an average slope of about 40 m/km (130 ft/mi). As the arroyos enter onto the alluvial fan, bed slope decreases to an average of about 30 m/km (100 ft/mi).

A "new" spring was recently rediscovered in the Arroyo del Coyote (SNL, 1991a). It was first described in Grant (1981) as being about 1.6 km (1 mi) up the arroyo, east of the Lovelace Road

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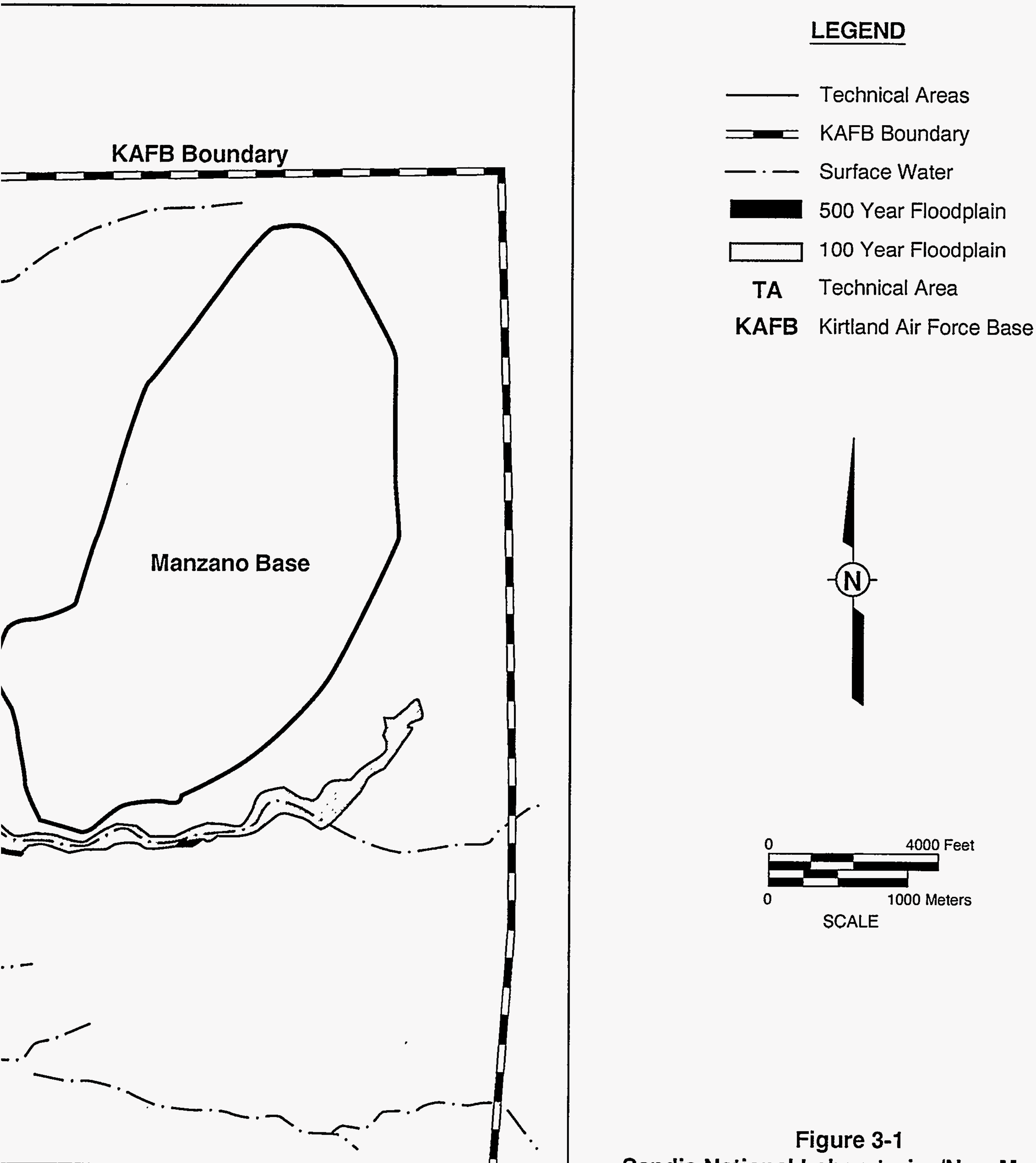
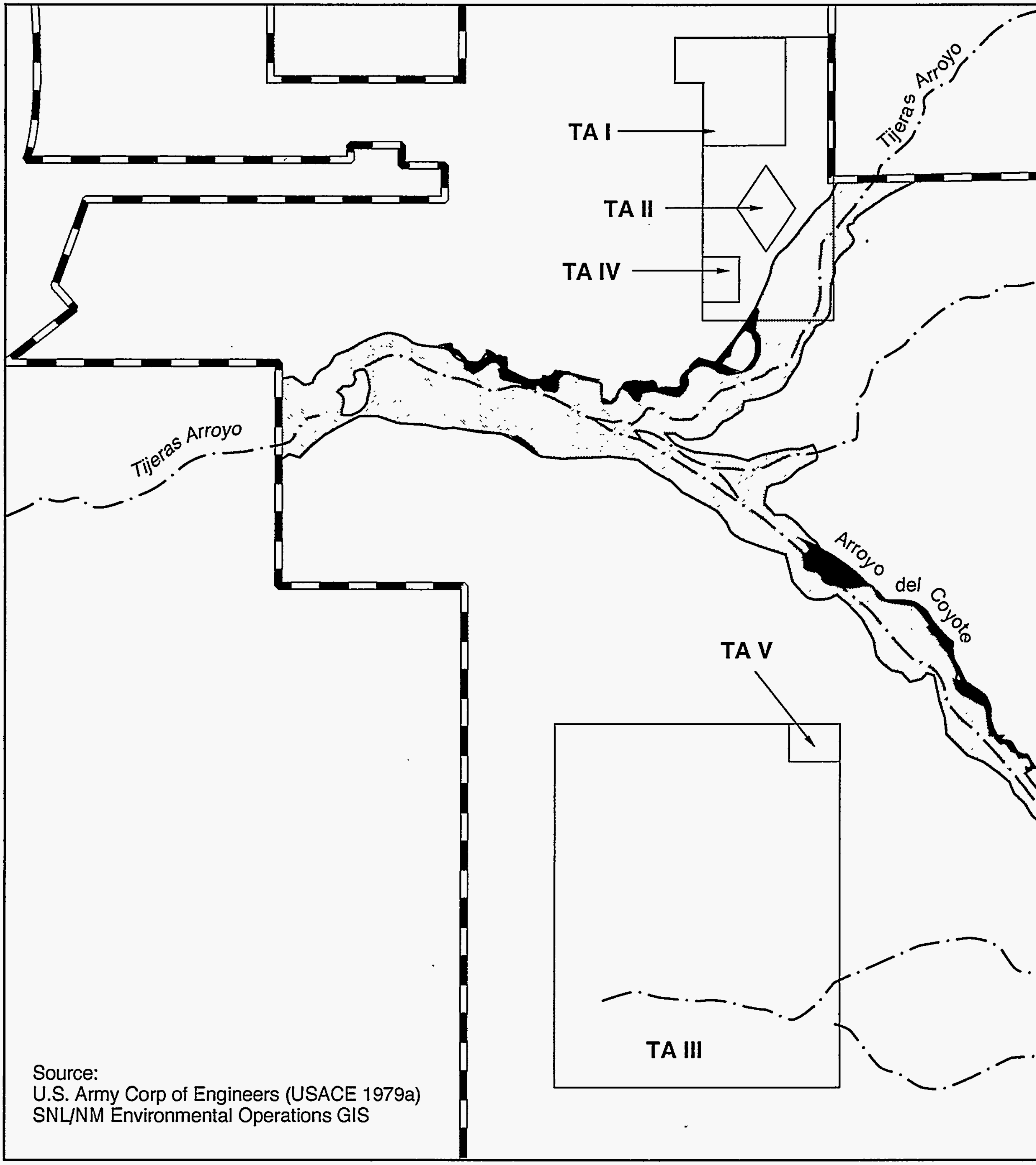


Figure 3-1
Sandia National Laboratories/New Mexico
Boundaries of
100-Year and 500-Year Floodplains



Source:
U.S. Army Corp of Engineers (USACE 1979a)
SNL/NM Environmental Operations GIS

bridge. The spring has been named "G Spring" (Figure 3-2). The spring's flow has cut a channel several centimeters deep that runs along the south side of the Arroyo del Coyote, then west for about 46 m (150 ft) until all flow infiltrates into the sand. The elevation of G Spring is about 1,719 m (5,640 ft) above sea level. This can be contrasted with Coyote Springs about 2.4 km (1.5 mi) further east that has an elevation of about 1,786 m (5,860 ft) above sea level, a difference of about 67 m (220 ft). Several smaller seeps were discovered about 400 m (1,320 ft) further upstream. These seeps formed small pockets of standing water and did not flow beyond the source (SNL, 1991a).

3.1.1 Flooding

Most of the floods in the Albuquerque area occur between May and October, during high-intensity thunderstorms (USACE, 1979b). About two-thirds of the annual 20-centimeters (cm) (8-inch [in]) rainfall occurs during this period; July and August account for almost one-third of the annual total. Floods in the Tijeras Arroyo and the Arroyo del Coyote are characterized by high peak flows, small volumes, and short durations. Obstructions, natural and man-made, within floodways impede flood flows, creating backwater and increased water heights. Natural obstructions to flood flows occur in the arroyos where vegetation has encroached into the channel areas. Tumbleweed and other plant debris that collect at culvert entrances and bridges create a potential obstruction to flood flows. Past experience in the Albuquerque area indicates culverts have a serious clogging tendency because of sediment.

The USACE (USACE, 1979a) provides information on the areas within the KAFB that are subject to flooding from the Tijeras Arroyo and the Arroyo del Coyote. The 100-year and 500-year floodplains are shown in Figure 3-1. The probability of a flood of a given magnitude being equaled or exceeded in any year is discussed. As shown in Figure 3-1, all SNL/NM facilities are located outside the 500-year floodplain of both arroyos. However, debris and boulder deposits in the Arroyo del Coyote suggest that a large volume of water was discharged down the arroyo in the not-too-distant past (SNL, 1991a). McCann and Boissennade (1988) assessed the flood potential at SNL/NM and found that SNL/NM facilities are not threatened by flooding.

3.1.2 Surface-Water Monitoring

SNL/NM has maintained an environmental radiological monitoring program in place since February 1959 (Hwang et al., 1991). The objectives of this surveillance program are to detect

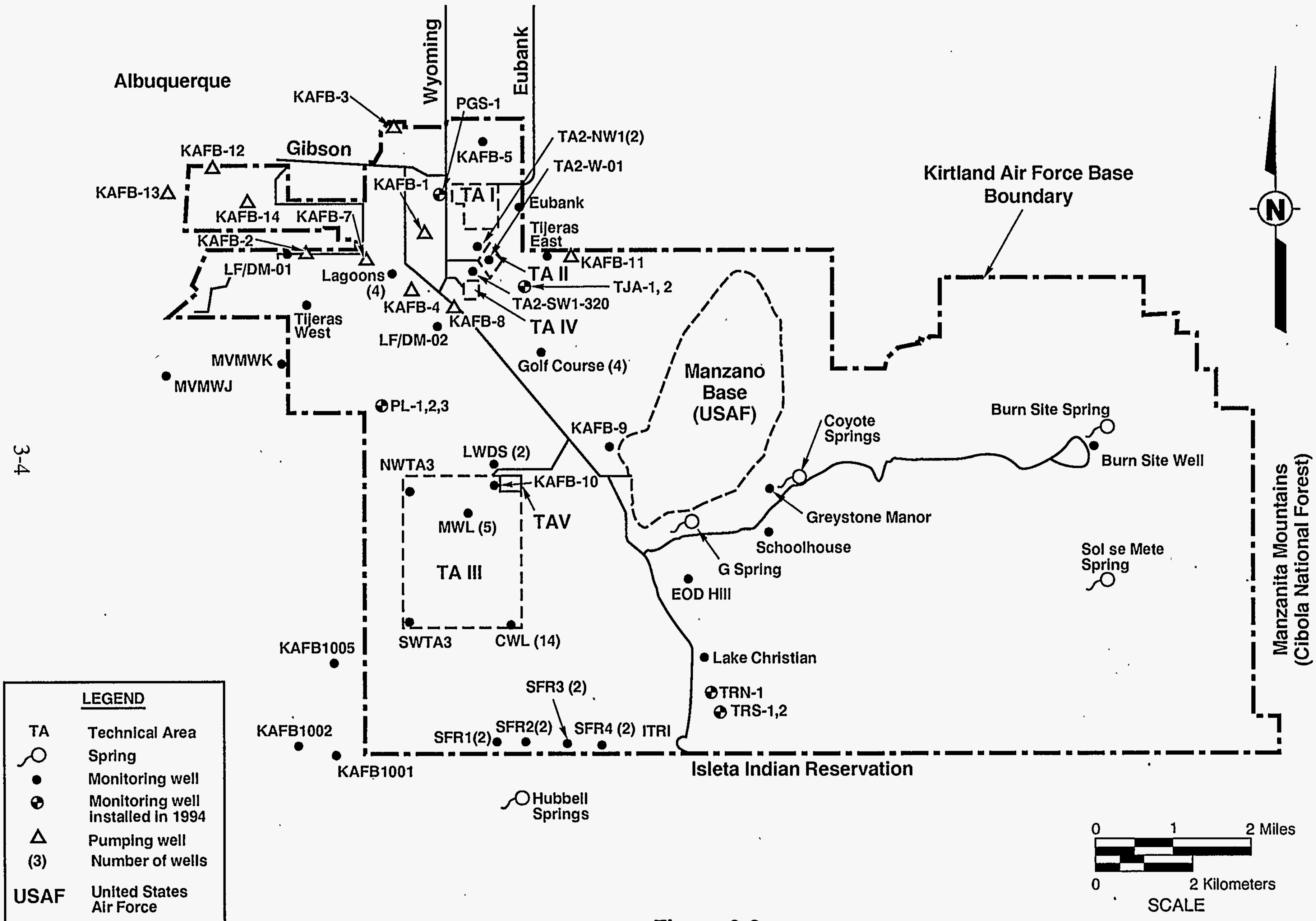


Figure 3-2
Location Map of Sandia National Laboratories/New Mexico and Kirtland Air Force Base Wells and Springs

any potential releases and/or migration of radioactive material from SNL/NM operations and to determine the resulting population exposures above normal background radiation levels. The radiological monitoring program also provides a check on the effectiveness of reactor radiological safety systems that are in effect at Technical Area V. Soil, vegetation, and water are monitored for radionuclides, primarily cesium-137 and tritium. Gross alpha and beta screening analysis is performed on water samples. Monitoring locations, frequencies, and sample types for SNL/NM and the Albuquerque area are provided in Hwang et al. (1991).

SNL/NM has nonradiological surface-water monitoring programs in place for wastewater, stormwater, and surface discharge (Hwang et al., 1991). SNL/NM performs scheduled periodic monitoring of its wastewater discharges to Albuquerque's publicly owned treatment works, as required by the EPA and City of Albuquerque (Hwang et al., 1991). Results of radiological sampling are contained in the Wastewater Monitoring Program Quarterly and Semiannual Reports for 1994 (IT, 1994, 1995). Stormwater and nonstormwater discharge sampling at SNL/NM has been conducted for completion of a National Pollutant Discharge Elimination System (NPDES) permit application under 40 CFR Parts 122, 123, and 124. Semiannual sampling will be conducted in the interim until the NPDES permit is issued by the EPA. There has also been some limited collection of surface-water quality data (McCord et al., 1993) by the USGS as part of the U.S. Air Force (USAF) IRP along the Tijeras Arroyo and by Riddle and Grant (1981) at selected springs.

3.1.3 USGS Surface-Water Stations

The USGS has measured surface-water discharges at ten gauging sites in and near the Tijeras Arroyo and the Arroyo del Coyote (Borland, 1991; Cruz et al., 1994; Thomas, 1995). Water quality assessments showed that most volatile organic compounds (VOCs) were not above the laboratory detection level in Tijeras Arroyo samples, with the exception of trichloroethylene and 1,2-transdichloroethylene. The dissolved-solid concentrations exceeded the U.S. Environmental Protection Agency (EPA) drinking-water standard of 500 milligrams per liter at Tijeras Arroyo (Thomas, 1995). Locations of gauging stations and dates for various record periods are shown in Table 3-1.

3.2 Vadose Zone Hydrology

The vadose (or unsaturated) zone is the region located between the land surface and the groundwater system (the saturated zone). The water table, defined as the surface on which the

Table 3-1

Sandia National Laboratories/New Mexico and Kirtland Air Force Base Surface Water Monitoring Stations

Site	Period of Record	WATSTORE No.[a]
1. Tijeras Arroyo at Albuquerque Crest stages only	1943-1949 1958-1990	08330500
2. Tijeras Arroyo at Albuquerque (Above Four Hills Bridge)[b]	1989-1991	08330505
3. Tijeras Arroyo at KAFB[b]	1987-1988	08330560
4. Tijeras Arroyo at Montessa Park[c]	1987-1993	08330580
5. Tijeras Arroyo near Albuquerque[c] Crest stages only	1974-1993 1951-1968	08330600
6. Tijeras Arroyo[c] (Below Arroyo Del Coyote)	1989-1993	08330569
7. Tijeras Arroyo (Below South Diversion)[b]	1980-1988	08330800
8. South Diversion Channel (Above Tijeras Arroyo)[c]	1988-1993	08330775
9. Arroyo del Coyote at KAFB	1989-1993	08330565
10. Arroyo del Coyote (Above Tijeras Arroyo)	1989-1993	08330567

KAFB = Kirtland Air Force Base.

[a]The National Water-Data Storage and Retrieval System (WATSTORE) is operated and maintained by the USGS at its National Center in Reston, Virginia. Address inquiries to:

Chief Hydrologist
U.S. Geological Survey MS 437
National Center
Reston, Virginia 22092

[b]Gauging station is not currently operational.

[c]Discharge data for water, 10/92 to 9/93, are published in: Cruz, R. R. et al., 1994, "Water Resources

Source: Data New Mexico Water Year 1993," *NM-93-1*, U.S. Geological Survey Water-Data Report.

fluid pressure in the pores is exactly atmospheric, is commonly defined as the boundary between the vadose zone and saturated zone (Freeze and Cherry, 1979). The vadose zone provides the link between the surface-water hydrology (which deals with surficial processes such as precipitation, snow melt, run-off, infiltration, overland flow, and evapotranspiration) and groundwater hydrology, which is concerned with the flow and transport processes in aquifer systems (Gee and Hillel, 1988).

The vadose zone is an important part of the hydrologic system in the SNL/NM-KAFB area. In this semiarid climate, the vadose zone thickness is generally quite large, from 15 m (50 ft) to greater than 152 m (500 ft). The depth to groundwater east of the Tijeras/Hubbell Spring/Sandia fault complex is shallower than the groundwater west of the faults. The regional groundwater recharge rate, which controls the upper boundary condition of the saturated zone, is also affected by vadose zone characteristics. Regional recharge is generally toward the Rio Grande to the west of SNL/NM.

However, where the water table is deep and the layers above it are very heterogeneous, flow through the vadose zone can be very difficult to define (Gee and Hillel, 1988). Part of the difficulties arise due to technological limitations in measuring vadose zone properties. Another problem is the incomplete understanding of vadose zone flow and transport processes, especially in areas with thick vadose zones. The influence of hydraulic property variability on unsaturated flow and transport, multiphase flow and transport, preferential flow and transport due to macropore flow (e.g., large pores from cracks and root channels) and unstable flow (i.e., fingering), advective and diffusive flow of soil gas, and prediction of groundwater recharge in arid and semiarid climates are topics of current vadose zone research described by Gee et al. (1991).

3.2.1 Vadose Zone Hydrogeologic Framework

Important flow and transport processes in the vadose zone are highly interconnected with and dependent on many other facets of the hydrogeologic picture, such as climate, geomorphology, vegetation, geology, and the location of the saturated zone. In general, in the SNL/NM-KAFB area, water enters the hydrologic system from rainfall and channel losses from flow in arroyos and leaves the system as evapotranspiration to the atmosphere and recharge into the underlying aquifer. The following discussion briefly describes the interrelated hydrogeologic features important to the vadose zone in terms of their effect on the current conceptual model for flow and transport through the vadose zone in the SNL/NM-KAFB area.

The SNL/NM-KAFB area has a semiarid climate characterized by low precipitation; wide temperature extremes; frequent drying winds; some heavy rain showers, usually of short duration, often with erosive effects; and an erratic, seasonal distribution of precipitation Chapter 4.0). The average precipitation typically increases with elevation; thus, the distribution of precipitation varies in an increasing fashion from the west to the eastern portion of the area. This climate implies low recharge rates to the groundwater system from areal infiltration due to the low precipitation and high evapotranspiration conditions. Whether any areal infiltration (and consequent downward transport of contaminants to the water table) occurs through the geologic media between major arroyos is presently unknown. Recharge studies conducted on open rangeland at the Sevilleta National Wildlife Refuge south of Albuquerque indicate modern deep drainage rates ranging from millimeters to a couple of centimeters per year (Stephens and Knowlton, 1986; McCord and Stephens, 1987; Phillips et al., 1988), and recent observations at the Walnut Gulch Experimental Watershed in southeast Arizona showed significant moisture pulses moving below the presumed root zone (USDA, 1992). However, recent environmental isotope studies in the nearby Santa Fe Basin suggest "negligible" recharge (USGS, 1992). Even a small interchannel areal recharge, integrated over a large area, can contribute a significant volume of water to the sitewide water balance.

There are no continuously running streams in the SNL/NM-KAFB area, although there is a system of arroyos that flow ephemerally, primarily during or after large thunderstorm events. In this vicinity, the Tijeras Arroyo and the Arroyo del Coyote are probably the largest localized recharge sources (USGS, 1992). The magnitude of arroyo flow loss due to evapotranspiration and infiltration into the vadose zone (causing possible recharge to the groundwater system) is unknown.

The major vegetation types in the SNL/NM-KAFB area also tend to vary with elevation, slope, and aspect. Generally, woodlands are found in the eastern portion of the area in the Manzanita Mountains and canyons, whereas grasslands cover the western portion of the area on the lower elevations. The land-surface percent slope in the SNL/NM-KAFB area varies from less than 1 percent to greater than 46 percent. Most mountain ridges trend to the northwest-southeast; therefore, many of the steep slopes face either southeast or northwest. Vegetation characteristics and slope affect the surface runoff and potential infiltration rates. Steep slopes facing the southeast receive more sunshine for longer periods of time than those facing northwest, possibly causing different evapotranspiration rates to occur on southeast-versus northwest-facing slopes.

Currently surface runoff characteristics and evapotranspiration rates in the area are not well understood. (See Chapter 5.0 for a discussion of vegetation types at SNL/NM-KAFB.)

Soils in the SNL/NM-KAFB area are dominated by well-drained loamy soils, with gravelly and stony soils along the arroyos and on the mountains. The U.S. Department of Agriculture (USDA) Soil Conservation Service (1977) has designated the permeabilities and available water capacities of the soils in the area based on the mapped soil textures. Permeabilities are mainly moderately slow to moderately rapid (0.5 to 15 cm/hour [hr] [0.2 to 6 in/hr]) in the area, whereas the canyon bottoms and the Tijeras Arroyo floodplains exhibit rapid (15 to 51 cm/hr [6 to 20 in/hr]) permeabilities. Available water capacity is inversely correlated with the permeabilities (i.e., high-water capacity corresponds with low permeability, as in a clayey soil). Infiltration is more likely to occur in areas with high permeabilities than in areas with low permeabilities where there is greater surface run-off potential. Where no permeability data exist, regions are classified as rock outcrop that might have very low matrix permeabilities. If the rock outcrops are fractured, the fracture-flow permeabilities might be very high, creating zones at high elevations (that correspond with the highest annual precipitation) at which large infiltration into the system could occur. The actual surface and subsurface conditions of the rock outcrop areas are unknown.

The vadose zone generally consists of unconsolidated valley fill deposits. The valley fill consists of unconsolidated and semiconsolidated sands, gravels, silts, and clays of the Santa Fe Group. On the west side of the SNL/NM-KAFB area, the valley fill is composed of highly heterogeneous alluvial fan, fluvial, and aeolian deposits. Farther west of SNL/NM facilities, the distal alluvial fan materials interfinger with generally finer Rio Grande sediments. In the eastern portion of the SNL/NM-KAFB area, there might be areas where the vadose zone is composed of bedrock materials (e.g., Precambrian, Pennsylvanian, or Permian formations) of relatively low permeability, but it might be highly fractured.

3.2.2 Previous Studies

Investigations conducted prior to 1994 are summarized in the 1993 Sitewide Hydrogeologic Characterization Annual Report (McCord et al., 1994). A summary of important saturated flow parameters and processes measured within the study area are presented in Table 4.2.2 of that report.

Four studies relevant to the SNL/NM Environmental Restoration Project were undertaken in calendar year 1993:

- An instantaneous profile (IP) test was implemented at the Mixed Waste Landfill (MWL) (SNL/NM, 1993). One of the objectives of the IP test was to determine soil hydraulic characteristics. Soil moisture content, saturated hydraulic conductivity, matrix flow potential, sorptivity, and the unsaturated hydraulic conductivity versus pressure head relationship were determined.

- A risk-based analysis of aqueous phase solute transport through the vadose zone under ambient fluxes was conducted (McCord et al., 1994).

- The impacts of geological heterogeneity on environmental tracer movement and the effects on recharge estimates were investigated (McCord et al., 1994).

- The use of environmental tracers to estimate aqueous phase diffusion and dispersion parameters was examined (McCord et al., 1994).

Specific vadose zone studies were conducted in calendar year 1994. These studies included determining vadose zone hydraulic and transport characteristics by initiating a series of induced infiltration studies. Vadose zone dispersion under natural conditions, as well as natural recharge studies, were also determined by performing environmental tracer experiments (McCord, 1995).

3.3 Groundwater Hydrology

The following subsections describe the groundwater utilization, the groundwater hydrology, and the groundwater monitoring program at SNL/NM.

3.3.1 Historical and Predicted Groundwater Utilization

Albuquerque obtains all of its drinking water from groundwater. Economic growth in the past 30 years and consequent increased pumping from KAFB and the city's deep municipal supply wells have significantly altered the saturated groundwater flow direction in the vicinity of SNL/NM (SNL, 1991a). The KAFB and nearby Albuquerque production wells greatly affect the groundwater level in the SNL/NM area, creating a lower groundwater surface elevation in the northern region. Over 1.6 billion gallons of water are pumped from the KAFB production wells annually (DOE, 1996). It is possible that the KAFB production well pumping is the cause of water-level fluctuations observed in some of the SNL/NM and KAFB monitoring wells. Pumping rates at KAFB production wells and hydrographs of water levels in all SNL/NM and KAFB monitoring wells are reported in the annual reports for the SNL/NM groundwater monitoring program (e.g., SNL/NM, 1992a). Water table levels were lower during the summer of 1983 than water levels measured in the spring of 1981 (Kues, 1986). In 11 out of 12 wells, the water levels were between 1 and 3 m (3 and 10 ft) lower in 1983 than in 1981 (Hudson, 1982).

By the year 2000, the water table is expected to undergo considerable decline east of the Rio Grande (USACE, 1979b). The greatest declines have occurred in the southeast portion of the Albuquerque greater urban area, where water levels have declined as much as 43 m (140 ft) since 1960, and possibly as much as 49 m (160 ft) below the original predevelopment level (Thorn et al., 1993). Continued monitoring of the well network, combined with statistical comparisons between KAFB pumping rates and SNL/NM monitoring well water levels, may help resolve the question of whether the observed fluctuations in water levels are predominately due to withdrawal from KAFB production wells, seasonal fluctuations, or "barometric fluctuations" (SNL, 1991a).

3.3.2 Saturated Zone Hydrogeology

The semiconfined groundwater system that underlies the SNL/NM-KAFB area is a part of the major basin aquifer in central New Mexico that supplies water to City of Albuquerque and the metropolitan area. The significance of groundwater to the people of this arid environment and its future availability and conservation has prompted an intensive investigation of the groundwater system by the USGS, New Mexico Bureau of Mines and Mineral Resources and the City of Albuquerque. Understanding the physical setting and the dynamics of the system is an important aspect in the wise management of the groundwater resource as well as an essential component in its protection from contamination.

3.3.2.1 Regional Setting

The SNL/NM-KAFB area is located in the eastern portion of a major groundwater system termed the Albuquerque Basin. The Albuquerque metropolitan area, including KAFB and SNL/NM, relies on the groundwater in this basin as the principal source of its water supply. The basin is part of a series of large basins extending from southern Colorado to the border with Mexico at El Paso. These basins are associated with south-trending structural features of the Rio Grande Rift system. This regional stretching of the earth's crust and the associated uplift and subsidence of crustal blocks over the past 25 million years (Hawley and Haase, 1992) has resulted in a series of grabens bounded by listric faults. These major depressions have filled over time with sediments of sand, gravel, and silt eroded from the surrounding uplifted areas, including the Colorado Plateau. The Rio Grande flows southward through most of these basins from its headwaters in the San Juan Mountains near the San Luis Basin in southern Colorado to the Hueco Bolsons of southern New Mexico and the Mexican state of Chihuahua (Hawley and Haase, 1992).

The Albuquerque Basin, located in central New Mexico, covers approximately 5,440 km^2 (2,100 mi^2). It is approximately 145 km (90 mi) long and ranges in width from 16 km (10 mi) in the north to almost 64 km (40 mi) near the center. The vertical thickness of the sediments exceeds 4,267 m (14,000 ft) in some areas (Hawley and Haase, 1992). The eastern boundary of the basin is a series of faults running parallel to the fronts of the Sandia, Manzanita, Manzano, and Los Pinos Mountains. The western edge is defined by faults that extend south-southeast from near the Jemez Caldera to the Ladron Mountains near Socorro (Thorn et al., 1993). The northern extent is defined by Hawley and Haase (1992) at the San Felipe Fault belt near Algodones. To the south the basin is bounded by the Joyita Uplift near Socorro.

The hydrostratigraphy of the basin fill is divided into the Lower, Middle, and Upper Santa Fe Group. The most productive fresh water aquifers in the basin are located within the Upper Santa Fe Group and to a limited extent in the middle unit of the Santa Fe Group. The deposition of the upper unit and its characteristic sedimentary structure are associated with the evolution of the basin from an internally drained, closed basin (conditions exemplified by sediments comprising the Middle unit) to one drained by the through-flowing Rio Grande. This significant alteration of the hydrology of the basin began approximately 5 million years ago (Hawley and Haase, 1992) and resulted in the aggradation of the Upper Santa Fe sediment sequence. These sediments attain depths of up to 457 m (1,500 ft) locally. The sedimentary structure is characterized by intertonguing piedmont-slope and fluvial valley-floor deposits. The alluvial and debris flow materials characteristic of piedmont slopes consist of poorly sorted, weakly stratified sand and conglomerate with a silt-clay matrix. The fluvial deposits include cross-stratified channel deposits characterized by thick zones of clean sand and well rounded gravel as well as fine- to medium-grained overbank sediments. Major basin aggradation ceased about 1 million years ago and post Santa Fe deposition is the result of a series of episodes of river incisions and partial backfilling. The most recent surficial sediments include fan, eolian, and floodplain deposits including some volcanics (Hawley and Haase, 1992).

Over the last 10,000 to 15,000 years the excess inflow of sediments from tributaries of the Rio Grande has resulted in aggradation of the central valley. This valley fill is as much as 61 m (200 ft) thick and functions as a shallow aquifer. In much of the inner valley, layers of clay up to 4.5 m (15 ft) in thickness within the alluvium disconnect the alluvial aquifer from the underlying

Santa Fe Group. North of Interstate 40, the clay layer is near the surface. The Rio Grande has downcut through the layer and has reestablished a hydraulic connection with the regional aquifer. South of Interstate 40 the clay layer occurs at greater depth, and the river remains isolated from the main aquifer (Thorn et al., 1993). This low permeability layer limits potential recharge from the river and other surface water sources.

Most of the City of Albuquerque's wells are completed in the Upper Santa Fe Group with some extending into the Middle Santa Fe. The processes and sediment sources that resulted in the deposition of the upper unit of the Santa Fe Group provide more suitable aquifer material and structure (interbedded sands and gravels) than do the lower units that are made up of basin-floor playa lake deposits (silts and clays) (Thorn et al., 1993). The most productive wells are located east of the present course of the Rio Grande and west of the most eastern excursions of the ancestral river channel. The lithologic characteristics of these axial channel deposits and to a lesser extent the materials of the pediment slope and alluvial fans provides the best aquifer material of the basin sediments. Conductivity values as high as 40 m (130 ft) per day have been determined through City of Albuquerque production well tests (i.e., Leyendecker 1) in this portion of the basin. In contrast, wells tested in the western portion of the basin may attain maximum values of conductivity no greater than 7.5 m (25 ft) per day (Thorn et al., 1993).

The water table slopes at a low gradient diagonally down-valley from the foothills of the Sandia and Manzano Mountains on the east and from the Rio Puerco on the west. The low point of the water table is located in a groundwater trough that trends southward approximately 12.8 km (8 mi) west of the course of the Rio Grande. The water table in the trough is reported to be 9 to 12 m (30 to 40 ft) lower than the water table under the river (Thorn et al., 1993). Local cones of depression associated with the large amount of groundwater pumping at the city's well fields has altered the direction of groundwater flow in the areas of influence of these fields. Pumping in excess of recharge has led to significant declines of the regional water table. This lowering is not uniform and is most pronounced along the eastern edge of the basin where the cones of depression of the wells in this area are bounded by the West Sandia Fault. Water level declines of 43 m (140 ft) since 1960 have been measured (Thorn et al., 1993). The fault juxtaposes lower permeability sediments east of the fault with the highly permeable sediments associated with the fluvial deposits of the eastern excursion of the ancestral Rio Grande. Similarly, drawdowns on the western margin of the basin are on the order of 6 m (20 ft) for wells near the Isleta Fault.

3.3.2.2 SNL/NM-KAFB Saturated Zone Setting

The fault system that forms the eastern boundary of the Albuquerque Basin bisects the area occupied by SNL/NM-KAFB. The north-south striking Sandia Fault enters the base from the north. Almost colinearly, the Hubbell Springs Fault extends from the south, and the Tijeras Fault cuts the base diagonally from the northeast. The topography is characterized by a series of coalescing alluvial fans of Holocene age that extend from the base of the mountains to the east to terraces along the river. East of the Hubbell Springs and Sandia Faults, the fan deposits rest on eroded pediment slopes (Thorn et al., 1993), Paleozoic and Precambrian rocks outcrop at various locations east of the faults. The north-south trending fault complex divides the groundwater system into three distinct hydrogeologic regions (Figure 3-3). The region west of the fault complex is identified as Hydrogeologic Region I (HR1). Hydrogeologic Region II (HR2) is associated with the fault complex, and Hydrogeologic Region III (HR3) is located east of the fault complex (McCord et al., 1993; Holdren et al., 1995). Descriptions of each region are included in Chapter 4.0 of McCord et al. (1994).

The faults of HR2 divide the regional water table into a deep zone west of the fault complex and a much shallower zone on the east side. The depth to saturated water bearing zones underlying SNL/NM facilities varies from 15 to 30 m (50 to 100 ft) east of the faults and from 115 to 150 m (377 to 492 ft) west of the faults (SNL, 1991a). Most SNL/NM facilities are located west of the fault system in the area of deeper groundwater. At KAFB and vicinity, the transmissivity of the aquifer is estimated at about 0.015 square meters/second (s) (0.16 square feet/s) (SAIC, 1985).

The apparent direction of groundwater flow west of the fault complex, is generally to the west and northwest (McCord et al., 1994) (Figure 3-3). Groundwater has been reported to generally move from north to south in the shallow zone (above 1,463 m or 4,800 ft), while deep-zone groundwater (below 1,463 m or 4,800 ft) moves from the northwest to the east and southeast (Kues, 1986). The direction of groundwater flow reported by Bjorklund and Maxwell (1961) is southwesterly. These differences are attributed to the influence of KAFB and nearby Albuquerque production wells (McCord et al., 1994).

The subsurface reservoir is recharged primarily from the Rio Grande and, to a lesser degree, through coarse alluvium at the openings of small canyons at the foot of the mountains (Kues, 1986). Recharge is nearly nonexistent from percolation through soils overlying the water table. Moisture in the form of rain or snowmelt flows into small channels that feed the Tijeras Arroyo and the Rio Grande, evaporates or is transpired by the local vegetation. The significance of the

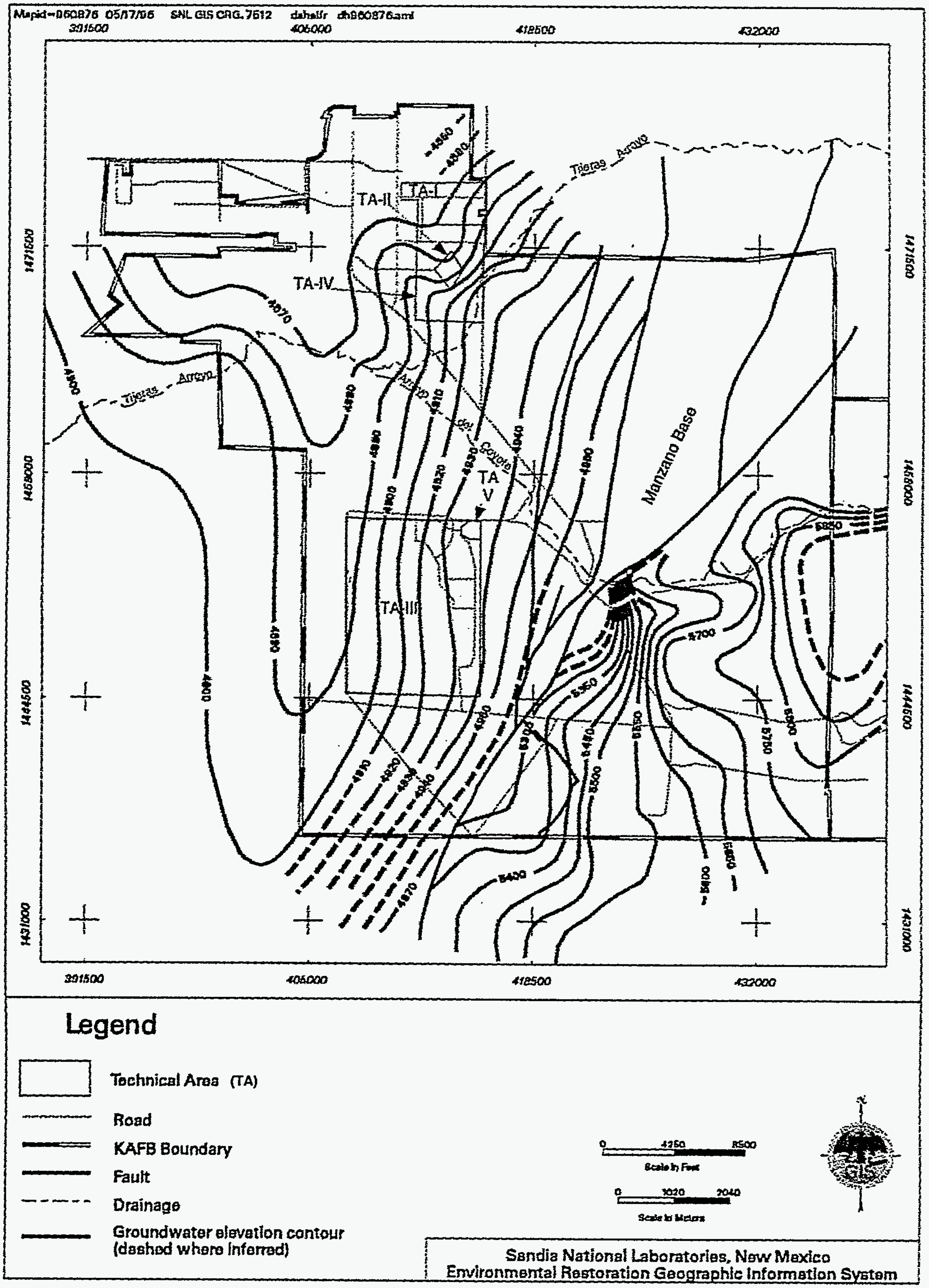


Figure 3-3
Groundwater Elevations Across Kirtland Air Force Base

Tijeras Arroyo as a source of recharge to the shallow groundwater zone remains undetermined (Kues, 1986).

3.3.2.3 Groundwater Monitoring Well Network

Prior to 1990, 11 groundwater monitoring wells were being monitored monthly for water levels. These wells included nine wells at the chemical waste landfill (CWL), one well at the MWL, and well KAFB-10 (Technical Area III). In December 1990, SNL/NM began monitoring 12 additional wells belonging to KAFB: four in the Tijeras Arroyo, four at the KAFB golf course, and four at the KAFB sanitary lagoons. These wells, along with the eleven monitoring wells SNL/NM completed in 1992 and 1993, brought the total to at least 54 wells by the end of 1993. A complete description of the physical characteristics of the wells (e.g., total depth, screened interval, casing material, filter pack material, geographic coordinates, etc.) is reported in SNL/NM (1992b) and SNL/NM (1994a) and McCord et al. (1994). Twelve more monitoring wells were installed in 1994, four of which are located at the CWL. Completion details of the new wells are reported in Appendix H of the 1994 Sitewide Hydrogeologic Characterization report (McCord et al., 1995).

The groundwater monitoring program at the CWL has been operational since 1985. The monitoring well system at the CWL consists of a network of 14 wells. Five of the wells (MW-1, MW-2, MW-3, BW-1, and BW-2) were installed at the CWL in 1985. These wells were completed at various vertical depths within the aquifer, with screened intervals ranging from 21 to 140 m (70 to 460 ft) in length. By June 1990, five additional wells (BW-3, MW-1A, MW-2A, MW-3A, and MW-4) were installed at the CWL. They have 6-m (20-ft) screened intervals located such that about 4.6 m (15 ft) of screen is below the water table. (In July 1988, MW-1 became plugged by a bailer and has not been monitored since, but is being maintained as a vapor sampling point.) Four additional monitoring wells (MW-2B, MW-4A, MW-5, and MW-6) were installed in 1994 (McCord et al., 1995).

A monitoring well network was established at the MWL in 1988, when MW-1 was installed. Three additional wells (MW-2, MW-3, and BW-1) were installed between June and September 1989. These wells have 6-m (20-ft) screened intervals located from 1.5 m (5 ft) above the water table to 4.6 m (15 ft) below the water table. An additional well (MW-4) was installed in 1992, using directional drilling methods, beneath the MWL and is screened in two different intervals (SNL/NM, 1994b). The general location of the monitoring well network is shown in Figure 3-2.

3.3.3 Groundwater Quality Monitoring

Background conditions of the groundwater quality at the CWL were determined for all of the current monitoring wells. Background values of the 40 CFR Part 265, Appendix III, drinking water supply parameters, contamination indicator parameters, and groundwater quality parameters were collected quarterly for a period of one year (December 1988 to January 1990). Each quarter, four replicate samples were collected for the indicator parameter (pH, specific conductance, total organic carbon [TOC], and total organic halogen [TOX]), and the initial background arithmetic mean and variance were determined by pooling the replicate measurements for the respective parameter concentrations or values in samples obtained from the upgradient well as required by 40 CFR §265.92(c)(2) (SNL/NM, 1992b).

The first semiannual contamination indicator sampling at the CWL was performed in March 1990. Groundwater monitoring parameters (40 CFR Part 264, Appendix IX) were also measured in anticipation of closure requirements (IT, 1990). A change from detection monitoring to assessment monitoring was required following the discovery of trichloroethene contamination in well MW-2A.

Annual sampling for assessment monitoring at the CWL occurred in February 1994; quarterly sampling took place in May, August, and October 1994. These sampling events were conducted in accordance with the "Sampling and Analysis Plan for Groundwater Monitoring at the Chemical Waste Landfill, Revision 4" (Appendix G of the CWL closure plan [SNL/NM, 1992b]), which includes annual sampling for all Appendix IX parameters and quarterly sampling for Appendix IX VOC and total metals. A summary of compounds detected at the CWL in 1994 is provided in SNL/NM (1995b).

In February 1993, the CWL final closure plan and postclosure permit application (SNL/NM, 1992b) were approved by all concerned parties. The current groundwater monitoring requirements for this site are discussed in detail in Chapters 2.0 and 7.0 of the closure plan (SNL/NM, 1992b). The sampling and analysis plan is provided in Appendix G of the closure plan.

Semiannual sampling for background groundwater quality monitoring at the MWL was performed in April and October 1994. These sampling events were conducted in accordance with the draft "Mixed Waste Landfill Groundwater Sampling and Analysis Plan" (SNL, 1990). Background monitoring parameters include Appendix III drinking-water supply parameters (metals, pesticides, herbicides, nitrate, coliform bacteria, alpha activity, beta activity, and radium), groundwater quality parameters (chlorine, iron, manganese, sodium, sulfate, and phenols) and groundwater contamination parameters (pH, specific conductance, TOX, and TOC). Analyses for metals included both a filtered fraction (<0.45 micrometers [μ]) for dissolved metals and an unfiltered fraction for total metals. Summaries of values for assessment parameters for 1994 are included in SNL/NM (1995a).

SNL/NM also initiated a large-scale groundwater sampling and analysis program in 1991 (SNL/NM, 1992a). That effort was initiated with a program to sample monitoring wells across SNL/NM and KAFB for background hydrogeochemical parameters. The objective of the program was to determine if regional trends in groundwater chemistry exist and if such trends are related to geologic structures or geographic location. The background hydrogeochemical data from the study will also provide KAFB-regional data that may be relevant to estimations of potential contaminant transport rates from hazardous waste sites. Samples were collected from 16 wells and four natural springs on KAFB and Isleta Pueblo in April, July, and October 1991; another series of samples were collected in January 1992. All samples were analyzed for magnesium, calcium, potassium, sodium, iron, fluorine, chlorine, bromine, nitrous oxides, alkalinity, pH, and temperature. Results are listed in SNL/NM (1992a). KAFB pumping wells are not included in this sampling program.

3.3.4 USGS Monitoring Program

The USGS has also installed wells to monitor groundwater contamination, under the USAF IRP (Wilcox, 1991). Ten sites administered by the USAF at and near KAFB were investigated. Initial characterization of the sites in 1989 included analysis of more than 100 soil samples and full Resource Conservation and Recovery Act (RCRA) 40 CFR Part 264, Appendix IX analysis of water samples from the wells. (The first ten wells are distributed among three of the study sites.) Quarterly sampling and analysis, begun in August 1990, have been for indicators found during initial characterization (Wilcox, 1991): TOC, TOX, nitrates, and total dissolved chromium. The soil and water data, quarterly sampling data, and results of the first semiannual sampling (completed in late 1991) were in a draft report submitted by the USGS to the USAF in early 1992, titled "Installation Restoration Program Phase II-Stage 2 Remedial Investigation," prepared for the USAF Center for Environmental Excellence/Environmental Restoration Division, Brooks Air Force Base, Texas.

The USGS also installed 25 additional groundwater monitoring wells in 1991 and 1992 at the seven sites that did not have wells. These 25 monitoring wells were sampled once by the USGS in the springs of 1993. The USGS also made monthly water level measurements in these wells until the end of 1993. This program was Phase IIA of the IRP and a report entitled "RCRA Facility Investigation, Stage 2A for Kirtland Air Force Base" was submitted by the USGS in spring of 1993. The USGS is no longer monitoring groundwater levels or collecting water quality samples at KAFB (Wilcox, 1995).

4.0 Climate and Meteorology

SNL/NM is located near the boundary between a "mid-latitude semiarid" and a "tropical semiarid" climate (Holdren et al., 1995). Historically, SNL/NM has used weather information obtained from the Albuquerque International Airport (ABQ) to support its meteorological requirements. The airport weather station is located 6.4 km (4 mi) west of Technical Area I at an elevation of 1,619 m (5,311 ft) and is the National Oceanic Atmospheric Administration (NOAA) meteorological station closest to SNL/NM. The most current climatological and meteorological data from this station can be directly obtained through the NOAA National Climatic Data Center in Asheville, North Carolina.

A meteorological monitoring program was implemented at SNL/NM on January 3, 1994. The 1994 climate and meteorological data are summarized in the 1994 Site Environmental Report for SNL/NM (SNL/NM, 1995b). (For 1993, the only available meteorological data are from the ABQ recorded by the National Weather Service.)

These available climatological data are probably adequate to characterize the majority of the facilities at SNL/NM. They are not, however, believed to be representative of the remote testing areas such as the Coyote Test Field and Thunder Range sites, which are 10 km (6 mi) or more from the airport. The airport information is inadequate for emergency situations when real-time meteorological data are needed for calculating plume dispersion resulting from accidental releases of hazardous materials into the atmosphere (DOE, 1991). SNL/NM has recently installed on-site continuous ambient air monitoring stations. Tables 4-1 through 4-4 present climatological data (i.e., normals, means, and extremes) from the ABQ for a 30-year period from 1951 through 1980. Table 4-5 summarizes the 1994 meteorological data from Tower A36, the official 60-m (198-ft) meteorological tower at SNL/NM.

4.1 Temperature and Humidity

The climate in the Albuquerque area is characterized by low precipitation; wide temperature extremes; frequent, drying winds; some heavy rain showers, usually of short duration and often with erosive effects; and erratic, seasonal distribution of precipitation. The average annual temperature in Albuquerque is 14 degrees Celsius (°C) (57.5 degrees Fahrenheit [°F]), with an average diurnal temperature range of 15.5°C (28°F) (NOAA, 1993). The average daily

Table 4-1

Temperature Normals, Means, and Extremes for Albuquerque, New Mexico

	a	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
TEMPERATURE °F:														
Normals														
- Daily Maximum		47.2	52.9	60.7	70.6	79.9	90.6	92.8	89.4	83.0	71.7	57.2	48.0	70.3
- Daily Minimum		22.3	25.9	31.7	39.5	48.6	58.4	64.7	62.8	54.9	43.1	30.7	23.2	42.1
- Monthly		34.8	39.4	46.2	55.1	64.3	74.5	78.8	76.1	69.0	57.4	44.0	35.6	56.2
Extremes														
- Record Highest	51	69	76	85	89	98	105	105	101	100	91	77	72	105
- Year		1971	1986	1971	1989	1951	1980	1980	1979	1979	1979	1975	1958	Jun 1980
- Record Lowest	51	-17	-5	8	19	28	40	52	52	37	25	-7	-7	-17
- Year		1971	1951	1948	1980	1975	1980	1985	1968	1971	1980	1976	1990	Jan 1971
NORMAL DEGREE DAYS:														
Heating (base 65°F)		936	717	583	302	81	0	0	0	12	242	630	911	4414
Cooling (base 65°F)		0	0	0	0	59	285	428	344	132	6	0	0	1254
AVG. STATION PRESS. (mb)	18	838.9	837.8	835.1	835.8	836.0	838.1	840.4	840.7	840.1	840.0	838.8	839.1	838.4
RELATIVE HUMIDITY (%)														
Hour 05	30	70	65	56	49	48	46	60	66	62	62	65	70	60
Hour 11	30	51	44	34	26	25	24	34	40	40	38	42	50	37
Hour 17 (local time)	30	40	33	24	19	18	18	27	30	31	30	36	43	29
Hour 23	30	61	53	43	36	34	33	47	53	52	50	54	61	48

[a]Length of record in years, although individual months may be missing. Normals are based on the 30-year period of record 1951-1980. Extremes dates are the most recent occurrence. The data were collected at the Albuquerque International Airport, Latitude: 35° 03¢N Longitude: 106° 37¢W Elevation 5,311 ft (1619 m).

Notes: To convert °F to °C, subtract 32 and multiply by 5/9.

Unless otherwise indicated, dimensional units used in this table are: temperature in degrees Fahrenheit (°F), relative humidity in percent (%), and avg. station pressure in millibars (mb).

Heating degree day totals are the sums of negative departures of average daily temperatures from 65 °F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65 °F.

Source: National Oceanographic and Atmospheric Administration (NOAA), 1990, "Local Climatological Data, Annual Summary with Comparative Data," Albuquerque, New Mexico.

Table 4-2
Precipitation Normals for Albuquerque, New Mexico

	a	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
PRECIPITATION (inches):														
Water Equivalent														
- Normal		0.41	0.40	0.52	0.40	0.46	0.51	1.30	1.51	0.85	0.86	0.38	0.52	8.12
- Maximum Monthly	51	1.32	1.42	2.18	1.97	3.07	2.57	3.33	3.30	2.63	3.08	1.45	1.85	3.33
- Year		1978	1948	1973	1942	1941	1986	1968	1967	1988	1972	1940	1959	Jul 1968
- Minimum Monthly	51	T	T	T	T	T	T	0.08	T	T	0.00	0.00	0.00	0.00
- Year		1970	1984	1966	1989	1945	1975	1980	1962	1957	1952	1949	1981	Dec 1981
- Maximum in 24 hours.	51	0.87	0.51	1.11	1.66	1.14	1.64	1.77	1.75	1.92	1.80	0.76	1.35	1.92
- Year		1962	1981	1973	1969	1969	1952	1961	1980	1955	1969	1940	1958	Sep 1955
Snow, ice pellets														
- Maximum Monthly		9.5	10.3	13.9	8.1	1.0	T	T	0.0	T	3.2	9.3	14.7	14.7
- Year	51	1973	1986	1973	1973	1979	1990	1990		1971	1986	1940	1959	Dec 1959
- Maximum in 24 hrs.		5.1	6.0	10.7	10.9	1.0	T	T	0.0	T	3.2	5.5	14.2	14.2
- Year	51	1973	1986	1973	1988	1979	1990	1990		1971	1986	1946	1958	Dec 1958

T = Trace amount

Blank entries denote missing/unreported data.

[a] Length of record in years, although individual months may be missing. Normals are based on the 30-year period of record 1951-1980. Data were collected at the Albuquerque International Airport, Latitude: 35° 03'N; Longitude: 106° 37'W; Elevation: 5,311 ft (1,619 m).

Notes: To convert inches to centimeters, multiply by 2.54.

Unless otherwise indicated, dimensional units used in this table are: precipitation, including snowfall in inches.

The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice.

Source: National Oceanographic and Atmospheric Administration (NOAA), 1990, "Local Climatological Data, Annual Summary with Comparative Data," Albuquerque, New Mexico.

Table 4-3

Average Atmospheric Conditions for Albuquerque, New Mexico

	a	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
Percent Of Possible Sunshine	51	73	73	73	77	79	83	76	75	79	79	77	72	76
MEAN SKY COVER (tenths)														
Sunrise to Sunset	51	4.8	5.0	5.0	4.6	4.2	3.4	4.5	4.4	3.6	3.5	4.0	4.6	4.3
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
- Clear	51	13.0	11.2	11.4	12.6	14.4	17.6	12.0	13.5	16.7	17.3	15.2	14.0	168.8
- Partly Cloudy	51	7.7	7.6	9.8	9.5	10.3	8.6	14.3	12.4	7.8	7.7	7.6	7.5	110.9
- Cloudy	51	10.3	9.5	9.7	8.0	6.3	3.8	4.7	5.1	5.5	6.0	7.2	9.5	85.5
Precipitation														
.01 inches or more	51	4.0	4.0	4.6	3.4	4.4	3.9	8.8	9.5	5.7	4.8	3.4	4.2	60.6
Snow, ice pellets														
1.0 inches or more	51	1.0	1.0	0.7	0.2	0.*	0.0	0.0	0.0	0.0	0.*	0.4	0.9	4.2
Thunderstorms														
Heavy Fog Visibility	51	0.1	0.3	0.9	1.6	3.9	5.0	10.9	10.9	4.6	2.3	0.5	0.2	41.4
1/4 mile or less														
Temperature °F	51	1.1	1.0	0.6	0.2	0.*	0.*	0.1	0.*	0.1	0.4	0.6	1.5	5.6
- Maximum														
90° and above	30	0.0	0.0	0.0	0.0	2.6	17.2	23.2	15.9	3.9	0.1	0.0	0.0	62.9
32° and below	30	2.3	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.8	5.2
- Minimum														
32° and below	30	29.0	22.8	15.8	4.5	0.2	0.0	0.0	0.0	0.0	2.0	16.1	28.5	118.9
0° and below	30	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.6

[a]Length of record in years, although individual months may be missing, based on the 30-year period of record 1950-1980. The data were collected at the Albuquerque International Airport, Latitude: 35° 03′N Longitude: 106° 37′W Elevation: 5,311 ft (1,619 m).

0.* = The value is between 0.0 and 0.5.

Notes: To convert inches to centimeters, multiply by 2.54 cm/in.
To convert °F to °C, subtract 32 and multiply by 5/9.
Sky cover is expressed in a range of zero for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Source: National Oceanographic and Atmospheric Administration (NOAA), 1990, "Local Climatological Data, Annual Summary with Comparative Data," Albuquerque, New Mexico.

Table 4-4

Wind Speed and Prevailing Wind Direction for Albuquerque, New Mexico

	a	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
WIND:														
Mean Speed (mph)	51	8.1	8.9	10.1	11.0	10.6	10.0	9.1	8.3	8.6	8.3	7.9	7.7	9.0
Prevailing Direction through 1963		N	N	SE	S	S	S	SE	SE	SE	SE	N	N	SE
Fastest Obs. 1 Min.														
- Direction (!!)	6	09	09	28	17	28	08	36	27	25	09	27	09	09
- Speed (mph)	6	52	40	41	46	46	40	52	41	40	32	48	47	52
- Year		1990	1989	1986	1985	1986	1990	1990	1990	1985	1986	1988	1987	Jan 1990
Peak Gust														
- Direction (!!)	7	E	W	NW	E	S	E	N	E	W	NW	W	E	N
- Speed (mph)	7	70	63	66	64	61	67	72	63	61	51	63	71	72
- Date		1990	1984	1986	1990	1987	1986	1990	1989	1985	1986	1988	1987	Jul 1990

[a]Length of record in years, although months may be missing, based on the 30-year period of record 1951-1980. Wind direction numerals show tens of degrees clockwise from true north. Resultant directions are given to whole degrees. The data were collected at the Albuquerque International Airport, Latitude: 35° 03′N Longitude: 106° 37′W Elevation: 5,311 ft (1,619 m).

Notes: To convert mph to kph, multiply by 1.6 km/mi.

Unless otherwise indicated, dimensional units used in this table are: wind movement in miles per hour.

Figures instead of letters in a direction column indicate direction in tens of degrees from true north, i.e., 09-east; 19-south; 27-west; 36-north, and 00-calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "fastest mile" the corresponding speeds are the fastest observed 1-minute values.

!! = to 8 compass points only.

Source: National Oceanographic and Atmospheric Administration (NOAA), 1990, "Local Climatological Data, Annual Summary with Comparative Data," Albuquerque, New Mexico.

Table 4-5
Annual Summary Meteorological Information for SNL/NM, 1994

Month[a]	Average Temperature (C°)	Maximum Temperature (C°)	Minimum Temperature (C°)	Average RH (%)	Average Wind (m/s)	Maximum Wind (m/s)	Average Rain (cm)	Maximum 24-hour (cm)	Pressure (mb)
January	3.6	19.8	-10.0	36.1	3.4	22.1	0.03	0.03	839.8
February	4.6	19.3	-11.2	40.2	3.4	22.1	0.66	0.51	836.7
March	9.7	23.4	-4.4	43.2	4.0	25.3	1.55	0.43	835.8
April	13.5	27.8	-2.6	31.5	4.2	21.3	0.15	0.13	833.0
May (99.9)	18.6	33.1	7.2	37.4	4.4	25.3	7.21	1.65	832.6
June (98.3)	26.1	39.3	13.6	24.4	3.6	22.9	1.12	0.97	832.1
July (97.4)	25.7	36.6	15.6	32.7	4.1	26.9	2.46	0.94	833.4
August	24.6	35.5	15.0	46.8	3.4	27.7	11.56	3.48	835.3
September	20.6	30.5	8.4	46.0	3.1	18.1	3.43	1.32	836.7
October	13.3	28.1	1.6	46.7	3.7	24.5	4.39	1.45	835.0
November	6.7	21.3	-7.6	51.2	3.6	19.7	3.78	1.88	836.8
December	4.7	14.8	-6.9	56.1	2.7	15.7	2.08	1.07	839.4
Annual Averages	14.3			41.0	3.6		38.43		835.5
Annual Extremes		39.3	-11.2			27.7		3.48	

[a]Monthly data recovery is 100 percent except where noted in parentheses.

°C = Degree(s) Celsius
RH = Relative humidity
% = Percent
m/s = Meters per second
cm = Centimeter
mb = Millibars.

Source: SNL/NM, 1995a.

temperature range is relatively high, but extreme temperatures are rare. In Albuquerque the temperature reaches 32°C (90°F) an average of 63 days a year, with 90 percent of these days occurring from June through August. A new record high temperature of 41.7°C (107°F) was set at ABQ on June 26, 1994 (NOAA, 1994). Freezing temperatures occur an average of 118 days each year, 95 percent of these days occurring from November through March. Normally, less than one day a year does the temperature reach minus 18°C (0°F) and below (NOAA, 1993). The average frost-free season in Albuquerque is 190 days, from mid-April to late in October, and the average frost-free season in the mountains is about 120 days, from late in May to early October. The air is normally dry, with an average annual relative humidity of about 44 percent, ranging from nearly 60 percent in the early morning to approximately 29 percent in the afternoon (NOAA, 1993). Another feature of this climate is the large number of clear days and high percentage of sunshine. The average number of clear days per year is 169, with 76 percent sunshine possible for the year. The average number of days per year with fog (visibility less than 0.4 km [0.25 mi]) is only six (NOAA, 1993).

4.2 Precipitation

The valley and mesa areas are arid, having an average annual precipitation near 225 millimeters (mm) (8.8 in). The average annual precipitation in the mountains is considerably heavier, with 510 mm (20 in) (SNL, 1989). Precipitation amounts generally increase with increasing elevation. Half of the average annual precipitation occurs in the form of brief but heavy thunderstorms during the summer period, July through September. Summer moisture is supplied by the general southeasterly circulation of moist air over the Gulf of Mexico from the Bermuda high-pressure area, which shifts westward in summer. Strong surface heating combined with the air movement over higher terrain causes convective air currents and condensation. The average number of days per year having 0.25 mm (0.01 in) or more precipitation for the Albuquerque area is 65 and the average number of days per year having 25 mm (1 in) or more of snow or ice pellets is 4.3 (NOAA, 1993). Evapotranspiration in the area has been estimated at 95 percent of the annual rainfall (Thomson and Smith, 1985).

The winter months, November through March, are generally very dry, with normally less than 60 mm (2 in) of moisture (NOAA, 1993). Winter precipitation is caused by moisture associated with Pacific Ocean storms moving west to east across the country and Arctic outbreaks from the north. Much of the moisture from these storms precipitates over the mountains west of New Mexico as the storms move eastward. Snow rarely remains on the ground in the valley for more than 24 hours. Snow cover in the mountains, however, is common from mid-November to early spring. The maximum monthly snowfall for the Albuquerque area was 37.3 cm (14.7 in), recorded in 1959 (NOAA, 1993).

4.3 Wind

The average annual wind speed for the Albuquerque area is 4 meters per second (m/s) (9 miles per hour [mph]). Sustained winds of 5.3 m/s (12 mph) or less occur approximately 80 percent of the time at the ABQ, while sustained winds greater than 11 m/s (25 mph) have a frequency less than 3 percent (NOAA, 1993). Winds blow most frequently from the north in winter and from the south along the river valley in summer. Winds are generally stronger in the late winter and early spring months, and occasionally dusty days occur due to blowing soils. At SNL/NM, winds are almost equally probable from all directions, under normal conditions, with speeds generally less than 3.5 m/s (8 mph). The wind speeds reach 13 m/s (30 mph) less than 48 days each year (DOE, 1987). The proximity of SNL/NM to the Rio Grande Valley and the Sandia/Manzano/Manzanita Mountains causes enhanced variabilities in weather conditions (particularly precipitation and winds) over the area covered by SNL/NM operations. Winds are particularly subject to orographic effects (effects caused by the presence of mountains and other topographical features).

A network of seven meteorological towers surrounding SNL/NM-operated nuclear reactors was established in July 1960 to monitor weather conditions; an eighth station was added in May 1965. The locations of these stations are described in Table 4-6. These studies indicate that the prevailing winds at SNL/NM are from the east, except that winter winds at the 30-m (100-ft) elevation are from the north. Rapid night-time ground cooling after sunset on cloudless or near cloudless nights produce strong temperature inversions (an atmospheric condition of reversal of the normal temperature lapse rate in which temperature increases with increasing elevation). This rapid cooling effect generates drainage winds (katabatic winds) out of the mountains, which are strongest at the mouths of the larger canyons. It also appears that Tijeras Arroyo diverts surface air flow between Technical Areas III, V, and Coyote Test Field on the one hand, and Technical Areas I, II, IV, and Albuquerque on the other.

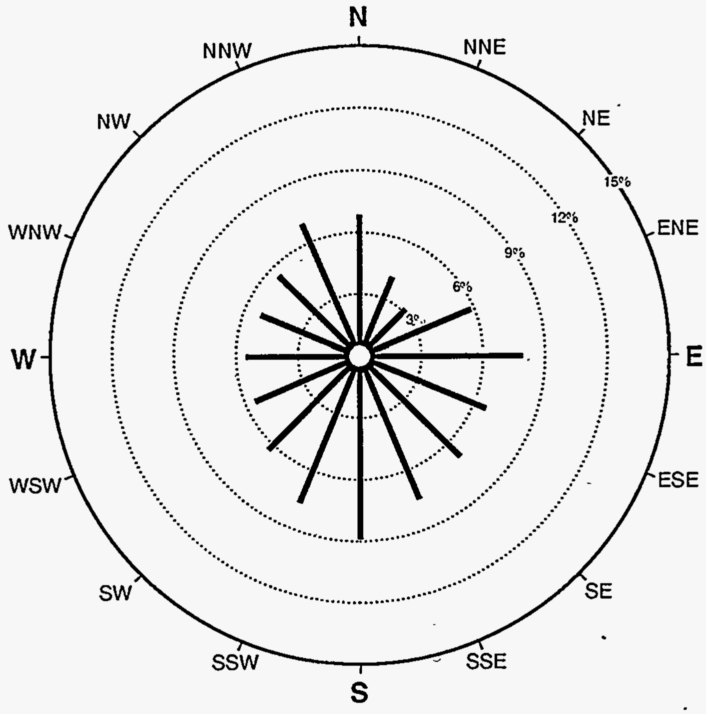
Specific wind information can be inferred from these studies, in particular Station One, which is located on the eastern boundary of Technical Area III, and Station Four, which is located in Technical Area I east of Building 880. The channeling of wind through Tijeras Canyon can be seen by comparing the wind roses from these two areas. Figure 4-1 shows the wind roses summarizing ten years of data from Stations One and Four (percent frequency at 30 m [100 ft]).

Table 4-6
Meteorological Tower Locations for Wind Study

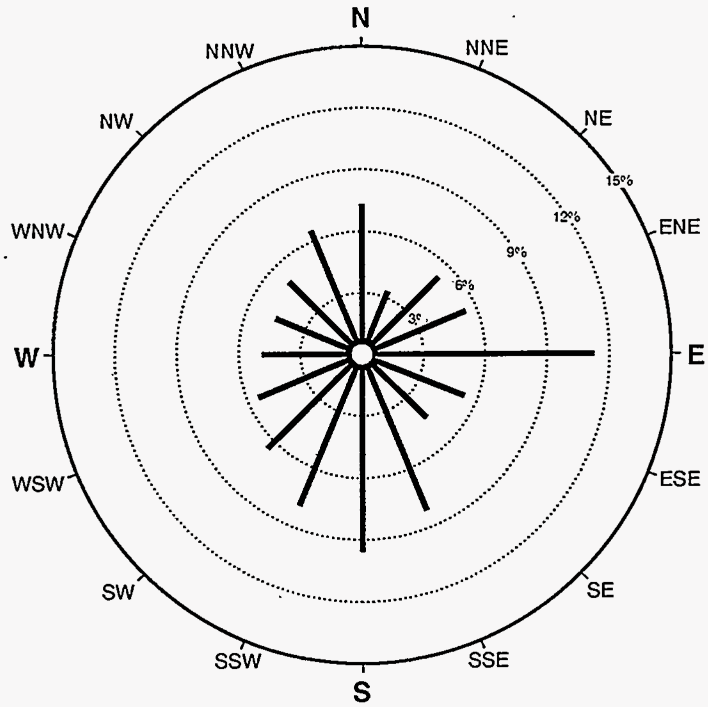
Station Number	Location
One	Eastern boundary of Technical Area III, 4 mi (6 km) south of Technical Area I
Two	6 mi (10 km) southwest of Technical Area I at the mouth of Tijeras Arroyo, near Broadway SE
Three	4 mi (6 km) southwest of Technical Area I on Old Police Prison Farm, in Tijeras Arroyo
Four	Technical Area I, east of Building No. 880
Five	7 mi (10 km) east northeast of Technical Area I in Tijeras Canyon near Seven Springs
Six	9 mi (14 km) west northwest of Technical Area I in the valley at Old Town School
Seven	2 mi (3 km) west of Technical Area I near the east end of the east-west runway at the Albuquerque Sunport KAFB
Eight	6 mi (10 km) south of Technical Area I in Coyote Test Field's Thunderwell Area

mi = Mile(s)
km = Kilometer(s)

Source: Olsen, O., M. H. Hall, and M. H. Plagge, 1970, "Wind Data for the Albuquerque Area," *SC-M-70-144*, Sandia National Laboratories, Albuquerque, New Mexico.



TECHNICAL AREA III



TECHNICAL AREA I

(Windrose Frequency in Percent Time)

Figure 4-1
Average Annual Wind Direction, Sandia National Laboratories/New Mexico (1960–1970)

Tijeras Arroyo. The arroyo effectively blocked the northerly drift beyond the arroyo and redirected the flow in a westerly direction, down canyon in one case and in both directions (westerly and easterly) along the arroyo in the other case. The clouds did not pass the arroyo until the inversion had disappeared.

As part of the new SNL/NM site-specific meteorological monitoring program, a nine-tower meteorological monitoring network was established across the SNL/NM area. The main objective of this monitoring program is to provide data that are representative of the conditions at SNL/NM, including the more remote areas of the eastern test area. Data from these towers were collected during 1994, and have been published in the 1994 Site Environmental Report for SNL/NM (SNL/NM, 1995b).

4.4 Severe Weather

The average number of thunderstorm days per year in the Albuquerque area is 41, the majority of which occur during the rainy summer period (NOAA, 1993). Often thunderstorms develop during the afternoon over the Sandia and Manzano Mountains and drift to the northwest over the Rio Grande Valley.

Tornadoes are virtually nonexistent in the Albuquerque area. Small tornadoes were observed in 1985 and 1987. Damage was very light and no official wind readings were noted. Based on climatological records, Albuquerque is classified as a region of low-tornado occurrence, with an annual frequency of 0.1 or less (Coats and Murray, 1985).

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5.0 Ecology

This chapter discusses the vegetation and wildlife of SNL/NM with an emphasis on threatened, endangered, and sensitive species and habitats. The requirements for listing threatened and endangered species at the federal and State of New Mexico levels are briefly discussed in the following paragraphs. Recommended mitigation measures for minimizing adverse impacts to biological resources are listed in Appendix B.

Under the provisions of the Endangered Species Act of 1973 (16 U.S.C, §§ 1531 *et seq.*), the USFWS has the authority to protect species and subspecies of animals and plants from threats to their continued existence. Species or subspecies afforded this protection are listed by the USFWS under one of two categories: Endangered and Threatened. The federal definition of an endangered species is any species that is in danger of extinction throughout all or a significant portion of its range. A threatened species is any species which is likely to become endangered within the foreseeable future throughout all or a significant portion of its range. In addition, proposed species are those that have been formally proposed in the *Federal Register* for listing as either threatened or endangered, but for which a final rule has not been made. Candidate species are those currently under review for possible listing. Also under the Endangered Species Act, areas of habitat deemed critical to the survival of a threatened or endangered species can also be designated (as Critical Habitat) by the U.S. Fish and Wildlife Service (USFWS) and protected from disturbance. Wetlands are defined by both the EPA and the USACE and are protected from disturbance (e.g., dredging and filling) through the provisions of the Clean Water Act (33 U.S.C., §§ 1251 *et seq.*) and Executive Order (EO) 11990.

The State of New Mexico also provides statutory protection to plant and animal species threatened with extinction or local extirpation. Under the provisions of the New Mexico Wildlife Conservation Act (New Mexico Statutes Annotated (NMSA) §§ 17-2-37 through 17-2-46, 1978 compilation), the New Mexico Department of Game and Fish (NMDGF) is given authority to list and protect endangered species of wildlife. As with the federal system, two categories for listing are used by the NMDGF. Endangered species (previously referred to as Group 1) are species or subspecies whose prospects of survival or recruitment in New Mexico are in jeopardy. Threatened species (previously referred to as Group 2) are species or subspecies whose prospects of survival or recruitment in New Mexico are likely to be in jeopardy within the foreseeable future (NMDGF, no date).

Under the provisions of the NMSA §§ 9-10-10, 1978 compilation, plant species may be listed as endangered and provided protection by the New Mexico Forestry and Resource Conservation Division (NMFRCD) of the Energy, Minerals, and Natural Resources Department. Four lists are maintained by the NMFRCD. List 1 includes plants endangered in New Mexico. These species must meet one of three criteria: (1) the species or subspecies is listed or proposed for listing under the Endangered Species Act, (2) the species or subspecies is rare across its entire range and of such limited distribution and population size that unregulated collection could jeopardize its survival in New Mexico, and (3) the species or subspecies is being significantly reduced to the extent that its survival in New Mexico for the foreseeable future is jeopardized, regardless of its population size outside of the state. List 2 includes plant species that are rare or may be otherwise sensitive to long-term or cumulative impacts. List 3 includes plant species under review by the NMFRCD for possible listing. List 4 includes plant species dropped from current consideration for listing. Of these four lists, only List 1 species are provided legal protection under state statutes (Sivinski and Lightfoot, 1992).

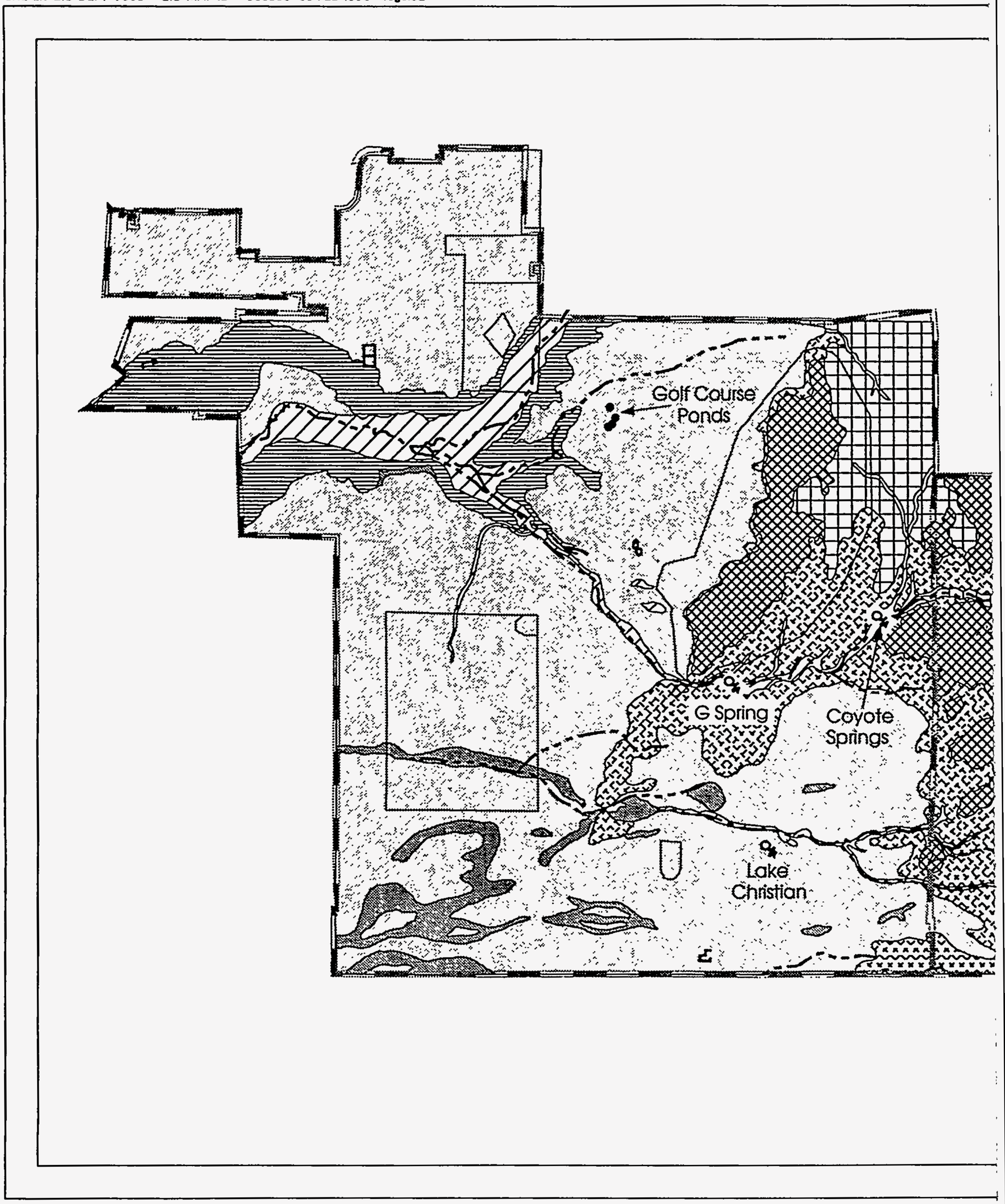
5.1 Vegetation

SNL/NM-KAFB are located at the juncture of four major North American physiogeographic and biotic provinces: the Great Basin, the Rocky Mountains, the Great Plains, and the Chihuahuan Desert. The biotic communities, or biomes, within SNL/NM-KAFB exhibit influences from each of these provinces, with the Great Basin influence generally dominating.

Based on Brown's (1982) hierarchical system for the classification of biomes in the southwestern United States, four vegetation formations are recognized at SNL/NM-KAFB: grassland, woodland, riparian scrubland, and riparian woodland. The grassland and woodland formations dominate SNL/NM-KAFB, while the riparian scrubland and riparian woodland formations are limited in extent to the surface drainage courses of the arroyos and canyons, respectively. The following sections describe each of these general vegetation formations as they occur within SNL/NM-KAFB. Figure 5-1 shows the areal extent of these types. A list of plant species that are known to occur or may occur on SNL/NM-KAFB is given in Appendix C.

5.1.1 Grasslands

Grassland vegetation covers the lower alluvial slopes and flat terrace surfaces of the western half of SNL/NM-KAFB. Soils supporting grassland vegetation are typically sandy loams to gravelly sandy loams with slopes less than 5 percent. These soils include the Latene, Wink, Madurez,


Golf Course
Ponds
G Spring
Coyote
Springs
Lake
Christian

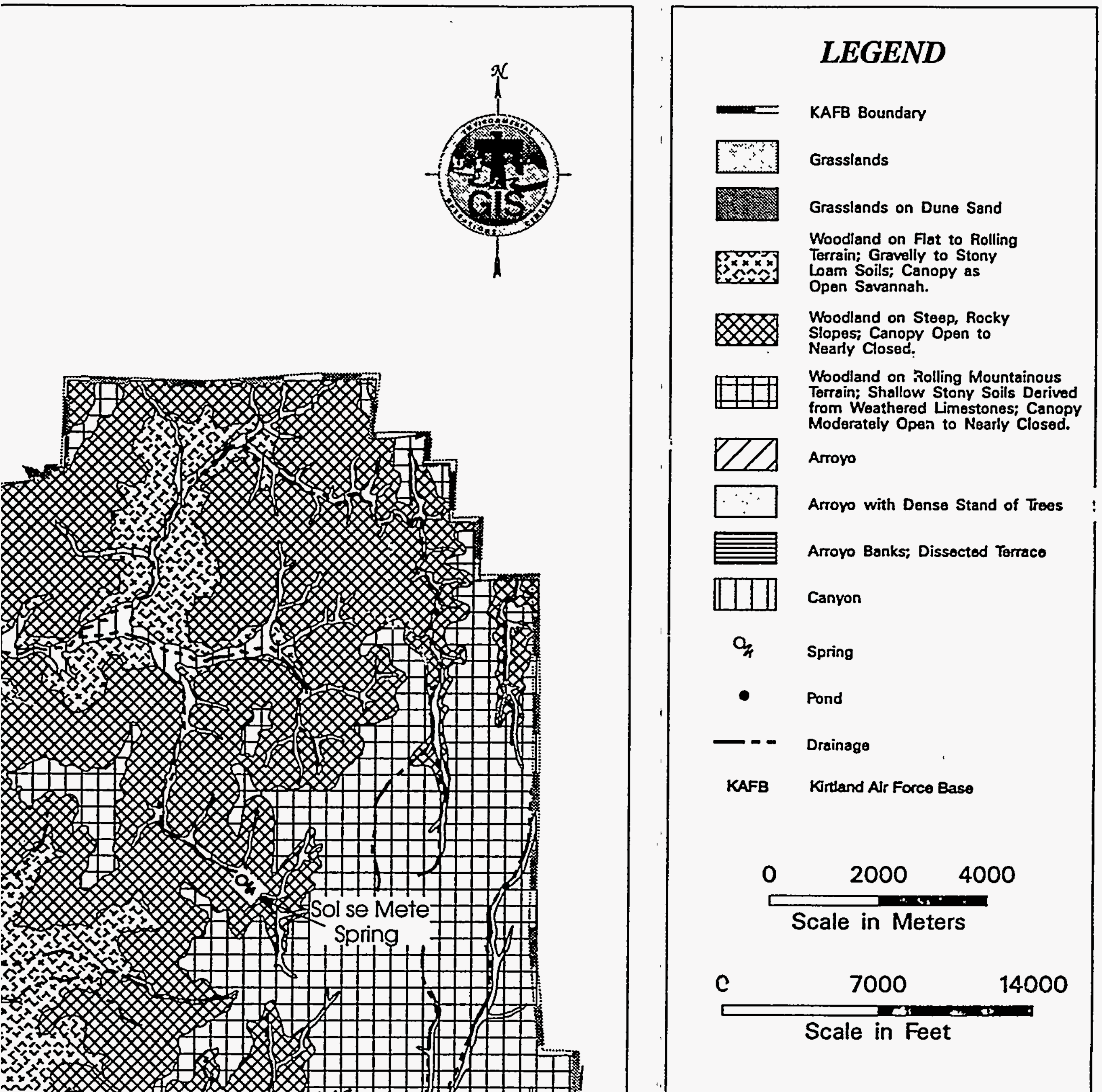


Figure 5-1
Location of Vegetation Types, Sandia National Laboratories/ New Mexico

Tijeras, Embudo, and Tome (USDA, 1977). The latter is found in the southwestern quadrant of SNL/NM-KAFB, where small drainages from the Manzano Mountains reach the flat internal basins near the McCormick Ranch, causing sediment deposition along broad fans. These sandy soils form low coppice dunes stabilized by grasses and shrubs.

