A Proposal for:

LONG-TERM ECOLOGICAL MONITORING IN THE UPPER RIO GRANDE BASIN AT BANDELIER NATIONAL MONUMENT, EL MALPAIS NATIONAL MONUMENT, AND PECOS NATIONAL HISTORICAL PARK

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A PROPOSAL FOR LONG-TERM ECOLOGICAL MONITORING IN THE UPPER RIO GRANDE BASIN AT BANDELIER NATIONAL MONUMENT, EL MALPAIS NATIONAL MONUMENT, AND PECOS NATIONAL HISTORICAL PARK

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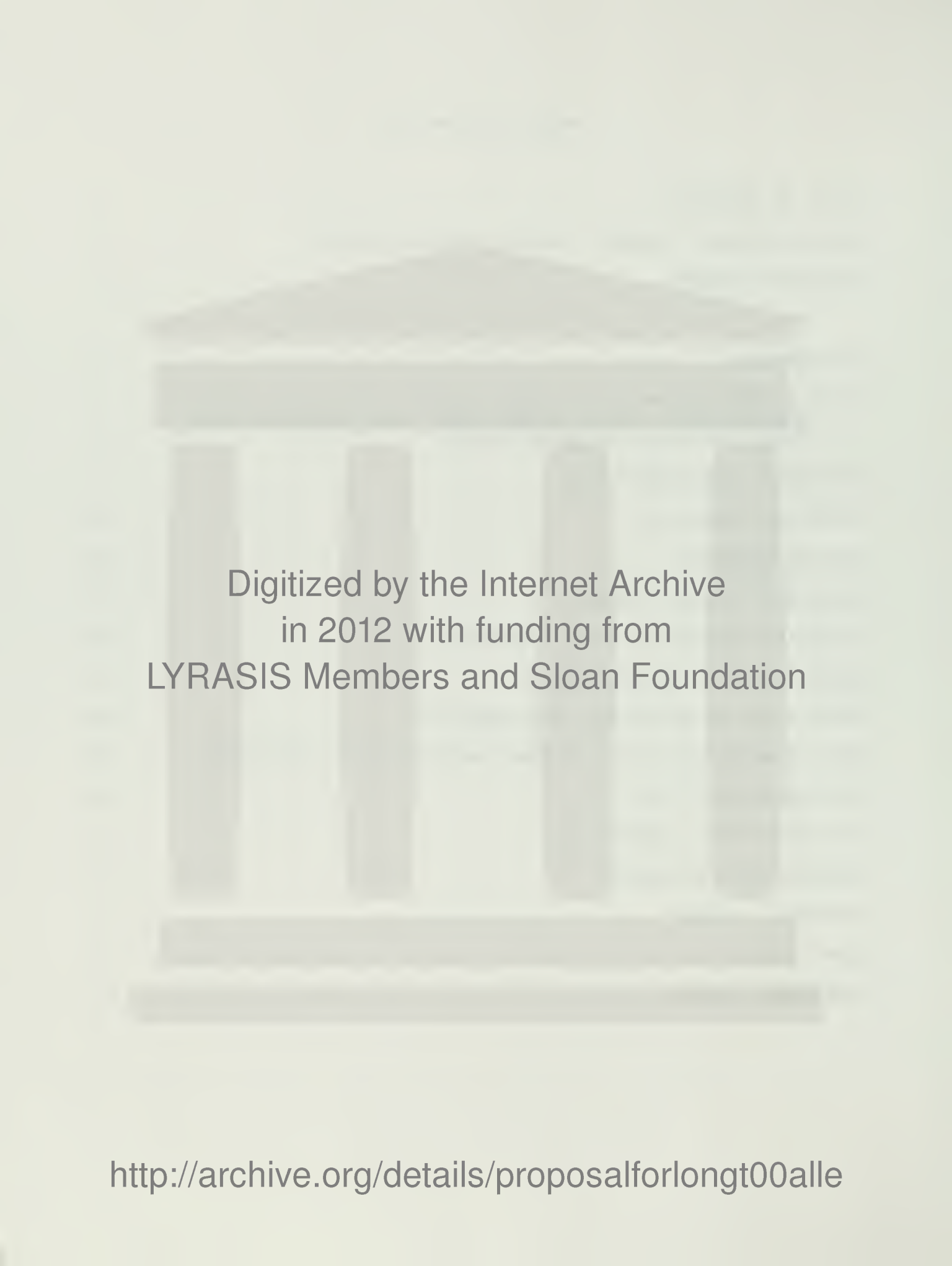

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EXECUTIVE SUMMARY:

PROPOSAL FOR LONG-TERM ECOLOGICAL MONITORING IN THE UPPER RIO GRANDE BASIN AT BANDELIER NATIONAL MONUMENT, EL MALPAIS NATIONAL MONUMENT, AND PECOS NATIONAL HISTORICAL PARK

Prototype Program Name: Upper Rio Grande Basin

Biogeographic Association: Coniferous Forest Units

Cluster park proposal involving Bandelier National Monument (BAND), El Malpais National Monument (ELMA), and Pecos National Historical Park (PECO).

We propose a collaboration between three NPS units and the University of New Mexico's Long-Term Ecological Research (LTER) Program to develop a network of long-term ecological monitoring (LTEM) sites within the mosaic of ecosystem types in central and northern New Mexico. Consistent data collection and analysis methods are already being employed across the geographic and ecological gradients of this network of sites. BAND, ELMA, and PECO will contribute a variety of coniferous forest monitoring sites to the network, as well as unique habitat types (montane riparian forests and ice caves) and disturbed ecosystems (post-fire ponderosa pine forests, cleared pastures in piñon-juniper woodlands).

Incorporating multiple, NPS LTEM sites into a larger regional network of NSF-funded LTER sites markedly increases the statistical interpretive power for examining the ecological responses to anthropogenic changes, natural disturbances, and climate changes at the NPS sites. This network of sites is an ecological analog to the Very Large Array radiotelescope (VLA), where a series of scattered, individual dish-antennae (ecological monitoring sites), when monitored simultaneously, reveal high-resolution data on obscure astronomical (ecological) phenomena. The information collected by this LTEM network will be valuable to ecosystem research scientists as well as NPS managers.

This proposal outlines an integrated program of ecosystem monitoring which includes these components:

1. Monitor meteorological variables.
2. Monitor soil erosion rates.
3. Monitor major components of nutrient cycles, including nutrient inputs from precipitation, nitrogen mineralization potentials in ponderosa pine forests, nutrient transfers during decomposition of organic materials, and nutrient/contaminant dynamics in one stream.
4. Monitor plant population distributions, demographics, structural compositions, and temporal dynamics within several NPS ecosystems.
5. Monitor selected animal population distributions, demographics, and temporal dynamics.

6. Monitor the ecological effects of major disturbances by comparing intensely burned **versus** lightly or unburned ponderosa pine forests in BAND, and cleared **versus** uncleared piñon-juniper woodland sites at PECO.
7. Monitor unique ice cave habitats in ELMA.

We propose to establish an "eco-swat team" based at the University of New Mexico (UNM) to implement the bulk of the monitoring activities in this LTEM program. Funding would be provided through a cooperative agreement with UNM to finalize development of field data collection sampling methodologies, collect field data at appropriate time intervals, sort/prepare/identify all field samples, curate any collected specimens, enter data into computerized formats, analyze the data, and produce annual summary reports. While UNM-based LTEM staff will conduct and manage most program activities, a LTEM Program Coordinating Committee, comprised of representatives of the NPS, NBS, and UNM, will oversee the project.

Data management for this LTEM program will be coordinated through the LTER's Sevilleta Information Management System (SIMS). Once archived copies of all data sets in ASCII format will be available for immediate on-line use and storage on any local NPS computer system.

The program proposed here is an attractive model for the NPS to consider as a prototype for long-term ecological monitoring throughout the NPS system. The coniferous forest types monitored in the Upper Rio Grande LTEM parks represent important, widespread ecosystems which are dominant components of many NPS units. The potential exists for developing an expanded cooperative LTEM network among other NPS units with similar ecosystems in the Four Corners area. The focus on a university-based, multi-park, "eco-swat team", with lesser emphasis on use of park-based staff, is a logistically and fiscally efficient way to collect and analyze large amounts of field data.

This program offers an appealing approach for small NPS units, as it links them to the critical mass of technical expertise and overall program resources needed to implement a high-quality monitoring program. By directly interacting with a LTER network site the NPS accesses the accumulated expertise of the best scientific personnel available, including their peer-reviewed experience with state-of-the art sampling and data management methods. Contracting with outside scientists to collect, analyze, interpret, and report on the data insures that **all** of these essential activities occur annually. Involving the faculty of a local university provides additional opportunities to promote the use of the parks as study sites for resource management purposes and public education, as well as for "the sake of science". Overall, the **Upper Rio Grande Basin** is an attractive candidate for inclusion in the NPS prototype long-term ecological monitoring program.