The influences of three biomes are evident in the grasslands at SNL/NM-KAFB: the Great Basin Grassland Biome, the Semidesert Grassland Biome, and the Plains Grassland Biome. The influence of the Great Basin Grassland Biome predominates in the grassland community. Galleta (*Hilaria jamesii*) is the dominant grass species in the SNL/NM-KAFB area that is associated with the Great Basin Grassland Biome. Others include sand dropseed (*Sporobolus cryptandrus*), ring muhly (*Muhlenbergia torreyi*), and Indian ricegrass (*Oryzopsis hymenoides*).

The influence of the Semidesert Grassland Biome is typified by the presence of black grama (*Bouteloua eriopoda*). This grass species is commonly found as a subdominant or co-dominant species with galleta and is, in places, the dominant grass, sometimes forming near monocultures. Other grasses associated with this biome are mesa dropseed (*Sporobolus flexuosus*), bush muhly (*Muhlenbergia porteri*), and fluffgrass (*Tridens pulchellus*). The Semidesert Grassland Biome is climatically classified within the Warm-Temperate Climatic Zone, while the other biotic communities at SNL/NM-KAFB are classified in the Cold-Temperate Climatic Zone. For this reason, species associated with the Semidesert Grassland Biome are more frequent on sites with a warmer, drier microclimate, such as south-facing slopes, calcareous soils, and sites exposed to high winds.

The third component influencing the grassland vegetation at SNL/NM-KAFB is the Plains Grassland Biome, which is centered in the Great Plains. Although none of the species associated with this biome reach dominance in the grassland communities, some of the important species with affinities to this biome include side-oats grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracilis*), little bluestem (*Andropogon scoparius*), and soapweed yucca (*Yucca glauca*). Several of these species are also common in the Great Basin Grassland Biome. Species associated with the Plains Grassland Biome are more common on sites with cooler, moister microclimates, such as those protected from the influences of sun or wind by virtue of slope and direction of exposure.

Where the soil has not been disturbed by construction, the grassland vegetation on SNL/NM-KAFB is generally in excellent condition and is relatively free of shrubs and subshrubs. This is due to the long period of protection from grazing within the SNL/NM-KAFB boundaries. Periodic burns, both natural and man-caused, are evident in the grassland areas. These fires are fueled and carried by the accumulated dead grass material from previous years and are probably important in maintaining the dominance of grasses over woody plants. The dominant shrub species in the grasslands are winterfat (*Eurotia lanata*), sand sagebrush (*Artemisia filifolia*), and four-wing saltbush (*Atriplex canescens*), all of which are widespread in the western United States.

5.1.2 Woodlands

Woodland vegetation occurs primarily on the upper alluvial slopes and in the mountainous areas in the eastern half of SNL/NM-KAFB. The soils of the woodland areas are coarser than those of the grasslands, ranging from gravelly sandy loams to rock outcrop. These include the Tijeras, Embudo, Tesajo, Millett, Ildefonso, Salas, and the Seis Series (USDA, 1977). The growth forms range from very open savannahs, with small, widely scattered trees and shrubs and a grass understory, to a well-developed piñon-juniper woodland, with a nearly closed canopy and scant understory.

Three biomes influence the composition of the woodlands. Predominant among these is the Great Basin Conifer Woodland, which is characterized by the presence of two tree species: the one-seed juniper (*Juniperus monosperma*) and the Colorado piñon (*Pinus edulis*). At lower elevations, the former is more abundant than the latter. At higher elevations and in cooler, moister sites, these two species codominate. The understory vegetation varies in composition from being essentially an extension of the grassland communities to a floristic mix of grasses, forbs (nonwoody plants, excluding grasses), and shrubs that is characteristic of montane habitats. Species in this understory include mountain muhly (*Muhlenbergia montana*), bear grass (*Nolina microcarpa*), banana yucca (*Yucca baccata*), mountain mahogany (*Cercocarpus montanus*), and shrub live oak (*Quercus turbinella*).

The other two biomes influencing the composition of the woodland communities are the Great Basin Montane Scrubland Biome and the Rocky Mountain Montane Conifer Forest Biome. The former is prevalent in warmer, drier microhabitats, while the latter is found in cooler, moister microhabitats. The Great Basin Montane Scrubland Biome is characterized by the dominance of shrubs, such as gray oak (*Quercus grisea*), Gambel oak (*Q. gambellii*), mountain mahogany, and skunkbush (*Rhus trilobata*). The very minor influence of the Rocky Mountain Montane Conifer Forest Biome is noted by the presence of ponderosa pine (*Pinus ponderosa*) and Rocky Mountain juniper (*Juniperus scopulorum)* in protected sites at the higher elevations of the U.S. Forest Service (USFS) withdrawal area to the east.

5.1.3 Riparian Scrublands (Arroyos)

The Tijeras Arroyo and the Arroyo del Coyote are the two principal arroyos on SNL/NM-KAFB. Where these arroyos have a developed soil in the channel bottom, this soil is typically classified as Gila (USDA, 1977). The dissected slopes of the channels are classified as the Bluepoint-Kokan association, which is generally gravelly to stony with steep slopes resulting in a drier soil (USDA, 1977). This is reflected in the vegetation that is a reduced grassland community, with greater amounts of drought-adapted species, such as club cholla (*Opuntia clavata*), prickly pear (*Opuntia phaeacantha*), soapweed yucca, and four-wing saltbush.

The vegetation in the arroyo bottoms is characteristic of the Great Basin Riparian Scrubland, dominated by shrubs such as rabbitbrush (*Chrysothamnus nauseosus*), Apache plume (*Fallugia paradoxa*), and four-wing saltbush. Alkali sacaton (*Sporobolus airoides*) is a dominant grass that is characteristic of the arroyos. Fremont cottonwood (*Populus fremontii*) is infrequent along the arroyos.

Salt-cedar or tamarisk (*Tamarix pentandra*), an exotic species that has become a nuisance in many drainages in the western United States, is dominant in isolated places along the arroyos. Two other exotic trees, Siberian elm (*Ulmus pumila*) and tree-of-heaven (*Ailanthus altissima*), have also become established along the arroyos as isolated individuals, small groups, or, in the case of the latter species, dense thickets.

In the Arroyo del Coyote, at the southern end of the Manzano Base, salt-cedars and tree-of-heaven thickets mark an area of near-surface ground water. A small spring, called G Spring, occurs at this location. This spring supports a surface flow and wetland grasses for a distance of about 45 m (150 ft) before infiltrating into the sandy arroyo bottom. The permanence of this flow has not been determined (SNL, 1991a; see Section 3.7.1).

5.1.4 Riparian Woodlands (Canyons)

The vegetation in the canyons of the Manzano Mountains is a complex mixture of elements from all of the biomes described above. Grassland and arroyo elements extend into the lower parts of the major canyons (Lurance, Madera, and Sol se Mete), mixing and eventually being replaced by woodland species. The soils in the canyons are typically the Tesajo-Millett stony sandy loam and members of the Seis Series.

Canyon vegetation is largely woody. Trees include one-seed juniper, piñon pine, ponderosa pine, Gambel oak, Siberian elm, and tree-of-heaven. A wide variety of shrubs occur in the canyons, including rabbitbrush, Apache plume, skunkbush, mountain mahogany, New Mexico olive (*Forestiera neomexicana*), New Mexico locust (*Robinia neomexicana*), cliff fendlerbush (*Fendlera rupicola*), and mock-orange (*Philadelphus microphyllus*).

Canyons are important as wildlife habitat, providing food, water, and shelter to many species. The streams in these canyons are ephemeral. Sol se Mete Spring, in Sol se Mete Canyon, and Coyote Springs, at the mouth of Lurance Canyon, are the most permanent sources of water in the canyon areas. In addition to these water sources, the USFS has constructed rainfall catchments or "guzzlers" in scattered locations within the canyons. These provide water to wildlife over extended periods, depending on rainfall amounts.

5.2 Wildlife

Wildlife communities, which include amphibians, reptiles, birds (both breeding and migratory), and mammals, are dependent upon the quality and quantity of available habitat that meets the needs of individual wildlife species in the community. The basic requirements of any wildlife species are food, water, and shelter. Each individual species has specific habitat requirements for these three basic factors, as well as behaviorally controlled requirements, such as corridors of travel, breeding sites, freedom from human intrusion, and others. The wildlife communities at SNL/NM-KAFB are typical of the equivalent woodland and grassland habitat types in central New Mexico. The NMDGF maintains a database on wildlife species found in the state called BISONM (Biota Information System of New Mexico), which contains information on county-by-county occurrences and habitat associations.

The poor availability of water has probably been a limiting factor to the wildlife communities in this area. The lack of permanent water sources is particularly prevalent in the grasslands where wildlife populations appear smaller and less diverse than the forage production could potentially support. In the Manzano Mountains, some springs have been lost to some or all species of wildlife through development. This loss is mitigated by the installation of wildlife guzzlers.

The following sections provide general descriptions of the wildlife known or expected to occur on SNL/NM-KAFB. These descriptions are based on species lists presented in Brown (1982), Fischer (1990), Biggs (1991a, 1991b), Sullivan and Knight (1994), and Sullivan (1994). Lists of amphibian, reptile, bird, and mammal species that are known or expected to occur on SNL/NM-KAFB are given in Appendix C.

5.2.1 Grassland Wildlife Communities

Amphibians of the grasslands are limited to those species that are adapted to long periods of dormancy during dry conditions and rapid breeding cycles when ephemeral water is available. These may include the western spadefoot (*Spea hammondi*), plains spadefoot (*S. bombifrons*), Woodhouse's toad (*Bufo woodhousei*), and Great Plains toad (*B. cognatus*). Common reptiles in the grasslands include the Great Plains skink (*Eumeces obsoletus*), little striped whiptail lizard (*Cnemidophorus inornatus*), Chihuahuan spotted whiptail lizard (*C. exsanguis*), short horned lizard (*Phrynosoma douglassi*), round-tailed horned lizard (*P. modestum*), lesser earless lizard (*Holbrookia maculata*), bullsnake (*Pituophis melanoleucus*), coachwhip (*Masticophis flagellum*), massasauga (*Sistrurus catenatus*), and western rattlesnake (*C. viridis*).

Raptors use the grassland areas for hunting throughout the year, but the lack of nesting sites (e.g., trees and cliffs) limits the use of this habitat type for breeding. Man-made structures may occasionally be used by some species for nesting. Raptor species known or expected to occur in the grassland type are northern harrier (*Circus cyaneus*), red-tailed hawk (*Buteo jamaicensis*), Swainson's hawk (*B. swainsoni*), ferruginous hawk (*B. regalis*), American kestrel (*Falco sparverius*), prairie falcon (*F. mexicanus*), barn owl (*Tyto alba*), long-eared owl (*Asio otus*), great horned owl (*Bubo virginianus*), and burrowing owl (*Speotyto cunicularia*). Turkey vultures (*Cathartes aura*) are common scavengers in this habitat.

Other common grassland birds are the scaled quail (*Callipepla squamata*), mourning dove (*Zenaida macroura*), greater roadrunner (*Geococcyx californianus*), horned lark (*Eremophila alpestris*), American crow (*Corvus brachyrhynchos*), western kingbird (*Tyrannus verticalis*), northern mockingbird (*Mimus polyglottos*), loggerhead shrike (*Lanius ludovicianus*), lark sparrow (*Chondestes grammacus*), black-throated sparrow (*Amphispiza bilineata*), western meadowlark (*Sturnella neglecta*), brown-headed cowbird (*Molothrus ater*), and house finch (*Carpodacus mexicanus*).

The mammal community in the grasslands is dominated by rodents and lagomorphs (rabbits and hares). These include desert cottontail (*Sylvilagus auduboni*), black-tailed jackrabbit (*Lepus californicus*), Gunnison's prairie dog (*Cynomys gunnisoni*), Botta's pocket gopher (*Thomomys bottae*), silky pocket mouse (*Perognathus flavus*), Ord's kangaroo rat (*Dipodomys ordii*), banner-tailed kangaroo rat (*D. spectabilis*), Merriam's kangaroo rat (*D. merriami*), western harvest mouse (*Reithrodontomys megalotis*), deer mouse (*Peromyscus maniculatus*), white-throated woodrat (*Neotoma albigua*), and northern grasshopper mouse (*Onychomys leucogaster*).

Mammalian predators in the grassland community include the coyote (*Canis latrans*), badger (*Taxidea taxus*), striped skunk (*Mephitis*), and bobcat (*Lynx rufus*). Although the black-footed ferret (*Mustela nigripes*) once may have occurred in this area, there are no recent recorded sightings of this federally listed endangered species from New Mexico. No large prairie dog "towns," upon which the ferret depends, remain on SNL/NM-KAFB, although some small prairie dog colonies are present.

Mule deer (*Odocoileus hemionus*) are the only large herbivores that use the grasslands. However, because this species is primarily a browser and not a grazer, mule deer are infrequent users of the grasslands.

5.2.2 Woodland Wildlife Communities

Most of the grassland species described in the previous section extend into the woodland community, at least into the open savannahs of the lower elevations. Amphibians are generally absent from the woodland community because of the rapid drainage of the coarser soils. Among the reptiles that become more prevalent in the woodlands are the collared lizard (*Crotaphytus collaris*), tree lizard (*Urosaurus ornatus*), eastern fence lizard (*Sceloporus undulatus*), western terrestrial garter snake (*Thamnophis elegans*), and the mountain patchnose snake (*Salvadora grahamiae*).

As the vertical habitat diversity increases in the woodlands, the diversity of bird species using the habitat also increases. Some of the more common birds found in the woodland habitat are the sharp-shinned hawk (*Accipiter striatus*), western screech owl (*Otus kennicottii*), common poorwill (*Phalaenoptilus nuttallii*), black-chinned hummingbird (*Archilochus alexandris*), northern flicker (*Colaptes auratus*), Lewis' woodpecker (*Melanerpes lewis*), red-naped sapsucker (*Sphyrapicus nuchalis*), Cassin's kingbird (*Tyrannus vociferans*), ash-throated flycatcher (*Myiarchus cinerascens*), western wood-pewee (*Contopus sordidulus*), western flycatcher (*Empidonax difficilis*), scrub jay (*Aphelocoma coerulescens*), piñon jay (*Gymnorhinus cyanocephalus*), Steller's jay (*Cyanocitta stelleri*), common raven (*Corvus corax*), plain titmouse (*Parus inornatus*), mountain chickadee (*Parus gambeli*), bushtit (*Psaltriparus minimus*), rock wren (*Salpinctes obsoletus*), Bewick's wren (*Thryomanes bewickii*), ruby-crowned kinglet (*Regulus calendula*), western bluebird (*Sialia mexicana*), mountain bluebird (*S. currucoides*), Townsend's solitaire (*Myadestes townsendi*), American robin (*Turdus migratorius*), yellow-rumped warbler (*Dendroica coronata*), western tanager (*Piranga ludoviciana*), black-headed grosbeak (*Pheucticus melanocephalus*), rufous-sided towhee (*Pipilo erythrophthalmus*), chipping sparrow (*Spizella passerina*), and Scott's oriole (*Icterus parisorum*).

The peregrine falcon (*Falco pereginus*) is a federally listed endangered species that may occur in the area. Because this species prefers cliff faces for nesting and often hunts in wooded areas, the woodland and canyon habitats of SNL/NM-KAFB are the most likely areas of use by this species, if it is present.

Mammal communities are also gradually replaced in the transition between grassland and woodland vegetation. Coupled with this transition is an increase in the coarseness of the soil and greater amounts of rock outcrops, which are an essential element in the habitat of some mammal species. Mammals found primarily in the woodlands include the mountain cottontail (*Sylvilagus floridus*), Colorado chipmunk (*Eutamias quadrivittatus*), Texas antelope squirrel (*Ammospermophilus interpres*), rock squirrel (*Spermophilus variegatus*), rock pocket mouse (*Perognathus intermedius*), brush mouse (*Peromyscus boylii*), piñon mouse (*P. truei*), rock mouse (*P. difficilis*), porcupine (*Erethizon dorsatum*), black bear (*Ursus americanus*), and mountain lion (*Felis concolor*).

5.2.3 Arroyo and Canyon Wildlife Communities

In general, the wildlife communities of the arroyos and canyons are derived from the adjacent grassland and woodland communities. The presence of ephemeral or permanent water sources and the greater diversity of trees and shrubs in these habitats provide microhabitats that are unique. True wetland habitat is extremely limited on SNL/NM-KAFB. The arroyo and canyon systems, however, do contain small wetland areas, such as those at Coyote Springs and at Sol se Mete Spring, where wetland species may occur. Amphibian and reptile species that are limited to the arroyos and canyons may include the red-spotted toad (*Bufo punctatus*), tiger salamander (*Ambystoma tigrinum*), and blackneck garter snake (*Thamnophis cyrtopsis*).

Birds that are generally limited to these habitats include the Cooper's hawk (*Accipiter cooperii*), killdeer (*Charadrius vociferus*), whip-poor-will (*Caprimulgus vociferus*), broad-tailed hummingbird (*Selasphorus platycercus*), acorn woodpecker (*Melanerpes formicivorus*), black phoebe (*Sayornis nigricans*), Say's phoebe (*S. saya*), violet-green swallow (*Tachycineta thalassina*), northern rough-winged swallow (*Stelgidopteryx serripennis*), house wren (*Troglodytes aedon*), red-breasted nuthatch (*Sitta canadensis*), gray vireo (*Vireo vicinior*), yellow-breasted chat (*Icteria virens*), summer tanager (*P. rubra*), northern oriole (*Icterus galbula*), green-tailed towhee (*Pipilo chlorurus*), dark-eyed junco (*Junco hyemalis*), and the song sparrow (*Melospiza melodia*).

Most large mammal species of the area use the canyons and arroyos for feeding, water, travel corridors, or shelter. Species that are essentially limited in range to these habitats are the gray fox (*Urocyon cinereoargenteus*), ringtail (*Bassariscus astutus*), western spotted skunk (*Spilogale gracilis*), and raccoon (*Procyon lotor*).

Bats range over various habitats, although the greatest diversity is in the canyons and riparian areas. Bat species of these areas include Yuma myotis (*Myotis yumanensis*), little brown myotis (*M. lucifugus*), southwestern myotis (*M. auriculus*), fringed myotis (*M. thysanodes*), long-legged myotis (*M. volans*), California myotis (*M. californicus*), small-footed myotis (*M. leibii*), silver-haired bat (*Lasionycteris noctivagans*), big brown bat (*Eptesicus fuscus*), hoary bat (*Lasiurus cinereus*), Townsend's big-eared bat (*Plecotus townsendii*), and the Brazilian free-tailed bat (*Tadarida brasiliensis*).

5.3 Threatened, Endangered, and Sensitive Species and Habitats

There are no federally listed endangered, threatened, or proposed species known to occur within SNL/NM-KAFB. The peregrine falcon (both federally and State-listed endangered) could potentially occur in the mountainous areas; however, the likelihood is low because of the poor habitat quality for this species (Sullivan, 1994). Similarly, the Mexican spotted owl (*Strix occidentalis lucide*) (federally listed threatened), southwest willow flycatcher (*Empidonax traillii extimus*) (federally proposed, State-listed threatened) and northern beardless tyrannulet (*Camptostoma imberbe ridgwayi*) (State-listed endangered) are potential inhabitants of the canyons, although favorable habitat conditions do not exist for any of these species. Two federally listed endangered species that are known from Bernalillo County but are unlikely to occur on SNL/NM-KAFB except as transients or accidentals are the bald eagle (*Haliaeetus leucocephalus*) (State-listed threatened) and the whooping crane (*Grus americana*) (State-listed endangered). The black-footed ferret (*Mustela nigripes*) is a federally listed endangered species that once occurred in central New Mexico, but for which no recent records from the state are known.

Three candidate species for federal listing are known to occur within SNL/NM-KAFB. These are the grama grass cactus (*Pediocactus papyracanthus*), Texas horned lizard (*Phrynosoma cornutum*), and burrowing owl (*Speotyto cunicularia*). Other federal candidate species that may occur on SNL/NM-KAFB are the northern goshawk (*Accipiter gentilis*), ferruginous hawk (*Buteo regalis*), mountain plover (*Charadrius montanus*), western snowy plover (*C. alexandrinus nivosus*), white-faced ibis (*Plegadis chihi*), occult little brown bat (*Myotis lucifugus occultus*), spotted bat (*Euderma maculatum*) (State-listed threatened), and meadow jumping mouse (*Zapus hudsonius luteus*) (State-listed threatened). Of these, the ferruginous hawk, occult little brown bat, and southern plains woodrat are the most likely to occur as resident or breeding species. The others have a low probability of occurrence due to unsuitable habitat or may only occur as migrants or transients.

Two State-listed species occur within SNL/NM-KAFB. The Santa Fe milk-vetch (*Astragalus feensis*), listed by the State as rare or sensitive (List 2), has also been recorded growing on the low limestone hills near the North Thunder Range (Sullivan and Knight, 1994). One State-listed (List 2) endangered species is known to occur in the foothills of the Manzanita Mountains within KAFB and USFS withdrawal lands. This is the gray vireo (*Vireo vicinior*).

The most sensitive habitat types on SNL/NM-KAFB are the wetlands and canyons. The two most significant natural wetland sites remaining on SNL/NM-KAFB are Coyote Springs, Sol se Mete Spring, and G Spring. Coyote Springs was developed as a picnic site by previous land users. Although the springs are reverting to more natural wetland conditions, the proximity to a major roadway and its easy accessibility for human use will limit the extent to which natural wetland conditions will develop through the process of natural succession. Sol se Mete Spring, which is much smaller than Coyote Springs, has been altered by the construction of a stone tub; however, because it is more isolated from human activity, it generally represents more natural wetland conditions.

Little information is available on the ecology of G Spring. With the exception of the growth of exotic species at this site (e.g., salt-cedar), G Spring is the most pristine wetland site within SNL/NM-KAFB. The more heavily wooded, undisturbed canyons and their adjacent slopes are considered highly sensitive wildlife habitat (Biggs, 1991a). This classification is based on the quality of the habitat for travel corridors, bedding areas, wintering areas, and foraging areas, as well as the amount of contiguous undisturbed area and the ability to support sensitive species.

Some artificial ponds provide wetland habitat that is available to wildlife, albeit they are within developed areas. Lake Christian is a 2-acre permanent pond adjacent to a USAF testing facility, 1.6 km (1 mi) northeast of the Inhalation Toxicology Research Institute. The margins of the pond support cattails (*Typha latifolia*), and the water contains a stocked population of carp. Permanent ponds are also found on the golf course, 1.6 km (1 mi) southeast of Technical Area IV. Open ponds are used by migratory waterfowl in the spring and fall.

Appendix A contains federal and state requirements with respect to endangered and threatened species.

6.0 Air Quality

The Albuquerque Environmental Health Department Air Pollution Control Division (AEHD APCD) promulgates regulations with respect to ambient air quality in the vicinity of SNL/NM. The AEHD APCD also monitors compliance with federal and state air quality regulations. The AEHD APCD has set up several ambient air sampling stations throughout the city, including a site 3 km (2 mi) northwest of SNL/NM, to monitor total suspended particulates (TSP), ozone, PM_{10}, carbon monoxide, and nitrous oxide (NOX) (AEHD APCD, Oct. 1994). No pollutants measured at the station near SNL/NM in 1992 and 1993 exceeded the established limits.

Several SNL/NM sources emit air pollutants that are controlled by the AEHD APCD regulations. SNL/NM conducted a preliminary inventory of the 189 hazardous air pollutants (HAPs) listed in the Clean Air Act (CAA) Amendments of 1990 using a two-phased approach during 1991 and 1992. Both the 1991 and 1992 inventories show that SNL/NM has used a wide variety of the chemicals listed in the CAA Amendments. The 1992 inventory showed that only 20 of these are used in quantities exceeding 454 kilograms (kg)/yr (1,000 pounds [lb]/yr) (Table 6-1). SNL/NM has over 1,000 emission sources (hood/vent) and over 300 individual emission points (or stacks) (SNL, 1991b). The 1992 chemical usage inventory forms were sent to Waste Minimization Network (MinNet) representatives for distribution to all chemical users. Approximately 600 inventory forms were received and were used in the emissions evaluation. A review of inventory results will determine which chemicals, based upon maximum potential emissions, require further investigation regarding individual usage and emission-point parameters. Chemical emissions inventories are now conducted annually, and more recent updated information is available from Department 7575, Air Quality (Culp et al., 1994).

In 1992, SNL/NM undertook a four-month intensive background air monitoring program to measure concentrations of both radioactive and nonradioactive ambient air pollutants from suspected source areas across SNL/NM (SNL/NM, 1993). The results were used to evaluate whether SNL/NM is contributing significantly to local air quality degradation and whether SNL/NM is in compliance with applicable state, federal, and local ambient air quality standards. In addition, the results were used to determine whether a long-term monitoring program is warranted to prove continued compliance with the CAA Amendments of 1990 and DOE regulations. The main emphasis of the 1992 background study was to establish the baseline levels at which airborne pollutants are present in and around SNL/NM. For this purpose, pollutant levels were monitored at selected locations around the periphery of Technical Area I in

Table 6-1
Hazardous Air Pollutants with a Usage Greater than 1,000 Pounds, 1992

CAS[a] Number	Chemical Name	Usage (in lb)
7664939	Sulfuric acid	23,510
71432	Benzene	22,520
75456	Hydrochlorofluorocarbon-22 (HCFC-22)	20,280
7647010	Hydrochloric acid	19,430
71556	1,1,1-trichloroethane	7,320
67641	Acetone	5,370
76131	Chlorofluorocarbon-113 (CFC-113)	5,070
107211	Ethylene glycol	3,670
123911	1,4-dioxane	3,120
78922	Sec-butyl alcohol	3,060
106887	1,2-butylene oxide	3,060
7697372	Nitric acid	2,53
123319	Hydroquinone	1,870
1310732	Sodium hydroxide	1,710
67561	Methanol	1,710
7664393	Hydrofluoric acid	1,540
67663	Chloroform	1,450
75718	Dichlorodifluoromethane (CFC-12)	1,330
8006619	Gasoline	1,310
55630	Nitroglycerin	1,270

[a]Chemical Abstract Services.
lb = pound(s)

Source: Sandia National Laboratories/New Mexico, 1993, "Mixed Waste Landfill Phase 2 RFI Work Plan," SNL/NM, Environmental Restoration Project, Albuquerque, New Mexico.

areas of the highest chemical usage and the heaviest automobile traffic. Monitoring was conducted for VOCs, acid gases, and PM_{10} around Technical Area I. Airborne radionuclide particles were also monitored at the Technical Area III MWL. The MWL contains buried radioactive and hazardous wastes and is a suspected source for contaminated fugitive dust (i.e., wind-blown dust).

The Technical Area I study monitored airborne levels of VOCs, PM_{10} for nonradiological metals and acid gases during a four-month period from May 2, 1992, to September 1, 1992. Monitoring for heavy-metal particulate matter included beryllium, lead, nickel, chromium, and arsenic. As shown in Figure 6-1, six stations around the Technical Area I periphery were selected for the study. Five of the six stations were intentionally located in the direction of the prevailing downwind direction to maximize potentially positive measurements. Other criteria used in site selection included close proximity to potentially affected personnel, to suspected pollutant sources, and to electrical power outlets for the samplers. The five downwind sites were named the Museum Site, the Parade Grounds Site, the Water Tower Site, the Photovoltaic Site, and the Special Studies Site. One Upwind Site was added to ensure pollutant detection in the event of an unusual prevailing wind direction (SNL/NM, 1993). SNL/NM (1993) describes the ambient air monitoring techniques in detail.

The Technical Area III MWL study monitored airborne levels of selected PM_{10} radionuclides. The most significant PM_{10} radionuclides detected during the four-month period from May 2, 1992, to September 1, 1992, included uranium, plutonium-238, and plutonium-239. Three stations were selected for the sampling program. Two stations (the MWL west site and the MWL east site) were intentionally located in the prevailing downwind direction from the MWL to maximize potentially positive measurements. Other criteria used in site selection included close proximity to the MWL and to electrical power outlets for the samplers. One upwind site was located in the prevailing upwind direction to act as a local reference background station, so that results could be compared to downwind sites. Section 6.3 presents the results of the monitoring program.

Air quality monitoring equipment was installed at nine sites in January, 1994. SNL/NM (1995a) reports data for calendar year 1994.

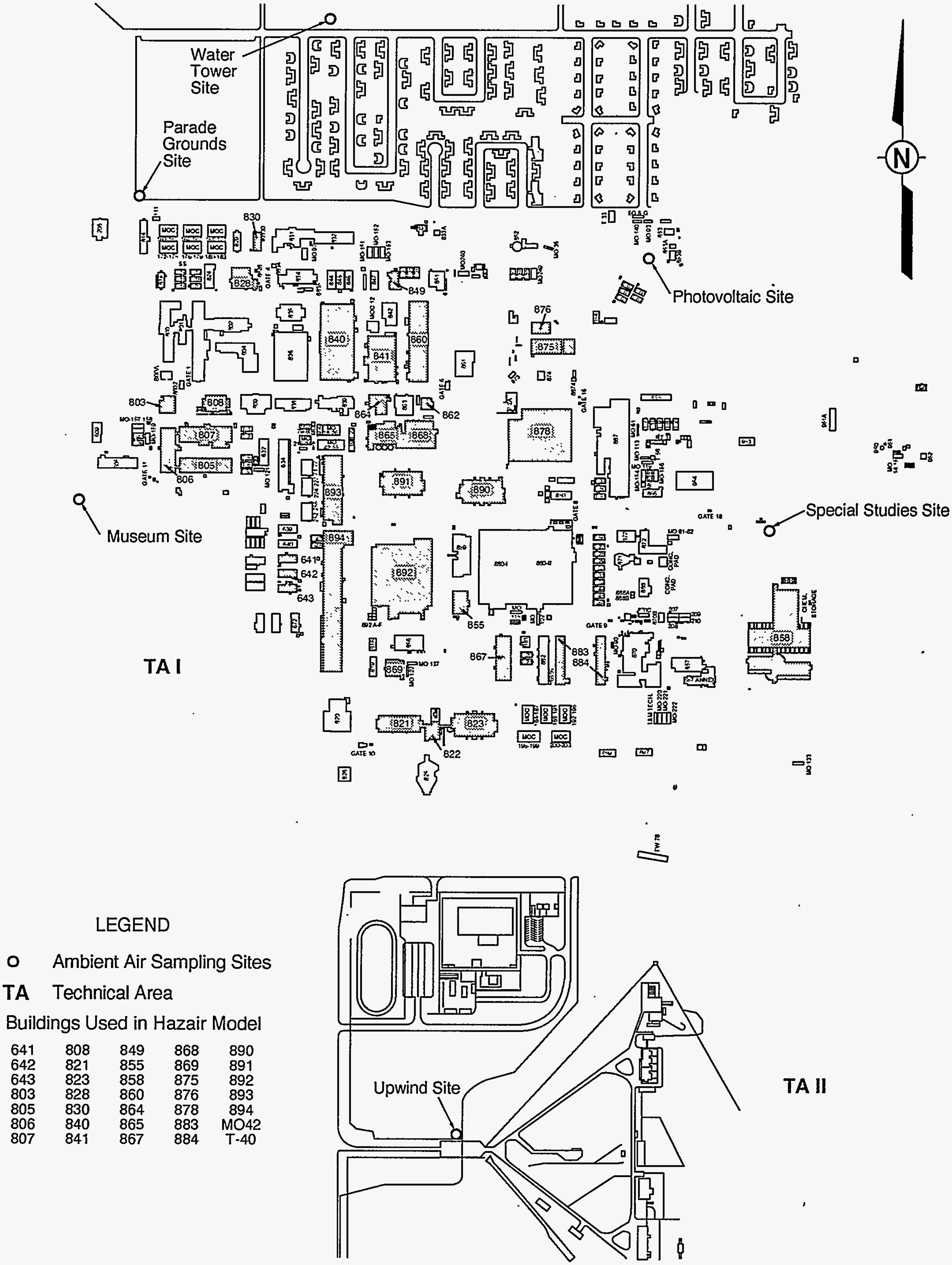


Figure 6-1
Sampling Site Locations and Buildings/Source Locations Used in Hazair Modeling, Technical Area I, Sandia National Laboratories/New Mexico

6.1 Radionuclide Airborne Emissions

The primary radiation sources at SNL/NM are in Technical Area II, Technical Area III, Technical Area IV, and Technical Area V, although there are some small sources in Technical Area I. The radioactive emissions have included argon-41, krypton-85, xenon-133, tritium, nitrogen-13, oxygen-15, iodine-129, uranium-238, depleted uranium, and other gaseous activation and gaseous fission products. Inhalation of airborne radionuclides is the most likely radiological human exposure pathway from SNL/NM operations. SNL/NM submits annual radionuclide emission reports to the DOE under the requirements of DOE Order 5400.1 and the National Emission Standards for Hazardous Air Pollutants (NESHAP). The EPA issues NESHAP permits for new sources and modifications to sources that result in 0.1 milliroentgen equivalent dose in man (mrem)/yr or greater to off-site members of the public. The dose criterion is based upon a potential maximum annual facility release, rather than upon a dose resulting from actual operations. SNL/NM reports radionuclide air emissions in accordance with NESHAP reporting requirements promulgated under 40 CFR Part 61, Subpart H.

Because SNL/NM's radiological air emissions are small and cannot readily be measured, the release data are calculated based on theoretical parameters, such as reactor operating power megajoules per year (MJ/yr) and the conversion factor for the activation products microcuries per megajoule (μCi/MJ) for the generation of noble gases from the reactors in Technical Area V. Releases from these reactors occur from stack exhaust that the AIRDOS-EPA code calculates as a momentum-type plume rise (Moore et al., 1979). Emissions from the Particle Beam Fusion Accelerator II (PBFA-II) in Technical Area IV were not included, because the contributions from this source are small compared to those of the 20 mega-electron-volt (MeV) Gamma Simulation (High Energy Radioactive Megavolt Electron Source-III [HERMES-III]). Descriptions of these facilities are discussed below.

Table 6-2 describes the seven facilities within SNL/NM that produced radioactive emissions in 1990, including the location, the type of operation, the material handled, specific emissions for each, and maximum capacity dosages. These seven facilities include:

- Annular Core Research Reactor (ACRR)
- Sandia Pulsed Reactor (SPR)
- Hot Cell Facility (HCF)
- HERMES-III
- PBFA-II
- SATURN Project
- Neutron Generator Test Facility (NGTF).

Table 6-2

Major Radiological Air Emission Sources
Sandia National Laboratories/New Mexico

Facility	Technical Area/Building Location	Type of Operation	Material Handled	Type of Emission	Calculated Maximum Capacity Dose[a]
ACRR	V/6588	Annular Core Research Reactor	Uranium fuel	Argon-41	<0.1 mrem/yr
SPR	V/6590	Sandia Pulsed Reactor	Enriched uranium	Argon-41	7.5×10^{-4} mrem/yr
HCF	V/6580	Hot Cell Facility	Various reactor fuels	Tritium, Krypton-85, Iodine-129	2.1×10^{-3} mrem/yr
HERMES-III	IV/970	20 MeV Gamma Simulator (photonuclear reactions)	Small quantity of depleted uranium	Nitrogen-13, Oxygen-15	1.3×10^{-4} mrem/yr
PBFA-II	IV/983	Particle Beam Fusion Accelerator	Various targets (mostly nonrad)	Nitrogen-13, Oxygen-15	4.2×10^{-3} Ci/yr[b] 5.0×10^{-3} Ci/yr
SATURN	IV/961	X-Ray Machine (pinch activation)	Deuterium gas	Tritium	7.0×10^{-9} mrem/yr
NGTF	II/935	Neutron Generator Test Facility (explosive tests)	Tritium in metal hydride	Tritium	1.1×10^{-4} mrem/yr

[a]The dose calculated for maximum capacity operation is to the maximally exposed off-site individual.
[b]Curies released in 1993. Calculated maximum capacity dose data not applicable to the PBFA-II operation.

ACRR = Annular Core Research Reactor.
Ci/yr = Curie(s) per year.
HCF = Hot Cell Facility.
HERMES-III = High-Energy Radioactive Megavolt Electron Source.
MeV = Mega-electron Volt.
mrem/yr = Millirem(s) (milliroentgen equivalent dose in man).
NGTF = Neutron Generator Test Facility.
PBFA-II = Particle Beam Fusion Accelerator-II.
SPR = Sandia Pulsed Reactor.

Source: Los Alamos Technical Associates, 1991, "AIRDOS-EPA Data Upgrade and Dose Calculations for Sandia National Laboratories Facilities at Sandia, and Sandia, Tonopah Test Range," prepared for Sandia National Laboratories, Albuquerque, New Mexico.

Calculations indicate that small quantities of radionuclides were emitted to the atmosphere by SNL/NM facilities as a result of 1993 operations. The emissions were so small that they were not measurable with existing monitors at the facilities. Figure 6-2 graphically summarizes the estimated annual air emissions from 1978 to 1993. Table 6-3 summarizes the estimated radiological airborne releases from 11 facilities at SNL/NM for 1994 (SNL/NM, 1995a).

Isokinetic monitoring systems were installed in the stacks of the HCF and the ACRR to collect air samples for gross alpha and beta radioactivity, noble gases, and iodine. Because the air quality data collected in 1992 and 1993 indicated very low emission concentrations, it is anticipated that future continuous emission monitoring will not be required at these facilities.

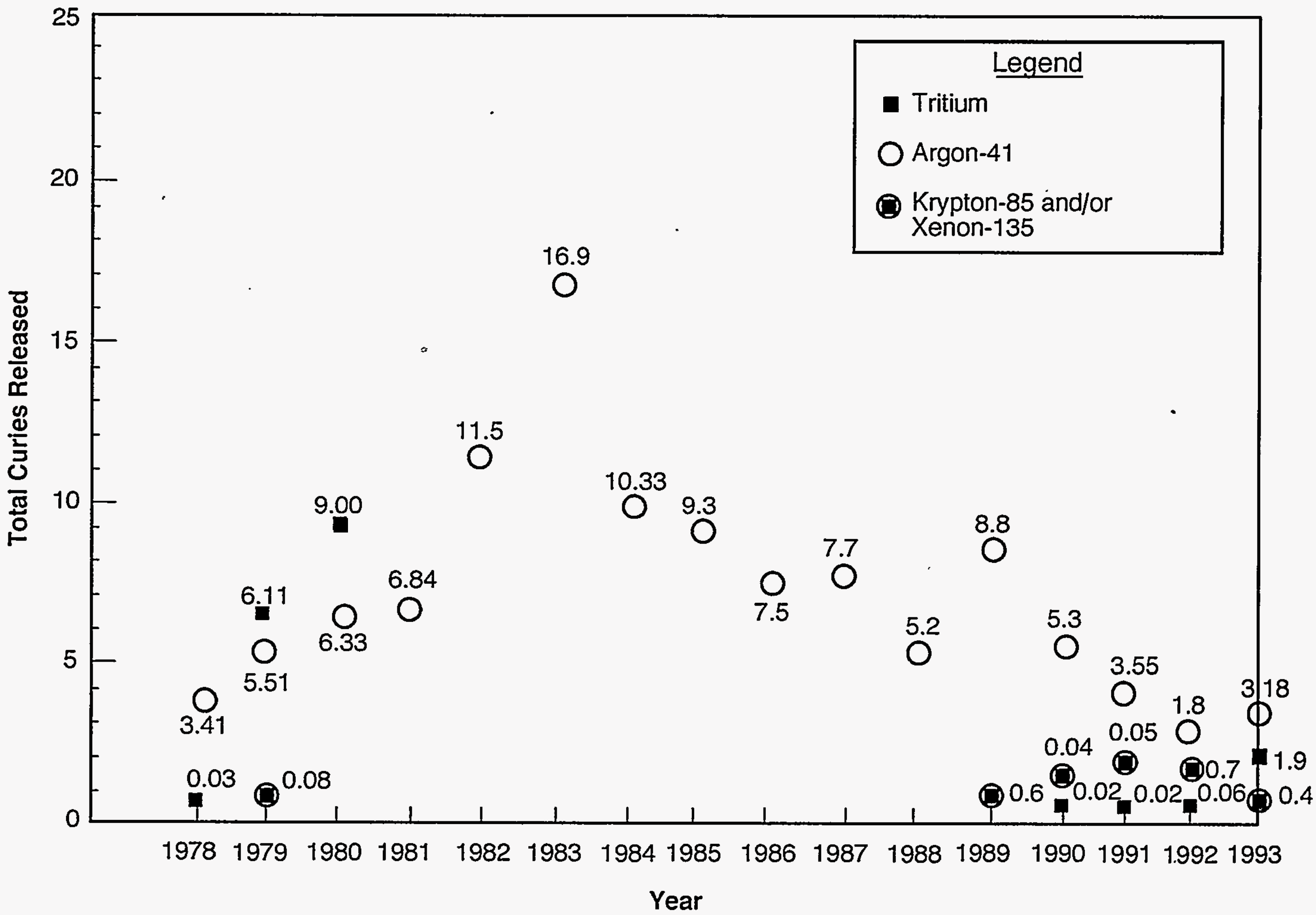
6.2 Nonradiological Airborne Emissions

As stated above, ambient air quality at SNL/NM is regulated through the AEHD APCD. The AEHD APCD has established several ambient air sampling stations throughout the city, including an area near SNL/NM, to monitor TSP, ozone, PM_{10}, carbon monoxide, and NOX. Section 6.5 describes the results of the AEHD APCD air monitoring for PM_{10} and carbon monoxide from 1989 through May of 1991. Several sources at SNL/NM emit nonradiological air pollutants (including NOX, carbon monoxide, sulfur dioxide, VOCs, and particulate matter) that are regulated by the Air Quality Control Regulations (AQCR). The emissions and their sources are listed below and summarized in Table 6-4:

- Hazardous Waste Management Facility (HWMF)
- Microelectronic Development Laboratory (MDL)
- Melting and Solidification Facility (MSL)
- Radiant Heat Testing Facility
- Reentry Burn-up Simulation Facility (ARC-Tunnel)
- Rocket Sled Track
- Thermal Treatment Facility (TTF)
- Lurance Canyon Test Site
- Thermal Test and Analysis Division Facilities
- Five steam boilers.

6.3 Monitoring Results

The results of a four-month-long monitoring study at Technical Area I during 1992 showed that the ambient levels of VOCs, acid gases, nonradioactive metals, and radioactive metals were all within expected background levels or levels normally found in urban ambient air (SNL/NM, 1993). The monitoring results (maximum concentrations measured) were compared to appropriate AQCRs to define air quality in and around the SNL/NM facilities.



(Values reported as less than 1 curie are not to scale)

Figure 6-2
Atmospheric Releases of Argon-41, Tritium, Krypton-85, and Xenon-135 from Sandia National Laboratories/New Mexico Since 1978

Table 6-3

Summary of Estimated Radionuclide Releases from Sandia National Laboratories/New Mexico Facilities for 1994

Facility	Source Type	Radionuclide	Release (Ci/yr)
Annular Core Research Reactor (ACRR), TA-V, Bldg. 6588	Point	Tritium	1.1×10^{-5}
		Argon-41	2.1
		Krypton-83m	1.7×10^{-2}
		Krypton-85	5.7×10^{-6}
		Krypton-85m	6.3×10^{-2}
		Krypton-87	3.2×10^{-2}
		Krypton-88	0.1
		Rubidium-86	1.5×10^{-7}
		Rubidium-87	1.4×10^{-4}
		Rubidium-88	1.9×10^{-2}
		Rubidium-89	4.8×10^{-5}
		Xenon-131m	5.8×10^{-6}
		Xenon-133	3.4×10^{-2}
		Xenon-133m	1.7×10^{-3}
		Xenon-135	0.4
		Xenon-135m	5.1×10^{-3}
		Xenon-137	2.2×10^{-3}
		Xenon-138	1.4×10^{-4}
Calibration Laboratory TA-I, Bldg. 869	Point	Tritium	1.5×10^{-6}
Chemical Processing Laboratory TA-III, Bldg. 6600	Point	Sodium-22	2.4×10^{-12}
		Gadolinium-153	1.0×10^{-13}
		Americium-241	1.0×10^{-13}
Metal Tritide Shelf-Life Laboratory TA-I, Bldg. 891	Point	Tritium	5.0×10^{-9}
Sandia Pulsed Reactor (SPR) TA-V, Bldg. 6591	Point	Argon-41	0.55
High-Energy Radioactive Megavolt Electron Source-III (HERMES-III) TA-IV, Bldg. 970	Point	Nitrogen-13	2.32
		Oxygen-15	3.0×10^{-2}
Particle Beam Fusion Accelerator-II (PBFA-II) TA-IV, Bldg. 983	Point	Nitrogen-13	4.2×10^{-2}
		Oxygen-15	5.0×10^{-3}

Refer to footnotes at end of table.

Table 6-3 (*Concluded*)

Summary of Estimated Radionuclide Releases from Sandia National Laboratories/New Mexico Facilities for 1994

Facility	Source Type	Radionuclide	Release (Ci/yr)
Time of Flight (TOF) TA-I, Bldg. 891	Point	Tritium	6.0×10^{-5}
Tandem Van de Graff Accelerator TA-I, Bldg. 884	Point	Oxygen-14	3.2×10^{-7}
		Oxygen-15	2.1×10^{-3}
		Nitrogen-13	1.2×10^{-4}
		Fluorine-17	8.0×10^{-6}
		Fluorine-18	1.2×10^{-5}
		Carbon-11	5.3×10^{-5}
Radiation Laboratory TA-I Bldg. 805	Point	Nitrogen-16	2.0×10^{-7}
		Americium-241	1.0×10^{-11}
		Argon-41	1.0×10^{-9}
		Curium-244	7.0×10^{-11}
		Lead-210	4.0×10^{-13}
		Plutonium-239	6.0×10^{-12}
		Uranium-natural	4.0×10^{-12}
Mixed Waste Landfill (MWL) TA-III	Diffuse	Tritium	0.29

TA = Technical Area
Bldg. = Building
Ci/yr = Curies per year

Source: Sandia National Laboratories/New Mexico, 1995a, "Site Development Plan," *SAND94-2173*, Sandia National Laboratories, Site Planning, Department 7256, Albuquerque, New Mexico.

Table 6-4
Nonradiological Airborne Emissions

Facility	Technical Area/ Building Location	Materials Handled	Type of Emissions
HWMF	TA-I	Vapor degreasers, solvents, petroleum products, spray paint	VOCs
MDL	TA-I	Hydrochloric acid; hydrofluoric acid	Acid emissions
MSL	TA-III	Metals	Vapors from closed-vacuum induction melting system
Radiant Heat Testing Facility	TA-III	Rubber, plastics, paint	Smoke, fumes from burning during test periods
ARC-Tunnel	TA-III	Nitric acid	Smoke and fumes from boiler combustion; nitric acid fumes
Rocket Sled Track	TA-III	Lead	Toxic discharges, smoke
TTF	TA-III	Explosive wastes	Smoke, fumes
Lurance Canyon Test Site	CTF		Smoke, fumes from burn tests
Thermal Test and Analysis Division Facilities	CTF	Unknown	Smoke, fumes from open burn tests
Five Steam Boilers and Emergency Diesel Generators	Unknown	Diesel	NOX, CO, TSP, SO_2, TOC
Machine Shops	TA-I	Unknown	Particulates
Carpentry Shops	TA-I	Unknown	Particulates
Pattern Shop	TA-I	Unknown	Particulates
Sandblasting Facilities	TA-I	Unknown	Particulates
Construction Sites	TA-I	Unknown	Particulates
Asbestos Abatement Activities	TA-I	Asbestos	Particulates
Steam Plant	TA-I	Unknown	NOX, CO, SO_2
Emergency Diesel Generator Plant	TA-I	Petroleum products	NOX, CO, SO_2
Portable Generators	TA-I	Petroleum products	NOX, CO, SO_2
Foundary	TA-I	Metals	NOX, CO, SO_2

CO = Carbon monoxide.
HWMF = Hazardous Waste Management Facility.
MDL = Microelectronic Development Laboratory.
MSL = Melting and Solidification Laboratory.
NOX = Nitrous oxide.
SO_2 = Sulfur dioxide.
TA = Technical Area.
TOX = Total organic halogen.
TSP = Total suspended particulates.
TTF = Thermal Treatment Facility.
VOC = Volatile organic compound.

The VOC data from Technical Area I were compared to the New Mexico Environment Department (NMED) health-effects screening levels. The NMED uses occupational exposure limits divided by a safety factor of 100 to account for the differences between a healthy working population and more sensitive individuals (such as the young and the elderly) in an entire population. The occupational exposure limits used by the NMED are the time-weighted averages (TWA) published by the National Institute for Occupational Safety and Health. Table 6-5 presents the maximum measured concentrations of VOCs detected during the study in 50 percent or more of the samples taken from the four sites located within Technical Area I. The table shows the analytical detection limit, the frequency of occurrence during the program, the maximum concentration (in parts per billion [ppb]), and the NMED screening values (in ppb) for those compounds with published levels. Normally, either mean or median values are compared with the screening levels; however, for a more conservative comparison, the maximum 24-hour measured pollutant concentrations were used.

Table 6-5 also shows that all but one of the measured maximum concentrations of the monitored VOCs are well below the TWA/100 limits. The one exception is the benzene concentration, which has an extremely low TWA because it is a carcinogen. The maximum benzene concentration measured during the study was 1.9 ppb, with an average concentration of 0.4 ppb. Therefore, the average benzene concentration does not exceed the TWA/100 value when a less conservative but more realistic analysis is performed. Because benzene is a major component in gasoline, it is ubiquitous in the urban environment. When the SNL/NM data for nonradiological parameters are compared with data from other urban areas monitored by the EPA during the Urban Air Toxics Monitoring Program, the average urban benzene concentrations for the 19 cities studied are also above the TWA/100 limit, ranging between 1.4 and 2.0 ppb for the years 1988 through 1990. Thus, SNL/NM may have lower benzene levels than do many urban areas.

Table 6-6 contains the analytical results from acid-gas sampling at the two sites at Technical Area I (one upwind site and one site monitoring station). The background concentrations found in the sampling media were very high compared to the detection limits; therefore, the acid-gas results are not corrected for background concentrations. Even if the media acid-gas contributions are included, the ambient concentrations shown in Table 6-6 were lower than the potential health risk level.

Table 6-5

Most Significant Technical Area I Volatile Organic Compound Measurements[a], 1992

Volatile Organic Compound	Analytical Detection Limit (ppb)	Frequency of Occurrence (%)	Maximum Concentration (ppb)	TWA/100[b] (ppb)
Toluene	0.50	100	5.5	1,000
Ethane	0.20	99	24.5	NA
Ethylene	1.00	99	10.2	NA
Propane	0.20	99	71.3	10,000
Propylene	0.20	98	9.7	NA
Benzene	0.40	98	1.9	1
Acetylene	1.00	98	9.0	NA
Ethanol	0.30	96	6,200	9,570
1-butanol	0.35	95	33.5	500
n-butane	1.00	95	9.6	8,000
n-pentane	0.10	87	13.2	1,200
Acetone	0.62	87	101	2,480
p-xylene + m-xylene	1.00	86	2.8	1,000
Isopentane	0.30	85	19.2	NA
Trichlorofluoromethane	0.50	85	24.9	NA
1,1,1-trichloroethane	0.20	85	4.4	3,480
Methanol (+)	1.53	83	964.0	1,990
Freon-113	0.40	81	1.2	NA
Dichlorodifluoromethane	0.20	81	2.1	10,000
Chloromethane	0.20	75	10.3	NA
Carbon tetrachloride	0.50	72	0.1	20
n-hexane	0.30	72	1.8	500
Butylraldehyde	0.18	68	8.1	NA
3-methylpentane	0.05	67	1.3	NA
Tetrachloroethylene	0.10	66	0.6	250
Methylene chloride	0.20	66	1.4	490
Isohexane	0.20	60	1.5	NA
n-undecane	0.07	58	2.0	NA
Trichloroethylene + BCM	0.02	58	1.0	46
1,2-dichloroethane	0.20	53	0.1	10
Isobutene + 1-butene	0.50	53	7.6	NA
a-pinene	0.07	52	1.1	NA
2,2,4-trimethylpentane	0.10	51	2.8	NA

[a]"Significant" is defined as detectable measurements that were 10 percent or greater of the time weighted average (TWA) divided by 100.

[b]TWA (published by the National Institute for Occupational Safety and Health and the American Conference of Governmental Industrial Hygienists) divided by 100.

ppb = Part(s) per billion.

TWA = Time-weighted average.

Source: Sandia National Laboratories/New Mexico, 1992b, "Chemical Waste Landfill Final Closure Plan

Table 6-6
Summary of Acid Gas Sampling Results[a], 1992

Analyte	Mean Concentration (μg/m³)	Standard Deviation from (μg/m³)	Minimum Concentration (μg/m³)	Maximum Concentration (μg/m³)	TWA/100 (μg/m³)
Site 1					
Fluoride	0.15	0.17	0.02	0.75	25
Chloride	0.48	0.24	0.11	1.0	70
Nitrate	0.65	0.37	0.12	1.6	50
Sulfate	1.0	0.64	0.05	2.6	10
Upwind Site					
Fluoride	0.15	0.15	0.02	0.55	25
Chloride	0.56	0.37	0.09	1.7	70
Nitrate	0.60	0.37	0.13	1.9	50
Sulfate	0.68	0.45	0.10	1.8	10

[a]All results are reported without correction for background concentrations.
μg/m³ = Microgram(s) per cubic meter.

Source: Sandia National Laboratories/New Mexico, 1992b, "Chemical Waste Landfill Final Closure Plan and Post-Closure Permit Modification," Sandia National Laboratories, Albuquerque, New Mexico.

Particulate matter and nonradioactive metal samples were collected at three of the monitoring sites around Technical Area I (including the upwind site). The average PM_{10} concentrations were consistent at all sites, being slightly greater than 10 micrograms per cubic meter (μg/m^3) and differing by less than 3 μg/m^3. The maximum PM_{10} concentration measured during the monitoring program was 106 μg/m^3, which is still well below the National Ambient Air Quality Standards of 150 μg/m^3. Because of the low particulate concentrations and, consequently, because of the low total mass concentrations of the particulate sample, run times were increased from 24 to 72 hours to increase the total particulate mass collected and consequently to lower the analytical detection limits for the metals analyses. The analytical results for metals showed very low levels of the target analytes; none of the maximum values exceeded TWA/100 values. Table 6-7 presents the minimum, maximum, average (as appropriate), and TWA/100 values for metals from the Technical Area I samples.

Table 6-8 presents the average, maximum, and minimum concentrations for PM_{10}, uranium, plutonium, and beryllium for three sampling sites at the Technical Area III MWL. Average PM_{10} concentrations were slightly lower than those measured at Technical Area I, with an average concentration of 10 μg/m^3 and a maximum concentration of 68 μg/m^3. Beryllium was not detected in any sample collected in this area. Uranium was detected at concentrations of 1 to 2 mg/filter, regardless of the volume of air collected. A threefold increase in the sample volume collected did not affect the mass of uranium collected on the filters. This indicates that the small amount of uranium detected in the filter samples may result from analytical background. Plutonium was detected in very low concentrations at the three sites; however, it was not consistently present. Where it was detected, there was little difference among the results from the three sampling locations, suggesting that the detected plutonium did not emanate from the MWL. Even the highest plutonium-238 concentration [1.9 x 10^{-3} picocuries per cubic meter] was an order of magnitude lower than the derived concentration guide value contained in DOE Order 5400.5.

6.3.1 Monitoring Results Conclusions and Recommendations

Pollutant concentrations measured during the 1992 sampling study were considerably lower than any federal, state, or local ambient air quality standards or health-based significance levels (Radian Corporation, 1992). As a result, there are no mandatory requirements to conduct a long-term sampling program. However, a set of recommendations for subsequent sampling was developed in this study to address the DOE Order 5400.1 requirement that each of its facilities

Table 6-7

Summary of Technical Area I Particulate Matter Monitoring Results, 1992

Parameter	Average Concentration (µg/m^3)	Minimum Concentration (µg/m^3)	Maximum Concentration (µg/m^3)	TWA/100 Concentration (µg/m^3)
Site 1				
PM_{10}	13.6	4.5	106.7	150[a]
Nickel	ND	ND	ND	10
Lead	0.004	ND	0.025	0.5
Chromium	ND	ND	0.009	5
Beryllium	ND	ND	0.004	0.005
Arsenic	ND	ND	ND	0.1
Site 2				
PM_{10}	11.5	4.3	24.9	150[a]
Nickel	ND	ND	0.021	10
Lead	0.005	ND	0.012	0.5
Chromium	ND	ND	0.013	5
Beryllium	ND	ND	ND	0.005
Arsenic	ND	ND	ND	0.1
Upwind Site				
PM_{10}	10.9	4.0	22.2	150[a]
Nickel	ND	ND	ND	10
Lead	0.004	ND	0.013	0.5
Chromium	ND	ND	0.009	5
Beryllium	ND	ND	ND	0.005
Arsenic	ND	ND	ND	0.1

[a]Value represents National Ambient air Quality Standard value of 150 µg/m^3.
ND = Not detected.
PM_{10} = Particulate matter.
µg/m^3 = Microgram(s) per cubic meter.

Source: Radian Corporation, 1992, "Results of the 1992 Sandia National Laboratories Hazardous Air Pollutant Baseline Study," prepared by Radian Corporation for Sandia National Laboratories, Albuquerque, New Mexico.

Table 6-8
Summary of Technical Area III Particulate Air Monitoring, 1992

Species	Average Concentration[a]	Maximum Concentration[a]	Minimum Concentration[a]
MWL East Site			
PM_{10}	9.5	18.4	3
Beryllium	ND[b]	ND	ND
Uranium	8.0×10^{-4}	1.4×10^{-3}	2.6×10^{-4}
Plutonium-239 and -240	NA[c]	$2.7 \times 10^{-4} \pm 1.9 \times 10^{-4}$	ND
Plutonium-238	NA	$4.6 \times 10^{-4} \pm 2.7 \times 10^{-4}$	ND
MWL West Site			
PM_{10}	10.5	68.5	0.9
Beryllium	ND	ND	ND
Uranium	6.9×10^{-4}	1.3×10^{-3}	2.4×10^{-4}
Plutonium-239 and -240	NA	$2.5 \times 10^{-4} \pm 2.0 \times 10^{-4}$	ND
Plutonium-238	NA	$1.9 \times 10^{-3} \pm 5.7 \times 10^{-5}$	ND
MWL Upwind Site			
PM_{10}	9.0	19.4	3
Beryllium	ND	ND	ND
Uranium	1.0×10^{-3}	1.4×10^{-3}	2.4×10^{-4}
Plutonium-239 and -240	NA	$2.2 \times 10^{-4} \pm 1.6 \times 10^{-4}$	ND
Plutonium-238	NA	$1.2 \times 10^{-4} \pm 9.2 \times 10^{-5}$	ND

[a]All concentrations in micrograms per cubic meter except for plutonium, which is given in picocuries per cubic meter.
MWL = Mixed Waste Landfill.
NA = Not applicable.
ND = Not detected.

Source: Radian Corporation, 1992, "Results of the 1992 Sandia National Laboratories Hazardous Air Pollutant Baseline Study," prepared by Radian Corporation for Sandia National Laboratories, Albuquerque, New Mexico.

conduct air quality sampling and analysis to address potential environmental impacts. These recommendations were as follows:

- Perform additional sampling if/when SNL/NM emissions have increased significantly.
- Establish long-term sampling sites downwind of major sources as a best management practice at a sensitive receptor location (i.e., school, residential area, or other non-SNL/NM office buildings).
- Establish routine sampling at locations where potential radionuclide fugitive emissions exist (e.g., at locations where contaminated soils are disturbed and the potential for resuspension of dust is greatest).
- Assess whether intermittent activities such as those occurring at burn sites warrant event sampling.
- Coordinate with the City of Albuquerque to establish a criteria pollutant sampling site at SNL/NM for verifying compliance with ambient air quality standards.

An ambient air quality monitoring station has since been established near Building 833A. The 1992 baseline study conducted at Technical Area I of SNL/NM was important both for evaluating the potential for community exposure near the facility and for confirming compliance with applicable standards (Radian Corporation, 1992). The study at the MWL established a solid set of data showing that the existing site is currently not a potential health hazard. It also provides a data set with which to compare future monitoring.

6.4 Air Dispersion Models

Prior to 1992, monitoring of ambient air quality at SNL/NM had not been conducted. Programs, however, that inventoried individual emissions of specific chemicals from identified sources, have been completed annually since 1991, and the 1991 data were used to evaluate the impact of emissions on local ambient air. The 1991 emissions inventory was limited to sources of chemicals specified by SNL/NM as they related to Superfund Amendments and Reauthorization Act, Title III, Section 313, and as listed in 40 CFR §§61.01(a) and (b), excluding radionuclides.

The data for both inventories were restricted to sources within Technical Area I. Figure 6-1 shows which buildings (emission sources) were used in the air dispersion models. These 1991 data, along with meteorological data from the airport, were used as input to an atmospheric dispersion model. The model calculates TWA concentrations of specified air pollutants at defined receptor locations (CCS, 1991).

6.4.1 Model Description

The model used is the EPA-approved Industrial Source Complex Short-Term (ISCST) Atmospheric Dispersion Model, Version 90346 (CCS, 1991), which is generally used to model specific sources at specific locations, with the options defined using EPA guidance. The model accepts input data describing the emission sources from the inventory, stack height and diameter, source location, emission velocity and temperature, and quantity of contaminant emitted per unit of time. Additional input data to the model include description of buildings in the vicinity of the source, desired impact averaging times, receptor locations, and meteorological information.

The 1991 emission sources inventoried in Technical Area I (Table 6-9) generally included stacks and exhaust vents and were considered discrete point sources. Each exhaust vent could have been treated as an individual point source; however, doing so could introduce unnecessary uncertainty into the modeling process. The major problems as described in the report were related to the following three characteristics:

- The emission rate of each vent or hood was not known.
- Modeling each vent as an individual source would require excessive model execution time.
- The actual use of any given vent could change with program requirements, so there is no assurance that any given chemical will always be exhausted through a given vent.

These problems were solved by replacing (in the model) the identified individual vents with a small cluster of pseudo-point sources. This approach is appropriate, because the vents are physically close together, and the emission height and plume rise parameters are similar.

Emissions from buildings with real stacks were modeled using individual stacks. The emission rates for each source (either real or pseudo) were equal to the total building emission, divided by the number of sources used to represent the building. The use of a small number of pseudo-sources to represent a large number of vent sources resulted in a conservative (higher) estimate of contaminant concentration in the atmosphere.

Table 6-9
Monitoring Results and Chemical Air Emission Standards

Daily Max. Impact (8 hr. avg.) (µg/m³)	Chemical Name	Max. Impact Referred to Air. (std. time) (µg/m³)	CAS No.	Percent of OEL/100 (mg/m³)	NMAQCR 201 (equiv. air stds. at 5,500 ft) (µg/m³)	Comments	Other Applicable Reg./Std.
14.825	Acetone	19.1	67641	17.800	94.5	NMHC	
0.626	Acrylonitrile	0.8	107131	0.045	94.5	NMHC	
— 2.706	Arsenic/arsenic compounds	 1.5	7440382	0.002	8.2 122.3	30-day avg. particle	40 CFR 61
0.334	Asbestos	NA	1332214	.1 f/cc	0.0	30-day avg.	40 CFR 61
0.671	Benzene	0.9	71432	0.320	92.3	NMHC	40 CFR 61
— 0.512	Beryllium	NA 0.3	7440417	0.00002	0.00 8.2 gm	30-day avg. Total/24 hr.	40 CFR 61
0.326	1,3-Butadiene	0.4	106990	22.00	93.4	NMHC	
— 2.818	Cadmium compounds	NA 1.6	7440439	0.0005	8.2 122.3	30-day avg. particle	
2.749	Carbon tetrachloride	3.5	56235	0.30	103.1	NMHC	
0.616	Chlorinated benzenes	0.8	108907	3.50	92.3	NMHC	
2.876	Chlorine	NA	7782505	0.03	None	Gas	
1.137	Chloroform	1.5	67663	0.50	103.1	NMHC	
0.028	Chloroprene	0.0	126998	0.35	93.4	NMHC	
—	Chromium/chromium compounds	NA	7440473	0.005	8.2	30-day avg.	
0.279		1.6			122.3	particle	
—	Coke oven emissions (benzene)		8007452	0.001	92.342	NMHC	40 CFR 61
— 2.881	Copper/copper compounds Fume Dust Any particle	 NA NA 1.642	7440408	 0.002 0.01		 8.152 8.152 122.3	 30-day avg. 30-day avg. particle

Refer to footnotes at end of table.

Table 6-9 (*Continued*)

Modeling Results and Chemical Air Emission Standards

Daily Max. Impact (8 hr. avg.) (µg/m³)	Chemical Name	Max. Impact Referred to Air. (std. time) (µg/m³)	CAS No.	Percent of OEL/100 (mg/m³)	NMAQCR 201 (equiv. air stds. at 5,500 ft) (µg/m³)	Comments	Other Applicable Reg./Std.
0.520	Epichlorohydrin	0.671	106898	0.10	94.489	NMHC	
0.595	Ethylene dichloride	0.768	107062	0.40	96.637	NMHC	
3.048	Ethylene glycol	3.932	107211	1.25	96.637	NMHC	
0.028	Ethylene oxide	0.036	75218	0.02	96.637	NMHC	
18.665	Freon-113 (CFCs)	24.078	0	0.45	96.637	NMHC	
0.028	Hexachlorocyclopentadiene	0.036	77474	0.001	92.773	NMHC	
—	Hydrochloric acid	NA	7647010	0.07	None	Gas	
3.194	Hydrochloric acid	1.821			122.276	Aerosol	
3.317	Hydrogen fluoride	1.891	7664393	0.025	122.276	Aerosol	
8.489	Isopropyl alcohol	10.950	67630	9.8	94.489	NMHC	
— — — 2.943	Manganese/manganese compounds Fume Dust Any particle	 NA NA 1.7	7439965	 0.0 0.1	 8.2 8.2 122.3	 30-day avg. 30-day avg. particle	
— 2.739	Mercury/mercury compounds	NA 1.6	7439976	0.00	8.2 122.3	30-day avg. particle	40 CFR 61
9.615	Methyl alcohol (Methanol)	12.4	67561	2.6	103.1	NMHC	
39.250	Methyl chloroform (1,1,1-trichloroethane)	50.6	71556	19.0	96.6	NMHC	
4.505	Methylene chloride	5.8	75092	3.5	103.1	NMHC	
— 2.943	Nickel/nickel compounds	NA 1.7	7440020	0.00	8.2 122.3	30-day avg. particle	
2.977	Nitric acid	1.7	7697372	0.1	122.3	Aerosol	
0.595	Perchloroethylene	0.8	127184	3.4	103.1	NMHC	
0.571	Phenol	0.7	108952	0.2	92.3	NMHC	
2.778	Phosphorus acid	1.6	7664382	0.0	122.3	Aerosol	

Refer to definitions at end of table

Table 6-9 (*Concluded*)
Modeling Results and Chemical Air Emission Standards

Daily Max. Impact (8 hr. avg.) (µg/m³)	Chemical Name	Max. Impact Referred to Air. (std. time) (µg/m³)	CAS No.	Percent of OEL/100 (mg/m³)	NMAQCR 201 (equiv. air stds. at 5,500 ft) (µg/m³)	Comments	Other Applicable Reg./Std.
0.626	Polycyclic organic matter			None	Depends on mixed waste and state		
2.947	Sulfuric acid	1.7	7664939	0.0	122.3	Aerosol	
—	Titanium tetrachloride	NA	7550450	0	8.2	30-day avg.	
0.355		0.2			122.3	Fume	
46.940	Toluene	60.6	108883	3.8	92.0	NMHC	
5.076	Trichloroethylene (TCE)	6.5	79016	2.7	96.6	NMHC	
2.711	Vinyl chloride	3.5	75014	0.1	96.6	NMHC	40 CFR 61
0.028	Vinylidene chloride	0.0	75354	0.2	96.6	NMHC	
51.459	Xylene	66.4	1330207	4.4	91.8	NMHC	
—	Zinc/zinc oxide	NA	7440666	0.1	8.2	30-day avg.	
2.943		1.678			122.3	particle	

CAS No. = Chemical Abstract Service Number.
CFCs = Chloroflourocarbons.
CFR = Code of Federal Regulations.
f/cc = Fibers per cubic centimeter.
ft = Feet.
gm = Gram.
hr = Hour.
µg/m³ = Micrograms per cubic meter.
NA = Not applicable.
NMAQCR = New Mexico Air Quality Control Regulation.
NMHC = Non-methane hydrocarbons.
OEL = Occupational exposure limit.

Source: Creative Computer Services, Inc., 1991, "Final Report Air Emission Inventory and Emission Impact Assessment," Draft, Albuquerque, New Mexico.

6.4.2 Receptor Fields

Three receptor location fields were developed for use in the modeling program (Figure 6-3):

- Receptor field 1 is located at 91-m (300-ft) intervals within the Zia Park and Sandia Base housing area. Other receptors are placed at the Wherry School, the Sandia Base School, the East Preschool, and the Education Center.
- Receptor field 2 outlines the Technical Area I fence with receptors spaced a maximum of 25 m (82 ft) apart.
- Receptor field 3 incorporates receptor field 2 and a square grid of receptors spaced every 91 m (300 ft). The receptor field determines the highest concentrations outside Technical Area I.

Model output can give contaminant concentrations at specified times at any or all of the receptor location nodes set up in the model grid. The general output from the model is the calculated concentration of each chemical at all receptor nodes. That large quantity of data may not all be useful in determining the final impact on air quality. The model can also look through all of these data to extract the maximum concentration values for a given chemical and point out the locations and times when these concentrations will exist. The model output listing the maximum concentrations at specific receptor locations can then be compared to various air quality criteria to determine compliance or impact.

6.4.3 Meteorological Data for the ISCST Model

Meteorological data used with the ISCST model included wind speed, wind direction, and atmospheric stability class data processed from the hourly 1987 Albuquerque National Weather Service observations. The year 1987 represented the most recent year of data available from the EPA. Figure 6-4 shows the average windrose diagram for the period from 1983 to 1991, based on data collected at the ABQ.

6.4.4 Land Use

The rural land-use type option was selected for use in the air dispersion model for SNL/NM. Selection of the rural option was made by examination of area land-use maps following the method proposed by CCS (1991), which considers land-use types. Review of land-use maps and field verification by technical consultants concluded that the majority of land was rural; and to be considered urban, it would have required that one of the following four classifications extend over a large area (CCS, 1991):

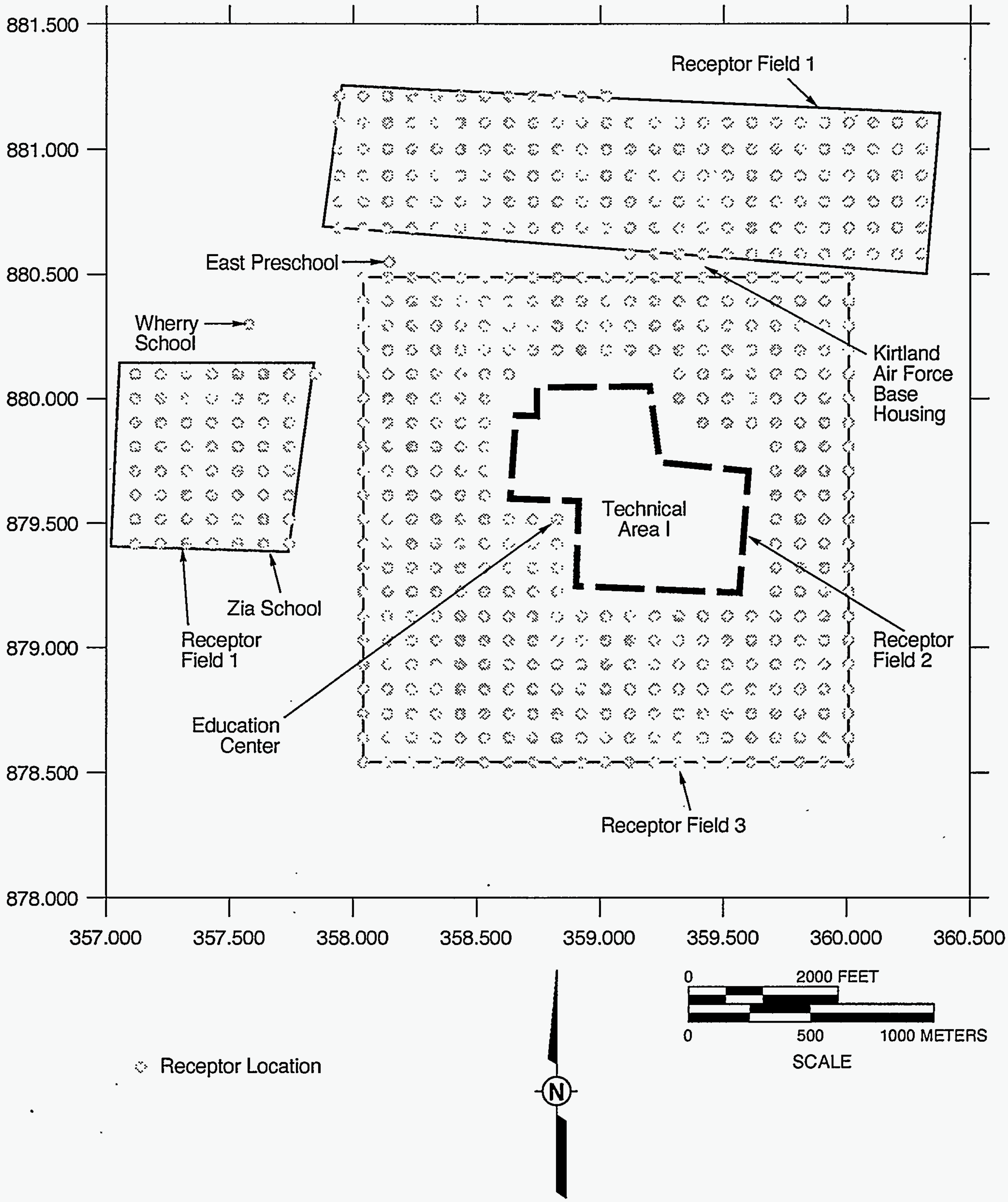
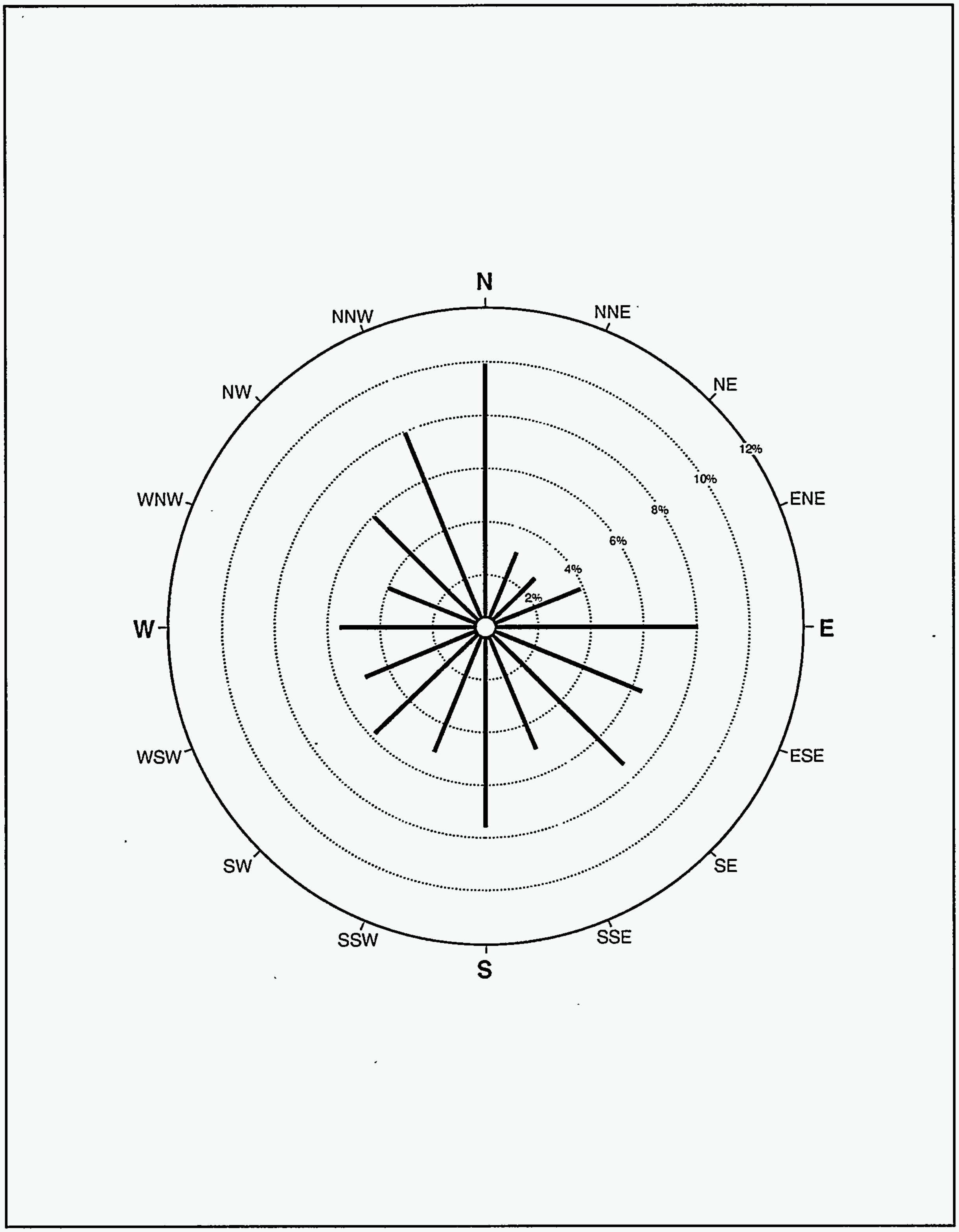


Figure 6-3

Combined Receptor Field Locations for Air Dispersion Modeling at Technical Area I



Note:Windrose indicates direction from which the wind blows. (Windrose Frequency in Percent Time.)

Figure 6-4
Average Annual Wind Direction, Albuquerque International Airport (1983–1991)

- Heavy industrial
- Light to moderate industrial
- Commercial
- Compact residential.

The land in and around Technical Area I did not meet this requirement; therefore, the rural option was selected for modeling purposes.

6.5 Summary and Comparison of Modeling Results and Monitoring Data

The impact on the ambient air of each chemical inventoried was calculated or estimated using the air-dispersion model. The impact was estimated at each of the 477 receptor points located along the Technical Area I fence and outside the area at a distance of 1 km (0.6 mi) from a point inside Technical Area I, located at E359.000, N879.500 (Figure 6-3). This point represents the center of the grid with receptor points 1 km (0.6 mi) away from the point. The location was selected after considering the meteorological data used in the modeling effort. Air dispersion models indicated that 1 km (0.6 mi) was sufficient to locate the maximum impact points. No receptors located within Technical Area I were considered. The most useful product from the model output is the estimated maximum 8-hour average concentrations calculated for each chemical and the location(s) in which they were calculated to occur (Table 6-9).

Analyses of modeling data were used to determine the compliance of any particular SNL/NM source with the New Mexico air standards. Compliance with standards is performed on an individual-source basis. That is, each individual source of an individual chemical must be considered by itself for compliance with the applicable standard. The model output was based on consideration of all of the sources in Technical Area I for each chemical in the inventory. Thus, the total impact for a given chemical from all sources does not exceed air quality standards.

When comparing the calculated maximum 8-hour concentrations model to the New Mexico standards, the air quality standards were referenced or adjusted to an elevation of 1675 m (5500 ft). The model results indicate that all of the ambient impacts of the emissions of all of the chemicals in the inventory are in compliance with the New Mexico standards. Although not directly comparable, the air-dispersion modeling results are supported by the 1992 ambient-air monitoring data. Both model results and monitoring data indicate that SNL/NM does not degrade local air quality and that all air quality parameters are within regulatory compliance guidelines.

6.6 Air Quality in the Southeast Heights

Atmospheric dispersion is a function of wind speed, duration, and direction; atmospheric stability; and mixing depth. Dispersion conditions are generally good if winds are moderate to strong, if the atmosphere is of neutral or unstable stratification and if there is a deep mixing layer. Less favorable dispersion conditions may occur when the wind speed is light and the mixing layer is shallow. These conditions are most common during the late fall and winter, when moderately to extremely stable atmospheric stratification exists.

Less favorable conditions also occur periodically for surface and low-level releases in all seasons from about sunset to about an hour after sunrise as a result of ground-based temperature inversions and shallow mixing layers. Occasionally there are extended periods of poor dispersion conditions that are associated with stagnant air in stationary high-pressure systems that occur primarily during the winter months. This stagnation is intensified by the mountain-valley geomorphology, with the Rio Grande Valley to the west and the Manzano Mountains to the east.

Currently Albuquerque has a citywide air monitoring program. Station 2ZN near Wilson Elementary School, located approximately 3 km (2 mi) northwest of Technical Area I, is the monitoring station closest to SNL/NM. Air monitoring data collected by the city from 1988 through 1990 in the city's southeast heights were evaluated for PM_{10} and carbon monoxide. The results indicated that air quality in the southeast heights has improved steadily from 1988 to 1990. In 1988 to 1989, the maximum PM_{10} reading was 77 mg/m^3 [2.4 x 10^{-13} grains/cubic feet (ft^3)] with 47 observations between 1 and 80 mg/m^3 (3 x 10^{-15} to 3 x 10^{-13} grains/ft^3). In 1990 to 1991, the maximum PM_{10} reading was 56 mg/m^3 (1.8 x 10^{-13} grains/ft^3), with 31 observations between 1 and 80 mg/m^3 (3 x 10^{-15} to 3 x 10^{-13} grains/ft^3) (COA, 1991a). Results of the City of Albuquerque ambient air monitoring for 1992 and 1993 showed no exceedances of these measured pollutants at the station near SNL/NM.

6.7 Carbon Monoxide Emissions from SNL/NM Vehicular Traffic

Carbon monoxide (CO) emissions have been calculated for vehicle traffic in and around SNL/NM. Emissions were modeled using numerous input parameters including but not limited to altitude, temperature, vehicle speed, and miles traveled, adjustment for exhaust emission rates, fuel volatility, and other parameters. The report "Estimation of the Carbon Monoxide Emissions due to Sandia National Laboratories Commuter and On-base Traffic for Conformity

Determination" (SNL/NM, 1995c), summarizes the results of this study. Table 6-10 summarizes total vehicular CO emissions at SNL/NM during 1995.

Table 6-10

Total Vehicular CO Emissions due to SNL/NM Activity for the Year 1995

Commuter	On-Base	Explanation of Equation Factors
37,727		Total KAFB commuters/day.
x .36		Estimated fraction caused by SNL/NM.
13,582	600	SNL/NM vehicles/day.
x 30	x 30	Miles/day/vehicle.
407,452	18,000	Total miles/day.
x 34.6	x 34.6	Emission factor (grams/mile).
1.41E7	6.22E5	CO emissions (grams/day).
x 1.10E–6	x 1.10E–6	Conversion: grams to tons.
15.5	0.69	CO emissions (tons/day).
x 261	x 261	Working days/year.
4,047	179	CO emissions (tons/year).
4,047 + 179 = 4,226 tons/year TOTAL		

Source: Sandia National Laboratories/New Mexico, 1995c, "Estimation of the Carbon Monoxide Emissions due to Sandia National Laboratories Commuter and On-base Traffic for Conformity Determination."

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7.0 Noise

This section provides an overview of SNL/NM noise sources and conditions. Except for noise baseline data collected for the ABQ and for the area east of Technical Area II, existing information is limited. A study of noise and vibration impacts from the SNL/NM Sol se Mete Aerial Cable Facility (ACF) was conducted in support of an EA (Matise et al., 1994); however, site-wide comprehensive noise monitoring has not been conducted for SNL/NM.

In order to present baseline noise conditions at SNL/NM, it is important to define the terminology used in noise studies. This will assist the lay reader in understanding the subject of noise and refamiliarize the technical reader with certain terms, defined in the Glossary (see Chapter 15.0).

7.1 Overview of Noise Sources

Familiar noises are recorded as decibels (Table 7-1). Noise sources in the vicinity of SNL/NM can be categorized into two major groups: transportation and stationary-type sources. Transportation sources are associated with moving vehicles that result in fluctuating noise levels above the ambient noise level for a short period of time. Transportation sources include aircraft, motor vehicles, and rail operations. An exception to this definition is a busy highway, which, when heard from a distance, results in a nonfluctuating transportation noise source. This type of source would sound like a constant low hum from such a distance. Stationary noise sources are those that either do not move or move relatively short distances. Noise-level fluctuations from stationary sources result from operational characteristics and other factors. Stationary noise sources in the vicinity of SNL/NM include items such as ventilation systems, air compressors, generators, power transformers, and earth-moving equipment.

The most pervasive type of noise found at SNL/NM is that of aircraft operations. The ABQ is located due west of SNL/NM. The major runways (oriented east/west) are adjacent to, and flight lines pass directly over, SNL/NM property. In addition, KAFB is located on the same property as SNL/NM and utilizes ABQ runways through a joint-use agreement. Operational commercial and military aircraft dominate all other noise sources that influence noise levels at SNL/NM, both in loudness and in percent contribution to above-average sound levels. Flight information provided by the ABQ in the Monthly Airfield Operations Report for January through December 1994 indicates that an average of 600 civil and military flight operations occur daily (ABQ, 1994). (The term "operation" refers to either one departure or one approach.) Military aircraft

Table 7-1

Typical Noise Levels in A-Weighted Decibels for Common Sounds

Noise Levels for Typical and Critical Sounds (dBA)[a]	Description of Typical and Critical Sounds[b]
140	(Threshold of pain)
121	Concord supersonic transport jet (near take-off flight path)
120	(Threshold of discomfort)
115	Pneumatic chipper at 5 feet (1.5 m)
110	Boeing 707 (near take-off flight path)
105	Diesel locomotive at 50 feet (15 m)
85	Diesel truck at 40 mph (64 kph) at 50 feet (15 m)
65	(Speech interference)
60	Conversation at 3 feet (0.9 m)
50	(Sleep interference)
40	Quiet room
0	Threshold of hearing

[a]The sound levels are shown on a logarithmic scale and are presented in adjusted, or A-weighted, decibels (dBA). A 6-decibel increase will be perceived as a doubling in noise level.

[b]Descriptions of critical sounds are in parentheses.

mph = miles per hour
kph = kilometers per hour
m - meter(s)

Sources: Noise Technical Assistance Center, 1988, "Community Noise Control Course Manual," Rutgers, The State University of New Jersey, New Brunswick, New Jersey, p. 2.

U.S. Environmental Protection Agency (EPA), 1978, "Protective Noise Levels—Condensed Version of EPA Levels Document," *EPA 550//9-79-100*, EPA Office of Scientific Assistant to DAA/Noise, Washington, D.C., pp. 1-25.

Wilson, C. E., 1989, *Noise Control—Measurements, Analysis, and Control of Sound and Vibration*, Harper and Row Publishers, New York, pp. 413-439.

contribute an average of 85 operations daily. Although aircraft noise is the dominant source type, it is also a periodic source, with maximum noise levels associated with take-off and landing operations. Take-off and landing flight paths for both civil and military operations vary according to meteorological conditions and air traffic volume through ABQ. Also, the type of aircraft that use ABQ influence the noise environment at SNL/NM (i.e., small commercial planes versus jet aircraft).

Motor vehicle (highway) noise is also prevalent at SNL/NM. On-site traffic as well as traffic on nearby roadways and major highways contribute to the overall noise levels at SNL/NM. The fluctuation of highway noise (over long periods of time) is associated with the time of day in which peak and off-peak traffic occurs. In addition, noise levels are influenced by vehicle type, road-surface conditions (wet or dry), and exhaust systems.

The least prevalent transportation noise source is that produced by rail operations. No major commuter or freight rail lines or yards are located near SNL/NM that could affect sound levels throughout SNL/NM property. Freight lines that are present on SNL/NM property may elevate noise levels for short periods of time on some portions of the facility.

Stationary noise sources that may influence the noise levels at SNL/NM include but are not limited to ventilation systems, air intake for electrical generating stations, and mechanical and construction equipment. These types of sources, when operated individually, produce noise levels with characteristics that can be predicted or measured. When these sources operate simultaneously, the noise environment becomes very complex, and it is difficult to predict or measure the noise levels from individual sources. Stationary noise sources, grouped together for easy measurement and prediction, may be compared to ambient noise levels.

Construction and industrial type stationary sources, found throughout the SNL/NM property, are concentrated mostly near the different technical areas. These types of sources contribute to the overall noise levels at SNL/NM.

7.2 Existing Noise Data

This section describes the studies from which noise data were obtained and how the data characterize the baseline noise levels at SNL/NM. Monitoring and modeling studies have contributed to the determination of baseline noise conditions. A description of the studies is presented below.

Noise studies have been conducted on both SNL/NM property and surrounding areas. Three surveys are discussed below that provide an estimated approximation of the sound level ranges experienced at SNL/NM. Two of the surveys utilized sound monitoring instrumentation. It should be emphasized that the results of these monitoring studies represent the particular conditions on those days during which monitoring took place and that longer-term studies are required in order to verify the existing monitoring data. The two instrumentation monitoring studies used for this baseline report are:

- A preliminary noise monitoring program conducted as part of the ABQ noise compatibility study in areas surrounding the airport.
- A noise monitoring study to establish background/aircraft and Technical Area II operational noise in areas east of Technical Area II.

A third survey was conducted at the Sol se Mete ACF to provide technical documentation for an EA. This survey was prepared from facility data generated from modeling efforts. A brief description of the three studies and their results follows.

7.2.1 ABQ Noise Monitoring Program

A noise monitoring program was conducted by Greiner, Inc. (1990), as part of a 1982 airport noise compatibility study. The monitoring program was designed, according to Federal Aviation Administration guidelines, to provide both 24-hour noise exposure data and selected individual fly-over noise data at various sites surrounding the airport. The measurements obtained during the study were applicable to the specific time period that was monitored. They do not necessarily reflect the average conditions presented at the individual monitoring sites over a long period of time.

Six monitoring locations were chosen for 24-hour measurements: the residential area west of the airport near Rio Grande High School; the Veteran Administration Hospital; the KAFB guardhouse off Eubank Boulevard near the SNL/NM complex and Kirtland Building 20686; the Four Hills Mobile Home Park; a residential area in the Northeast Heights; and the Four Hills Country Club area. Other sites, typically for short-duration overflight studies, were identified and monitored when conditions existed for aircraft operations in those areas. Simultaneous monitoring was conducted at the various sites during each 24-hour monitoring period using two Bolt, Beranek, and Newman Model 614 portable sound-level meters. The meters recorded ambient sound levels on the A-weighted scale. They also produced hourly summaries, sound-exposure levels, and maximum-noise levels (Greiner, Inc., 1990). Table 7-2 summarizes the data.

7.2.2 Technical Area II Noise Monitoring Program

A second monitoring program was conducted during the fall of 1990 by IT Corporation to establish background and aircraft noise levels and current Technical Area II operational noise levels in areas east of Technical Area II (IT, 1990b). The monitoring program's measurements were obtained on a continuous (real-time) basis in the following center band frequencies: 31.5, 63, 125, 250, 500, 1000, 2000, 4000, and 8000 Hertz. Two monitoring locations simultaneously recorded sound-level data in the aforementioned frequencies from 7 a.m. to 6 p.m. for five days. The first monitoring location was near the mobile home park, approximately 1.6 km (1 mi) east of SNL/NM; the second was adjacent to Technical Area II, approximately 469 m (1,540 ft) east of Building 907. The sound-level measurements were collected and recorded with Bruel and Kjaer (B&K) Model 2143 Real-Time Frequency Analyzers, B&K Model 2639 Pre-Amp and Cable Interfaces, and B&K Model 4165, 1 cm (0.39 in) Free Field Microphones (IT, 1990b). Table 7-3 summarizes the data.

7.2.3 Noise Investigation of the Sol se Mete ACF

A third study was conducted on noise and vibration from the Sol se Mete ACF (Matise et al., 1994). Figure 7-1 shows the Sol se Mete ACF study location. Numerous sources of noise were identified, including vehicles and trucks, construction equipment, generators, testing operations, and air traffic. Air traffic was considered to be the greatest contributor to noise at the Sol se Mete ACF.

Noise impacts were assessed by models that incorporated various parameters. The ABQ runways are located approximately 15.3 to 16.9 km (9.5 to 10.5 mi) west-northwest of the Sol se Mete ACF. Noise modeling was based on the assumption that there are 220 commercial and 120 air taxi (commuter) operations at ABQ daily. Assumptions on types of aircraft, distance of approach or take-off from the Sol se Mete ACF, sound absorption in air, sound attenuation rate, and other parameters, as appropriate, were incorporated into the model.

Table 7-2

Noise Level Ranges and Day/Night Averages Measured in Areas Adjacent to North and East Sections of SNL/NM, 1982

Area	Maximum Hourly Noise Level Ranges (dBA)	L_{dn} (dBA)
Site C (KAFB Guardhouse at Eubank Blvd. Entrance)	82-95	68
Site D (Four Hills Mobile Home Park on Ram SE)	76-93[a]	62
Site F (Lampost Circle in the Four Hills Country Club Area)	64-86	59
Site G (KAFB at Building 20686 North of Runway 8-26)	90-102[a]	75

[a]These maximum hourly noise levels coincide with peak airport operational hours.

Source: Greiner, Inc., 1990, "FAR Part 150 Noise Exposure Maps and Noise Compatibility Plan for Albuquerque International Airport," Albuquerque, New Mexico.

SNL/NM = Sandia National Laboratories/New Mexico
dBA = A-weighted decibels
KAFB = Kirtland Air Force Base
Blvd. = Boulevard
SE = Southeast
L_{dn} = Day-night average sound level

Table 7-3

Average and Maximum Noise Levels as Measured in Areas East of SNL/NM Technical Area II, Fall 1990

Area	Background/Aircraft Noise (dBA)[a]		TA-II Operational Noise (dBA)
	Average	Maximum	Maximum[b]
Location No. 1 (Near mobile home park adjacent to SNL/NM, east of Technical Area II)	47.9	85.8	Not Applicable
Location No. 2 (1,540 ft east of Bldg. 907 on SNL/NM property)	54.1	93.7	83.1

[a]The A-weighted noise levels presented in this Table have been estimated by combining octave band noise-level data collected during the fall 1990 noise survey. The levels are given in adjusted decibels (dBA).

[b]Technical Area II operational noise occurred as peaks; therefore, only maximum noise levels are available. The maximum noise level at Location No. 1 did not result from Technical Area II operations; therefore, it is not applicable.

SNL/NM = Sandia National Laboratories/New Mexico
ft = Feet

Source: IT Corporation (IT), 1990b, "Sandia National Laboratories Sound Level Monitoring Report for Background, Aircraft and Tech Area II Operations," prepared for Sandia National Laboratories, Albuquerque, New Mexico.

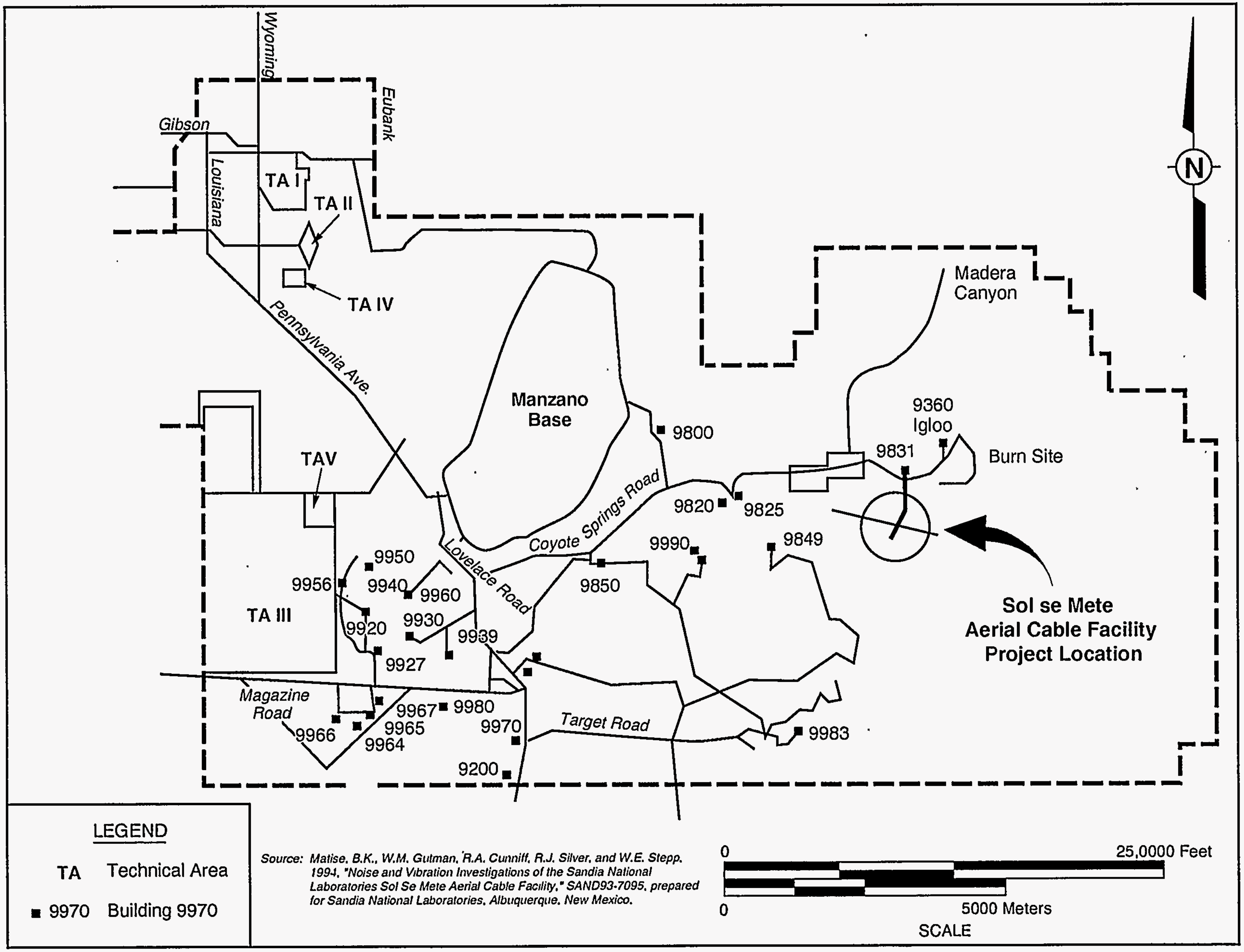


Figure 7-1
Location of Sol se Mete Aerial Cable Facility

Noise from military activity was modeled after data generated from a study of the SNL/NM North Thunder Range, located 8 km (5 mi) west of the Sol se Mete ACF. This model took into account the altitude of the military craft, the ground topography at the Sol se Mete ACF, and numerous other parameters. All of the data generated from the civilian and military models were utilized to generate decibel averages. Two methodologies were used to mathematically compute average decibels per day generated from aircraft noise. The most conservative model indicated a daily average of 70.1 dBA per day that would be generated by aircraft noise at the Sol se Mete ACF (Table 7-4).

Another significant source of noise identified in the Sol se Mete ACF study is noise generated from high-explosives (HE) testing. This type of noise is an "impulse sound," which though not of long duration, is of high intensity in the case of HE testing, and can result in sound pressure levels exceeding 115 decibels (dB) (the SNL/NM-mandated limit in which hearing protection for workers is required) (Table 7-5). HE testing is conducted up to 100 times per year.

Rocket boosters also contribute significantly to short-term, high-intensity noise levels at the Sol se Mete ACF. Receptor locations can be subject to 97 to 148 A-weighted decibels (dBA) during a motor-firing episode. The actual motor-burn duration during a firing episode is approximately one second. Table 7-6 summarizes sound levels at receptor locations.

7.3 Existing Noise Conditions

Existing noise-level ranges for several areas of SNL/NM have been estimated using the noise data presented in Section 7.2. Figure 7-2 provides the noise-level ranges for the northern section of SNL/NM, near Technical Area I, Technical Area II, and Technical Area IV east of the ABQ east/west runway. Much of these SNL/NM Technical Areas lies within the ABQ east/west runway day-night average sound levels (L_{dn}). The L_{dn} can be simply defined as the average sound level during a 24-hour period with a 10-decibel penalty applied to noise events occurring at night. The ABQ 75, 70, and 65 L_{dn} contours extend north, south, and east of the ABQ runway into KAFB and SNL/NM (Coffman Associates, 1993).

According to the monitoring data, the overall noise-level range for this section of SNL/NM is 54 to 102 dBA. The higher-intensity noise levels (90 to 102 dBA) were recorded at Monitoring Location G, near Building 20686, during peak airport operational hours. Noise levels ranging from 54 to 95 dBA were recorded at different locations east of monitoring Location G along the

Table 7-4

Computation of L_{eq} (8)[a] and L_{dn}[a] Due to Aircraft Operations

Noise Source (category)	SEL[b] (dBA)	No. of Day Events	No. of Night Events	Contribution to $L_{eq}(8)$	Contribution to L_{dn}
Boeing 727	67.6	71.5	38.5	65.4	68.6
2-engine turboprop	49.6	48.0	12.0	45.6	46.3
F-15 takeoff, overhead	76.7	2.1	0.1	59.1	56.1
F-15 takeoff, 1 mile	64.8	2.1	0.1	47.2	44.2
F-15 takeoff, 3 miles	58.2	2.1	0.1	40.6	37.6
5-15 approach, overhead	57.4	2.1	0.1	39.8	36.8
F-15 approach, 1 mile	46.5	2.1	0.1	28.9	25.9
F-15 approach, 3 miles	39.9	2.1	0.1	22.3	19.3
C-130 takeoff, overhead	59.4	0.2	0.1	31.6	34.6
C-130 takeoff, 1 mile	48.6	0.2	0.1	20.8	23.8
C-130 takeoff, 3 miles	42.1	0.2	0.1	14.3	17.3
C-130 approach, overhead	57.1	0.2	0.1	29.3	32.3
C-130 approach, 1 mile	44.5	0.2	0.1	16.7	19.7
C-130 approach, 3 miles	37.4	0.2	0.1	9.6	12.6
HH-53, overhead	81.9	1.1	0.4	61.5	63.4
HH-53, 1 mile	71.8	1.1	0.4	51.4	53.3
HH-53, 3 miles	65.6	1.1	0.4	45.2	47.1
$L_{eq}(8)$ (all aircraft sources)	67.7	—	—	—	—
L_{dn} (all aircraft sources)	70.1	—	—	—	—

[a]$L_{eq}(8)$ = Equivalent sound level for an 8-hour day. L_{dn} = Day-night average sound level. (Data generated from models.)
[b]SEL = Sound exposure level.

Source: Matise, B. K., W. M. Gutman, R. A. Cuniff, R. J. Silver, and W. E. Stepp, 1994, "Noise and Vibration Investigations of the Sandia National Laboratories Sol se Mete Aerial Cable Facility," SAND93-7095, prepared for Sandia National Laboratories, Albuquerque, New Mexico.

Table 7-5

Noise Levels at Several Sites Due to Detonation of High-Explosive Charges at the Sol se Mete Aerial Cable Facility South Arena, SNL/NM

Explosive Yield (kg HE[a] [lb HE])	Sound Pressure Level (dB)			
	Building 9831	Building 9825	Sol se Mete Spring	Nearest Housing
1.4 (3)	126	111	122	107
1.8 (4)	127	112	123	108
22.7 (50)	135	120	131	116
54.4 (120)	137	123	133	119
454.0 (1,000)	144	130	140	126

[a]HE = High explosive
SNL/NM = Sandia National Laboratories/New Mexico
kg = Kilogram
lb = Pound
dB = Decibel(s)

Source: Matise, B. K., W. M. Gutman, R. A. Cuniff, R. J. Silver, and W. E. Stepp, 1994, "Noise and Vibration Investigations of the Sandia National Laboratories Sol se Mete Aerial Cable Facility," SAND93-7095, prepared for Sandia National Laboratories, Albuquerque, New Mexico.

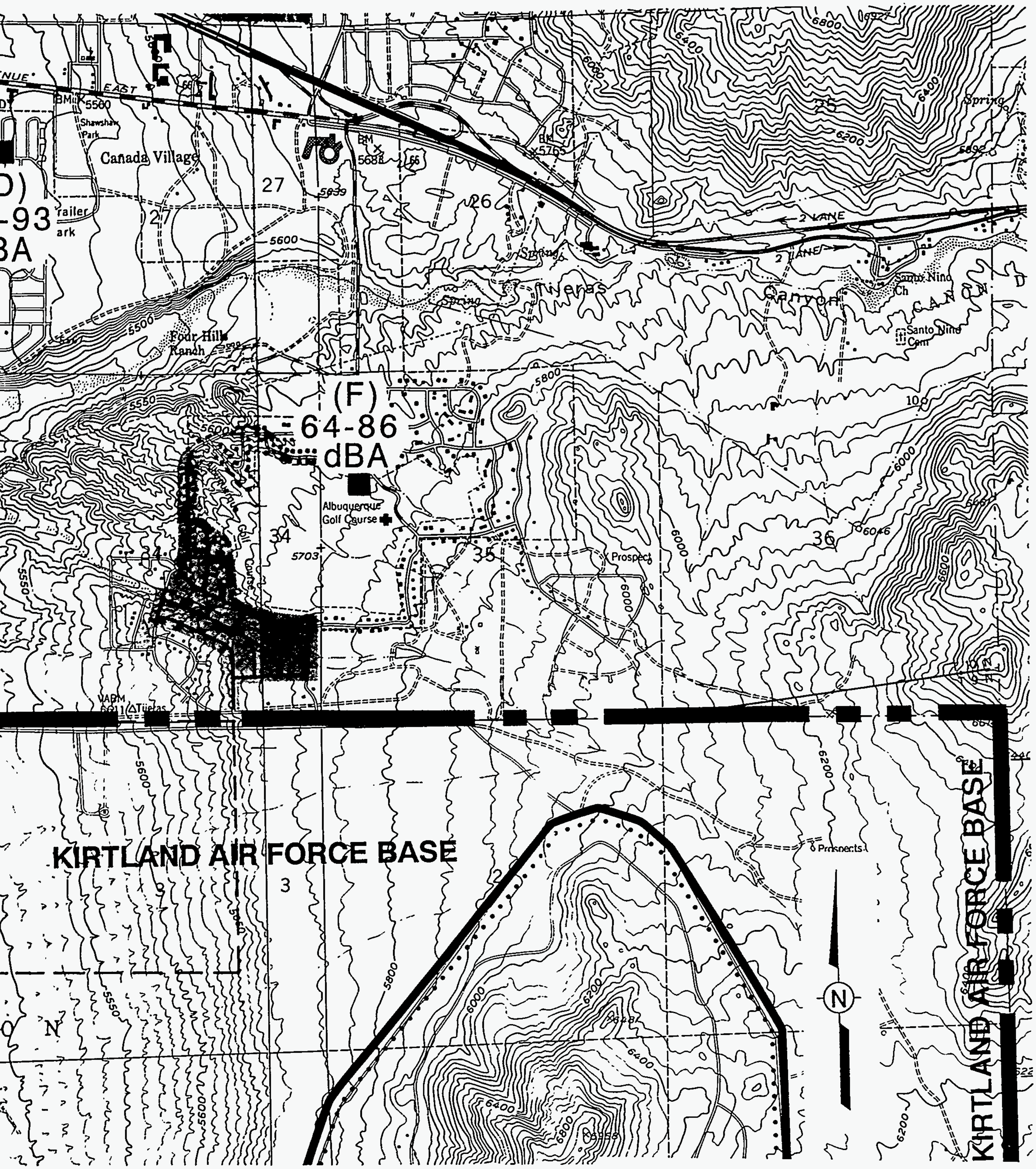
Table 7-6

Sound Levels at Sandia National Laboratories/New Mexico Receptor Locations

Location	Noise Level (dBA)[a]							
	Single Motor on Sled	Single Motor on Cable	Five Motors on Sled	Five Motors on Cable	Ten Motors on Sled	Ten Motors on Cable	Twenty-five Motors on Sled	Twenty-five Motors on Cable
Source (15.2 m)	141	141	144	144	146	146	148	148
Nearby Area (100 m)	125	125	128	128	130	130	132	132
Building 9831 (1.3 km)	101	101	104	104	106	106	108	108
Sol se Mete Spring	97	98	100	101	102	103	104	105

[a]dBA = Adjusted decibels
m = Meter(s)
km = Kilometer(s)

Source: Matise, B. K., W. M. Gutman, R. A. Cuniff, R. J. Silver, and W. E. Stepp, 1994, "Noise and Vibration Investigations of the Sandia National Laboratories Sol se Mete Aerial Cable Facility," SAND93-7095, prepared for Sandia National Laboratories, Albuquerque, New Mexico.



undary

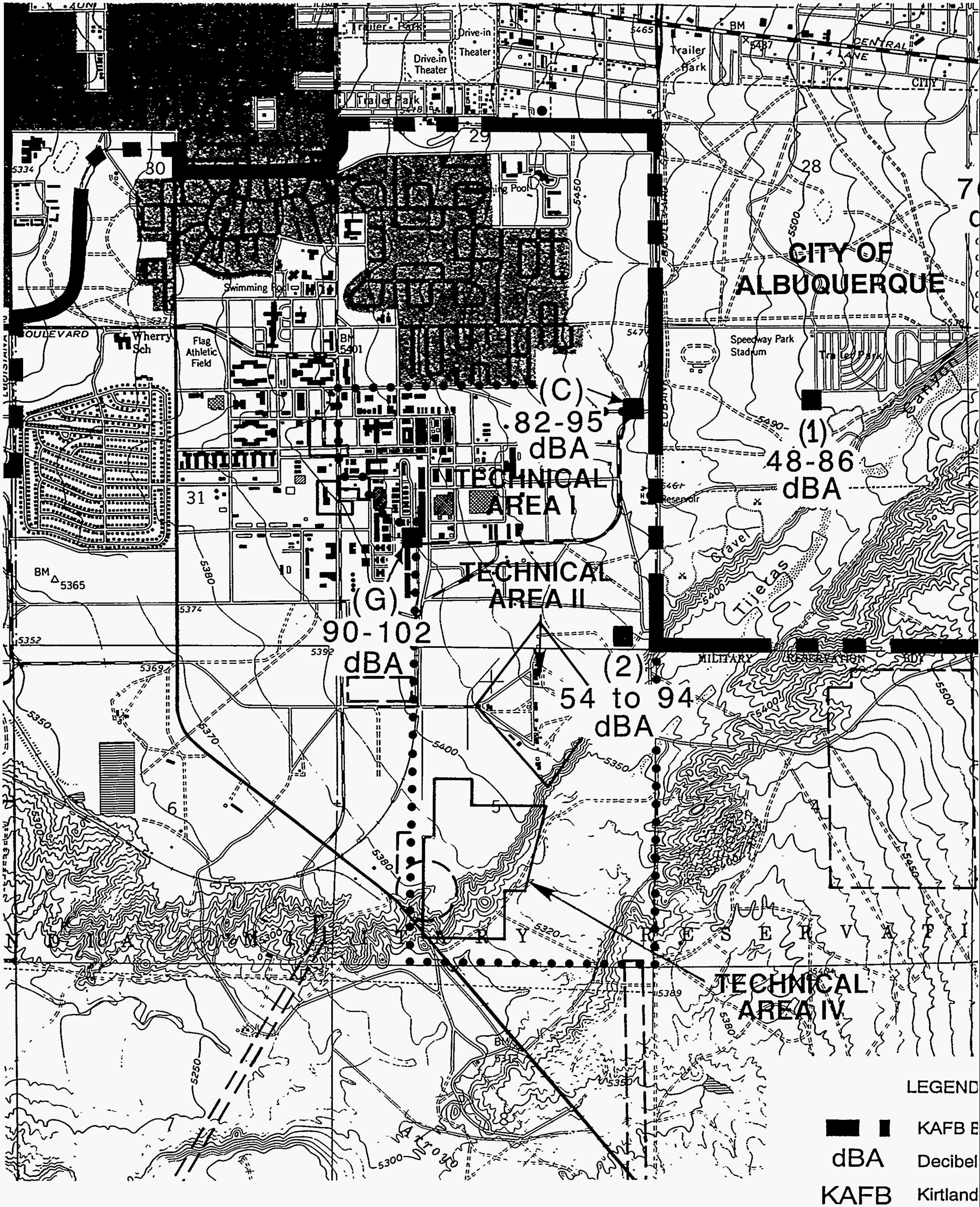
A-Weighted

ir Force Base

0 2000 8000 Feet

0 2000 4000 Meters

Figure 7-2
Noise Levels for the Northern Section of Sandia National Laboratories/ New Mexico



Trailer Park
Drive-in Theater
Drive-in Theater
Trailer Park
Trailer Park
CENTRAL
4 LANE
CITY
Swimming Pool
Swimming Pool
BOULEVARD
Wherry Sch
Flag Athletic Field
CITY OF ALBUQUERQUE
Speedway Park Stadium
Trailer Park
Canyon
(C) 82-95 dBA
(1) 48-86 dBA
TECHNICAL AREA I
Reservoir
Gravel
Tijeras
TECHNICAL AREA II
(G) 90-102 dBA
(2) 54 to 94 dBA
MILITARY RESERVATION BDY
TECHNICAL AREA IV
Arroyo
LEGEND
KAFB B
dBA Decibel
KAFB Kirtland

SNL/NM property boundary and were not necessarily recorded during peak airport operational hours.

The most significant contributors to the current noise levels at the Sol se Mete ACF include aircraft noise and HE and rocket motor noise. Modeling has approximated noise levels from aircraft to average 71 dBA per day at the Sol se Mete ACF. More impulsive sources of noise are generated from HE testing and the firing of rocket motors. An HE test may create pressure in excess of 115 dB, while the firing of a rocket motor may result in noise levels exceeding 140 dBA. No actual instrumentation studies were performed for the Sol se Mete ACF.

Noise-monitoring data is sparse for other areas of SNL/NM. KAFB personnel indicated through personal communication (January 1995) that several noise studies have been performed utilizing the Air Installation Compatible Use Zone (AICUZ) model. No actual instrumentation has been used in these studies to date. The areas that have been targeted for noise model surveys include the northeast/southwest runway 2103; Hanger No. 333, used for military purposes near the southernmost end of Carlisle; and a third as yet unbuilt facility for the Air National Guard. The locations of these facilities are within the study area monitored by Greiner, Inc., in 1990. As the two military facilities do not yet exist, and flight data from runway 2103 have already been included in database statistics made available by the ABQ, it is not anticipated that these modeling studies will alter results of data on noise impacts as presented in this baseline assessment. The overall noise-level range of 54 to 102 dBA appears to be representative of the SNL/NM property. Additional noise monitoring utilizing instrumentation in previously unsurveyed areas may provide future verification of this noise-level range.

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8.0 Cultural Resources

The prehistory (pre-1540) and history (post-1540) of the Albuquerque area includes four major cultural and temporal periods. PaleoIndian, Archaic, Anasazi, and Historic. Cordell (1979) and in the more abbreviated form in Stuart and Gauthier (1981) summarize these periods for the Albuquerque area. A brief summary, as presented in Hoagland (1993a) and Hoagland and Dello-Russo (1995), is included below as background to the following discussion on cultural resources located on KAFB and lands used by SNL/NM. Appendix B lists recommended mitigation measures for minimizing adverse impacts to cultural resources.

8.1 Cultural History of the Middle Rio Grande Valley

The following subsections summarize the various cultural periods represented in the Middle Rio Grande Valley.

8.1.1 PaleoIndian Period

The PaleoIndian Period in the Middle Rio Grande Valley is thought to date from 9500 to 5500 BC. Major time periods are named after temporally diagnostic projectile points: Clovis (9500 to 9000 BC), Folsom (9000 to 8000 BC), Belen (8000 to 7000 BC), and Cody (7000 to 5500 BC). A pre-Clovis occupation has been hypothesized (Hibben, 1941, 1951), because radiocarbon dates associated with cultural remains from a cave in Las Huertas Canyon, located in the Sandia Mountains about 24 km (15 mi) northeast of Albuquerque, range from 33,000 to 15,000 BC. The radiocarbon-dated fossil bone from Sandia Cave was not, however, well associated with the diagnostic projectile points, and considerable controversy surrounds interpretations concerning the "Sandia Culture" (Cordell, 1979). Various researchers suggest that Sandia points may actually be Clovis knives (Cordell, 1979; Stevens and Agogino, 1975; Judge, 1973).

The PaleoIndian adaptation is generally believed to represent a culture (or cultures) whose existence was based on high residential mobility and the hunting of large, prehistoric game animals such as mammoth, camel, horse, and bison. The degree to which PaleoIndian dependence was based on large animals has, however, recently been questioned. The hunting of smaller game, scavenging, and the collection of plant foods undoubtedly provided a major part of their subsistence (Judge, [n.d]; Cordell, 1979). Sites are generally identified by distinctive tools such as large spear points, knives, and end scrapers. Also suggestive of PaleoIndian sites is the presence of a high percentage of nonlocalized, high-quality raw materials left over from tool making activities.

In the Albuquerque area, PaleoIndian materials are most commonly found as surface finds in areas of active erosion, especially areas of active aeolian erosion and deposition (Doleman, 1989). Documented locales containing PaleoIndian sites include Sandia Cave (Hibben, 1941), Rio Rancho (Judge and Dawson, 1972), the West Mesa volcanic area, and the Southwest Mesa (Judge, 1973). Judge (1973) also located a number of PaleoIndian camp sites south of KAFB. These were situated on the East Mesa, near the Manzano Mountain foothills. Blevins and Joiner (1977) reported isolated PaleoIndian materials in the Tijeras Canyon area, and Rodgers (1980a) reported the same on KAFB.

8.1.2 Archaic

The Archaic Period from about 5500 BC to 1 AD, is usually defined as the continued adaptation of PaleoIndian groups to the post-Pleistocene climatic conditions, which included the shrinking of grassland areas. Economically, the Early Archaic Period is characterized by mobile populations relying on a variety of subsistence strategies that centered on hunting small game and collecting local vegetation. A greater reliance was placed on groundstone implements used for seed processing. This adaptation resulted in increased population and decreased area available for any one group. Through the Archaic period, subsistence patterns changed from small, repeatedly used residential base camps with little seasonal patterning to more diverse assemblages and larger base camps representing seasonal gathering (Irwin-Williams, 1973).

The Late Archaic Period continues this hunting-and-gathering pattern, and adds cultivated maize to the daily diet (Cordell, 1979). This widespread tradition in the Southwest continues to sometime between 1 AD and 600 AD, when it forms the cultural foundation for succeeding Hohokam, Mogollon, and Anasazi cultures.

The Oshara tradition is interpreted by Irwin-Williams (1973) to be the cultural ancestor of the Anasazi, who became the principal inhabitants of the post-Archaic Albuquerque area. Irwin-Williams views the evolution from Archaic to Anasazi peoples as a gradual and uninterrupted process. The Oshara cultural sequence spans over 6,000 years and is divided into six phases, which are named for their diagnostic spear points: Jay (5500 to 4800 BC), Bajada (4800 to 3200 BC), San Jose (3200 to 1800 BC), Armijo (1800 to 800 BC), En Medio (800 BC to 400 AD), and the Trujillo (400 to 600 AD). The major event associated with the Late Archaic

Period, Armijo Phase, is the documented appearance of corn, which originated in Mexico. Corn cultivation, however, can only be substantiated as early as the En Medio Phase, which is the transitional period from the Late Archaic Period to early Anasazi traditions (Basketmaker).

Criteria for recognizing of the Archaic Period remains in the Albuquerque area are poorly defined and are commonly based on the presence of fire-cracked rock and the absence of ceramics. These sites are generally located well above the floodplain, near arroyos and sand dunes (Cordell, 1979; Lintz et al., 1988). The majority of sites of Archaic Period have been reported from north and west of Albuquerque between the West Mesa and the San Ysidro area. Manifestations of the Archaic Period, however, have also been found within the confines of KAFB on the East Mesa of Albuquerque (Rodgers, 1980a; Franklin and Rodgers, 1981; Hoagland, 1991a; Hoagland and Dello-Russo, 1995) and in the Mesa del Sol area, situated directly west of KAFB (Doleman, 1989). Also, a survey along the mesa rim situated above Hell's Canyon, which is located on the Isleta Reservation south of KAFB, revealed a number of large Archaic camps (Wozniak, 1981; Winter, 1981).

8.1.3 Anasazi

Several phases of the Anasazi culture are represented in the Albuquerque area. These phases include the Early Developmental/Basketmaker III Pueblo I, Late Developmental/Pueblo II, Coalition/Pueblo III, and Classic/Pueblo IV.

Early Developmental/Basketmaker III/Pueblo I (? 1 to 900 AD). Major changes in adaptation were well under way by about 500 BC in the Middle Rio Grande Valley. These changes include development of the bow and arrow for hunting, production of ceramic vessels, cultivation of corn, and dwellings which suggests the beginnings of village life. As a result of these changes, a mixed foraging and agricultural economy developed during the Early Developmental Period, and a major commitment toward agriculture.

Early Developmental villages consisted of pithouses, which became better constructed and larger toward the end of the period. The increased numbers of storage features found inside and outside the pithouse dwellings show that villages may have been occupied for longer periods (Schmader, 1990). These villages were located near intermittent tributaries of the Rio Grande at elevations that also offered abundant game and edible vegetation as well as a view of game migration paths (Cordell, 1979; Anschuetz, 1984). Bullard (1962) argues that the pithouses were strategically placed with respect to both water and farmable land.

Pithouse sites generally contain both Anasazi gray wares (ceramics) and various brown wares, which either were directly imported from the Mogollon area or were local imitations of Mogollon ceramics. Pithouse architecture, however, tended to be more similar to that found in the San Juan area than to that in the Mogollon region (Cordell, 1979). In addition to ceramics, basketry, matting, sandals, nets, blankets, bead work, flat grinding stones, and one-hand grinding stones have been recovered from Late Basketmaker/Pueblo I sites (Cordell, 1979; Schmader, 1990).

Frisbie (1967) reported that Late Pueblo I sites at the North Hills area of Rio Rancho were dated from between 600 and 650 AD for transitional sites and from between 850 and 890 AD. Two Early Developmental/Basketmaker III/Pueblo I sites were located in the foothills portion of KAFB (Hoagland, 1991a).

Late Developmental/Pueblo II (900 to 1200 AD). During the Late Developmental Period, settlements moved into a wider range of environmental zones, site size increased, and architecture became more complex. It is believed that these changes reflected an increasing population relying to a greater extent on agriculture. The Late Developmental Period was also marked by the abundance of decorated ceramics.

Pithouses persisted throughout the period, although there is evidence for the transition to aboveground structures constructed of mud and sticks (Anschuetz, 1984). In general, artifacts show considerable continuity, although full-grooved axes and two-hand grinding stones are innovations (Vytlacil and Brody, 1958).

In general, the site density and the range of environmental settings increased during the Late Developmental period (Lintz et al., 1988). In the Albuquerque area, however, Pueblo II sites are generally regarded as uncommon, although this assumption may be the result of the insufficient diagnosing of ceramics at some sites (Schmader, 1990). Pueblo II sites are found in Albuquerque's north and south valleys, near the Sandia Pueblo, the eastside foothills, and several sites along the Tijeras Canyon (Cordell, 1979). Blevins and Joiner (1977) suggest that the Tijeras Canyon sites were only seasonally used during this period. Most of the numerous, small Pueblo II and Transitional Pueblo II–Pueblo III sites in the Tijeras Canyon are concentrated at relatively low elevations (below 1,900 m [6,400 ft]) adjacent to major drainages (Blevins and Joiner, 1977; Cordell, 1977a; Lintz et al., 1988). This pattern appears to hold for sites located on the western foothills of the Manzanita and Manzano Mountains (Rodgers, 1980a; Neal, 1980, 1981; Franklin, 1981; Payne, 1982; Gauthier, 1977; Acklen and Earls, 1987; Condie, 1989; Hoagland, 1991a, 1995; Seymour, 1992).

Coalition/Pueblo III (1200 to 1300 AD). Although pithouse architecture persisted, the Coalition period saw a substantial increase in the number, size, diversity, durability, and distribution of aboveground dwellings (Cordell, 1979; Anschuetz, 1984; Lintz et al., 1988; Schmader, 1990). The construction of terraces, rock gardens, and dams (Moore, 1981) and the return from upland settings to farmable land adjacent to waterways (Lintz et al., 1988) suggests an even greater reliance on agriculture. Initiation of the Coalition Period coincides with the shift from mineral to organic painted pottery and the emergence of localized decorated ceramic types and design styles (Lang, 1982). In the Albuquerque area, the population growth and expansion was more gradual; thus, there appears to have been more continuity with the prior populations (Schmader, 1990).

Sixteen Pueblo III sites or components of sites have been documented from the Tijeras Canyon (Cordell, 1979), and at least another 30 have been recorded from the west side of the Manzanita and Manzano Mountains. There have also been 67 transitional Pueblo III–Pueblo IV sites recorded from Tijeras Canyon (Earls and Biella, as reported in Lintz et al., 1988). The Tijeras Canyon Coalition period sites are also in settings immediately adjacent to major drainages and farmable land (Oakes, 1979; Cordell, 1979). This shift in site locations reflects an internal population growth and a decrease in agricultural land caused by a postulated change in the seasonality of rainfall and subsequent arroyo cutting (Frisbie, 1967). Blevins and Joiner (1977) suggest that it was during the Coalition Period that the Tijeras Canyon was first used on a year-round basis (Cordell, 1979).

Classic/Pueblo IV (300 to 1600 AD). The Classic Period in the Middle Rio Grande Valley reflects a period of rapid social and technological change, with prehistoric population levels reaching their greatest numbers. The Rio Grande Classic Period include the time when the population of the northern Rio Grande reached its maximum prehistoric extent (Wendorf and Reed, 1955). Large communities developed, and there was an elaboration of the material culture. The beginning of this period is generally thought to be 1300 AD, which coincides with the introduction of glaze-decorated ceramics.

Characteristic of the period were large communities and multiroom pueblos. In the Albuquerque area, both adobe and stone masonry were used in house construction, the latter of which was more common east of the Sandia Mountains (Lintz et al., 1988). Although settlement of the valley floodplains continued to intensify during this period, communities in the Albuquerque area were not exclusively associated with lower elevations. Sites in the Tijeras Canyon and within canyon areas on KAFB continued to occupy upland locations near reliable water resources (Cordell, 1979; Hoagland, 1991a, 1995). The number of Classic Period sites that have been documented in the canyon is about the same as in the previous Coalition Period. However, except for the few large communities, the remains consist of small, limited-activity areas such as chipping stations and hunting and/or gathering localities (Cordell, 1977b). The Tijeras Canyon communities did not appear to have been occupied continuously, and all were abandoned by 1425 AD (Cordell, 1979; Lintz et al., 1988).

8.1.4 Historic (1600 to Present AD)

Although the Historic Period begins with Coronado's exploratory expedition up the Rio Grande in 1540–1541, most researchers date the period from about 1600 AD. This date corresponds with Oñate's settlement in New Mexico, which is when the European population began to have a significant direct effect on the Rio Grande populations (Cordell, 1979). The patronage or estate system of 17th century New Mexico was tied directly to the exploitation of native Pueblo populations, which were in close proximity to the Hispanic "hacienda." The colonists quickly enslaved the Pueblo Indians, who revolted against Spanish domination in 1680.

With the reconquest of New Mexico (1693 to 1696), the economic and settlement systems were completely revised (Simmons, 1969). Land was granted to dozens of Hispanic communities and individuals who worked the property themselves. In 1706, Albuquerque was established by Governor Cuervo as the military and administrative focus for the lower portion of the Rio Abajo (Simmons, 1982). During the early 18th century, Hispanic settlers rapidly occupied the extensive agricultural lands from Bernalillo to Belen that had been progressively abandoned by the Pueblos as a result of the events in the 17th century.

The Tijeras Canyon has been a major artery connecting the High Plains with the Rio Grande Valley. In colonial times, it was known as "el Cañon de Carnue." Spanish settlement of the Tijeras Canyon occurred in 1763 with the Cañon de Carnue land grant. The settlement was short-lived, as it was abandoned after an Apache raid in 1770, when all surviving residents fled to Albuquerque. From 1770 through 1817, there is no record of Hispanic settlement in the Tijeras Canyon. With the urgent need of a buffer community, a new community grant was warded in 1818. Despite poor harvests and recurrent Indian attacks that caused numerous temporary or permanent abandonments, the community was able to survive (Swadesh, 1980).

In the 19th century, the expansion of trade, especially with the United States, and the introduction of manufactured goods had a profound effect on New Mexican society (Weber, 1982). The Cañon de Carnue settlers raised crops, and because of the excellent mountain pastures, they depended heavily on livestock raising. Some of the Hispanic settlers were also woodcutters, traders, raiders, hunters, miners, and bootleggers. Patterns of Hispanic land ownership began to change in the 1850s with the dissolution of Spanish land grant claims by the U.S. Office of the Surveyor General (Westphal, 1983). However, the establishment of American sovereignty did not affect the Rio Grande Valley between Bernalillo and Belen until after the introduction of the railroad in the 1880s (Cordell, 1979). Cañon de Carnue communities began to fail in 1890, when the land grant rights failed to be confirmed. In the 1930s, grant heirs lost their grazing rights and forest lands to the Cibola National Forest.

Lead mines and gold mines at Real de San Francisco del Tuerto (Golden) and at San Pedro attracted residents to seasonal prospecting and work in the mines (Swadesh, 1980). Historic mining operations at KAFB emphasized the recovery of gold and silver, along with copper, lead, and fluorspar (Lintz et al., 1988). In the 20th century, there were three major mining districts located in the Manzanita and north Manzano Mountains. The Tijeras Mining District extended southward into the northern portion of KAFB, the Coyote Canyon District was situated within the USFS withdrawal lands portion (Fulp et al., 1982), and the Hell Canyon District was located within the southern edge of the base (Lintz et al., 1988). Most of the mining on KAFB was terminated in the early 1930s, when the U.S. Navy began testing the proximity fuse in several of the existing shafts (Humble, 1987, as reported in Lintz et al., 1988). Occupation of the National Forest withdrawal lands by some ranchers and miners continued into the 1940s. Thereafter, the area was incorporated into KAFB.

During the Prohibition Era, some families supported themselves by making bootleg whiskey to sell in Albuquerque. The Coyote Springs was the site of a production and bottling plant for effervescent water and soda pop during the 1930s and after. The water was apparently hauled in converted spring wagons to the processing plant in downtown Albuquerque (Hoagland and Dello-Russo, 1995). Health resorts and the recreation industry started to become an economic factor in the canyon sometime before World War I. This industry flourished when Highway 66 was rebuilt after World War II and a ski area opened on Sandia Peak. Construction of the ski area and Interstate 40 helped contribute to a continuous population growth and the subsequent establishment of bedroom communities (Swadesh, 1980).

8.2 History of KAFB and SNL/NM

Section 8.2 contains a history of KAFB and the development of SNL/NM.

8.2.1 Kirtland Air Force Base

On April 3, 1942, the Secretary of War declared his intention of taking 4.5 km^2 (1,100 acres) of land on Albuquerque's East Mesa for military purposes (Alexander, 1963). This site included Oxnard Field, which had been Albuquerque's first airport. Frank G. Speakman and William Franklin constructed the airport in 1928. It was located on 0.57 km^2 (140 acres) of homestead land situated near the east side of present National Atomic Museum on KAFB. Later in 1928, James G. Oxnard, a New York air transportation promoter, bought out Franklin's interest and established Aircraft Holdings, Inc., to operate the venture. Oxnard also furnished additional funding for expansion and improvements to the airport (Alberts and Putnam, 1982).

In 1929, Western Air Express (WAE) began its westbound passenger service through Albuquerque, and Transcontinental Air Transport (TAT) inaugurated its first passenger and cargo service soon after. The Albuquerque Airport served both airlines for only a short time, because in 1929 WAE moved to the West Mesa where it had constructed new facilities. TAT continued to use the airport until 1930, when it merged with WAE to form Transcontinental and Western Air, Inc., which used the new West Mesa facility (Alberts and Putnam, 1982). Following the departure of TAT, Oxnard Field resumed its status as a private general aviation airport. In the subsequent years, it was used as, among other things, a stopover for air racing, a locale for flight instruction, a refueling stop for Fast Air Express (a Los Angeles-to-New York freight-and-express company), and a refueling and maintenance locale for several U.S. Army and Navy bomber and military flights (Alberts and Putnam, 1982).

Fulfilling the desires of the City of Albuquerque, Transcontinental and Western Air, Inc., and local businessmen, a new municipal airport was opened in mid-1939 on the East Mesa approximately 4 miles west of Oxnard Field. In late 1939, the Army leased 8 km^2 (2,000 acres) adjacent to the Municipal Airport and a small Air Corps detachment soon arrived to service transient U.S. Army and Navy aircraft. On January 7, 1941, construction began on buildings for the Albuquerque Army Air Base. The Albuquerque Army Air Base officially became Kirtland Field on February 25, 1942. During World War II, the air base was used by bombardier training schools, flight training schools, an aviation mechanics school, a navigator school, and a ground school for glider pilots. Also, because Kirtland Field was the closest facility to Los Alamos, where the initial special weapons work was conducted for the atomic bomb, field runways and a bombloading pit were used to support the Los Alamos program during 1944 and 1945 (Alberts and Putnam, 1982).

By the end of World War II (August of 1945), Kirtland Field had not only become significant to the military community but also to the local community and economy as well. Kirtland Field had 402 buildings, 82 of which were war-time housing units that had been transferred to Kirtland's jurisdiction in November 1943. As of 1982, many of the World War II buildings, including the noncommissioned officers quarters, remained in use at KAFB (Alberts and Putnam, 1982).

8.2.2 Sandia National Laboratories/New Mexico

Section 8.2.2 presents a brief history of the evolution of Sandia Base to SNL/NM.

Wartime Sandia Base. As the United States actively entered World War II, the U.S. Army Air Forces (changed from Army Air Corps on June 20, 1941) had an urgent need for trained aircraft mechanics and air depot service personnel. Army Air Forces officials planned to establish a training center for such personnel near Albuquerque and decided to condemn approximately 4.5 km^2 (1,100 acres) of land adjacent to the eastern boundary of Kirtland Field. The Army Air Forces acquired the land (including Oxnard Field) on May 12, 1942. The resultant base was called the Albuquerque Air Depot Training Station and unofficially referred to as Sandia Base. In October 1943, the training station became the Albuquerque Army Air Field when the last of the trained aircraft mechanics and repairmen had been sent overseas. In mid-1944, the field became the Army Air Forces Convalescent Center, with barracks and support facilities used as quarters for wounded pilots and crewmen who were recovering from surgery and other medical service. The Convalescent Center was subsequently closed during April 1945, and the facility again became an Army Air Field. At the end of World War II, the air field began to receive war-weary and surplus military aircraft. Temporary tow roads and parking spaces were graded on the mesa land surrounding Oxnard Field (Alberts and Putnam, 1982).

Postwar Sandia Base. A few months prior to the successful completion of the Trinity Project (detonation of the first atomic bomb) and of the Alberta Project (delivery of the first airborne atomic weapon), J. Robert Oppenheimer, Director of Los Alamos Laboratory, and his technical advisor, Hartly Rowe, began looking for a new site convenient to Los Alamos for the continuation of weapons development, especially in its nonnuclear aspects. They felt that a separate division would best suit these functions (Furman, 1990).

Los Alamos had used Kirtland to meet transportation needs for both the Trinity and Alberta Projects. Thus, Oxnard Field, which was conveniently situated adjacent to Kirtland Air Field on the Albuquerque East Mesa, was transferred from the jurisdiction of the Army Air Forces to the U.S. Army Service Forces Chief of Engineer District and thereafter assigned to the Manhattan Engineer District (the project to develop an atomic weapon). The official change of command took place on July 21, 1945 (Furman, 1990; Alberts and Putnam, 1982). The "Z" Division (named for its head, Jerald Zacharias) was formed to stockpile and improve the Fat Man Model atomic bomb (the type that was dropped on Nagasaki). The "Z" Division became the nucleus from which the Sandia Corporation would evolve (Furman, 1990).

The "Z" Division facilities consisted of wood sheds and buildings, a portion of which had been built by the Civilian Conservation Corps (Johnson, 1985). Upon its arrival, the Manhattan Engineer District authorized construction of guard, storage, administrative, and laboratory facilities for "Sandia Base," which was the first time that name had been officially recognized. To separate the "Z" Division facilities from the ongoing aircraft storage and salvage operations, a fenced area for classified activities was required. This locale, which was bounded by "F," "H," 5th, and 8th Streets, became Technical Area I at SNL/NM. It included some of the older, wood-frame, tar-papered, temporary buildings dating from the Air Depot training days (1942 to 1943) and additional wood-frame construction to provide space for personnel and functions (Alberts and Putnam, 1982; Furman, 1990). Technical Area I was completed during 1946/1947 and was used until construction of more permanent buildings for an expanded facility began in 1948.

Early manufacturing activities included the practically complete assembly of nuclear weapons. This resulted in the development of a separate area (Technical Area II), located about 0.8 km (0.5 mi) south of Technical Area I, for the handling and incorporation of explosives into the weapons. Construction of Technical Area II, which paralleled the Technical Area I development, was initiated in 1948. Resultant construction included two identical assembly buildings and a control building completed in 1949 (Alexander, 1963; Johnson, 1985).

The increasing use of missiles as delivery vehicles led to the full-scale environmental testing of weapons with and without explosives. As a result, there was a need for complex equipment and specialized engineers to analyze the test results. A decision was made to centralize a group of test devices in Technical Area III, located some 11 km (7 mi) south of Technical Area I. Planning for this area began in 1952, and the first group of facilities–consisting of a centrifuge, a rocket-sled, a vibration facility, and an instrument control center–was completed in 1953 (Alexander, 1963). Most of the Technical Area III test facilities were constructed from 1954 to 1960 (Johnson, 1985).

In 1957, a nuclear reactor facility was proposed for Technical Area III, which later became Technical Area V (Johnson, 1985). Technical Area IV was developed into the test location for x-ray, gamma-ray, and particle-beam fusion accelerators. As the need for test sites grew beyond the capacity of DOE-owned lands, use permits were acquired from KAFB, the Cibola National Forest, and other agencies to obtain land now known as the Coyote Canyon Test Field.

As new weapons were developed, additional laboratory space became necessary; and as weapons evolved, new environmental testing facilities were required. SNL/NM building and facility construction continued at an average rate of about 4,600 m^2 (50,000 ft^2) per year prior to 1963 (Alexander, 1963). Sandia Base officially became Sandia National Laboratories in 1979. One of SNL/NM primary missions is still to design, test, evaluate, prepare for production, and to maintain a stockpile of nuclear weapons systems. In recent years, however, activities have expanded to include energy research and development that complements weapons technologies plus development of technologies to reduce or prevent environmental contamination.

8.3 SNL/NM Cultural Resource Inventories

Between July and November 1990, SNL/NM Technical Areas I through V were surveyed and/or assessed for the presence of potentially eligible National Register of Historic Places (NRHP) properties (Hoagland, 1990a through e). A block of land situated within the USFS withdrawn land located along some of the ridges and within portions of Lurance, Madera, and Sol se Mete Canyons was also inventoried. These inventories resulted in the survey, resurvey, and/or ssessment of 17.4 km^2 (4,275 acres) and the documentation or redocumentation of 40 cultural resources sites.

The only potentially significant cultural resources located were documented during the 5.9-km^2 (1,447-acre) Burn Site survey (Hoagland, 1991a). During this project, 33 archaeological sites and 88 isolated occurrences were located on withdrawal lands in and around Lurance and Sol se Mete Canyons. Twenty-three of the sites were thought to be potentially significant and should be avoided, according to the State Historic Preservation Officer (SHPO) (Hoagland, 1991a).

During 1994, Butler Service Group, Inc., completed a comprehensive cultural resources survey and review of 9.9 km^2 (2,445.4 acres) of property for SNL/NM's Environmental Restoration Project (Hoagland and Dello-Russo, 1995). The project involved the survey or resurvey of 6.6 km^2 (1,635.8 acres) of land and the compilation of data from previous surveys of 3.3 km^2 (809.6 acres).

The survey and records review resulted in the documentation of 31 new sites, 39 previously recorded sites, 128 isolated occurrences (IO), and one potential historic district (Technical Area I). Of these sites, 29 of the prehistoric sites, 15 of the historic sites, 13 of the historic/prehistoric sites, and one site of unknown temporal affiliation are thought to be eligible or potentially eligible for nomination to the NRHP.

Only two historic properties, Building 904 and Building 907 in Technical Area II, have been recorded on DOE-owned lands. Technical Area II has been determined by the DOE and the SHPO to be potentially eligible for nomination to the NRHP as an historic district because of its association with the development of the first thermonuclear weapons (Romero Taylor, 1995). All other cultural resources sites have been located on leased on withdrawn lands.

8.4 Cultural Resource Studies at KAFB

Over 200 cultural resources sites and hundreds of IOs have been recorded on KAFB lands. In 1988, Mariah Associates, Inc., prepared an assessment of cultural resource studies conducted at KAFB (Lintz et al., 1988). This assessment reviewed all of the previous archaeological work conducted on the base and is an excellent source for details concerning previous archaeological resources. In 1992, Mariah Associates, Inc., prepared a second document that also reviewed previously conducted work, with an emphasis on the studies completed between 1988 and 1992 (Seymour, 1992).

The earliest surveys were probably conducted during the 1930s, prior to the development of KAFB. According to Lintz et al. (1988), one site was recorded in the 1930s by Herbert Yeo, and a second site was recorded at some unspecified time by J. Robert Jones. Between 1978 and 1985, a series of 13 cultural resource inventory surveys were conducted by the Center for Anthropological Studies and Cultural Heritage Research Services (Rodgers 1978, 1980a, 1980b, 1980c). These surveys were intended to provide 100 percent coverage of the inventory of historic and prehistoric sites on various management areas of the base. Only Management Area J and J-Addendum involved a survey primarily dealing with the area perimeter rather than total coverage (Lintz et al., 1988). These cultural resource inventory surveys covered 130 km^2 (31,943 acres) in KAFB management areas A through M (59.8 percent of KAFB and USFS withdrawal lands) and documented or redocumented 94 historic or prehistoric cultural resource sites.

Also noted were three publicly funded surveys and two USFS para-archaeologist surveys (Lintz et al., 1988). Prior to 1991, there appears to have been at least another five USFS para-archaeologist surveys with no sites recorded (Hayden, 1987a through e), two privately funded inventories documenting three sites (Condie 1989; Cushman, 1989), and two KAFB project-specific surveys recording four sites (Swift, 1988; Hoagland, 1989a). The vast majority of other KAFB cultural resources surveys prior to 1992 were smaller inventories conducted for specific projects scattered throughout the base (e.g., Hoagland, 1990a through n). These smaller surveys lead to the discovery and documentation of 39 additional cultural resource sites.

As of November 1992, there had been 100 KAFB cultural resource projects (Seymour, 1992) conducted by 15 contractors, agencies, and individuals, including Herbert Yeo, Robert Jones, James Judge, the Center for Anthropological Studies, Chambers Group Inc., Human Systems Research, Butler Service Group Inc., Cultural Heritage Research Services, the Office of Contract Archaeology, Mariah Associates, Inc., the Agency for Conservation Archaeology, Quivera Research Center, the Public Service Company of New Mexico, the Laboratory of Anthropology, and the USFS. The bulk of these projects were inventory surveys and/or area assessments, with five testing or data recovery projects (Rodgers, 1981; Condie, 1989; Hoagland, 1989a; Dean, 1991); one site evaluation (Cushman, 1989); one historic buildings evaluation [Historic American Buildings Survey (HABS)] (Hoagland 1991b); and one general evaluation (Lintz et al., 1988). Five projects combined a survey with a HABS review (Geister, 1990; Hoagland, 1990c, Hoagland, 1990d; Hoagland, 1990e, Hoagland, 1990o).

By 1992, of the 213.6 km^2 (52,577.38 acres) of property located within KAFB, approximately 138.8 km^2 (34,000 acres) (65 percent) had received a cultural resource inspection, and about 24.4 km^2 (6,000 of those acres) had been resurveyed by 1992. The total number of recorded sites was 173, with one additional site that field personnel remember recording, although no form or report has been found and no unaccounted-for site numbers have been identified. In addition, there are at least 60 IOs that could qualify as sites. Other cultural remains were also encountered that were not recorded as IOs or sites (Seymour, 1992).

Subsequent to the survey by Seymour (1992), Advanced Sciences, Inc. (1993a through j; Advanced Sciences, Inc., 1994) conducted 12 cultural resource inventories and one HABS evaluation. Mariah Associates, Inc., also conducted eight project-specific surveys (Evaskovich, 1992; Evaskovich, 1993; Evaskovich et al., 1993; Evaskovich and Seymour, 1993; Poague, 1993a, 1993b; Crollett, 1993; Hawkins, 1993). PRC Environmental Management Inc. (Alexander and Stuckey, 1994) conducted one survey, Gram Inc. (Vierra, 1994) conducted one survey, and Butler Service Group, Inc., conducted one HABS evaluation (Hoagland, 1993a) and four project-related inventories (Hoagland 1994a through c; Hoagland and Dello-Russo, 1994). These projects resulted in the documentation of four additional historic sites; the updating of three prehistoric sites; the rerecording of one prehistoric site and one historic site; and the recommendation that SNL/NM Technical Area II has at least two buildings (Buildings 904 and 907) eligible for the NRHP and is potentially eligible as an historic district (Kammer, 1994). With the addition of these sites, the total of sites recorded on KAFB lands between 1936 and 1994 was 211.

The 13 KAFB Management Area surveys contain most of the culturally inventoried locales. Within the management area surveys, the 0.3-km^2 (75-acre) Military Training Facility (Acklen and Earls, 1987) and the 5.9-km^2 (1,447-acre) SNL/NM Burn Site survey area (Hoagland, 1991a) contain a fairly large section with several sites recorded. Other surveyed areas include small areas associated with a proposed KAFB Starfire observation site and portions of the associated access and distribution line corridors (Swift, 1988) and a small portion of the proposed M60 Firing Range relocation survey (Hoagland, 1989a). These project areas are situated at the base or within the Manzano Mountains east of KAFB Management Area D. Most of the other nonmanagement area inventories involved the resurvey of small project-specific areas or linear utility alignments (Hoagland, 1989b; Hayden and Wilkes, 1987). Survey locations and site locations are defined in Hoagland (1993b).

Based on the sites recorded on KAFB from 1936 to 1994, it appears that approximately 11 percent of the sites have Archaic components, 69 to 70 percent have Anasazi components, 15 percent contain prehistoric unknown components, and 39 to 40 percent have historic components. (It is not uncommon for sites to contain multiple components.) All of the documented sites located within KAFB are situated on base-owned property or on USFS withdrawal lands.

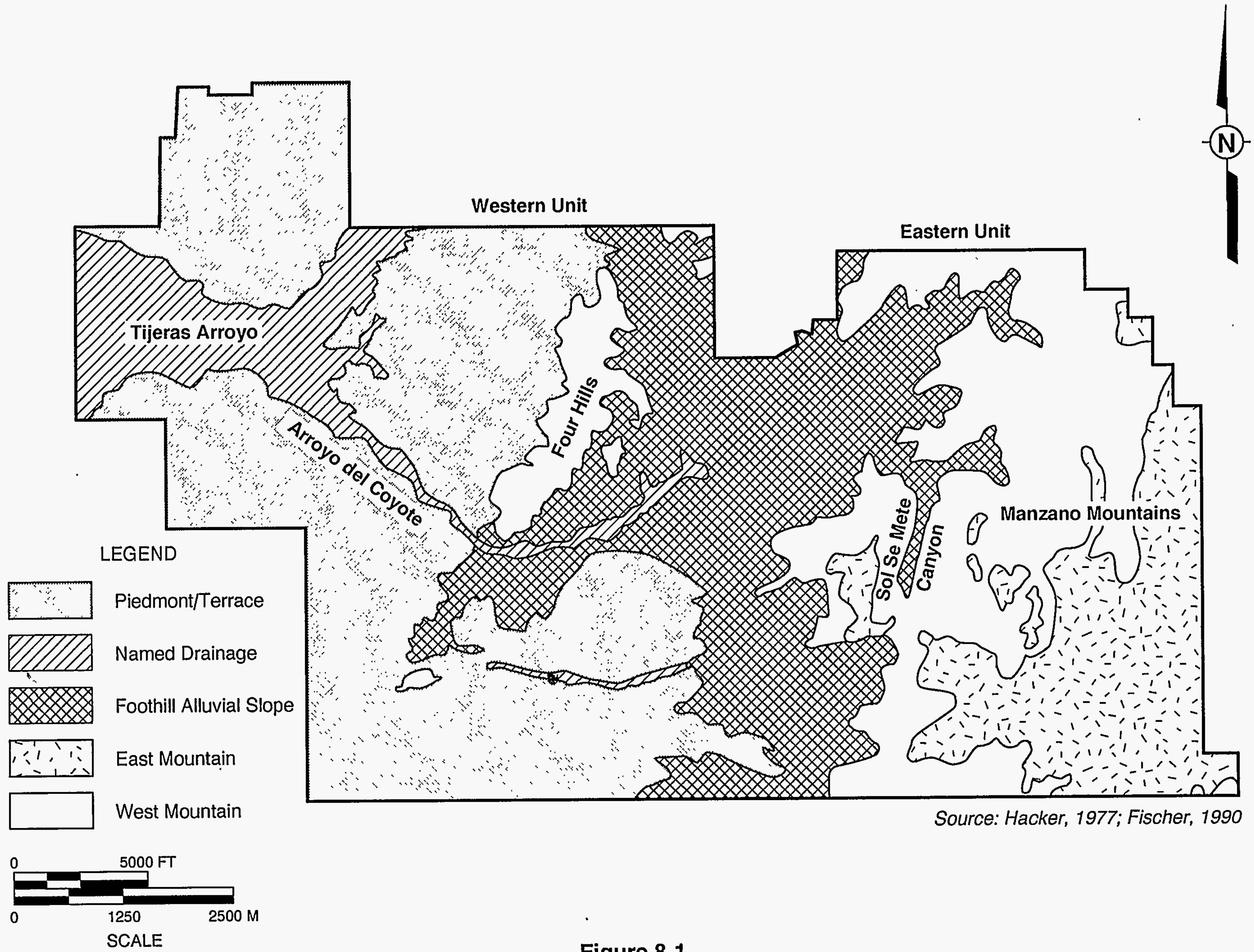
An Historic Preservation Plan is being prepared for KAFB through the National Park Service National Preservation Programs. This project includes reviewing literature; preparing a research design; producing a site locational predictive model for prehistoric resources; evaluating cultural resources, including relocating and rerecording known sites; preparing an NRHP Multiple Properties documentation; preparing a computerized cultural resource management database and geographic information system database; and producing the historic preservation plan.

8.5 KAFB Cultural Resource Site Location Summary

Topographically and vegetatively, Fischer's (1990) compilation of soil types and locations tends to correlate with KAFB cultural resource site situations. The vast majority of cultural resource sites are situated within or directly adjacent to Fischer's Named Drainage Zone or Foothill Alluvial Slope Zone (Figure 8-1). Approximately 72 percent of the sites are located within the Named Drainage Zone or the Foothill Alluvial Slope Zone. However, when sites are included that are situated within 0.2 km or 1/8th of a mi (200 m [660 ft]) of these zones, the percentage of sites is increased to approximately 94 percent, and approximately 96.5 percent of all sites are within 0.4 km (¼ mi) of these zones.

The majority of previously recorded sites are situated on what has been classified as Lower Alluvial Fans (KAFB Management Areas C, D, E, G, and L) or Upper Alluvial Fans (Management Areas F, I-west and I-east, J, and J Addendum). Based on previous classifications, it is assumed that sites from KAFB Management Area M (which include most of the sites recorded by archaeologists not associated with the Center for Anthropological Studies or Cultural Heritage Research Services) and about six of the Burn Area survey sites are also situated on alluvial fans (Hoagland, 1993a). The vast majority of these sites are located within Fischer's Foothill Alluvial Slope Zone on soils classified as Tesajo-Millett Association. About 35 to 38 percent of other KAFB sites appear to be adjacent, within close proximity, or overlooking alluvial fans containing Tesajo-Millett soils. Vegetatively, this zone tends to be transitional between the Great Basin Plains and Grasslands and the Great Basin Conifer Woodland.

KAFB sites are generally located along one of the major drainages, along canyons, or in the mountain foothills on or within close proximity of Tesajo-Millett soils. This is the base area that has the highest diversity of natural resources. Historic sites are primarily located on upper alluvial fans or along the base and sides of canyon-forming ridges. Prehistoric sites are situated within similar settings; however, there appears to be a greater abundance of sites along the foothill



Source: Hacker, 1977; Fischer, 1990

Figure 8-1

Correlation of Cultural Resource Site Locations with Soil Zones at Kirtland Air Force Base

canyon valleys and drainages. This site density is potentially a function of greater vegetation and animal diversity, farmable lands, and the presence of canyon springs.

It is hypothesized that the majority of nondocumented KAFB cultural resources will continue to be located within the mountain foothills and especially within the vicinity of major canyons and drainages. The highest prehistoric site density is thought to be along foothill canyons that have potential arable lands and springs. Additional sites are also likely along the two major base drainages (i.e. Tijeras Arroyo and Arroyo del Coyote).

Additional historic mining sites have been and will continue to be located within the foothills at locations with potentially exploitable ore deposits. Corresponding with the foothill location of both historic and prehistoric sites, it appears that additional sites will tend to be located within or in close proximity to locales with foothill and alluvial slope zone soils, especially Tesajo-Millett stoney sandy loams.

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9.0 Visual Resources

This chapter is based on a study conducted by Consensus Planning/Zephyr Design, 60 Gold, SW, Suite 216, Albuquerque, New Mexico.

It is part of the congressional declaration of national environmental policy contained in Section 101 of NEPA, to use all practicable means and measures to ensure aesthetically pleasing surroundings. According to Section 102(2)(B) of NEPA, federal agencies are directed to the fullest extent possible to " . . . identify and develop methods and procedures . . . which will insure that presently unquantifiable amenities and values may be given appropriate consideration in decision making." Visual resources fall in the category of "unquantifiable amenities" because it is difficult to quantify "aesthetically and culturally pleasing surroundings" (§101[b]).

Visual resources encompass those aspects of an area or project that pertain to its appearance and to the manner in which it is viewed by people. Visual resources studies review the aesthetic qualities of natural landscapes and their modifications, the perceptions and concerns of people for landscapes and their modifications, and the physical or visual relationships that influence the visibility of proposed landscape modifications. The purpose of this chapter is to provide baseline information concerning the visual resources of SNL/NM and KAFB. Terminology for this chapter is defined in the Glossary (see Chapter 15.0).

9.1 Study Area

The study area is located on the south and east edge of Albuquerque, New Mexico, approximately 8 km (5 mi) from the downtown area. It is situated within the eastern Mexican Highlands section of the Basin and Range physiographic province (Fenneman, 1931). The area can be divided into several subregions based on topography and geology (see Chapter 2.0), ranging from the Manzanita Mountains on the east to the Rio Grande Valley on the west. The area's vegetation (see Chapter 5.0) varies greatly, as does its physiography, and both characteristics can impact visual resources. Photographs taken of the study area on October 15 and December 11, 1991, are shown in Figures 9-1 through 9-4.