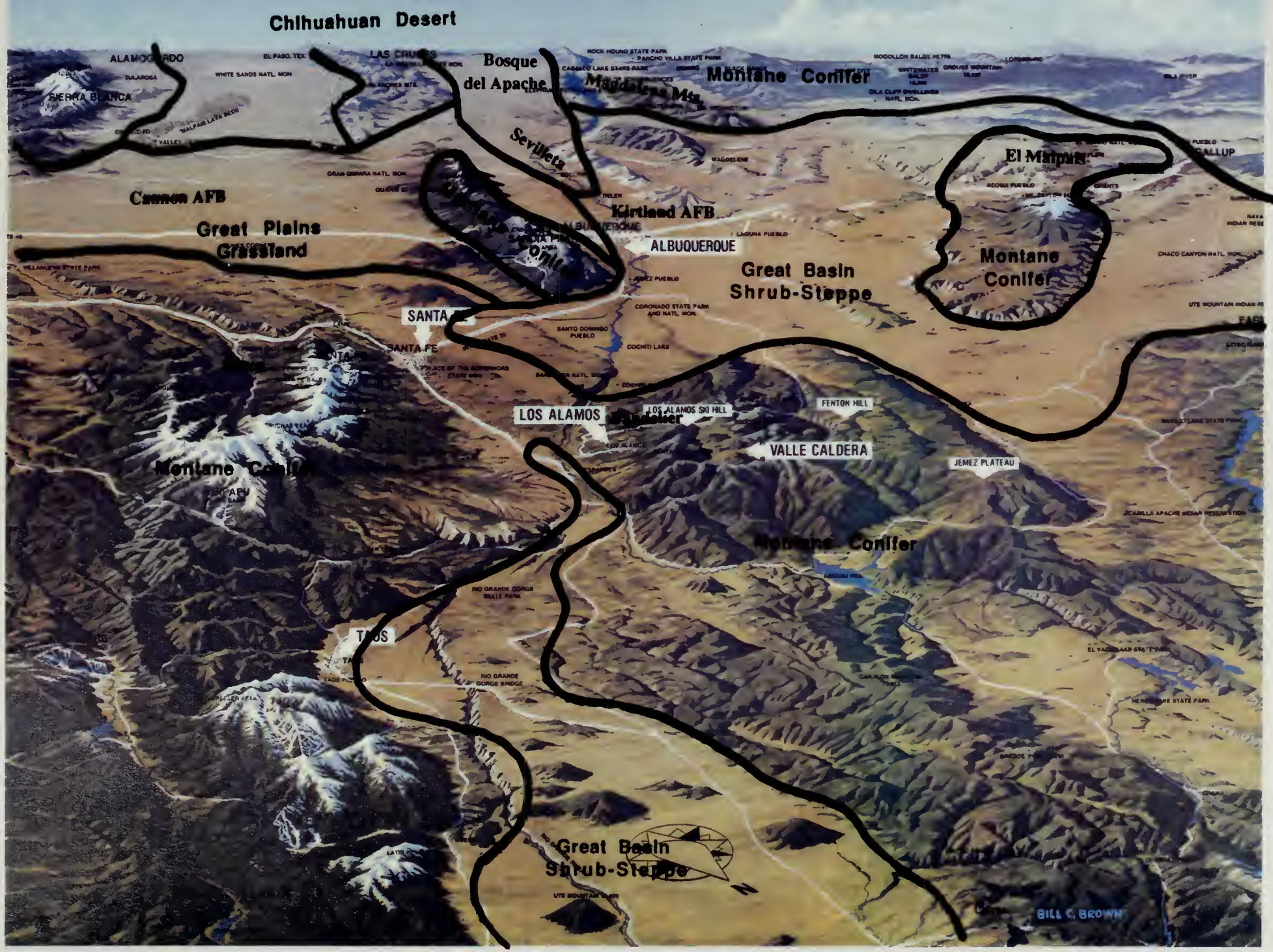
INTRODUCTION

We propose a unique collaboration between a cluster of smaller NPS units and a NSF-funded, long-term ecological research (LTER) site that will provide a progressive, state-of-the-science model for long-term ecological monitoring (LTEM) in the National Park Service. The prototype monitoring proposal builds upon existing strong ecological inventory and research linkages between Bandelier National Monument (BAND), El Malpais National Monument (ELMA), Pecos National Historical Park (PECO), and the University of New Mexico's Sevilleta LTER site (SEVI). These three NPS sites are clustered in the coniferous forests of northern New Mexico's mountains and uplands (Plate 1). Coniferous forests and woodlands currently cover over 80% of BAND and about 70% of ELMA and PECO, with 96% conifer coverage of BAND prior to a large fire in 1977 and over 90% coverage of PECO prior to land-clearing in the 1970's. The designation of BAND, ELMA, and PECO as a NPS prototype LTEM program will formalize already established linkages with the Sevilleta LTER program.

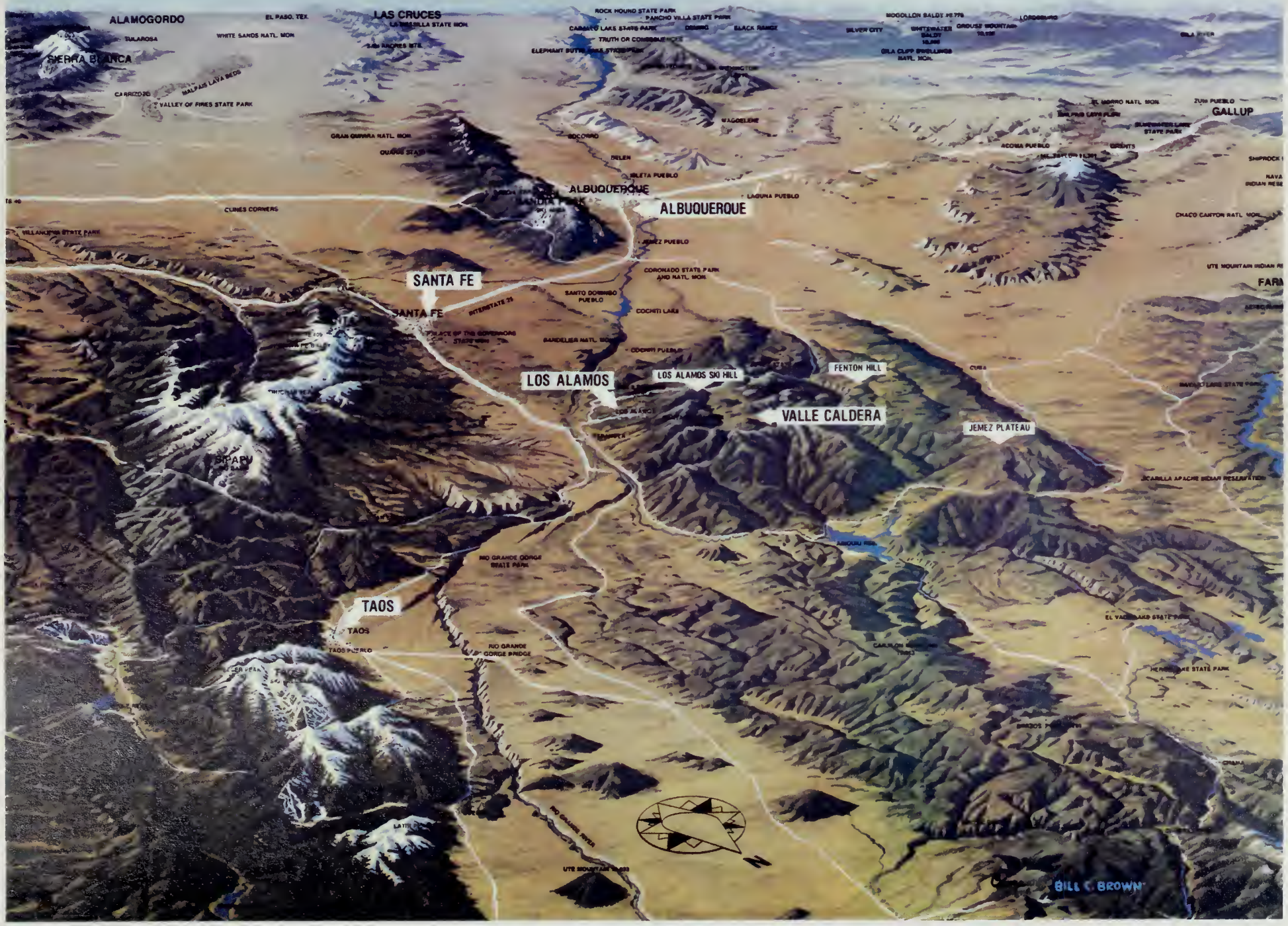
This regional network of three northern New Mexico LTEM sites will work in unison with the SEVI LTER sites in utilizing standardized data collection methods across a gradient of ecological, physiographic, climatic, and cultural influences. Utilization of a comparative, multi-scale, landscape approach across this network of sites will increase the sensitivity, reliability, and management utility of results as applied to long-term ecological monitoring issues, and will allow results to be scaled up to landscape and regional levels. We believe that the multi-park/university partnership proposed here will optimize the quantity and quality of monitoring results which can be leveraged from limited NPS funds. This will be the case because close linkages with the UNM LTER program will provide enhanced methodological coordination, data management support, expertise in interpreting the data, access to needed facilities and equipment, and overall lower program costs.

GENERAL DESCRIPTION OF THE STUDY SITES WITHIN THE UPPER RIO GRANDE BASIN: BAND, ELMA, PECOS, AND SEVILLETA LONG TERM ECOLOGICAL RESEARCH SITES

Bandelier National Monument is located in the southeast flank of the Jemez Mountains in north-central New Mexico (Plate 1). Established in 1916, BAND contains 13,260 ha, largely in the Bandelier Wilderness. The Jemez Mountains rise as a volcanic island of mesic environments above semi-arid plateaus and valleys. BAND provides a representative elevational transect of the Jemez Mountains landscape, with a rise from 1625 m at the Rio Grande to 3111 m at the caldera rim. The park is dissected by numerous 100 to 300 m deep canyons, resulting in diverse topography. This broad range of elevational and topographic conditions creates significant temperature and precipitation gradients, resulting in a complex altitudinal zonation of vegetation from extensive woodlands of piñon (Pinus edulis) and


Chihuahuan Desert
Bosque del Apache
Montane Conifer
Sevilleta
El Malpais
Cannon AFB
Kirtland AFB
Great Plains Grassland
ALBUQUERQUE
Great Basin Shrub-Steppe
Montane Conifer
SANTA FE
LOS ALAMOS
VALLE CALDERA
JEMEZ PLATEAU
Montane Conifer
Montane Conifer
TAOS
Great Basin Shrub-Steppe
BILL C. BROWN


Chihuahuan Desert
Montane Conifer
Magdalena Mts.
Bosque del Apache
Sevilleta
El Malpais
Kirtland AFB
Montane Conifer
Cannon AFB
Great Plains Grassland
Montane Conifer
Great Basin Shrub-Steppe
Pecos
Bandelier
Montane Conifer
Montane Conifer
Great Basin Shrub-Steppe


ALAMOGORDO
LAS CRUCES
SIERRA BLANCA
ALBUQUERQUE
ALBUQUERQUE
SANTA FE
SANTA FE
LOS ALAMOS
LOS ALAMOS SKI HILL
FENTON HILL
VALLE CALDERA
JEMEZ PLATEAU
TAOS
TAOS
GALLUP
BILL C. BROWN

Juniperus spp. up through ponderosa pine (Pinus ponderosa) and mixed conifer forests of white fir (Abies concolor), Douglas-fir (Pseudotsuga menziesii), and limber pine (Pinus flexilis) into forests of Engelmann spruce (Picea engelmanni) and corkbark fir (Abies lasiocarpa var. arizonica) (Plates 2 and 3).

El Malpais National Monument was established in 1987 and contains 46,135 hectares (Plate 1). Elevations within ELMA vary from 1952 m to 2537 m. ELMA consists of a complex of eight forested lava flows. These basalt flows range in age from about 1.0 million years BP to circa 3,000 BP. The sources of the monument's lava flows are 12 major volcanic vents located within and around the park. The broken terrrain of these lavafields makes travel through the landscape of EL Malpais ("the bad country") extremely difficult. Thus the core of the park constitutes one of North America's least disturbed environments. ELMA also contains many kipukas, non-lava islands within a surrounding lava flow, which vary in size from .05 hectare to 3,000 hectares. Because the lava surrounding the islands is usually a barrier to domestic livestock, many ELMA kipukas have little history of livestock grazing, which is rare in the Southwest.

Ponderosa pine dominates ELMA's vegetation, along with piñon and Juniperus species, while Douglas-fir is important in some areas. Unusual vegetation types include ice-cave and below-ground-ice dependent micro-ecosystem (e.g., isolated fern, moss, lichen, sedge, and algae dominated communities) and a variety of stressed pygmy forests of ponderosa pine, douglas-fir, and aspen (Populus tremuloides) growing on recent lava flows (Plates 2 and 3).