In the past, urban development has occurred up to the boundary of KAFB. Extensive development has occurred at SNL/NM, especially in and around the technical areas. However, since 1991 no significant development has occurred that has adversely impacted the visual

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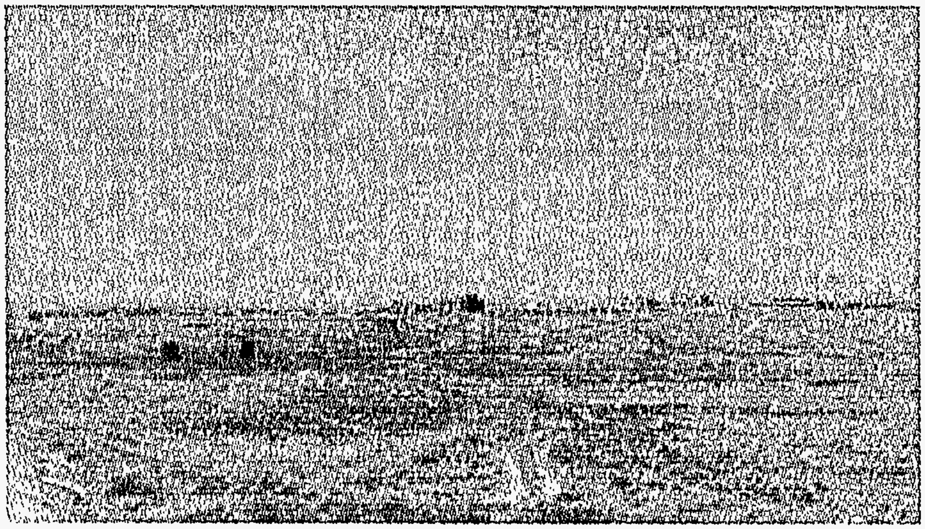
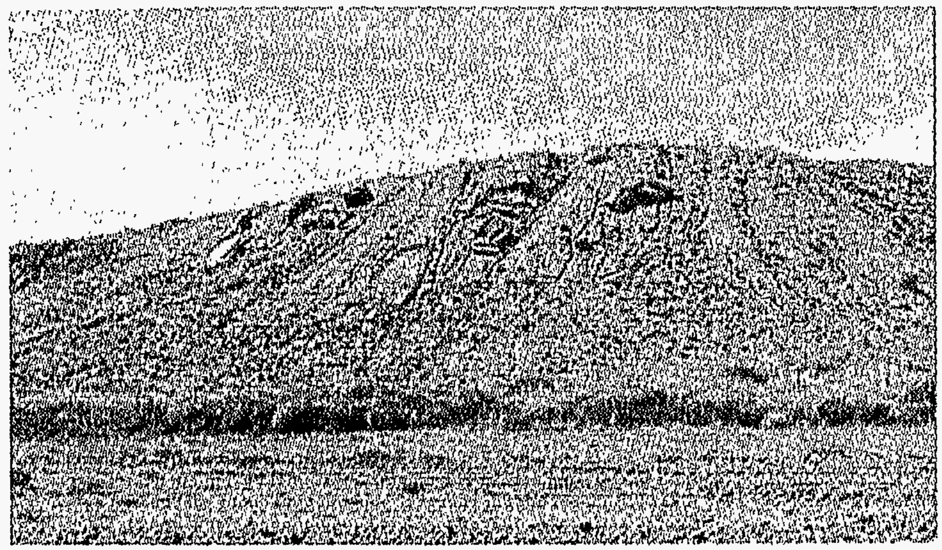
Technical Area II

Technical Area IV from Tijeras Arroyo

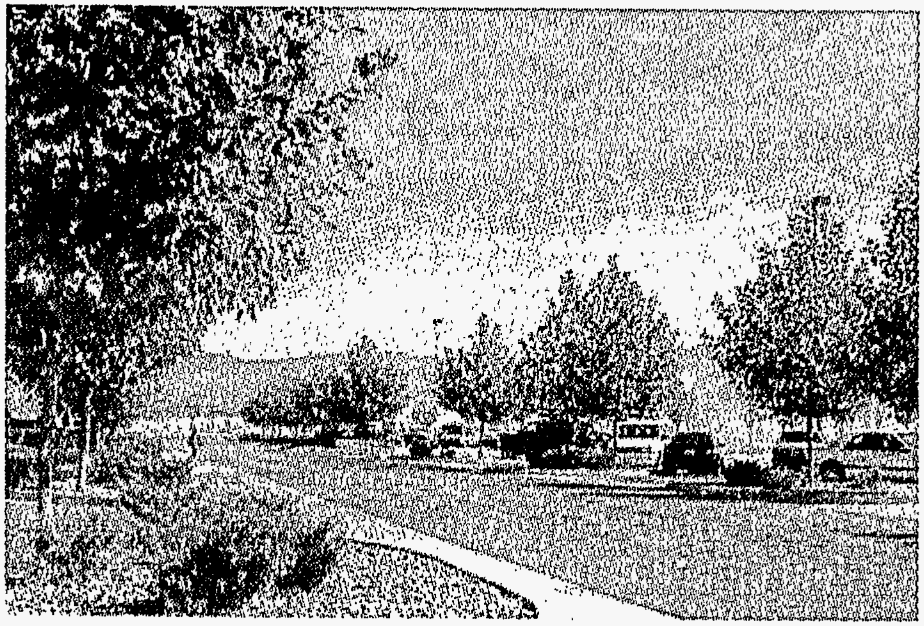


View Across Tijeras Arroyo to Technical Areas I, II, and IV

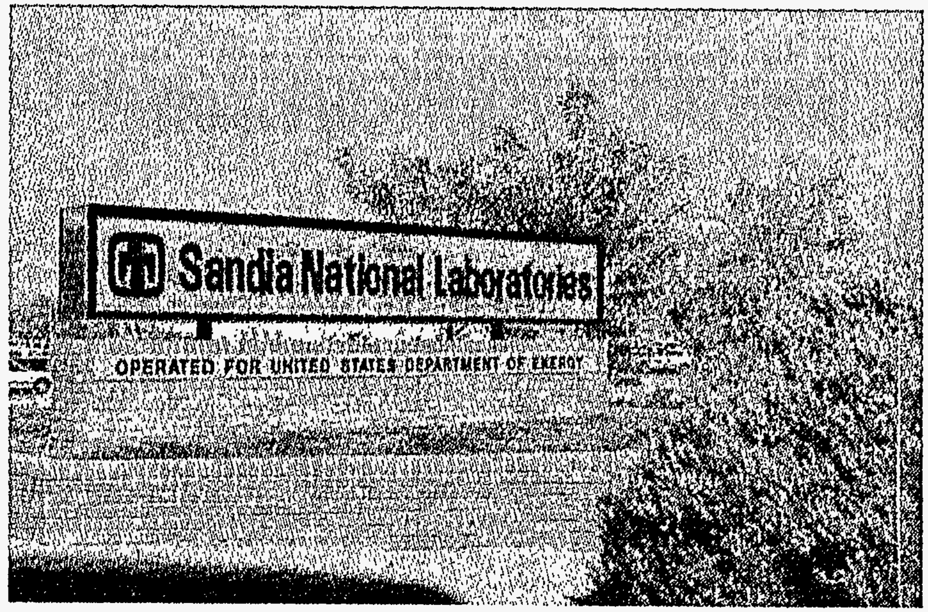


View Along Tijeras Arroyo Edge

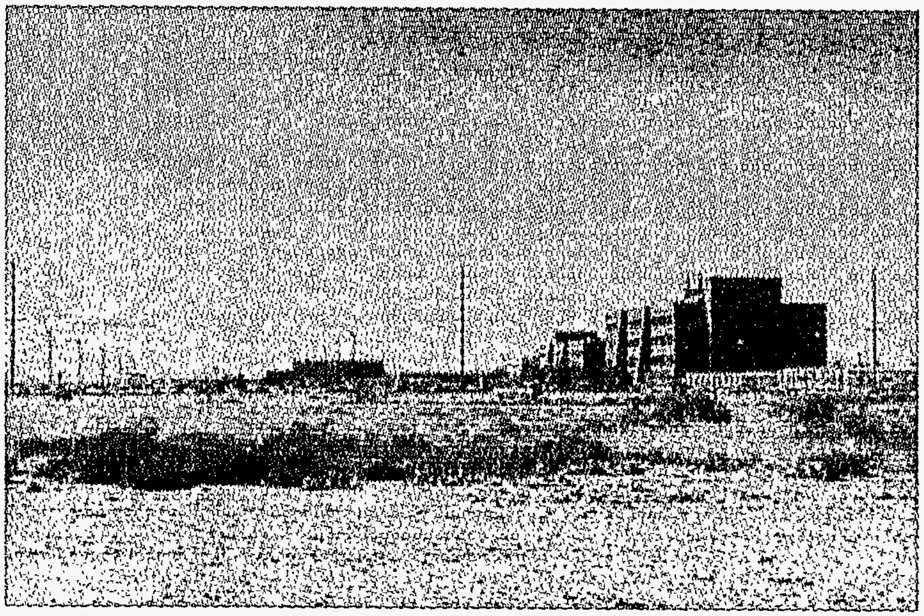
Figure 9-1
Visual Resource Photographs



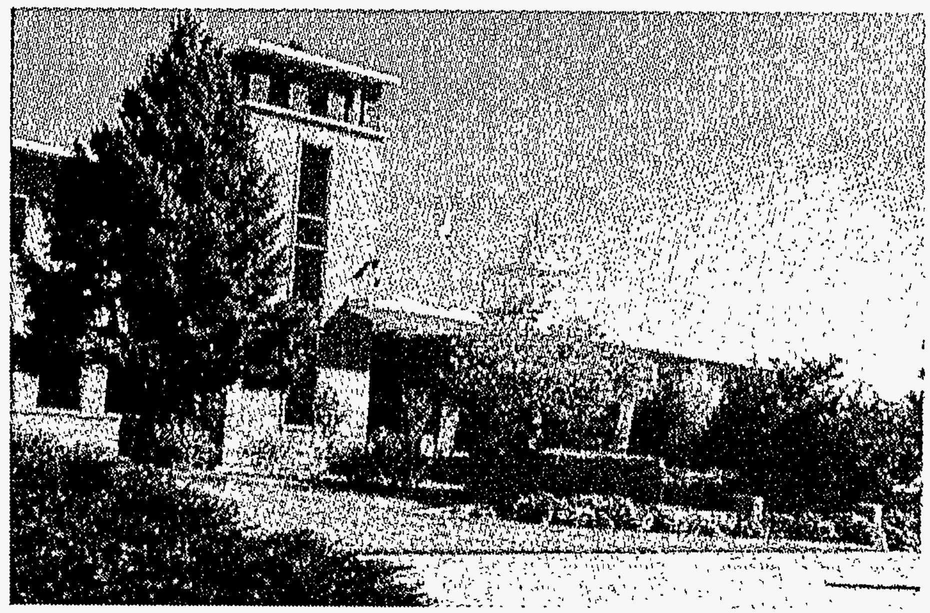
Landscaped Parking Lot, Technical Area I



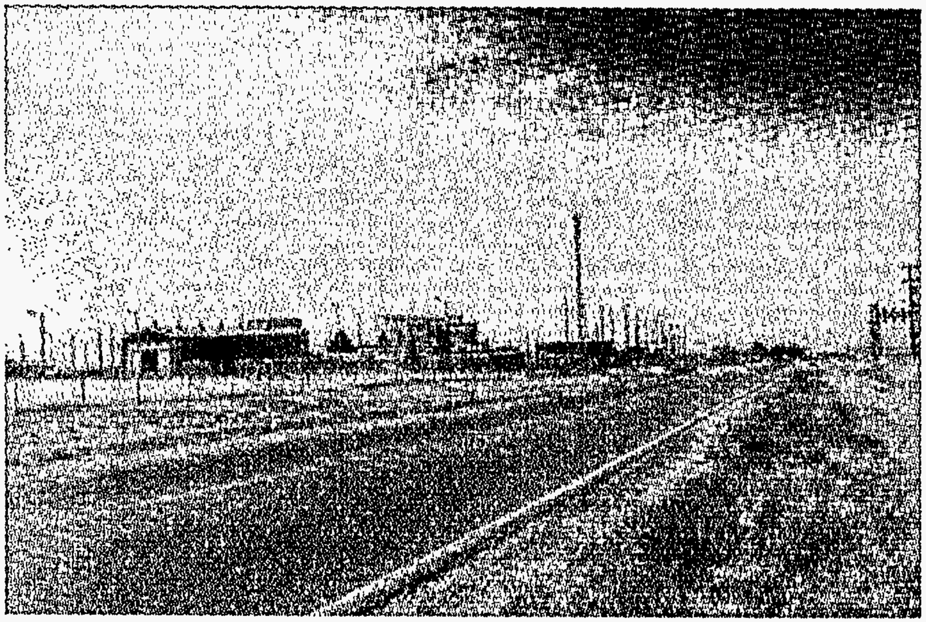
Landscaped Sign, Main Entrance



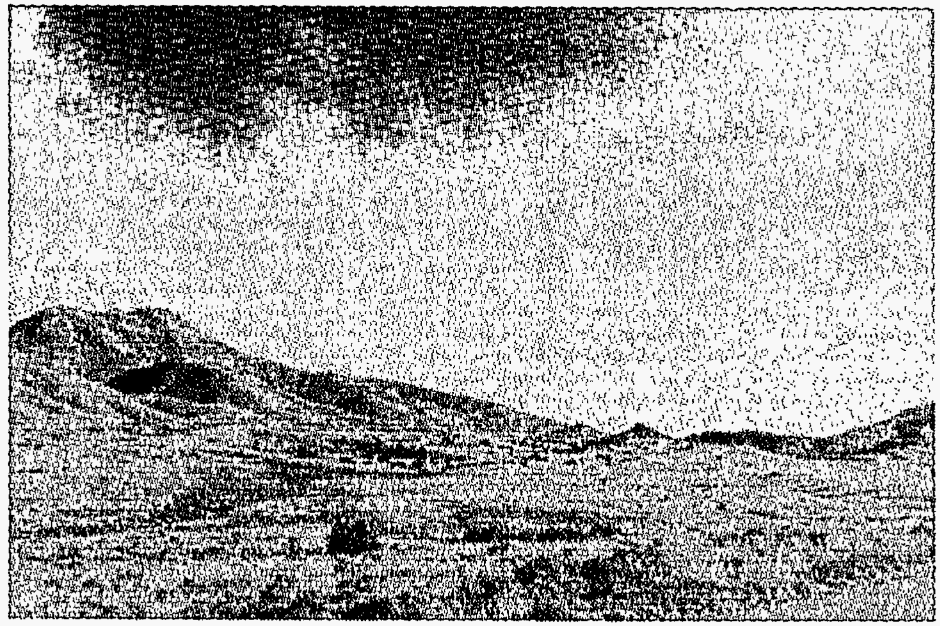
Eastern Edge of Technical Area I



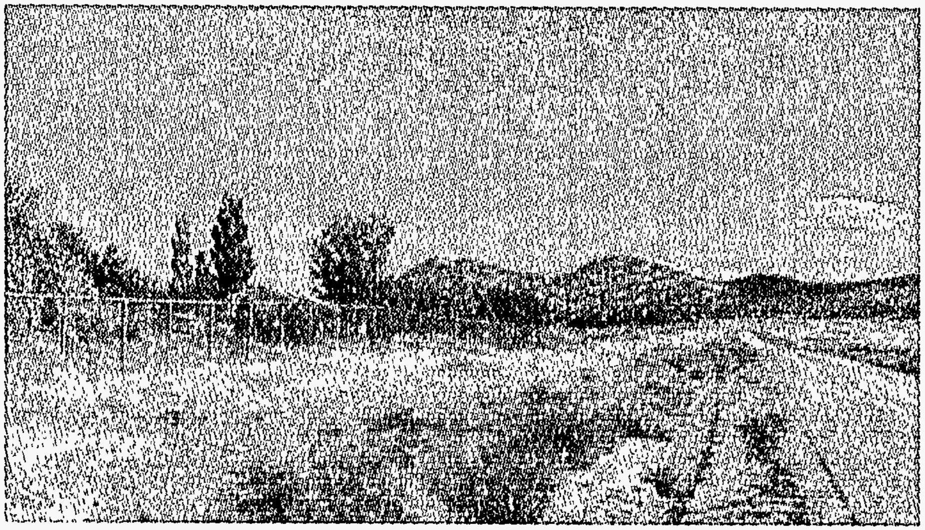
Landscaped Entry, Main Building



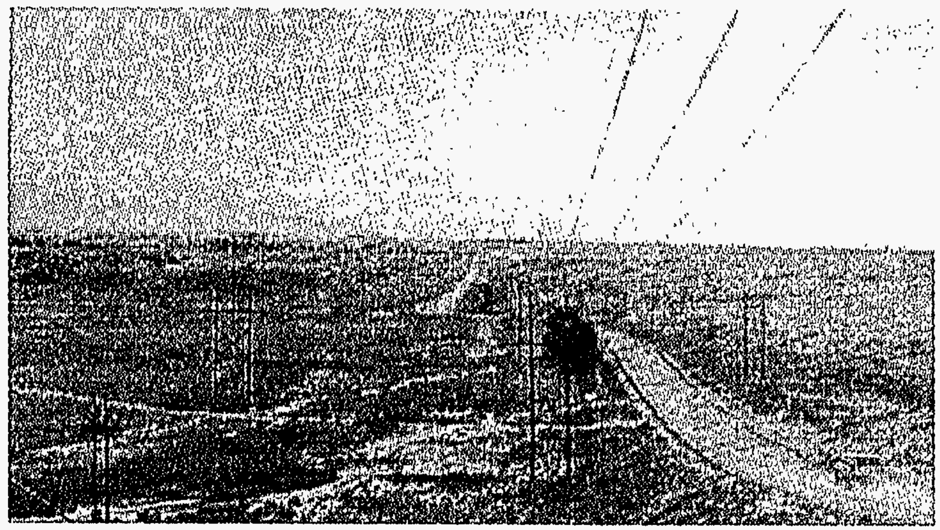
Technical Areas III and V



Northern Edge of Manzano Base, Four Hills Landform



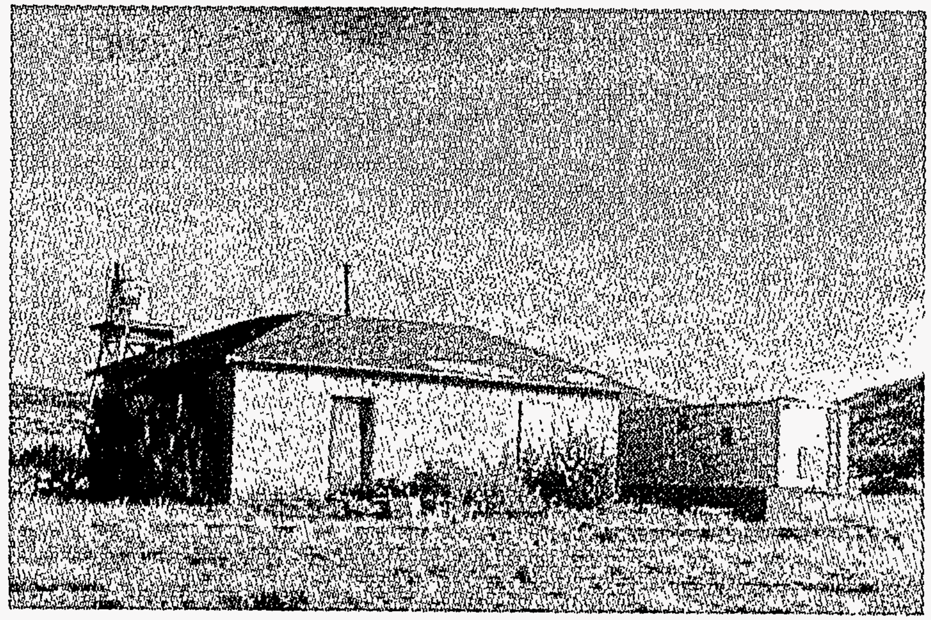
Boundary Adjacent to Four Hills Neighborhood



Powerlines Crossing Tijeras Arroyo

Golf Course Provides Visual and Vegetative Variety

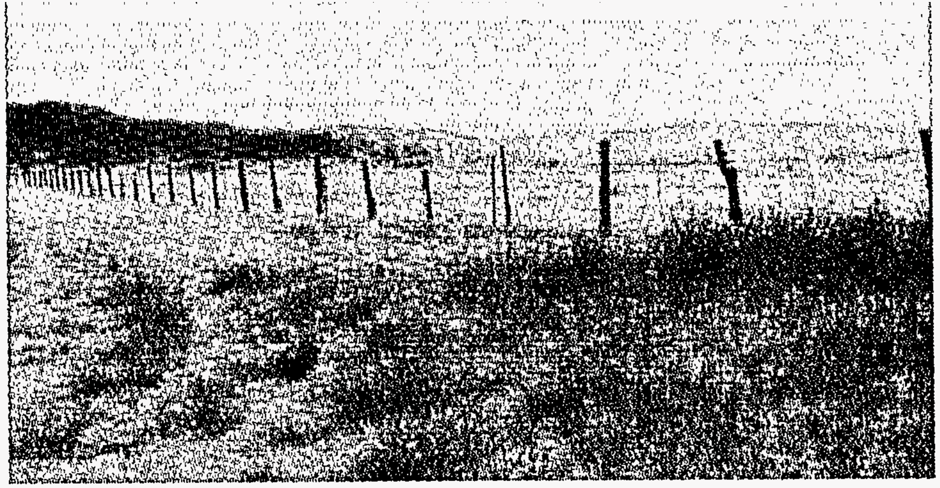
Abandoned Historic Building, Withdrawal Area



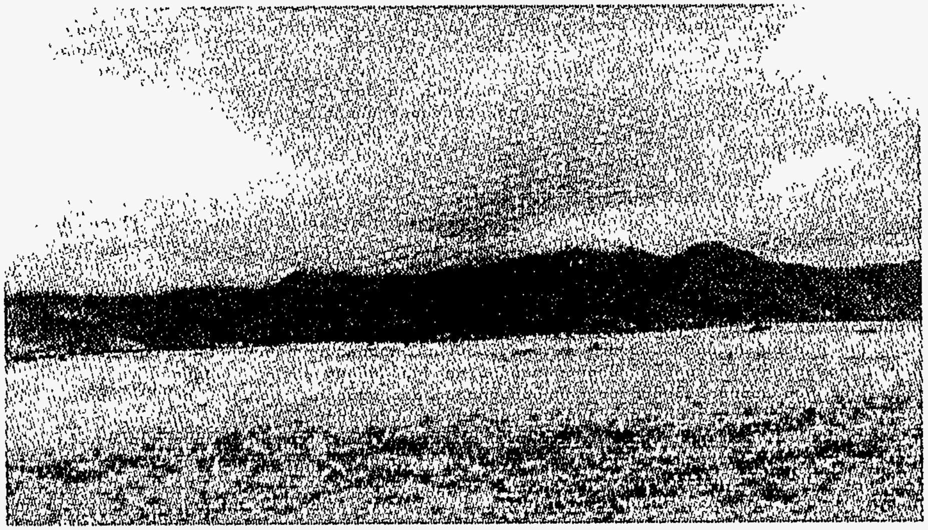
Historic Building

Figure 9-2
Visual Resource Photographs

Shock Tube, Flat Terrain of Western Third of Site

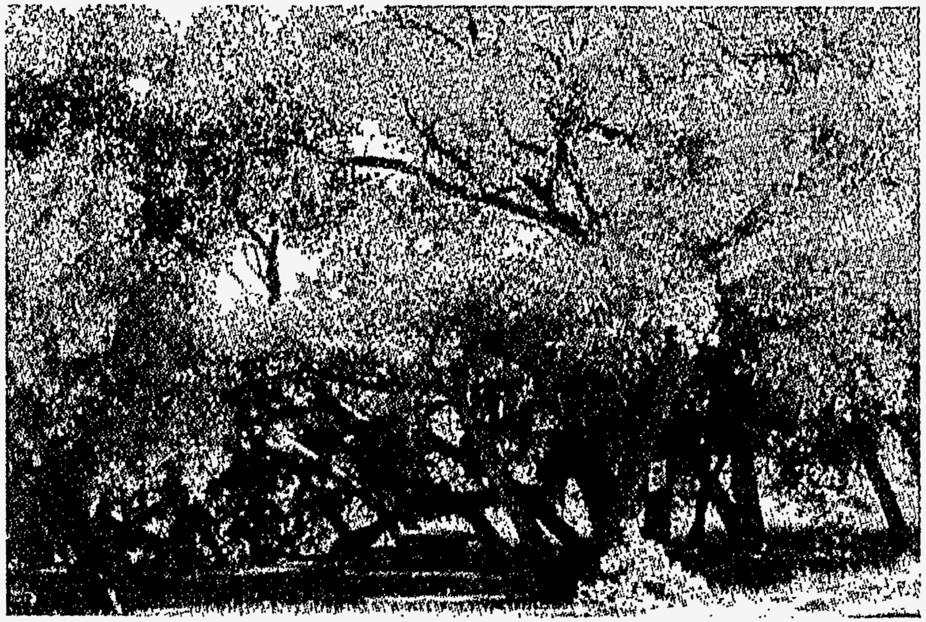


Isleta Boundary, View into Buffer Zone

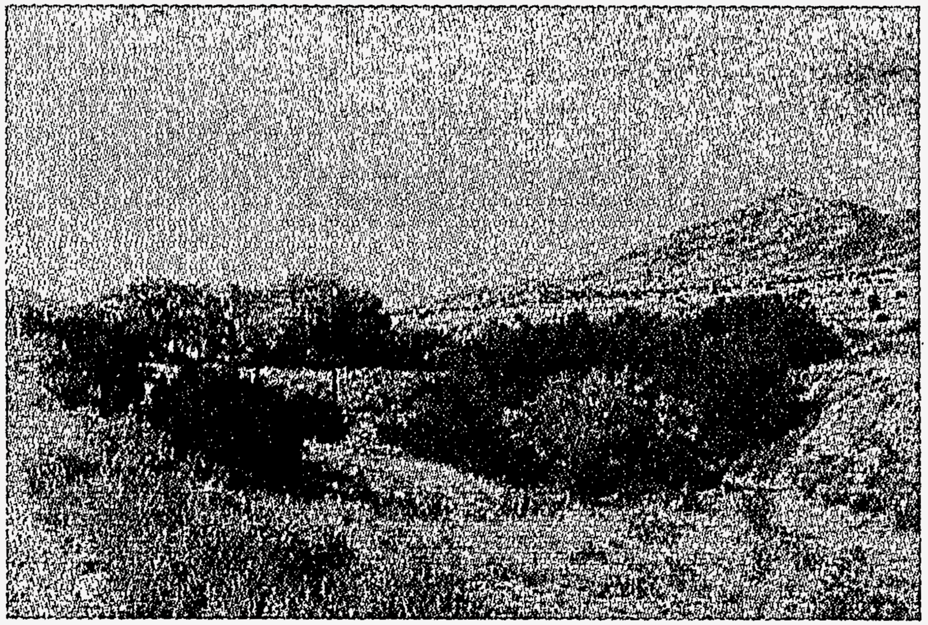


Hubble Bench (foreground), Mt. Washington (background)

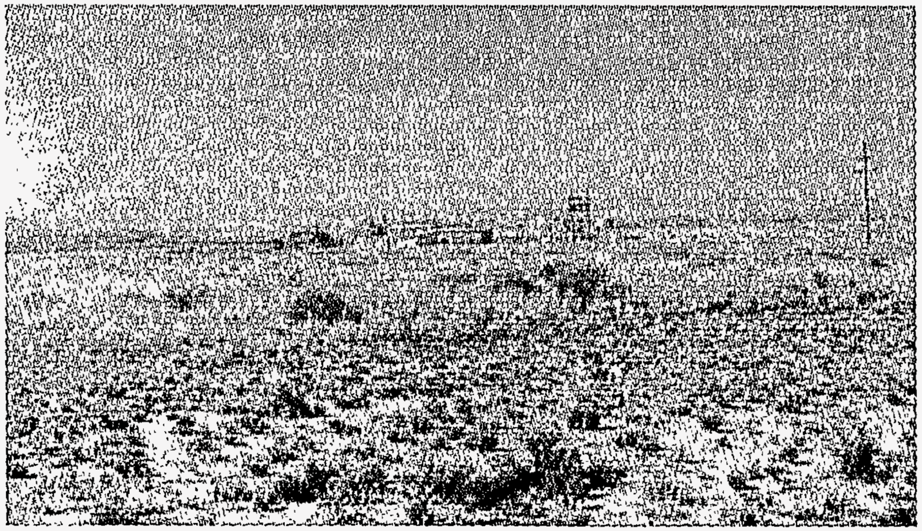
Figure 9-3
Visual Resource Photographs



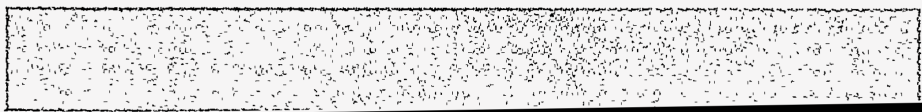
Coyote Springs Picnic Site



Arroyo del Coyote, Four Hills (background)

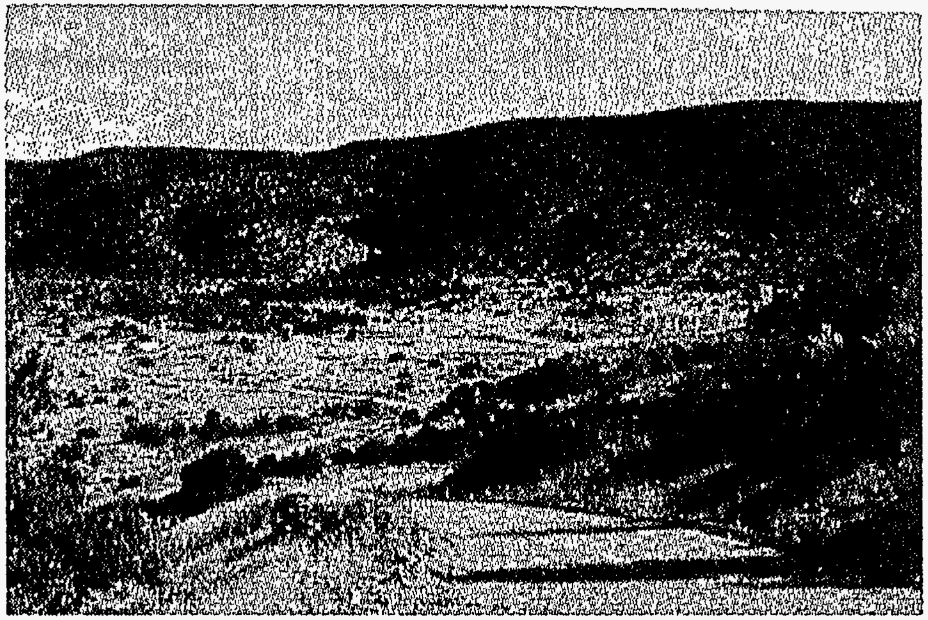


Large Melt Facility, Minimal Terrain and Vegetation, SW Quadrant



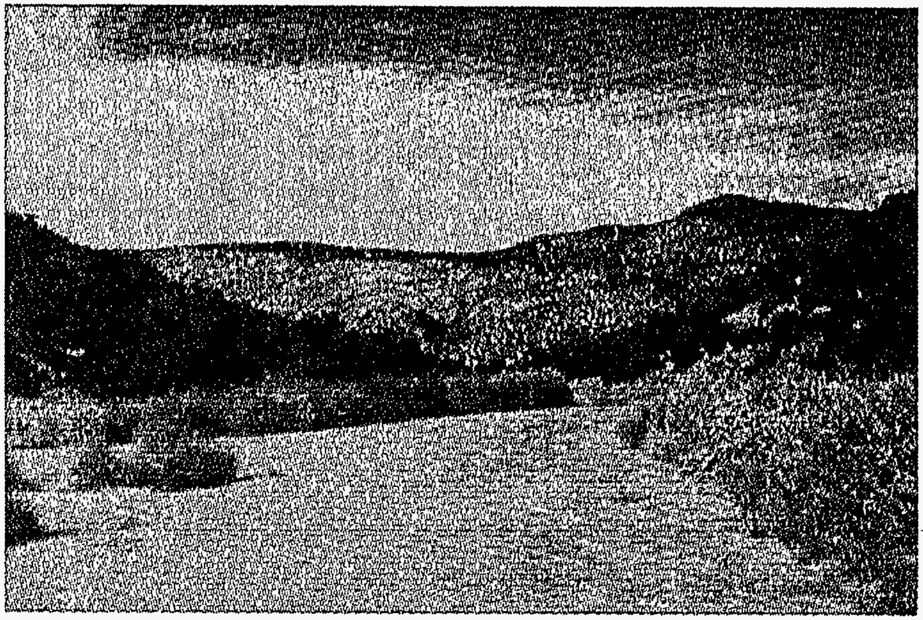
Forest Fire Burn Site, Withdrawl Area

Varied Vegetation of Foothills, Typical Outlying Facility Siting

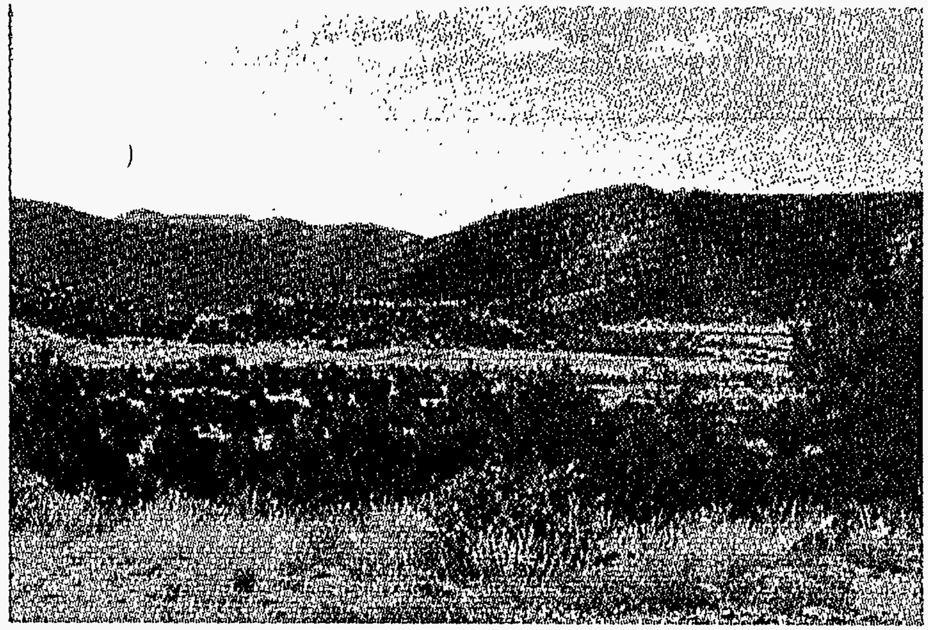


Burn Facility, Typical Siting and Clearing of Larger Facilities

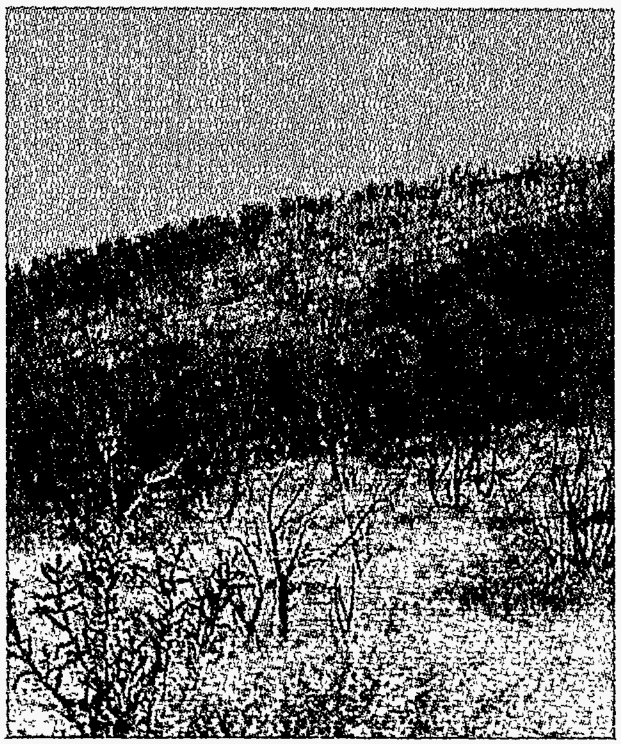
Figure 9-4
Visual Resource Photographs

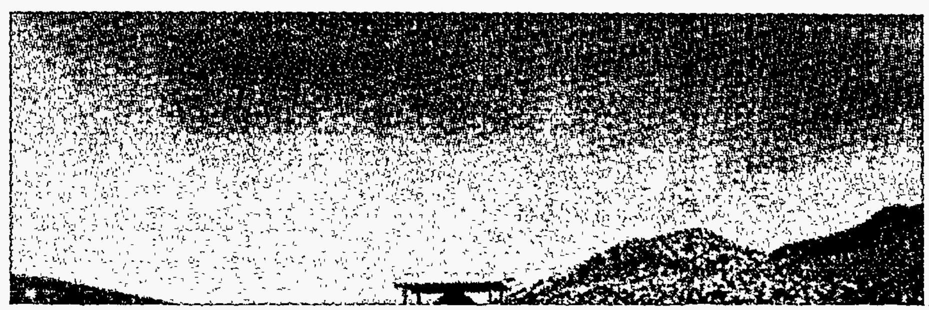


Madera Canyon Road, Manzanita Mountains



Lurance Canyon, Withdrawal Area





surroundings depicted in the study area photographs. In theory, the land could be returned to something resembling its original state. In practice, this would be difficult because the arid climate retards natural revegetation. In any case, if SNL/NM were to cease to exist, it is more likely that the buildings and facilities would be converted to other uses. The historic and continuing impact of land use by the SNL/NM and its predecessors is permanent (ERDA, 1977).

9.2 Study Approach

The visual resource inventory for this report followed the Visual Management System (VMS), an approach developed and used by USFS (USDA, 1974). The VMS was compatible with the visual resource inventory previously compiled for the Cibola National Forest, which forms the eastern two-thirds of the study area. A portion of the Cibola National Forest is leased by SNL/NM. The VMS system was modified for this study due to the impacts of extensive cultural modification (man-made changes) and the restricted access (limited visibility) of some areas of the site. Section 9.3 describes these modifications.

Existing inventory and evaluation data were not available for BLM land, the Isleta Indian Reservation, KAFB, or other military agencies located within the area. If feasible in the future, an integrated visual resource analysis should be conducted for the whole site (as part of a broader baseline environmental study). Some activities with potentially negative impacts on visual resources affect views to and from SNL/NM areas, even when SNL/NM is not responsible for the action (e.g., the KAFB landfill at the edge of the Tijeras Arroyo) which can be seen from other use areas.

The visual resource investigation addressed all SNL/NM technical areas and leased lands as determined from the land use permit boundaries (see Chapter 12.0, Figure 12-2).

9.3 Methodology

The visual resource assessment was conducted from September through December 1991. The primary data were obtained from field reconnaissance; the USFS Visual Resource Analysis for Cibola National Forest; 1:24,000 topographic maps; and aerial photos provided by SNL/NM for the years 1980 and 1989. Additional resources from the SNL/NM Environmental Restoration Project Geographic Information System (GIS) database have recently become available. These resources include updated aerial photographs and current digitized GIS maps.

The major components of the USFS VMS include:

- A description of landscape character types and a determination of variety classes

- A determination of sensitivity levels through identification of use areas or viewer locations, viewer concern, and associated distance zones

- A combination of the above elements to identify visual quality objectives, which refer to the degree of acceptable alteration of the characteristic landscape. Visual resource assessments are closely tied to land use (see Section 12.0 for related information).

9.4 Visual Resource Analysis

This section addresses the variety class, sensitivity levels, representative key views, and visual quality objectives of the visual resources analysis.

9.4.1 Variety Class

Variety classes are obtained by classifying the landscape into different subregions, based on degrees of variety within the rock forms, the topography, drainage features, and vegetation. This process determines which landscapes are more important in terms of scenic quality.

The first step in determining variety class is to identify character types. A character type is a large physiographic area of land that has common characteristics of landform, rock formations, water forms, and vegetative patterns. The Mexican Highlands character type is located in Sonora and Chihuahua, Mexico; southeastern Arizona; and southwestern and central New Mexico (Fenneman, 1931). The SNL/NM study area lies within the Eastern Mexican Highlands character subtype, which determines the definitions for the classes of variety used.

Features such as landforms, water forms, rock formations, and vegetative patterns are compared singularly or in combination with other features commonly found in the same character type. Through this comparison, an area's overall degree of scenic quality and the resultant variety class rating are determined. Table 9-1 lists the landscape features of the Eastern Mexican Highlands character subtype by variety class. Adjacent scenery and cultural modifications not listed in the VMS were added in order to fully address the scenic quality of the study area. It was determined that adjacent scenery and the extensive man-made modifications would affect the scenic quality of the SNL/NM landscape. Therefore, the variety classes listed vary from those of the USFS system.

Table 9-1
Landscape Features

	Class A—Distinctive	Class B—Common	Class C—Minimal
Landform	Terrain that is highly varied and distinctive. Unique features: isolated mountain peaks with distinctive form and color contrast or escarpments or cliffs that dominate the surrounding landscape because of scale, color, and/or texture.	Terrain that is moderately varied broad slopes and rounded hills that are not visually dominant but are surrounded by similar landforms or features such as bluffs or rock formations that are subordinate to the surrounding landscape.	Terrain that is unvaried, vast expanses of landform that provides little spatial definition. Landforms may be sloping but are lacking in visual interest.
Rock Form	Escarpments, cliffs, and talus slopes that dominate the surrounding landscape because of scale, color, or texture or volcanic cones and sharp, jagged ridges.	Bluffs or boulders that are subordinate to surrounding landscape, ridges, and outcrops that are not visually dominant.	No noticeable rock form.
Vegetation	Vegetation that is highly varied and distinctive pinion-juniper woodland combined in strongly defined patterns with grasslands or with dramatic seasonal color or with unusual form, color, or texture compared to surrounding vegetation.	Vegetation that is moderately varied and woodlands that exhibit the normal range of size, form, color, texture, and spacing. Subtle seasonal contrasts.	Vegetation that is unvaried or vegetation that has limited variation in texture and color.
Drainage	Reservoirs; perennial watercourses; unique features, such as falls, rapids, pools, or significant wetlands or marshes.	Canyons and drainages that lack distinctive configuration or colors. Interrupted watercourses.	Ephemeral or absent watercourses.
Adjacent Scenery	Adjacent scenery that greatly enhances overall visual quality.	Adjacent scenery that moderately enhances overall visual quality.	Adjacent scenery that has little or no influence on overall visual quality.
Cultural Modification	Free from aesthetically undesirable sights and influences or modifications that add favorably to visual variety.	Scenic quality that is somewhat depreciated by inharmonious intrusions but is not entirely negated or modifications that add little or no visual variety to the area.	Modifications that are so extensive that scenic qualities are mostly nullified or are substantially reduced.

Source: U.S. Department of Agriculture (USDA), 1974, "Visual Management System," *Handbook Number 462*, Vol. 2, Ch. 1, U.S. Forest Service.

The three variety classes used to identify the scenic quality of the natural landscape at SNL/NM are as follows:

- Class A—Distinctive. Refers to those areas where features are of unusual or outstanding visual quality.
- Class B—Common. Refers to areas where features contain variety in form, line, color, and texture, or have a combination of these features, that tends to be common throughout the character type and that are not outstanding in visual quality.
- Class C—Minimal. Refers to those areas where features have little change in form, line, color, or texture. This includes all areas not found under Classes A and B.

SNL/NM's visual characteristics consist of mostly flat, gently sloping terrain to the west and mountains to the east. From the adjacent Four Hills neighborhood, views to the east and southeast are limited by the features of Manzano Base. From the five SNL/NM technical areas, views are generally open in all directions. Views from Interstate 40 are limited to views of the Four Hills features and background views. The views from Interstate 25 are background views only, with no visible detail. The study area cannot be seen from Interstate 40 east of Tramway Boulevard or from anywhere along State Highway 337 because of mountainous topography. The western portion of SNL/NM is mostly open and flat (the Rio Grande Valley landform) and is not visually interesting. The eastern portion (the Hubbell Bench and the Manzanita Mountains), however, exhibit greater variety and diversity. Four major elements affect the eastern area's scenic quality:

- The Tijeras Arroyo. This large arroyo is a unique feature that provides visual variety.
- The adjacent scenery, which enhances the visual quality of the study area, particularly with views to the east of the Manzano Mountains. The undisturbed areas of USFS's withdrawn lands add to this scenic beauty.
- The largely industrial cultural modifications, including dumping in the arroyo, grading of hillsides and ridge tops, and placement of electric utility lines that cross the area, depreciating the scenic quality.
- Other important visual resources, including the Manzanita Mountains; the Madera, Lurance, and Sol se Mete Canyons; the small arroyos; the Coyote Springs area; and the Tijeras Arroyo Golf Course (which provides visual variety and recreational opportunities).

9.4.2 Sensitivity Level

Sensitivity levels measure the particular degrees of viewer interest in the scenic qualities of a landscape. Sensitivity levels are determined in two steps: (1) identifying travel routes and usage within the area of consideration and establishing their importance (either primary or secondary), and (2) identifying the major or minor concern of users or viewers of the area's scenic qualities. Both steps depend on the number of viewers and the distance from the viewed feature.

Table 9-2 provides the distance zones used in this study. Table 9-3 describes general areas of primary and secondary importance to the USFS. Table 9-4 presents sensitivity levels that have been customized for the SNL/NM study.

The two steps together determine which areas become Sensitivity Level 1, 2, or 3, with Level 1 being the highest sensitivity and Level 3 being the lowest. The sensitivity levels are combined with distance zones (areas of a landscape denoted by specified distances from the observer) to determine the total area observed. Combining sensitivity levels with variety class results in the visual quality objectives.

In the context of the USFS visual assessment approach, major concern is typically expressed by people who enjoy the recreational aspects of an area or who drive through an area for pleasure. Major concerns for this study have been broadened to include nearby residential viewers, individuals who work at SNL/NM, individuals who utilize adjacent areas, and visitors. Minor concern is typically expressed by commuters or people involved in commercial uses of the forest. Minor concerns for this study have been broadened to include individuals who interact with SNL/NM for short periods or who are separated from critical features of the area because of distance.

It is difficult to measure subjective individual attitudes toward a landscape without public input. However, general assumptions can be made through the VMS process that reflect general attitudes and/or perceptions. SNL/NM's restricted access limits area usage to employees of SNL/NM, KAFB, and DOE and to residents of KAFB. It has been assumed that these individuals, primarily employees in Technical Area I, residents of the Four Hills neighborhood, and motorists along Interstate 40, have a major concern about visual quality.

Table 9-2

Distance Zones

Zone	Distance
Foreground	Within 0.25 mi (0.4 km) of the observer
Middle ground	Extends from foreground to 3 mi (4.8 km) from observer
Background	Extends from middle ground to infinity

Source: Consensus Planning/Zephyr Design.

Table 9-3

Primary and Secondary Importance Classification Utilized by the U.S. Forest Service

	Primary Importance	Secondary Importance
Travel Route	National importance High-use volume Long-use duration Forest land access roads	Local importance Low-use volume Short-use duration Project roads
Use Areas	National importance High-use volume Long-use duration Large size	Local importance Low-use volume Short-use duration Small size

Source: U.S. Department of Agriculture (USDA), 1990, *Landscape Character Types of the National Forests in Arizona and New Mexico*, U.S. Forest Service, Southwestern Region, Albuquerque, New Mexico.

Table 9-4
Visual Resources Sensitivity Levels

Level 1	
Primary	**Secondary**
I-40 Four Hills Neighborhood I-25 Technical Area 1	Pennsylvania Road (north of Tijeras Arroyo) Eubank Boulevard Central Avenue Gibson Boulevard
Level 2	
Primary	**Secondary**
Technical Areas II through V State Highway 337 and neighborhoods Shaw Mobile Home Park and other Southeast Heights neighborhoods Coyote Springs Road Pennsylvania Road (south of Tijeras Arroyo) Other SNL/NM use areas outside of the technical areas Commercial air routes	USFS recreation areas Historic sites USFS trails in the Manzanita Mountains All interior roads within KAFB/DOE-owned and leased boundaries Trails and roads in bottom of the Tijeras Arroyo
Level 3	
All other areas not specifically listed. When mapped, all of the study area falls within foreground, middle ground, and background views of a feature within Level 1 or 2. Therefore, no Level 3 areas appear on Figure 9-5.	

USFS = U.S. Forest Service
SNL/NM = Sandia National Laboratories/New Mexico
KAFB = Kirtland Air Force Base
DOE = Department of Energy

Source: Consensus Planning/Zephyr Design.

9.4.3 Representative Key Views

Representative key views concern principal viewing locations or viewpoints from which an area is seen or from which significant views within the study area can be seen. Based on field observations and examination of topographic maps of the study area, there are five key views at SNL/NM:

- The Tijeras Arroyo
- Four Hills area of Manzano Base
- The Arroyo del Coyote and Coyote Springs
- The Manzanita Mountains and associated canyons and foothills
- The Manzano and Sandia Mountains.

9.4.4 Visual Quality Objectives

Visual quality objectives refer to the degree of acceptable alteration of a natural landscape, based on the importance of aesthetics. At SNL/NM, these visual quality objectives are as follows:

- P - Preservation. This objective mostly applies to wilderness areas, where no visual quality objectives are to be met.

- R - Retention. This objective allows activities that are not visually evident.

- PR - Partial Retention. This objective allows activities that are visually subordinate to the characteristic landscape.

- M - Modification. This objective allows activities that visually dominate the original characteristic landscape. Activities of vegetative and landform alteration must reflect an established form, line, color, and/or texture that is compatible with the surrounding landscape.

- MM - Maximum Modification. This objective allows activities that alter vegetation and landform which visually dominate the characteristic landscape.

Figure 9-5 presents the visual quality objectives that have been determined for SNL/NM. (The objectives mapped in Figure 9-5 should be used as a guide at a conceptual planning stage for siting and designing future SNL/NM development. A detailed visual analysis should be completed prior to any major development [i.e., new buildings or construction that is permanent and could potentially impact visual resources] as part of the environmental analyses.) At a broad conceptual level, the visual quality objectives show that most of SNL/NM is in the Partial Retention or Modification category. The northwestern part of the site around Technical

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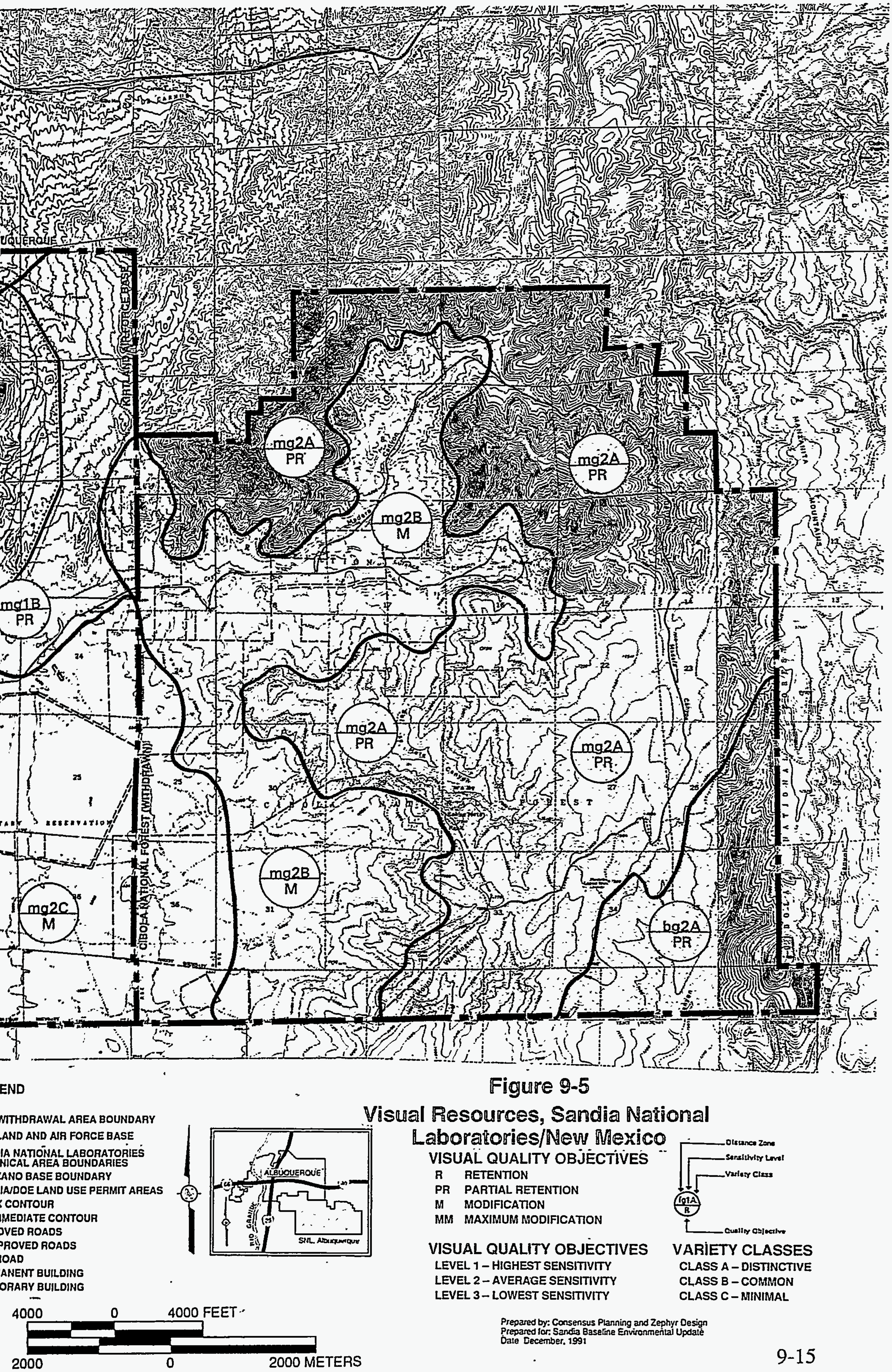
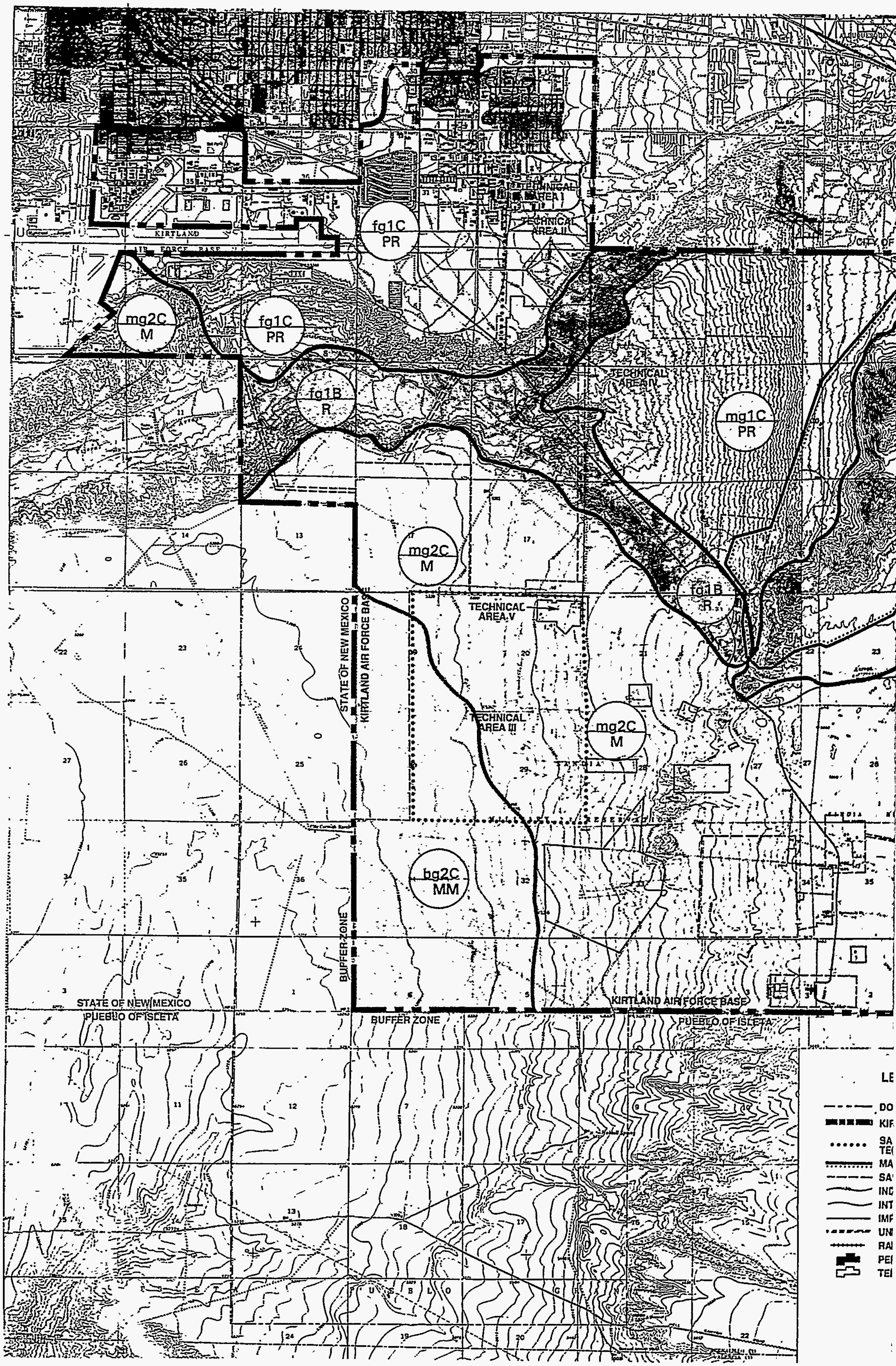


Figure 9-5

Visual Resources, Sandia National Laboratories/New Mexico

Prepared by: Consensus Planning and Zephyr Design
Prepared for: Sandia Baseline Environmental Update
Date December, 1991



KIRTLAND
AIR FORCE BASE
TECHNICAL AREA I
TECHNICAL AREA II
fg1C
PR
mg2C
M
fg1C
PR
fg1B
R
TECHNICAL AREA IV
mg1C
PR
mg2C
M
fg1B
R
TECHNICAL AREA V
STATE OF NEW MEXICO
KIRTLAND AIR FORCE BASE
TECHNICAL AREA III
mg2C
M
bg2C
MM
BUFFER ZONE
STATE OF NEW MEXICO
PUEBLO OF ISLETA
BUFFER ZONE
KIRTLAND AIR FORCE BASE
PUEBLO OF ISLETA

Area I and several other portions of the study area have been mapped as Partial Retention, even though the area has been extensively modified by development. This is due to the number of viewers and sensitivity Level I classification that apply to the area. Tijeras Arroyo has been mapped in the Retention category, which requires that no new visible development be placed within that characteristic feature. This is due to the arroyo's close proximity to areas with high sensitivity levels and to its major landform characteristics. Some of the areas that have lower sensitivity levels and more common landscape features and that have already been highly modified by SNL/NM/DOE/KAFB activities have been mapped in the Modification category. SNL/NM may choose to site future developments that may be visually dominant over the characteristic landscape in these areas. Appendix B provides the recommended measures for establishing visual compatibility, which qualify as "mitigation measures" for an EA or EIS.

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10.0 Socioeconomics/Demographics

As a major employer in New Mexico, SNL/NM has a major economic and social impact on the state and, in particular, on the Albuquerque metropolitan area. Approximately 7,445 full-time people, 499 part-time people, and 1,686 contractors are employed by SNL/NM at several New Mexico locations (SNL/NM, 1995a). In addition, approximately 3,000 pensioners (former SNL/NM employees) reside in New Mexico. This section focuses on the two major impacts SNL/NM has had on New Mexico, Bernalillo County, and Albuquerque: economic and social.

10.1 Economic Impact

Employment, overall economic impact, and construction of SNL/NM will be discussed in the following sections. Total impact represents direct, indirect, and induced effects. The multipliers used to determine impacts result from information released by the U.S. Department of Commerce, Bureau of Economic Analysis in 1994, input-output models developed by economists at DOE-Albuquerque (DOE/AL) and New Mexico State University (NMSU) (Lansford et al., 1995). SNL/NM expenditures for salaries and purchases go to households, local businesses, and other regions.

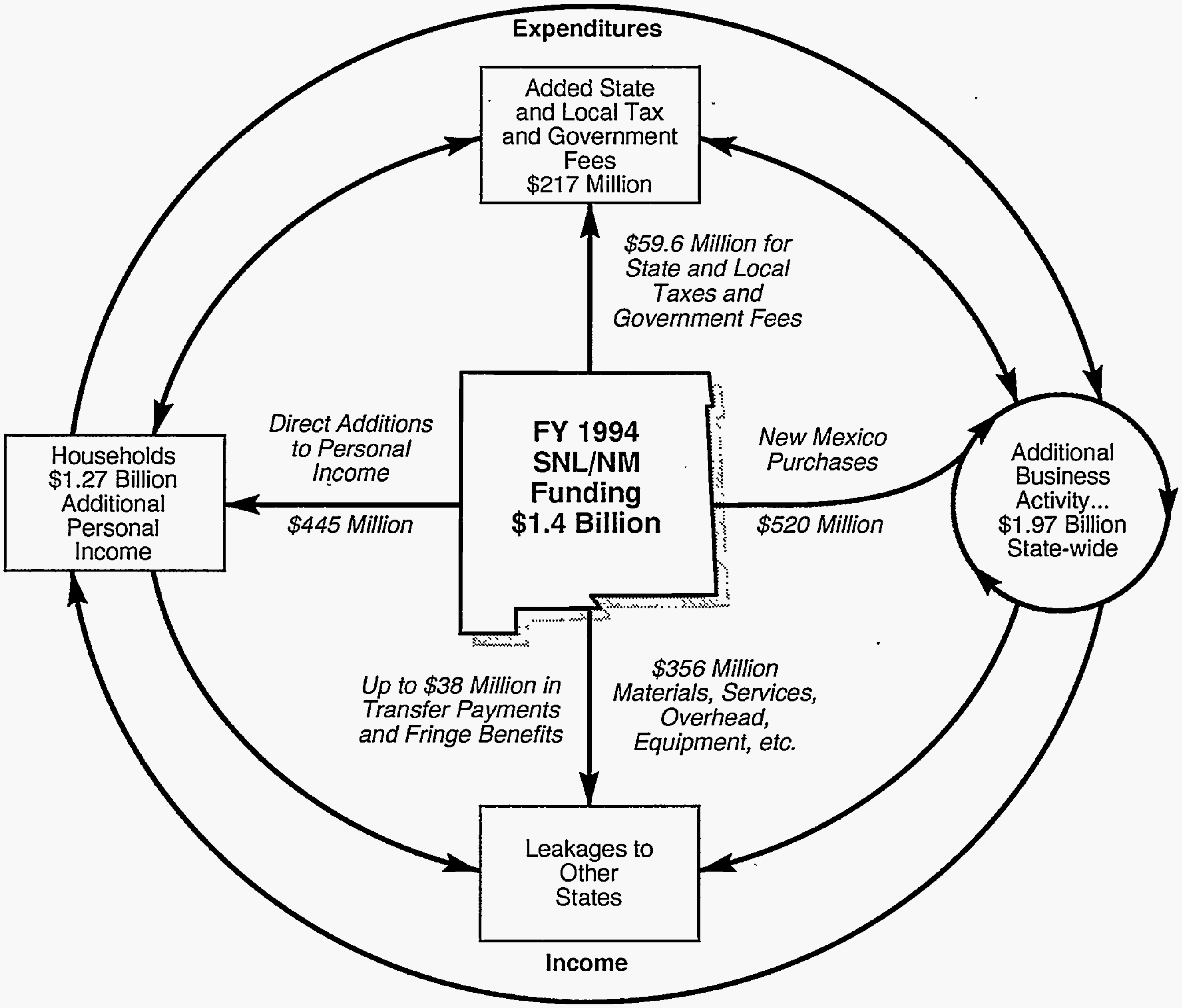
10.1.1 Employment

SNL/NM is the fifth largest employer in New Mexico. Figure 10-1 charts the movement of moneys spent by SNL/NM in Fiscal Year (FY) 1994. An average of 8,069 full-time jobs were created at SNL/NM during FY 1994 (Lansford et al., 1995). This resulted in a statewide total increase in FY 1994 of 37,348 jobs (including contractors and consulting services), due to the multiplier effect of 4.63 additional jobs supporting each of the 100 direct jobs at SNL/NM. This amounts to 5 percent of all employment in New Mexico.

10.1.2 Overall Economic Impact

Based on the $1.4 billion FY 1994 SNL/NM budget, econometric modeling techniques were used to calculate the effects of this funding (Lansford et al., 1995). SNL/NM operations in central New Mexico have a significant influence on the economy of central New Mexico. The funding for SNL/NM in central New Mexico was about $1.4 billion in FY 1994, yielding a total economic impact of $4.7 billion or about 12.2 percent of the total economic activity in the region.

Total personal income impact was nearly $1.2 billion in FY 1994 or nearly 10 percent of personal income derived in Sandoval, Bernalillo, Valencia, and Torrance Counties. The



Total State-wide Economic Impact -- $4.88 Billion

SNL/NM = Sandia National Laboratories/New Mexico

FY = Fiscal Year

Source: *Lansford, R.R., L.D. Adcock, and S. Ben-David, 1995, "The Economic Impact of the Sandia Laboratories on Central New Mexico and the State of New Mexico Fiscal Year 1994," prepared for the Office of Energy, Science and Technology, Albuquerque Operations Office, U.S. Department of Energy.*

Figure 10-1
Sandia National Laboratories/New Mexico Economic Impacts on the State of New Mexico, Fiscal Year 1994

employment multiplier, 4.45 for the region, means that the 8,047 average employment level in FY 1994 resulted in a total impact of 35,828 (including contractors and consulting services). In effect, nearly one of every nine jobs in the region was created or supported by SNL/NM. Approximately 73 percent of the jobs created indirectly by SNL/NM in the region occurred in the wholesale and retail trade, other services, and education sectors (Lansford et al., 1995).

As Table 10-1 indicates, the total impact of SNL/NM on economic activity in New Mexico was $4.88 billion in FY 1994, due to the initial infusion of $1.4 billion. SNL/NM in-state direct expenditures of $0.48 billion for wages and salaries generated $1.3 billion of personal income in the state. Actual SNL/NM in-state expenditures were over $1.06 billion in FY 1994 for salaries and wages, materials and services, capital equipment, and construction (Table 10-2) (Lansford et al., 1995). The direct spending in New Mexico of $1.06 billion is equivalent to over $500 for each resident. SNL/NM funding accounts for an economic impact of $4.9 billion or about 6 percent of total economic activity in New Mexico.

By far, the largest expenditure in the State of New Mexico was on labor ($484 million), which was almost 45 percent of the total state expenditures, or approximately 34 percent of the total operating and capital budget for FY 1994. Another $344 million (23.6 percent) was spent locally for materials, services, and utilities, while $21 million was spent on manufactured goods (2.0 percent). Construction accounted for about 12 percent ($126 million); other sectors accounted for $28 million (2.6 percent).

State and local taxes and government fees accounted for 5.6 percent of the $1.06 billion in state expenditures (Lansford et al., 1995). SNL/NM and its contractors paid state and local governments nearly $60 million in taxes and government fees in FY 1994. Out-of-state purchases and salaries for those living elsewhere amounted to $356 million in 1994.

10.1.3 Construction

Several new facilities are under construction at SNL/NM, and a number of facilities are being modernized. Table 10-3 lists the largest funded projects and construction costs.

Table 10-1

Sandia National Laboratories/New Mexico Influence on New Mexico's Economy, Fiscal Year 1994

Economic Measure	FY 1994 SNL/NM	FY 1994 Total State	FY 1994 SNL/NM as % of State
	Dollars in Billions		
Economic Activity			
Direct Expenditures	$1.42		
Indirect and Induced[a]	3.46		
Total	$4.88	$81.6	6.0%
Economic Activity Multiplier	3.44		
Personal Income			
Gross Labor Costs	$0.48		
Net Wages and Salaries	0.45		
Indirect and Induced[a]	0.83		
Total	$1.27		
Personal Income Multiplier	2.86	$24.3	4.5%
	(No. of Employees)		
Employment			
Direct	8,069		
Indirect and Induced[a]	29,279		
Total	37,348		
Employment Multiplier	4.63	722,000[b]	5.2%

[a]Based on the results of the econometric model
FY = Fiscal Year
SNL/NM = Sandia National Laboratories/New Mexico
% = Percent

Source: New Mexico Department of Labor, Economic Research and Analysis Bureau, Table A, 1992, as included in Lansford et al., 1995.

Table 10-2

SNL/NM Expenditures in New Mexico (in Dollars) by Major Sector and Total Operation Budget, Fiscal Year 1994

	Sectors	SNL/NM Expenditures		Sectors	SNL/NM Expenditures
1.	Livestock and livestock products	0	22.	Electric and gas utilities	16,350,451
2.	Other agricultural products	0	23.	Water and other utilities	723,598
3.	Forestry and fishery products	0	24.	Wholesale trade	37,552,043
4.	Agricultural, forestry, and fishery services	366,522	25.	Retail trade	55,971,108
5.	Mining, crude petroleum, and natural gas	3,030,436	26.	Finance, insurance, and real estate	433,829
6.	Construction	126,198,906	27.	Hotel, restaurant, and other personal services	57,678
7.	Ordnance and chemical manufacturing	111,489	28.	Data processing and computer services	43,982,770
8.	Food and kindred products	0	29.	Management and consulting services	54,620,593
9.	Textiles products & apparel	121,467	30.	Engineering and related services	59,095,388
10.	Lumber and wood products	119,309	31.	Other business services	73,597,796
11.	Paper and publishing	1,869,603	32.	Automobile and other repair services	379,521
12.	Petroleum refining and products	235,330	33.	Amusements, recreation, and video services	123,759
13.	Glass, stone, and clay products	23,087	34.	Health, education, and social services	19,055,884
14.	Primary and fabricated metals	3,888,829	35.	Government services	1,753,083
15.	Computer, office, and service equipment	5,856,359	36.	Local government	21,954,024
16.	Electrical equipment	5,396,199	37.	State government	33,877,652
17.	Scientific instruments	3,187,256	38.	Sandia National Laboratories[a]	--
18.	All other manufacturing	269,980	39.	Households	483,863,468
19.	Motor freight transportation and warehousing	1,350			
20.	All other transportation	124,099		Total New Mexico expenditures	1,063,090,208
21.	Communication	6,897,342		Total operating and capital budget	1,419,057,813

[a]Any transfer of money for services or products between specified activities is counted only in the activity of the last receiving agency.

SNL/NM = Sandia National Laboratories/New Mexico

Source: Lansford, R. R., L. Adcock, and S. Ben-David, 1995, The Economic Impact of Sandia Laboratories on Central New Mexico and the State of New Mexico, Fiscal Year 1994, prepared for the Office of Energy, Science and Technology, Albuquerque Operations Office, U.S. Department of Energy.

Table 10-3
Examples of Major Construction Projects at SNL/NM, Fiscal Year 1995

Project Title	Start Date	Occupy Date	Total Cost ($ millions)
Integrated Materials Research Laboratory	1/91	FY 95	$27.9
Explosive Components Facility	3/89	FY 95	$27.8
Weapons Production Primary Standards Laboratory	4/88	FY 95	$17.7
Center for National Security and Arms Control	6/90	FY 95	$34.5
Robotics Manuf. Science and Engineering Laboratory	1/93	FY 97	$33.0
Technology Support Center	12/91	FY 95	$30.0
Investment Casting Addition	1993	FY 96	$34.2

FY = Fiscal Year
SNL/NM = Sandia National Laboratories/New Mexico

Source: Sandia National Laboratories/New Mexico (SNL/NM), 1995a, "Site Development Plan," Sandia National Laboratories, Site Planning, Department 7256, Albuquerque, New Mexico.

10.2 Social Impact

In addition to economic impacts, there are the effects on the quality of life. SNL/NM influences all sectors of the state's economic and social infrastructures, particularly in Bernalillo County. The following sections discuss the social impact SNL/NM has on the local community.

10.2.1 SNL/NM Community Involvement

Launched in April 1983, SNL/NM's Volunteers in Action program is a clearinghouse linking on-roll and retired employees and their families to community volunteer opportunities that suit their personal interests and talents. Volunteers in Action provides information on specific needs for volunteers in varied community agencies and provides assistance in making initial contact. Currently there are more than 1,000 volunteers enrolled in the program. In FY 1994, 281 volunteers were assigned in response to requests from 46 different agencies. SNL/NM actively supports civic functions and United Way agencies with funds and volunteers (personal communication, SNL/NM Org. 12671).

SNL/NM Community Relations Department provided 50 tours for more than 1,883 visitors from the general public during FY 1994. More than 1,800 visitors were students from New Mexico and surrounding states. Typical tours included stops at solar facilities, semiconductor research and development laboratories, environmental testing sites, inertial confinement fusion operations the robotic vehicle range, and virtual reality facilities. Through the Community Relations Department's Speakers Bureau, 10 SNL/NM employees spoke to audiences totaling 592 people during FY 1994 (personal communication, SNL/NM Org. 12671).

10.2.2 Political and Public Affairs

Current and retired SNL/NM employees and members of their families also serve as elected officials on school boards, city councils, county commissions, and the state legislature. Many employees participate in various other political entities by appointment to city, county, state, and regional boards, commissions, and councils and on national advisory boards. Employees and their family members assist with voter registration and election polls, and they participate in precinct activities and political campaigns throughout New Mexico. SNL/NM and its contractors' employees and their families are active in various political activities at the state, county, pueblo, and other local levels. Several contractor employees are elected officials. A former president of

SNL/NM serves as the chairman of the Economic Development and Tourism Commission. An executive loaned by SNL/NM currently serves as Special Assistant to the Governor, and several retirees are working on the Privatization Project and the educational upgrade program.

10.3 Technical Impact

SNL/NM has been active in technology transfer for which it has documented 170 transfer actions to 600 users. In addition to working on individual technologies with a single client, SNL/NM communicates through meetings with industrial groups, technical papers, and presentations to professional organizations. SNL/NM also publishes articles in trade and professional journals and daily responses to inquiries of individuals from industry.

Although technology transfer is a major nationwide effort, as in all national research programs, SNL/NM provides New Mexico with a proximity advantage to the state. SNL/NM has been and continues to be active with the state government's efforts to achieve high-technology economic development. The technology transfer programs provide both economic and social benefits to the state, as well as the nation. Examples of the recent technology transfer program activities and accomplishments are described in the following:

- The chief executive of SNL/NM is a member of the Governor's Commission on Technical Excellence.
- SNL/NM executives are members of the New Mexico Technical Foundation Network and Rio Grande Technical Foundation organizations.
- The Sandia Airborne Computer is a high-performance, parallel-processing computer that operates on batteries and can solve certain problems as efficiently as large general purpose computers.
- Medical researchers at the University of New Mexico (UNM) are considering the applications for SNL/NM-developed polymer (plastic) foams.
- SNL/NM's patented downhole seismic source transmits sound waves into rock and helps locate oil and gas.
- SNL/NM developed an underground stress-measurement technique that is making an impact throughout the world by improving the placement of oil and gas wells. This technique measures the microscopic change in well-bore core samples to reveal the direction and magnitude of stresses in rock formations and predicts fractures from boreholes.

- A new method for igniting explosives, the Semiconductor Bridge (SCB) developed through a collaboration of SNL/NM and UNM engineers, has shown such promise that a new private company (SCB Technology, Inc., of Albuquerque) has been formed to make and market the devices.

- SNL/NM cooperates with the UNM Technology Innovation Center and with the Federal Laboratory Consortium to draw on the expertise of other federal laboratories in addressing local requests for assistance and to serve as resources for entities outside the Southwest.

- The UNM Cancer Center has successfully tested an SNL/NM-developed miniature radiation-sensing field effect transistor.

10.4 SNL/NM Impact on Local Education

There is a close relationship between SNL/NM and New Mexico's institutions of higher learning. More than a quarter (28 percent) of SNL/NM staff members with university degrees earned their highest degree within the state of New Mexico, with most such degrees awarded by UNM. In fact, one-third of all SNL/NM administrative staff members and about one-sixth of its technical staff members attained or earned their highest degrees at UNM (Adcock and Lansford, 1991). Realizing that quality educational institutions are key to SNL/NM's future, the laboratory contributes much time and money in support of higher education. In addition, SNL/NM spends in excess of $4 million a year in partnership with New Mexico higher education and has loaned equipment valued at more than $1 million to UNM.

SNL/NM's commitment to improving technical literacy in New Mexico and the nation is being implemented by the Diversity Leadership and Education Outreach Center. The Center has the primary responsibility for all kindergarten through postsecondary educational outreach activities. It also provides studies and services to education and education-related institutions. During 1995, important contributions were made in supporting math and science education. The following are some of the more significant contributions:

- SNL/NM provides research funds, grants, equipment, and facilities to most of the state universities (see Demography, in the following section, for university enrollment).

- SNL/NM provides technical expertise to the Centers of Technical Excellence at UNM (High-Technology Materials and Non-Invasive Diagnosis), to the New Mexico Institute of Mining and Technology (Explosives Technology Research), and to the NMSU (Computer Robotics and Plant Genetics Engineering). The laboratories also cooperate with the Technology Innovation Center at UNM in new business start-up where technical issues are involved.

- Through the Science Advisors Program, nearly 100 technical staff members spend up to one day a week at participating schools supporting teachers in math and science instruction. The program served 104 schools in the Albuquerque and Rio Rancho Public Schools systems, 71 rural schools, and 30 affiliated with the Bureau of Indian Affairs. More than 2,411 teachers and 35,662 students have been directly affected each week by the program.

- The School Partners Program supplements the science curriculum of schools by conducting in-class experiments and demonstrations at five Albuquerque Public Schools for a total of approximately 5,000 contact hours.

- SNL/NM continued its technical support at New Mexico Highlands University (NMHU) and the Mendez Foundation. Research and summer employment opportunities were made available to participating education institution members.

- SNL/NM has an Educational Assistance Program through which employees can increase their knowledge while earning credit toward degrees. This program provides the educational system with a steady stream of capable students, while enabling SNL/NM to help its employees advance their careers.

- SNL/NM is working or has worked closely with UNM to establish instructional television as part of the EAP program, as well as special noncredit courses taught on SNL/NM premises.

- The Specialized Engineering Development Program permits outstanding students throughout the nation to complete their master's degrees at UNM while working part-time at SNL/NM.

- SNL/NM provides some teaching assistance to UNM. At present, about 25 members of the SNL/NM staff are adjunct professors at UNM. Most teach in the College of Engineering while others are in the Anderson School of Business.

- SNL/NM works with UNM on a joint education program to stimulate the overall academic strength of the university and to support its national standing as a home to industrial research programs. SNL/NM is also represented on the Board of the New Mexico Mathematics, Engineering, and Science Achievement Group.

- Through the Sandia University Research Program (SURP), SNL/NM sponsors research at UNM. SURP research areas include astronomy, biology, chemistry, civil engineering, geology, mathematics, and physics. Some UNM professors also serve as consultants to SNL/NM.

- The High School Summer Faculty Program brings teachers in both technical and nontechnical fields to participate in a teacher enrichment program offered by SNL/NM in conjunction with the New Mexico Institute of Mining and Technology and other institutions.

- The Hands-On, Minds-On Technology Programs, targeted to the needs of minority pre-college students in the Albuquerque area, reaches about 400 students each year.

- SNL/NM is developing (with the College of Engineering at UNM) a Model Minority Engineering Program that addresses the needs of Hispanic and Native American engineering students, while including all minority engineering students.

- At NMHU, SNL/NM is supporting the Engineering Program. The purpose of the alliance is to increase the representation of African-American, Hispanic, and Native American scientists and engineers in the U.S. work force by strengthening three large minority institutions of higher education.

10.5 Demography

The population of Bernalillo County, according to the 1992 preliminary census, grew a relatively modest 0.96 percent since 1990 to 499,262, with the Albuquerque city population being 398,492 (Boatman's Sunwest, 1994). From 1970 to 1980, New Mexico's population grew 28.1 percent. Much of the growth in the 1970s resulted from relatively strong economic expansion, which attracted new migrants to the state. Generally, weaker economic conditions in the 1980s led to decline in growth through emigration, contributing to a considerably smaller 16.2 percent population increase. Growth rates in the 1980s were highest within the metropolitan counties, such as Bernalillo County where SNL/NM is located.

New Mexico's racial and ethnic composition continued to shift in the 1980s. The non-Hispanic white population fell from 52.6 percent of the total in 1980 to 50.4 percent in 1990. Of all the states, New Mexico had the highest proportion of Hispanics and the second highest proportion of Native Americans. The smaller African-American and Asian/Pacific Islander groups accounted for 2 percent and 0.9 percent of New Mexico's population, respectively (DOC, 1991). Table 10-4 presents the ethnic demography of the area.

Table 10-4

Sex, Race, and Ethnic Origin in the Vicinity of Sandia National Laboratories/New Mexico, 1990

State; County; County Subdivision; Place	All Persons	Sex		Race					
		Male	Female	White	African-American	American Indian, Eskimo, or Aleut	Asian or Pacific Islander	Other Race	Hispanic Origin (of any race)
The State of New Mexico	1,515,069	745,253	769,816	1,146,028	30,210	134,355	14,124	190,352	579,224
Bernalillo County	480,577	234,602	245,975	359,445	13,199	16,296	7,389	74,251	178,310
Albuquerque Division	464,725	226,573	238,152	358,156	13,124	13,020	7,329	73,096	175,238
Albuquerque city (pt)	384,734	186,583	198,151	301,010	11,484	11,708	6,660	53,872	132,704
Corrales village (pt)	535	272	263	517	--	6	3	9	49
Los Ranchos de Albuquerque village	3,955	1,909	2,046	3,346	18	43	36	512	1,351
North Valley CDP	12,507	6,218	6,289	9,063	69	232	54	3,089	6,648
Paradise Hills CDP	5,513	2,700	2,813	4,902	112	111	74	314	1,158
Sandia CDP	6,742	3,750	2,992	5,091	829	85	267	470	1,116
Sandia Heights CDP	3,519	1,086	1,713	3,420	18	28	26	27	218
South Valley CDP	35,701	17,621	18,080	21,928	463	596	150	12,564	25,886
Bernalillo East Division	12,480	6,419	6,061	11,099	75	136	53	1,117	2,891
Tijeras village	340	179	161	295	2	3	2	38	185
Bernalillo West Division	1,201	576	625	119	--	1,070	--	12	50
Albuquerque city (pt)	2	1	1	--	--	--	--	2	2

Source: U.S. Department of Commerce (DOC), 1991, "1990 Census of Population and Housing - Summary Population and Housing Characteristics, New Mexico," Washington, D.C.

10.5.1 Housing

In 1990, over 92 percent of all housing units (of 166,869 total units) within the Albuquerque city limits were occupied. Single-unit housing represents the largest percentage of total housing, with nearly 61 percent. Multiple-unit housing, defined as housing with two or more units, accounts for approximately 34 percent of total housing units. The remaining 5 percent of housing units are mobile homes (DOC, 1991). Over 42 percent of Albuquerque's housing inventory has been built since 1970. Only 6.1 percent was built before 1939. The average price of a single family home in 1990 was $99,600. There are approximately 67,000 apartment units with an average month's rent, on a per-square-foot basis, of about 50 cents. The apartment vacancy rate was 7.19 percent in October 1990, the lowest in six years.

10.5.2 Educational Services

Primary and secondary education are served by the Albuquerque Public Schools District. The enrollment in Bernalillo County for 1992–1993 was 87,965, up from the previous school year, when it was 86,738. Currently the Albuquerque Public Schools District is running at capacity. The school district has 11 high schools, 23 middle schools, 79 elementary schools, and 6 alternative schools to serve its students (AED, 1994). About 10 percent of Albuquerque's students attend 50 private or parochial schools in the Albuquerque metropolitan area. Postsecondary education in the Bernalillo County area is provided by UNM. UNM offers a variety of accredited degree programs including associate, bachelor's, master's and doctorate. In 1993, total enrollment including satellite campuses was 31,199 (Boatman's Sunwest, 1994).

10.5.3 Employment

In the Albuquerque Metropolitan Statistical Area (MSA) (Bernalillo County), nonagricultural wage and salary employment increased 3.7 percent from 1992. The civilian labor force for the MSA in 1993 was 272,893, with 254,851 employed. The number of unemployed work force people was 18,042, for a 6.6 percent unemployment rate.

10.5.4 Income

Overall, income growth was moderately good between 1992 and 1993, as total personal income rose 7.7 percent to $26.3 billion. Per capita income stood at $16,297. The Albuquerque MSA per capita in 1992 was $17,758 (Boatman's Sunwest, 1994).

10.5.5 Government/Services

Albuquerque has a mayor-council form of government. The mayor is elected at large to a four-year term and may succeed himself once. The nine-member nonpartisan council is elected from geographic districts to four-year terms. The council president is selected by the councilors from among the members. The city currently has approximately 779 law enforcement officers that include patrolmen, detectives, and Special Weapons and Tactics team. There are fire stations located throughout the metropolitan area manned by 515 full-time fire fighters (AED, 1994).