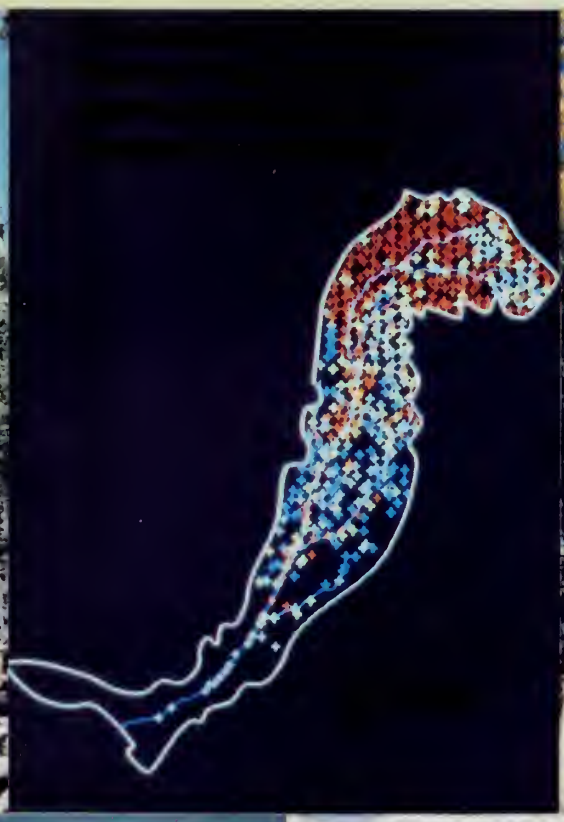
Pecos National Historical Park, located in the south flank of the Sangre de Cristo Mountains (Plate 1), was established in 1990, expanding upon Pecos National Monument, and contains 2375 hectares. Elevations range from 2117 m along the Pecos River to 2263 m. Major vegetation types include piñon-juniper woodlands, previously cleared woodland in the process of returning to woodland, ponderosa pine forests, and riparian forest (Plates 2 and 3).

We propose to link these three park units with the NSF-funded Sevilleta LTER site (Gosz **et al** 1988), located 50 miles south of Albuquerque (Plate 1). SEVI is operated by the University of New Mexico on the Sevilleta National Wildlife Refuge, which is managed by the United States Fish and Wildlife Service (USFWS). Primary LTER site size is 100,000 hectares and its uniqueness lies in the fact that four major biomes intersect within the site (Gosz **et al** 1988). Elevations range from 1350 m at the Rio Grande to 2195 m in the Sierra Los Pinos. Major vegetation types range from conifer woodlands of piñon and Juniperus spp. through shrublands of Artemesia spp. and Larrea tridentata to grasslands of Boutelou and Oryzopsis spp. (Plate 4). The SEVI LTER program is described in Appendix A.

In addition to the primary SEVI site, the LTER also includes coniferous woodlands and forests in the Sierra Ladrones

Plate 2. NPS Ecosystem Types

ixed-conifer forest,
andelier Nat. Mon.



Douglas Fir – Aspen forest,
Bandelier Nat. Mon.

Forest habitat mosaic, Frijoles watershed,
Bandelier National Monument

Cottonwood-willow riparian zone, Pecos River

Ponderosa/Piñon/Juniper forest,
El Malpais National Monument

ce cave, El Malpais Nat. Mon.

Plate 2. NPS Ecosystem Types

Mixed-conifer forest, Bandelier Nat. Mon.

GIS data layer of Bandelier Frijoles Creek watershed, showing distributions of Douglas Fir populations.

Douglas Fir – Aspen forest, Bandelier Nat. Mon.

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Cottonwood-willow riparian zone, Pecos River

Forest habitat mosaic, Frijoles watershed, Bandelier National Monument

Ponderosa/Piñon/Juniper forest, El Malpais National Monument

Ice cave, El Malpais Nat. Mon.

Plate 3. Disturbance Regimes

Prescribed fire at Bandelier Nat. Mon.

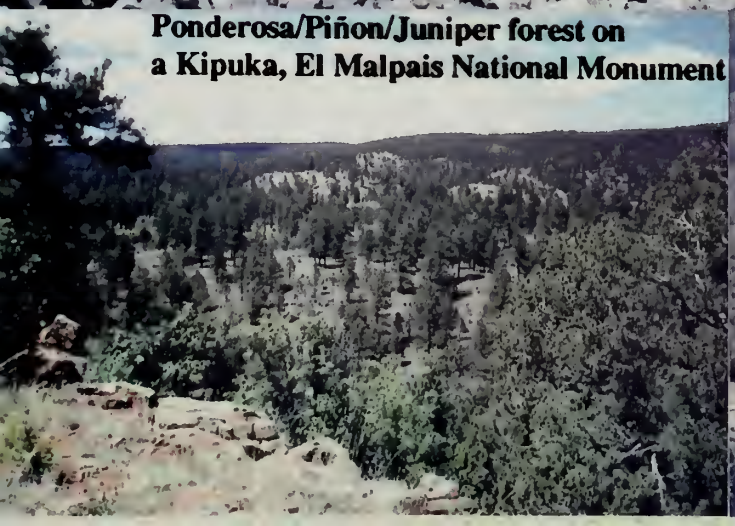
Vegetation recovering from the La Mesa forest fire, Bandelier National Monument

Undisturbed Ponderosa/Piñon/Juniper forest, Pecos National Historic Park

Livestock pasture, Pecos NHP (bulldozed in 1973)

Collapsed lava tube, El Malpais Nat. Mon.

Stratified cryptogam assemblage at cave opening near tourist entry



Ponderosa/Piñon/Juniper forest on a Kipuka, El Malpais National Monument

Ponderosa/Piñon/Juniper forest on lava flow, El Malpais National Monument

Forest recovering from the La Mesa forest fire,
Bandelier National Monument

Prescribed fire at Bandelier Nat. Mon.

Undisturbed Ponderosa/Piñon/Juniper forest,
Pecos National Historic Park

Livestock pasture, Pecos NHP (bulldozed in 1973)

Stratified cryptogam assemblages
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Collapsed lava tube, El Malpais Nat. Mon.

Ponderosa/Piñon/Juniper forest on
a Kipuka, El Malpais National Monument

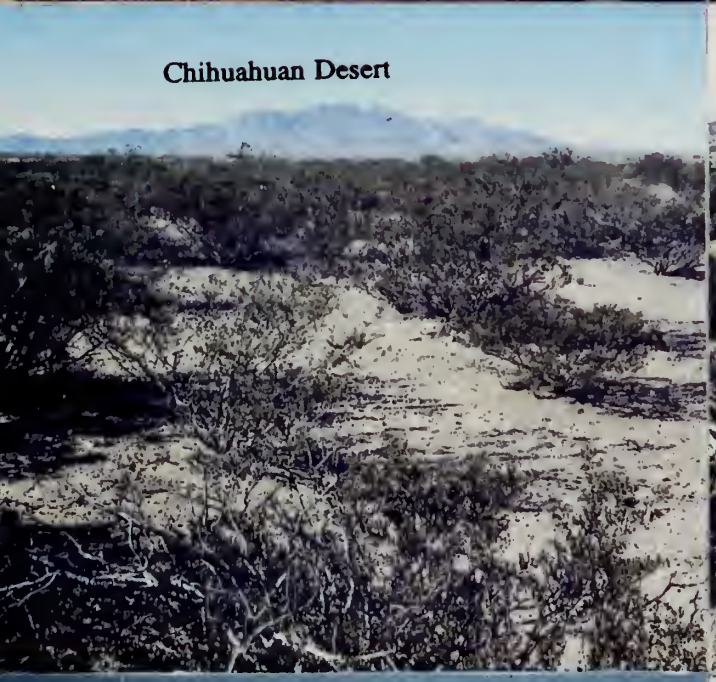
Ponderosa/Piñon/Juniper forest on lava flow,
El Malpais National Monument

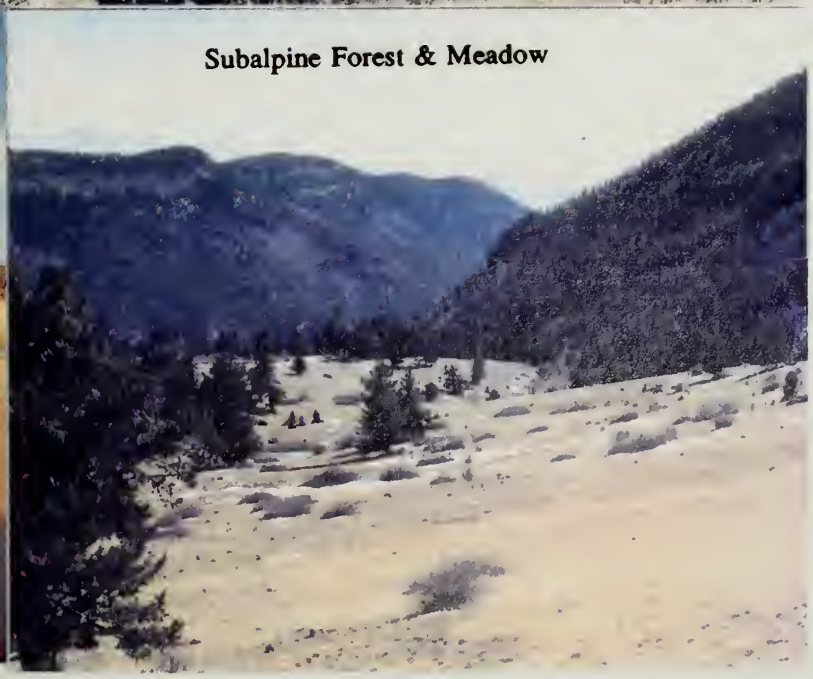







Plate 4. Ecosystems of the UNM LTER Program





Great-Basin Shrub Steppe

Short-Grass Prairie

Pinon-Juniper Woodland

Chihuahuan Desert

Subalpine Forest & Meadow

Cottonwood Riparian Forest

Wilderness Study Area (BLM managed; 28,390 hectares, elevations to 2797 m), mixed conifer forests and subalpine grasslands in the Magdalena Mts. Research Area (USFS managed; 15,000 hectares, elevations to 3450 m), riparian forests at the Bosque del Apache National Wildlife Refuge (USFWS managed; 23,000 hectares), and grasslands at Kirtland and Cannon Air Force bases (Plates 1 and 4).

RECOGNIZED MANAGEMENT NEED:

All three NPS units highlight the need for long-term ecological monitoring in their resource management plans (RMP's). BAND's detailed RMP, currently in review at WASO, places high priority on inventory and monitoring projects. Relevant BAND project statements include:

N-003.1, Inventory and monitor biotic resources (Appendix B);
N-003.2, Inventory and monitor sensitive animals;
N-003.3, Inventory and monitor sensitive plants;
N-004.2, Inventory and monitor soils;
N-005.0, Develop long-term weather database;
N-006.1, Monitor air quality and related values;
N-007.1, Evaluate and redesign water quality monitoring program;
N-008.1, Develop and maintain a geographic information system;
N-009.2, Inventory and monitor wilderness/backcountry impacts;
N-015.3, Conduct La Mesa Fire research (monitoring);
N-017.0, Evaluate effects of unnatural ungulate populations;
N-021.0, Monitor and mitigate Cochiti lakeshore impacts;
N-024.0, Conduct global climate change research;
N-025.1, Characterize piñon-juniper ecosystem condition and erosion rates;
N-026.2, Monitor land use trends (protect from external threats).