10.5.6 Recreation

The City of Albuquerque has a number of recreational facilities that include developed parks, tennis courts, ball fields, etc. Table 10-5 lists the outdoor recreational facilities found in the Albuquerque metropolitan area. Open space accounts for most of the recreational area with 19,659 acres, followed by developed parks with 724 acres (RBH, 1991).

Table 10-5

City of Albuquerque Parks and Recreational Facilities

Parks/Open Space	Acres
Park Acreage (Developed)	724.29
Undeveloped Parks	375.75
Open Space Areas	19,659.15
Facilities	Number
Developed Parks	163
Undeveloped Parks	39
Community Centers	18
Golf Courses	4
Swimming Pools	13
Tennis Complex	1
Tennis Courts	30
Handball Courts	4
Horseshoes Courts	1
Baseball/Softball Fields	11
Basketball Courts	40
Football Fields	10
Picnic Tables	at 62 parks
Barbecue Grills	at 8 parks
Other Recreational Facilities (Excluding City Facilities)	
Facilities	Number
Swimming Pools	19
Golf Courses	5
Tennis Facilities	8
Courts	102
Bowling Alleys	10
Lanes	298
Auto Racing Tracks	1
Ice Skating Rinks	1
Roller Skating Rinks	6
Motion Pictures Theaters	38
Opera and Play Theaters	10
Racquetball Clubs	7

Source: RECA/Better Homes and Gardens (RBH), 1991, "New Resident Information," Albuquerque, New Mexico.

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11.0 Transportation

This chapter includes a discussion of the regional transportation system and the traffic patterns within SNL/NM and KAFB.

11.1 Regional Transportation

Albuquerque is located at the junction of two major interstate highways: Interstate 40, which runs east-west, and Interstate 25, which runs north-south (see Figure 1-1 for a regional map). Approximately 129,490 cars per day traveled Interstate 25 south of Interstate 40 in 1993, making this the most traveled stretch of road in New Mexico. Access to Interstate 25 to the west is provided by Gibson Boulevard; and access to Interstate 40 to the north is by Wyoming Boulevard and Eubank Boulevard, all located at the northwest end of the Base (Figure 11-1).

In 1993, there were approximately 445,461 registered vehicles in Bernalillo County, with passenger cars having the highest registration (285,130) (Boatman's Sunwest, 1994). In addition to private transportation, the city is serviced by a citywide bus service that operates seven days per week. Rail service to the Albuquerque area is provided by the Santa Fe and Burlington Northern and by Amtrak.

ABQ served 5,613,275 passengers in 1993 (Boatman's Sunwest, 1994). The airport's leading airline, Southwest, also set a record in 1990. Its traffic jumped 19.2 percent to 1,842,884 passengers, while its market share climbed from 32.8 percent to 36.9 percent. Passenger totals and market shares of other carriers serving the city in 1990 were as follows:

- American, 650,641 passengers (13 percent)
- Delta, 626,847 (12.6 percent)
- America West, 591,359 (11.9 percent)
- Continental, 303,725 (6.1 percent)
- United, 280,541 (5.6 percent)
- Transcontinental and Western Air, 266,833 (5.4 percent)
- Mesa, 241,047 (4.8 percent)
- USAir, 154,901 (3.1 percent)
- Ross, 27,005 (0.5 percent)
- PanAm, 1,789 (0.04 percent)
- Aspen, 1,117 (0.02 percent)
- Territorial, 124 (less than 0.01 percent).

PanAm, Aspen, and territorial have all suspended service to Albuquerque (COA, 1991b).

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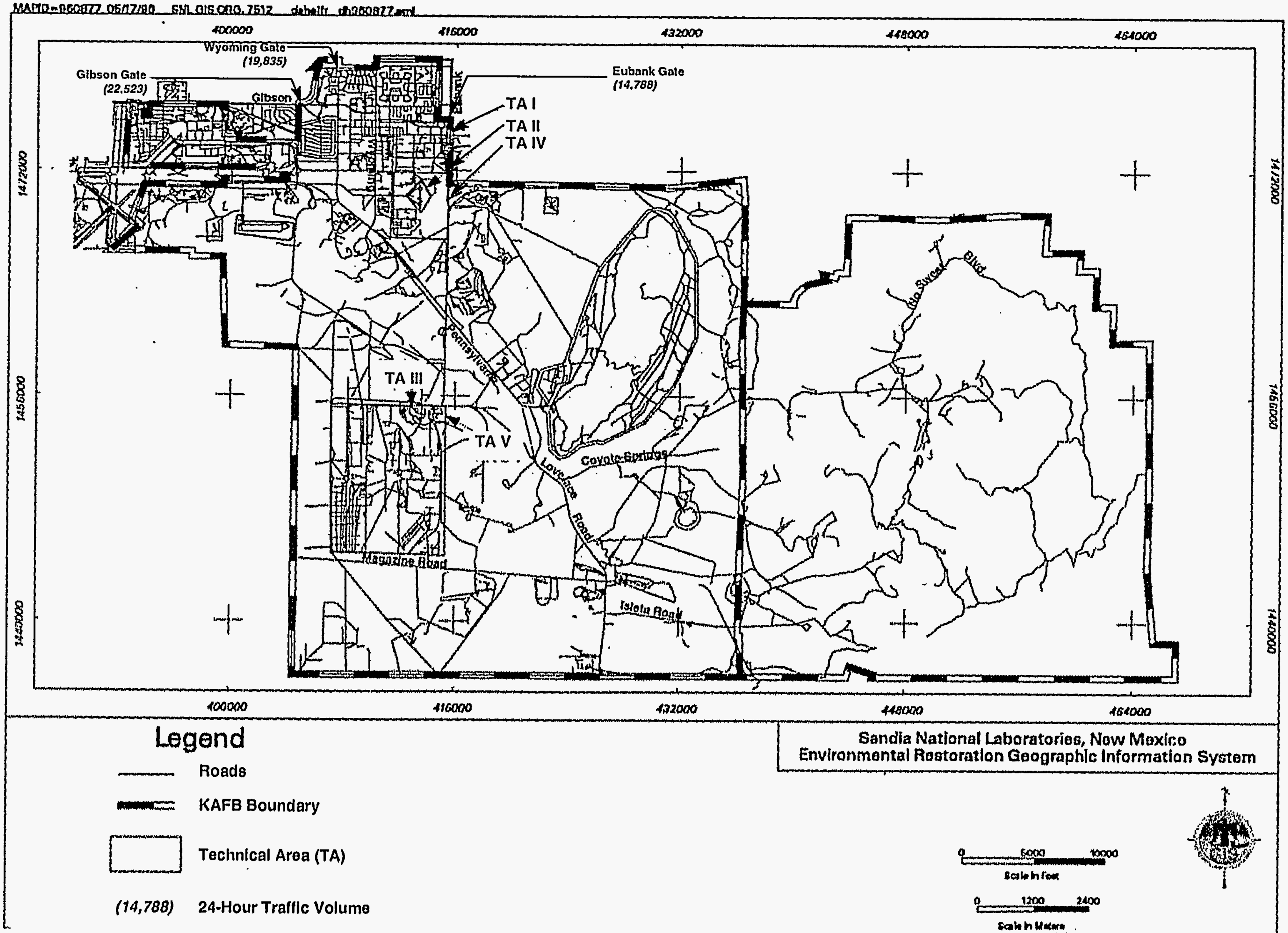

Figure 11-1
Roads and Main Gate Traffic Volumes at Kirtland Air Force Base (1995)

11.2 SNL/NM Transportation Patterns

Access to SNL/NM-KAFB from surrounding roadways is through three main vehicular gates located on Gibson Boulevard, Wyoming Boulevard, and Eubank Boulevard (Figure 11-1). The hours of operation are 24 hours a day for the Gibson and Wyoming Gates, and 6:00 a.m. to 6:00 p.m., Monday through Friday, for the Eubank Gate. During seven-day traffic counts conducted by SNL/NM for KAFB 377th Civil Engineering Squadron in October 1995, the total of bidirectional traffic counts for all three gates was 57,146 vehicles. The Gibson Gate had the most 24-hour bidirectional volume (22,523 vehicles) (Bohannan-Huston, Inc., 1995). Peak traffic volumes at all gates occurred between 7:30 and 8:15 a.m. and between 4:15 and 5:15 p.m. (Bohannan-Huston, Inc., 1995).

The total number of vehicle decals issued for KAFB, SNL/NM employees, SNL/NM contractors, and DOE personnel in 1995 was 19,729, with the following distribution (SNL/NM, 1995c):

- KAFB—14,473 (approximately 73 percent)
- SNL/NM employees—2,422 (approximately 12 percent)
- SNL/NM contractors—2,298 (approximately 12 percent)
- DOE personnel—536 (approximately 3 percent).

(Note that the number of decals issued does not represent the number of SNL/NM employees and contractors—approximately 10,000.)

SNL/NM employees or contractors accounted for 24 percent of the decals issued and approximately the same percentage of the commuter vehicles entering KAFB each day. By dividing the seven-day bidirectional gate counts by two (to obtain a one-way count), and applying the 24-percent ratio, one can calculate that approximately 6,858 SNL/NM and contractor vehicles entered KAFB each day during 1995. (Note that this is based on a seven-day count; therefore, the daily figure becomes an average to account for lower weekend traffic rates.)

Primary arterial roads leading into or within KAFB are Kirtland Drive, Texas Drive, Main Street, Wyoming Boulevard, and Eubank Boulevard running north-south, and Gibson Boulevard, D Street, F Street, G Street, H Street, Hardin Boulevard running east-west (Figure 11-1). Traffic counts were conducted at major intersections along the Eubank Boulevard corridor by SNL/NM in October 1995 (Bohannan-Huston, 1995). These counts indicated that the heaviest volumes of traffic entering the Eubank Gate travel west on G Street or turn south onto 20th Street, in approximately equal amounts (Bohannan-Huston, Inc., 1995). Approximately 91.3 square miles of paved roads have been constructed within the SNL/NM Technical Areas I through IV (Technical Area V has not been assessed at this time) (SNL, 1995). Access to outlying SNL/NM Technical Areas is as follows:

- Technical Areas II and IV are reached by traveling south on Ninth Street.
- Technical Areas III and V are reached by traveling south on Wyoming Boulevard to Pennsylvania, then southeast to the Technical Area III Road.

11.3 Parking

Parking accommodations within KAFB, and particularly SNL/NM, are limited to parking lots associated with specific facilities or grouping of facilities. Parking at Technical Area I is concentrated in six to eight paved lots of varying sizes, with a total of approximately 24 hectares (ha) (60 acres) of parking, about 4,000 spaces available. Technical Area II has parking associated with buildings or groups of buildings, with approximately 1 ha (2.4 acres), about 260 spaces available. Technical Area III and Technical Area V are areas of open space for testing, with fewer industrial/office facilities. Consequently, the parking consists of smaller lots associated with specific facilities. Approximately .6 ha (1.6 acres) in Technical Area III and .7 ha (1.7 acres) in Technical Area V are available for parking, about 300 spaces total. Technical Area IV has approximately .6 ha (15.3 acres) of paved parking spaces, about 680 spaces. Coyote Test Field has approximately .2 ha (.62 acres), or 68 spaces, of parking. The 6000 Igloo Area parking areas have not been assessed at this time (SNL, 1995).

12.0 Land Use

The SNL/NM facility is located in Bernalillo County, New Mexico, and is situated entirely within the boundaries of KAFB. At a mean elevation of 1,630 m (5,350 ft), KAFB is situated on two broad mesas bisected by the Tijeras Arroyo, which forms a canyon that trends east-west. These mesas are bounded by the Manzano Mountains to the east and the Rio Grande to the west. Albuquerque, the largest population center in Bernalillo county, is the closest population center to KAFB. Technical Area I, in the northeast portion of SNL/NM, is located approximately 2.4 km (1.5 mi) east of downtown Albuquerque. An estimated total population of 571,677 people live within an 80-km (50-mi) radius of KAFB (DOC, 1992). This population includes permanent residents of KAFB living in the KAFB housing areas. Figure 12-1 shows residential areas within a 1.6-km (1-mi) radius of the KAFB boundary in relation to SNL/NM (SNL/NM, 1995b).

SNL/NM is essentially surrounded by KAFB, with co-use agreements on some portions of KAFB. An additional 9,106-hectare (22,500-acre) area to the east of KAFB has been withdrawn from the USFS for the exclusive use of KAFB. High explosives tests, explosives storage, and other hazardous operations are buffered and barricaded by the mountainous terrain toward the eastern edge of this withdrawal area. Areas to the west and south, by agreements with the State of New Mexico and Isleta Pueblo, serve as buffer zones for certain other test operations. Figure 12-2 shows land-use agreements in relation to SNL/NM.

The SNL/NM facility is composed of five technical areas and several additional test areas spread over 7,227 hectares (17,845 acres) which are under diverse land ownership (Figure 12-3). SNL/NM occupies 1,151 hectares (2,842 acres) owned by the DOE and an additional 6,076 hectares (15,003 acres) that have been made available through a series of land use agreements or permits among DOE/AL Operations, DOE Transportation Safeguards Division, KAFB, the USFS, the Bureau of Land Management (BLM), the State of New Mexico, Phillips Laboratory (a private contractor), Central Training Academy, the Isleta Pueblo, and privately owned lands (SNL/NM, 1995b) (Figure 12-2). The 820 major structures plus other miscellaneous square footage utilized at SNL/NM comprise a total of over 5,430,000 gross square footage (SNL/NM, 1995b).

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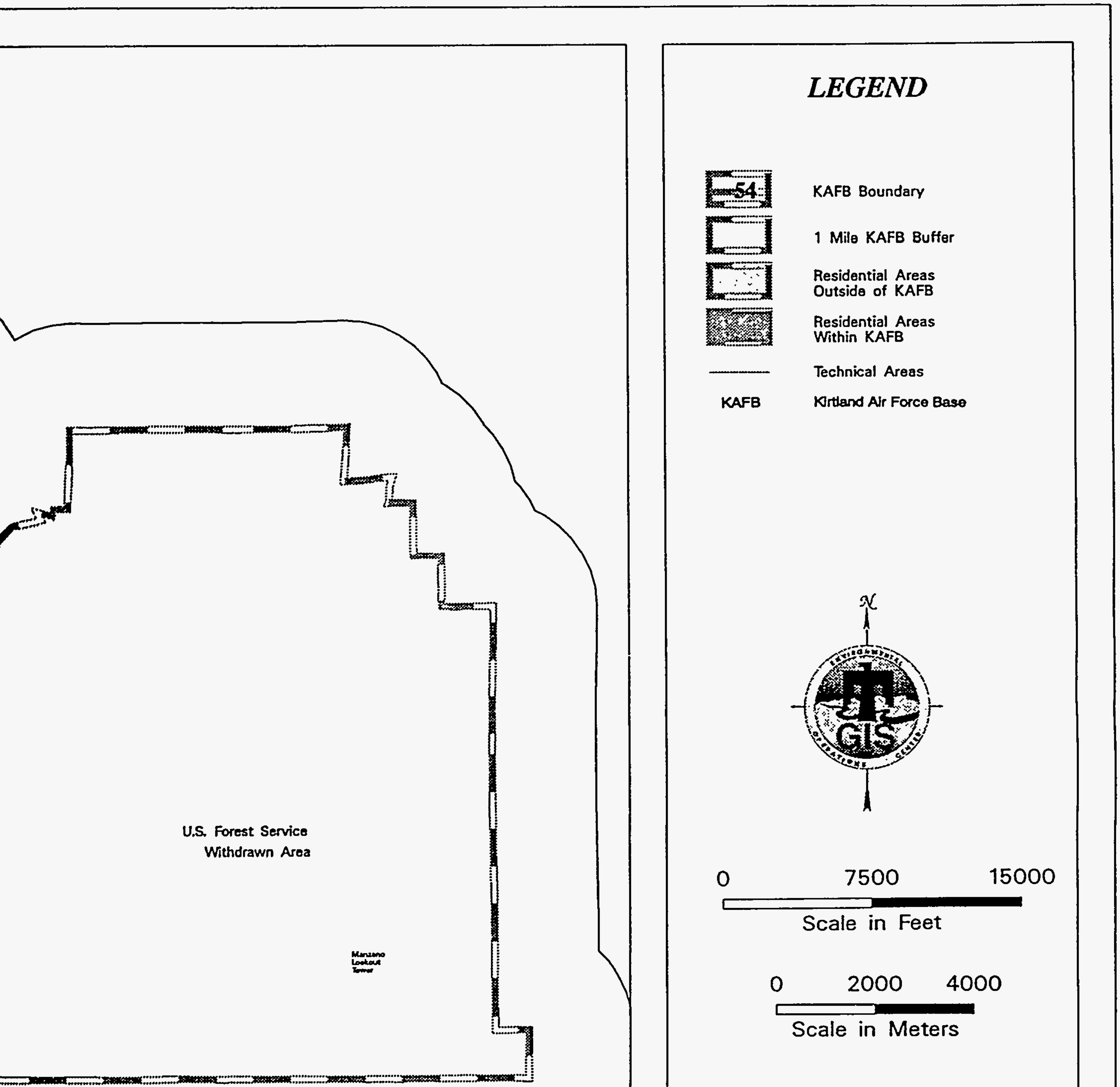
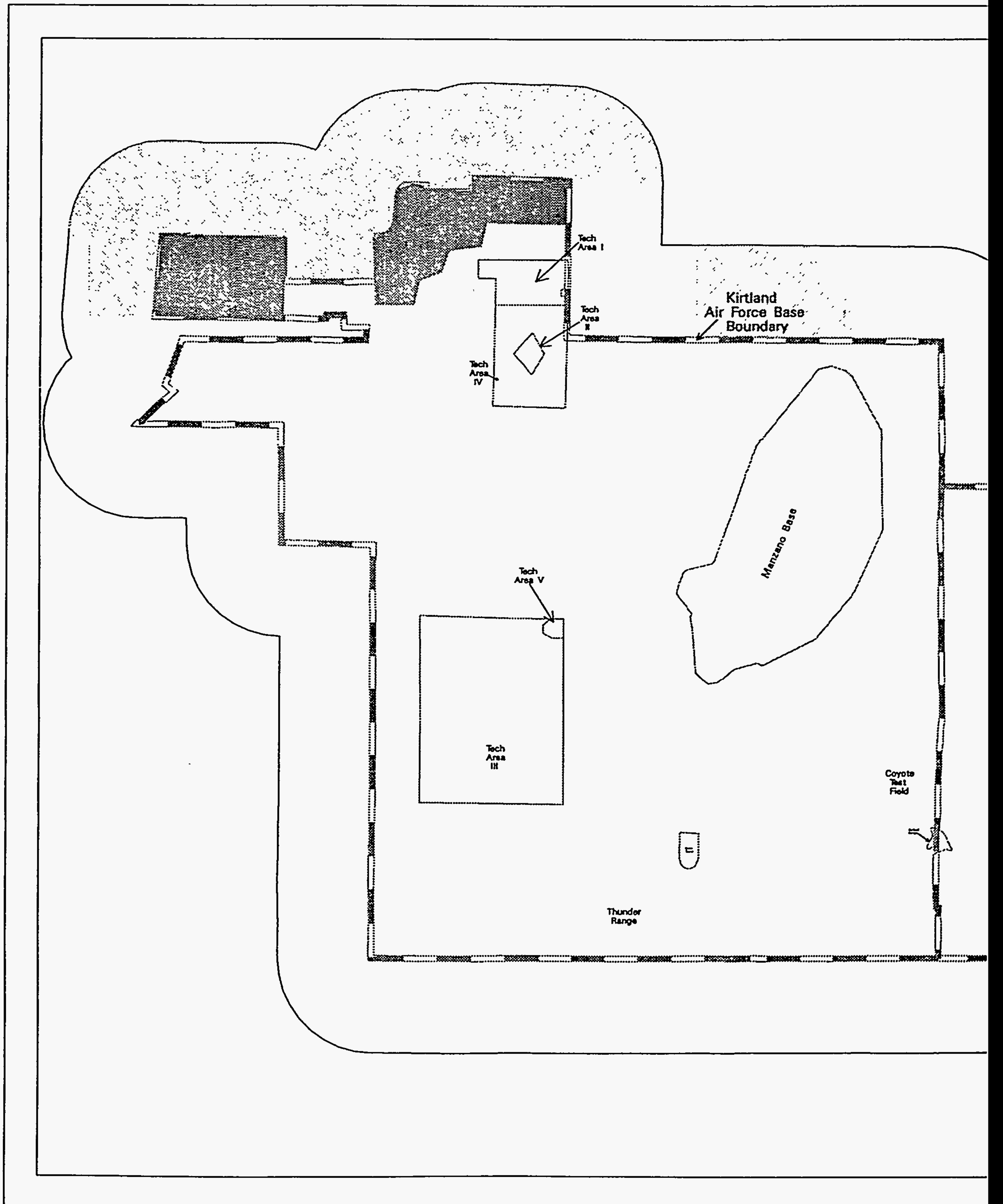


Figure 12-1

Residential Areas Within One Mile of KAFB Boundary in Relation to SNL/NM

SNL ER GIS DEPT 7583 GIS MAP-ID =950353 13-FEB-1995 resersb



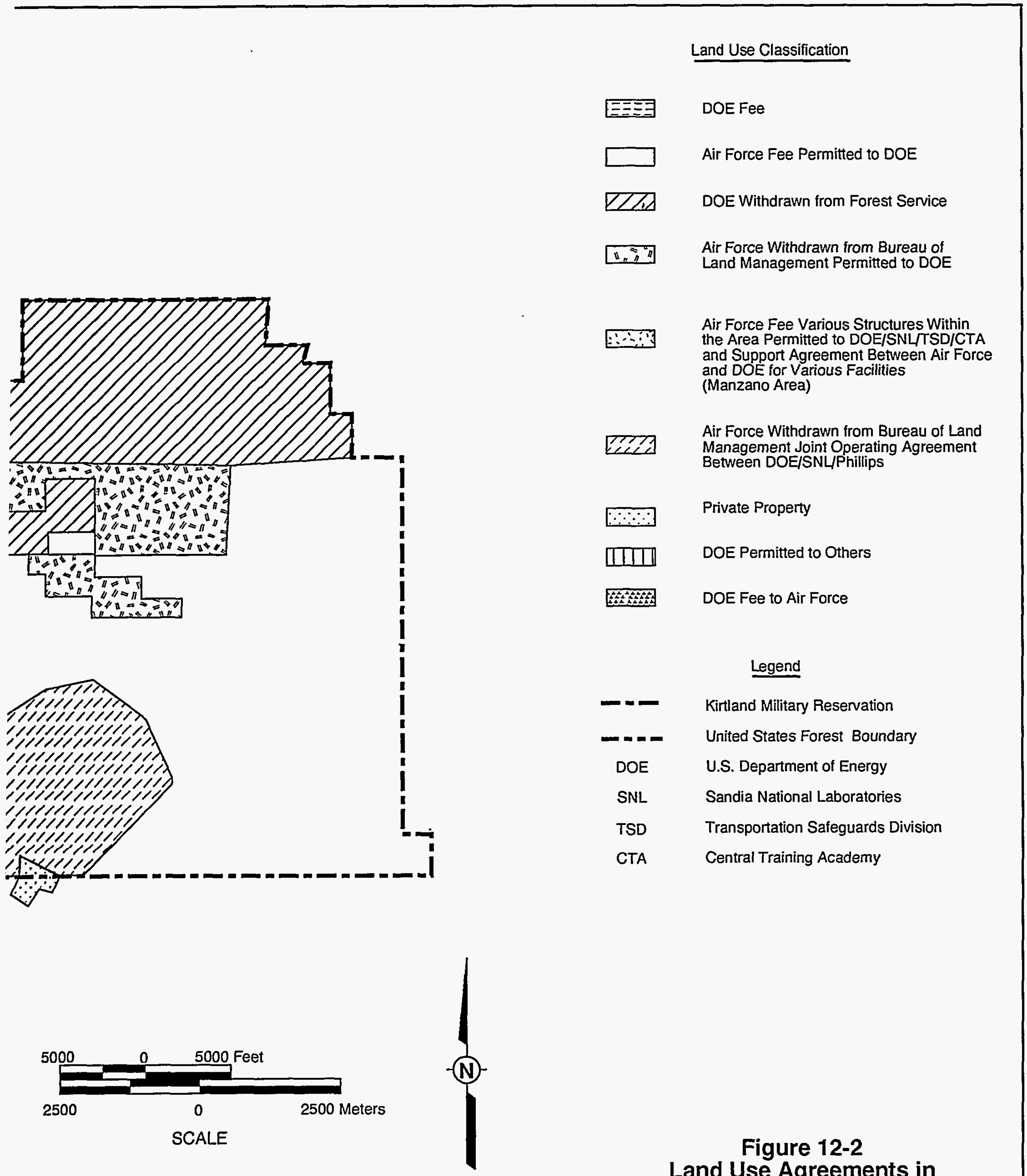
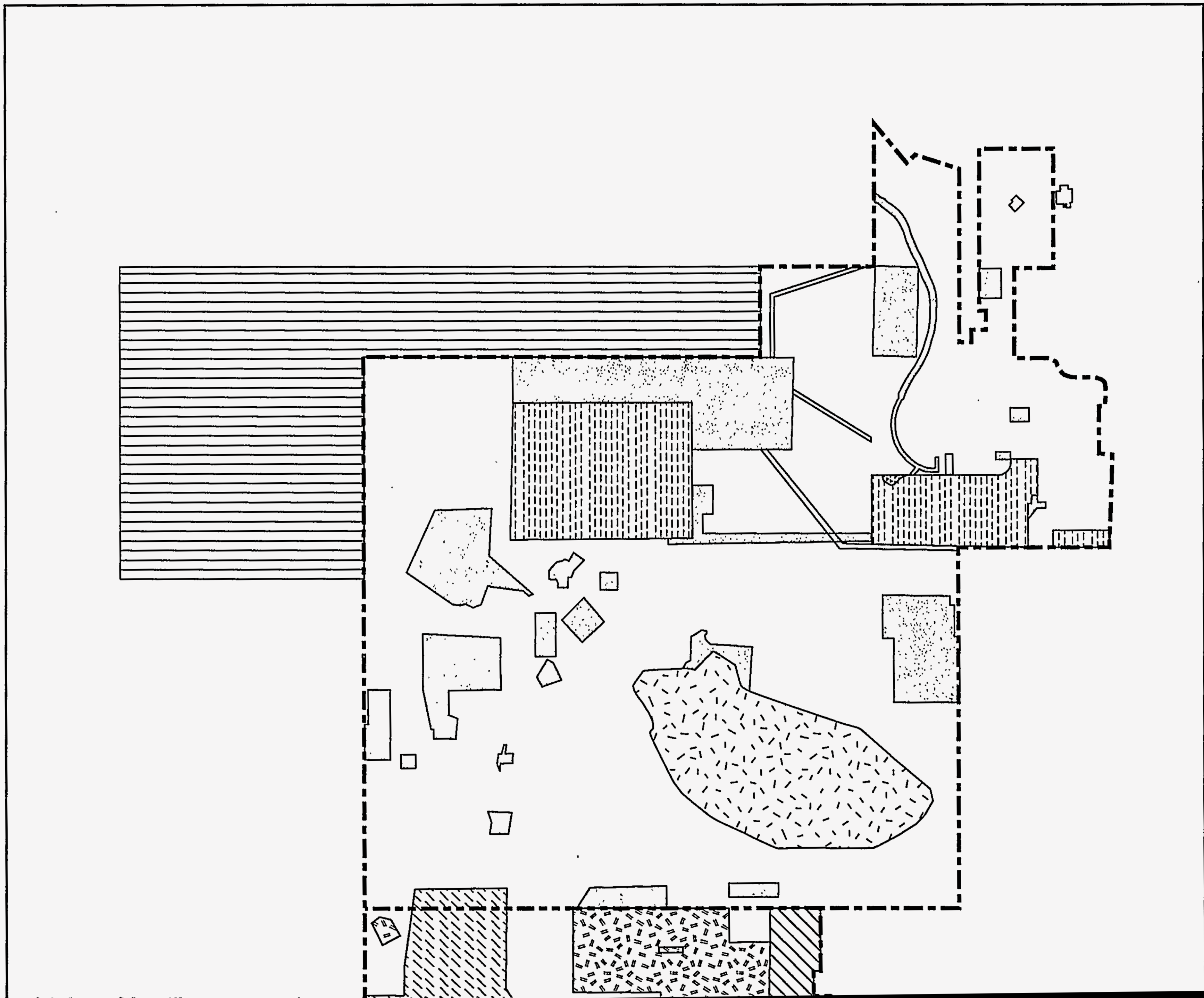


Figure 12-2
Land Use Agreements in Relation to Sandia National Laboratories/New Mexico



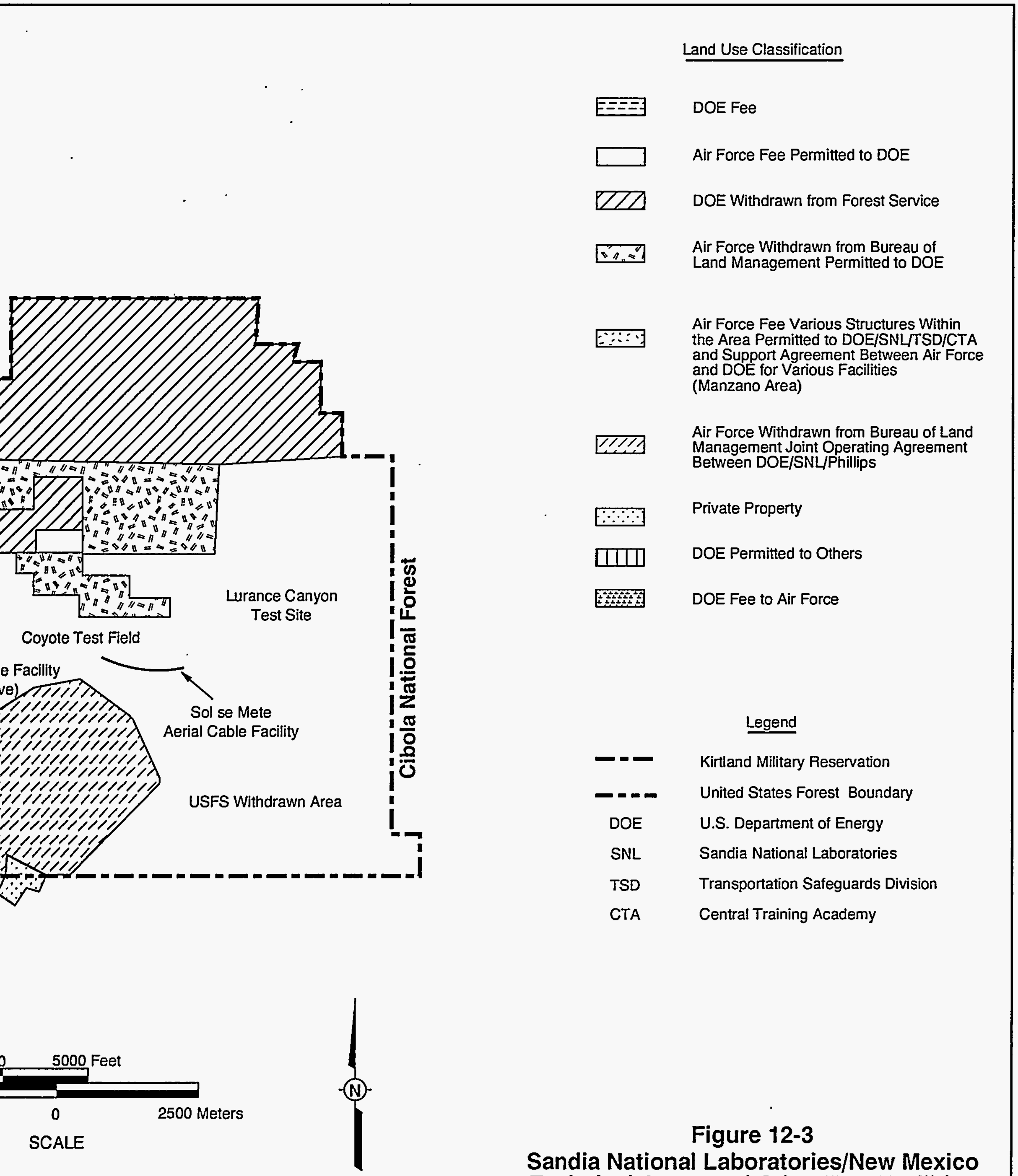
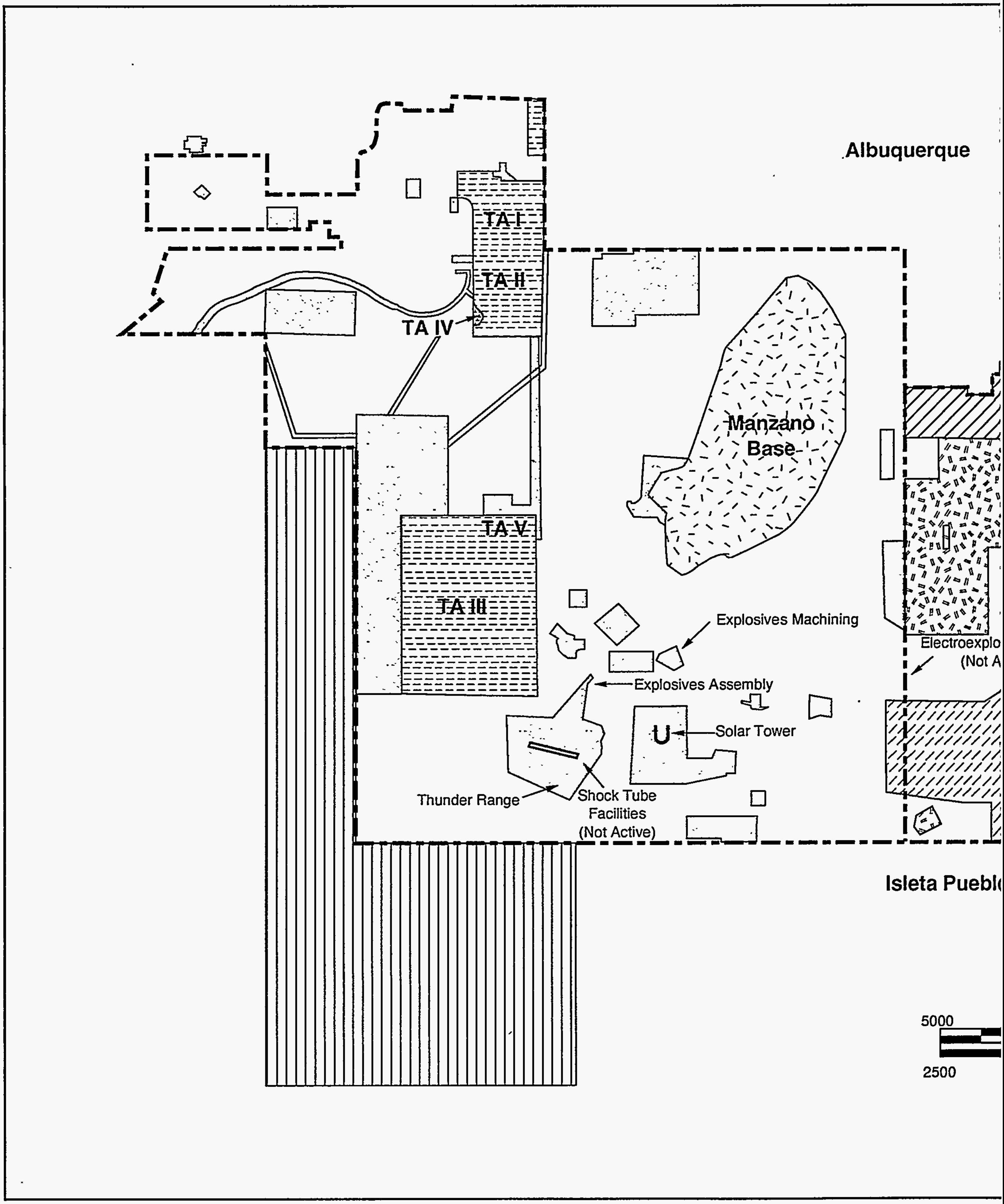


Figure 12-3
Sandia National Laboratories/New Mexico Technical Areas and Other Test Facilities



Albuquerque
TA I
TA II
TA IV
Manzano
Base
TA V
TA III
Explosives Machining
Explosives Assembly
Solar Tower
Thunder Range
Shock Tube
Facilities
(Not Active)
Isleta Puebl
5000
2500

12.1 Technical Areas

SNL/NM is divided into five technical areas, each with distinctive operations. In addition, SNL/NM operates facilities located in the Coyote Test Field, Lurance Canyon, and Thunder Range area (Figure 12-3). The following discussion briefly describes the technical areas and other test facilities located at SNL/NM.

12.1.1 Technical Area I

Technical Area I has the largest employee population, with approximately 5,000 employees. The range of use encompassed by this area includes administration, site support, technical support, basic research, defense programs, component development, microelectronics, energy programs, exploratory systems, technology transfer, and business outreach. This area includes laboratories and shops used by administrative and technical staff. Facilities also include a paint shop, a process development laboratory, an emergency diesel generator plant, a foundry, a solvent spray booth, and a steam plant (Figure 12-4). Future planning efforts are directed at developing the east side of Technical Area I, along Eubank Boulevard, with additional expansion into the area outside of the KAFB Eubank gate. One possible use for the additional expansion could be an unclassified, public interface, business outreach "district" (SNL/NM, 1995b).

12.1.2 Technical Area II

Technical Area II (Figure 12-5) contains a low-level waste (LLW) disposal site, which has been inactive for over 20 years, a small radioactive material decontamination and storage facility, and a storage facility designed to temporarily hold polychlorinated biphenyl (PCB)-contaminated materials. The PCB-contaminated materials are temporarily held at the LLW site and then transported to an EPA-licensed facility. A new Explosive Components Facility (ECF) has been recently completed, resulting in an increase in use of laboratory functions. The 60.8 hectares (150 acres) which comprise Technical Area II are currently fully developed; suitable facilities, however, may be reassigned for use as warehouses or other limited-occupancy uses (SNL/NM, 1995b).

12.1.3 Technical Area III

Technical Area III is located 8 km (5 mi) south of Technical Area I and is composed of 20 test facilities. These facilities include extensive environmental test facilities (such as sled tracks, centrifuges, and a radiant heat facility). Other facilities in Technical Area III include a paper

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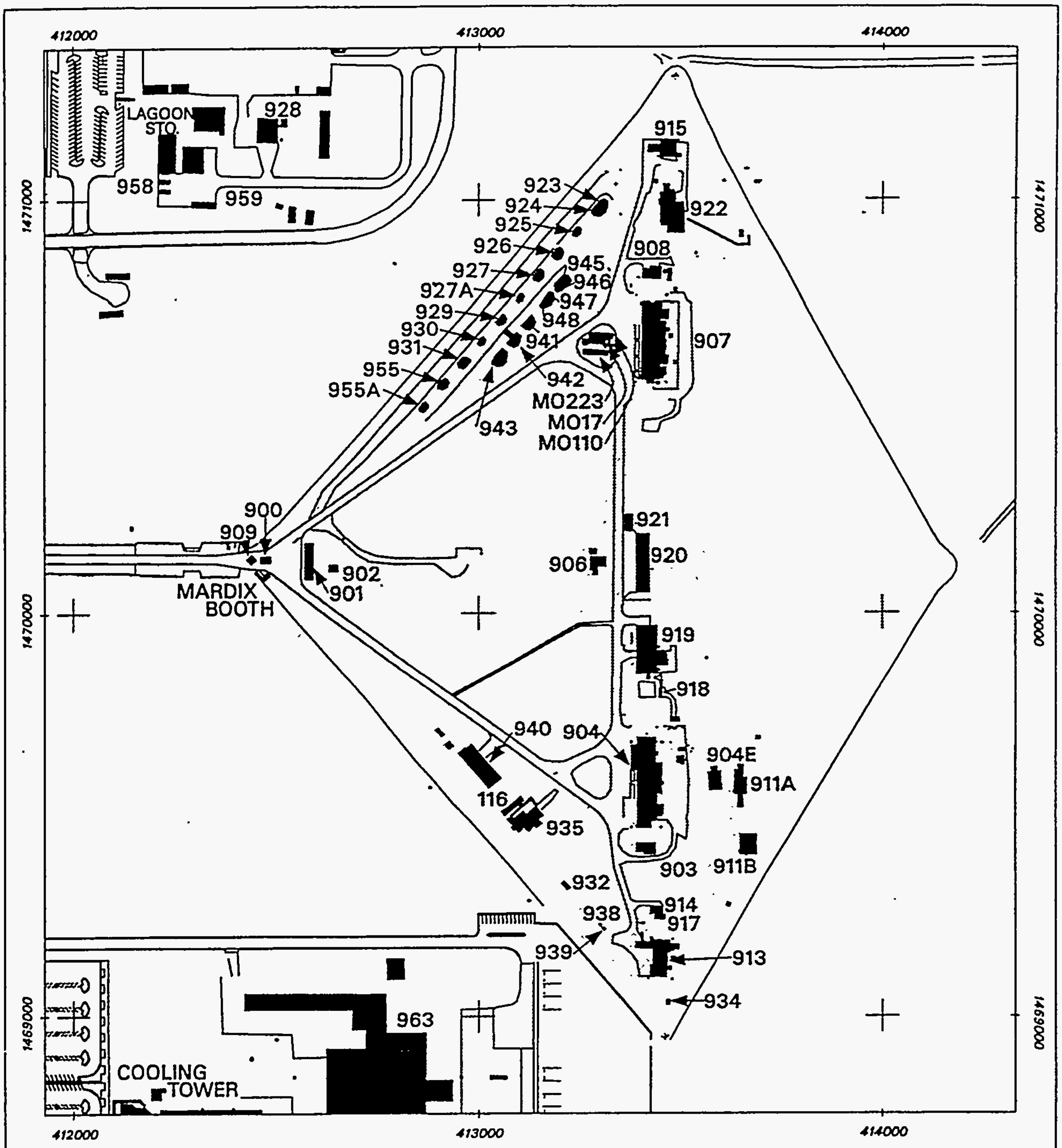

Legend

- Technical Area II
- Buildings
- Roads

Sandia National Laboratories, New Mexico
Environmental Restoration Geographic Information System

Figure 12-5
Technical Area II & Vicinity

0 200 400
Scale in Feet

0 48 .96
Scale in Meters

Unclassified

1:4800
1 in=400'

Transverse Mercator Projection, New Mexico State Plane Coordinate System, Central Zone
1927 North American Horizontal Datum, 1929 North American Vertical Datum

dwstrec SNL GIS ORG. 7512 02/09/95 MAPID=950355

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incinerator, an inactive chemical waste landfill, an inactive LLW landfill, a mixed waste landfill, a large melt facility, a MSL, and a solar research facility. The inactive LLW site in Technical Area III consists of two adjoining fenced areas that occupy 5.9 km^2 (1.5 acres) (SNL, 1991b). One area was used for LLW disposal and consists of seven trenches. The second area consists of 37 pits that were used for disposal of classified LLW. Three other pits in the second area were used for disposal of depleted and natural uranium. An inactive hazardous waste disposal and storage site is located near the southern boundary of Technical Area III (SNL, 1991b). Technical Area III development is limited due to safety and buffer zones for test activities. Land to the north and west, adjacent to Technical Area III, is used through a permit from KAFB for the Rocket Sled Track. Land to the west and south is leased from the State of New Mexico and Isleta Pueblo via the Bureau of Indian Affairs to provide additional safety buffers for the rocket sled tests (Figure 12-2).

12.1.4 Technical Area IV

Technical Area IV consists of several inertial confinement fusion research and pulsed-power research facilities. A large accelerator, the PBFA-II, was completed in 1985. A large accelerator facility, the Simulation Technology Laboratory, houses seven pulsed-power accelerators: HERMES-III, RLA, TROLL, STF, SPEED, HYDRAMITE, and PROTO II. Several of these accelerators have been transferred from Technical Area V. Another accelerator facility, SATURN, and a major research facility, the Strategic Defense Facility, also are part of Technical Area IV facilities. With the exception of the Tijeras Arroyo floodplain, Technical Area IV has land available for construction of new facilities.

12.1.5 Technical Area V

Technical Area V houses several electron beam accelerators, three research reactors in two reactor facilities, an intense gamma irradiation facility, and an HCF. HERMES-II is the largest accelerator located in Technical Area V. Due to safety buffers in the vicinity of Technical Area V, only a limited amount of land is available for construction of additional facilities.

12.1.6 Other Test Facilities

SNL/NM has three test areas outside of the five technical areas (Figure 12-3). They are located south of Technical Area III and in the canyon on the west side of the Manzano Mountains. These areas include the Coyote Canyon Test Field, Lurance Canyon, and Thunder Range.

The Coyote Test Field consists of several test activity facilities (Physical Science Laboratory [PSL], in preparation):

- 10,000-Foot Sled Track. Test articles are carried on sleds pushed by various types of surplus military rocket motors. During a typical year, about 50 tests are conducted.

- Centrifuge Complex. This complex consists of two centrifuge units located in TA-III. The units are a 29-foot centrifuge located in Building 6526 and a 35-foot centrifuge located in a "bullring"-type concrete enclosure surrounded by an earthen barrier.

- Drop Tower Complex. Two towers are associated with the Water Impact Facility. Collision impacts to different test articles including warheads, fuel system assemblies, torpedoes, and nuclear material shipping containers.

- Terminal Ballistics Facility. The complex consists of an indoor firing range for controlled firing of small arms ammunition, a laboratory, control room, machine shop, office area, and storage areas. There is also a facility that is used for propellant assembly.

- Radiant Heat Facility. This facility is composed of four structures within a fenced enclosure. It uses high intensity electrically produced radiant energy, furnaces, or other facilities to pyrolyze test items up to 1,010°C (1,850°F).

- Explosives Devices Test Facility. The Explosives Applications Laboratory performs open air detonation of explosive materiel, explosive components, and explosive systems and subsystems in support of research, design, and testing. There are also explosive storage bunkers.

Lurance Canyon Test Site is a remote area to the east of the Technical Areas and Coyote Test Field. It is the location designed for conducting experiments involving up to 4,767 kg (10,500 lbs) of explosives per shot, requiring a 4-km (2.5-mi) fragment-hazard radius. While explosives testing is no longer conducted at Lurance Canyon Test Site, burn tests in open pools and two enclosed facilities are being conducted.

Thunder Range consists of approximately 522 acres containing explosives firing sites, control and instrumentation buildings and bunkers, and explosives assembly building, and explosives storage buildings. The complex is separated into North Thunder Range and South Thunder Range. North Thunder Range is actively used for testing of weapon system components, explosives systems, and conducting explosive technology research. South Thunder Range consists of three active firing sites, several inactive firing sites, a range control station and instrumentation building, instrumentation bunkers, and auxiliary support buildings. The facilities provide capabilities to create environments to simulate threats to existing and emerging weapon systems (PSL, in preparation).

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15.0 Glossary

AIRDOS-EPA	Computerized methodology for estimating environmental concentrations and doses to man from airborne releases of radionuclides.
AIRDOS-PC	Computerized methodology for calculating the effective dose equivalent values to maximally exposed individuals, as required by 40 CFR Parts 617-93(a).
A-Weighted sound level (dBA)	A weighting network which is standardized both nationally and internationally that deemphasizes the lower frequencies (those below 1,000 Hertz) and the higher frequencies (those above 6,000 Hertz) because they are generally inaudible to the human ear (Harris, 1979). With A-weighting, a single-number sound level description is obtained. These sound levels are recorded as adjusted decibels (dBA).
Ambient noise level	The overall composite of sounds in a given environment, excluding the specific noise under investigation; the A-weighted sound pressure level exceeded 90 percent of the time and based on a maximum of a 1-hour period (Albuquerque, 1975).
Background	The distant part of a landscape, picture, etc.; surroundings, especially those behind something and providing harmony or contrast; surrounding area or surface. Area located from 3 miles to infinity from the viewer.
Characteristic landscape	The naturally established landscape within a scene or scenes being viewed.
Character type	Large physiographic area of land that has common characteristics of landforms, rock formations, water forms, and vegetative patterns.
Common	Refers to prevalent, usual, or widespread landscape variety within a character type. It also refers to ordinary or undistinguished visual variety.
Contrast	a. Diversity of adjacent parts, as in color, tone, or emotions. b. The closer the juxtaposition of two dissimilar perceptions, in time or space, the more powerful the appeal to the attention.

dB	See Decibel.
dBA	See A-weighted sound level.
Decibel (dB)	A convenient means for describing the logarithmic level of sound intensity, sound power, or sound pressure above arbitrarily chosen reference values. The range of acoustic energy density for the human ear between the threshold of hearing and the sensation of pain is as large as 10^{14} (hundred million of millions). In order to handle this tremendous range, use is made of a logarithmic scale to compare different values of energy with a reference value (threshold of hearing). Making use of the logarithmic scale reduces the average human hearing range to a manageable scale of 140 units known as decibels (Saenz and Stephens, 1986).
Distance zones	Areas of landscapes denoted by specified distances from the observer. Used as a frame of reference in which to discuss landscape characteristics or activities of man.
Distinctive	Refers to unusual and/or outstanding landscape variety that stands out from the common features in the character type.
Dominance elements	Form, line, color, and texture. They are the visual recognition parts that make up the characteristic landscape.
Edge	The line where an object or area begins or ends; serves as boundaries.
Energy equivalent sound level (Leq)	A single-value sound level that describes time-varying sound energy over the time during which the measurements were obtained.
Equivalent day/night sound level (Ldn)	The Ldn is a series of Leq (see Energy-equivalent sound level) measurements over a 24-hour period. 10 dBA (see A-weighted sound level) are added to Ln (nighttime level) to compensate for low background noise, i.e., those during nighttime hours. Ln lasts from 10 p.m. to 7 a.m., while Ld (daytime level) lasts from 7 a.m. to 10 p.m.
Esthetics (aesthetics)	a. Generally, the study, science or philosophy dealing with beauty and with judgments concerning beauty. b. Giving visual pleasure. c. The theory of perception or of susceptibility.

Far field	That portion of the radiation field of a noise source in which the sound pressure level decreases by 6 dB (see Decibel) for each doubling of a distance.
Feature	A visually distinct or outstanding part, quality, or characteristic of something.
Foreground	The detailed landscape found within 0.40 to 0.80 km (0 to 0.25 to 0.5 mi) from the observer.
Form	The shape or structure of something as opposed to the material of which it is composed.
Graben	A down-dropped block of rock bounded on both sides by a pair of normal faults. (The German word "grabe" means "ditch.")
Horst	A relatively uplifted block of rock bounded by a pair of normal faults. (The German word "horst" means "a retreat" or "eyrie.")
Listric fault	A concave, upward fault, i.e., a fault whose dip decreases with increasing depth.
Maximum modification	A Visual Quality Objective, meaning man's activity may dominate the characteristic landscape but should appear as a natural occurrence when viewed as background.
Middle ground	The space between the foreground and the background in a picture or landscape. The area located from 0.40 to 4.87 km (0.25 to 3 mi) from the viewer.
Minimal	Refers to little or no visual variety in the landscape. Monotonous or below average compared to the common features in the character type.
Modification	A Visual Quality Objective, meaning man's activity may dominate the characteristic landscape but must, at the same time, utilize naturally established form, line, color, and texture. It should appear as a natural occurrence when viewed in foreground or middle ground.

Partial retention	A Visual Quality Objective, which in general means man's activities may be evident but must remain subordinate to the characteristic landscape.
Preservation	A Visual Quality Objective that provides for ecological change only.
Retention	A Visual Quality Objective, which in general means man's activities are not evident to the casual visitor.
Saturated zone	Soil layer(s) whose contents are saturated with water to the extent to be considered a groundwater or aquifer system.
Sensitive receptor	Sensitive receptor are defined as humans or other organisms that are, or may be, sensitive to noise. They can be defined by type or location.
Sound source	Any person, animal, device, operation, process, activity, or phenomenon that emits or causes sound.
Sound exposure level (SEL)	The level of the time integral of the squared, A-weighted sound pressure over a stated time interval or event with reference to the squared sound pressure (20 micropascals) and a reference duration of 1 second.
Vadose or unsaturated zone	Soil layer(s) whose contents have not been saturated by water to the extent to be considered a groundwater-containing soil layer. It is the region located between the land surface and the groundwater system.

APPENDIX A

RELATIONSHIP OF NEPA TO OTHER FEDERAL ENVIRONMENTAL LAWS

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Appendix A
Relationship of NEPA to Other Federal Environmental Laws

This Appendix provides a summary of federal environmental laws and regulations, executive orders (EO), and DOE orders that interrelate with or may be triggered by compliance with NEPA. The requirements are described in terms of their application to the SNL/NM facility.

Compliance with other environmental laws (such as the Clean Air Act [CAA], the Clean Water Act [CWA], the Safe Drinking Water Act [SDWA], the National Historic Preservation Act [NHPA], and the Resource Conservation and Recovery Act [RCRA]) (1) helps fulfill the policy objectives enumerated in NEPA §101(b), and (2) strongly indicates the nature and magnitude of environmental consequences to be addressed in the NEPA documentation process. For example, if a permit or other form of agency authorization is required for a certain type of air emission, water discharge, or land disturbance, it is a good indication of the type of impact or potential impact that a NEPA document must address. At the same time, implementing another environmental law (e.g., a hazardous substance cleanup required under the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA]) might create impacts that a NEPA document would need to address.

Also, compliance with other environmental laws serves as a method of preventing what might otherwise be unacceptable environmental consequences (e.g., contributing to significant deterioration of air quality or destroying archaeological resources). Although compliance with other regulatory requirements is not required under NEPA, it may be appropriate to include such a discussion in NEPA documents in the context of identifying specific mitigation measures.

Coordination of NEPA documentation requirements with the documentation requirements of other laws and regulations whenever possible will help avoid delays and needless duplication of effort. The CEQ regulations recognize this need by requiring agencies to integrate NEPA requirements with other planning and environmental review procedures (§1500.2[c]) and to integrate environmental impact analyses and related studies required by other laws (§1502.25). Also, DOE Order 5440.1E (November 10, 1992) (superseded by DOE Order 451.1 on September 11, 1995) established a policy of integrating NEPA and CERCLA Remedial Investigation (RI)/Feasibility Study (FS) documentation requirements.

Document integration, however, may not always be feasible or practical. For example, the "Secretarial Policy on the National Environmental Policy Act" (June 1994) calls for "streamlining" the NEPA process by incorporating NEPA values (such as the analysis of cumulative, off-site, ecological, and socioeconomic impacts) into CERCLA documents to the extent practicable in order to avoid unnecessary delays and minimize costs.

The requirements addressed in this section are grouped by category under the following headings:

- Environmental Policy
- Endangered and Threatened Species/Sensitive and Critical Habitat
- Fish and Wildlife Conservation
- Heritage Conservation
- Floodplains and Wetlands
- Discharge Permits
- Pollution Prevention and Control.

A.1 Environmental Policy

National Environmental Policy Act (42 United States Code [U.S.C.] §4321 et seq.).

NEPA is the nation's most comprehensive legislative and public policy statement on the protection of the environment. The act is divided into two titles: Title I, "Declaration of National Environmental Policy," and Title II, "Council on Environmental Quality." The policy statement is contained in Section 101 of Title I. Under this Congressional mandate, the federal government is directed to use "all practicable means" to improve and coordinate federal plans, functions, programs, and resources so that the nation can:

- Fulfill the responsibilities of each generation as trustee of the environment for succeeding generations

- Ensure for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings

- Attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences

- Preserve important historic, cultural, and natural aspects of our national heritage and maintain, wherever possible, an environment that supports diversity and variety of individual choice

- Achieve a balance between population and resource use that will permit high standards of living and a wide sharing of life's amenities

- Enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources.

Federal agencies are required to consider the environmental consequences of their proposed actions. To this end, NEPA requires agencies to follow certain procedures, the major one being to:

> (I)nclude in every recommendation or report on proposals for . . . major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on . . . the environmental impact of the proposed action . . . . (§102[2][c])

There is a common misunderstanding that NEPA is the "environmental impact statement" law. While the "detailed statement" requirements receive most of the attention, there are seven other "action-forcing" provisions in §102(2) of the act. They require all federal agencies to:

- Use an interdisciplinary approach in planning and decision-making
- Ensure appropriate consideration of unquantified environmental values
- Study and develop alternatives to proposals involving unresolved conflicts over the use of resources
- Recognize the global and long-range character of environmental problems
- Make environmental information generally available
- Initiate ecological information for resource-oriented projects
- Assist the CEQ.

Perhaps with the exception of providing assistance to the CEQ, all of these provisions relate directly or indirectly to the preparation of the detailed statement.

Council on Environmental Quality NEPA Implementation Regulations (40 CFR Parts 1500-1508). All federal agencies must abide by the CEQ regulations that implement the procedural requirements of NEPA. In addition, the federal agencies must develop specific procedures for implementing the CEQ regulations. If the NEPA decision-making process is challenged, the responsible agency would be subject to judicial review in a federal court. The requirement to prepare detailed statements on proposals for major federal actions is not the only action-forcing provision of NEPA. The CEQ regulations, however, focus almost exclusively on the preparation and review of EISs and (to a lesser extent) of EAs. The regulations in 40 CFR Parts 1500-1508 are subdivided as follows:

- Part 1500: Purpose, Policy, and Mandate
- Part 1501: NEPA and Agency Planning
- Part 1502: Environmental Impact Statement
- Part 1503: Commenting
- Part 1504: Predecision Referrals to the CEQ
- Part 1505: NEPA and Agency Decision-making
- Part 1506: Other NEPA Requirements
- Part 1507: Agency Compliance
- Part 1508: Terminology and Index.

The CEQ regulations require that all federal agencies interpret and administer the policies, regulations, and public laws of the United States in accordance with the national environmental policies set forth in NEPA and the CEQ regulations (§1500.2). Agencies are required to revise their policies, procedures, and regulations as necessary to ensure full compliance with NEPA "to the fullest extent possible" (§1500.6). Agencies are urged to "reduce paperwork" by adopting any of 17 enumerated methods (including producing "analytic rather than encyclopedic" documents, focusing on significant issues, writing in "plain language," incorporating by reference, and "integrating" NEPA requirements with other environmental review and documentation) (§1500.4).

The CEQ regulations do not specify when and under what circumstances an EIS (or an EA) must be prepared. This must be determined under procedures adopted by individual agencies and according to a number of criteria (§§1501.3 and 1501.4). The regulations (§§1501.5 and 1501.6) explain in some detail the relative roles of both "lead" and "cooperating" agencies, and §1501.7 covers the "early and open process for determining the scope of issues to be addressed."

According to the CEQ regulations, the "primary purpose of an environmental impact statement is to serve as an action-forcing device to ensure that the policies and goals defined in the act be infused into the ongoing programs and actions of the Federal Government" (§1502.14). Agencies must properly define the proposal based on which an EIS is to be prepared (§1502.4). When proposals are related closely enough to be a "single course of action," they must be evaluated in a single impact statement (§1502.4). Section 1502.4 defines broad policy or "programmatic" statements, and §1502.9 addresses the distinctions between "draft," "final," and "supplemental" statements.

Sections 1502.10 (recommended format), 1502.11 (cover sheet), 1502.12 (summary), 1502.13 (purpose and need), 1502.14 (alternatives including the proposed actions), 1502.15 (affected environment), and 1502.16 (environmental consequences) contain the fundamental EIS/EA instructions. The regulations make clear that the discussion of the proposed action and alternatives is the "heart" of the EIS process. Agencies must "rigorously explore and objectively evaluate all reasonable alternatives" and present the environmental impacts of the proposed action and the alternatives in comparative form (§1502.14). The discussion of alternatives is critical, because a large number of cases brought before the courts under NEPA have included the allegation that the agency failed to evaluate alternatives adequately.

The CEQ regulations require that an EIS succinctly describe the environment that would be affected by the proposed action and alternatives, with descriptions no longer than are necessary to understand the effects of the alternatives (§1502.15). The regulations point out that "verbose descriptions of the affected environment are themselves no measure of the adequacy of an environmental impact statement."

Section 1502.16 provides a recipe for assessing environmental consequences (impacts), the most difficult part of any NEPA documentation. While any discussion of environmental consequences must include, among other things, a discussion of "direct" and "indirect" effects and their significance, the requirement for addressing "cumulative impacts" is not addressed until much later in the regulations (§1508.25).

Protection and Enhancement of Environmental Quality (EO 11514 [as amended by EO 11991]). EO 11514 directs federal agencies to:

- Monitor, evaluate, and control their activities in order to protect and enhance the quality of the environment
- Develop procedures to ensure public information and understanding of federal programs with environmental impact
- Ensure that information regarding existing or potential environmental problems as a result of research, development, demonstration, test, or evaluation activities is made available to federal agencies, states, counties, municipalities, institutions, and other appropriate entities

- Review the statutory authority, the regulations, the policies, and the procedures of their agencies in order to identify any deficiencies or inconsistencies that limit compliance with NEPA
- Comply with CEQ regulations, except where such compliance would be inconsistent with statutory requirements.

Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (EO 12898). This EO is designed to focus the attention of federal agencies on the environmental and human health conditions in minority and low-income communities with the goal of achieving environmental justice. The EO is intended to promote nondiscrimination in federal programs that substantially affect human health and the environment and to provide minority and low-income communities access to public information on, and an opportunity for public participation in, matters relating to human health or the environment.

NEPA Compliance Program (DOE Order 451.1). DOE Order 451.1 (September 11, 1995) establishes DOE internal requirements and responsibilities for implementing NEPA, the CEQ regulations, and the DOE NEPA Implementing Procedures (10 CFR Part 1021). The goal of the requirements is to ensure efficient and effective implementation of DOE's NEPA responsibilities through teamwork. A key responsibility for all participants is to control the cost and time for the NEPA process while maintaining its quality. The order establishes a system of DOE NEPA Compliance Officers, internal scoping procedures for EAs and EISs, NEPA quality assurance plans and public participation plans, annual NEPA planning summaries, a DOE NEPA Document Manager for each EA and EIS, a system for reporting lessons learned and encouraging continuous improvement, and an annual reporting procedure. The order also outlines responsibilities of DOE personnel in implementing NEPA.

The DOE-Albuquerque (DOE/AL) Field Office issued Draft Order AL 5440.1D (August 27, 1991) as a supplement to the DOE Order 5440.1E series (now canceled and replaced by DOE Order 451.1). Although Draft Order AL 5440.1D has been cancelled, SNL/NM follows the NEPA document tracking and numbering system that was established in response to the draft order. Also, Appendix D of the draft order provided guidelines for completing an environmental checklist/action description memorandum (ECL/ADM). The purpose of the ECL/ADM is to provide the appropriate decision makers with sufficient information on a proposed action to make a NEPA determination. SNL/NM personnel are required to fill out an ECL/ADM for any proposed action that may have environmental concerns. The ECL/ADM is submitted to SNL/NM Organization 7315 Risk Management and NEPA professionals.

Compliance with NEPA and Final Guidelines (10 CFR Part 1021) [45 Federal Register (FR) 20694 as amended by 47 FR 7976 and 52 FR 47662]. In 40 CFR Part 1021, as amended, the DOE establishes procedures to comply with NEPA. The CEQ regulations are adopted in §1021.2. The regulations establish requirements for the planning stages of proposed DOE actions, implementation procedures, and a listing of typical DOE actions, including those that are categorically excluded from the requirements to prepare either an EA or EIS.

General Environmental Protection Program (DOE Order 5400.1). DOE Order 5400.1 (November 9, 1988) presents a comprehensive overview of general environmental protection issues. This order defines environmental protection requirements, authorities, and responsibilities for DOE operations. The purpose is to ensure compliance with federal and state environmental protection laws and regulations, federal executive orders, and internal department policies. The order lists mandatory environmental protection standards, describes various environmental protection program plans, and contains environmental monitoring requirements.

Secretarial Policy on the National Environmental Policy Act.
In June 1994, the Secretary of Energy issued a policy statement with respect to streamlining the NEPA process, minimizing the cost and time for document preparation and review, emphasizing teamwork, and making the process more useful to decision-makers and to the public. The policy delegates authority for EAs, findings of no significant impact, and associated floodplain and wetland action documentation requirements to the DOE field organizations. The policy also addresses changes in the NEPA process, NEPA contract reform, additional reforms for high-priority projects, enhanced public involvement, and continuing improvement. One of the notable process changes, according to the policy statement, will be to incorporate NEPA values (such as the analysis of cumulative, off-site, ecological, and socioeconomic impacts) into DOE CERCLA documents "to the extent practicable." These types of values would not normally be addressed in a typical CERCLA document.

Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements. The DOE Office of NEPA Oversight provides guidance in this paper published in May 1993. The purpose of the paper is to improve the quality of EAs and EISs and to expedite their review and approval. The guidance provides recommendations with respect to the format and content of EAs and EISs and principles intended to improve the readability of NEPA documents. The recommendation for DOE NEPA documents is to use a "sliding-scale" approach. Key elements of this instruction are to focus effort on significant environmental issues and alternatives and to discuss impacts in proportion to their significance. The term "scale" refers to the spectrum of significance of environmental impacts. Generally, those proposals with greater potential for significant environmental impacts require more analysis than those proposals with very small environmental impacts.

Environmental Assessment Checklist. The DOE Office of NEPA Oversight has developed a checklist to aid in the preparation and review of EAs. Although this EA checklist is not considered a policy or guidance document, the checklist questions are based on the CEQ regulations, the DOE NEPA regulations, and the "Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements." The EA checklist is intended to be adapted to suit particular needs and circumstances.

A.2 Endangered and Threatened Species/Sensitive and Critical Habitat

Endangered Species Act (16 U.S.C. §1531 et seq.). The Endangered Species Act provides for the protection of threatened and endangered species of flora and fauna. Under Section 7 of the act, a federal agency is required to:

- Obtain a scientific permit for capturing, killing, monitoring, or performing scientific studies involving threatened or endangered wildlife and plant species
- Confer with the U.S. Fish and Wildlife Service (USFWS) regarding listed or proposed species or critical habitat
- Prepare a biological assessment of the proposed action if necessary
- Perform "formal consultation" with the USFWS on potential impacts to species or habitat if necessary.

[See Section 6.3 for a compilation of threatened or endangered species known to exist at SNL/NM-Kirtland Air Force Base (KAFB).]

Prior to beginning construction or ground-disturbing activities, SNL/NM representatives (with DOE approval) should confer with the USFWS; the New Mexico Department of Game and Fish (NMDGF); and/or the New Mexico Energy, Minerals, and Natural Resources Department with respect to these or any other species that are suspected to be present at the project location. Before beginning construction or ground-disturbing activities on U.S. Forest Service (USFS) withdrawal lands, however, SNL/NM needs to confer with the USFS. The USFS assumes the responsibility for species surveys and consultation with the agencies on withdrawn lands.

If the DOE or SNL/NM determines that a potential presence of a listed or proposed species or habitat exists within the project area, a biological assessment must be prepared. The assessment will address how the project "may affect" proposed or listed endangered species, threatened species, or critical habitat. If an adverse effect on these species or habitat is anticipated, formal consultation can be requested by the DOE or by the USFWS. The formal consultation will result in a written biological opinion containing a "jeopardy" or "no-jeopardy" decision by the USFWS regarding the fate of endangered species within the project area or within other affected areas. It is generally advisable to include documentation regarding compliance with the Section 7 process (e.g., correspondence with the USFWS and/or the NMDGF) in an EA or EIS.

The NMDGF also has procedures that the DOE must follow in order to comply with federal and state regulations concerning threatened and endangered species. When the DOE or SNL/NM anticipates an action that might affect endangered species in New Mexico, the NMDGF must be contacted. The department will provide the current state list of endangered species in New Mexico, a handbook of endangered species, and the state requirements for compliance with the New Mexico Wildlife Conservation Act. This act gives jurisdiction to the department over all indigenous, nondomestic vertebrate species (i.e., amphibians, birds, fishes, mammals, and reptiles) as well as to crustaceans and mollusks.

Using the material provided by the NMDGF Endangered Species Program and/or field studies, SNL/NM must determine the species that might be affected within the proposed project area. A list of endangered animal and plant species must be developed and the potential impacts assessed. The assessments can lead to one of three results:

- That no endangered species are present, and that there are no impacts resulting from the proposed action
- That although endangered species are present, the proposed project will not have an impact on the species
- That endangered species are present, and that there are projected impacts to the species.

The assessment must be submitted to the NMDGF for review. SNL/NM must seek consultation with the NMDGF concerning steps to avoid or mitigate known adverse effects to endangered species.

[The New Mexico Energy, Minerals, and Natural Resources Department uses the same criteria and procedures in its Endangered Plants Act for endangered plant species within the state.]

List of Endangered and Threatened Species (50 CFR Part 17 [as republished on August 20, 1994]). This regulation lists those species that have been designated endangered or threatened by the USFWS. It also designates critical habitat areas within the United States and its possessions. In 50 CFR Part 424, instructions are provided for agencies seeking to list endangered and threatened species or to designate critical habitat. The USFWS and the state use this list to check the likely presence of these species or habitat at a project area.

Interagency Cooperation - Endangered Species Act of 1973 (50 CFR Part 402). Part 402 implements, among other things, Section 7 of the Endangered Species Act. Federal agencies are required to confer with the USFWS and seek consultation, if necessary. Agencies are prohibited from authorizing activities likely to jeopardize the continued existence of any threatened or endangered species or its critical habitat.

A.3 Fish and Wildlife Conservation

Fish and Wildlife Coordination Act (16 U.S.C. §§661-666c). The Fish and Wildlife Coordination Act was enacted to ensure that fish and wildlife resources receive equal consideration with other values during the planning of development projects that modify any stream or other body of water ten acres or greater in size. The act requires that federal agencies (1) consult with the USFWS and appropriate state wildlife agencies to assess project impacts on wildlife resources, and (2) modify project plans by "justifiable means and measures" in order to prevent the loss of or damage to wildlife resources, as well as to provide concurrently for the development and improvement of such resources.

The DOE or SNL/NM must consult with the USFWS prior to impounding, diverting, or deepening the channel or otherwise controlling for any purpose the waters of any stream or other body of water.

Bald and Golden Eagle Protection Act (16 U.S.C. §§668-668d). The Bald and Golden Eagle Protection Act makes it unlawful to take (capture, kill, or destroy), molest, or disturb bald (American) and golden eagles or their nests or eggs anywhere in the United States. A permit must be obtained from the U.S. Department of the Interior to relocate a nest that interferes with resource development or recovery operations.

Migratory Bird Treaty Act (16 U.S.C. §703 et seq.). The Migratory Bird Treaty Act codifies a treaty between the United States, Great Britain, Canada, Mexico, and Japan that prohibits the taking, killing, hunting, or possession of migratory birds or their nests or eggs. Permits must be obtained for engaging in such activities. Penalties for violating the act include either fines or imprisonment.

A.4 Heritage Conservation

National Historic Preservation Act, as amended (16 U.S.C. 470 et seq.). The NHPA was enacted to protect the nation's cultural resources. The NHPA established the Advisory Council on Historic Preservation (ACHP), the State Historic Preservation Officers (SHPO), and the National Register of Historic Places (NRHP). Section 106 directs federal agencies to take into account the effects of their actions on properties included on or eligible for the NRHP. Under Section 110(a) and EO 11593, federal agencies are required to locate, inventory, and nominate all properties under their control that may qualify for inclusion in the NRHP. Section 110(f) requires specific planning and actions to minimize harm to any national historic landmark that may be directly and adversely affected by a federal agency's actions.

The Section 106 process involves five steps that SNL/NM, as the representative of the DOE, may have to follow:

- Identification of the historic properties within the area of a proposed action's potential effects
  (Note: This step may include a literature/records search and a pedestrian cultural resources survey.)

- Determination of the effects of a proposed project on those properties

- Early consultation among the DOE, the SHPO, and others to seek ways to avoid or reduce the effects on the historic properties

- Affording the ACHP a reasonable opportunity to comment on the undertaking

- Proceeding with the agency's decision-making process.

The NHPA was amended in 1992. The primary effect of the amendments was to pass the authority for consultation activities from the ACHP to the SHPO. In addition, the amendments give Indian tribes the authority to act as SHPO on Indian lands.

Archeological and Historic Preservation Act (16 U.S.C. §469a et seq.). The NHPA has been amended by the Archeological and Historic Preservation Act (AHPA) of 1974. The AHPA directs federal agencies to recover and preserve historic and archaeological data that would otherwise be lost as a result of federal construction, activities, or programs affecting cultural resources.

Archaeological Resources Protection Act (16 U.S.C. §470aa et seq.). The NHPA has also been amended by the Archaeological Resources Protection Act (ARPA), which requires a permit from the U.S. Department of the Interior for excavation or removal of archaeological resources from public or Indian lands. The act establishes criminal and civil penalties for the illegal excavation, removal, damage, sale, purchase, or exchange of archaeological items.

Any excavations conducted on, or removal of archaeological resources from, SNL/NM lands require an ARPA permit obtained through the National Park Service.

Protection of Historic and Cultural Properties (36 CFR Part 800). These regulations implement the NHPA, specifically defining the process used by a federal agency (DOE) to meet the responsibility of taking into account the effects of its actions on cultural resources. This process, known as the Section 106 process, requires that an agency complete the following steps prior to the approval of the expenditure of any federal funds on an undertaking or the issuance of any license or permit:

- Identifying historic properties by:
  - Assessing information needs by reviewing existing data on historic properties potentially affected by the undertaking, requesting the views of the SHPO on further actions to identify properties, and seeking information from parties likely to have knowledge of historic properties in the area
  - Locating historic properties that may be affected by the undertaking and gathering sufficient information to evaluate the eligibility of these properties for the NRHP
  - Evaluating historical significance in cooperation with the SHPO

- Documenting the finding to the SHPO that there are no historic properties likely to be affected by the undertaking

- Assessing the effects of the undertaking if historic properties are found.

- Assessing effects by:

  - Applying the Criteria of Effect in 36 CFR §800.9(a)

  - Notifying the SHPO and interested persons when no effect is found

  - Consulting with the SHPO and applying the Criteria of Adverse Effect (§800.9[b]) when an effect is found

  - Obtaining the SHPO's concurrence when the effect is not considered adverse

  - Consulting with the SHPO and notifying the ACHP or reaching a Memorandum of Agreement (MOA) with the SHPO on treatment of historic properties.

- Affording the Advisory Council the opportunity to comment on the documentation prepared or review the MOA.

It is generally advisable to include documentation regarding compliance with the Section 106 process (e.g., concurrence letters from the New Mexico SHPO) in an EA or EIS.

Other Regulations for Reference. Other regulations pertaining to historic preservation include:

- 36 CFR Part 60: National Register of Historic Places

- 36 CFR Part 62: National Register of Natural Landmarks

- 36 CFR Part 63: Determinations of Eligibility for Inclusion in the National Register of Historic Places

- 36 CFR Part 65: National Historic Landmarks Program.

American Indian Religious Freedom Act (42 U.S.C. §1996). The American Indian Religious Freedom Act (AIRFA) states that it is the policy of the United States to protect and preserve the right of Native Americans (American Indians, Eskimos, Aleuts, and Native Hawaiians) to believe, express, and exercise their traditional religious and ceremonial rites. Consultation with potentially affected Native Americans (e.g., the Isleta Pueblo) by either the

DOE or U.S. Air Force (USAF) is necessary if infringement on religious rites or ceremonial sites by a proposed action is likely.

Native American Graves Protection and Repatriation Act (25 U.S.C. §3001 et seq.). The Native American Graves Protection and Repatriation Act (NAGPRA) provides for the protection of Native American graves, human remains, and funerary objects. Intentional excavation and removal of Native American human remains and objects from tribal or federal lands can be conducted only after consultation with the appropriate (if any) Indian tribe. In the event of inadvertent discovery of Native American remains and objects (e.g., during construction) on federal or tribal lands, the secretary of the federal agency having management authority over the federal lands (Interior, Agriculture, or Energy in the case of SNL/NM) must be notified in writing. Activity in the area of the discovery must cease, and a reasonable effort must be made to protect the items discovered before activity is resumed. Following notification of the appropriate agency (or tribal organization for tribal lands), and upon certification from the secretary of the agency that notification has been received, activity in the area may resume 30 days after such certification.

Protection and Enhancement of the Cultural Environment (EO 11593). This EO directs federal agencies to (1) administer the cultural properties under their control in a "spirit of stewardship and trusteeship for future generations;" (2) initiate measures to preserve, restore, and maintain federally owned sites, structures, and objects of historical, archaeological, or architectural significance; and (3) institute procedures to ensure that federal programs contribute to the preservation of nonfederally owned sites, structures, and objects of historical, architectural, or archaeological significance. The DOE is required to initiate procedures to preserve cultural resources recorded on DOE and SNL/NM lands.

A.5 Floodplains and Wetlands

Floodplain Management (EO 11988). EO 11988 directs federal agencies to avoid adverse impacts associated with the modification of floodplains, to consider alternatives to a proposed action, to provide early public review of proposed actions, and to propose mitigation measures for proposed actions within floodplains.

The term "floodplain" means the 100-year floodplain, as defined by the Federal Emergency Management Agency Flood Insurance Rate Maps. This EO must be followed if a proposed action includes acquiring, managing, or disposing of SNL/NM facilities; conducting

DOE/SNL/NM construction or financed construction activities; or conducting SNL/NM activities and programs affecting land use.

Protection of Wetlands (EO 11990). EO 11990 requires that federal agencies consider the effects of proposed actions on wetlands, determine whether wetlands are present, assess the impacts, consider alternatives to a proposed action, provide for early public review, and propose mitigation measures for proposed actions that could affect wetlands.

Compliance with Floodplain/Wetlands Environmental Review Requirements (10 CFR Part 1022). These regulations establish DOE policy with respect to implementing EO 11988 and EO 11990. Part 1022 also defines procedures for floodplain/wetlands review, including:

- Floodplain/wetlands determination:
  - Concurrence with NEPA requirements
  - Using Flood Insurance Rate Maps or Flood Hazard Boundary Maps prepared by the Department of Housing and Urban Development
  - Using USFWS, Soil Conservation Service, or U.S. Geological Survey (USGS) topographic maps.
- Floodplain/wetlands assessment containing:
  - Project description
  - Floodplain/wetlands effects
  - Alternatives.
- Public review through EIS or Notice in *Federal Register*
- Notification of decision in EA or EIS or *Federal Register*.

As a contractor to the DOE, SNL/NM may be required to follow Part 1022 procedures with respect to floodplains and wetlands.

A.6 Discharge Permits

Clean Water Act (or the Federal Water Pollution Control Act of 1972) (33 U.S.C. §1251 et seq.). Section 402 of the CWA is the basis for regulating discharges of pollutants into navigable waters of the United States under the National Pollutant Discharge Elimination System (NPDES). The NPDES regulates discharges from point sources to navigable (surface) waters. The act also sets forth goals to eliminate the discharge of pollutants into waters of the United States and develop technology toward that end.

Section 404 of the act prohibits the discharge of dredged or fill material into waters of the United States. Dredged or fill material includes such material as fill for road crossings, fill for water impoundment structures, and bedding for transmission line crossings. The act enables the U.S. Army Corps of Engineers (USACE) to issue permits for the discharge of dredged or fill material into waters of the United States at specific sites.

U.S. Environmental Protection Agency - Administered Permit Programs: The National Pollutant Discharge Elimination System (40 CFR Part 122). These regulations cover the basic U.S. Environmental Protection Agency (EPA) permitting requirements for discharges of pollutants from any point source into waters of the United States under Section 402 of the CWA. Waters of the United States include waters that were or are used in interstate commerce, lakes, streams, rivers, mudflats, sandflats, arroyos, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, and natural ponds.

It is the duty of the operator of a facility that discharges or proposes to discharge a pollutant into United States waters to apply to the EPA for a permit under the NPDES. The New Mexico Environment Department (NMED) has the authority to issue NPDES permits in New Mexico. (Also, a discharge plan must be submitted to the director of the NMED prior to the discharge of any contaminant into the ground water.) Under recent federal stormwater regulations, any ongoing or new construction activities conducted after October 1, 1992, that total 5 acres or more, will be required to obtain an NPDES permit. Permit applications should contain the following information:

- Activities that require an NPDES permit
- Name, address, and location of facility
- Standard Industrial Classifications that best reflect products or services of the facility
- Name, address, phone number, and status of operator
- Whether the facility is located on Indian lands
- List of permits or construction approvals

- Topographic map extending one mile past the property boundaries of the source
- Description of the nature of the business.

Existing manufacturing facilities (dischargers) that apply for NPDES permits must provide such information as outfall locations, line drawings, average flows and treatment, maximum product, and effluent characteristics.

Permits will generally specify a schedule of compliance and reporting requirements. The following requirements are potentially applicable to SNL/NM and must be followed according to the NPDES permit regulations:

- NHPA
- Endangered Species Act
- Fish and Wildlife Coordination Act
- NEPA
- Appropriate EOs.

Permits for Discharges of Dredged or Fill Material into Waters of the United States (33 CFR Part 323). Part 323 describes the implementation of Section 404 of the CWA by the USACE. The following types of discharge permits are issued by the USACE:

- General or "nationwide" permits for categories of activities that are similar in nature
- General or "regional" permits issued by a district or division
- "Individual" permits or those issued for specific projects.

Permits are required for any addition of excavated or dredged materials into the waters of the United States except as noted in 33 CFR 323.4. *(Note: Section 404 permits may be required for activities carried out in wetlands. Contact with the USACE district engineer for a determination of wetlands status for the project area is advisable.)*

Processing of Department of the Army Permits (33 CFR Part 325). Potential permit applicants should contact the USACE district engineer in Albuquerque to request a preapplication consultation. A standard application form must be submitted containing the following information:

- Description of the proposed activity, including such items as location and scheduling of the activity, purpose and need, etc.

- Activities that are related to the proposed project

- Description of the type, composition, and quantity of the material to be dredged, method of dredging, and plans for disposal
- If the activity involves an impoundment, demonstration that the structure has been designed by qualified persons.

Applications will be reviewed for potential impact to historic properties and endangered species.

A.7 Pollution Prevention and Control

Pollution Prevention Act (42 U.S.C. §§13101 to 13109). The Pollution Prevention Act of 1990 (PPA) affirmed a new approach to improving environmental quality consistent with one of the purposes of NEPA: "to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man" (NEPA §2; 42 U.S.C. §4321). The PPA also reflects the CEQ regulations policy provision that requires federal agencies to "avoid or minimize any possible adverse effects of their actions upon the quality of the human environment" [§1500.2(f)]. The PPA establishes a national policy toward increased pollution reduction and prevention comprising the following hierarchy of actions:

- Prevention or reduction of pollution at the source ("source reduction")
- Recycling of materials in an environmentally safe manner when pollution cannot be prevented
- Treatment in an environmentally safe manner of pollutants that cannot be prevented or recycled
- Disposal in an environmentally safe disposal facility or other release into the environment only as a last resort.

DOE's "Policy on Waste Minimization and Pollution Prevention" was issued on August 20, 1992 (DOE, 1992). The policy expresses a commitment to "the inclusion of cost-effective waste minimization and pollution prevention in all (DOE) activities, including considerations of these concepts and approaches in DOE's program planning and major assessment processes . . . such as NEPA."

Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act (42 U.S.C. 6901 et seq.). RCRA is designed to track hazardous waste from "cradle to grave" (i.e., from waste generation to final disposal) through requirements for generators, handlers, shippers, and transporters of hazardous waste, as well as for facilities that treat, store, dispose of, or recycle hazardous wastes. Subtitle C of RCRA regulates hazardous wastes only; Subtitle D addresses all nonhazardous waste disposal in general.

Sections 3004(u) and 3008(h) of the Hazardous and Solid Waste Amendments of 1984 to RCRA require "corrective action" for releases of hazardous constituents from solid waste management units at facilities operating under interim status. Facilities operating under a RCRA treatment, storage, or disposal permit must meet the requirements of the 40 CFR §264.100 corrective action program. A federal agency must prepare documentation that analyzes the appropriateness of the agency's proposed corrective action and alternative actions.

Identification and Listing of Hazardous Waste (40 CFR Part 261). Part 261 defines solid and hazardous wastes, allows for exclusions of certain wastes, and provides special considerations for small-quantity generators and for hazardous wastes that are used, reused, recycled, or reclaimed. The characteristics of hazardous waste (ignitability, corrosivity, reactivity, and toxicity) are defined. Finally, lists of wastes that are hazardous are presented. SNL/NM personnel who are involved in the generation or handling of wastes should be familiar with the identification of hazardous waste.

Standards Applicable to Generators of Hazardous Waste (40 CFR Part 262). Part 262 establishes the responsibilities of hazardous waste generators—primarily, obtaining an identification number, preparing a manifest, ensuring proper packaging and labeling, and record keeping and reporting.

Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR Part 264). Part 264 establishes the requirements and technical standards that owners and operators of hazardous waste treatment, storage, and disposal (TSD) facilities must meet. General requirements include obtaining identification numbers, conducting waste analyses, preparing contingency plans and emergency procedures, complying with manifests, record keeping and reporting, and establishing groundwater monitoring systems.

In addition, the standards specify technical requirements for categories of facilities, including:

- Containers
- Tanks
- Surface impoundments
- Waste piles
- Land treatment facilities

- Landfills
- Incinerators
- Miscellaneous units.

Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR Part 265). Part 265 establishes the requirements and technical standards that owners and operators of existing hazardous waste TSD facilities must meet in order to continue operating until a final permit can be written for their facility. Existing hazardous waste TSD facilities are defined as those in operation or under construction by November 19, 1980. General requirements include obtaining identification numbers, conducting waste analyses and inspections, preparing contingency plans and emergency procedures, complying with manifests, and record keeping and reporting. In addition, the standards specify technical requirements for the following categories of facilities:

- Containers
- Tanks
- Surface impoundments
- Waste piles
- Land treatment facilities
- Landfills
- Incinerators
- Thermal treatment facilities
- Chemical, physical, and biological treatment facilities
- Underground injection facilities.

Groundwater monitoring, financial requirements, and closure and postclosure requirements are also included.

Interim Standards for Owners and Operators of New Hazardous Waste Land Disposal Facilities (40 CFR Part 267). Part 267 establishes temporary standards for owners and operators of new hazardous waste landfills, surface impoundments, land treatment facilities, and Class I underground injection wells that require individual RCRA permits under the 40 CFR Part 122 NPDES regulations.

Land Disposal Restrictions (40 CFR Part 268). Part 268 identifies hazardous wastes that are restricted from land disposal and defines those limited circumstances under which an otherwise prohibited waste may continue to be disposed of on land. SNL/NM personnel who are responsible for arranging for the transport and disposal of hazardous waste must be familiar with the land disposal restrictions.

Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (40 CFR Part 280). Part 280 prohibits the installation of any new underground storage tank for regulated substances unless the tank is protected against corrosion and structural failure and is compatible with the substance to be stored.

Hazardous Materials Transportation Act (49 App. U.S.C. §1801 et seq.; 40 CFR Parts 106-179). The Hazardous Materials Transportation Act (HMTA) provides for safe intrastate and interstate transportation of hazardous materials. Hazardous materials include hazardous substances, hazardous wastes, marine pollutants, elevated temperature materials, and those materials listed in the HMTA regulations hazard class tables. The HMTA allows states to regulate the transport of hazardous/nuclear materials as long as such regulations are consistent with the HMTA or U.S. Department of Transportation (DOT) regulations.

CERCLA/Superfund Amendments and Reauthorization Act (42 U.S.C. 9601 et seq.). CERCLA, or Superfund Act, enacted by Congress in 1980, has provided the springboard for massive environmental cleanup of both private and government facilities. It provides the basic authority and regulatory framework for responses to releases (or threats of releases) of hazardous substances, pollutants, or contaminants that may pose an imminent and substantial endangerment to public health or the environment. Removals or remedial actions at hazardous substance sites are required under 40 CFR Part 300, Subpart E. The nature of the threat and the type of remedy required are determined by an RI/FS.

CERCLA also requires a person in control of a hazardous substance to immediately report spills of reportable quantities to the National Response Center (NRC). Under §120 of the Superfund Amendments and Reauthorization Act (SARA), federal agencies must comply with CERCLA. This means, in part, that an agency must prepare CERCLA documentation for its proposed remedial and removal actions.

National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR Part 300). CERCLA is implemented by the EPA through 40 CFR 300, the revised National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The NCP establishes an organized structural plan for effective responses to discharges of oil and releases of hazardous substances, pollutants, or contaminants. The various subparts of the NCP are as follows:

- Subpart A contains new statutory definitions.
- Subpart B covers specific responsibilities of federal agencies as members of a National Response Team.
- Subpart C consists of information on existing plans and their relationship to Title III of SARA.
- Subpart D deals with operational response phases for oil removal.
- Subpart E contains most of the revisions to the NCP. In the final NCP, maximum contaminant levels goals (MCLG) that are set at levels above zero will generally be the cleanup levels for ground and surface waters where relevant and appropriate. Where MCLGs are set at levels equal to zero, the maximum contaminant level (MCL) generally will be the cleanup level as appropriate. Factors used in determining applicable or relevant and appropriate requirements have been modified.
- Subpart F deals with state involvement in CERCLA response actions.
- Subpart G clarifies designations of trustees for natural resources.
- Subpart H groups discussion from other NCP sections regarding participation by other persons in response activities.
- Subpart I documents appropriate response actions for CERCLA sites.
- Subpart J covers use of dispersants and other chemicals.

Appendix A to 40 CFR Part 300 contains the Hazard Ranking System, which is used to prioritize sites for the National Priorities List (NPL). The NPL is provided as Appendix B to Part 300.

Designation, Reportable Quantities, and Notification (40 CFR Part 302). Under §102(a) of CERCLA, this regulation designates hazardous substances referred to in §101(14) of the act and identifies reportable quantities (RQ) for each substance on the List of Hazardous Substances and Reportable Quantities. This part also sets forth notification requirements for releases of these substances from a vessel or facility. SNL/NM must notify the NRC of any release of a hazardous substance equal to or exceeding the RQ listed in 40 CFR §302.4.

Emergency Planning and Notification (40 CFR Part 355). Part 355 establishes the list of extremely hazardous substances, threshold planning quantities, and facility notification responsibilities necessary for the development and implementation of state and local emergency response plans.

Hazardous Chemical Reporting: Community Right-To-Know (40 CFR Part 370). Reporting requirements that provide the public with important information on the hazardous chemicals in their communities are set forth in Part 370. The purpose of the regulations is to enhance community awareness of chemical hazards and to facilitate the development of state and local emergency response plans.

The facility is required to notify the local emergency planning committee of any hazardous substances at the facility that exceed the minimum threshold levels established by the committee. An inventory form must be prepared and submitted on a yearly basis to the local emergency planning committee and the fire department having jurisdiction over the facility.

Toxic Chemical Release Reporting: Community Right-To-Know (40 CFR Part 372). Requirements for submitting information regarding the release of toxic chemicals under §313 (Toxic Chemical Release Forms) of Title III of SARA are included in Part 372. Information collected under this part is intended to inform the general public and the communities that surround facilities covered under community right-to-know about releases of toxic chemicals; to assist research; and to aid in the development of regulations, guidelines, and standards. Also set forth in this part are notification requirements for suppliers of mixtures or trade name products containing toxic chemicals. SNL/NM must prepare and submit yearly §313 reporting forms to EPA Region 6 and the NMED.

Clean Air Act, as amended (42 U.S.C. §7401 et seq.). The CAA amendments of 1990 will have far-reaching effects on environmental compliance activities, procurement, maintenance, and motor vehicle operation activities. The new law does the following:

- Strengthens measures for attaining air quality standards (Title I)
- Establishes tighter emission standards for vehicles and fuels (Title II)
- Expands the regulation of hazardous air pollutants (HAP) (Title III)

- Requires substantial reductions in power plant emissions for control of acid rain (Title IV)
- Establishes operating permits for all major sources of air pollution (Title V)
- Establishes provisions for stratospheric ozone protection (Title VI)
- Expands enforcement powers and penalties (Title VII).

The provisions most pertinent to SNL/NM are the National Ambient Air Quality Standards (NAAQS) for sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, lead, and particulate matter (PM_{10}) (10 micrometers [μ] or smaller total particulate matter for nonradioactive metals). All areas of the United States are required to maintain ambient levels of these pollutants below the ceilings established by the NAAQS. Local environmental agencies may impose more stringent standards and include more contaminants than those on the NAAQS list. Any area that does not meet these standards is a nonattainment area. The CAA amendments redefine "major source" with respect to how serious the pollution is in a nonattainment area.

HAPs are specific chemical compounds that pose unique negative health effects. Congress expanded the number of HAPs from 8 to 189. More sources of HAPs, especially small sources, will come under operating permit requirements because of the new definition of major source. Title V establishes a federal permitting program that is to be administered by the states. Under the new permitting program, there is no distinction between new and existing sources; all major sources will be required to have an operating permit.

Federal and state ambient air quality standards and the air quality control regulations of the Albuquerque/Bernalillo County (ABC) Air Quality Control Board (AQCB) are implemented at SNL/NM by the Albuquerque Environmental Health Department, Air Pollution Control Division (APCD). Ambient air quality goals and guidelines have been established by the Board for the following air contaminants: arsenic, copper, zinc, beryllium, carbon monoxide, hydrocarbons (nonmethane), hydrogen sulfide, lead, nitrogen dioxide, photochemical oxidants, soiling index, sulfur dioxide, total reduced sulfur, and total suspended particulates (TSP). Regulated air contaminants include those for which New Mexico and federal standards have been established, including those for which NAAQS have been established. Other regulated air contaminants include, but are not limited to visible air contaminants, airborne particulates, process equipment emissions, and volatile organic compounds (VOC). The Air Quality Control Board's Regulation

(AQCR) No. 31 adopts the EPA National Emission Standards for Hazardous Air Pollutants (NESHAP) contained in 40 CFR Part 61.

The Board's potentially relevant standards and regulations are as follows:

- AQCR No. 3 - Open Burning
- AQCR No. 8 - Topsoil Disturbance
- AQCR No. 11 - Volatile Organic Compounds
- AQCR No. 20 - Authority-to-Construct Permit
- AQCR No. 22 - Registration of Air Contaminant Sources
- AQCR No. 29 - Prevention of Significant Deterioration (PSD)
- AQCR No. 32 - Construction Permits in Nonattainment Areas.

National Primary and Secondary Ambient Air Quality Standards (40 CFR Part 50). Part 50 lists the national standards for sulfur dioxide, PM_{10}, carbon monoxide, ozone, nitrogen dioxide, and lead. The national primary standards define levels, with an adequate margin of safety, that are intended to protect public health. The national secondary standards are set at a level that is necessary to protect public welfare from the adverse effects of a pollutant. When the air quality of an area is dirtier than the NAAQS for a particular pollutant (i.e., concentration above the level of the standard), the area is said to be in nonattainment for that pollutant. Major facilities (see definition of major stationary source in 40 CFR 51.166[b][1][i]) planning to locate in attainment areas must comply with PSD requirements. Major sources of air pollution planning to locate in nonattainment areas must comply with emissions offset and other restrictions designed to reduce the air pollution loading so the area may achieve attainment by a specified date.

(Note that the new definition in §112 of the CAA amendments tightens the definition of major source from a stationary source that has the potential to emit 100 tons per year of any pollutant to 10 tons per year of hazardous pollutant or 25 tons per year of any combination of pollutants.)

National Emission Standards for Hazardous Air Pollutants (40 CFR Part 61). The NESHAP are established to control pollutants that may be reasonably anticipated to result in an increase in mortality or an increase in serious irreversible or incapacitating reversible illness. Due to the serious health implications that NESHAP are intended to control, the standards apply to both existing and new sources.

Title III of the CAA amendments greatly expanded the number of HAPs regulated. Only eight HAPs had been designated previously (arsenic, asbestos, beryllium, mercury, vinyl chloride, benzene, radionuclides, and radon). This number has increased to 189. In addition, the revisions to §112 represent a major shift in approach from regulation of HAPs using health-based, chemical-specific standards to regulation under technology-based standards applicable to categories of emission sources rather than to chemicals themselves. New standards for the increased number of HAPs will have to be promulgated in order to implement the CAA amendments.

Determining Conformity of General Federal Actions to State or Federal Implementation Plans (40 CFR Parts 6, 51, and 93). This rule, promulgated after the CAA amendments of 1990, requires that federal agencies determine whether their actions conform to a State Implementation Plan (SIP). The SIP must be approved by the EPA and becomes federally enforceable, although the state is given the first opportunity to enforce the SIP. Agencies must prepare a written conformity analysis and determination for proposed actions in nonattainment areas for which the total of direct and indirect emissions of criteria pollutants (i.e., ozone [VOCs, nitrous oxide], carbon monoxide, sulfur dioxide, nitrogen dioxide, PM_{10}, and lead) caused by the action will equal or exceed the threshold emission levels (in tons per year) shown in 40 CFR §51.853. The rule also requires that draft conformity determinations must be made available for public review and comment.

If it is determined that air emissions are associated with a proposed action, a determination must be made as to whether the emissions conform to the SIP. As published in various memoranda, the DOE has decided to integrate the implementation of the conformity requirements with the implementation of the NEPA process, through either the ECL/ADM or the EA/EIS.

Clean Water Act (33 U.S.C. §1251 et seq.). See discussion in Subsection A.6.

Oil Pollution Prevention (40 CFR Part 112). This regulation establishes procedures, methods, and equipment to prevent discharge of oil from nontransportation-related onshore and offshore facilities into or upon navigable waters of the United States or adjoining shorelines. It also provides for preparation and implementation of Spill Prevention Control and Countermeasures Plans.

Determination of Reportable Quantities for Hazardous Substances (40 CFR Part 117). Part 117 lists RQs for discharges of substances designated as hazardous in 40 CFR Part 116. Under the

CWA, SNL/NM must report any discharge of a hazardous substance equal to or above the RQ to EPA Region 6.

Safe Drinking Water Act (42 U.S.C. §300f et seq.). The SDWA of 1974, as amended, provides the regulatory strategy for protecting public water supply systems and underground sources of drinking water. Primary drinking water standards (40 CFR Part 141) promulgated under the SDWA apply to water "at the tap" as delivered by public water supply systems. As defined in implementing regulations in 40 CFR §141.2, these are systems that provide water for human consumption and that have at least 15 connections or regularly serve at least 25 people. The regulations also define a "non-transient, non-community water system" as one that regularly serves at least the same 25 people for six months per year (e.g., work places and hospitals). The act provides for the establishment of MCLs and monitoring for several parameters, including organic and inorganic chemicals and radioactivity.

The SDWA, in Part C, also protects underground sources of drinking water from underground injections of contaminated fluids. Underground injections, defined as "subsurface emplacement of fluids by well injection" in §1421(d) of the SDWA, is governed by the Underground Injection Control program under the Part C regulations in 40 CFR Part 144.

Toxic Substances Control Act (15 U.S.C. §2601 et seq.). The Toxic Substances Control Act (TSCA) applies primarily to manufacturers, importers, and processors of toxic chemicals for commercial purposes. SNL/NM is not considered a manufacturer or processor of chemical products; therefore, most of the provisions of TSCA do not apply. Section 6(e) of TSCA regulates the use of polychlorinated biphenyls (PCB) and PCB-containing items. DOE policy prohibits the use of PCB items or equipment in DOE-installed equipment at facilities. Therefore, TSCA would not apply to DOE-installed equipment at SNL/NM. The facility must comply with TSCA regulations contained in 40 CFR §§761.60 and 761.65 with respect to any possible disposal of any PCB-contaminated materials.

Federal Insecticide, Fungicide, and Rodenticide Act (7 U.S.C., §136 et seq.). The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), authorizes the EPA to regulate the registration, certification, use, storage, disposal, transportation, and recall of pesticides. The EPA, at its discretion, may exempt federal agencies from any FIFRA provisions if emergency conditions exist (40 CFR Part 166). Recommended procedures for storage and disposal of pesticides and pesticide containers are contained in 40 CFR Part 165. FIFRA standards are considered mandatory for DOE facilities. SNL/NM must comply with the standards of FIFRA because pesticides are used in limited amounts at the facility.

Noise Control Act of 1972 (42 U.S.C. §4901 et seq.). According to the Noise Control Act's policy clause in §2(a)(3), the primary responsibility for noise control is vested in state and local governments. Federal regulation is deemed essential only for commercial noise sources requiring national uniformity of treatment (e.g., aircraft noise). However, federal agencies are required to comply with federal, state, interstate, and local requirements respecting control and abatement of environmental noise "to the fullest extent consistent with their authority" (§§4[a], 4[b][1], and 4[b][2]).

Although SNL/NM is located outside the city limits of Albuquerque, the City does enforce a local noise ordinance within adjacent city areas defined as residential, office, or commercial in the Comprehensive Zoning Ordinance. The general noise regulation states that, "Except as otherwise provided in this ordinance, it shall be unlawful for any person to make or continue, cause to be made or continued, or allow to be made or continued, any noise in excess of 50 A-weighted decibels (dBA) or 10 dBA above the ambient noise level, whichever is higher, at any residential property line" (COA, 1975).

DOE facilities are required to comply with the Occupational Safety and Health Administration standards in 29 CFR Part 1910, which include the Occupational Noise Exposure standards in 29 CFR §1910.95. Any SNL/NM noise sources that exceed these standards must be mitigated.

Federal Compliance with Pollution Control Standards (EO 12088). EO 12088 directs the head of each federal agency to ensure that all necessary actions are taken for the prevention, control, and abatement of environmental pollution. Each agency is responsible for compliance with applicable pollution control standards established by such statutes as the CWA, the CAA, radiation guidances under the Atomic Energy Act of 1954, and others. Each agency must submit an annual plan for the control of environmental pollution at its facilities. This EO applies to the DOE and SNL/NM in controlling pollution at SNL/NM.

APPENDIX B

RECOMMENDED MITIGATION MEASURES

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Appendix B
Recommended Mitigation Measures

Mitigation measures are defined in §1508.20 of the CEQ regulations as actions that include:

- *Avoiding* the impact altogether by not taking an action or certain aspect of the action
- *Minimizing* impacts by limiting the degree or magnitude of the action and its implementation
- *Rectifying* the impact by repairing, rehabilitating, or restoring the affected environment
- *Reducing or eliminating* the impact over time by preservation and maintenance operations during the life of the action, and/or
- *Compensating for* the impact by replacing or providing substitute resources or environments.

The following mitigation measures for biological resources, cultural resources, and visual resources are presented as examples of possible mitigation measures that could be proposed in a NEPA document as means to minimize environmental harm. They should be tailored to meet the environmental issues and analysis associated with a proposed project. It must be noted that some of the measures listed below are the responsibility of SNL/NM (some at the direction of DOE), while others are the responsibility of DOE or DOE with input from SNL/NM. The reader is directed to the SNL NEPA Compliance Guide (SAND95-1648) (Hansen, 1995) and Chapter 10 of the SNL, ES&H Manual (SNL, 1996) for information with respect to roles and responsibilities.

Recommended Mitigation Measures for Biological Resources

Mitigation measures for biological resources are focused primarily on threatened, endangered, and/or sensitive species and/or critical or sensitive habitat. The status of particular species with respect to their legal protection or sensitivity to human disturbance changes with time. However, because several sensitive species and other species of concern (such as the grey vireo and the burrowing owl) have been identified on SNL/NM-KAFB lands by past biological surveys, it is important to minimize potential harm to species and habitat under Section 7 of the Endangered Species Act and equivalent New Mexico statutes.

Impacts to biotic communities could be reduced or mitigated by including the following activities in project planning:

- Identify known sensitive biological resource locations on the SNL/NM geographical information system database.
- Conduct biological resources surveys to identify biological resources in the area of a proposed action.
- Conduct biological assessments as necessary for endangered, threatened, or sensitive species.
- Conduct consultation with the USFWS and the NMDGF concerning the effects of proposed projects on endangered or threatened species.
- Demarcate the locations of sensitive biotic communities with fencing or flagging.
- Avoid disturbing areas where populations of sensitive species have been identified.
- Avoid distubances during critical periods of the life cycle of sensitive species, such as the nesting period of birds.
- Avoid disturbing sensitive or unique habitats, such as wetlands and areas occupied by vigorous populations of sensitive species.
- Transplant individual plants to suitable habitats outside the area to be disturbed if avoidance is not possible.
- Replace, create, or improve comparable new habitats outside of the area to be disturbed if avoidance is not possible.
- Encourage new development to occur in areas of SNL/NM that have already been developed.

Recommended Mitigation Measures for Cultural Resources

The regulations implementing the National Historic Preservation Act (NHPA) define undertakings as having (1) no effect, (2) no adverse effect, or (3) adverse effect on historic properties. Mitigation measures can be employed to lessen adverse effects, or to obtain a determination from the SHPO that the mitigated undertaking would have no adverse effect or even no effect. Similarly, mitigation can lessen the effects of an undertaking already determined to have no adverse effect, or could possibly lead to a determination of no effect. Generally, undertakings having no effect would require no mitigation.

The only known historic properties within the boundaries of SNL/NM Technical Areas are historic structures located in Technical Area II. Therefore, most SNL/NM actions taking place within the boundaries of a Technical Area are not likely to result in potential effects on historic properties. However, there are some historic properties known to exist on or near sites that are used by SNL/NM within KAFB or USFS property. Although the management of these historic properties is the responsibility of the USAF or the USFS, under the terms of the land use agreements, SNL/NM must be aware of these properties and take steps to avoid impacting them.

Several mitigation measures can be proposed for minimizing the impacts of a proposed action or undertaking under Sections 106 and 110 of the NHPA:

- Initiate a survey program to identify and evaluate cultural resources in the area of a proposed action or undertaking.
- Conduct consultation with the SHPO, Native American tribes, and other interested parties, as necessary, concerning the effects of projects on cultural resources.
- Avoid impacts to the property by not performing the action or relocating the action.
- Minimize the impacts to the property by creating a buffer zone between the area of the proposed action and the property.
- Demarcate the locations of sensitive cultural sites with fencing or flagging.
- Develop a data recovery plan (e.g., excavation and/or collection) for those sites that will be impacted.
- Develop a monitoring plan to be carried out by a qualified archaeologist during projects entailing subsurface disturbance.
- Evaluate historic structures that approach 50 years of age for their potential architectural and artistic quality, current integrity, and historical importance.
- Conduct Historic Architectural Buildings Survey (HABS) or Historic American Engineering Record (HAER) documentation on historic structures.

- Develop a reuse or rehabilitation plan for historic structures.

- Design new construction to be architecturally compatible with the existing historic environment.

- Develop an operations and maintenance plan for sensitive cultural areas or historic structures.

- Submit nomination forms for properties that are eligible for the National Register of Historic Places.

- Prepare covenants or a Memorandum of Agreement between the appropriate agency (DOE, USAF, USFS), the SHPO, and the Advisory Council on Historic Preservation with respect to the treatment of cultural properties.

- Prepare a cultural resources management plan for properties under the jurisdiction of DOE.

Recommended Measures for Visual Compatibility

Several measures should be considered to ensure visual compatibility with future development. They are:

- Conduct a detailed site-specific visual assessment prior to the siting and design of any new development of significant size.

- Prepare a detailed Visual Absorption Capability Study for the site.

- Improve the visual appeal of existing facilities, especially around Technical Areas I, II, and IV, which are highly visible, using the following methods:

  - Screening mechanical, electrical, and solid waste equipment

  - Landscaping parking areas and building entrances

  - Creating additional landscaped pedestrian areas between buildings

  - Screening storage areas and temporary buildings with massing of landscaping and/or screen walls

  - Defining entries to SNL/NM and enhancing their appearance

  - Utilizing landscape and architectural design guidelines for consistency and improvement in the visual appearance of SNL/NM

- Planting native or drought-tolerant plant materials in an aggressive landscaping program around all use areas

- Using consistent signage of appropriate scale and colors for all use areas.

- Encourage future development to occur in the portion of the SNL/NM that is already developed.

- Protect the edges and bottom of the Tijeras Arroyo. Establish a setback area from the edge to preserve open space and eliminate encroachment into this characteristic feature.

- Maintain views of the arroyos, canyons, mountains, and landscaped areas through detailed visual assessments in the future.

- Use "environmentally compatible paint colors" (matched to background soil and vegetation colors) for new structures and buildings. The U.S. Forest Service uses environmental paint colors from Kansas Paint and Color Company (316-264-6353).

- If Federal Aviation Administration regulations will allow it, repaint all red and white checkerboard water towers in an environmentally compatible color and mount lights on top instead. They are currently very visually intrusive.

- Locate future power lines within existing corridors rather than creating new ones. They now criss-cross the site individually.

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APPENDIX C

SPECIES LISTS FOR SANDIA NATIONAL LABORATORIES/NEW MEXICO AND KIRTLAND AIR FORCE BASE

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Appendix C
Species Lists for Sandia National Laboratories/New Mexico and Kirtland Air Force Base

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico

Scientific Name	Common Name	Habitat
Class: Filicineae	**Ferns**	
Family: Polypodiaceae		
Cheilanthes eatonii	Eaton's Lip Fern	Rocky slopes
Pellaea fendleri	Zigzag Cliffbrake	Rocky slopes
Pellaea longimucronata	Cliffbrake	Rocky slopes
Woodsia mexicana	Woodsia	Woodlands
Class: Gymnospermae	**Cone-bearing plants**	
Family: Ephedraceae		
Ephedra nevadensis	Rough Joint-fir	Grasslands/lower slopes
Ephedra viridis	Green Joint-fir	Grasslands/lower slopes
Ephedra torreyana	Mormon Tea	Grasslands/lower slopes
Family: Pinaceae		
Pinus edulis	Colorado Pinyon	Canyons/rocky slopes
Pinus ponderosa	Ponderosa Pine	Canyons/higher elevations
Family: Cupressaceae		
Juniperus scopulorum	Rocky Mountain Juniper	Canyons/higher elevations
Juniperus monosperma	One-seed Juniper	Lower slopes/rocky slopes/canyons
Class: Angiospermae	**Flowering plants**	
Subclass: Monocotyledoneae	Monocots	
Family: Typhaceae		
Typha latifolia	Cattail	Wetlands
Family: Poaceae		
Aristida divaricata	Poverty Three-awn	Disturbed ground
Aristida adscensionis	Six-weeks Three-awn	Grasslands
Aristida arizonica	Arizona Three-awn	Grasslands
Aristida glauca	Reverchon Three-awn	Rocky slopes
Aristida wrightii	Wright's Three-awn	Grasslands
Aristida fendleriana	Fendler Three-awn	Grasslands/lower slopes

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Aristida purpurea	Purple Three-awn	Grasslands/lower slopes
Aristida longiseta	Red Three-awn	Grasslands/lower slopes
Oryzopsis micrantha	Littleseed Ricegrass	Woodlands
Oryzopsis hymenoides	Indian Ricegrass	Grasslands/lower slopes
Stipa neomexicana	New Mexico Porcupinegrass	Canyons/rocky slopes
Stipa scribneri	Scribner Needlegrass	Canyons/rocky slopes
Stipa comata	Needle-and-thread	Canyons/rocky slopes
Piptochaetium fimbriata	Pinyon Ricegrass	Woodlands
Phleum pratense	Timothy	Canyons
Muhlenbergia pungens	Sandhill Muhly	Grasslands
Muhlenbergia torreyi	Ring Muhly	Grasslands
Muhlenbergia arenicola	Sand Muhly	Grasslands
Muhlenbergia porteri	Bush Muhly	Grasslands/arroyos/lower slopes
Muhlenbergia arenacea	Ear Muhly	Grasslands
Muhlenbergia asperifolia	Scratchgrass	Arroyos
Muhlenbergia sinuosa	Marsh Muhly	Canyons
Muhlenbergia richardsonis	Mat Muhly	Arroyos
Muhlenbergia wrightii	Spike Muhly	Rocky slopes
Muhlenbergia montana	Mountain Muhly	Rocky slopes
Muhlenbergia monticola	Mesa Muhly	Rocky slopes
Muhlenbergia pauciflora	New Mexican Muhly	Rocky slopes
Blepharoneuron tricholepis	Pine Dropseed	Woodlands
Sporobolus flexuosus	Mesa Dropseed	Grasslands
Sporobolus cryptandrus	Sand Dropseed	Grasslands
Sporobolus airoides	Alkali Sacaton	Arroyos
Sporobolus contractus	Spike Dropseed	Grasslands/arroyos
Lycurus phleoides	Wolftail	Rocky slopes
Polypogon monspeliensis	Rabbitfoot Grass	Wetlands
Koeleria cristata	Junegrass	Woodlands/canyons
Scleropogon brevifolius	Burro Grass	Grasslands
Enneapogon desvauxii	Spike Pappusgrass	Grasslands/arroyos/lower slopes
Tridens pulchellus	Fluffgrass	Grasslands/disturbed ground
Tridens pilosus	Hairy Tridens	Grasslands
Munroa squarrosa	False Buffalo Grass	Grasslands

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Eragrostis cilianensis	Stinkgrass	Disturbed ground
Eragrostis mexicana	Mexican Lovegrass	Disturbed ground
Eragrostis pilosa	India Lovegrass	Disturbed ground/rocky slopes
Distichlis stricta	Desert Saltgrass	Arroyos
Poa pratensis	Kentucky Bluegrass	Canyons/arroyos
Bromus polyanthus	Foothills Brome	Canyons/rocky slopes
Bromus japonicus	Japanese Chess	Disturbed ground
Bromus tectorum	Downy Chess	Disturbed ground
Bromus anomalus	Nodding Brome	Canyons
Festuca octoflora	Six-weeks Fescue	Grasslands/arroyos
Festuca arizonica	Arizona Fescue	Canyons/rocky slopes
Cynodon dactylon	Bermuda Grass	Arroyos/canyons/disturbed ground
Chloris virgata	Feathery Fingergrass	Disturbed ground
Chloris verticillata	Windmill Grass	Disturbed ground
Schedonnardus paniculatus	Tumble Grass	Grasslands
Bouteloua aristidoides	Needle Grama	Grasslands/disturbed ground
Bouteloua barbata	Six-weeks Grama	Grasslands/disturbed ground
Bouteloua hirsuta	Hairy Grama	Grasslands
Bouteloua curtipendula	Side-oats Grama	Canyons/rocky slopes
Bouteloua gracilis	Blue Grama	Grasslands/lower slopes
Bouteloua eriopoda	Black Grama	Grasslands
Hilaria jamesii	Galleta	Grasslands/arroyos/lower slopes
Agropyron smithii	Western Wheatgrass	Arroyos
Agropyron pseudorepens	False Quackgrass	Arroyos/canyons
Agropyron trachycaulum	Slender Wheatgrass	Arroyos
Hordeum jubatum	Foxtail Barley	Disturbed ground
Sitanion hystrix	Squirreltail	Grasslands/arroyos/lower slopes
Elymus canadensis	Canada Wild Rye	Arroyos/canyons
Andropogon scoparius	Little Bluestem	Rocky slopes
Andropogon barbinodis	Cane Beardgrass	Grasslands/arroyos/lower slopes
Sorghum halepense	Johnson Grass	Arroyos/canyons
Cenchrus echinatus	Sandbur	Disturbed ground
Setaria verticillata	Bur Bristlegrass	Disturbed ground
Setaria viridis	Green Bristlegrass	Arroyos/disturbed ground

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Setaria macrostachya	Plains Bristlegrass	Arroyos/canyons/rocky slopes
Panicum capillare	Witchgrass	Arroyos/canyons
Panicum obtusum	Vine Mesquite	Arroyos
Echinochloa crusgalli	Barnyard Grass	Wetlands/Disturbed ground
Digitaria sanguinalis	Crabgrass	Arroyos/canyons/disturbed ground
Family: Cyperaceae		
Cyperus fendlerianus	Fendler Flatsedge	Wetlands
Cyperus esculentus	Yellow Nutgrass	Wetlands
Eleocharis montana	Mountain Spikerush	Wetlands
Scirpus americanus	Three-square	Wetlands
Family: Juncaceae		
Juncus balticus	Wire Rush	Wetlands
Juncus saximontanus	Rocky Mountain Rush	Wetlands
Juncus torreyi	Torrey Rush	Wetlands
Family: Liliaceae		
Yucca baccata	Banana Yucca	Rocky slopes
Yucca glauca	Soapweed Yucca	Grasslands
Nolina microcarpa	Bear Grass	Canyons/rocky slopes
Asparagus officinalis	Asparagus	Arroyos/disturbed ground
Allium macropetalum	Onion	Canyons
Allium cernuum	Nodding Onion	Canyons/higher elevations
Subclass: Dicotyledoneae	Dicots	
Family: Saururaceae		
Anemopsis californica	Yerba Mansa	Wetlands
Family: Salicaceae		
Salix exigua	Coyote Willow	Arroyos/wetlands
Populus fremontii	Fremont Cottonwood	Arroyos/wetlands
Family: Fagaceae		
Quercus gambelii	Gambel Oak	Canyons/higher elevations
Quercus turbinella	Shrub Live Oak	Rocky slopes
Quercus grisea	Gray Oak	Rocky slopes
Family: Ulmaceae		
Celtis reticulata	Netleaf Hackberry	Arroyos
Ulmus pumila	Siberian Elm	Arroyos/disturbed ground

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Family: Loranthaceae		
Phoradendron juniperinum	Juniper Mistletoe	Woodlands (on junipers)
Arceuthobium divaricatum	Dwarf Mistletoe	Woodlands (on pinyons)
Family: Polygonaceae		
Eriogonum abertianum	Wild Buckwheat	Grasslands/woodlands
Eriogonum annuum	Annual Wild Buckwheat	Grasslands/lower slopes
Eriogonum polycladon	Sorrel Wild Buckwheat	Arroyos/disturbed ground
Eriogonum jamesii	Antelope-sage	Grasslands/woodlands
Eriogonum wrightii	Wright's Wild Buckwheat	Grasslands/woodlands
Rumex hymenosepalus	Canaigre	Arroyos/disturbed ground
Rumex mexicanus	Dock	Arroyos/disturbed ground
Polygonum convolvulus	Black Bindweed	Arroyos/disturbed ground
Polygonum aviculare	Knotweed	Disturbed ground/wetlands
Family: Chenopodiaceae		
Salsola kali	Russian Thistle	Disturbed ground
Eurotia lanata	Winterfat	Grasslands/arroyos
Atriplex canescens	Four-wing Saltbush	Grasslands/arroyos
Chenopodium botrys	Jerusalem Oak	Disturbed ground
Chenopodium album	Lamb's Quarters	Disturbed ground
Chenopodium incanum	Gray Goosefoot	Grasslands/lower slopes
Chenopodium fremontii	Fremont Goosefoot	Lower slopes
Kochia scoparia	Summer Cypress	Disturbed ground
Family: Amaranthaceae		
Amaranthus graecizans	Prostrate Pigweed	Disturbed ground
Amaranthus hybridus	Pigweed	Disturbed ground
Amaranthus powellii	Pigweed	Disturbed ground
Amaranthus retroflexus	Green Amaranth	Disturbed ground
Acanthochiton wrightii		Grasslands/lower slopes
Tidestromia lanuginosa		Grasslands/arroyos
Family: Nyctaginaceae		
Allionia incarnata	Umbrellawort	Grasslands/disturbed ground
Oxybaphus linearis		Woodlands/arroyos
Mirabilis multiflora	Four O'Clock	Woodlands
Mirabilis oxybaphoides	Four O'Clock	Woodlands/arroyos

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Abronia fragrans	Sand Verbena	Grasslands/arroyos
Family: Aizoaceae		
Mollugo verticillata	Carpetweed	Disturbed ground
Family: Portulaceae		
Portulaca oleracea	Common Purslane	Disturbed ground
Family: Caryophyllaceae		
Stellaria longifolia	Chickweed	Canyons/higher elevations
Family: Berberidaceae		
Berberis repens	Creeping Mahonia	Canyons/rocky slopes
Berberis haematocarpa	Red Barberry	Canyons/rocky slopes
Family: Fumariaceae		
Corydalis aurea	Golden Corydalis	Canyons/rocky slopes
Family: Brassicaceae		
Draba cuneifolia	Whitlow Grass	Arroyos/rocky slopes
Erysimum capitatum	Western Wallflower	Grasslands/arroyos/rocky slopes
Descurainia sophia	Tansy Mustard	Disturbed ground
Descuriania obtusa	Tansy Mustard	Canyons
Sisymbrium altissimum	Tumble Mustard	Disturbed ground
Sisymbrium irio	London Rocket	Disturbed ground
Rorippa nasturtium-aquaticum	Water Cress	Wetlands
Dithyrea wislizenii	Spectacle Pod	Grasslands/arroyos/disturbed ground
Lepidium montanum	Peppergrass	Arroyos/canyons/rocky slopes
Lepidium medium	Peppergrass	Grasslands/arroyos/disturbed ground
Capsella bursi-pastoris	Shepherd's Purse	Grasslands/arroyos/disturbed ground
Thlaspi alpestre	Wild Candytuft	Canyons/higher elevations
Lesquerella fendleri	Bladderpod	Arroyos/rocky slopes
Family: Capparidaceae		
Cleome serrulata	Rocky Mountain Bee-plant	Arroyos/rocky slopes
Polanisia trachysperma	Clammyweed	Arroyos
Family: Saxifragaceae		
Fendlera rupicola	Cliff Fendlerbush	Canyons/rocky slopes
Philadelphus microphyllus	Mock-orange	Canyons

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Ribes cereum	Wax Currant	Canyons/higher elevations
Family: Rosaceae		
Prunus virginiana	Western Black Chokecherry	Canyons
Rosa Woodsii	Woods' Rose	Canyons
Fallugia paradoxa	Apache Plume	Arroyos
Cercocarpus montanus	Alder-leaf Mountain Mahogany	Canyons/rocky slopes
Family: Fabaceae		
Calliandra humilis	False Mesquite	Lower slopes
Hoffmanseggia jamesii	Rush Pea	Grasslands
Psoralea lanceolata	Lemon Scurfpea	Grasslands/arroyos/woodlands
Psoralea tenuiflora	Slender Scurfpea	Grasslands/arroyos/lower slopes
Dalea formosa	Feather Indigobush	Grasslands/arroyos
Dalea leporina	Pea Bush	Grasslands/arroyos
Dalea scoparia	Broom Indigobush	Grasslands/arroyos
Dalea nana	Dwarf Indigobush	Grasslands/arroyos
Medicago sativa	Alfalfa	Disturbed ground
Medicago lupulina	Black Medic	Disturbed ground
Melilotus albus	White Sweet Clover	Disturbed ground
Melilotus officinalis	Yellow Sweet Clover	Disturbed ground
Lotus wrightii	Deer Vetch	Woodlands
Astragalus missouriensis	Missouri Milkvetch	Grasslands/arroyos/rocky slopes
Astragalus amphioxys	Crescent Milkvetch	Grasslands/arroyos/rocky slopes
Astragalus humistratus	Ground Milkvetch	Grasslands/arroyos/rocky slopes
Astragalus nuttallianus	Nuttall Milkvetch	Arroyos/rocky slopes
Astragalus flexuous	Locoweed	Grasslands/arroyos
Astragalus crassicarpus	Ground Plum	Grasslands/arroyos
Astragalus emoryanus	Emory Milkvetch	Grasslands/arroyos/rocky slopes
Astragalus mollissimus	Woolly Locoweed	Grasslands/arroyos/rocky slopes
Astragalus lentiginosus	Blue Locoweed	Arroyos/rocky slopes
Astragalus feensis	Santa Fe Milkvetch	Grasslands/rocky slopes
Astragalus allochrous	Hassayampa Milkvetch	Grasslands/arroyos/rocky slopes
Petalostemum candidum	White Prairie Clover	Grasslands/arroyos/lower slopes
Robinia neomexicana	New Mexico Locust	Canyons
Oxytropis lambertii	Lambert Locoweed	Grasslands/arroyos/rocky slopes

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Family: Geraniaceae		
Geranium caespitosum	Purple Geranium	Canyons/rocky slopes
Erodium cicutarium	Red-stem Filaree	Grasslands/arroyos/disturbed ground
Family: Oxalidaceae		
Oxalis stricta	Yellow Woodsorrel	Canyons
Family: Linaceae		
Linum lewisii	Western Blue Flax	Grasslands/arroyos
Linum aristatum	Flax	Grasslands/arroyos
Family: Zygophyllaceae		
Larrea tridentata	Creosote Bush	Dry slopes at low elevation
Tribulus terrestris	Goathead	Disturbed ground
Kallstroemia californica	California Caltrop	Grasslands/arroyos/lower slopes
Kallstroemia hirsutissima	Hairy Caltrop	Grasslands/arroyos
Kallstroemia parviflora	Caltrop	Grasslands/arroyos/lower slopes
Family: Rutaceae		
Ptelea trifoliata	Narrow-leaf Hoptree	Canyons
Family: Simaroubaceae		
Ailanthus altissima	Tree-of-Heaven	Arroyos/canyons
Family: Polygalaceae		
Polygala alba	White Milkwort	Arroyos
Family: Euphorbiaceae		
Euphorbia stictospora	Spurge	Grasslands/arroyos/lower slopes
Euphorbia serpyllifolia	Thymeleaf Spurge	Grasslands/arroyos/lower slopes
Euphorbia fendleri	Fendler Spurge	Grasslands/arroyos/lower slopes
Euphorbia revoluta	Spurge	Grasslands/arroyos
Euphorbia exstipulata	Spurge	Grasslands/arroyos
Euphorbia dentata	Spurge	Grasslands/arroyos
Euphorbia lurida	Spurge	Canyons
Croton texensis	Doveweed	Grasslands/disturbed ground
Tragia stylaris	Noseburn	Canyons
Family: Anacardiaceae		
Rhus trilobata	Skunkbush	Canyons/rocky slopes
Family: Vitaceae		
Vitis arizonica	Canyon Grape	Canyons

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Parthenocissus inserta	Virginia Creeper	Canyons
Family: Malvaceae		
Malva neglecta	Common Mallow	Disturbed ground
Sphaeralcea grossulariaefolia	Globemallow	Grasslands/arroyos/lower slopes
Sphaeralcea leptophylla	Silvery Globemallow	Rocky slopes
Sphaeralcea coccinea	Red Globemallow	Grasslands/arroyos/lower slopes
Sphaeralcea subhastata	Globemallow	Grasslands/arroyos/lower slopes
Sphaeralcea incana	Globemallow	Grasslands/arroyos/lower slopes
Sphaeralcea fendleri	Fendler Globemallow	Grasslands/arroyos/lower slopes
Sphaeralcea angustifolia	Globemallow	Grasslands/arroyos/lower slopes
Family: Tamaricaceae		
Tamarix pentandra	Salt-cedar	Arroyos
Family: Loasaceae		
Mentzelia pumila	Stickleaf	Arroyos/disturbed ground
Family: Cactaceae		
Opuntia imbricata	Tree Cholla	Grasslands/arroyos/lower slopes
Opuntia whipplei	Whipple's Cholla	Dry slopes at low elevation
Opuntia clavata	Club Cholla	Grasslands
Opuntia polyacantha	Plains Prickly Pear	Grasslands/woodlands
Opuntia erinacea	Prickly Pear	Woodlands
Opuntia macrorhiza	Plains Prickly Pear	Grasslands/woodlands
Opuntia phaeacantha	Prickly Pear	Grasslands/woodlands
Echinocereus triglochidiatus	Red-flowered Hedgehog	Woodlands/canyons
Echinocereus fendleri	Hedgehog Cactus	Grasslands/woodlands
Pediocactus simpsonii	Simpson's Pediocactus	Grasslands/arroyos/lower slopes
Pediocactus papyracanthus	Grama Grass Cactus	Grasslands/arroyos/lower slopes
Neolloydia intertexta	Pineapple Cactus	Lower slopes
Coryphantha vivipara	Pincushion Cactus	Grasslands/woodlands
Mammillaria heyderi	Pincushion Cactus	Lower slopes
Mammillaria wrightii	Wright's Pincushion Cactus	Arroyos/lower slopes
Family: Elaeagnaceae		
Elaeagnus angustifolia	Russian Olive	Arroyos/canyons
Family: Onagraceae		
Calylophus hartwegii	Hartweg's Primrose	Grasslands/arroyos

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Gaura coccinea	Scarlet Gaura	Grasslands/lower slopes
Oenothera coronopifolia	Evening Primrose	Rocky slopes
Oenothera albicaulis	Evening Primrose	Arroyos/disturbed ground
Oenothera pallida	Pale Evening Primrose	Grasslands/arroyos
Family: Apiaceae		
Cymopterus fendleri	Chimaya	Arroyos/canyons/lower slopes
Aletes acaulis		Canyons/rocky slopes
Family: Primulaceae		
Androsace septentrionalis	Rock Jasmine	Canyons/rocky slopes
Family: Oleaceae		
Menodora scabra	Rough Menodora	Arroyos/lower slopes
Forestiera neomexicana	New Mexico Olive	Canyons
Family: Asclepiadaceae		
Asclepias asperula	Antelope Horns	Grasslands/arroyos/lower slopes
Asclepias viridiflora	Green Milkweed	Rocky slopes
Asclepias subverticillatus	Poison Milkweed	Grasslands/arroyos/disturbed ground
Asclepias latifolia	Broad-leaved Milkweed	Grasslands/arroyos
Family: Convolvulaceae		
Cuscuta megalocarpa	Dodder	Grasslands/woodlands
Evolvulus pilosa		Grasslands/woodlands
Ipomoea hirsutula	Morning Glory	Disturbed ground
Ipomoea costellata	Morning Glory	Arroyos/lower slopes
Convolvulus sepium	Hedge Bindweed	Disturbed ground
Convolvulus arvensis	Field Bindweed	Disturbed ground
Family: Polemoniaceae		
Ipomopsis longiflora		Grasslands/arroyos
Ipomopsis aggregata	Skyrocket	Canyons/rocky slopes
Gilia rigidula	Gilia	Grasslands/rocky slopes
Family: Hydrophyllaceae		
Nama hispidum		Arroyos/canyons
Phacelia corrugata	Scorpionweed	Grasslands/arroyos
Phacelia crenulata	Scorpionweed	Grasslands/rocky slopes
Family: Boraginaceae		
Lappula redowskii	Stickweed	Disturbed ground

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Lithospermum incisum	Puccoon	Grasslands/rocky slopes
Cryptantha crassisepala	Plains Hiddenflower	Grasslands/arroyos/rocky slopes
Cryptantha jamesii		Grasslands/arroyos
Family: Verbenaceae		
Verbena bipinnatifida	Dakota Vervain	Arroyos/rocky slopes
Verbena ambrosifolia	Vervain	Arroyos/lower slopes
Verbena wrightii	Vervain	Arroyos/lower slopes
Verbena macdougalii	New Mexico Vervain	Canyons/higher elevations
Verbena bracteata	Vervain	Grasslands/arroyos/disturbed ground
Family: Lamiaceae		
Hedeoma drummondii	False Pennyroyal	Grasslands/rocky slopes
Salvia reflexa	Rocky Mountain Sage	Canyons/woodlands
Marrubium vulgare	Common Horehound	Canyons
Family: Solanaceae		
Datura meteloides	Indian-apple	Arroyos/disturbed ground
Datura stramonium	Jimsonweed	Arroyos/disturbed ground
Physalis virginiana	Groundcherry	Arroyos/disturbed ground
Physalis hederaefolia		Canyons/arroyos/disturbed ground
Solanum elaeagnifolium	Horse Nettle	Disturbed ground
Chamaesaracha conioides		Grasslands/arroyos
Chamaesaracha coronopus		Grasslands/arroyos
Family: Scrophulariaceae		
Maurandya antirrhiniflora	False Snapdragon	Grasslands/arroyos/rocky slopes
Penstemon barbatus	Scarlet Beardtongue	Canyons/rocky slopes
Penstemon ambiguus	Cow Tobacco	Grasslands/arroyos
Penstemon jamesii	Beardtongue	Grasslands/lower slopes
Mimulus glabrata	Monkeyflower	Canyon (springs)
Cordylanthus wrightii	Clubflower	Rocky slopes
Castilleja integra	Indian Paintbrush	Rocky slopes
Family: Martyniaceae		
Proboscidea parviflora	Devil's Claw	Grasslands/arroyos
Family: Plantaginaceae		
Plantago purshii	Woolly Indian-wheat	Grasslands/rocky slopes
Plantago major	Rippleseed Plantain	Disturbed ground

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Plantago lanceolata	Buckhorn Plantain	Disturbed ground
Family: Cucurbitaceae		
Cucurbita foetidissima	Buffalo Gourd	Grasslands/disturbed ground
Family: Asteraceae		
Stephanomeria pauciflora	Wire Lettuce	Grasslands/woodlands
Tragopogon dubious	Goat's Beard	Arroyos/disturbed ground
Lactuca serriola	Prickly Lettuce	Disturbed ground
Taraxacum officinale	Dandelion	Disturbed ground
Sonchus asper	Sow Thistle	Disturbed ground
Malacothrix fendleri	Desert Dandelion	Grasslands/arroyos/rocky slopes
Perezia nana	Dwarf Desert-holly	Arroyos
Cirsium neomexicanum	New Mexican Thistle	Grasslands/arroyos/disturbed ground
Cirsium ochrocentrum	Santa Fe Thistle	Grasslands/arroyos/lower slopes
Arctium minus	Burdock	Disturbed ground
Xanthium strumarium	Cocklebur	Disturbed ground/wetlands
Ambrosia artemisiifolia	Common Ragweed	Disturbed ground
Ambrosia psilostachya	Western Ragweed	Arroyos/canyons
Franseria acanthicarpa	Burweed	Grasslands/arroyos/disturbed ground
Eupatorium herbaceum	Thoroughwort	Canyons/rocky slopes
Kuhnia chlorolepis	False Boneset	Grasslands/rocky slopes
Brickellia brachyphylla	Bricklebush	Arroyos/canyons/rocky slopes
Brickellia californica	California Bricklebush	Canyons/rocky slopes
Brickellia grandiflora	Bricklebush	Canyons/rocky slopes
Grindelia aphanactis	Gumweed	Disturbed ground
Gutierrezia sarothrae	Snakeweed	Grasslands/disturbed ground
Gutierrezia microcephala	Little-head Snakeweed	Grasslands/disturbed ground
Chrysopsis villosa	Hairy Golden Aster	Grasslands/arroyos/lower slopes
Solidago canadensis	Canada Goldenrod	Arroyos/canyons
Solidago occidentalis	Western Goldenrod	Arroyos/canyons
Solidago spathulata	Dwarf Goldenrod	Canyons
Haplopappus spinulosus	Spiny Goldenweed	Disturbed ground
Haplopappus gracilis	Goldenweed	Grasslands/arroyos
Haplopappus heterophyllus	Rayless Goldenrod	Grasslands

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Townsendia exscapa	Townsend's Aster	Grasslands/lower slopes
Townsendia formosa	Townsend's Aster	Woodlands/canyons
Conyza canadensis	Horseweed	Arroyos/canyons/disturbed ground
Erigeron flagellaris	Trailing Fleabane	Grasslands/disturbed ground
Erigeron divergens	Spreading Fleabane	Disturbed ground/lower slopes
Leucelene ericoides	White Aster	Grasslands/arroyos/lower slopes
Aster commutatus	Aster	Arroyos/disturbed ground
Aster hesperius	Purple Aster	Canyons/wetlands
Baccharis wrightii	Wright's Baccharis	Arroyos/canyons
Chrysothamnus nauseosus	Rabbitbrush	Grasslands/arroyos/lower slopes
Senecio douglasii	Threadleaf Groundsel	Grasslands/arroyos
Senecio multicapitatus	Shrub Groundsel	Grasslands/woodlands/canyons
Artemisia bigelovii	Bigelow Sagebrush	Woodlands
Artemisia filifolia	Sand Sagebrush	Grasslands/arroyos
Artemisia dracunculus	False Tarragon	Arroyos/canyons
Artemisia frigida	Estafiata	Arroyos/lower slopes
Artemisia ludoviciana	Louisiana Wormwood	Woodlands
Dyssodia acerosa	Dogweed	Rocky slopes
Baileya multiradiata	Desert-marigold	Grasslands/lower slopes
Psilostrophe tagetina	Paper Daisy	Grasslands/arroyos
Hymenoxys argentea	Bitterweed	Rocky slopes
Hymenoxys richardsonii	Colorado Rubberweed	Rocky slopes
Flaveria campestris		Grasslands/arroyos
Hymenopappus filifolius	White Ragweed	Grasslands/arroyos/rocky slopes
Gaillardia pinnatifida	Blanketflower	Grasslands/arroyos
Bahia dissecta	Yellow Ragweed	Grasslands/arroyos/rocky slopes
Melampodium leucacanthum	Plains Blackfoot	Grasslands/lower slopes
Parthenium incanum	Mariola	Rocky slopes/arroyos
Engelmannia pinnatifida	Engelmann Daisy	Grasslands/lower slopes
Berlandiera lyrata		Grasslands/rocky slopes
Zinnia grandiflora	Rocky Mountain Zinnia	Grasslands/lower slopes
Sanvitalia abertii		Grasslands/arroyos
Thelesperma megapotamicum	Hopi Tea	Grasslands/arroyos/disturbed ground
Ratibida tagetes	Prairie Coneflower	Arroyos/disturbed ground

C.1 List of Plant Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Verbesina enceliodes	Crownbeard	Grasslands/lower slopes
Helianthus annuus	Annual Sunflower	Grasslands/arroyos/disturbed ground
Helianthus petoilaris	Prairie Sunflower	Grasslands/arroyos/disturbed ground
Viguiera dentata	Goldeneye	Woodlands/canyons

Based on:

N.T. Fischer, 1990, "Revision of Species Inventory Checklists for Sandia National Laboratories, Albuquerque, Bernalillo County, New Mexico," *SAND90-7098*, Sandia National Laboratories, Albuquerque, New Mexico.

R.M. Sullivan and P.J. Knight, 1994, "Biological Surveys for the Sandia National Laboratories Coyote Canyon Test Complex, Kirtland Air Force Base, Albuquerque, New Mexico," *SAND93-7089,* Sandia National Laboratories, Albuquerque, New Mexico.

C.2 List of Animal Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico

Scientific Name	Common Name	Habitat
Class: Amphibia	**Amphibians**	
Order: Salientia	Frogs and toads	
Family: Pelobatidae		
Scaphiopus couchii	Couch's spadefoot	Grasslands/arroyos
Spea multiplicata	New Mexico spadefoot	Grasslands/arroyos
Spea bombifrons	Plains spadefoot	Grasslands/arroyos
Family: Bufonidae		
Bufo punctatus	Red-spotted toad	Grasslands/arroyos/canyons
Bufo woodhousei	Woodhouse's toad	Grasslands/arroyos/canyons
Bufo cognatus	Great Plains toad	Grasslands/arroyos
Order: Caudata	Salamanders	
Family: Ambystomatidae		
Ambystoma tigrinum	Tiger salamander	Arroyos/canyons/wetlands
Class: Reptilia	**Reptiles**	
Order: Testudines	Turtles	
Family: Emydidae		
Terrapene ornata	Western box turtle	Grasslands
Order: Squamata		
Suborder: Lacertilia	Lizards	
Family: Scincidae		
Eumeces multivirgatus	Many-lined skink	Grasslands
Eumeces obsoletus	Great Plains skink	Grasslands/arroyos/rocky slopes
Family: Teiidae		
Cnemidophorus inornatus	Little striped whiptail	Grasslands/arroyos/lower slopes
Cnemidophorus velox	Plateau striped whiptail	Canyons/lower slopes
Cnemidophorus uniparens	Desert grassland whiptail	Grasslands/arroyos
Cnemidophorus exsanguis	Chihuahuan spotted whiptail	Grasslands/arroyos/lower slopes
Cnemidophorus neomexicanus	New Mexico whiptail	Grasslands/arroyos
Cnemidophorus tessalatus	Colorado checkered whiptail	Canyons/lower slopes
Family: Iguanidae		
Crotaphytus collaris	Collared lizard	Arroyos/rocky slopes/canyons
Gambelia wislizenii	Longnose leopard lizard	Grasslands/lower slopes
Uta stansburiana	Side-blotched lizard	Grasslands/arroyos/lower slopes
Urosaurus ornatus	Tree lizard	Canyons/woodlands

C.2 List of Animals Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Sceloporus undulatus	Eastern fence lizard	Arroyos/canyons/woodlands
Phrynosoma cornutum	Texas horned lizard	Grasslands/arroyos/lower slopes
Phrynosoma douglassi	Short horned lizard	All habitats
Phrynosoma modestum	Roundtail horned lizard	Grasslands/arroyos
Holbrookia maculata	Lesser earless lizard	Grasslands/arroyos
Suborder: Serpentes	Snakes	
Family: Leptotyphopidae		
Leptotyphlops dulcis	Texas blind snake	Grasslands
Family: Colubridae		
Thamnophis elegans	Western terrestrial garter snake	Canyons/wetlands
Thamnophis cyrtopsis	Blackneck garter snake	Canyons
Diadophis punctatus	Ringneck snake	Canyons/rocky slopes
Gyalopion canum	Western hooknose snake	Grasslands/arroyos/lower slopes
Rhinocheilus lecontei	Longnose snake	Grasslands/arroyos
Heterodon nasicus	Western hognose snake	Grasslands/arroyos
Tantilla nigriceps	Plains blackhead snake	Lower slopes
Hypsiglena torquata	Night snake	Lower slopes
Arizona elegans	Glossy snake	Grasslands/arroyos
Elaphe guttata	Plains rat snake	Canyons
Pituophis melanoleucus	Gopher snake	All habitats
Masticophis flagellum	Coachwhip	Grasslands/arroyos/lower slopes
Masticophis taeniatus	Desert striped whipsnake	Canyons/lower slopes
Salvadora grahamiae	Mountain patchnose snake	Woodlands
Family: Viperidae		
Sistrurus catenatus	Massasauga	Arroyos/lower slopes
Crotalus atrox	Western diamondback rattlesnake	Grasslands/arroyos/lower slopes
Crotalus molossus	Blacktail rattlesnake	Canyons/rocky slopes
Crotalus viridis	Western rattlesnake	All habitats
Class: Aves	**Birds**	
Order: Falconiformes	Birds-of-prey	
Family: Cathartidae		
Cathartes aura	Turkey vulture	All habitats
Family: Accipitridae		
Aquila chrysaetos	Golden eagle	Grasslands

C.2 List of Animals Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Circus cyaneus	Northern harrier	Grasslands/woodlands
Accipiter striatus	Sharp-shinned hawk	Canyons/woodlands
Accipiter cooperii	Cooper's hawk	Canyons
Accipiter gentilis	Northern goshawk	Canyons/higher elevations
Buteo jamaicensis	Red-tailed hawk	Grasslands/woodlands
Buteo swainsoni	Swainson's hawk	Grasslands/lower slopes
Buteo regalis	Ferruginous hawk	Grasslands/woodlands
Family: Falconidae		
Falco sparverius	American kestrel	All habitats
Falco mexicanus	Prairie falcon	Grasslands/woodlands
Order: Galliformes	Quail	
Family: Phasianidae		
Callipepla squamata	Scaled quail	Grasslands/arroyos
Callipepla gambelii	Gambel's quail	Grasslands/arroyos
Order: Charadriiformes	Shorebirds	
Family: Charadriidae		
Charadrius vociferus	Killdeer	Grasslands/arroyos/disturbed ground
Charadrius montanus	Mountain plover	Grasslands/arroyos/disturbed ground
Family: Scolopacidae		
Actitis macularia	Spotted sandpiper	Wetlands/arroyos
Order: Columbiformes	Doves and pigeons	
Family: Columbidae		
Columba fasciata	Band-tailed pigeon	Canyons/higher elevations
Zenaida macroura	Mourning dove	All habitats
Order: Cuculiformes	Cuckoos	
Family: Cuculidae		
Coccyzus americanus	Yellow-billed cuckoo	Canyons
Geococcyx californianus	Greater roadrunner	Grasslands/arroyos/lower slopes
Order: Strigiformes	Owls	
Family: Tytonidae		
Tyto alba	Barn owl	All habitats
Family: Strigidae		
Asio otus	Long-eared owl	Canyons/woodlands

C.2 List of Animals Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Bubo virginianus	Great horned owl	All habitats
Otus kennicottii	Western screech-owl	Canyons/woodlands
Otus flammeolus	Flammulated owl	Canyons
Glaucidium gnoma	Northern pygmy-owl	Canyons/higher elevations
Aegolius acadicus	Northern saw-whet owl	Canyons/higher elevations
Speotyto cunicularia	Burrowing owl	Grasslands/arroyos
Order: Caprimulgiformes	Goatsuckers	
Family: Caprimulgidae		
Caprimulgus vociferus	Whip-poor-will	Canyons/woodlands
Phalaenoptilus nuttallii	Common poorwill	Grasslands/rocky slopes
Chordeiles minor	Common nighthawk	Grasslands/rocky slopes
Order: Apodiformes	Hummingbirds and swifts	
Family: Apodidae		
Aeronautes saxatalis	White-throated swift	Canyons
Family: Trochilidae		
Archilochus alexandris	Black-chinned hummingbird	Canyons/woodlands
Selasphorus platycercus	Broad-tailed hummingbird	Canyons/higher elevations
Order: Piciformes	Woodpeckers	
Family: Picidae		
Colaptes auratus	Northern flicker	Woodlands
Melanerpes erythrocephalus	Red-headed woodpecker	Canyons/higher elevations
Melanerpes formicivorus	Acorn woodpecker	Canyons/higher elevations
Melanerpes lewis	Lewis' woodpecker	Canyons/woodlands
Sphyrapicus thyroideus	Williamson's sapsucker	Canyons
Sphyrapicus nuchalis	Red-naped sapsucker	Canyons/woodlands
Picoides pubescens	Downy woodpecker	Canyons/higher elevations
Picoides villosus	Hairy woodpecker	Canyons/higher elevations
Picoides scalaris	Ladder-backed woodpecker	Woodlands
Order: Passeriformes	Perching birds	
Family: Tyrannidae Flycatchers		
Tyrannus tyrannus	Eastern kingbird	Canyons/woodlands
Tyrannus verticalis	Western kingbird	Grasslands/arroyos/buildings
Tyrannus vociferans	Cassin's kingbird	Canyons/woodlands
Myiarchus cinerascens	Ash-throated flycatcher	Woodlands

C.2 List of Animals Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Contopus sordidulus	Western wood-pewee	Canyons/woodlands
Sayornis nigricans	Black phoebe	Canyons/wetlands
Sayornis saya	Say's phoebe	Canyons/wetlands
Empidonax difficilis	Western flycatcher	Canyons/woodlands
Family: Alaudidae Larks		
Eremophila alpestris	Horned lark	Grasslands
Family: Hirundinidae Swallows		
Tachycineta bicolor	Tree swallow	Canyons/woodlands/wetlands
Tachycineta thalassina	Violet-green swallow	Canyons/woodlands/wetlands
Riparia riparia	Bank swallow	Canyons/woodlands/wetlands
Stelgidopteryx serripennis	Northern rough-winged swallow	Canyons/woodlands/wetlands
Hirundo pyrrhonota	Cliff swallow	Canyons/woodlands/wetlands
Hirundo rustica	Barn swallow	Buildings
Family: Corvidae Crows, ravens, and jays		
Aphelocoma coerulescens	Scrub jay	Woodlands/canyons
Gymnorhinus cyanocephalus	Pinyon jay	Woodlands
Cyanocitta stelleri	Steller's jay	Higher elevations
Corvus brachyrhynchos	American crow	Buildings
Corvus cryptoleucus	Chihuahuan raven	Grasslands/woodlands
Corvus corax	Common raven	Canyons/higher elevations
Family: Paridae Titmice and chickadees		
Parus inornatus	Plain titmouse	Canyons/woodlands
Parus gambeli	Mountain chickadee	Canyons/woodlands
Family: Aegithalidae Bushtits		
Psaltriparus minimus	Bushtit	Canyons/woodlands
Family: Sittidae Nuthatches		
Sitta carolinensis	White-breasted nuthatch	Canyons/higher elevations
Sitta pygmaea	Pygmy nuthatch	Canyons
Family: Certhiidae Creepers		
Certhia americana	Brown creeper	Canyons/higher elevations
Family: Troglodytidae Wrens		
Troglodytes aedon	House wren	Canyons/woodlands
Thryomanes bewickii	Bewick's wren	Canyons/arroyos/woodlands
Catherpes mexicanus	Canyon wren	Canyons

C.2 List of Animals Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Salpinctes obsoletus	Rock wren	Canyons/rocky slopes
Family: Muscicapidae Thrushes		
Regulus calendula	Ruby-crowned kinglet	Canyons/woodlands
Polioptila caerulea	Blue-gray gnatcatcher	Canyons/woodlands
Sialia mexicana	Western bluebird	Canyons/woodlands
Sialia currucoides	Mountain bluebird	Canyons/woodlands
Catharus guttatus	Hermit thrush	Canyons/woodlands
Turdus migratorius	American robin	Canyons/higher elevations
Family: Mimidae Thrashers		
Mimus polyglottos	Northern mockingbird	All habitats
Toxostoma curvirostre	Curve-billed thrasher	Grasslands/lower slopes
Toxostoma dorsale	Crissal thrasher	Grasslands/lower slopes
Family: Laniidae Shrikes		
Lanius ludovicianus	Loggerhead shrike	All habitats
Family: Sturnidae Starlings		
Sturnus vulgaris	European starling	Buildings
Family: Vireonidae Vireos		
Vireo vicinior	Gray vireo	Canyons
Vireo solitarius	Solitary vireo	Canyons/woodlands
Vireo gilvus	Warbling vireo	Canyons
Family: Emberizidae		
Subfamily: Parulinae	Warblers	
Vermivora virginiae	Virginia's warbler	Canyons/woodlands
Dendroica coronata	Yellow-rumped warbler	Canyons/woodlands
Dendroica nigrescens	Black-throated gray warbler	Canyons/woodlands
Dendroica graciae	Grace's warbler	Canyons/woodlands
Dendroica petechia	Yellow warbler	Canyons/woodlands
Oporornis tolmiei	MacGillivray's warbler	Canyons/woodlands
Wilsonia pusilla	Wilson's warbler	Canyons/woodlands
Geothlypis trichas	Common yellowthroat	Canyons/wetlands
Icteria virens	Yellow-breasted chat	Canyons/wetlands
Subfamily: Thraupinae	Tanagers	
Piranga ludoviciana	Western tanager	Canyons/woodlands
Piranga rubra	Summer tanager	Canyons/woodlands

C.2 List of Animals Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Piranga flava	Hepatic tanager	Canyons/woodlands
Subfamily: Cardinalinae	Grosbeaks and buntings	
Pheucticus melanocephalus	Black-headed grosbeak	Canyons/woodlands
Guiraca caerulea	Blue grosbeak	Canyons/woodlands
Passerina cyanea	Indigo bunting	Canyons/woodlands
Passerina amoena	Lazuli bunting	Canyons/woodlands
Subfamily: Emberizinae	Towhees and sparrows	
Pipilo chlorurus	Green-tailed towhee	Canyons/woodlands
Pipilo erythrophthalmus	Rufous-sided towhee	Canyons/higher elevations
Pipilo fuscus	Brown towhee	Grasslands/arroyos/lower slopes
Melospiza melodia	Song sparrow	Canyons/wetlands
Chondestes grammacus	Lark sparrow	Grasslands/arroyos/lower slopes
Amphispiza bilineata	Black-throated sparrow	Grasslands/arroyos/lower slopes
Aimophila ruficeps	Rufous-crowned sparrow	Grasslands/arroyos/lower slopes
Spizella passerina	Chipping sparrow	Canyons/woodlands
Spizella atrogularis	Black-chinned sparrow	Canyons/woodlands
Subfamily: Icterinae	Meadowlarks, blackbirds, and orioles	
Sturnella neglecta	Western meadowlark	Grasslands/lower slopes
Molothrus ater	Brown-headed cowbird	Grasslands/lower slopes
Quiscalus mexicanus	Great-tailed grackle	Buildings
Icterus parisorum	Scott's oriole	Canyons/woodlands
Icterus galbula	Northern oriole	Canyons/woodlands
Family: Fringillidae		
Carduelis psaltria	Lesser goldfinch	Grasslands/arroyos/canyons
Carpodacus mexicanus	House finch	All habitats
Family: Passeridae		
Passer domesticus	House sparrow	Buildings
Class: Mammalia	**Mammals**	
Order: Insectivora	Moles and shrews	
Family: Soricidae		
Notiosorex crawfordi	Desert shrew	Grasslands/arroyos/lower slopes
Order: Chiroptera	Bats	
Family: Vespertilionidae		
Pipistrellus hesperus	Western pipistrelle	Grasslands/arroyos

C.2 List of Animals Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Myotis yumanensis	Yuma myotis	All habitats (below 7000')
Myotis lucifugus	Little brown myotis	Canyons/woodlands/wetlands
Myotis auriculus	Southwestern myotis	Canyons/woodlands
Myotis thysanodes	Fringed myotis	Canyons
Myotis volans	Long-legged myotis	Canyons/woodlands
Myotis californicus	California myotis	Grasslands
Myotis leibii	Small-footed myotis	Canyons/woodlands
Euderma maculatum	Spotted bat	Canyons (possibly lower habitats)
Lasionycteris noctivagans	Silver-haired bat	All habitats
Eptesicus fuscus	Big brown bat	All habitats
Lasiurus cinereus	Hoary bat	All habitats
Plecotus townsendii	Townsend's big-eared bat	Canyons/woodlands
Antrozous pallidus	Pallid bat	All habitats (below 7200')
Family: Molossidae		
Tadarida brasiliensis	Brazilian free-tailed bat	All habitats
Order: Lagomorpha	Rabbits and hares	
Family: Leporidae		
Sylvilagus floridus	Mountain cottontail	Woodlands/canyons
Sylvilagus audubonii	Desert cottontail	Grasslands/arroyos
Lepus californicus	Black-tailed jack rabbit	Grasslands/arroyos
Order: Rodentia	Rodents	
Family: Sciuridae		
Eutamias quadrivittatus	Colorado chipmunk	Rocky slopes/canyons
Ammospermophilus interpres	Texas antelope squirrel	Rocky slopes/arroyos/canyons
Spermophilus spilosoma	Spotted ground squirrel	Grasslands/arroyos
Spermophilus variegatus	Rock squirrel	Canyons/rocky slopes
Cynomys gunnisoni	Gunnison prairie dog	Grasslands
Family: Geomyidae		
Thomomys bottae	Botta's pocket gopher	All habitats (in deep, friable soil)
Family: Heteromyidae		
Perognathus flavus	Silky pocket mouse	Grasslands/lower slopes
Chaetodipus intermedius	Rock pocket mouse	Rocky areas
Dipodomys ordii	Ord's kangaroo rat	Grasslands
Dipodomys spectabilis	Banner-tailed kangaroo rat	Grasslands

C.2 List of Animals Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Dipodomys merriami	Merriam's kangaroo rat	Lower slopes
Family: Cricetidae		
Reithrodontomys megalotis	Western harvest mouse	All habitats
Peromyscus maniculatus	Deer mouse	All habitats
Peromyscus leucopus	White-footed mouse	Grasslands/arroyos/lower slopes
Peromyscus boylii	Brush mouse	Woodlands/canyons
Peromyscus truei	Pinyon mouse	Woodlands
Peromyscus difficilis	Rock mouse	Rocky slopes/canyons
Onychomys leucogaster	Northern grasshopper mouse	Grasslands/arroyos
Neotoma micropus	Southern plains woodrat	Grasslands/arroyos
Neotoma albigua	White-throated woodrat	Rocky slopes/canyons
Family: Muridae		
Mus musculus	House mouse	Buildings
Family: Erethizontidae		
Erethizon dorsatum	Porcupine	Arroyos/canyons/woodlands
Order: Carnivora	Carnivores	
Family: Canidae		
Canis latrans	Coyote	All habitats
Vulpes macrotis	Kit fox	Grasslands/arroyos
Urocyon cinereoargenteus	Gray fox	Canyons
Family: Procyonidae		
Bassariscus astutus	Ringtail	Canyons/rocky slopes
Procyon lotor	Raccoon	Canyons
Family: Ursidae		
Ursus americanus	Black bear	Canyons/higher elevations
Family: Mustelidae		
Mustela frenata	Long-tailed weasel	All habitats
Taxidea taxus	Badger	Grasslands/arroyos
Spilogale gracilis	Western spotted skunk	Arroyos/canyons/rocky slopes
Mephitis mephitis	Striped skunk	All habitats
Family: Felidae		
Lynx rufus	Bobcat	All habitats
Felis concolor	Mountain lion	Canyons/higher elevations
Order: Artiodactyla		

C.2 List of Animals Species Known or Expected to Occur on Kirtland Air Force Base, New Mexico *(Continued)*

Scientific Name	Common Name	Habitat
Family: Cervidae		
Odocoileus hemionus	Mule deer	Woodlands/canyons

Based on:

N.T. Fischer, 1990, "Revision of Species Inventory Checklists for Sandia National Laboratories, Albuquerque, Bernalillo County, New Mexico," *SAND90-7098*, Sandia National Laboratories, Albuquerque, New Mexico.

APPENDIX D

MODELS USED TO ESTIMATE ENVIRONMENTAL IMPACTS

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Appendix D
Models Used to Estimate Environmental Impacts

D.1 Introduction

Often, NEPA documentation must contain documentation that the proposed facility operation will not create significant environmental deterioration if emissions of hazardous materials are anticipated as a result of normal operations, off-normal operations, or credible accidents. This documentation typically involves the use of computer models that simulate the generation of emissions or a hazardous plume, its movement through the environment, and its impact on the surrounding population. The results of the modeling are compared with standards of acceptability, in terms of air or water pollution and human exposure. The selection of an appropriate model is critical to producing relevant results.

This appendix provides a brief and comprehensive summary of the computer models commonly used at SNL/NM for estimating the impact on the environment due to a variety of activities that involve hazardous and radioactive materials (Table D-1). The computer models contain mathematical simulations of estimated radiation dose, transport, or health risk of both radionuclides and chemicals. Most of these models operate on one or more computer systems from supercomputer to personal computers (PC). Most of these programs have good user documentation and include source-code listings and special instructions for users. The use of a modular programming format and restricted use of machine-dependent code also appear to be characteristic of most programs. These features allow for easier modification (or upgrading) of the codes and generally increase program transportability.

Descriptions of the models appearing in this appendix include (1) a summary of the key features and primary application of each program, (2) a list of important assumptions and limitations that apply to each program, (3) special programming considerations, including the software and hardware requirements of the current version of the program and, if applicable, a list of supplemental documentation, and (4) a listing of selected source documentation for each program. Information summarized in this appendix was obtained from users at SNL/NM. Much of the descriptive information on these models comes directly from summaries or introductory sections of the original program documentation. Because many programs undergo frequent revision, material documenting their mathematical models and computer implementation is

Table D-1

Summary of Computer Programs Commonly Used at Sandia National Laboratories/New Mexico

Program	Category	Description or Primary Use
CAP-88	Radiation dose	Calculates maximum individual and population dose for chronic air releases of radionuclides.
HIGHWAY	Highway transportation	Calculates optimum route for highway shipments of radioactive and hazardous materials.
INTERLINE	Rail transportation	Calculates optimum route for rail shipments of radioactive and hazardous materials.
ISC2	Air pollutant dispersion	Calculates maximum air concentrations and deposition of air pollutants and the corresponding distances from the source.
MACCS	Health risk and economic consequence	Calculates health and economic consequences from atmospheric releases of radioactive materials.
MARINRAD IV	Marine transportation	Calculates radiation dose associated with release of radioactive materials in marine environments.
ORIGEN2	Radionuclide inventory	Calculated radionuclide generation and decay in nuclear reactors.
PRÉCIS	Radiation dose, chemical intake/risk/hazard	Calculates radiation dose, cancer risk, hazard index, and residual contamination guidelines for radionuclides and chemicals in soil.
RADTRAN 4	Radiation dose	Evaluates health and economic impacts associated with transportation of radioactive materials.
SCREEN	Air pollutant dispersion	Provides coarse comparison of air concentrations with regulatory limits. Further refinements using ISC2 can be done.
TRANSNET	Transportation program network	Provides network of transportation programs, databases, and utilities.

frequently updated. Therefore, the name and address of a user who can provide further information about a program is provided.

The uncertainty associated with model predictions deserves special mention. Computer models use mathematical analogues to describe complex physical and chemical processes, and for this reason, often provide a greatly simplified view of real world phenomena. The ability of a model to provide an accurate simulation of a particular process is dependent on many factors. For instance, errors can result from (1) invalid assumptions concerning key model parameters (e.g., boundary conditions, dispersion characteristics, etc.), (2) the use of inappropriate or overly simplistic analogues, (3) calculational errors in the computer codes, and (4) basic inadequacies in the input data. In some cases, program predictions may be significantly improved by more rigorous sampling, but additional data collection does not improve underlying assumptions or errors in the code. Verification is very important for any computer code, particularly if it is to be used in licensing or other regulatory matters. Serious errors can also result from misuse or misinterpretation of computer program output. Computer programs are designed for specific applications, and users must be aware of their limitations. Consultation with the program author(s) or an experienced user should serve to avoid most problems of this nature.

There are several standard procedures for testing the validity of mathematical models and computer programs that use them. Initial model verification involves comparing program output with results generated by hand calculations. Most models are thoroughly verified during the course of program development. Program output may also be compared with results from a related and previously verified model. This is referred to as benchmarking. The most rigorous test of model uncertainty includes some form of field validation. Model predictions are often tested against actual field measurements or data obtained from the laboratory that simulate conditions similar to those the model was designed to evaluate. Field validation is not an absolute test of model accuracy, however, and great care should be exercised in interpreting the results from these kinds of studies. Generally, validation studies only provide a limited assessment of model performance because results might apply only to the conditions defined for the test. Models used to predict long-term trends (e.g., 10,000-year dose) or impacts resulting from postulated accidents generally cannot be validated. Nevertheless, validation studies provide an additional level of confidence that is highly desirable for engineers, scientists, and management personnel who must make decisions regarding the selection and operation of computer programs used in environmental assessments. In addition, validation adds credibility to the results of the model because decisionmakers and the public have some assurance that the model reflects reality.