Note that for reasons of clarity only a single project statement from each NPS unit is attached here (Appendices B, C, and D) - namely that project statement which most specifically addresses the long-term ecological monitoring proposed here.

As a new NPS unit, El Malpais is currently preparing it's RMP, which will be submitted to the Southwest Regional Office in 1993. ELMA's RMP states the need for long-term ecological monitoring in the following project statements:

N-001, Develop a long-term ecological monitoring program (Appendix C);
N-002, Implement fire management plan (includes monitoring fire effects);
N-013, Monitor global climate change;
N-014, Monitor and manage vegetation;
N-019, Monitor grazing effects;
N-029, Monitor existing cave uses;
N-031, Monitor and manage wildlife;
N-038, Monitor and manage threatened and endangered species;
N-039, Monitor and manage air quality; and
N-040, Monitor and manage water resources.

Pecos National Historical Park is another new unit which is currently developing an RMP which places a high priority on long-term ecological monitoring, as illustrated by the following project statements:

N-003.0, Establish long-term ecological monitoring (Appendix D);
N-003.1, Monitor small mammals;
N-003.2, Monitor large mammals;
N-003.3, Monitor resident and transient avian populations;
N-003.4, Monitor Pecos River fish population;
N-003.5, Monitor Glorieta Creek fish population;
N-004.0, Water quality study;
N-008.0, Establish air quality/meteorological baseline;
N-017.0, Monitor temporal vegetation composition change;
N-019.0, Conduct intensive soil survey;
N-020.0, Study Pecos River riparian biodiversity;
N-021.0, Monitor rate of erosion along Pecos River and Glorieta Creek.

This RMP will be submitted for regional review in 1993.

2) STATUS OF INVENTORY:

The status of inventory information varies between the three NPS units included in this proposal. While the two new NPS units of ELMA and PECO have had less time and opportunity than BAND to undertake inventory work, baseline inventory data have been collected in each park using consistent methodologies for many of the ecosystem components which we propose to monitor. These NPS units have worked hard to develop the baseline data, methodological approaches, and programmatic vision needed to develop a coherent, sustainable, monitoring program. For example, BAND has reallocated significant amounts of base funding in recent years in an effort to make the transition from a mosaic of loosely-related inventory projects to establish and begin implementing the framework for a comprehensive monitoring program. However, all three parks recognize that additional fiscal/human resources are needed to develop and sustain an adequate monitoring program - thus this effort to participate in the prototype monitoring initiative.

The fauna and flora of all three NPS units considered in this proposal and the Sevilleta LTER site have been inventoried, or are in the process of being inventoried, using consistent methodologies. Since 1991 individual inventory projects at BAND, ELMA, and PECO have been conducted by the Department of Biology, University of New Mexico, through a general cooperative agreement between the National Park Service and the University of New Mexico. Inventory and monitoring studies on plants and animals have been ongoing at the Sevilleta LTER site since 1987. Inventory information for each of the NPS units is described below.

Bandelier National Monument:

A significant amount of inventory work has been conducted at

BAND in the past two decades which provides a solid foundation for a comprehensive monitoring program. Inventory efforts which will be incorporated as primary components of our proposed LTEM program are highlighted here, although other inventory activities are briefly described.

Since 1991 BAND has been working with UNM faculty to establish long-term ecological monitoring activities which mirror portions of the SEVI LTER program. The short-term goal has been to develop a program which monitors vegetation, small mammals, and ground-dwelling arthropods using LTER methods across an elevational gradient in the three main vegetation zones of the park (piñon-juniper woodland, ponderosa pine forest, mixed conifer forest). Currently there are ten, 300 meter vegetation line transects established in piñon-juniper woodland and ponderosa pine forests at BAND. Thirty-six erosion monitoring transects ("bridges") were established in association with the vegetation transects in 1991 and read annually since. Six, small mammal, trapping webs (148 traps/web) have been established in mixed conifer forests and piñon-juniper woodlands. A network of 90 arthropod pitfall traps (30 per vegetation type) on a 6-8 week collection schedule has been established (Lightfoot 1992). Soft money has been used to conduct the initial inventories which have been completed or are in progress. Monitoring is now occurring with some elements of this network, although we currently lack the base-funded resources to sustain this program on a long-term basis.

From 1991 to present BAND and the NPS Southwest Regional Office have supported efforts to follow up on earlier studies and monitoring work conducted after the 1977 La Mesa Fire to assess its ecological effects (see Foxx, 1984, for an overview of the earlier work). Current follow up efforts include: monitoring of permanent bird transects (Wauer 1991) and vegetation plots (in progress) established before the fire; landscape-wide fire history and paleoclimatic studies (Touchan and Swetnam 1992, and in progress); reassessment of erosion in six small, permanently-instrumented watersheds (W.White 1993); establishment of permanent vegetation/pellet transects and assessment of elk grazing impacts in fire-created grasslands (Conley **et al** 1979, Wolters - in progress); fungal and arthropod inventories in burns of different ages and intensities (in progress); and nitrogen mobilization and fixation in different burn types and ages (C.White 1993). Results from these and other monitoring and research studies will be presented in March 1994 at the Second La Mesa Fire Symposium in Los Alamos, New Mexico. Maintenance of some of these monitoring activities is incorporated into this proposal's LTEM program design.

Since 1992 BAND has established over thirty, permanent, vegetation plots designed to monitor short and long-term effects of our prescribed fire program (USDI NPS 1992). Baseline data have been collected at all plots, and post-fire monitoring has occurred on a number of the plots. Some of these plots will utilized to monitor vegetation as part of this LTEM proposal.

In 1993 BAND, Los Alamos National Laboratory, and a University of Colorado-Boulder researcher established a 1.5 hectare watershed study site on BAND to determine runoff, erosion, and sediment transport dynamics in a piñon-juniper woodland. The ephemeral mainstem drainage is gauged, an electronic remote weather station is located on-site, 19 small sediment traps dispersed through the watershed along with 20 sets of erosion bridges, 3 thirty-meter line transects established to characterize vegetation conditions, and a detailed topographic survey of the watershed completed. This project is planned as a long-term study which is incorporated as a no-cost component of the LTEM program proposed here.

In 1993 the USGS established a National Water Quality Assessment Program site on Frijoles Creek which is monitoring biotic and abiotic components of this stream. This stream monitoring program has been incorporated into this proposal's LTEM program.

Through cooperation with adjoining Los Alamos National Laboratory BAND has acquired 1992, color, aerial imagery (stereophotos at 1:7200 and 1:24,000, orthophotos at 1:4800) in both photographic hard copy and scanned digital GIS formats. Detailed topographic maps were also developed for the park in digital and hardcopy forms at 10-foot and 2-foot contour intervals. BAND has additional aerial photographic coverage of the park from 1935, 1965, 1977, and 1981.

Other natural resource inventory work conducted at BAND includes:

Vegetation: All or parts of the park's vegetation has been mapped a number of times, including Anonymous (1934), Koehler (1974), Potter and Foxx (1981), Potter (1981), Hink and Ohmart (1984), Cully (1985), Cully (1986), and Allen (1989). Eighteen permanent plots were established to examine the impacts of the La Mesa Fire (Foxx and Potter 1978, Potter and Foxx 1979-a). Potter and Tierney (1985) established 20 permanent line transects and associated clip plots in the grasslands and meadows of the Cerro Grande Accession. Three sets of permanent burro (Equus asinus) exclosures were constructed in 1975, with data collected in 1978 (Potter and Foxx, 1979-b), 1984 (Potter 1985), and 1992 (Chong 1992). Gosz and Marks (1974) examined the reproductive status of alligator juniper (Juniperus deppeana) in western portions of Bandelier. Lathja (1988) established two permanent plots in piñon-juniper woodland areas to look at nutrient cycling and plant demographic patterns. Koehler (1974) sampled and mapped range trends in different portions of the park. Potter and Berger (1977) examined deer-burro utilization of vegetation. Potter and Foxx (1979-c) reviewed the success of grass seeding after the La Mesa Fire. Oppenheimer (1979) examined the patterns of early revegetation after the La Mesa Fire. Jones (1979) provided a barebones checklist of lichens, and Weber (1980) made a lichen collection which the park stores physically and in database format. Tierney (1977), Potter (1981), Hink and Ohmart

(1984), and Allen **et al** (1993) studied the vegetation along the Rio Grande. Barnes (1983) sampled piñon-juniper vegetation types in Bandelier and adjoining Los Alamos National Laboratory (LANL) lands. Allen (1984-a) examined montane grasslands and tree invasion on Cerro Grande. Tierney and Potter (1985) studied the plant ecology of felsenmeers. Jacobs and Jacobs (1988) and Jacobs (1989) made extensive plant collections and integrated previous collections into an excellent herbarium and associated database. Allen (1989) sampled vegetation and other landscape features at 969 points across the Frijoles watershed, with results in a database and GIS files; this research also documented historic vegetation changes throughout Bandelier. Jarmie and Rogers (1993) are conducting a fungal inventory of the park and LANL lands, with results in a database format.

Forester (1976), Patton (1978), and Allen (1984-b) inventoried and mapped downed woody fuel loads in the park. Fire history research, using fire-scars, has been conducted by Foxx and Potter (1978, 1984), Potter and Foxx (1981), Caprio **et al** (1989), Allen (1984-c, 1989), and Touchan and Swetnam (1992). The effects of the La Mesa Fire on vegetation were studied by Foxx and Potter (1978, 1984), Potter and Foxx (1979-b), Potter and Foxx (1979-c, 1984), Potter **et al** (1982), Allen (1989), and Foxx (in progress).