Radiation dose models are used to calculate dose to selected targets (e.g., organs, individuals, or populations) from all major environmental pathways (i.e., air, soil, water, and food chain). Calculations may be performed for acute (single) exposures and for chronic (single years, human lifetimes, or thousands of years) exposures. Annual and human lifetime exposures are assessed in many of the programs, as well as exposures anticipated to occur thousands of years in the future. Three types of radiation doses are generally reported:

- Annual dose: the population or individual dose resulting from 1 year of external exposure and from internal emitters
- Committed dose: the population or individual dose resulting from 1 year of external and internal exposure plus the continued internal dose accumulated from that year's combined inhalation and ingestion exposure
- Accumulated dose: the population or individual dose (external plus internal) accumulated from a lifetime exposure (or 70 years of continuous exposure).

Some programs described in this appendix include hydrologic and hydrogeochemical models. They are used to simulate subsurface flow and solute transport through geologic media, and have been adapted to include geologic and climatic features that characterize the SNL/NM site.

Because the number of computer programs used at SNL/NM for assessing human health or environmental impacts far exceeds those listed in this document, only programs that are commonly used to meet regulatory permits or requirements are described. Further information on other useful computer programs can be obtained from the SNL/NM user. The models are described below in alphabetical order.

D.2 Clean Air Assessment Package–1988 (CAP-88)

CAP-88 is a software package currently specified by the EPA to perform the atmospheric transport and dose assessment required to demonstrate compliance with the NESHAP for radionuclides. This requirement was established by 1990 amendments to the CAA. CAP-88 is an update of the previous EPA AIRDOS and DARTAB codes. The package consists of programs to perform atmospheric dispersion, radiation dosimetry, and risk calculations for chronic radionuclide releases to the atmosphere. CAP-88 has been reviewed in the open literature (Moore and Maheras, 1994).

Three versions of the software are currently approved by the EPA for demonstrating compliance with the NESHAP at DOE facilities: CAP-88, AIRDOS-PC, and CAP-88-PC. The CAP-88 version of the compliance software runs on minicomputer systems (IBM or DEC VAX). The programs supplied with the CAP-88 package include AIRDOS2, which performs the atmospheric dispersion and deposition calculations and DARTAB2, which performs the dosimetry and risk calculations. The dose and risk factor library supplied with the package consists of output from the RAD RISK code. The package also includes several utility programs: PREPAR—a preprocessor that assists the user by converting a FORTRAN name list input file to the format used by AIRDOS2; PREDA—a preprocessor to create DARTAB2 input data sets from AIRDOS2; and RADFMT—a utility to convert RADRISK.BCD data file of dose and risk factors (for use by DARTAB) to binary format. The AIRDOS-PC and CAP-88-PC versions of the software are somewhat simplified versions of the mainframe CAP-88 package that operate on IBM compatible personal computers using a menu-driven interface.

The CAP-88 software is used to estimate radionuclide concentrations in air, rates of deposition on ground surfaces, and ground surface concentrations. The program estimates human intake rates via inhalation of air and ingestion of vegetables, milk, and meat contaminated by airborne releases of up to 36 radionuclides. A modified Gaussian plume equation is used to estimate both horizontal and vertical dispersion of radionuclides released from one to six stacks or area sources. Exposure pathways considered by the code include air submersion, inhalation, ground irradiation, immersion in water (deposition into swimming pools), and ingestion of food products produced in the region. Radiation dose to populations and individuals are estimated as the effective dose equivalent using calculated concentrations in environmental media.

The code is distributed with a set of radionuclide-specific data that generally correspond to the International Commission on Radiological Protection Publication 30 internal dosimetry models (ICRP, 1979) for calculating a 50-year effective dose equivalent. The risk of health effects from specific radionuclides, including genetic effects and fatal cancers, can also be estimated for specific organ. Dose and risk factors are generated by the RADRISK code, and are supplied as a text or binary data file with the CAP-88 package.

Assumptions/Limitations. The following assumptions have been incorporated into the CAP-88 program:

- A straight-line Gaussian plume dispersion model is used with Pasquill dispersion coefficients calculated using Briggs' equation.
- Plume rise (described by either momentum or buoyancy terms) is calculated by the code, or a pre-calculated value for the plume rise term can be supplied directly by the user.
- Plume depletion is calculated for both wet and dry deposition.
- Both point and area sources are supported.
- Radionuclide concentrations in fresh vegetables, milk, and meat are estimated using the food chain models in U.S. Nuclear Regulatory Commission Regulatory Guide 1.109.
- Each calculation is limited to 36 radionuclides, 20 downwind distances, and 16 directions.
- Atmospheric dispersion and environmental uptake models are appropriate for low-level chronic releases; but they are not applicable to short-term or accidental releases of radionuclides.

Programming Considerations. The program is written in FORTRAN IV using the IBM 3081 or 3033 computer running under the OS/VMS operating system and using FORTRAN 77 for the DEC VAX running under VMS. At present an IBM PC version, CAP-88-PC, is available from the EPA. The code packages are also distributed by the Oak Ridge Radiation Shielding Information Center (RSIC) as CCC/542A (IBM Mainframe version), CCC/542B (DEC VAX version), CCC/542C (CAP-88-PC for IBM or compatible computers), and CCC/551 (AIRDOS-PC for IBM or compatible PC).

Verification/Validation. CAP-88 has been compared to monitored atmospheric releases (Maheras et. al., 1994).

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D.3 HIGHWAY

The HIGHWAY program provides a flexible tool for evaluating highway routes for transporting radioactive materials in the United States. The HIGHWAY database is essentially a computerized road atlas that currently describes over 240,000 miles of highways. Complete descriptions of the entire Interstate System and most United States highways (except those that parallel a nearby interstate highway) are included in the database. Many state highways and a number of local and county highways are also identified. The database also includes locations of nuclear facilities and major airports.

Several different types of transport routes may be calculated, depending on a set of user-supplied constraints. Routes are calculated by minimizing the total impedance between the origin and the destination. The impedance is defined as a function of distance and driving time along a particular highway segment. Several routing constraints can be imposed during the calculations. One of the special features of the HIGHWAY model is its ability to calculate routes that maximize use of Interstate System highways. This feature allows the user to project routes for shipments of radioactive and hazardous materials that conform to the U.S. Department of Transportation (DOT) routing regulations. Other features of the model include the ability to identify routes that bypass a specific state, city, town, or highway segment.

Two special features have been incorporated in HIGHWAY Version 3.1. The first is the capability to automatically calculate alternative routes. Most routing models will produce only a single route although there are often different routes between the source and destination that vary slightly in distance and estimated driving time. With the alternative routing feature, the HIGHWAY program offers a selection of different but nearly equal routes. The second special feature is the capability to calculate route-specific population density statistics. The population density distribution, based on the U.S. Bureau of Census block group data, is calculated for each highway segment in the route and reported on a state-by-state basis.

HIGHWAY is accepted by the DOE and the Nuclear Regulatory Commission.

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D.4 INTERLINE

A rail routing model, INTERLINE, has been developed at the Oak Ridge National Laboratory to investigate potential routes for transporting radioactive materials. In INTERLINE Version 5.0, the routing algorithms have been enhanced to include the ability to predict alternative routes, barge routes, and population statistics for any route.

The INTERLINE railroad network is essentially a computerized rail atlas describing the United States railroad system. All rail lines, with the exception of industrial spurs, are included in the network. Inland waterways and deep water routes along with their interchange points with the United States railroad system are also included. The network contains over 15,000 rail and barge segments (links) and over 13,000 stations, interchange points, ports, and other locations (nodes).

The INTERLINE model has been converted to operate on an IBM-compatible personal computer. A personal computer with an 80286 processor and a hard disk containing approximately 6 Megabytes of free space is recommended. Enhanced program performance will be obtained by using a random-access memory drive on a computer equipped with an 80386 or 80486 processor.

INTERLINE is accepted by both the DOE and the Nuclear Regulatory Commission.

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D.5 Industrial Source Complex (ISC2)

The ISC2 dispersion models described here refer to the restructured and reprogrammed versions of the original ISC models, which were developed for the EPA to provide guidance on regulatory applicability of air quality dispersion models in general. The ISC models were reprogrammed to improve the user interface and to improve documentation of the models. Any air quality regulatory application of the ISC2 models should conform to the procedures set forth in the Guideline on Air Quality Models (Revised) (EPA, 1987). Nonregulatory applications should have approval of the applicable reviewing agency (e.g., EPA regional office or a state or local air pollution control agency).

The ISC2 comprises a short term (ISCST2) and a long term (ISCLT2) model. These two models include a wide range of options for modeling air quality impacts of stationary pollution sources, making them popular choices for a variety of applications. The user has the choice of selecting either a regulated or a nonregulated mode of operation and can choose between rural or urban dispersion parameters depending upon the land use category of the site in consideration. ISC2 has the capability of handling multiple sources, including point, volume, and area sources. Line sources are handled by modeling them as a string of volume sources. Many source types may be combined in a single run, with the source contributions combined for each group. This is particularly useful for applications under the CAA (1990) when it is necessary to address PSD issues.

Algorithms for modeling the effects of aerodynamic downwash caused by the presence of nearby buildings on point source emissions and the effects of settling and removal of large particulates (through dry deposition) are contained in the ISC2 source code. The ISC2 can use either user-specified constant or variable source emission rates for either a single source or a group of sources options for multiple receptors can be specified in a single run, and the user has the flexibility of mixing Cartesian and polar grid networks in the same run. Elevated receptor heights can be specified for modeling the effects of terrain above or below the stack base.

Meteorological data formats are different for both the ISCST2 and the ISCLT2 models. The ISCST2 utilizes unformatted or ASCII formatted sequential files of meteorological data generated by the RAMMET and MPRM preprocessors. The ISCLT2 uses joint frequency distributions of wind speed class according to wind direction sector and stability category, known as STAR summaries.

The user has a great deal of flexibility and numerous options for hardcopy outputs. Primarily the printed outputs consist of summaries of high values and overall maximum values for each averaging period and source group combination. Tables of concurrent values are also summarized by receptor for each averaging period and source group combination for each day that data are processed.

Assumptions/Limitations. Assumptions of the ISC2 programs include:

- A steady-state Gaussian plume model is used to model continuous releases of primary toxic and hazardous waste pollutants. Settling and deposition are also treated. Fumigation is not treated.

- Briggs plume rise equations are used to model final plume rise. Equations for stack tip downwash are provided.

- The Huber-Snyder algorithm is used to model emissions from stacks higher than building height plus one-half the lesser of the building height or building width. For lower stacks, the Schulman-Scire algorithm is used, without consideration of stack tip downwash and buoyancy induced dispersion.

- Flat, rolling terrain is assumed, but with elevations above the stack top reduced to stack top elevation (terrain chopping). The plume centerline is assumed to be horizontal at the height of final rise above the source.

- Constant, uniform horizontal wind speed is assumed for each hour and vertical wind speed is assumed to equal zero. Straight-line plume transport to all downwind locations is assumed.

- Separate wind speed profile exponents are assumed for rural and urban sources and optional treatment for calm winds is available for purposes of short term modeling.

- Six stability classes are used in the programs and buoyancy-induced dispersion is included. Mixing height of the vertical plume radius is accounted for, with multiple reflections until the standard deviation equals 1.6 times the mixing height. Uniform vertical mixing is assumed for greater mixing heights. Perfect reflection at the ground is assumed.

- Chemical transformations are modeled using exponential functions with time constants specified by the user.

Verification/Validation Studies. A number of field studies have been conducted on the ISC2 models to test the validity of the model's predictions. Some of these studies have compared internal parameters set in the ISC2 models (e.g., downwash modifications, etc.) whereas others have been comparisons with other existing models, namely, buoyancy line and point source model. All the evaluation studies have been formalized into reports/technical papers and are documented in either journals or are available from the EPA.

Programming Considerations. The ISC2 program, though developed primarily for the IBM-compatible PC, can be operated on many other platforms such as the DEC VAX, IBM 3090 and others UNIX platforms. The current ISC2 versions were developed on a PC using the Microsoft FORTRAN Optimizing Compiler (Version 5.1), and have been designed to run on machines with a minimum of 640 Kilobytes of RAM and MS-DOS Version 3.2 or higher. Though optional, a math coprocessor chip is highly recommended as the execution speed will increase by a factor of about five to ten. Extended memory versions of this model are also available for use with scenarios involving a large number of sources, receptors, source groups, and averaging periods.

D.6 MELCOR Accident Consequence Code System (MACCS)

MACCS was developed at SNL/NM under Nuclear Regulatory Commission sponsorship. MACCS was publicly released in 1990, and was developed as a tool to support the Nuclear Regulatory Commission's Level Three probabilistic safety assessment analyses. MACCS performs probabilistic health and economic consequence assessments of hypothetical accidental releases of radioactive material from nuclear power plants. It includes models for atmospheric dispersion and transport, wet and dry deposition, the stochastic treatment of meteorology, environmental transfer, countermeasure strategies, dosimetry, health effects and economic impacts.

MACCS models the transport and dispersion of plumes of radioactive material released to the atmosphere and deposition of material on the ground via wet and dry deposition processes. MACCS models seven pathways through which the general population can be exposed to radiation: cloudshine, groundshine, direct and resuspension inhalation, ingestion of contaminated food and water, and deposition on the skin. Emergency response and protective action guides for both short and long times after the accident are also considered as means to mitigate the extent of the exposures. As a final step, the model provides estimates for economic costs associated with the mitigative actions.

MACCS is organized into three modules. The ATMOS module performs the atmospheric transport and deposition portion of the calculation. The EARLY module estimates the consequences of the accident immediately following the accident (usually within the first week), and the CHRONIC model estimates the long-term consequences of the accident.

Since its most publicized application in the NUREG-1150 study, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," MACCS has been used in a variety of applications. Two examples are the DOE Safety Survey and the evaluation of the proposed changes to 10 CFR Part 100. MACCS has also been used for the probabilistic consequence assessment of advanced reactor designs.

MACCS has been applied in two international collaborative efforts: the Second International Comparison of PCA Codes organized by the Nuclear Energy Agency of the Economic Cooperation and Development and Commission of the European Communities (CEC) and in a pilot probabilistic consequence uncertainty study sponsored by the Nuclear Regulatory Commission and CEC.

Assumptions/Limitations. Assumptions and limitations associated with the MACCS program include:

- Momentum plume rise is not modeled.
- Plume rise is prevented in the model if the windspeed at release is greater than the critical windspeed.
- The 16 compass sector population distributions are assumed to constitute a representative set of downwind exposed populations (trajectories are neglected).
- The exposure probability of each of the 16 compass sector population distributions is assumed to be given by the frequency with which the wind blows from the site into the sector.

- Dispersion of the plume in the vertical and horizontal directions is estimated during transport using an empirical Gaussian plume model.
- Early injuries and fatalities are estimated using nonlinear dose-response models.
- Latent cancers are estimated using a piecewise linear-dose response model that is discontinuous. Two equations are implemented in the code; one for high exposures and one for low exposures.
- The model takes into account the following costs: evacuation costs, temporary relocation costs, costs of decontaminated land and buildings, lost return-on-investments from temporarily interdicted properties, the value of crops destroyed or not grown, and the value of condemned property.
- Costs associated with damage to the reactor, the purchase of replacement power, medical care, life-shortening, and litigation are not considered.

Programming Considerations. The MACCS program is designed to run on the following computer systems: 386/486/Pentium IBM-compatible PC, VAX/VMS, IBM RISC S/6000, Sun SPARC, and Cray UNICOS.

D.7 Marine Radionuclide Transport and Dose Program (MARINRAD IV)

The MARINRAD IV consists of three computer programs for assessing the consequences of release of radionuclides into the oceans. The MARRAD program computes radionuclide concentrations resulting from ocean transport and generates food chain concentration factors. The MAROUT program evaluates human exposure pathways and radiation dose, generates printed reports, and produces graphic plots. The ADJOINT program applies the adjoint analysis technique for computing model parameter sensitivities.

The MARRAD program consists of two modules, an ocean transport model and a steady-state food chain model. The ocean transport model is used to partition the ocean(s) into an arbitrary number of sediment and water compartments, in order to compute the concentration of each radionuclide in each compartment of the system as a function of time. The second module consists of a steady-state food-chain model that simulates the uptake of radionuclides in biota. Stable-element concentration factors are used to calculate radionuclide concentrations in compartment biota, and the food-chain module computes concentration factors for predators that prey on compartment biota but which do not reside in the compartment.

MAROUT, the second program within the MARINRAD IV system, primarily calculates radiation doses and health effects for all pathways leading to human exposure. Pathways included are ingestion of aquatic biota, external exposure to contaminated water or sediments, inhalation of airborne spray or shore sediments, and several others miscellaneous pathways. Radiation doses to aquatic biota are also calculated.

The third program, ADJOINT, enables computation of model parameter sensitivities by the adjoint analysis technique. The sensitivity, or first derivative of concentration, peak dose, or integrated dose, may be calculated with respect to any of the ocean transport model parameters.

Assumptions and/or Limitations. The ocean models require that each compartment be "well-mixed" with respect to the time scale appropriate to the rate at which material is transported outward (referred to as the turnover time for the compartment). If the compartment is not well-mixed, the flow rate of material outward will be incorrectly calculated unless the concentration field is statistically homogeneous.

Verification/Validation Studies. MARINRAD has been compared with results of several similar models that calculate ocean radionuclide concentrations, and has been used by the DOE and the International Atomic Energy Agency (IAEA) in the revised definition concerning high-level wastes unsuitable for disposal at sea.

Programming Considerations. MARINRAD was developed in FORTRAN 77 on an IBM 4381 under the CMS operating system. It is compatible for use on a CDC CYBER 170/855 under the NOS 2 operating system. Nominally, the program executes in a 1220 Kilobyte partition on the IBM system or a 112 Kiloword region on the CDC machine. On the IBM computer, the execution time is approximately 1 CPU minute for a simulation involving eight radionuclides, and is about a factor of five faster on the CDC system.

Contact.

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Albuquerque, New Mexico
Phone: (505) 844-0531

The latest version, MARINRAD IV, may be obtained from:

The Analytical Sciences Corporation (TASC)
55 Walkers Brook Drive
Reading, MA 01867

D.8 Oak Ridge Isotope Generation and Depletion Code (ORIGEN)

ORIGEN calculates the buildup, decay and processing of radioactive materials. ORIGEN2 is a revised version that incorporates updates of reactor models, cross-sections, fission product yields, decay data, and decay photon information, as well as the source code. The most recent version, ORIGEN2.1 incorporates additional libraries for standard and extended burnup calculations for boiling water reactors and pressurized water reactors.

ORIGEN uses a matrix exponential method to solve a large system of coupled, linear, first-order ordinary differential equations with constant coefficients. Provisions are included for incorporating data generated by reactor physics codes, a free-format input, and a highly flexible and controllable output. As a result, ORIGEN2 is a versatile point-depletion and radioactive-decay computer code for use in simulating nuclear fuel cycles and calculating the nuclide compositions and characteristics of materials.

Assumptions and/or Limitations. The cross-sections utilized in ORIGEN should be the result of a multi-dimensional depletion and not a static spectrum calculation. Static spectrum calculations do not generate cross-sections appropriate for the system present in thermal reactors; therefore, more detailed reactor physics codes are necessary to provide spectra which account for all relevant effects.

Verification/Validation Studies. Unfortunately, few adequate verification benchmarks exist, particularly in the case of modern light water reactors. However, comparisons have been made between ORIGEN2 and other well-characterized benchmarks. For example, the decay heat predictions of ORIGEN2 have been compared with the decay heat standard from the American Nuclear Society (ANS) and were found to be within ±2 percent at decay times between ~20 seconds and 30 years. A second and more encompassing verification of ORIGEN2 was conducted at Hanford Engineering Department Laboratory using spent fuel from pressurized water reactors. ORIGEN2 overpredicted the decay heat by 5 to 6 percent at decay times between two and three years, which is considered to be in agreement when the uncertainties in burnup and other parameters are taken into account. Verification of the composition predictions made by ORIGEN2 is a very wide-ranging subject due to the large number of nuclides accommodated by the code. Results for a comparison to samples from a pressurized water reactor-discharged spent fuel are quite good in overall agreement, however, a few significant anomalies exist. The first is that plutonium-239 is both significantly and consistently underpredicted. The exact source of this error is unknown because experimental values for plutonium-239 are unavailable. Secondly, the same error is observed for plutonium-242 and the source is once again difficult to isolate. Because no information is available on the absolute amounts of americium and curium, it is impossible to determine whether the plutonium-242 destruction rate is too high or if the production rate is too low.

Due to its relative simplicity of execution and convenient detailed output, ORIGEN rapidly gained acceptance as the most widely used program in the United States for calculating radionuclide compositions and characteristics. The Nuclear Regulatory Commission used ORIGEN for the Reactor Safety Study, and the DOE is continuously using the code for projecting and calculating the composition and characteristics of radioactive wastes. In addition, ORIGEN calculations form the basis for regulatory efforts and proposed rulemaking efforts by the EPA, as well as the DOE and Nuclear Regulatory Commission. ORIGEN is so widely used and accepted internationally that approximately 200 organizations have acquired the code.

Programming Considerations. ORIGEN Version 2.1 (A) executes on a VAX computer and on PC equipped with 80336 or 80486 processors and a math coprocessor. At least 4 Megabytes of extended memory and 20 Megabytes of hard disk space are required. Because the same source code executes on the both VAX and PC computers, conversion to other platforms should not be difficult. For the IBM PC, Version 2.1 (D), a PC, XT, AT, or PS/2 with fixed disk, 640 Kilobytes RAM, and an 8087, 80287 or 80387 numeric coprocessor is required.

ORIGEN Version 2.1 (A) for the PC was compiled and linked with the Lahey F77L-EM/32 extended memory FORTRAN compiler version 4.00 and the Lahey/Ergo OS/386 extended memory operating system version 2.1.05 under DOS 5.00. The VMS operating system was used on the VAX computer, and a FORTRAN compiler is required to execute on mainframes.

The model was originally developed by Oak Ridge National Laboratories as ORIGEN, with a primary application of source term development. ORIGEN has undergone continuous revision to the present form with contributions from:

Oak Ridge National Laboratories, Oak Ridge, Tennessee
Tennessee Valley Authority, Chattanooga, Tennessee
Office of Nuclear Waste Isolation, Battelle Project Management Division, Columbus, Ohio

Sargent and Lundy Engineers, Chicago, Illinois
Century Research Center Corporation, Tokyo, Japan
NUKEM GmbH, Alzenau, Federal Republic of Germany
Battelle Columbus, Columbus, Ohio

ORIGEN2 may be acquired from the RSIC located in Oak Ridge, Tennessee by formal request to:

Codes Coordinator
Radiation Shielding Information Center
P.O. Box X
Oak Ridge National Laboratory
Oak Ridge, TN 37831-6362

Contact.

J.D. Smith
Department 6641
Mail Stop 0718
Sandia National Laboratories/New Mexico
Albuquerque, New Mexico
Phone: (505) 844-0531

D.9 Probabilistic Risk Evaluation and Characterization Investigation System

Probabilistic Risk Evaluation and Characterization Investigation System (PRÉCIS) consists of a series of computer tools for conducting human health risk assessments within a probabilistic framework. With this system, a risk assessor can calculate the risks and hazard indices associated with chemicals at hazardous waste sites and the doses resulting from exposure to environmental contamination from radioactive waste. PRÉCIS can be used for deterministic (or single risk) estimates of risk as well as stochastic estimates using Monte Carlo Simulation techniques, i.e., tools to generate probabilistic risk assessments. As many as nine environmental pathways and three general forms of exposure pathways can be invoked in the system.

In addition to providing quantitative estimates of risk, PRÉCIS is designed to aid operable unit leaders, responsible parties, stakeholders, and regulators in establishing concentration thresholds for contaminants in soils, as well as in prioritizing site characterization needs. Because a stochastic methodology forms the underlying foundation of the code, it can be used to quantify endpoints for a variety of decision-making processes. Such endpoints include, but are not limited to, action levels, data quality objectives, and cleanup levels.

The process of computing concentration thresholds is accomplished with "inverse" calculations. The results of the inverse calculations are referred to as soil guidelines. In addition to determining guidelines for single contaminants, PRÉCIS is designed to compute contaminant guidelines for mixtures of contaminants. The mixture/soil guidelines take into account what are assumed to be the "additive" effects of multiple contaminants on dose, risk, and toxicity. In doing so, a mixture guideline for a given contaminant is, by definition, always more restrictive (i.e., less) than the comparable single-source guideline resulting from a simulation with the PRÉCIS code.

Performing assessments in a stochastic manner allows the PRÉCIS user to quantitatively account for the propagation of parameter uncertainty to uncertainty in risk. Consequently, an assessor can compute a realistic range of risks associated with a site rather than a single risk estimate based on traditionally conservative assumptions that lead to both compounding and additive errors. Comparisons made between traditional and stochastic approaches to risk assessment typically show that a baseline of risk is two orders of magnitude larger than the Monte Carlo risk estimate made at the 95 percent probability level (i.e., only 5 percent of the risk assessments are larger). Accordingly, the zones identified for cleanup in various media with the ultra-conservative conventional methodology are orders of magnitude larger than the cleanup area identified by the stochastic approach.

PRÉCIS is a totally self-contained application that is designed to be user-friendly. The current version of the system allows only exposure assessment parameters (including environmental transport parameters) to be treated as uncertain. Versions now in development also allow factors that affect risk characterization, such as cancer slope factors and reference doses, to be treated as uncertain. Several features have been incorporated in PRÉCIS that make it both efficient and useful for a variety of purposes. All data entry and postcomputing risk analysis is handled through an easily-mastered graphical user interface. Risk assessment results for computed radiation doses, intakes, risks, hazard indices, and soil guidelines (i.e., acceptable soil concentrations) can be examined in both report and graphical form. Graphical output from probabilistic assessments consists of complementary cumulative distribution functions of risk, hazard index, doses, and soil guidelines.

Pathway Models. PRÉCIS contains two separate models to evaluate risk at a site. The first model, based on the RESRAD code (Gilbert et al., 1989), computes equivalent dose resulting from radioactive contaminants in soil. As with RESRAD, PRÉCIS accounts for three exposure pathways: direct gamma radiation, inhalation, and ingestion. Nine environmental pathways are modeled, including drinking water ingestion and radon inhalation.

The second model, RISKCHEM, is a hazardous chemical version of RESRAD developed at SNL/NM. It includes the chemical equivalent of the environmental pathways in RESRAD, with the exception of the direct radiation and radon pathways. In addition to calculating chemical intakes, RISKCHEM computes incidents of cancer risk and the hazard indices resulting from exposure to toxic constituents (EPA, 1989).

An enhanced version of PRÉCIS that incorporates a variety of pathway model changes is currently being developed. Most of the changes are focused on RISKCHEM and include the following: (1) a dermal absorption pathway, (2) inhalation of volatile organic chemicals, and (3) improved groundwater pathway estimates using the BOSS process models. The last of these enhancements will enable simulation of additional fate and transport processes such as dispersion, retardation, and biodegradation (e.g., Domenico and Schwartz, 1990). This enhancement will in turn enable the calculation of attenuated groundwater concentrations and associates exposures at receptors located considerable distances downgradient of the waste site. Similar groundwater pathway improvements are planned for the radioactive waste model.

Stochastic input to the process models for the Monte Carlo analysis is accomplished using Latin Hypercube Sampling (LHS), a stratified sampling procedure that has been developed and routinely applied at SNL/NM (Iman and Shortencarrier, 1984; Iman and Helton, 1985; Zimmerman et al., 1990). LHS provides a method to force the sampling to select numbers over the whole range of variation of a parameter while reducing the total number of samples to reduce computer time.

For each uncertain parameter, the PRÉCIS user can select a normal, lognormal, uniform, or loguniform distributions. A distinct advantage of the LHS procedure is that it allows for various levels of correlation between two or more input parameters (Iman and Conover, 1982). For example, parameters such as hydraulic conductivity and porosity can be correlated anywhere from 1 to 100 percent.

Sensitivity Analysis. The current version of PRÉCIS contains tools for conducting two types of sensitivity analysis, the results of which can be used to identify parameters for future site characterization activities. The first tool is analogous to the dose-versus-time graphs included with the RESRAD package (Gilbert et al., 1989). These graphs allow the user to plot radiation doses, risks, and hazard indices resulting from a single PRÉCIS run for an original input parameter value and for perturbed values of the parameter. The effects on computed risks are, therefore, seen subjectively. A more quantitative sensitivity analysis tool built into PRÉCIS also allows the user to examine the effects of parameter perturbation but also to compare the relative importance of each parameter through the calculation or normalized sensitivity coefficients (Cheng et al., 1991). Because parameters producing the largest coefficients have the greatest influence on computed risk uncertainty, this approach can be used to prioritize future waste-site characterization needs on the basis of risk.

Both of the above-described sensitivity analysis techniques provide local evaluation of parameter sensitivity in the sense that they are applied only to a single model run based on a specific site of parameter inputs. A more global approach to sensitivity analysis is currently being added to PRÉCIS in the form of stepwise multiple regression analysis (Zimmerman et al., 1990). This method will facilitate an evaluation of correlation between computed risks and the input parameters over the full suite of Monte Carlo Simulations. Thus, the user can determine which parameters are most import for the full probability space examined in the Monte Carlo analysis. Regression analysis techniques can be applied to original variables, standardized variables, or rank-transformed data.

Guidelines, Action Levels and Cleanup Levels. In addition to calculating risk, PRÉCIS performs an inverse calculation that yields estimates of acceptable contaminant soil concentrations on the basis of prescribed limits on cancer risk, toxic hazard index, or radiation dose. Such concentrations are commonly referred to as soil guidelines, concentration limits, or threshold concentrations. They can be used as "action levels" in RCRA investigations or as cleanup levels in assessing remedial alternatives.

Soil guidelines calculated with PRÉCIS serve a variety of purposes in that they can be used to (1) guide the selection of field-screening equipment, (2) allow an early determination of whether a site is safe (resulting in a No Further Action proposal early in the assessment process), and (3) determine which constituents are of concern. Another benefit of computed soil guidelines, when used early in the assessment process, is the identification of sites that pose unacceptable risk. These sites are candidates for remedial alternatives selection, and characterization needs can be focused on parameters needed for optimizing the preferred alternative. PRÉCIS may also be used to provide an estimate of the risk reduction achievable with a potential remedial alternative.

As previously discussed, soil concentration guidelines are computed assuming that individual chemicals are either (a) the only source of contamination or (b) part of a mixture of several chemicals. The method for computing a single-source guideline for a radioactive contaminant is presented in Gilbert et al. (1989). Similar algorithms have been developed for hazardous chemicals and for chemical and radionuclide mixtures and incorporated in PRÉCIS. The calculation of single-source guidelines is accomplished without any foreknowledge of or assumptions about the contaminant mixtures at a site. In contrast, to calculate mixture guidelines, PRÉCIS requires that estimates be given for the soil concentrations of all contaminants in the source area. Given this information, guidelines can be calculated by assuming any of numerous possible relationships between the contaminants in the mixture. Such relationships are referred to as weighting schemes, in which the relative weight of the guideline for a given contaminant is defined by an explicit mathematical formula that makes use of either model input or model results. Two separate schemes are invoked in the current version of the system to calculate soil guidelines for radioactive waste. Four schemes are applied in the hazardous chemical risk module of PRÉCIS. Additional or alternative weighing schemes are anticipated for future versions of the code.

Assumptions/Limitations. Many of the assumptions intrinsic to RESRAD (Gilbert et al., 1989) are also included in PRÉCIS. Two important assumptions are:

- The total risk is assumed to derive only from contaminated soil. Direct contamination of water or air (without prior contamination of soil) is not assessed.
- Vapor phase exposure from volatile organic compounds in soil is not assessed.

Verification/Validation. PRÉCIS has not been released to the public.

Programming Considerations. Current versions of PRÉCIS are being developed on Apple Power Macintosh, Macintosh Quadra, PC Windows, and Windows NT platforms. The various versions of the system make use of universal, standardized programming languages and libraries that make possible the transfer of the software to additional platform and operating systems.

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D.10 RADTRAN 4

RADTRAN 4 is used to evaluate potential health and economic impacts associated with the transportation of radioactive materials. The program uses a combination of meteorological, demographic, health physics, transportation, packaging, and material factors to assess risks associated with both normal transport (incident-free) and various user-selected accident scenarios.

The RADTRAN 4 program consists of seven submodels: (1) a material model that allows users to select basic material parameters including number of curies of each isotope per package, average total photon energy per disintegration, the rate at which released material is deposited on the ground, cloudshine dose factors, the physical character of the waste, half-life, and measures of the radiotoxicity of the dispersed material; (2) a transportation model that considers accident rates for each transportation mode (truck, van, rail, cargo and passenger air, barge, and ship), traffic patterns (fraction of travel occurring on various road types, through different population zones, and under both rush hour and normal traffic conditions), and basic shipment information (number of crew per vehicle, handling and storage times, duration and number of stops); (3) an accident severity and package release model that allows the user to classify accidents according to severity (i.e., fire, crush, impact, and puncture forces), and define the respirable fraction (particles < 10μ) of airborne material released from packages; (4) a meteorological dispersion model that describes the diffusion of a cloud of aerosolized debris released during an accident; (5) a population distribution mode that describes the distribution and relative densities of people in three population zones (rural, suburban, and urban) and in certain specific areas, such as pedestrian walkways, warehouses, and air terminals; (6) a health effects model[1] evaluates the radiotoxicity of materials in terms of potential for producing acute fatalities, early morbidities, genetic effects, and latent cancer fatalities; and (7) an optional economic model that evaluates the economic impacts connected with surveillance, cleanup, evacuation, and long-term land-use denial activities.

The RADTRAN model is constantly revised and updated as additional information and experience becomes available. The new features of RADTRAN 4 include the following:

- The capability to perform link-by-link route-specific analyses
- Addition of an internal radionuclide library
- Improved logic for multiple-radionuclide packages
- Allowance for separate treatment of gamma and neutron exposures
- Definition of up to 20 accident severity categories.

Perhaps the most significant new feature is the capability to perform route-specific analyses. Up to 40 separate transportation "links" or route segments may be defined. Each link may incorporate route-specific parameters, such as population density, vehicle velocity, accident rate, segment length, transport mode, and zone designation (rural, suburban, or urban). Aggregate data may still be used, if desired.

The radiological impacts from transportation accidents are expressed according to the level of consequence, probability of occurrence, and level of risk. A risk figure-of-merit is calculated by summing the products of the probability of each specific accident and its associated level of consequence.

Assumptions/Limitations. The following assumptions have been incorporated into the RADTRAN 4 program:

- Dose calculations in the population exposure model assume that the package or shipping cask is a point source or line source of radiation (line-source is used for handlers who work in close proximity to packages; point-source is used elsewhere).

[1]This model does not incorporate BEIR V or ICRP 60 health effects conversion factors. The authors recommend obtaining results as radiation dose and applying BEIR V or ICRP 60 health effects conversions to them.

- Radioactive materials released from a package during an accident are assumed to be dispersed according to standard Gaussian puff-type models. However, the user may define alternative dispersion factors if desired.

- External radiation exposures from ground contamination are calculated using an infinite plane source model.

Verification/Validation Studies. Sensitivity analyses have been performed for several applications (e.g., incident-free transportation, vehicular accidents) of the RADTRAN III program and are documented in Neuhauser and Reardon (1986) and Madsen et al. (1986).

RADTRAN 4 is in compliance with ANSI/IEEE 730-89 for software quality assurance and all benchmarking is documented in the accompanying software verification and validation plan.

Programming Considerations. A user's manual (Neuhauser and Kanipe, 1992) documents the various options for generating accident scenarios and provides additional instructions for computer operators (described in Section 13.13).

Peripheral Software and Files. Sample input files for analyses performed by SNL/NM are available on the TRANSNET system (described in Section 13.13). Individual downwind dose calculations to accompany RADTRAN population dose-risk output may be performed with the TIC/D companion code, also on TRANSNET.

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D.11 SCREEN

The SCREEN model was developed to provide an easy-to-use method of obtaining pollutant concentration estimates based on the new EPA screening procedures document (EPA, 1992). These screening procedures provide a coarse estimate of pollutant concentrations and are based on conservative assumptions. If the SCREEN estimates indicate that air quality standards are not being met, then more refined estimates should be made using the ISC2 models. SCREEN is an interactive program that asks the user a series of questions in order to obtain the necessary input data, and to determine which options to apply.

The SCREEN2 model includes several modifications relative to the original release of SCREEN2. These changes were made in order for the SCREEN2 model to be more consistent with the ISCST2 models especially for the downwash algorithms. Significant portions of the ISCST2 model code have been incorporated into the SCREEN2 model, both to ensure consistency of calculations and to facilitate potential revisions that might affect both models. The changes include modifications to the iteration procedure used to locate the peak concentration, the addition of wind speeds in 0.5 m (1.6 ft)/s increments for wind speeds less than 5.0 m (16.5 ft)/s, the addition of the F stability class with a 0.35 km/min lapse rate for the urban dispersion option, and an option for specifying volumetric flow rate in lieu of stack gas exit velocity. The revised code also simulates the area and volume sources as a finite line segment and as a virtual point source respectively.

The model performs the single-source, short-term calculations as given in the screening procedures document (EPA, 1992). These calculations estimate maximum ground-level concentrations and the distance to the maximum concentrations, incorporate the effects of building downwash on the maximum concentrations for both the near wake and far wake regions, estimate concentrations resulting from inversion break-up and shoreline fumigation, and determine plume rise for flare releases. The model incorporates the effects of simple elevated terrain on maximum concentrations, and can also estimate 24-hour average concentrations associated with plume impaction in complex terrain using the VALLEY model 24-hour screening procedure. SCREEN2 models simple area sources using a finite line segment approach, consistent with the ISC2 model. Volume sources are modeled as virtual point sources (consistent with the virtual point source algorithm discussed in ISC2). The program can calculate maximum concentration at user-specified distances in flat or elevated simple terrain, including distances out to 100 km (38 mi) for long range transport, down to distances less than 100 m (330 ft).

SCREEN2 examines a full range of meteorological conditions, including all stability classes and wind speeds to determine areas of maximum impacts. The model explicitly calculates the effects of multiple reflections of the plume off an elevated inversion and off the ground when calculating concentrations under limited mixing conditions. The model results also include the effects of buoyancy-induced dispersion, which can either increase or decrease the estimated maximum concentrations by as much as 25 percent, depending on the source and distance.

Assumptions/Limitations. The following assumptions have been incorporated into the program:

- A Gaussian plume model that incorporates source-related factors and meteorological factors to estimate pollutant concentration from continuous sources.
- It is assumed that the pollutant does not undergo any chemical reactions, and that no other removal processes, such as wet or dry deposition act on the plume during its transport from the source.
- For stable conditions and/or mixing heights greater than or equal to 10,000 m (33,000 ft), unlimited mixing is assumed, and for unstable and neutral conditions a mechanically driven mixing height is assumed.
- Volume sources are modeled as virtual point sources, whereas a finite line segment is used for area sources.
- SCREEN2 examines the worst case meteorological conditions (i.e., the combination of wind speed and stability that results in the maximum ground level concentrations).
- For building downwash, cavity recirculation region calculations are based on procedures developed by Hosker (1984), and building wake effects are based on the ISC2 models.

Verification/Validation Studies. SCREEN is accepted by the EPA. Several studies have examined the SCREEN and ISC models: Rhodes, 1981; Moore et al., 1982; and Bowne and Londergan, 1983.

These models can be obtained from:

BEE-Line Software
P.O. Box 59916
Dallas, Texas 75229
Phone: (214) BEE-LINE

Programming Considerations. SCREEN2 can be run on an IBM-PC compatible personal computer with at least 256 Kilobytes of RAM, at least one 5-1/4 inch double-sided, double-density (360 Kilobyte disk drive), a 5-1/4 inch high density (1.2 Megabyte disk drive), or a 3.5-inch-high density (1.4 Megabyte disk drive). Execution time will be greatly enhanced if a math coprocessor chip is available.

Contact.

Hue-Su A. Hwang
Department 7575
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Sandia National Laboratories/New Mexico
Albuquerque, New Mexico
Phone: (505) 848-0970

D.12 TRANSNET System

TRANSNET is a compilation of risk, systems analysis, routing and cost models, and related data pertaining to radioactive materials transportation. This system of codes and associated data resides on a dedicated Micro VAX 3800 at SNL/NM. After obtaining a user name and password, users can access TRANSNET with a personal computer and modem.

The goal of the TRANSNET system is to transfer technology and data to qualified users by permitting access to the most comprehensive and up-to-date transportation risk and systems analysis codes, and associated databases. Any agency or organization requiring access to TRANSNET should write to:

Richard Orzel
Transportation Systems Analysis Department 6641
Mail Stop 0718
Sandia National Laboratories/New Mexico
P.O. Box 5800
Albuquerque, NM 87185-0718

TRANSNET development and operations are sponsored by the U.S. Department of Energy Office of Environment Restoration and Waste Management Transportation Management Division.

TICLD—Transportation Individual Centerline Dose. TICLD uses coding identical to that in RADTRAN 4 to determine doses to individuals located at specific downwind distances from a hypothetical accident release site. Threshold values may be entered as well. For example, the user may determine at what distance the downwind dose becomes less than the Negligible Individual Dose (1 mrem). Downwind distances are given for meteorological data sets commonly used in RADTRAN, but user-defined meteorological data may be entered.

TRANSAT—Atmospheric Dispersion Model. The TRANSAT atmospheric dispersion model was developed by P. Pages and F. Rancillac for use with the IAEA INTERTRAN code which is based upon RADTRAN. In addition to supplying an input to RADTRAN, running TRANSAT gives further information on the consequences of an atmospheric release and help in complementary (e.g., sensitivity) analyses.

INTERSTAT Highway Routing Model. INTERSTAT was developed at SNL/NM to find optimal routes on the Interstate Highway System. Optimization is based on user-defined weights of distance, population, and/or truck accident rate. Some input data required by RADTRAN can be supplied from INTERSTAT.

StateGEN/StateNET Local Routing Model. This model was developed at SNL/NM to assist state and other agencies in performing local routing analysis. The code builds a network from user input and finds routes on the network based on user-defined weights of user-defined data categories. The code offers full compatibility with the U.S. Department of Transportation guidelines for selection of preferred routes for highway quantity route controlled shipments of radioactive materials.

RMIR—Radioactive Materials Incident Reporting Database. RMIR database contains information on transportation-related accidents and incidents involving radioactive materials from 1971 to the present. RMIR is continually being updated at SNL/NM, with the addition of new incidents to the existing records.

RAMPOST—Radioactive Materials Post-notification Database. The RAMPOST database is a compilation of the highway route controlled quantity shipments that have been made since 1987. Data includes shipment date, carrier, shipper, consignee, and highway route segments. Radionuclides and total curies shipped are usually listed.

Contract. Requests for assistance or comments on the TRANSNET system or its components may be transmitted as follows:

• TRANSNET Customer Assistance	Cheryl Crockett (505) 856-1635
• TRANSNET Communications	Rick Orzel (505) 845-8094
• TRANSNET Systems Development	Jim McClure (505) 845-8753
• TRANSNET System Operations	Jim McClure (505) 845-8753
• TRANSNET FAX	(505) 844-0244
• RADTRAN/TICLD/TRANSAT	Fran Kanipe (505) 844-1121
• RMIR/RAMPOST	Cheryl Crockett (505) 856-1635
• INTERSTAT/StateGEN/StateNET	Jim McClure (505) 845-8753

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APPENDIX E

SELECTED ANNOTATED BIBLIOGRAPHY

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Appendix E
Selected Annotated Bibliography

Alexander, F.C., 1963. "History of Sandia Corporation Through Fiscal Year 1963," Sandia Corporation, Albuquerque, New Mexico.

Summary: The document represents a chronological outline of the history of Sandia National Laboratories starting with the events leading to the formation of the Corporation and its subsequent founding and growth through 1963.

Biggs, J., 1991, "Sensitive Species Survey for Sandia National Laboratories Burn Site, KAFB, New Mexico," *CGI Report No. 8067AJ*, Chambers Group, Inc., Santa Ana, California.

Abstract: This document summarizes the results of a biological field investigation for SNL/NM. This document specifically addresses threatened, endangered, or otherwise sensitive plant and wildlife species as listed by the federal government and the state of New Mexico that possibly occur in the project area and does not constitute a complete biological assessment for the proposed project. However, a description of the area and its biological resources has been completed (see Chambers Group, Inc., 1991).

SNL/NM requested a survey of sensitive species for the existing Burn Site (Figure 1). The project area is approximately 40.0 acres in size and includes existing buildings, trailers, parking areas, and other structures, resulting in most of the area being disturbed to some degree.

The purpose of the survey was to ensure that future projects within the Burn Site will not result in adverse impacts to sensitive species actually or potentially occurring in this area. The primary objective of the field survey was to locate sensitive species and identify potential impacts to these species. This document discusses the potential impacts, if any, and mitigation measures necessary to minimize or eliminate any adverse impacts.

Information provided in this document was gathered from literature research, personal contact with state and federal natural resource agencies, and an on-site field survey.

Based on the results of this field survey, future construction and/or other activities conducted within the Burn Site boundaries should not result in impacts to the grama grass cactus or Wright's pincushion cactus.

Borland J.P., R.R. Cruz, R.L. McCracken, R.L. Lepp, D. Ortiz, and D.A. Shaull, 1991, "Water Resources Data New Mexico Year 1990," *Water Data Report NM-90-1*, U.S. Geological Survey, Albuquerque, New Mexico.

Summary: Water-resources data for the 1990 water year for New Mexico consist of records of discharge and water quality of streams; stage, contents and water quality of lakes and reservoirs; and water levels and water quality in wells and springs. This report contains discharge records for 167 gaging stations; stage and contents for 26 lakes and reservoirs; water quality for 59 gaging stations and 168 wells; and water levels at 114 observation wells. Also included are 109 crest-stage partial-record stations. Additional water data were collected at various sites, not involved in the systematic data collection program, and are published as miscellaneous measurements. Also, three seepage investigations are published this year. These data represent that part of the National Water Data system collected by the U.S. Geological Survey and cooperating state and federal agencies in New Mexico.

Brown, D.E., 1982, "Biotic Communities of the American Southwest United States and Mexico," *Desert Plants*, University of Arizona, Vol. 4, No. 1-4.

Summary: This special issue deals with the country between 27° and 37°30' N Latitude and 103° and 118° W Longitude. Although the "southwest" thusly defined clearly centers on Arizona and New Mexico, it also includes Baja California del Norte, major parts of Sonora, Chihuahua, California, Nevada and Texas, as well as minor parts of Baja California del Sur, Coahuila, Utah, and Colorado. This part of the North American continent is well known for its checkerboard of vegetation which includes major arid and subarid categories.

Chambers Group Incorporated, (CGI), 1989 Albuquerque, New Mexico. Summations of Cultural Resource Surveys

May 8, 1990 Project #8067X

A cultural resource review was conducted for a 39.37 acre area scheduled for incorporation into Sandia National Laboratories, Area III, through a land use permit with Kirtland Air Force Base (KAFB). The proposed extension area is currently located along the southern boundary of Parcel A for KAFB Management Area C. The short term effect will be the construction of a perimeter fence extension for enclosure of the approximate 39 acre area.

Summary: It is our opinion, based on the previous cultural resource survey, that the extension of the existing Area III boundary fence will have no effect on any significant cultural resources. Since no significant cultural resources will be effected by the proposed undertaking, cultural resource clearance is recommended for incorporation of the approximate 39 acre area into Area III. However, if any subsurface cultural resource manifestations are located during fence construction, or any future construction activities, work must be halted, and a qualified archaeologist notified.

May 8, 1990 Project #8067Y

A cultural resource review was conducted for a 204 acre area currently utilized by Sandia National Laboratories through a land use permit. The area, which currently serves as the Robotic Vehicle Range (RVR), is scheduled for two minor earth modifying construction projects.

Summary: It is the opinion of the Chambers Group, Inc., based on the previous cultural resource survey, that blading conducted within the RVR will have no effect on any significant cultural resources. Since no significant cultural resources will be effected by the proposed undertaking, cultural resource clearance is recommended for the limited earth modifying scheduled and anticipated for the range. If subsurface cultural resource manifestations are located during any construction or earth modifying activities, work must be halted, and a qualified archaeologist notified. With this stipulation, cultural resource clearance is recommended for any earth modifying activities conducted within the current Department of Energy land use permit area utilized as the RVR which is situated within Kirtland Air Force Base Management Area .

November 30, 1990 Project #8067AF

This letter is in response to an Sandia National Laboratories request for an Executive Order 11593 compliance cultural resource inventory of Sandia National Laboratories Area V.

Summary: The 28-acre area in question is devoted to reactor research and operations, and currently contains 19 permanent buildings and one substandard structure. Between previous blading and graveling, construction of facilities and their associated infrastructures, i.e., parking areas, utility lines, walkways, etc., there appear to be no earthen areas remaining that have not been extremely dislocated. Based on all this previous disturbance, it is extremely unlikely that any cultural resources would have survived these previous construction and landscaping activities. It is also very unlikely that any archaeological sites ever existed within this locale. However, if any subsurface cultural resource manifestations are located during fence construction, or any future construction activities, work must be halted, and a qualified archaeologist notified.

January 23, 1991

This letter deals with the eligibility of five historic sites recorded during the 1981 (Franklin and Neal) cultural resources survey of Kirtland Air Force Base (KAFB), Management Area G. These sites (NM I:15:3:9 through NM I:15:3:13) are documented as being features, foundations, and/or collapsed structures associated with 1910 to 1940, Anglo American ranch or mining activities.

Summary: Based on the negative State Historic Preservation Officer (SHPO) eligibility determination on the known cultural resources in the northern portion of KAFB Management Area G, and on the field reconnaissance performed by Mariah Associates Inc. (Lintz et. al. 1988:121), there are no known NRHP eligible cultural resources sites situated within the area you are considering. We therefore feel that, from a cultural resource perspective, there is no reason not to pursue a KAFB Use Permit for the northern portion of Management Area G.

Cordell, L.S., 1977 a, "The 1975 Excavation of Tijeras Pueblo, Cibola National Forest, New Mexico," *Archaeological Report No. 18*, USDA Forest Service, Southwestern Region, Albuquerque, New Mexico.

Summary: This report deals with the excavation at Tijeras Pueblo, east of Albuquerque, New Mexico. The ruin dates to the 14th century and underwent at least two population fluctuations. Three-ring dates, burial data, and summaries of the field work are presented.

Energy Research and Development Administration (ERDA), 1977, "Environmental Impact Statement," *EIA/MA 77-1*, Sandia Laboratories, Albuquerque, New Mexico.

Abstract: This omnibus Environmental Assessment describes the ongoing operations of the SNL Albuquerque (SNLA) and evaluates the actual and possible impacts on the environment that continuation of these operations entails. Since the Laboratories predates the National Environmental Policy Act of 1969 (NEPA) by two decades, there previously has been no overall formal retrospective environmental assessment of the whole of its facilities and operations, although each facility that post-dates NEPA has been assessed for its potential environmental impact.

The SNLA plant and facilities are owned by the U.S. Government, and are operated by the Bell System through a contract between the Western Electric Company and the U.S. Atomic Energy Commission (now the U.S. Energy Research and Development Administration [ERDA]) as a prime contractor (Sandia Corporation) of the ERDA.

All laboratory ongoing activities are discussed, except that this assessment does not evaluate the consequences of possible terrorist activity against the laboratory facilities, nor does it concern itself with transportation hazards outside Kirtland AFB East. Precautionary measures are in effect to assure that all nuclear materials are secure. The internal accounting system shows the locations and quantities of all nuclear materials at all times.

Fenneman, N.M., 1931, *Physiography of the United States*.

Original descriptions and maps of the physiographic provinces in the west, long recognized as the authority on physiography of the region. It includes a map of the basin and range provinces, including delineation of the Eastern Mexican Highlands region, the physiographic location of SNL/NM.

Fischer, N.T., 1990, "Revision of Species Inventory Checklists for Sandia National Laboratories, Albuquerque, New Mexico," *SAND90-7098*, Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: This report revises and updates the 1974 report by W. C. Martin and W. L. Wagner, *Biological Survey of KAFB (East).* The biological communities of Kirtland Air Force Base (KAFB) are described with respect to the biome classification system of Brown (1982), and a standardized system of habitat types is proposed based on biome and soil type. The potential occurrence of State or Federally endangered species if discussed. No species listed as endangered or threatened is known to occur on KAFB, although five are identified as potentially occurring. Updated lists of amphibians, reptiles, breeding birds, mammals, and plants are presented.

Furman, N.S., 1990, *Sandia National Laboratories: The Postwar Decade*, University of New Mexico Press, Albuquerque, New Mexico, 858 pp.

The development of Sandia Corporation is given from its origin at Los Alamos to its development at Albuquerque, Tonopah, and the test sites in the Pacific. This book is informative and gives personnel perspectives on the development of Sandia Corporation.

Goodrich, M.T., 1991, "Preliminary Report on a Surface Gravity Survey for Fault Delineation and Hydrogeologic Characterization," *SAND81-7141*, Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: The Albuquerque Basin is one of a north-south trending line of basins that make up the Rio Grande Rift Zone. KAFB is located on the eastern edge of the basin in an area of complex faulting. Monitoring well water levels measured on KAFB indicate a natural, westward hydraulic gradient of about 0.005 that changes sharply to about 0.07 near the fault zone. Depth to groundwater is about 50 feet on the east side of the faults and about 500 feet on the west. Because inactive hazardous waste sites exist on both sides of the faults, reducing uncertainty about the location and structure of the faults, and the rate and direction of groundwater flow near the faults, is critical to predicting the potential subsurface fate of contaminants.

Six monitoring wells are to be drilled in an east-west line perpendicular to the estimated fault locations. To help site those wells, a surface gravity survey was performed to more accurately describe the fault complex. The survey was made along 5 east-west transects in the southern portion of KAFB. The gravitational anomaly caused by the large limestone and granite mass that comprises bedrock in this area is distinguishable from the overlying alluvial materials and other surface features when the appropriate terrain, elevation, latitude, and density corrections are made to the field data. Hence, the depth to bedrock can be estimated and fault locations inferred where the depth changes.

Results indicate the depth to bedrock varies from about 90 feet east of the faults to well over 700 feet to the west. The structure is consistent with an en echelon pattern and shows an eastward tilt to the fault blocks. The data were used to site six monitoring wells such that they can be completed in different fault blocks and can yield the most information about ground-water flow and contaminant transport. The results will be further calibrated when drilling commences and the true depth to bedrock is known.

Grant, P.R., 1981, "Geothermal Potential on Kirtland Air Force Base Lands, Bernalillo County, New Mexico," *SAND81-7141*, Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: The Rio Grande Rift has been identified as a major geothermal resource area. The western part of Kirtland Air Force Base is in the Albuquerque Basin segment of the Rio Grande Rift. Extensive sampling and geochemical analysis of groundwater in and near the base disclosed no significant geothermal parameters.

Evidence is presented for a shallow magma body beneath the Albuquerque Basin; favorable terrestrial heat flow, water chemistry, and shallow temperature gradient holes on the nearby mesa west of the Rio Grande; interpretation of regional gravity data; and geological data from nearby deep wells tend to confirm structural, stratigraphic, and hydrologic conditions favorable for developing an extensive intermediate to high-temperature hydrothermal regime on portions of Kirtland Air Force Base lands where intensive land use occurs.

Hansen, R.P., 1995, "National Environmental Policy Act (NEPA) Compliance Guide Sandia National Laboratories," SAND95-1648, Sandia National Laboratories, New Mexico.

Abstract: This report contains a comprehensive National Environmental Policy Act (NEPA) Compliance Guide for the Sandia National Laboratories. It is based on the Council on Environmental Quality (CEQ) NEPA regulations in 40 CFR Parts 1500 through 1508; the U.S. Department of Energy (DOE) NEPA implementing procedures in 10 CFR Part 1021; DOE Order 5440.1E; the DOE "Secretarial Policy Statement on the National Environmental Policy Act" of June 1994; Sandia NEPA compliance procedures; and other CEQ and DOE guidance. The Guide includes step-by-step procedures for preparation of Environmental Checklists/Action Descriptions Memoranda (ECL/ADMs), Environmental Assessments (EAs), and Environmental Impact Statements (EISs). It also includes sections on "Dealing With NEPA Documentation Problems" and "Special NEPA Compliance Issues."

Harris, J.M., 1995, "Annotated Bibliography of National Environmental Policy Act (NEPA) Documents for Sandia National Laboratories," SAND94-2032, Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: The annotated bibliography lists documents prepared by the Department of Energy (DOE), and predecessor agencies, to meet the requirements of the National Environmental Policy Act (NEPA) for activities and facilities at Sandia National Laboratories sites. For each NEPA document summary information and a brief discussion of content is provided. This information may be used to reduce the amount of time or cost associated with NEPA compliance for future Sandia National Laboratories projects. This summary may be used to identify model documents, documents to use as sources of information, or documents from which to tier additional NEPA documents.

Hawley, J.W., and C.S. Haase, 1992, "Hydrogeologic Framework of the Northern Albuquerque Basin," New Mexico Bureau of Mines and Mineral Resources Open-File Report 387.

Summary: In January 1992, the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) entered into a cooperative agreement with the City of Albuquerque Public Works Department to develop a conceptual hydrogeologic model for the Bernalillo County area of the northern Albuquerque Basin. The resultant characterization of the study area's hydrogeologic framework, which is described in this report, represents a significant advancement over previous models (e.g., Bjorklund and Maxwell, 1961; Kelly, 1974). The NMBMMR model will, therefore, provide a much improved basis for the development of numerical models of the basin's groundwater flow system (Kernodle, 1992). These, in turn, are absolutely essential for quantitative evaluation of future water-resource development and conservation strategies.

In its simplest form, the conceptual model is a description of the textural character, composition, and geometry of (1) the various parts of the Santa Fe Group, which is the major geological unit that fills the Albuquerque Basin (as well as other intermontane basins of the Rio Grande rift region) and (2) the overlying river-valley and basin-fill deposits. When firmly based on adequate subsurface geological and geophysical data, the model describes the "architecture" of basin and valley fills with respect to the three-dimensional distribution of mappable subdivisions that have distinct differences in geophysical and geological properties and aquifer characteristics.

The conceptual model has three basic components, which are graphically presented in a map and cross-section format (Plates 1 through 7):

- Structural and bedrock features include basin-bounding mountain uplifts, bedrock units beneath the basin fill, fault zones within and at the edges of the basin that influence sediment thickness and composition, and igneous intrusive and extrusive (volcanic) rocks that penetrate or overlap basin-fill deposits.

- Hydrostratigraphic units comprise mappable bodies of basin and valley fill that are grouped on the basis or origin and position in a stratigraphic sequence. Genetic classes include ancestral-river, present river valley, basin-floor playa, and alluvial-fan piedmont deposits. Time-stratigraphic classes include units deposited during early, middle, and late stages of basin filling (i.e., lower, middle, and upper Santa Fe Group), and post-Santa Fe valley and basin fills (e.g., channel and floodplain deposits beneath the modern valley floors or preserved as alluvial terraces).

- Lithofacies units are the fundamental building blocks of the model. Lithofacies are mappable bodies defined on the bases of texture, mineralogy, sedimentary structures, and degree of postdepositional alteration. They have distinctive differences in geophysical and geochemical properties and in hydrologic behavior. In this study, basin deposits are subdivided into ten lithofacies and associated sublithofacies, and their three-dimensional distribution is described.

This open-file report has been released primarily to allow immediate use of the information that it contains by the City of Albuquerque and cooperating water resource agencies such as the U.S. Geological Survey and the Bureau of Reclamation. Formal publication was planned for 1993 as part of the NMBMMR Hydrologic Report Series (No. 8). The document is organized into nine major sections, including an expanded list of technical references, with supporting data in eight appendices, and a glossary of geological terms.

The conceptual model of the Albuquerque area's hydrogeologic framework developed for this report (Plates 1 through 7 and the color-coded three-dimensional arrangement of these plates) is clearly what its name implies:

- It is only a *model* of a very complex, real-world system (Kernodel, 1992, pp. 6-7).

- The intellectual construct that is a *concept* can only be as good as the quality of the scientific information used in its development.

- The models' graphic portrayal is at least partly an artistic effort that reflects the talents of its creator (or lack thereof).

The authors of this report believe that the major features of the model will stand the test of time but that there will also always be need (and space) for improvements. The positive feedback loop between assimilation of additional scientific information and improved conceptualization and artistic skill will continue to be enhanced as the model is being tested and further developed.

Hoagland, S.R., 1992, "Cultural Resources Regulatory Analysis, Area Overview, and Assessment of Previous Department of Energy and Kirtland Air Force Base

Inventories for Sandia National Laboratories," Chambers Group, Inc., Santa Ana, California.

Abstract: On September 1, 1989, Sandia National Laboratories (SNL) contracted Chambers Group Inc. (CGI) to provide consulting services in the areas of archaeological research and investigation, architectural and historic resource identification and preservation, and related regulatory analysis and coordination as required to facilitate SNL's compliance with all applicable laws, regulations, guidelines and policies governing properties controlled by the U.S. Department of Energy (DOE), and occupied by SNL. The contract involved the production of a regulatory analysis and literature review of archaeological and historic resources on the SNL-occupied properties. The contract was amended on February 28, 1991, to encompass production of a document to be used to facilitate future project planning, environmental assessments, and the protection of significant cultural resources.

This document included the regulatory discussion and, based on the literature review, a brief overview of known historic and prehistoric resource utilization at SNL, Kirtland Air Force Base (KAFB) and vicinity. It also contained details of the work conducted on DOE controlled lands and a generalization of previous work conducted on KAFB and United States Forest Service (USFS) Withdrawal Lands. To aid in this discussion a map depicting previously inventoried locales and a corresponding table detailing the results were to be produced. Finally, there was a discussion by general areas at SNL, KAFB, and USFS Withdrawal Lands as to their potential for containing significant cultural resources. This report is the document produced in response to the above noted contract requirements.

Hoagland, S.R., 1992, "A Cultural Resources Survey of 56.7 Acres for Sandia National Laboratory's Containment Technology Test Facility-West Land Use Permit, Kirtland Air Force Base, New Mexico," Butler Service Group, Inc., Albuquerque, New Mexico.

Abstract: An archaeological survey of 56.7 acres of property situated within Kirtland Air Force Base (KAFB), Bernalillo County, New Mexico, yielded no significant cultural resources. The area surveyed is located west and southwest of a knoll situated just south southwest of the Four Hills (KAFB Manzano Area). This project site, which is located a short distance west of Lovelace Road, is situated on the western piedmont of the Manzanita Mountains, south of Albuquerque, New Mexico. The survey was conducted for Sandia National Laboratories proposed Containment Technology Test Facility-West (CTTF-West) Land Use Permit.

No significant cultural resource sites were located during the pedestrian survey. The results of this survey concur with a previous cultural resource inventory conducted for KAFB Management Area B, which included this proposed permit area. This previous survey, which was conducted by the Center for Anthropological Studies in 1979 (Rodgers 1980), located no significant archaeological sites.

The current inventory resulted in the recordation of one isolated occurrence. It was a white chalcedony interior flake located on the northern edge of a very small knoll. This lithic artifact could potentially be affected by activities conducted within the use permit area. However, due to assumed lack of associated subsurface deposits and to the recordation of the artifact, it is the opinion of the author that the isolated occurrence is no longer potentially significant. Based on the apparent lack of significant intact archaeological remains, cultural resource clearance is recommended for use and potential construction within the proposed Sandia National Laboratories 56.7 acre Containment Technology Test Facility-West Land Use Permit.

Hoagland, S.R., 1991, "A Cultural Resources Survey Conducted in the Vicinity of the Sandia National Laboratories Burn Site, Kirtland Air Force Base, New Mexico," *CGI Report 8067AF*, Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: An archaeological survey was conducted on approximately 1,447 acres of property situated within Kirtland Air Force Base (KAFB), Bernalillo County, New Mexico. This survey was conducted on the Burn Site, New Cable Site and portions of the surrounding area for Sandia National Laboratories (SNL). These test facility sites are located within and along ridges forming portions of Lurance, Sol se Mete, and Madera Canyons. These canyons are a portion of the system which drainages the foothills and western piedmont of the Manzanita Mountains. This portion of KAFB, which is situated south-southeast of Albuquerque, New Mexico, is located within Cibola National Forest Withdrawn Lands. These withdrawn lands are currently utilized by SNL/NM through land use permits from KAFB.

This inventory yielded one previously recorded and 33 newly discovered cultural resource sites and 88 isolated occurrences (IOs). Of these, one was a multicomponent prehistoric/historic site and 26 were prehistoric sites ranging in affiliation from the Late Archaic and/or Basketmaker periods through to the Classic Anasazi period. Six were historic sites apparently associated with the mining activities periodically conducted in the area during the first half of the 20th century. The remaining historic site (LA 81730) has a potential lime kiln and associated structures that may date to the late 19th or early 20th century.

Four of the prehistoric sites which appear to lack intact subsurface remains are no longer thought to be significant as their informational value has been mitigated through recordation. The six 20th century historic sites are also no longer thought to be eligible as site recordation has collected the potentially significant information not contained in historic documentation.

The historic kiln(?) site and 23 of the sites with prehistoric components are thought to be potentially eligible for inclusion onto the National Register of Historic Places under criterion (d), as they are likely to contain or have potential to contain significant intact cultural deposits. It is recommended that all of these sites be avoided and protected from any future adverse impacts.

Three of these potentially eligible sites (LA 81724, LA 81730, and LA 81734) are likely to be adversely impacted by continued road maintenance activities or through continued testing in the area. It is, therefore, recommended that road maintenance activities be ceased and/or new alignments considered and that the explosive detonations be ceased or relocated. If these alternatives are not feasible then an archaeological testing program should be conducted to determine whether significant cultural remains are being adversely effected.

All of the artifacts and features recorded as isolated occurrences are no longer thought to be potentially significant as adverse effects were mitigated through field recordation.

Hoagland, S.R., 1991, "An Evaluation for National Register of Historic Places Eligibility of Sandia National Laboratory's Buildings 814 and 815, Kirtland Air Force Base, New Mexico," Butler Service Group, Inc., Albuquerque, New Mexico.

Abstract: A National Register of Historic Places (NRHP) evaluation has been conducted for Sandia National Laboratories (SNL) Buildings 814 and 815. This evaluation was conducted in response to a New Mexico State Historic Preservation Officer (SHPO) response (Lynne Sebastian, letter of 7/12/91 to Albert Chernoff) that questioned the significance of these and five other early laboratory buildings. The SHPO response went on to recommend that historical and architectural evaluations be conducted as soon as possible since these buildings were rapidly approaching 50 years of age.

This evaluation was conducted on Buildings 814 and 815 as they are scheduled to be razed as soon after Christmas 1991 as possible. The assessment of these structures suggest that they are not eligible for inclusion in the NRHP under any of the criterion, nor are they eligible as part of or as a district. These two buildings are, therefore, no longer thought to be significant as potential important information has been recovered and preserved through recordation and existing documentation. Based on this finding, it is recommended that a determination of no effect be requested from the Department of Energy and the SHPO for the proposed razing of SNL Buildings 814 and 815.

Hoagland, S.R., 1990, "A Cultural Resource Survey and Literature Review for Construction of a Proposed Sewer Line System Within Area III, Sandia National Laboratories, and Kirtland Air Force Base, New Mexico," Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: An archaeological survey of approximately 14 acres of property situated within Area III, Sandia National Laboratories, Kirtland Air Force Base (KAFB), Bernalillo County, New Mexico, yielded no cultural resources. The area surveyed is located on the western piedmont of the Manzano Mountains, south of Albuquerque, New Mexico. The survey was conducted for an approximate 7.4 k (4.6 mi) portion of a proposed 19.3 k (12 mi)-long sanitary sewer system to be constructed as a trunk line and five laterals. All of the proposed alignments situated within SNL/NM Area III were surveyed at a 8 m (25 ft) width. No significant artifacts or cultural features were observed within any of the proposed alignments.

The additional 11.9 k (7.4 mi) of sewer trunk line and lateral segments are proposed for construction on KAFB properties. These remaining sections of sewer line were not resurveyed as the areas were previously inventoried in 1979 through 1981 by the Center for Anthropological Studies. The proposed portions of sewer line scheduled for construction on KAFB will not impact any of the previously recorded historic or prehistoric sites.

Cultural resource clearance is, therefore, recommended for construction of the entire 19.3-kilometer-long proposed sewer line system as no significant cultural resources will be effected by this proposed undertaking.

Hoagland, S.R., 1990, "A Cultural Resource Survey for Several Proposed Multiple Exterior Improvements Situated Within Areas I, II, and IV, Sandia National Laboratories, Kirtland Air Force Base, New Mexico," *CGI Project 8067P*, Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: An archaeological inventory for multiple exterior improvement projects situated on approximately 31.7 acres of property located within Areas I, II, and IV, Sandia National Laboratories (SNL), Kirtland Air Force Base, Bernalillo County, New Mexico, yielded no cultural resources. The inventoried areas are located on the western piedmont of the Manzano Mountains, south of Albuquerque, New Mexico. The Area I investigations include an approximate 18.5 acre (99-percent paved) parking area situated south of Facility 825, a 3.2-acre gravel and dirt parking lot located east of Facility 887, a 0.46-acre area proposed for a paved extension of "K" Street, concrete lining for 0.25 acres forming an existing drainage ditch, and about 0.37 acres in a 413-meter-long (4-m wide) proposed sewer route. Other investigations include 0.92 acres included in a 609-m long (20-ft wide) natural gas line route proposed for SNL Areas II and IV, and 8.0 acres for a paved and graveled parking area located in Area IV.

No significant artifacts or cultural features were observed within any of the proposed construction locals. Cultural resource clearance is, therefore, recommended for construction of the three parking lots, the concrete ditch lining, the "K" Street extension, the sewer line segment, and the proposed natural gas line as no significant cultural resources will be effected by these proposed undertakings.

Hoagland, S.R., 1990, "A Cultural Resources Survey and Review for Sandia National Laboratories, Area I, North of O Street, Kirtland Air Force Base, New Mexico," *CGI Report 8067Z*, Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: A cultural resources inventory of Area 1, North of "O" Street, an approximately 365-acre locale, situated on Sandia National Laboratories (SNL), Kirtland Air Force Base, Bernalillo County, New Mexico, yielded no prehistoric or historic significant cultural resources. This portion of Area I is the highly disturbed main facilities complex situated at SNL. The investigated area is located on the western piedmont of the Manzano Mountains, south of Albuquerque, New Mexico. This inventory included an archaeological survey of approximately 87 acres of the Department of Energy (DOE)-owned property and an inventory and review of the buildings located throughout the area. The survey and review was conducted in compliance with Executive Order 11593, which directs Federal Agencies to inventory for National Register of Historic Places (NRHP) eligible cultural resources on all properties under their ownership or control. As these properties are owned by DOE, SNL/NM is initiating the inventory process.

No archaeological properties were located, and the existing facilities lack sufficient antiquity to be considered eligible for inclusion in the NRHP. Therefore, it is felt that no significant cultural artifacts, features or structures qualifying under NRHP criterion (d) ("have or likely to yield information important in prehistory or history") are present in the area north of "O" Street.

Hoagland, S.R., 1990, "A Cultural Resources Survey and Review for Sandia National Laboratories, Area I, South of O Street, Kirtland Air Force Base, New Mexico," *CGI Report 8067AB*, Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: A cultural resources inventory of Sandia National Laboratories (SNL), Tech Area 1, South of "O" Street, which is located in Kirtland Air Force Base, Bernalillo County, New Mexico, yielded no prehistoric or historically significant cultural resources. This portion of Area I containing approximately 432 acres is located on the western piedmont of the Manzano Mountains, south of Albuquerque, New Mexico. The survey and review was conducted in compliance with Executive Order 11593, which directs Federal Agencies to inventory for National Register of Historic Places eligible cultural resources on all properties under their ownership or control. As these properties are owned by Department of Energy, SNL/NM is initiating the inventory process.

An historic trash dump apparently dumped in the late 1950s and the few existing facilities appear to lack sufficient antiquity to be considered eligible for inclusion to the NRHP. An isolated obsidian decortication flake was also documented, however, it is no longer thought to be potentially significant as adverse effects were mitigated through field recordation. Detailed recordation of the dump should also facilitate a no adverse effect determination for the dump should future earth modifying activities be conducted in its vicinity. Therefore, it is felt that no significant cultural artifacts, features or structures qualifying under NRHP criterion (d) ("have or likely to yield information important in prehistory or history") are present in Tech Area I, south of "O" Street.

It is recommended that a more formal evaluation be conducted on remaining structures scheduled for remodeling or demolition when they reach 50 years of age or older. This examination and evaluation should be undertaken to document the construction style and methods and to determine the degree and nature of previous remodeling and modernization. This assessment should be geared toward verifying the NRHP eligibility of the structure(s), thus conducted by a qualified historical architect or architectural historian. Without additional antiquity (if then), it is felt that these facilities are not currently eligible to the NRHP.

Hoagland, S.R., 1990, "A Cultural Resources Survey and Review for Sandia National Laboratories, Area II, Kirtland Air Force Base, New Mexico," "*CGI Report 8067AC*, Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: A cultural resources inventory of Area II, an approximately 45.5 acre locale, situated on Sandia National Laboratories (SNL), Kirtland Air Force Base, Bernalillo County, New Mexico, yielded no prehistoric or historically significant cultural resources. The investigated area is located on the western piedmont of the Manzano Mountains, south of Albuquerque, New Mexico. This inventory and review was conducted in compliance with Executive Order 11593, which directs federal agencies to inventory for National Register of Historic Places (NRHP) eligible cultural resources, on all properties under their ownership or control. As these properties are owned by DOE, SNL is initiating the inventory process.

Area II has been extremely disturbed over the last 50 years. In fact, based on a reconnaissance of the area, there are currently no locales situated within Area II that have not been severely disturbed in the past. No prehistoric or historic cultural resources were observed and none are expected to have survived previous construction and earth modifying activities. The few existing facilities lack sufficient antiquity to be considered eligible for inclusion in the NRHP. Therefore, it is felt that no significant cultural artifacts, features or structures qualifying under NRHP criterion (d) ("have or likely to yield information important in prehistory or history") are present within Area II.

It is recommended that a more formal evaluation be conducted on remaining structures scheduled for remodeling or demolition in 1998 or later when they would be 50 years old or older. This examination and evaluation should be undertaken to document the construction style and methods and to determine the degree and nature of previous remodeling and modernization. This assessment should be geared toward verifying the NRHP eligibility of the structure, thus conducted by a qualified historical architect or architectural historian. Without additional antiquity (if then), it is felt that these facilities are not currently eligible to the NRHP.

There is the possibility that one of two originally similar structures is associated with a significant historical event, thus potentially qualifying for inclusion onto the NRHP

under criterion (a) ("association with events that have made a significant contribution to the broad patterns of our history"). The first hydrogen bomb was assembled in Building 904 or 907 (Doug Dugan, SNL Org. 2514, personal communication), which could be considered by some to be a major contribution to our history. It is, therefore, recommended that this structure be identified and its NRHP eligibility be assessed prior to conducting any additional renovations or to its demolition.

Hoagland, S.R., 1990, "A Cultural Resources Survey and Review for Sandia National Laboratories, Area IV, Kirtland Air Force Base, New Mexico," *CGI Report 8067AD*, Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: A cultural resources inventory of Area IV, an approximately 67.4 acre-locale, situated on Sandia National Laboratories (SNL), Kirtland Air Force Base, Bernalillo County, New Mexico, yielded no prehistoric or historically significant cultural resources. The investigated area is located on the western piedmont of the Manzano Mountains, south of Albuquerque, New Mexico. This inventory and review was conducted in compliance with Executive Order 11593, which directs Federal Agencies to inventory for National Register of Historic Places (NRHP) eligible cultural resources on all properties under their ownership or control. As these properties are owned by the Department of Energy, SNL is initiating the inventory process.

Area IV has been extremely disturbed with all locales not containing structures having been bladed, landscaped, graveled, and/or paved. In fact, based on a reconnaissance of the area, there are currently no locales situated within Area IV that have not been severely disturbed in the past. No prehistoric or historic cultural resources were observed, and none are expected to have survived previous construction and earth modifying activities. The few existing facilities lack sufficient antiquity to be considered eligible for inclusion in the NRHP. Therefore, it is felt that no significant cultural artifacts, features, or structures qualifying under NRHP criterion (d) ("have or likely to yield information important in prehistory or history") are present in the area.

It is recommended that a more formal evaluation be conducted on remaining structures scheduled for remodeling or demolition when the oldest structure would become 50 years old, or later as the other structures also become potentially eligible. This examination and evaluation should be undertaken to document the construction style and methods, and to determine the degree and nature of previous remodeling and modernization. This assessment should be geared toward documenting the NRHP eligibility of the structure, thus conducted by a qualified historical architect or architectural historian. Without additional antiquity (if then), it is felt that these facilities are not currently eligible to the NRHP.

Hoagland, S.R., 1990, "A Cultural Resources Survey and Review for Sandia National Laboratories, Area III, Kirtland Air Force Base, New Mexico," *CGI Report #8067AE*, Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: A cultural resources inventory of Tech Area III, an approximately 1,890-acre locale, situated on Sandia National Laboratories (SNL), Kirtland Air Force Base, Bernalillo County, New Mexico, yielded no prehistoric or historically significant cultural resources. The investigated area is located on the western piedmont of the Manzano Mountains, south of Albuquerque, New Mexico. This inventory and review was conducted in compliance with Executive Order 11593, which directs Federal Agencies to inventory for National Register of Historic Places (NRHP) eligible cultural resources, on all properties under their ownership or control. As these properties are owned by DOE, SNL is initiating the inventory process.

Tech Area III has been extremely disturbed over the last 50 years. Much of this previous disturbance appeared to be the byproduct of tests involving explosives or the construction of facilities, test equipment and targets, and their associated infrastructures.

Twenty-three isolated occurrences (IOs) were located within the boundaries of SNL Tech Area III. The IOs consisted of historic trash, historic and/or prehistoric chipped stone items, and prehistoric pot sherds. All of these items appear to represent isolated activities. There is no indication that any subsurface cultural resources are in association with any of these artifacts. Due to the assumed lack of subsurface deposits and to the recordation of the observed artifacts, it is the opinion of the author that these cultural materials are no longer significant. The few existing facilities lack sufficient antiquity to be considered eligible for inclusion in the NRHP. Therefore, it is felt that no significant cultural artifacts, features or structures qualifying under NRHP criterion (d) ("have or likely to yield information important in prehistory or history") are present within Area III.

It is recommended that a more formal evaluation be conducted on remaining structures scheduled for remodeling or demolition as they become 50 years old or older. This examination and evaluation should be undertaken to document the construction style and methods, and to determine the degree and nature of previous remodeling and modernization. This assessment should be geared toward verifying the NRHP eligibility of the structure, thus conducted by a qualified historical architect or architectural historian. Without additional antiquity (if then), it is felt that these facilities are not currently eligible to the NRHP. Therefore, there appear to be no cultural resources located within Area III that are currently eligible for inclusion onto the NRHP under any of the eligibility criterion.

Hoagland, S.R., 1989, "A Cultural Resource Survey of Approximately 37 Acres Proposed for Construction of Infrastructures at Sandia National Laboratories, Kirtland Air Force Base, New Mexico," Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: An archaeological survey of approximately 37 acres situated on Sandia National Laboratories, Kirtland Air Force Base, Bernalillo County, New Mexico, yielded no significant cultural resources. The area surveyed is located on the west piedmont of the Manzanita Mountains, south of Albuquerque, New Mexico. The proposed project area is scheduled for construction of a track, a road and road extension, a parking lot and an unknown number of utility lines. The proposed construction zone has previously been disturbed by blading and asphalt paving during the 1940s for use as an aircraft parking area. No significant prehistoric or historic artifacts were observed within the survey area. Cultural resource clearance is, therefore, recommended for construction of the above-listed facility support modifications.

Hoagland, S.R., 1989, "A Cultural Resources Survey of 5.66 Acres Slated for Construction of an Integrated Materials Research Laboratory and Powerline, Kirtland Air Force Base, New Mexico," Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: An archaeological survey has recently been completed by Chambers Group, Inc., for 5.66 acres of land situated on Sandia National Laboratories, Kirtland Air Force Base, Bernalillo County, New Mexico. The survey was performed prior to construction on a 4.16 acre site of a building to serve as the Integrated Materials Research Laboratory (IMRL) and 1.6 acres in an alignment proposed for a new 115-kv powerline. The proposed facility construction zone and most of the powerline alignment have been disturbed by previous activities. One isolated occurrence (IO) was located along the portion of powerline exhibiting the least amount of previous disturbance. This IO consists of several shards of aqua-colored bottle glass. These shards appear to be from the same vessel, thus representing a single isolated activity. There is no indication that any subsurface cultural resources are in association. Due to the assumed lack of subsurface deposits and to the recordation of the observed artifact, cultural resource clearance is recommended for construction of both the IMRL facility and the proposed powerline.