Animals: Ro Wauer (1978-a) established permanent transects to monitor bird population trends in Bandelier. Subsequent work on these transects has been done by Wauer and Dennis (1979), Johnson (1983-a), Wauer and Johnson (1984), and Wauer (1991). T. Johnson (1979, 1980, 1981, 1982, 1983-b, 1984, 1985, 1986, 1988, 1990, 1992) has studied bald eagles (Haliaeetus leucocephalus) in Bandelier since 1978, and has also worked with the park to monitor peregrine falcons (Falco peregrinus). Kennedy (1985, 1989) and Kennedy and Crowe (1991) have monitored zone-tailed hawks (Buteo albonotatus) and other raptors in the Jemez Mts. Johnson and Johnson (1988) inventoried Upper Frijoles Canyon for spotted owls (Strix occidentalis) in 1988, and T. Johnson (1991) inventoried Frijoles Canyon again in 1991 for spotted owls. Degenhardt (1975) surveyed the park for herpetofauna, with surveys for Jemez Mt salamander (Plethodon neomexicanus) conducted by the park in 1991 and 1992. Guthrie (1984) and Guthrie and Large (1980) trapped small mammals at 11 locations in Bandelier from 1977 - 1979. Conley **et al** (1979) and Sivinski (1979) looked at changes in mule deer (Odocoileus hemionus) and Rocky Mountain elk (Cervus elaphus nelsoni) utilization and migration in and around Bandelier. Many studies of local burros occurred during the 1970's. Mid-winter helicopter surveys have mapped the distribution of elk and other ungulates in 1984, 1985, 1987, 1990, 1991, 1992, and 1993 (Allen 1993). Arganbright (1988, 1991) studied two bat colonies in Frijoles Canyon from 1987 to 1989, with followup monitoring by the park (Judson 1991). Pippin (1978), Pippin and Nichols (1978), and Pippin and Pippin (1980, 1981, 1984-a, 1984-b) collected arthropods in the park;

this work provides some baseline information on arthropod species diversity in Bandelier, with provenience data on about 40 percent of 1,200 species listed from this collection in the Automated National Computer System (ANCS) and dBASE files. Jacobi (1989) inventoried some aquatic invertebrates from Frijoles Creek. Occasional sampling of park streams for fish species has occurred, including inventories of the Rio Grande and Frijoles Creek by S. Platania (1991, 1992) of UNM.

From 1932 through 1989, a total of 2,207 wildlife observations were made at Bandelier; these data have been entered into DBASE files. A revised, joint wildlife observations database was established with LANL, but the entry of observations since 1991 is currently backlogged.

Aquatic Resources: General physical descriptions, flow data and baseline chemistry data exist for all surface flows (Purtymun and Adams 1980, Purtymun 1984, Purtymun **et al** 1980). The Rito de los Frijoles has been sampled for various constituents at Monument Headquarters since 1957. Intermittent sampling has occurred on the Capulin stream since 1975. Coliform bacteria levels have been measured in the Rito de los Frijoles between 1975-1978 and 1982-85. In compliance with E.O. 11988, a flood hazard survey was completed for Frijoles Canyon in 1987. The Water Resource Division is preparing an updated Water Resource Management (and monitoring) Plan for Bandelier.

Geologic Resources: Smith **et al** (1970) published a 1:125,000 scale geologic map of the entire Jemez Mountains, which includes the Bandelier area. Goff **et al** (1990) published a 1:24,000 geologic map of the St. Peter's Dome area, including most of Bandelier. Olinger (1972) described the geological features of lower Frijoles Canyon. Boden (1978) examined the stratigraphy and faulting history of the Bandelier area. Wells (1978) and White and Wells (1984) studied the geomorphic effects of the La Mesa Fire, establishing three small study watersheds each on Burnt and Apache Mesas with permanently marked erosion pin transects in each watershed. S. Reneau (1991) of LANL has been conducting detailed studies of the fault systems of the Pajarito Plateau and of stream terraces in Frijoles Canyon in an effort to assess local seismic hazards and rates of stream downcutting.

Earth Environmental Consultants (1974, 1978) conducted low intensity soil surveys of Bandelier. Nyhan **et al** (1978) surveyed the soils of adjoining Los Alamos County. The Soil Conservation Service and U.S. Forest Service have also conducted high quality soil surveys on adjoining lands. Freeman (1984) examined the effects of the La Mesa Fire on total soil nitrogen. Orcutt and Powers (1992) documented the widespread impacts of erosion to archeological sites as part of the work of the Bandelier Archeological Survey. This erosion documentation continues under in-house archeological surveys which began in 1992. Allen (1989) documented the widespread occurrence of sheet erosion across the Frijoles watershed.

Air Resources: BAND weather records begin in 1925 for the park headquarters area (1900 m), with a RAWS station collecting climatic data year-round from a site at 2900 m. Numerous weather stations across an elevation gradient exist around the park, particularly at LANL, which has just completed a detailed climatological review of the NERP (Bowen 1990). Records extend to 1911 at the Los Alamos townsite (2300 m).

A permanent snow course has been maintained since 1958 by the Soil Conservation Service at 2900 m in BAND, with total annual precipitation data for most years. Other snow courses and a new SCS "snotel" exist near the park.

Visibility monitoring was also begun in 1978 for this BAND location, using teleradiometers and automated cameras. Visibility has been monitored at Bandelier since 1978 using a variety of instrumentation. From 1978 through 1982 a manual teleradiometer was employed sighting five different targets three times a day. From 1985 through mid-1988 visibility was measured using the color slides produced from an automated 35mm camera on one target. From October 1988 to present, visibility has been measured using a transmissometer. A particulate monitor operated during the period of June 1982 through February 1985 using a single two-stage stacked filter. The Interagency Monitoring of Protected Visual Environments (IMPROVE) sampler was installed in 1987 and is currently operating using four filter modules and eight filter cassettes which measure different atmospheric constituents. A National Atmospheric Deposition Program (NADP) site has been operated at Bandelier since 1982.

<u>El Malpais National Monument</u>:

This is the final year of a three-year vegetation and wildlife inventory of El Malpais, by LTER biologists from UNM. This inventory includes an assessment of plant and lichen taxa, and vertebrate and invertebrate animals over the entire monument. Lists of all taxa found at El Malpais and a voucher plant and animal collection are being provided to the Park Service. The inventory has focused on all plants and lichens, all vertebrate animals, and ground-dwelling arthropods. Special emphasis has been given to identifying and inventorying both "typical" and unique environments, such as lava tubes and other geological features associated with lava flows. Comparative sampling of lava flow and adjacent non-lava areas has been an important aspect of the inventory. A final report, and animal and plant voucher specimen collections, will be submitted to the Monument in December of this year. Earlier vegetation inventory work at ELMA includes Lindsey (1951), Spellenberg (1979), McCallum (1981), and DeBruin (1984).

Maxwell (1986) presents a detailed geologic map of the ELMA area. Carlton (1988) completed a cave inventory of the northwest quarter of the park, the area with the highest occurrence of lava tubes. A lichen inventory of one square mile was completed in 1989. On-site weather data exist from 1985 to present. A basic

geologic inventory will be completed under contract during 1994, while in-depth inventories by a volunteer research team (Los Alamos National Laboratory) are ongoing. The soils in and around ELMA have recently been inventoried and mapped (USDA SCS 1993). Detailed ecological and geological inventories of the six most heavily visited caves in the park will be completed during the summer, 1994. An ongoing fire history and paleoclimate inventory extending from **at least** 180 B.C. to the present will be completed in spring of 1994 (see Grissino-Mayer and Swetnam 1993) - ELMA will soon known as perhaps the most extraordinary tree-ring research site in the Southwest. ELMA has more than 20 permanent plots which have been established following detailed NPS protocols (USDI NPS 1992) to intensively monitor the ecological effects of the park's prescribed fire program - these will be incorporated into this LTEM program design. The BLM maintains an air quality monitoring station one mile from the park's east boundary - these data are available to the NPS. ELMA has color, aerial stereophotos taken in 1987 at a scale of 1:24,000. Basic data exist on the age and chemical composition of the ice in the most heavily visited ice cave, Bandera Ice Cave.

Pecos National Monument:

UNM LTER scientists are midway through a two-year inventory of the Pecos National Historical Park. This inventory includes vertebrate and invertebrate animals, excluding birds and fish, which have already been inventoried (Creighton 1985, Pittenger 1993). A vegetation inventory of PECO is currently being conducted by botanists from the Forestry and Resource Conservation Division of the State of New Mexico. The animal and vegetation inventories cover the entire park, with emphasis on piñon-juniper woodlands, riparian corridors, and aquatic sampling of the Pecos River. Comparative, quantitative sampling of previously cleared piñon-juniper woodlands to uncleared piñon-juniper woodlands is also underway. Final reports for both the faunal and vegetation inventories will be submitted by September, 1994. Animal and plant voucher specimen collections will also be provided to the park. PECO has 1:6000 scale, 1992, color aerial photographs of the entire park. The soils in and around PECO have been surveyed and mapped (USDA SCS 1981).

3) PROGRAM READINESS:

These three parks are well situated to immediately implement a comprehensive, integrated monitoring program in conjunction with the SEVI LTER because of the recent history of cooperative inventory work between the LTER and each of the NPS units. The Sevilleta LTER program began in 1987, and many of the proposed monitoring protocols have been successfully implemented there for several years. As noted above, the LTER has been conducting inventory and monitoring work using these same protocols at ELMA, BAND, and PECO since 1991, 1991, and 1993, respectively. Thus strong formal contractual relations, as well as informal personal

contacts, have become well-developed between the LTER group and the key staff in the respective parks.

BAND currently has cooperative agreements in place with the Tree-Ring Lab of the University of Arizona for fire history work and with the UNM Biology Department for work on arthropod monitoring, nutrient cycling in ponderosa pine forests, and the determination of nitrogen fixation by cryptogamic crusts. BAND has separate interagency agreements with the US Forest Service for monitoring elk grazing impacts and for landscape ecology studies, with a third interagency agreement with the USDA Soil Conservation Service Plant Materials Center for work on developing native plant materials.

ELMA has cooperative agreements in effect with the UNM LTER group for biotic inventories, the UNM geology dept. for geologic inventories, the Cave Research Foundation for cave inventories, and the University of Arizona Laboratory of Tree-Ring Research for paleoclimate and paleofire work. Also, an interagency agreement exists with BLM for the management of the park and adjoining national conservation area.

Pecos has ongoing cooperative agreements with the UNM LTER team and two State of New Mexico agencies to conduct baseline inventories of terrestrial and aquatic invertebrates, mammals, amphibians, reptiles, and vegetation.

The funding to support the proposed monitoring program is included in outyear budget requests in the Resource Management Plans for all three NPS units (see Appendices B, C, and D).

4) MONITORING PROGRAM DESIGN:

Conceptual Design:

The three NPS units, in collaboration with the University of New Mexico's Long-Term Ecological Research Program (LTER), will constitute a network of long-term monitoring sites within the mosaic of ecosystem types in central and northern New Mexico. Consistent data collection and analysis methods will be employed across this network of sites. The existing LTER sites include Chihuahuan Desert, Great Plains Grassland, Great Basin Shrub-Steppe, Riparian Cottonwood Forests, Juniper Savanna, Piñon-Juniper Woodlands, Subalpine Forests and Subalpine Meadows (Plate 4). The proposed NPS LTEM Program will add significantly to the geographic scope of these long-term monitoring efforts, by extending study sites northward to incorporate the fauna and flora of the southern Rocky Mountains. The three NPS units in the proposed LTEM program will contribute additional coniferous forest study areas to the network, as well as unique habitat types (montane riparian forests and ice caves) and disturbed ecosystems (cleared pastures in piñon-juniper woodlands, post-fire ponderosa pine forests, and volcanically altered landscapes).

Incorporating multiple, NPS LTEM sites into this larger regional network of LTER sites markedly increases the statistical

interpretive power for examining the ecological responses to anthropogenic changes, natural disturbances, and climate changes at the NPS sites. This network of sites is an ecological analog to the Very Large Array radiotelescope (VLA), where a series of scattered, individual dish-antennae (ecological monitoring sites), when monitored simultaneously, reveal high-resolution data on obscure astronomical (ecological) phenomena (see discussion in Appendix A). The information collected by this LTEM network will be valuable to NPS managers and planners, as well as to ecosystem research scientists.

We propose to establish an "eco-swat team" based at the University of New Mexico to implement the bulk of the monitoring activities in this LTEM program. Funding would be provided through a cooperative agreement with UNM to finalize development of field data collection sampling methodologies, collect field data at appropriate time intervals, sort/prepare/identify all field samples, curate any collected specimens, enter data into computerized formats, analyze the data, and produce annual summary reports. The data collection and analysis methodologies would largely mirror those developed and utilized at the UNM Sevilleta LTER site.

Most of the abiotic and biotic attributes to be measured by the NPS LTEM program, along with the field sampling procedures (see Plate 5), are identical to those of the existing UNM LTER Program. This will ensure that all data sets are completely compatible and comparable between the NPS and LTER sites (see Data Management Section below). All data sets from LTEM and LTER sites will be archived and stored on-line on the LTER's Sevilleta Information Management System (SIMS), so as to allow both groups immediate and equal access to all data. Copies of all data sets in ASCII format will be available for use and storage on any local NPS computer system or PC.

Overview and Justification of Major Components of Monitoring Program:

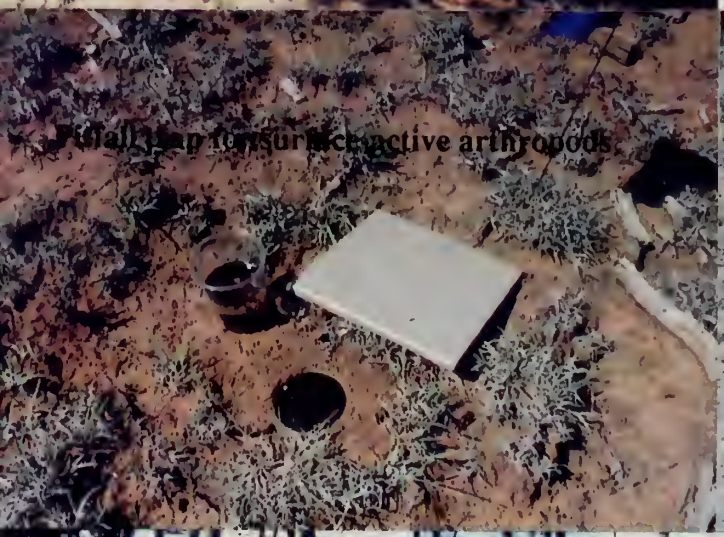
The major components of this LTEM program are outlined below, along with general rationales for inclusion in this LTEM program. Certainly far more detailed rationales are available or could be developed for each specific component of the monitoring plan, but that level of extensive discussion was considered inappropriate for this context and will instead be treated in the monitoring handbooks which will be developed for each component (e.g., Davis and Halvorson 1988).

1. Monitor meteorological variables. Changes in many biotic and abiotic ecosystem parameters in the Southwest are known to be highly correlated with climatic variability (Gosz **et al** 1988, Molles and Dahm 1990). Thus monitoring of meteorological variables is necessary in order to accurately interpret other ecosystem monitoring data.

Plate 5. Field Monitoring Methods

Small mammal live-tra
(center of trappin

Body measurements on a captured deer mouse



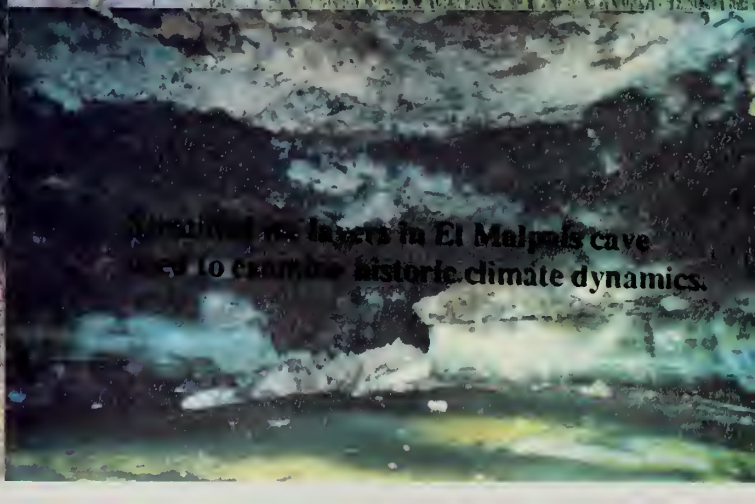
Pitfall trap for surface-active arthropods

Field pr essing of
samples

easuring post-fire colonization and
th of Ponderosa Pine

Sweep-netting insects

Soil-erosion bridge



Stratified ice layers in El Malpais cave
to examine historic climate dynamics.

Plate 5. Field Monitoring Methods

Body measurements on a captured deer mouse

Small mammal live-traps
(center of trapping "web")

Pitfall trap for surface-active arthropods

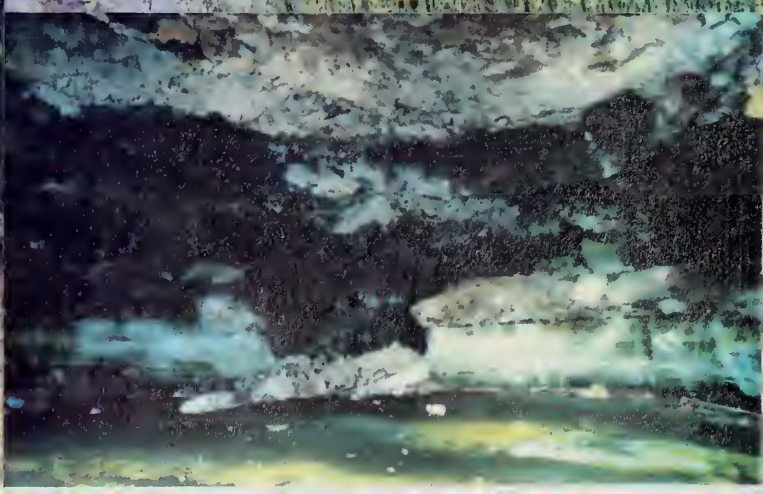
Field processing of pitfall trap samples

Measuring post-fire colonization and
growth of Ponderosa Pine

Sweep-netting insects from riparian foliage

Stratified ice layers in El Malpais cave
used to examine historic climate dynamics.

Soil erosion bridge



2. Monitor soil erosion rates. Soil erosion is a prominent ecosystem process in many piñon-juniper woodlands, although quantitative data on rates and trends are largely non-existent for NPS lands. Better data on the spatial and temporal variability of soil erosion rates are necessary to interpret woodland dynamics and determine possible NPS management needs.

3. Monitor major components of nutrient cycles, including nutrient inputs from precipitation, nitrogen mineralization potentials in ponderosa pine forests, nutrient transfers during decomposition of organic materials, and nutrient/contaminant dynamics in one stream. Nutrient cycles drive ecological dynamics in some ecosystems, thus warranting at least a limited degree of monitoring. Nutrient inputs from precipitation are relatively simple and cheap to measure, making them a good starting point for monitoring. Maintaining the existing monitoring of nitrogen mineralization potentials and monoterpene concentrations after fire in a ponderosa pine forest opportunistically builds upon the base of existing work (C.White 1993), allowing an inexpensive test of the utility of this methodology. The important functions performed by coarse woody debris in forested ecosystems have increasingly been recognized by ecosystem scientists (Maser **et al** 1988) - thus the incorporation of cheap, easy-to-collect, wood decomposition data into the LTEM program will contribute important insights to major nutrient cycles and soil fertility changes in this region. The USGS National Water Quality Assessment Program site on Frijoles Creek provides another high-quality window into ecosystem dynamics and human effects, and it needs only tiny sums of money to insure the maintenance of long-term water quality monitoring.

4. Monitor plant population distributions, demographics, structural compositions, and temporal dynamics within several NPS ecosystems. Plants are entities of interest in their own right which will be monitored for the purpose of ascertaining the impacts of various perturbations (park management practices, other human disturbances, fires, climate changes, past volcanic eruptions). In addition, it is impossible to understand variation in other ecosystem parameters without data on vegetation composition and dynamics, as plants are primary components of park ecosystems which affect much of the structure and function of these systems.

5. Monitor selected animal population distributions, demographics, and temporal dynamics. Certain animal populations will be monitored because of their rarity or sensitivity to human perturbations, as they may indicators of ecosystem health or because management requires ongoing information on their status. Other, more abundant, animal populations will be monitored because they are represent functional groups which perform essential ecosystem roles and for which we need monitoring information to determine the impacts of various perturbations

(park management practices, other human disturbances, fires, climate changes, past volcanic eruptions). Again, monitoring of certain animal populations is necessary if an overall assessment of ecosystem condition is to be made.

6. Monitor the ecological effects of major disturbances by comparing intensely burned **versus** lightly or unburned ponderosa pine forests in BAND, and cleared **versus** uncleared piñon-juniper woodland sites at PECO. Recurrent fire is a dominant disturbance process in most Southwestern forest types (Swetnam 1990), including those found in these three NPS units (Allen 1989, Grissino-Mayer and Swetnam 1993). Maintaining and elaborating upon the ecological monitoring begun with the La Mesa Fire in Bandelier (see overviews in Foxx 1984) will continue to provide essential information for managers of this widespread forest type. Similarly, millions of acres of piñon-juniper woodland were cleared in recent decades, but surprisingly little long-term monitoring of ecological effects has been conducted. Thus long-term ecological monitoring of cleared **versus** uncleared woodland at PECO will yield valuable management information as well as interesting ecological insights.

7. Monitor unique ice cave habitats in ELMA. These ecosystems are unusual and and their response to various perturbations, especially human disturbances, is little known. Different monitoring methods are proposed for these novel ecosystems. Monitoring these sites will certainly provide basic ecological science insights as well as essential applied information to guide park management of these rare resources.

Specific Research Site Descriptions:

Specific research site descriptions for each NPS unit are outlined below, and illustrated in Plates 2 and 3.

I. Bandelier National Monument will have 4 study areas along an elevational gradient, including a riparian forest site (Frijoles Canyon), a piñon-juniper woodland site, a ponderosa pine forest site, and a high-elevation, mixed-conifer forest site. In addition, severely burned ponderosa pine forest habitats in various stages of successional recovery from a 1977 fire will also be monitored.

II. El Malpais National Monument will have 2 primary study areas, one of which will be a ponderosa pine/piñon-juniper woodland site on the old, non-volcanic soils of a kipuka, while the other site will be located on relatively recent volcanic lava flows. Substrate type (non-volcanic sandy-loam soil vs. lava flow) imparts significant differences in vegetation densities, plant growth rates, faunal communities, and numerous abiotic variables which merit monitoring. In addition, ecological monitoring of 5 sensitive ice caves will be conducted at ELMA.