Hoagland, S.R., 1989, "A Cultural Resources Survey of 21.7 Acres Slated for Construction of an Explosive Components Facility for Sandia National Laboratories, Kirtland Air Force Base, New Mexico," *CGI Report 8067G*, Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: An archaeological survey has recently been completed by Chambers Group, Inc., for 21.7 acres of land situated on Sandia National Laboratories, Kirtland Air Force Base, Bernalillo County, New Mexico. The survey was performed prior to construction on a 21.5-acre building site to serve as the Explosive Components Facility (ECF) and 0.26 acres in a road segment proposed for access. Three isolated occurrences (IO) were located within the proposed facility construction site. These IOs include a limestone flake that is likely a "road-a-fact," a concentration of aqua-colored flat (windowpane-like) bottle glass, and a partially crushed enamel-coated pan. These artifacts appear to represent three separate isolated activities. There is no indication that any subsurface cultural resources are in association with any of these IOs. Due to the assumed lack of subsurface deposits and to the recordation of the observed artifacts, cultural resource clearance is recommended for construction of the Explosive Components Facility and associated access road.

Hoagland, S.R., 1989, "A Cultural Resources Survey of 13.1 Acres Slated for Construction of the Deployable Seismic Verification System Site II for Sandia National Laboratories, Kirtland Air Force Base, New Mexico," *CGI Report 8067I*, Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: An archaeological survey has recently been completed by Chambers Group, Inc., for 13.1 acres of land leased by Sandia National Laboratories from Kirtland Air Force Base, Bernalillo County, New Mexico. The survey was performed prior to construction on a 10.6-acre building site of a facility to serve as the Deployable Seismic verification System Site II and on a 2.5-acre alignment scheduled for construction as an access road. One isolated occurrence (IO) was located within the proposed facility construction site. The IO was a limestone decortication flake that appears to represent a single isolated activity. There is no indication that any subsurface cultural resources are in association with this flake. Due to the assumed lack of subsurface deposits and to the recordation of the observed artifact, it is the opinion of the author that cultural resource clearance should be granted for construction of the Deployable Seismic Verification System Site II and for its associated access road.

Hoagland, S.R., "A Cultural Resource Survey for Proposed Construction of an Overhead Power Line, Four Substations, and CNSAC Facility, for Sandia National Laboratories, Kirtland Air Force Base, New Mexico," *CGI Project 80670*, Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: An archaeological survey of approximately 11.8 acres of property situated within Area I, Sandia National Laboratories, Kirtland Air Force Base, Bernalillo County, New Mexico, yielded no cultural resources. The area surveyed is located on the western piedmont of the Manzano Mountains, south of Albuquerque, New Mexico. The survey was conducted for an approximate 2.9-k (1.8-mi) segment, 6.4 acres, of a proposed overhead power line, 1.7 acres of property situated within four proposed power line substations and about 3.7 acres scheduled to be impacted during construction of a proposed Center for National Security and Arms Control. No significant artifacts or cultural features were observed within any of the proposed construction locales.

Cultural resource clearance is recommended for construction of the power line, substations, and Center for National Security and Arms Control Facility as no significant cultural resources will be effected by this proposed undertaking.

Hoagland, S.R., "A Cultural Resources Survey of 45.8 Acres for Use Permit No. DACA 47-4-70-141, Kirtland Air Force Base, New Mexico, for Sandia National Laboratories," *CGI 8067AH*, Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: An archaeological survey of approximately 45.8 acres of property situated within Kirtland Air Force Base (KAFB), Bernalillo County, New Mexico, yielded no significant cultural resources. The area surveyed is located in the bottom of a small unnamed drainage situated at the western base of the Manzanita Mountains, south southeast of Albuquerque, New Mexico. The survey was conducted for a continuation and extension of KAFB Use Permit DACA 47-4-70-141 established between Sandia National Laboratories and KAFB.

The permit area has been extensively disturbed by use of the area over the past twenty to thirty years. In part due to this previous disturbance and the fact that much of the area is situated within the valley drainage bottom and within the floodplain, no significant cultural resource sites were located.

The results of this survey concur with previous cultural resources inventories conducted on KAFB which included this proposed Permit Area. These surveys were conducted by the Center for Anthropological Studies in 1978 and 1980 (Rodgers 1978; Franklin 1981). No significant archaeological sites were located within the Permit Area during either of these previous projects. All observed isolated occurrences (IOs) were collected.

Four isolated occurrences were located during this current inventory, however, only one of these was physically situated within the Permit Area. This IO (#4) could potentially be affected by activities conducted within the use area. The three isolated occurrences situated outside the Permit Area should not be impacted by activities conducted from the locality. Isolated Occurrence #1 (two lithics) has previously been impacted by grading of a dirt road which aids in providing access to the Permit Area. These isolated artifacts could sustain additional impacts from future grading activities. However, all of the artifacts and features recorded as IOs, are no longer thought to be potentially significant as adverse effects were mitigated through field recordation. Based on the apparent lack of significant intact cultural resources, clearance is recommended for the 19.28-acre area established in KAFB Use Permit DACA 47-4-70-141 and for the proposed 26.52 acre addition.

Hoagland, S.R., "A Cultural Resources Survey of 65 Acres for Use Permit No. DACA 47-4-70-141, Kirtland Air Force Base, New Mexico, for Sandia National Laboratories," Chambers Group, Inc., Albuquerque, New Mexico.

Abstract: An archaeological survey of approximately 65 acres of property situated within Kirtland Air Force Base (KAFB), Bernalillo County, New Mexico, yielded no significant cultural resources. The area surveyed is located in the bottom of a small unnamed drainage situated at the western base of the Manzanita Mountains, south southeast of Albuquerque, New Mexico. The survey was conducted for a continuation and extension of KAFB Use Permit DACA 47-4-70-141 established between Sandia National Laboratories and KAFB.

The permit area has been extensively disturbed by use of the area over the past twenty to thirty years. In part due to this previous disturbance and the fact that much of the area is situated within the valley drainage bottom and within the floodplain, no significant cultural resource sites were located.

The results of this survey concur with previous cultural resources inventories conducted on KAFB which included this proposed Permit Area. These surveys were conducted by the Center for Anthropological Studies in 1978 and 1980 (Rodgers 1978; Franklin 1981). No significant archaeological sites were located within the Permit Area during either of these previous projects. All observed isolated occurrences (IOs) were collected.

Four isolated occurrences were located during this current inventory, however, only one of these was physically situated within the Permit Area. This IO (#4) could potentially be affected by activities conducted within the use area. The three isolated occurrences situated outside the Permit Area should not be impacted by activities conducted from the locality. Isolated Occurrence #1 (two lithics) has previously been impacted by grading of a dirt road which aids in providing access to the Permit Area. These isolated artifacts could sustain additional impacts from future grading activities. However, all of the artifacts and features recorded as IOs, are no longer thought to be potentially significant as adverse effects were mitigated through field recordation. Based on the apparent lack of significant intact cultural resources, clearance is recommended for the 45.8 acre area established in KAFB Use Permit DACA 47-4-70-141 and for the proposed 19.3 acre addition.

Hoagland, S.R., and R.D. Dello-Russo, 1995, "Cultural Resource Investigation for Sandia National Laboratories, New Mexico, Environmental Restoration Project, Kirtland Air Force Base, New Mexico," Butler Service Group, Inc., Albuquerque, New Mexico.

Abstract: Butler Service Group, Inc. (BSG), has completed a 100-percent pedestrian cultural resources survey and records review for approximately 2,445.4 acres of property situated on Kirtland Air Force Base (KAFB), New Mexico. The survey was conducted through IT Corporation (IT) for the Sandia National Laboratories, New Mexico (SNL/NM) Environmental Restoration (ER) Program. The 166 ER sites are scattered throughout KAFB, which includes properties under the jurisdiction of the U.S. Department of Defense (DoD); the U.S. Department of Energy (DOE); and the U.S. Forest Service (USFS) withdrawn properties in the Cibola National Forest. 1,635.8 acres of property were surveyed or resurveyed, and previous surveys for 809.6 acres of property were reviewed. Of the areas surveyed during the 1994 field season, 4.6 acres are located on DOE properties, 1,272.9 acres are located on DoD properties, and 358.3 acres are located on Cibola National Forest withdrawn properties. Of the previously surveyed areas that were reviewed, 596.3 acres are located on DOE properties, 27.9 acres are located on DoD properties, and 185.4 acres are located on

Cibola National Forest withdrawn properties. Three SNL/NM ER areas (20, 61B, and 225) were not inventoried during this phase of the project.

The survey and records review resulted in the documentation of 31 new sites, 39 previously recorded sites, and 128 isolated occurrences from the SNL/NM ER sites. Twenty-nine of the prehistoric sites, 15 of the historic sites, 13 of the historic/prehistoric sites, and the one site of unknown temporal affiliation are thought to be eligible or potentially eligible for the National Register of Historic Places (NRHP). Although the likelihood for significant remains is thought to be fairly limited for some sites, they are still listed as potentially eligible because it is uncertain that their research potential has been exhausted. The vast majority of the sites are considered eligible under criterion (d), sites that are "likely to yield information important in prehistory or history." Four sites, however, are potentially eligible under criterion (a), sites in "association with an event that has made a significant contribution to the broad patterns of our history," and/or criterion (c), sites with "distinctive characteristics of types, periods, and methods of construction." Some of these sites may also be eligible under criterion (d): One of these sites, SNL Technical Area II, may also be eligible under criterion (g), sites that are "properties that have achieved significance within the last 50 years."

All of the SNL/NM ER locales will be assessed for the presence of physical, chemical, and/or radiological contaminants that could require cleanup activities. However, as potential cleanup activities will depend on initial geophysical and radiological studies, specific impacts to ER sites and associated cultural resources will have to be determined on a site-by-site basis. All cultural resource sites listed as eligible or potentially eligible to the NRHP should be avoided. If avoidance is not feasible, further testing and/or additional research should be conducted on all potentially eligible sites for a definitive determination as to their eligibility. All unavoidable sites determined to be eligible to the NRHP and subject to potential damage will require the preparation and implementation of an approved data recovery plan to mitigate any adverse project effects. With implementation of an approved mitigation plan, there should be no adverse effects to any significant cultural resources. Therefore, a "Determination of No Adverse Effect" is recommended for the proposed undertakings associated with the SNL/NM Environmental Restoration Project.

Hoagland, S.R., and R. Dello-Russo, 1995, *Cultural Resource Investigation for Sandia National Laboratories/New Mexico Environmental Restoration Program, Kirtland Air Force Base, New Mexico*, Butler Service Group, Inc., Albuquerque, New Mexico.

Abstract: Butler Service Group, Inc. (BSG), has completed a 100 percent pedestrian cultural resources survey and records review for approximately 2,445.4 acres of property situated on Kirtland Air Force Base (KAFB), New Mexico. The survey was conducted through IT Corporation (IT) for the Sandia National Laboratories/New Mexico (SNL/NM) Environmental Restoration Program. The 166 ER sites are scattered throughout KAFB, which includes properties under the jurisdiction of the U.S. Department of Defense (DoD); the U.S. Department of Energy (DOE); and the

U.S. Forest Service (USFS) withdrawn properties in the Cibola National Forest. In all, 1,635.8 acres of property were surveyed or resurveyed, and previous surveys for 809.6 acres of property were reviewed. Of the areas surveyed during the 1994 field season, 4.6 acres are located on DOE properties, 1,272.9 acres are located on DoD properties, and 358.3 acres are located on Cibola National Forest withdrawn properties. Of the previously surveyed areas that were reviewed, 596.3 acres are located on DOE properties, 27.9 acres are located on DoD properties, and 185.4 acres are located on Cibola National Forest withdrawn properties. Three SNL/NM ER areas (20, 61B, and 225) were not inventoried during this phase of the project.

The survey and records review resulted in the documentation of 31 new sites, 39 previously recorded sites, and 128 isolated occurrences from the SNL/NM ER sites. Twenty-nine of the prehistoric sites, 15 of the historic sites, 13 of the historic/prehistoric sites, and the one site of unknown temporal affiliation are thought to be eligible or potentially eligible for the National Register of Historic Places (NRHP). Although the likelihood for significant remains is thought to be fairly limited for some sites, they are still listed as potentially eligible because it is uncertain that their search potential has been exhausted. The vast majority of the sites are considered eligible under criterion (d), sites that are "likely to yield information important in prehistory or history." Four sites, however, are potentially eligible under criterion (a), site in "association with an event that has made a significant contribution to the broad patterns of our history," and/or criterion (c), sites with "distinctive characteristics of types, periods, and methods of construction." Some of these sites may also be eligible under criterion (d). One of these sites, SNL Technical Area II, may also be eligible under criterion (g), "properties that have achieved significance within the last fifty years"

All of the SNL/NM ER locales will be assessed for the presence of physical, chemical, and/or radiological contaminants that could require cleanup activities. However, as potential cleanup activities will depend on initial geophysical and radiological studies, specific impact to ER sites and associated cultural resources will have to be determined on a site-by-site basis. All cultural resource sites listed as eligible or potentially eligible to the NRHP should be avoided. If avoidance is not feasible, testing and/or additional research should be conducted on all potentially eligible sites for a definitive determination as to their eligibility. All unavoidable sites determined to be eligible to the NRHP and subject to potential damage will require the preparation and implementation of an approved data recovery plan to mitigate any adverse project effects. With the implementation of an approved mitigation plan, there should be no adverse effects to any significant cultural resources. Therefore, a "Determination of No Adverse Effect" is recommended for the proposed undertakings associated with the SNL/NM Environmental Restoration Program.

Hudson, J. D., 1982, "Water-Table Map, Spring 1981, in the vicinity of the San Jose Well Field, Albuquerque, New Mexico," *Open File Report 82-375*, U.S. Geological Survey, Albuquerque, New Mexico.

Summary: In the spring of 1981, water level measurements were made within and near the San Jose well field in Albuquerque, New Mexico. The water-table contours have a steep eastward slope from the Rio Grande into the San Jose well field and a lesser slope eastward from the well field.

Hwang, S., G. Yeager, T. Wolff, A. Parsons, M. Goodrich, D. Dionne, C. Massey, B. Schwartz, J. Fish, and D. Thompson, 1991, "1990 Environmental Monitoring Report Sandia National Laboratories, Albuquerque, New Mexico," *SAND91-0592*, Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: This 1990 report contains monitoring data from routine radiological and nonradiological environmental surveillance activities. Summaries of significant environmental compliance programs in progress such as National Environmental Policy Act documentation, environmental permits, environmental restoration, and various waste management programs for Sandia National Laboratories in Albuquerque are included. The maximum off site dose impact was calculated to be 2.0×10^{-3} mrem. The total 50-mile population received a collective dose of 0.82 person-rem during 1990 SNL/NM operations as in the previous year, had no adverse impact on the general public or on the environment. This report is prepared for the U.S. Department of Energy in compliance with DOE Order 5400.1.

IT Corporation (IT), 1992, "Sandia National Laboratories, Albuquerque, Environmental Monitoring Plan," prepared for SNL/NM.

Abstract: SNL/NM conducts an environmental monitoring program in accordance with the requirements of DOE Order 5400.1, "General Environmental Protection Program," and DOE's "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance." This plan defines the scope and extent of SNL/NM effluent monitoring and environmental surveillance program during the facility's active lifetime.

IT Corporation (IT), 1991, "Report on Background Ground-Water Sampling at the Mixed Waste Landfill, Sandia National Laboratories, Albuquerque, New Mexico September 1990," prepared for SNL/NM.

Abstract: During the September 1990 sampling at MWL, samples were collected by dedicated pumping systems. Groundwater samples from MWL wells were analyzed for all RCRA ground water quality, drinking water supply, and contamination indicator parameters (40 CFR 265, Subpart F), as well as RCRA Appendix IX parameters and selected radionuclides.

No volatile or semivolatile organic compounds were detected in any September 1990 samples from MWL wells. Total organic carbon (TOC) and total organic halogen (TOX) were not detected above method reporting limits in any MWL samples.

Total metals detected were barium, chromium, and zinc. Dissolved metals detected were barium, nickel, lead, and zinc. All metals detected were at concentrations below the limits defined in the New Mexico Water Quality Regulations.

Four inorganic constituents were detected in all MWL wells: chloride, fluoride, nitrate, and sulfate. All four constituents were detected at concentrations below the limits defined in the New Mexico Quality Regulations.

One inorganic constituent was found at concentrations above regulatory limits. Phenolics were detected in one sample, at 0.019 mg/L; the detection limit for the analysis was 0.010 mg/L, and the maximum containment level for phenolics is 0.005 mg/L.

Several radionuclides were detected in both unfiltered and filtered fractions. Be-7, C-14, Co-60, Mn-54, Pu-238, Pu-239/40, H-3, and Zn-65 were not detected in any MWL samples. Gross alpha activity was detected in all sample fractions at values from 5.10 pCi/L to 13.9 pCi/L; gross beta activity was measured in all sample fractions from 4.48 pCi/L to 7.28 pCi/L.

IT Corporation (IT), 1990, "Ground-Water Sampling for Halogenated Volatile Organic Compounds at the Chemical Waste Landfill, May 15-30," prepared for Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: Sandia National Laboratories sampled the ground water at the Sandia Chemical Waste Landfill (CWL) during the period between May 15 and 30, 1990. This groundwater sampling was a follow-up to semiannual groundwater monitoring at the CWL, conducted in March 1990, in which the detection of trichloroethene (TCE) in one well indicated that further sampling was desired.

Samples from each of the wells were analyzed for selected indicators of groundwater contamination (pH, SC, TOC), as well as for volatile organics. TCE was detected in duplicate samples collected from well MW-2A at concentrations of 15 and 16 µg/L, respectively. TCE was also detected in well MW-3A at 0.59 µg/L. The regulatory limit (maximum contaminant level allowed) for TCE is 5 µg/L. In addition, 1,1,1-trichloroethane (TCA) was detected in well MW-2A duplicate samples at concentrations of 7.1 and 8.0 µg/L, respectively; the regulatory limit for TCA is 6 µg/L.

IT Corporation (IT), 1990, "Indicator Parameter Resampling Report for the Chemical Waste Landfill, Sandia National Laboratories, Albuquerque, May 15-30, 1990," prepared for Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: SNL/NM conducted groundwater monitoring resampling at the Chemical Waste Landfill (CWL) during the period between May 15 and 30, 1990. The resampling was a follow-up to semiannual groundwater monitoring at the CWL, conducted in March 1990, in which significant statistical changes in the concentrations of some parameters dictated the need for further sampling. The results of statistical analyses of March 1990 semiannual sampling data indicated a significant change in pH in wells BW-3 and MW-2A, as well as a significant increase in total organic carbon (TOC) in wells BW-3 and MW-3A. Based on these statistical results, CWL monitor wells were resampled for TOC in May 1990.

This report details groundwater sampling and analytical results obtained from the May 1990 resampling which are necessary to verify statistically significant changes in ground water contamination indicator parameters (TOC and pH). This verification is required by 40 CFR §265.92(c) prior to the initiation of assessment monitoring activities. In accordance with the groundwater monitoring requirements of the New Mexico Hazardous Waste Management Regulations [NMHWMR-5/40 CFR §265.92(c)], samples were collected and analyzed for parameters indicative of ground water contamination. Descriptions of field methods employed and a discussion of analytical and quality control results are provided.

IT Corporation (IT), 1990, "Semiannual Ground-Water Sampling Report for the Chemical Waste Landfill, Sandia National Laboratories, Albuquerque, March 26-30, 1990," prepared for Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: SNL/NM conducted semiannual RCRA Interim Status detection groundwater monitoring at the Sandia Chemical Waste Landfill (CWL) during the period between March 26 and 30, 1990.

This report describes groundwater sampling methods and analytical results used to determine concentrations of ground water contamination indicator parameters (total organic halogen, total organic carbon, pH and specific conductance) as specified in 40 CFR §265.92(c).

TOX compounds were not detected in any samples at the method reporting limit of 30 µg/L. Traces of TOX were identified and reported below the reporting limit. TOC compounds were detected in the one to five mg/L range in most samples.

The metals barium, chromium, nickel, tin, and zinc were detected as total concentrations in one or more wells. All total metals reported were below 0.1 mg/L and all are below Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCLs). Dissolved chromium was analyzed for all samples but was not detected in any sample at the reporting limit of 1 µg/L. The only detected Appendix IX constituent was trichloroethene (TCE).

Jacobs Engineering Group Inc., 1991, *Final Environmental Assessment Explosive Components Facility, Sandia National Laboratories*, Albuquerque, New Mexico.

Summary: The United States Department of Energy (DOE) has prepared an environmental assessment (EA) of the proposed Explosive Components Facility (ECF) at the SNL/NM. This facility is needed to integrate, centralize, and extend many of the explosive, neutron generation, and weapons testing programs currently in progress at SNL/NM. In general, there is insufficient space in existing facilities for the development and testing activities required by modern explosives technologies.

In accordance with the Council on Environmental Quality (CEQ), requirements contained in 40 CFR 1500-1508, the EA examined the environmental impacts of the proposed ECF project and discussed potential alternatives. Based on the analyses in the EA, the DOE believes that the proposed action does not constitute a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act (NEPA) of 1969, and CEQ regulations in 40 CFR 1508.18 and 1508.27. Therefore, an environmental impact statement (EIS) is not required, and the DOE is issuing this Finding of No Significant Impact (FONSI).

Jaksha, L.H., A.R. Sandford, "Earthquakes near Albuquerque, New Mexico, 1976-1981," *Journal of Geophysical Research,* Vol. 91, No. B6, pp. 6293-6303.

Summary: From January 1976 to November 1981, the U.S. Geological Survey (USGS), Los Alamos National Laboratory (LANL), and the New Mexico Institute of Mining and Technology (NMT) operated a radio-telemetered network of seismograph stations near Albuquerque, New Mexico. The study had as its goal the identification and description of seismically active parts of the crust near the city. The study was focused on the city of Albuquerque and the Albuquerque Basin because most of the population of New Mexico resides there.

Judge, W.J. and J. Dawson, 1972, "PaleoIndian Settlement Technology in New Mexico," *Science* Vol. 176, pp. 210-216.

Summary: The central Rio Grande Valley is known to have been occupied continuously for at least 12,000 years. Recently, a formal archaeological survey was conducted to investigate evidence of variation in the settlement locations of the PaleoIndians who occupied the area some 7,000 to 10,000 years ago. Previous evidence derived from surface collections indicate the area was occupied by at least four PaleoIndian cultures: Clovis, Folsom, Belen, and Eden (Cody complex). The archaeological information provided by this survey is used to explore the intercultural and intracultural variations in settlement for these PaleoIndian cultures.

Kelley, V.C., 1978, "Geology of the Espanola Basin, New Mexico," *Map #48*, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico.

Summary: Description of map of major rock classification units and structural delineation for the Espanola basin, including and overview map of the Rio Grande Rift which extends into the Albuquerque basin.

Kelley, V.C., 1977, "Geology of the Albuquerque Basin, New Mexico," *Memoir 33*, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico.

Abstract: The Albuquerque Basin of central New Mexico is about 102 mi long (north-south) and 25-40 mi wide (east-west). The Rio Grande, rising in Colorado and emptying into the Gulf of Mexico, flows southward through the basin which is surrounded by diverse Laramide and late Cenozoic uplifts. Several structural benches are delineated within the basin; fault scarps face the trough in most places. Ends of the basin are formed by convergence of side boundaries toward narrower structural and depositional channels that connect with basins north and south. The basin fill consists of up to 12,000 ft of sandstone, mudstone, and gravel of the Santa Fe Formation or Group (Miocene-Pliocene). In the northern part of the fill is divided into the units of Bryan and McCann (1937) named in this report Zia, Middle Red, and Ceja members. Elsewhere the fill generally is not divisible but may include equivalents of Zia and Ceja. Several facies of Santa Fe such as fanglomerates, playa, and river deposits and dunes are present. Late Pliocene deformation widened the basin, elevated the uplifts, and locally faulted and folded the Santa Fe. The deformation was followed by widespread pedimentation producing the Ortiz surface (probably early Pleistocene). Pleistocene and Holocene rejuvenation, deformation, and widespread dissection destroyed most of the surface. New correlations of Ortiz remnants are presented and the surface reconstructed. Numerous new faults are mapped and classified by relative ages, and several new folds and warpings or erosion surfaces are identified.

Kues, G., 1986, "Groundwater Levels and Direction of Groundwater Flow in the Central Part of Bernalillo County, New Mexico, Summer 1983," *Water Resources Investigation Report 85-4325*, U.S. Geological Survey, Albuquerque, New Mexico.

Abstract: In 1980, toxic chemicals were detected in water samples from wells in and near Albuquerque's San Jose well field. At the request of the Environmental Improvement Division of the New Mexico Health and Environment Department, the U.S. Geological Survey conducted a study to determine groundwater levels and flow direction.

Water levels were measured in 44 wells in a 64-square-mile area along the Rio Grande and adjacent areas during a period of near-maximum municipal pumpage. Based on the altitude of screened interval, wells were grouped into shallow (screened interval above an altitude of 4,800 feet) or deep (screened interval below and altitude of 4,800 feet) zones.

Groundwater in the shallow zone generally moves from north to south parallel to flow in the Rio Grande. Groundwater in the deep zone generally moves from the northwest to the east and southeast. A poorly developed cone of depression within the deep zone was present in the northeast. Water levels in wells were as much as 18 feet higher in the shallow zone than in the deep zone in the vicinity of the San Jose well field, indicating a downward gradient.

Lambert, P.W., 1968, "Quaternary Stratigraphy of the Albuquerque Area, New Mexico," Ph.D. Dissertation, University of New Mexico, Albuquerque, New Mexico.

Summary: This Ph.D. dissertation describes the regional geologic setting, geologic structure, geomorphology, climate, vegetation, soils, history, and culture of the Albuquerque area. The pre-Tertiary, Tertiary, and Quaternary stratigraphy of the area is described in detail, including paleontological discoveries.

Lander, J.F., ed. 1966, "Seismological Notes," *Bulletin of the Seismological Society of America*, Vol. 56, p. 975.

Abstract: January 23, 1966. 37.0 N, 106.9 W; focal depth about 10 km restricted (USCGS). Maximum intensity VII at Dulce, where it was reported many houses and buildings were damaged. Porches were displaced from houses; walls and foundations cracked; water pipes broken; etc. Shock was felt over a wide area. In New Mexico, 70 miles west of Dulce to Farmington; about 30 miles southeast of Dulce at Tierra Amarilla. In Colorado, at Pagosa Springs, about 30 miles north of Dulce, and at Durango, about 65 miles northwest of Dulce. Many aftershocks were felt. Damage estimated at $200,000.

Between January 23 and January 28, 119 events were recorded at the Albuquerque Observatory, a distance of about 225 km from Dulce. Three temporary seismic stations were installed by the USCGS on January 28 near the Dulce area. During their first week of operation, 218 events were recorded by these stations. All of the aftershocks are located in a small area close to the town of Dulce.

Lansford, R.R., and L. Adcock, 1990, "The Social and Economic Impact of Sandia National Laboratories on the State of New Mexico FY 1989," Albuquerque Operations, U.S. Department of Energy, in cooperation with Agriculture Experiment Station College of Agriculture and Home Economics.

Conclusions: In summary, the foregoing socioeconomic analysis illustrates how Sandia National Laboratories' operations in New Mexico have a significant and positive influence in the communities where facilities are located, as well as on the state as a whole.

Funding for SNL/NM was about $1.2 billion in 1989. The total economic impact was $3.71 billion in FY 1989. The percentage of SNL/NM activities in the state was 6.5 percent in FY 1989. The average number of SNL/NM employees was 7,605 in FY 1989.

The income impacts were almost $1.0 billion in FY 1989. This is because many jobs created directly by SNL/NM pay above-average wages, compared to those sectors where SNL/NM's indirect impact is large in terms of employment, such as the retail and service sectors. However, these sectors tend to generate a great deal of economic activity.

Over the past few years, SNL/NM's expenditures in New Mexico have increased each year. This may or may not continue, depending on future interest in the Strategic Defense Initiative, Nuclear Weapons Development, DoD Non-Nuclear Programs, Environmental Research & Development and other variables related to Congressional budget decisions.

The most apparent and easily quantifiable impacts are on employment (a total of 29,600 jobs created), and the total increase in economic activity to the state of $3.71 billion. However, related and equally and important effects on the quality of life in the state are noted. SNL/NM's influence pervades all sectors of the state's economic and social infrastructure.

Lansford, R.R., L.D. Adcock, and S. Ben-David, 1995, "The Economic Impact of Sandia Laboratories on Central New Mexico and the State of New Mexico, Fiscal Year 1994," Office of Energy, Science and Technology, Albuquerque Operations Office, U.S. Department of Energy, Albuquerque, New Mexico.

Conclusions: In summary, the foregoing socioeconomic analysis illustrates how Sandia National Laboratories' operations in New Mexico have a significant and positive influence in the communities where facilities are located, as well as the state as a whole.

As a major employer in New Mexico, SNL/NM has a major economic and social impact on the state and, in particular, on the Albuquerque metropolitan area. A total of 8,047 jobs were created at SNL/NM during Fiscal Year (FY) 1994 (Lansford et al., 1995). This resulted in a statewide total increase in FY 1994 of 37,348 jobs, due to the multiplier effect of 4.63 additional jobs supporting each of the 100 direct jobs at SNL/NM. This amounts to 5 percent of all employment in New Mexico.

The total impact in economic activity in New Mexico was $4.9 billion in FY 1994, due to the initial infusion of $1.4 billion. SNL/NM in-state direct expenditures of $0.48 billion for wages and salaries generated $1.3 billion of personal income in the state. Actual SNL/NM in-state expenditures were over $1.06 billion in FY 1994 for salaries and wages, materials and services, capital equipment, and construction. SNL/NM funding accounts for about 6 percent of total economic activity in New Mexico.

Lintz, C., A. Earls, N. Trierweiler, and J. Biella, 1988, "An Assessment of Cultural Resources Studies Conducted at Kirtland Air Force Base, Bernalillo County, New Mexico," Mariah Associates, Albuquerque, New Mexico.

Abstract: Since 1978 Kirtland Air Force Base and Sandia Laboratories have contracted for thorough on-ground surveys for the identification and evaluation of prehistoric and historic archaeological sites. These surveys are required by law in order to identify and protect locations that are important to understanding America's heritage. A total of 13 surveys was completed for 31,281 acres on the Base and Forest Service Withdrawal Lands between 1978 and 1985.

One May 7, 1987, Mariah Associates, Inc. was awarded the first of a three-phase contract designed to provide a comprehensive historic preservation plan for Kirtland Air Force Base. The previously completed survey results are evaluated in order to determine if they provide adequate information necessary to prepare a plan for managing the significant archaeological sites. The assessment determined that site locations were sometimes in error, that few sites had been mapped, that some sites had not been recorded, that observations about the kind and importance of sites were often erroneously evaluated, and that inconsistent information was obtained from the surveys. Furthermore, these problems have been compounded by errors introduced during the production of the comprehensive management plan map. Considerable problems exist in the reliability and replicability of information gathered to date. No consistent criteria were used in identifying important or significant sites that require protection.

This report recommends that some surveys should be completely redone to obtain a realistic inventory and evaluation of sites, and other survey areas be sampled to determine the adequacy of the surveys. Furthermore, known historic and prehistoric sites over 50 years old should be revisited to obtain comparable kinds of basic information to determine their importance and to gather locational information necessary to properly manage the sites.

Los Alamos Technical Associates (LATA), 1991, "AIRDOS-EPA Data Upgrade and Dose Calculations for Sandia National Laboratories Facilities at Sandia, and Sandia, Tonopah Test Range," prepared for Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: This report was prepared for two purposes: (1) to upgrade the currently available data used to run the AIRDOS-EPA radiation dose assessment computer code and (2) to use that upgraded data and code to calculate off site doses at SNL/NM for U.S. Environmental Protection Agency (EPA) dose compliance purposes. The sites operated by SNL/NM are the facilities in Albuquerque and operations at the Tonopah Test Range (TTR).

The computer code data which were upgraded include the meteorological data and demographic data. The latter consist of population, beef cattle, dairy cattle, and food crop data in the 50-mile radius surrounding each site.

The emphasis on meteorological data was placed on the wind direction and stability class. A five-year average-joint frequency distribution for wind data was used. Wind direction data for SNL/NM and the TTR were derived from National Climatic Center data measured at the Albuquerque International Airport and the Tonopah Municipal Airport. Population data was used from the 1990 census. Agricultural data, based on 1987 and 1988 farm statistics, were extracted from U.S. Department of Agricultural publications. All demographic data were gridded for use with the 16 wind direction sectors, five distances format for inclusion in the AIRDOS-EPA code.

In December 1989, the EPA promulgated new requirements regarding the location of the maximally exposed individual for whom a radiation dose must be calculated. Previously, this individual under the NESHAP receptor was located at any public access location where an individual could possibly reside. This individual was hypothetical in many instances since no individual was actually present. The new regulations redirect the maximally exposed location to a location where a member of the public actually resides or abides.

In addition, it has been determined that occupants and personnel who work on KAFB are to be considered members of the public. Thus, NESHAP regulations are to include members of the armed forces, KAFB contractors and employees, and all other non-SNL/NM employees. Consequently, as part of the AIRDOS-EPA data upgrade, surveys were conducted to determine the exact locations of the public in and around each SNL/NM operation.

During 1990, the location of the NESHAP maximally exposed individual at Sandia operations occurred at the KUMSC facility (U.S. Army) site approximately 1,610 northwest of the SNL/NM Area V. The maximum effective dose equivalent (EDE) at this location was calculated to the 2.0 x 10^{-3} mrem. In addition, a population dose to the public was calculated to be 2.6 x 10^{-2} man-rem to the 571,677 people living within a 50-mile radius of SNL/NM. The population dose to the 6,636 residents of KAFB was calculated to be 0.79 man-rem. The population dose at KAFB is disproportionately greater than the dose to the much larger regional population because of the close proximity to the SNL/NM release locations.

Machette, M.N., "Quaternary and Pliocene Faults in the La Jencia and Southern Part of the Albuquerque-Belen Basins, New Mexico: Evidence of Fault History from Fault-Scarp Morphology and Quaternary Geology," *MS 913*, U.S. Geological Survey, Denver, Colorado.

Summary: The La Jencia and Albuquerque-Belen basins contain many faults that displace basin deposits of Pliocene and Quaternary age and surficial deposits of middle

and late Quaternary age. None show evidence of Holocene movement, and many show evidence of late Pleistocene movement. This report considers only faults with Quaternary or Pliocene movement and includes information on the amount of fault displacement, the age of displaced deposits, the recency of fault movement, and the morphology of some fault scarps. These data were derived from published and unpublished geologic maps and reports, from low-altitude actual photography, from studies of Quaternary deposits along the faults, and from an analysis of fault-scarp morphology. The faults shown provide direct evidence of Quaternary or Pliocene movement: those faults that lie entirely within Pliocene or older rocks are not shown. The reader should be aware of this selection, especially if data from this report are used in hazards assessment, in regional structural analysis, or in other studies.

McCord, J., et al., 1994, "Sandia National Laboratories Site-Wide Hydrogeologic Characterization Project - Calendar Year 1993 Annual Report," U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico.

Abstract: The SNL/NM Site-Wide Hydrogeologic Characterization (SWHC) project has been implemented as part of the SNL/NM Environmental Restoration Project to develop the regional hydrogeologic framework and baseline for the approximately 100 square miles of KAFB and adjacent withdrawn public lands upon which SNL/NM has performed research and development activities. Additionally, the SWHC project will investigate and characterize generic hydrogeologic issues associated with more than 200 ER sites owned by SNL/NM across its facilities on KAFB. Examples of generic issues exist in all components of the hydrogeologic system, including surface water (erosion), the vadose zone (groundwater recharge), and the saturated zone (regional groundwater flow to receptors).

As called for in the Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA) Part B permit agreement between the U.S. Environmental Protection Agency (EPA) as the permitter and the DOE and SNL/NM as the permittees (EPA, 1993), an annual report is to be prepared by the SWHC project team. This document serves two primary purposes:

- To identify and describe the conceptual framework for the hydrogeologic system underlying SNL/MM

- To describe characterization activities undertaken in the preceding year that add to our understanding (reduce our uncertainties) regarding the conceptual and quantitative hydrogeologic framework.

This 1993 SWHC project annual report is the second in this series of reports. Last year's report (McCord et al., 1993) established the baseline hydrogeologic conceptual model for the SNL/NM/KAFB area. This year's annual report provides a high level summary of the general hydrogeologic framework, discusses details of the 1993 characterization activities that have improved our understanding of this framework, and updates our current understanding of the sitewide conceptual model.

The hydrogeologic setting includes the meteorological environment, surface water run-off, percolation through the vadose zone, and saturated groundwater flow. This report summarizes the current understanding of the occurrence, movement, and interaction of a surface and subsurface water. Refining this understanding will help establish a quantitative basis for understanding the potential pathways for transport of contaminants from SNL/NM/KAFB sites to receptors that could lead to adverse impact to human health and safety.

A sitewide, subsurface conceptual hydrogeological model (CM) is developed by constructing the hydrogeologic framework and evaluating the spatial distribution of geologic features that control hydrologic and contaminant transport parameters. This CM accounts for all relevant hydrogeologic processes, from surficial processes to vadose zone processes to saturated zone processes. The CM is being implemented, as required, by mathematical models that will permit is to make quantitative predictions regarding the behavior of the total hydrogeologic system and will be used to help guide site-specific field characterization activities.

There are many aspect of the hydrogeologic system not fully understood; thus, our current conceptualization of flow and transport processes and our conceptual model(s) are limited. Future characterization work will be planned and prioritized according to the methodology described in Chapter 3.0, which is driven by critical uncertainties and identified performance measures. The critical uncertainties are largely dictated by data needs for the Environmental Restoration Project operable units. This strategy will reflect close coordination with all Environmental Restoration Project task leaders. Once processes in need of characterization are identified, we will implement an iterative stochastic-simulation/field-characterization procedure to define particular field characterization activities and refine our understanding of the sitewide hydrogeologic system.

Moore, R.E., C.F. Baes III, L.M. McDowell-Boyer, A.P. Watson, F.O. Hoffman, J.C. Pleasant, and C.W. Miller, 1979, "AIRDOS-EPA: A Computerized Methodology for Estimating Environmental Concentrations and Dose to Man from Airborne Releases of Radionuclides," *ORNL-5532*, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Abstract: The AIRDOS-EPA computer model is used to estimate the off-site environmental concentrations, human exposure, and radiation doses resulting from the atmospheric release of radionuclides. The code, which is a modified version of AIRDOS-II is used for both routine and accidental release assessments. Most input parameters required by the code characterize the area surrounding the site or are specific to the radionuclide released. These input data are identical for both routine and accident release assessments. Other input, such as the source terms and the meteorological assumptions, are specific to the release assessment.

In general, AIRDOS-EPA estimates the radiation dose to either a maximally exposed individual or to an exposed population resulting from a specified airborne release of radionuclides. Based upon a characterization of the area around the site and the specified meteorological conditions, the code estimates: (1) concentrations of radioactivity in air, (2) rates of deposition on ground surfaces, and (3) ground surface concentrations. These results are coupled with the intake rates for man to estimate the radiation dose to an adult receptor associated with all possible exposure pathways.

National Oceanographic and Atmospheric Administration (NOAA), 1990, "Local Climatological Data, Annual Summary with Comparative Data," Albuquerque, New Mexico.

Summary: This document summarizes the local climatological data (i.e., normals, means, and extremes) for Albuquerque, New Mexico, for the year 1990. The NOAA weather station representing the Albuquerque area is located in the Albuquerque International Airport, Latitude: 35° 03'N Longitude: 106° 37'W at an elevation on 5,311 feet (1,619 meters). Parameters measured include: temperature, barometric pressure, relative humidity, precipitation, average sky cover, percent possible sunshine, and wind. Averaged long term historical data taken from the Albuquerque International Airport are also presented for comparison, i.e., normals are based on the 1951 - 1980 record period.

New Mexico Department of Game and Fish, no date, "Handbook of Species Endangered in New Mexico," New Mexico Department of Game and Fish, Santa Fe, New Mexico.

Summary: The purpose of this publication is to provide background information about the species of animals listed as endangered by the New Mexico Department of Game and Fish. This document was originally released in the mid-1980s and revised in the late 1980s, but it has not been revised in recent years. For this reason, some of the data, particularly that of status, is outdated and some species currently listed are not covered. Much valuable information, however, is still available in this document.

The introductory section provides definitions of endangered species (group 1 and group 2) and summarizes the legal protection provided to these species. This is followed by an annotated outline of the species accounts that follow. The remainder of the document is devoted to the species accounts.

Each species is provided one double-sided page (loose-leaf) for its species account. These are presented in taxonomic order. The header for each account gives the common and scientific names, and the State and federal status (now outdated). This is followed by eight standard sections. The first gives the distinguishing taxonomic features of the species. this is followed by a section giving other descriptive features of the species (not distinguishing). A section describing the distribution of the species is then provided. This is illustrated with a map of its known distribution in New Mexico (county lines are delineated in these maps). The next three sections verbally describe the species' biology (natural history), status, and conservation. The final two sections provide a bibliography for the species and a citation for the species account.

New Mexico Native Plants Protection Advisory Committee, 1984, *A Handbook of Rare and Endemic Plants of New Mexico*, University of New Mexico Press, Albuquerque, New Mexico.

Abstract: The New Mexico Native Plant Protection Advisory Committee is an ad hoc group of professionals in the field of botany, representing the academic community, land managers, and private industry. The committee has served informally at the discretion of the governor, under the direction of the secretary of Natural Resources of New Mexico since 1977. The New Mexico Natural Heritage Program serves as secretary for the committee.

Although the committee has provided the U.S. Fish and Wildlife Service and the New Mexico Natural Heritage Program with information and advice regarding the status of our rarer plant species, this is the first major work produced as a committee effort.

In compiling data for this book, the committee has attempted to provide a single source of information on rare and endemic plants useful both to land managers and to the general public. Plants covered either are principally found in New Mexico or require special management attention. All plants nominated for protection under the Endangered Species Act are included, regardless of their relative abundance.

Physical Science Laboratory (PSL), in preparation, "Environmental Assessment of the Sandia National Laboratories, Coyote Canyon Test Complex, Kirtland Air Force Base, Albuquerque, New Mexico," prepared for U.S. Department of Energy, Albuquerque Operations Office.

Abstract: The Sandia National Laboratories (SNL) Coyote Canyon Test Complex (CCTC) Environmental Assessment (EA) evaluates impacts associated with maintaining full-scale testing and test support capabilities at the following facilities.

- 10,000-Foot Sled Track
- Terminal Ballistics Facility
- Radiant Heat Facility
- Mechanical Shock Lab
- Pressure Lab
- Photometric Facility
- Centrifuge Complex
- Drop Tower Complex
- Explosive Devices Test Facility

- Vibration Lab
- Radiographic Facility
- System Certification and Model Validation Test Center.

At these facilities, DOE conducts safety and reliability evaluations of weapon systems and their components, qualifies nuclear material shipping containers, and develops new data analysis capabilities to support research and development. The EA evaluates the consequences of these activities on health and safety, air quality, noise, water resources, biological resources, cultural resources, soils, socioeconomic effects, and waste generation. The draft EA is being reviewed by DOE and completion is expected in early 1996.

Reeder, H.O., L.J. Bjorklund, and G.A. Dinwiddie, 1967, "Quantitative Analysis of Water Resources in the Albuquerque Area, New Mexico, Computed Effects on the Rio Grande of Pumpage of Ground Water," *Technical Report 33*, New Mexico State Engineer, Santa Fe, New Mexico.

Abstract: From basic assumptions of water requirements in the Albuquerque area and aquifer characteristics, the greatest lowering of the water level from 1960 to 2000 is computed to be 86 feet in an area about 6 miles east of downtown Albuquerque and 3 miles north of Highway 66 (Central Avenue). It is computed that water levels declined almost 11 feet in this area from 1920 to 1960. West of the Rio Grande, the water levels are expected to decline 34 feet in a small area about 9 miles northwest of downtown Albuquerque from 1960 to 2000. Water levels in that area declined little, if any, before 1960. Outward from these areas the lowering will be less in all directions, particularly toward the Rio Grande.

The water-level declines, as computed in this report, will reverse the water-table gradient east of the Rio Grande, causing ground water to flow away from the river, and the water table 5 to 8 miles east of the Rio Grande at Albuquerque will be lower than the adjacent part of the river.

About 80 percent of the water pumped by the city from 1920 to 1960 was derived from the flow of the Rio Grande, either decreasing the flow to the river or increasing the flow from the river. From 1960 to the year 2000 between 71 and 76 percent of the water pumped will be derived from the Rio Grande. In the decade 1950-60 an average of 46,000 acre-feet of water was pumped annually of which 37,200 acre-feet was derived from the Rio Grande. In the decade 1990-2000, it is computed that an average of 226,000 acre-feet of water will be pumped annually, of which 165,000 acre-feet will be derived from the Rio Grande. Average flow of the river at Albuquerque during the 17 years prior to 1959 was 1,006 cfs (cubic feet per second) or about 728,000 acre-feet per year. Part of the decreased flow of the river caused by pumping is offset by effluent from the sewage-disposal plant.

Schmidt, O.L., 1991, "An Inside Look at the Relationship of NEPA to other Federal Laws," Bonneville Power Administration, Portland, Oregon.

Abstract: The Checklist of 16 is nothing more or less than the foundation of environmental assessment at BPA. It is a listing of all the environmental statutes, regulations, executive orders, procedures, guidelines, and other administrative directives that may be relevant to a decision making process. It is what an environmental professional at BPA must know in order to prepare a decision maker to make a fully-informed, environmentally-informed decision.

It is more than a listing, actually. It has "threshold questions" to prompt the user to make the relevant inquiry, to ask the right questions, to get the right answers. It has a "where to get started" section to steer the new user in the right direction or to remind the user who hasn't seen the Checklist in a while where to go to get onto the right track.

The Checklist of 16 is large. Over 30 pages, dozens of statutes, scores of regulations, hundreds of directives. It is large, but it is the minimum. It is the minimum number of directives that must be understood and followed in order to inform decision makers, in order to inform the public, restore, and enhance the environment, in order to minimize or avoid adverse impacts, in order to faithfully execute the laws of the United States, in order to meet obligations to future generations.

Seymour, D.J., 1992, "Results of the Phase I Background Research and Evaluation for Kirtland Air Force Base," Mariah Associates, Inc., Albuquerque, New Mexico.

Mariah Associates, Inc., prepared an assessment of previously conducted cultural resources work at KAFB, with an emphasis on studies completed between 1988 and 1992.

Abstract: As of November 1992, there had been 100 KAFB cultural resource projects conducted by 15 contractors, agencies, and individuals, including Herbert Yeo, Robert Jones, James Judge, the Center for Anthropological Studies (CAS), Chambers Group Inc. (CGI), Human Systems Research (HSR), Butler Service Group Inc. (BSG), Cultural Heritage Research Services (CHRS), the Office of Contract Archaeology (OCA), MAI, the Agency for Conservation Archaeology (ACA), Quivera Research Center (QRC), the Public Service Company of New Mexico (PNM), the Laboratory of Anthropology (LAB), and the U.S. Forest Service (USFS). The bulk of these projects were inventory surveys and/or area assessments, with five testing or data recovery projects (Rodgers, 1981; Condie, 1989b; Hoagland, 1989a; Dean, 1991; also one for which documentation has not yet been completed); one site evaluation (Cushman, 1989); one historic buildings evaluation (Historic American Buildings Survey [HABS]) (Hoagland 1991d); and one general evaluation (Lintz et al., 1988). Five projects combined a survey with a HABS review (Geister, 1990; Hoagland, 1990e, Hoagland, 1990g; Hoagland, 1990h, Hoagland, 1990i).

Of the 52,577.38 acres of property located within KAFB, approximately 34,000 acres (65 percent) have received a cultural resource inspection, and about 6,000 of those acres had been resurveyed by 1992. The total number of recorded sites was 173, with one additional site that field personnel remember recording, although no form or report has been found and no unaccounted-for site numbers have been identified. In addition, there are at least 60 isolated occurrences (IO) that would qualify as sites if a consistent USFS site definition was used. Other cultural remains were also encountered that were not recorded as IOs or sites but would be sites under this definition.

Sivinski, R., and K. Lightfoot, 1992, "Inventory of Rare and Endangered Plants of New Mexico," New Mexico Forestry and Resource Conservation Division, Energy, Minerals, and Natural Resources Department, Santa Fe, New Mexico.

Abstract: This publication of the New Mexico Forestry and Resource Conservation Division presents four lists of plant species and varieties covering endangered plants (List 1), rare and sensitive plants (List 2), plants under review (List 3), and plants dropped from consideration as potentially endangered, rare, or sensitive. The introductory section provides information on the criteria used in categorizing plants into these four lists and the legal protection provided to these species and varieties (only List 1 plants are legally protected from collection in New Mexico). Other coded information provided for each listed species is described in the introduction, including the R-E-D Code (rarity, endangerment, and distribution), federal status, distribution in New Mexico (by county), and habitat. Addresses for collecting permits from the New Mexico Forestry and Resource Conservation Division, U.S. Fish and Wildlife Service, and U.S. Forest Service are also provided. Within the four lists, each species or variety is listed alphabetically by scientific name. In addition to the information described above, the species' common name, family, and range outside of New Mexico (by state or country) are given. For some species, special habitat requirements (e.g., soil substrate) and pertinent notes are also provided. Finally, the species and varieties are cross-listed by family and by county.

Sandia National Laboratories (SNL), 1991, "Preliminary Inventory of the 189 Hazardous Air Pollutants Listed in the New Clean Air Act Amendment of 1990," Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: Sandia has conducted a preliminary inventory of the 189 chemicals listed in the New Clean Air Act Amendment. Attached is a copy of the inventory for your information submittal to the City of Albuquerque, Environmental Health Department Air Pollution Control Division.

The SARA Title III, Section 312 (Tier 2) data base was used to summarize the maximum usage quantity for each chemical. The emission factors of selected chemicals having usage quantities exceeding 400 lb/yr were estimated from either the material balance method or process knowledge and control method. Conservative assumptions and approaches were adopted when determining the emission factors. Therefore, the final column for emission (lb/yr) is believed to represent the "maximum potential" emission for the specific chemicals. Due to the time constraint, chemicals with less usage quantities (<400 lbs) were not investigated in regarding to their emission factors.

The preliminary inventory, although not in completeness, gives a broad overview of the scope and extent of the chemicals in concern. SNL/NM has used 107 chemicals out of the 189 chemicals listed. Among the 107 chemicals used, only 30 of them are used more than 100 lb/yr, only 12 of them are used more than 1000 lb/yr. Furthermore, among the top 12 chemicals, four metals (namely Nickel, Chromium, Lead and Cobalt) were not used in "reactive" process. For example, lead was used in radiation shielding in the form of lead bricks. Nickel, chromium, and cobalt were used largely in alloy metal processes which involved physical melting and solidification with very minimum (if any) emissions.

Sandia National Laboratories (SNL), 1990, "Chemical Waste Landfill Sampling and Analysis Plan, Revision 2.0," Sandia National Laboratories, Albuquerque, New Mexico.

Summary: These are procedures to be used for the sampling and analysis of the nine groundwater monitoring wells at SNL/NM Chemical Waste Landfill. These procedures were developed in accordance with the Resource Conservation and Recovery Act (RCRA) and are intended to insure that the samples collected are representative of the ground water at the time of sampling. They are written to comply with Federal Regulation 40 CFR Part 265, Subpart F, Section 265.91-94, and New Mexico Hazardous Waste Management Regulation 5 (NMHWMR-5).

Sandia National Laboratories (SNL), 1990, "Draft Mixed Waste Landfill Sampling and Analysis Plan, Ground-Water Monitoring Program," Sandia National Laboratories, Albuquerque, New Mexico.

Summary: These are procedures to be used for the sampling and analysis of the four groundwater monitoring wells at Mixed Waste Landfill located in Technical Area III at SNL/NM. These procedures were developed in accordance with the Resource Conservation and Recovery Act (RCRA) and are intended to provide for the collection of samples that are representative of the ground water at the time of sampling. They are written to comply with Federal Regulation 40 CFR Part 265, Subpart F, Section 265.91-94, and New Mexico Hazardous Waste Management Regulation 5 (NMHWMR-5).

Sandia National Laboratories/New Mexico (SNL/NM), 1995, "Site Development Plan," Sandia National Laboratories, Albuquerque, New Mexico.

Summary: Sandia National Laboratories' 1995 Site Development Plan (SDP) encompasses the multi-sites for New Mexico (SNL/NM), California (SNL/CA), Nevada (SNL/NV/TTR) and Hawaii (SNL/HI/KTF). In accordance with DOE Order 4320.1B, this annual update presents current issues for all four sites and anticipated changes through 20 years. Each specific site provides for facilities and areas that accommodate unknown or changing programs within the current construction budget submission and the requirements for environment, safety, and health regulatory standards.

Sandia National Laboratories/New Mexico (SNL/NM), 1995, "1994 Site Environmental Report, Sandia National Laboratories, Albuquerque, New Mexico," SAND95-1953, Sandia National Laboratories, Albuquerque, New Mexico.
Abstract: This 1994 report contains data from routine radiological and nonradiological environmental monitoring activities. Summaries of significant environmental compliance programs in progress, such as National Environmental Policy Act documentation, environmental permits, environmental restoration, and various waste management programs for Sandia National Laboratories in Albuquerque, New Mexico, are included. The maximum off-site does impact from air emissions was calculated to be 1.5×10^{-4} millirem. The total population within a 50-mile radius of Sandia National Laboratories/New Mexico received an estimated collective dose of 0.012 person-rem during 1994 from the laboratories' operations. This report is prepared for the U.S. Department of Energy in compliance with DOE Order 5400.1.

Sandia National Laboratories/New Mexico (SNL/NM), 1994, "Noise and Vibration Investigations of the Sandia National Laboratories Sol se Mete Aerial Cable Facility," Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: This document assesses noise, vibration, and overpressure impacts from the operation of the Sol se Mete Aerial Cable Facility (ACF). Studies were conducted by utilizing models into which numerous parameters were incorporated. Major noise sources at the Sol se Mete ACF include noise from aircraft, and noise associated with explosives and rocket motor testing. Vehicular traffic, construction, and other on-site testing operations also contribute to overall noise at the facility. Results of noise modeling indicate that while most noise generated from the facility would not have adverse impacts, some operations associated with impulse noises (such as heavy-weight [>54 kg/120 lb] explosives testing) could result in the need for evacuation or hearing protection for on-site personnel.

Effects of vibration and fragmentation hazards associated with testing were also evaluated. Most testing operations except for heavy-weight (>54 kg/120 lb) explosives would not require extraordinary protective measures.

Sullivan, R.M., 1994, "Biological Investigations of the Sandia National Laboratories Sol se Mete Aerial Cable Facility," Contractor Report, SAND93-70793, Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: This report presents the results of a comprehensive biological field survey conducted by the author in late September to late October, 1991, at the Sol se Mete Aerial Cable Facility in Sol se Mete Canyon in the Manzano Mountains. The survey covered approximately 3,840 acres and included surveys of vegetation and wildlife, with special emphasis on sensitive species and habitats.

The survey area and the operations at the Aerial Cable Facility are described in detail in the first chapter of this report. The second chapter describes the methods used in the survey. Vegetation and birds were surveyed using transects. Small mammals were surveyed by trapping. Other classes of wildlife (amphibians, reptiles, and large mammals) were noted wherever observed, either directly or through tracks or sign. The third chapter discusses results of surveys at specific sites and the fourth summarizes the bird and mammal data and relates it to the vegetation analyses. The last three chapters discuss the presence of sensitive plants, wildlife, and habitat in the survey area. Only one of seven potentially occurring sensitive plant species was found in the survey area and 11 of 25 potentially occurring sensitive wildlife species were found in the survey area. Sensitive habitats discussed in this report include bedding areas and travel corridors for mammals, mule deer foraging areas, raptor use areas, and water sources, including Sol se Mete Spring, which was observed in detail.

Nine appendices are provided, covering lists of plant and animal species observed and expected in the survey area; lists of threatened, endangered, and sensitive plant and animal species potentially occurring in the survey area; lists of the categories used in designating sensitive species and their definitions; and a letter report by Roger Skaggs concerning the potential presence of the Mexican spotted owl in the survey area. This report finds the potential for this federally listed threatened species to be present in the area is low due to poor habitat conditions.

Sullivan, R.M., 1991, "Biological Assessments," *Sandia National Laboratories Aerial Cable Site Environmental Assessment*, Appendix C, Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: This study summarizes results of biological field investigations of the SNL/NM Aerial Cable Site (ACS), at the east end of KAFB, Bernalillo County, New Mexico. ACS occupies a 440 acre tract of land withdrawn by the U.S. Forest Service for use by KAFB, and in turn placed under operational control of SNL/NM. In addition, SNL/NM uses roadways and other land adjoining the dedicated 440-acre tract. All land used by SNL/NM for the ACS is part of a 15,851-acre tract of land withdrawn by the U.S. Forest service. There also are a number of different organizations that use the 15,851-acre area, including KAFB, other SNL/NM users, different departments within the Department of Energy (DOE), and the Department of Transportation.

Information contained in this document is a result of literature research, consultation with the U.S. Fish and Wildlife Service, the U.S. Forest Service, the New Mexico

Energy and Natural Resources Department, the New Mexico Department of Game and Fish, and on-site biological field surveys. Information on Threatened, Endangered, and Sensitive species potentially or actually occurring in the project area, as listed by the federal government and the New Mexico Department of Game and Fish, is also included.

The purposes of the field survey were to determine the existing and potentially existing plant and wildlife species in the project area and to identify sensitive wildlife habitats (i.e., travel corridors, foraging areas, nesting sites, sensitive species habitat, etc.). Additionally, the survey was designed to ensure that future projects within the ACS will not result in adverse impacts to sensitive species actually or potentially occurring in the immediate area. Impacts to the existing environment resulting from possible future use of the area by military personnel and SNL/NM were evaluated and recommended guidelines to alleviate or minimize these impacts are discussed.

This report has been prepared for use as a planning document for consideration of all operations of the ACS and associated test facilities. Its implementation is in complete accordance with the 1985 Cibola National Forest Master Plan (and 1991 Proposed Amendment), and the New Mexico Department of Game and Fish Recommendations for Wildlife Baseline Study Guidelines for Construction Projects (May 1990). Potential impacts are discussed in both a specific and general case, as are the mitigation guidelines. This document, therefore, can serve as a general guide for future land planning and resource assessment if supplemented with additional detailed biological assessments that address potential impacts on specific projects at SNL/NM.

Sullivan, R.M., and P.J. Knight, 1994, "Biological Surveys for the Sandia National Laboratories Coyote Canyon Test Complex—Kirtland Air Force Base, Albuquerque, New Mexico," Contractor Report, SAND93-7089, Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: This report presents the results of a comprehensive biological field survey conducted by the authors in April through July, 1992, and in September, 1992, at the Coyote Canyon Test Complex in the southwestern corner of Kirtland Air Force Base. The survey covered approximately 3,760 acres and included surveys of vegetation and wildlife, with special emphasis on sensitive species and habitats.

The specific survey areas within the Coyote Canyon Test Complex are described. Those sites receiving 100 percent survey include the 10,000-Foot Rocket Sled Track Facility and its impact area, the Centrifuge Complex, the Light-Initiated High-Explosive Facility, the Terminal Ballistics Facility, the Drop Tower Complex, and the North and South Thunder Ranges. In addition to the first five facilities listed (which are all located in Technical Area III), the remaining parts of Technical Area III were surveyed at 10 percent intensity.

Vegetation and bird populations were surveyed using transects. Small mammals were surveyed by trapping. Other classes of wildlife (amphibians, reptiles, and large mammals) were noted wherever observed, either directly or through tracks or sign. The third chapter discusses results of surveys at specific sites and the fourth summarizes the bird and mammal data and relates it to the vegetation analyses. The last three chapters discuss the presence of sensitive plants, wildlife, and habitat in the survey area. Only one of seven potentially occurring sensitive plant species was found in the survey area and 11 of 25 potentially occurring sensitive wildlife species were found in the survey area. Sensitive habitats discussed in this report include bedding areas and travel corridors for mammals, mule deer foraging areas, raptor use areas, and water sources, including Sol se Mete Spring, which was observed in detail.

Nine appendices are provided, covering lists of plant and animal species observed and expected in the survey area; lists of threatened, endangered, and sensitive plant and animal species potentially occurring in the survey area; lists of the categories used in designating sensitive species and their definitions; and a letter report by Roger Skaggs concerning the potential presence of the Mexican spotted owl in the survey area. This report finds the potential for this federally listed threatened species to be present in the area is low due to poor habitat conditions.

Thorn, C.R., D.P. McAda, and J.M. Kernodle, 1993, "Geohydrologic Framework and Hydrologic Conditions in the Albuquerque Basin, Central New Mexico," *U.S. Geological Survey Water Resources Investigations Report 93-4149*, 106 pp.

Abstract: Recent investigations indicate that the zone of highly productive aquifer, on which the City of Albuquerque has depended for its water supply, is much less extensive and thinner than was formerly assumed. The investigation described in this report focused on gathering recent information to requantify the groundwater resources of the Albuquerque Basin in Central New Mexico. This report describes the geohydrologic framework and current (1993) hydrologic conditions in the Albuquerque Basin.

The Santa Fe Group aquifer system in the Albuquerque Basin comprises the Santa Fe Group (late Oligocene to middle Pleistocene) and post-Santa Fe Group valley and basin-fill deposits. The Santa Fe Group and post-Santa Fe Group deposits recently have been divided into four hydrostratigraphic units by other investigators: the lower, middle, and upper parts of the Santa Fe Group and post-Santa Fe Group valley and basin-fill deposits. The hydrostratigraphic units were further divided into lithofacies units characterized by bedding and compositional properties that exhibit distinctive geophysical, geochemical, and hydrologic characteristics. The Santa Fe Group ranges from less than 2,400 feet in thickness near the margins of the basin to 14,000 feet in the central part of the basin.

The most productive part of the Santa Fe Group aquifer system is the upper part of the Santa Fe Group and to some extent the middle part of the Santa Fe Group. The most productive lithologies are axial channel deposits of the ancestral Rio Grande and, to a lesser extent, piedmont-slope and alluvial-fan deposits. The most productive part of the aquifer system is 2 to 6 miles wide and has a remaining saturated thickness of about 600 feet. The basin-floor playa lake deposits of the lower part of the Santa Fe Group generally do not yield large quantities of water to wells.

Water levels in the east Albuquerque area declined 140 feet from 1960 to 1992. Water levels declined 40 feet from 1989 to 1992 in eastern, northwestern, and south-central Albuquerque. The magnitude of these declines is due in part to shifts in pumping centers, the presence of fault barriers, and the limited extent of the axial channel deposits. On the basis of an assumed storage coefficient of 0.2, the water-level declines in the Santa Fe Group aquifer system in the Albuquerque area represent a decrease in storage from groundwater withdrawal of an estimated 994,000 acre-feet from 1960 to 1992. The decrease in storage from groundwater withdrawal from 1989 to 1992 is estimated to be 305,000 acre-feet. The average total annual surface- and groundwater inflow to the basin from 1974 through 1992 was estimated to be 1,458,000 acre-feet, and the total outflow and consumptive loss was estimated to be 1,459,000 acre-feet. The average annual change in storage was independently estimated to be minus 31,100 acre-feet.

U.S. Air Force (USAF), 1990, "Environmental Assessment of the Realignment of Units at Kirtland Air Force Base, New Mexico," Scott Air Force Base, Illinois.

Abstract: The action for this environmental assessment (EA) is the relocation of the Air Force Inspection and Safety Center (AFISC) from Norton Air Force Base (AFB), California, to Kirtland AFB, New Mexico. The relocation action will include transfer of personnel authorizations and various items of equipment and material. Additional, previously programmed force structure actions at Kirtland AFB also are assessed in order to identify possible cumulative impacts.

This EA assesses the environmental impacts associated with these actions. The areas of potential impact analyzed are air quality, noise, hazardous materials, wastes and stored fuels, water resources, vegetation and wildlife resources, threatened and endangered species, cultural resources, land use, and socioeconomics. The EA describes the baseline conditions, potential environmental impacts (beneficial and adverse), and possible mitigation of adverse impacts. The Base Closure and Realignment Act specifically exempts this EA from considering the need, purpose, or reason for the realignment of the AFISC from Norton AFB to Kirtland AFB.

U.S. Army Corps of Engineers (USACE), 1979a, "Special Flood Hazard Information Tijeras Arroyo and Arroyo del Coyote, KAFB, New Mexico," U.S. Army Corps of Engineers, Albuquerque, New Mexico.

Summary: This report provides information on the areas within the KAFB Reservation that are subject to flooding from Tijeras Arroyo and Arroyo del Coyote. It identifies the 100- and 500-year floodplains for the two arroyos, and discusses flood frequency for 1-, 10-, 50-, 100-, and 500-year floods.

U.S. Army Corps of Engineers (USACE), 1979b, "Albuquerque Greater Urban Area Water Supply Study," Hydrologic Engineering Center, Albuquerque, New Mexico.

Summary: This report presents the results of a study of water supply and use in the Albuquerque Greater Urban Area (AGUA). It is one part of a larger, comprehensive study being conducted by the Albuquerque District, Corps of Engineers on the water resources of that area. The report includes data on water supply and use for the period 1967-1977 and the resulting water balance for the AGUA. Technical information on the ground water aquifer, water table levels, and the impact of drought conditions is discussed.

U.S. Department of Agriculture (USDA), 1991, *Changing Forest Landscapes - Five Years of Progress (1986-1990)*, U.S. Forest Service, Southwestern Region, Albuquerque, New Mexico.

Summary: This report documents the current conditions of the land covered by the Cibola National Forest Plan and describes changes made since Plan approval. It also identifies emerging issues facing the forest presently, and includes accomplishments to data as compared to the Plan's goals and objectives.

U.S. Department of Agriculture (USDA), 1990, *Landscape Character Types of the National Forests in Arizona and New Mexico*, U.S. Forest Service, Southwestern Region, Albuquerque, New Mexico.

Summary: This document establishes specific criteria for establishing variety classes within each distinct character type. It provides a written description and representative photographic examples of each character type. It also summarizes criteria for sensitivity levels used in the U.S. Forest Service Visual Management System.

U.S. Department of Agriculture (USDA), 1985, *Cibola National Forest Plan*, amended 1990, U.S. Forest Service, Southwestern Region, Albuquerque, New Mexico.

Summary: The Plan defines long-term direction for managing Cibola National Forest Lands and provides land management prescriptions, standards, and guidelines which define the Plans management direction for the future.

U.S. Department of Agriculture (USDA), 1979, *Visual Resource Plan for Cibola National Forest*, U.S. Forest Service, Southwestern Region, Albuquerque, New Mexico.

Summary: The visual quality objectives map of the Cibola National Forest, including mapping of the SNL/NM Forest Service withdrawn lands, as based on the Visual

Management System. The original mapping of the withdrawal area was prepared by Forest Service personnel using aerial photographs.

U.S. Department of Agriculture (USDA), 1977, "Soil Survey of Bernalillo County and Parts of Sandoval and Valencia Counties, New Mexico," Soil Conservation Service, U.S. Department of the Interior, Bureau of Indian Affairs and Bureau of Land Management.

Summary: This is a publication of the National Cooperative Soil Survey, a joint effort of the U.S. Department of Agriculture and agencies of the states, usually the Agricultural Experiment Stations. In some surveys, other Federal and local agencies also contribute. The Soil Conservation Service has leadership for the Federal part of the National Cooperative Soil Survey.

Major fieldwork for this soil survey was completed in the period 1965-72. Soil names and descriptions were approved in 1973. Unless other wise indicated, statements in the publications refer to conditions in the survey area in 1973. This survey was made cooperatively by the U.S. Department of the Interior, Bureau of Indian Affairs and Bureau of Land Management, and the New Mexico Agricultural Experiment Station. It is part of the technical assistance furnished to the Central Rio Grande Natural Resource District, the Sandia Ranger District, the Southern Pueblos Agency, the Crownpoint Agency, and the Middle Rio Grande Council of Governments of New Mexico.

U.S. Department of Agriculture (USDA), 1974, "Visual Management System," *Handbook Number 462*, Vol. 2, Ch. 1, U.S. Forest Service, Southwest Region, Albuquerque, New Mexico.

Summary: Volume 2 describes the methodology used in the Forest Service Visual Management System including: variety class; sensitivity levels, including distance zones; and determination and mapping of the visual quality objectives. The system process is described along with implementation applications. This is the system used to conduct visual resource analyses on all U.S. Forest Service lands.

U.S. Department of Energy (DOE), March 1996, "Environmental Assessment for the Environmental Restoration Project at Sandia National Laboratories/New Mexico," *DOE/EA-1140*, Sandia National Laboratories, Albuquerque, New Mexico.

Abstract: The Environmental Restoration Project at SNL/NM prepared an environmental assessment (EA) for the U.S. Department of Energy Albuquerque Operations (DOE/AL).

In 1984, DOE/AL created a site cleanup program called the Comprehensive Environmental Assessment and Response Program (CEARP). Under the goals of the CEARP, assessment and remediation activities were conducted from 1984 until 1987 until the DOE Established the Office of Environmental Restoration and Waste

Management. The programs of site remediation, waste management, and decontamination/decommissioning were consolidated into this office. One of the primary goals of DOE ER activities is to ensure that risks to human health and the environment posed by inactive sites be either eliminated or reduced to safe levels.

The CEARP studies compiled in the 1980s and several additional investigations have identified the suspected presence of 157 potential hazardous, radiological, or mixed waste and release sites at SNL/NM. The DOE is proposing to conduct ER site corrective action (site characterization and cleanup) activities at SNL/NM. The overall purpose of and need for site characterization and cleanup is to reduce risk to human health and the environment posted by potential releases of wastes. The EA assessed the potential impacts of proposed corrective action activities on environmental and human resources.

U.S. Department of Energy (DOE), 1991, "Countermine Technology Test Facility (CTTF) Environmental Assessment, Sandia National Laboratories, Albuquerque, New Mexico," Albuquerque, New Mexico.
Abstract: This environmental assessment has been prepared pursuant to the National Environmental Policy Act (NEPA), which requires federal agencies to assess the environmental impacts of a proposed action to determine whether that action requires preparation of an environmental impact statement or a finding of no significant impact can be issued.

This environmental assessment has been prepared to evaluate the construction and operation of a Countermine Technology Test Facility (CTTF) at SNL/NM.

A comparison of the proposed action and various alternatives, including no action, indicates that the proposed action best serves the national need, while causing minimum adverse environmental impact.

U.S. Department of Energy (DOE), 1990, *Environmental Assessment for the Radioactive and Mixed Waste Management Facility, Sandia National Laboratories*, U.S. Department of Energy, Albuquerque, New Mexico.

Executive Summary: SNL/NM proposes to operate a central Radioactive and Mixed Waste Management Facility (RMWMF) for purposes of packaging and storing low-level radioactive waste (LLW) and mixed waste (MW) generated by SNL/NM. The operation of the RMWMF is part of a consolidated approach to ensure that SNL/NM LLW and MW are managed in compliance with applicable requirements of federal, state, and local environmental regulations and U.S. Department of Energy (DOE) Orders. The waste is generated by various design, development, and experimental facilities at SNL/NM that are responsible for the testing of weapons and nonweapons systems. Most of the radioactive waste at SNL/NM is solid, noncombustible material consisting primarily of uranium-contaminated waste. Mixed waste streams may contain lead, solvents and oils, beryllium, lithium, cadmium, explosive contaminants,

or other hazardous components. From 1957 to 1988, LLW and MW were buried in a land disposal facility on site; because this site not longer used to dispose of wastes, a facility is needed that can safely handle, package, and store the wastes for shipment to an off site facility.

The RMWMF will have a staging and packaging area and a storage area for LLW and MW generated by SNL/NM programs. The total estimated storage capacity of the facility is about 6000 ft^3 during normal operation, of which 600 ft^3 is reserved for liquid storage and 600 ft^3 for tritium storage. The remainder will be used to store uranium waste, high activity wastes, and miscellaneous waste. The facility if designed to store waste containing classified items and accountable nuclear material. The RMWMF and associated structures will be enclosed in a security-fenced area with controlled access. An extensive radiation monitoring system is part of the facility design to provide early warning of any abnormal operation conditions.

Appropriate measures have been taken in the design and construction of the facility to minimize any potential impacts on the environment from construction and operation of the RMWMF. The impacts to all areas of the existing environment are minimal, and all potential routine releases are well below regulatory standards, including the effects of hazardous and/or radioactive materials release. Air dispersion modeling indicates that exposure to radioactive materials at all receptor locations from total site emissions (all existing facilities plus expected released from the RMWMF) is 0.011 percent of the U.S. Environmental Protection Agency (EPA) standard.

This Environmental Assessment (EA) was prepared in response to the National Environmental Policy Act (NEPA) of 1969 and Executive Order 12088 "Federal Compliance With Pollution Control Standards." The Council on Environmental Quality regulations for the implementation of NEPA (40 CFR Parts 1500-1508) require the preparation of an EA as a method to determine significance of a proposed action. The assessment presents a description of the proposed action; the need for this action; a description of the existing environment at the proposed site; an impact assessment for each aspect of the environment; discussion on cumulative effects, unavoidable adverse effects, and irreversible and irretrievable commitment of resources; a health and safety risk section; and a section on agencies and/or individuals contacted.

U.S. Department of Energy (DOE), 1988, "Strategic Defenses Facility Environmental Assessment, Sandia National Laboratories, Albuquerque, New Mexico," Albuquerque, New Mexico.

Summary: This environmental assessment was prepared to provide environmental input into decisionmaking and to facilitate a determination as to whether to prepare an environmental impact statement or a finding of no significant impact for the proposed construction and operation of the SDF at SNL/NM. This assessment presents a description of the proposed action, brief analysis of alternatives, and the need for

action; a description of the existing environment at the proposed site; an impact assessment for each aspect of the environment; discussion on cumulative effects, unavoidable adverse effects, and irreversible and irretrievable commitment of resources; a health and safety risks section; a mitigation section; and a section on agencies and/or individuals contacted.

Impacts to all areas of the existing environment are deemed minimal, including the effects of hazardous and/or radioactive materials release.

U.S. Department of Energy (DOE), 1988a, "General Environmental Protection Program," *DOE Order 5400.1*, Washington, D.C.

Purpose: To establish environmental protection program requirements, authorities, and responsibilities for Department of Energy (DOE) operations for assuring compliance with applicable federal, state, and local environmental protection laws and regulations, executive orders, and internal department policies. The Order more specifically defines environmental protection requirements that are generally established in DOE 5480.1B.

U.S. Department of Energy (DOE), 1987, draft, "Comprehensive Environmental Assessment and Response Program, Phase I: Installation Assessment," Sandia National Laboratories, Albuquerque, New Mexico.

Summary: The U.S. Department of Energy (DOE), Sandia National Laboratories, Albuquerque (SNL/NM), has been evaluated under Phase I of the Comprehensive Environmental Assessment and Response Program (CEARP). The Phase I Installation Assessment examined inactive waste disposal sites; accidentally contaminated sites; current waste management practices; existing and potential ground and surface water contamination; and compliance with applicable federal, state, and local environmental regulations. This CEARP Phase I report documents implementation of Phase I of the DOE Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Order and implements the U.S. Environmental Protection Agency (EPA) CERCLA guidance for federal facilities. A major objective of CEARP is to determine whether waste disposal practices followed before the recognition of potential environmental hazards and/or the passage of environmental legislation have resulted in environmental problems that require remedial action today.

The CEARP Phase I findings are based on a records search, an open literature survey, interviews with current and former Sandia employees, preliminary assessments, and preliminary site inspections. Therefore, this report is unavoidably subject to some uncertainty. Situations in which there is uncertainty regarding actual environmental risk will be further studied through field studies and data collection during CEARP Supplemental Phase I (site inspection) and Phase II (remedial investigation).

The CEARP Phase I investigation was conducted in two steps. The first step identified sites that may contain hazardous materials because of past and current waste disposal operations, handling/processing of hazardous materials, or research/test activities. The second step evaluated current operations for compliance with environmental regulations.

U.S. Fish and Wildlife Service (USFWS), 1990, "Endangered and Threatened Plants," *50 CFR 17.12*, Revised as of March 14, 1990.

Summary: The list in this section contains the names of all species of plants which have been determined by the Service to be endangered or threatened. It also contains the names of species of plants treated as endangered or threatened because they are sufficiently similar in appearance to endangered or threatened species.

U.S. Fish and Wildlife Service (USFWS), 1990, "Endangered and Threatened Wildlife," *50 CFR 17.11*, Revised as of March 14, 1990.

Summary: The list in this section contains the names of all species of wildlife which have been determined by the Service to be endangered or threatened. It also contains the names of species of wildlife treated as endangered or threatened because they are sufficiently similar in appearance to endangered or threatened species.

U.S. Fish and Wildlife Service (USFWS), 1990, "Endangered and Threatened Wildlife and Plants; Review of Plant Taxa for Listing as Endangered or Threatened Species," *55 FR 6184*, February 21, 1990.

Summary: In this notice the Service presents an updated compilation of vascular plant taxa native to the United States that are being reviewed for possible addition to the List of Endangered and Threatened Plants under the Endangered Species Act of 1973, as amended (Act). Such taxa are generally referred to as listing candidates. The changes in this document from previous notices of review primarily involve: (1) the addition of taxa; (2) changes in category for some candidates; (3) the omission of taxa that have been listed under the Act; (4) candidates in previous notices; and (5) additions and deletions in state distributions. While it is prudent to take candidate taxa into account during environmental planning, none of the substantive or procedural provisions of the Act apply to a species that is designated as a candidate for listing.

Through the publication of this notice, the Service also requests any additional status information that may be available. This information will be considered in preparing listing documents and future revisions and/or supplements to the notice of review. It will also assist the Service in monitoring changes in the status of listing candidates.

U.S. Fish and Wildlife Service (USFWS), 1989, "Endangered and Threatened Wildlife and Plants; Animal Notice of Review," *45 FR 554*, January 6, 1989.

Summary: The Service issues a revised notice identifying vertebrate and invertebrate animal taxa, native to the U.S. being considered for possible addition to the List of Endangered and Threatened Wildlife. The Service emphasizes that this notice is not a proposal for such addition and that the involved taxa do not receive substantive or procedural protection pursuant to the Endangered Species Act of 1973, as amended, as a result of this action. The Service does, however, encourage federal agencies and other appropriate parties to take these taxa into account in environmental planning. Also identified in this notice (in "category 3") are animal taxa that were previously under consideration for listing, but that are currently presumed either to be extinct, to not be valid species or subspecies, or to be more abundant and/or widespread than previously thought, and not subject to substantial threats to their continued existence.

U.S. Geological Survey (USGS), 1977, "Water Resources Data for New Mexico, Water Year 1977," *Water-Data Report NM-76-17*, U.S. Geological Survey, Albuquerque, New Mexico.

Summary: Water resources data for the 1976 water year for New Mexico consist of records of discharge, and water quality of streams; stage, contents and water quality of lakes and reservoirs; and water levels and water quality of groundwater. This report contains discharge records for 212 gaging stations; stage and contents for 24 lakes and reservoirs; water quality for 67 gaging stations, 19 partial-record stations, 1 reservoir, 8 springs, and 205 wells; and water levels for 98 observation wells. Also included are 155 crest-stage partial-record stations and 3 low-flow partial-record stations. Additional water data were collected at various sites, not involved in the systematic data collection program, and are published as miscellaneous measurements. These data represent that part of the National Water Data System collected by the U.S. Geological Survey and cooperating State and Federal agencies in New Mexico.

U.S. Geological Survey National Earthquake Information Center (USGS/NEIC), 1995, *Earthquake Data Base Information Packet*, "Earthquake Data Base System," U.S. Geological Survey National Earthquake Information Center, Federal Center, Box 25046, Mail Stop 967, Denver, Colorado 80225-0046. Please mark all correspondence: "Attention: Glen Reagor".

Summary: A seismicity search may be requested directly from the Golden, Colorado, based USGS/NEIC *Earthquake Data Base System (EDBS)* for any catalog or data bases including those catalogs which are not available on the *Global Hypocenter Data Base CD-ROM*. The data base spans a time period from 2100 BC through 4 weeks previous to the current week. The *EDBS* and the *Global Hypocenter Data Base CD-ROM* searches are similar; search elements may vary between retrieval systems.

Each earthquake in the data base contains all the information available concerning the date, origin time [Universal Time Coordinated (UTC)], location, depth, magnitude estimates, Modified Mercalli Intensity, cultural effects (damage/casualties), miscellaneous information: [International Data Exchange (IDE)] events, fault

plane/moment tensor solutions, and related seismic phenomena (e.g., diastrophism, tsunamis).

A seismicity Search Request Order Form is included in the *Earthquake Data Base Information Packet*. The form explains the order procedure and the fee schedule for earthquake data retrievals. Each retrieval may be returned to the user by electronic mail (FTB or Internet), 3½-inch diskettes, or paper listing. Each retrieval includes a page-size seismicity map of the selected data (see *Packet* for map examples).

For more information concerning the data base, refer to the *Earthquake Data Base Documentation*; the documentation is free and available on request.