III. Pecos National Historical Park will have 3 study areas. The first will be an undisturbed piñon-juniper woodland area typical of the Park's vegetation. A second area will consist of the historic livestock pastures that were created via clearing of woodlands in the 1970's by the former landowner. These pastures are now undergoing succession and recolonization by piñon pines and junipers. The third site will be in the riparian cottonwood forest along the Pecos River.

Outline of Monitoring Methods:

The LTEM program will collect the following types of monitoring data at each of the primary study sites in the three NPS units:

1. Meteorology: Automated weather stations will be established at each NPS unit. Campbell Weather Stations will be used to measure the following variables: precipitation (rain and snow), air temperature, soil temperature (surface, 25 cm and 50 cm depth), air relative humidity, soil moisture, wind speed and direction, total solar radiation. These variables are monitored continuously at minute time intervals, and stored on data loggers. Data storage modules will be changed monthly, and data downloaded onto computers for synthesis and analysis. Software for performing synthesis and analysis is currently operational on the LTER's SIMS. Three stations would be established along an eleveational gradient in BAND (in piñon-juniper woodland, ponderosa pine forest, and mixed conifer forest), with single stations at ELMA and PECO serving to characterize meteorological conditions.

2. Soil erosion: Simple but accurate "bridges" for measuring soil erosion (Plate 5) will be maintained at BAND, and installed and monitored in association with the vegetation line transects at piñon-juniper woodland sites in ELMA and PECO. The basic erosion bridge methodology is reviewed by Ranger and Frank (1978), with documented improvements as applied to BAND outlined in Allen and Beeley (1992), and Bracker (1992).

Soil erosion will also continue to be monitored with erosion bridges and sediment traps in the 1 ha Frijolito study watershed, along with onsite precipitation, runoff, sediment transport, and vegetation cover in separately funded but parallel work.

3. Nutrients: Nutrient inputs from the atmosphere will be measured using wet/dry precipitation collectors (one collector at each NPS unit). Samples of precipitation, which are collected monthly and separated by the instrument, will be analyzed for Na, K, Ca, Mg, NO(3)-N, NH(4)-N, SO(4), Cl, conductivity, and total Kjeldahl N and P.

Nutrient content and water quality of Frijoles Creek in BAND will be continue to be monitored through the USGS National Water Quality Assessment Program.

Decomposition and nutrient cycling from the major source of biomass (woody vegetation) will be measured at each site using long-term measurements of tree-log mass and nutrient losses.

4. Plants: Long-term population demographics, diversity, and percentage cover of vegetation will be measured for the three main plant categories: (1) trees and shrubs, (2) forbs and cacti, and (3) grasses. Plant communities will be measured on three replicated sites in each study area listed above. Populations of woody plants (trees and shrubs) will be marked, mapped, and annually measured, in 20 x 50 m quadrat plots. A subset of the 50+ fire monitoring plots established the past two years at BAND and ELMA (USDI NPS 1992), as well as of 18 similar plots established in 1977 in BAND (Foxx and Potter 1978), will be directly incorporated into this LTEM program. Forbs, grasses, subshrubs, and cacti will be measured along permanently marked, 100-m line transects. There will be two such transects at each replicate vegetation sampling area. All plant populations will be sampled in late spring (May-early June) and late summer (September). BAND and SEVI have developed a line transect data analysis software which provides data error checking, separate overstory and understory analyses, and analysis by lifeform. A variety of permanent photographic stations will be maintained at all permanent vegetation plots and transects.

The three sets of line transects in animal exclosures which were established in 1978 in BAND's piñon-juniper woodlands will continue to be read annually. In addition, annual monitoring will be conducted of known, mapped populations of several rare or sensitive species (e.g., in BAND Cypripedium calceolus and Botrychium virginianum will continue to be monitored).

5. Animals: Various representative and ecologically important groups of animals will be monitored at all sites. These include selected arthropods, birds, mammals, and amphibians.

Arthropods: Ground-dwelling arthropods will be sampled from pitfall traps situated near each of the three replicate vegetation sites on each site at each NPS unit. A series of six pitfall traps will be placed at each web (Plate 5). The traps will be positioned in a line, at ten-meter intervals. Each pitfall trap will consist of a three-inch diameter by four-inch deep metal can placed in the ground with the top of the can flush with the ground surface. A plastic cup will be placed within each can, also flush with the ground surface. The cup will be partially filled with propylene glycol (a non-toxic antifreeze solution) to capture and preserve arthropods. A small cover will be elevated over the trap to exclude rainfall.

The pitfall traps will be left open year-round. The contents will be collected every 6-8 weeks. The contents of each trap will be stored in individual jars, and sorted in the lab. The numbers of individuals of select groups of arthropods in each trap will be tabulated for each 6-8 week sampling period. The

mean number of individuals of a given species, or of several species pooled into ecological functional groups, will be used to compare statistically the arthropod composition among and between all of the sites and NPS units over time.

Only select groups of arthropods representing particular trophic groups will be used for monitoring purposes. These taxa will be selected based on their numerical abundance and ecosystem importance. These groups have been identified in the previous inventory studies. These taxa also were selected because they are appropriately sampled by pitfall traps. The groups that will be emphasized for monitoring purposes include beetles, crickets, arachnids (spiders, etc.), and thysanurans. All arthropods will be identified and counted, and voucher specimens will be added to the arthropod collection for the project. An arthropod species database will also be maintained to document the known arthropod fauna of each area.

Birds: Local avifauna reflect the status of on-site as well as more distant habitats, as evidenced by recent changes in bird community compositions which track vegetational changes in the La Mesa Fire area of BAND (Wauer 1991) and the highly publicized declines in some neotropical migratory bird species. Avian communities and population densities at each site will be measured using replicated variable circular plots. A trained avian biologist will sample the bird populations using accepted Standard Methods provided by the American Ornithological Union (AOU). Birds will be sampled on all sites four times per year, in order to estimate (1) spring breeding populations, (2) summer resident populations, (3) autumn migratory species, and (4) over-winter resident populations.

Raptors often receive monitoring attention as indicator species because they are high trophic level, publicly popular species with low population densities which are relatively easy to count. This LTEM program will monitor the breeding distribution and success of several sensitive or endangered raptor species through censuses of known, traditional nesting areas - target species include peregrine falcon (Falco peregrinus), zone-tailed hawk (Buteo albonatus), Mexican spotted owl (Strix occidentalis lucida), and northern goshawk (Accipter gentilis). In addition, the numbers, distribution, and diet (through pellet analysis) of overwintering bald eagles (Haliaeetus leucocephalus) at BAND will continue to be monitored annually (cf. Johnson 1992).

Mammals: Population abundance indices for large mammals, such as deer, elk, rabbits, and coyotes, will be measured using pellet-count transects. Replicate transects in each of the study areas will be established to monitor the temporal changes in site use by these species.

Populations of small mammals (mice, squirrels, chipmunks) will be sampled using mark-recapture techniques and Sherman-style live traps (Plate 5). Three replicate trapping "webs" (a trap

dispersion design that allows direct estimation of absolute densities) will be located at each of the vegetation sampling sites. Each web will consist of 148 traps, and cover approximately 3 ha. Rodents will be trapped for 3 consecutive days and nights. Data will be analyzed using program DISTANCE, to calculate absolute densities of each species (number of individuals per hectare). Populations will be sampled twice per year, once in the spring to assess pre-growing season densities, and once in the fall to estimate maximum population density.

Also small breeding colonies of bats, dominated by Tadarida braziliensis, are known from caves at ELMA and BAND, where they have been studied since the mid-1980's. Using computer-aided technology to process videotapes of bat flights (Fletcher 1986), the populations of two colony sites, one each in ELMA and BAND, will be counted three times per summer season by park staff. Bats are at relatively high trophic levels and are subject to pesticide impacts and other human disturbances, making them attractive to study as indicators of ecosystem health. These conveniently located and concentrated bat colonies provide an opportunity to cheaply collect data on this ecosystem indicator.

NOTE: In addition to the ecological importance of rodents in ecosystems (i.e., consumers of seeds, insects, fungi, and comprising a major prey base for raptors, carnivores, and reptiles), certain species of mice have a direct effect on human health (and clearly, by extension, on park operations and management). The recent epidemic of **Hantavirus-Associated Adult Respiratory Distress Syndrome (HARDS)** in the Southwest has been attributed to a population outbreak of rodents during 1992-93. Preliminary discussions among scientists from NPS, UNM, and the Federal Centers for Disease Control (CDC) in Atlanta have suggested that, if long-term rodent population monitoring sites are established at the NPS units, the CDC will collaborate in testing all captured rodents for the HARDS virus (at no additional expense to the LTEM budget). Blood samples can be collected humanely from the rodents before releasing the animals, and sent to the CDC laboratory in Atlanta. All field researchers involved with rodent sampling will be trained by UNM in the safe handling of rodents, and will wear all the recommended safety equipment (i.e., gloves, goggles, masks, lab coats) to prevent possible contamination with HARDS virus.

Amphibians: Amphibians may be sensitive indicators of ecosystem stress, as declines in amphibian populations are being documented worldwide, including many sites in the western U.S. (IUCN/SSC Declining Amphibians Populations Task Force 1993). Amphibian populations at numerous inventoried sites in BAND will be monitored annually for the continued presence of known species, while similar monitoring will be conducted at ELMA and PECO as inventory data become available. Target species range from a variety of aquatic frogs and toads (including Hyla arenicolor, Pseudacris triseriata, Bufo punctatus, and Bufo woodhousei) to

the tiger salamander (Ambystoma tigrinum) and an endemic terrestrial salamander (Plethodon neomexicana).

General: In addition, a computerized wildlife observations database will be continued at BAND and implemented at ELMA and PECO. Since 1989 BAND has maintained a computerized wildlife observations program patterned after the Sequoia-Kings Canyon and Yosemite programs which has greatly increased the number and utility of observations made by staff and visitors. Los Alamos National Laboratory has also adopted this program, and BAND and Los Alamos have been maintaining a joint wildlife observations database since 1991.

6. Monitoring Disturbance Effects:

Fire Effects Monitoring: The 1977 La Mesa Fire created a mosaic of successional communities out of dense ponderosa pine forest in BAND (Plate 3). The whole panoply of LTEM methods listed above will be utilized in BAND pine forest sites which were set back to open grassland or savanna conditions by the intense 1977 fire; these open, fire-affected sites will be compared to heavily forested ponderosa pine sites. Also, permanent vegetation plots (Potter and Foxx 1986) and avifaunal monitoring transects (Wauer 1991) which were established before the fire and monitored several times since will be maintained to continue to follow the long-term effects of this fire.

In addition, the array of permanent vegetation plots which are being established to monitor the ecological effects of the prescribed fire programs at BAND and ELMA will continue to be monitored using NPS FIREPRO funds and well-developed methods (USDI NPS 1992). Over thirty plots have been established at BAND and twenty at ELMA to date for this intensive fire monitoring program.

Disturbance/Succession Monitoring at PECO: Pecos National Historical Park has recently expanded to include the former "Forked Lightning Ranch", which until 1991 was a working cattle ranch. During the 1970's approximately 30% of the ranch's forests and woodlands were cleared to create livestock pastures (Plate 3). These pastures have been undergoing succession for the last two decades, and many are now being colonized by piñon pines, junipers, and ponderosa pines. With the recent removal of all livestock, the question arises as to the nature and rate of future ecological changes on these areas. Will the removal of cattle have an influence on wildlife populations and local vegetation? As the pastures return to woodlands and forests, will overall biodiversity decrease? If so, should the NPS manage the woodlands in a fashion that maintains selected areas of open grassland?

The newly acquired park land also contains approximately 2 miles of riparian canyon-bottom along the Pecos River (Plate 2).

Long-term monitoring of riparian vegetation and animal populations along the river and it's associated wetlands will be needed to evaluate the effects of human visitors (fishermen, hikers, etc.) on these fragile habitats. Immediately upstream from the park boundary lies the town of Pecos; the southern-most homes of Pecos' residents have been built on the park's border. The impact of additional development (both north and south of the park) on the biotic resources has yet to be determined, but may become evident as monitoring continues.

7. Ice Caves at ELMA: Lava tube ice caves are important natural features of El Malpais National Monument (Plate 2). The ice caves represent geologically and ecologically unique situations. Human visitors to the cave can have serious impacts on both the ice sheets and the highly-specific flora that occurs at the mouths of the caves; monitoring of such anthropogenic influences is needed to guide NPS management strategies. Specific monitoring studies will be initiated at a select set of ice caves to document any long-term changes in the physical environment and the associated biota.

The initial surveys of all the Monument's biological resources, including the cave flora and fauna, have been completed by UNM LTER scientists under a Park Service funded NPS-UNM Cooperative Agreement. Monument-wide surveys have allowed the selection of long-term monitoring sites that represent both typical and unique habitats on the Monument lands.

Air temperature and moisture gradients are key characteristics of the ice caves. During the summer season, the ice caves are cold and humid relative to the area outside of the cave mouth. Unique moss and lichen communities occur along this moisture and temperature gradient. Component species exhibit distinct zonation patterns on the rocks at the mouths of these caves (Plate 3). Each species occupies a narrow band of substrate across the openings of the ice caves at particular distances from the cave mouths. This consistent zonation of cryptogams appears to be in response to steep temperature, moisture, and light gradients in the mouths of caves. The principal goal of this monitoring program will be to measure cryptogam species abundance and distribution, across the environmental gradient at the mouths of the ice caves. Relationships to long-term regional weather data will be examined.

Five ice caves will be selected for monitoring. Replicate 0.5 x 0.5 meter quadrats will be established on rocks at the mouth and at more interior portions of each cave. Each quadrat will be photographed once each year. The total cover of each cryptogam species will be measured from each photograph using computer image processing techniques. This procedure will provide data on the status of each cryptogam species across the gradient of each ice cave.

This program may be expanded to compare caves with visitor impacts to those that are closed to visitors. Such a monitoring

program would not only provide information on how climate affects the ice caves, but also on how visitor activities may be impacting ice cave cryptogam communities.

) SCIENTIFIC CREDIBILITY AND CAPABILITY:

The strong linkages developed with the University of New Mexico's LTER program provide high levels of scientific capability to this proposed program. The SEVI LTER program builds upon UNM's strong biology department, which is particularly well-suited to conduct this type of work (see listing of relevant UNM staff in Appendix E). A resume for the SEVI LTER program director, Bob Parmenter, is provided in Appendix F. By adopting many of the methodologies developed by UNM's NSF-funded, peer-reviewed LTER program we insure the scientific credibility of our proposed LTEM program.

This LTEM program will have direct linkages to the newly formed National Biological Survey (NBS), as BAND's ecologist has been transferred to the NBS through the formation of the Bandelier Field Station of the National Ecological Research Center (based in Fort Collins, CO) of the NBS. These NBS linkages will be helpful in the testing and development of a comprehensive set of monitoring protocols.

This proposal builds from the perspective that NPS units need to be treated as long-term ecological monitoring and research sites, both to meet their management objectives as well as to fulfill a larger societal need to determine the impact of human beings on this planet. NPS units are uniquely suited for this purpose since these areas are already set aside for protection of "natural" processes in perpetuity, and because management needs the information that only long-term ecological monitoring can provide. Formal linkages to NSF-funded and university operated LTER sites are a logical way to implement this vision. This approach is explicity supported by recommendations recently made by the National Research Council report on **Science and the National Parks** (Committee on Improving the Science and Technology Programs of the NPS, 1992, pp. 10, 90-93, 96-98, 108) and the **Report of a Workshop for a National Park Service Ecological Research Program** (Risser and Lubchenko 1992).

) BUDGET AND COST EFFECTIVENESS:

The proposed budget is summarized in Table 1, with extensive detail provided in Appendix G. Additional explanation of this budget is provided below.

The University of New Mexico, under cooperative agreement with the National Biological Survey, will implement most of the monitoring activities in this LTEM program. Thus UNM will conduct most of the hiring, supervision, and procurement required for this program, resulting in significant savings to the federal government and a more efficient program. For example, to hire

TABLE 1. SUMMARY PROPOSED BUDGET, LTEM PROGRAM, FY's 1994-1998

BUDGET CATEGORY	1994	1995	1996	1997	1998
PERSONNEL SALARIES:	$161,655	$234,951	$246,736	$259,014	$271,973
SUPPLIES/TRAVEL:	$ 36,800	$ 40,530	$ 40,475	$ 42,480	$ 44,558
EQUIPMENT:	$ 76,225	$ 0	$ 0	$ 0	$ 0
UNM INDIRECT COSTS:	$ 25,408	$ 36,744	$ 38,274	$ 40,178	$ 42,181
	$300,088	$312,225	$325,485	$341,672	$358,712

Annual budget increases are based on 5% cost-inflation per year.

TOTAL BUDGET, 5 YEARS: $1,638,182

and supervise the personnel needed for this project from **within** the federal government system would be extremely costly in terms of NBS/NPS staff time. Also, we will be able to access higher quality candidates for the highly technical work required for this LTEM program as the university has greater flexibility in hiring practices than does the federal government. Benefit rates and travel/per diem costs are much lower through the university than through the federal government. Certain sampling costs will be much lower through economies of scale, such as the costs of sampling atmospheric nutrient inputs and log nutrients which are greatly decreased by lumping the NPS LTEM samples in with the larger batches of LTER samples already being collected by UNM. A low indirect cost (university overhead) rate of 15% has been negotiated for this project with UNM, and indirect costs are not charged on equipment or NPS temporary employee salaries. We believe that delegating most project functions to UNM-based staff will result in significant overall cost efficiencies and a more productive monitoring program.

UNM would provide the labor and expertise for the NPS LTEM program through the following personnel:

-1 part-time (0.5 month/yr) program director, to assure attainment of LTEM program goals and insure coordination with the LTER program;
-1 full-time Ph.D. project manager, to directly oversee the LTEM program;
-2 full-time M.S.-level field biologists for sample collections and identifications, and for data analysis and report writeups (1 botanist, 1 zoologist);
-1 part-time (2 months/yr) data manager to coordinate and manage overall project data sets;

-1 part-time (2.5 months/yr) technician to maintain weather stations and manage associated data sets; and
-6 part-time (6 months/yr) biological technicians for 2 field crews (2 botany, 2 entomology, 2 zoology).

In addition, 3 part-time (6 months/yr) biological technicians would be hired by the NPS to provide 1 on-site field person dedicated to this project at each of the NPS units. During the busiest field season these NPS employees would provide logistical support to, and conduct fieldwork with, the LTEM field crews when they were operating in particular parks. These NPS technicians would also conduct some monitoring activities on their own, and serve as important liasons between the LTEM program staff and the staffs of the NPS field sites.

Note that in year 1 (FY 1994) personnel costs are low because staff can only be hired for the part of the year remaining after a prototype program is selected. However, these low first-year personnel costs are balanced by one-time equipment costs needed to start the program.

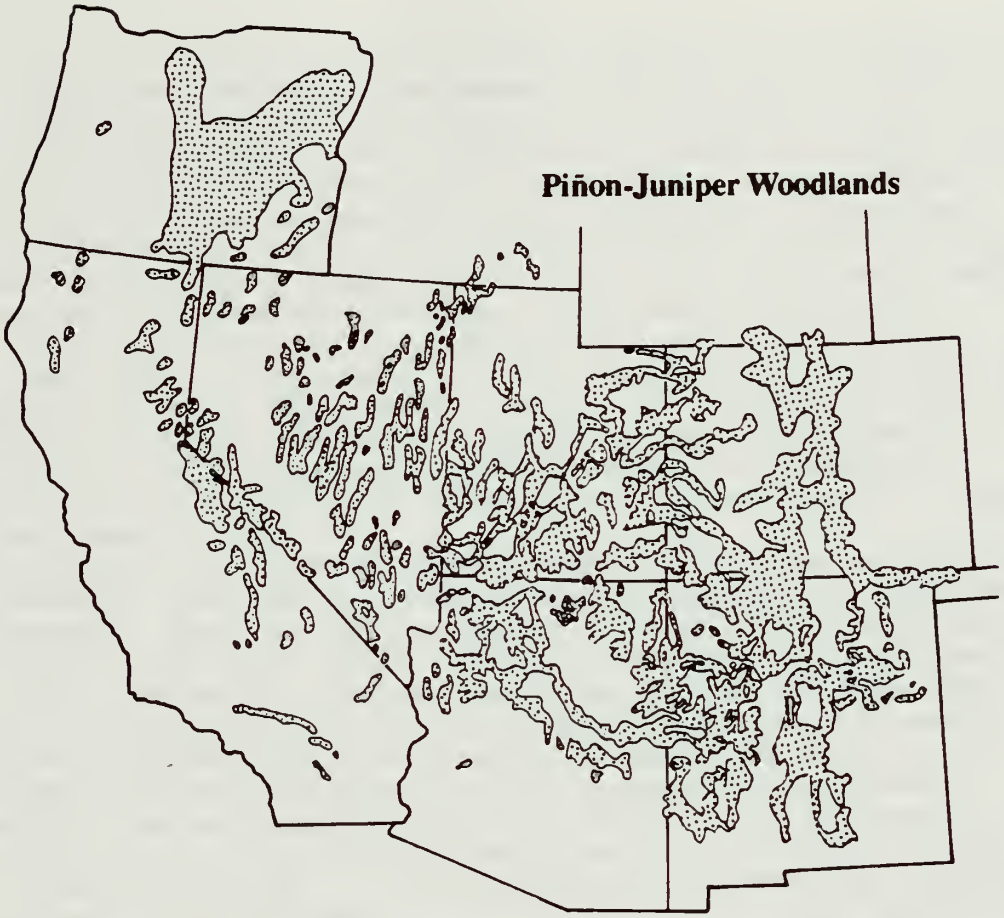
SERVICEWIDE OR MULTIPARK APPLICABILITY:

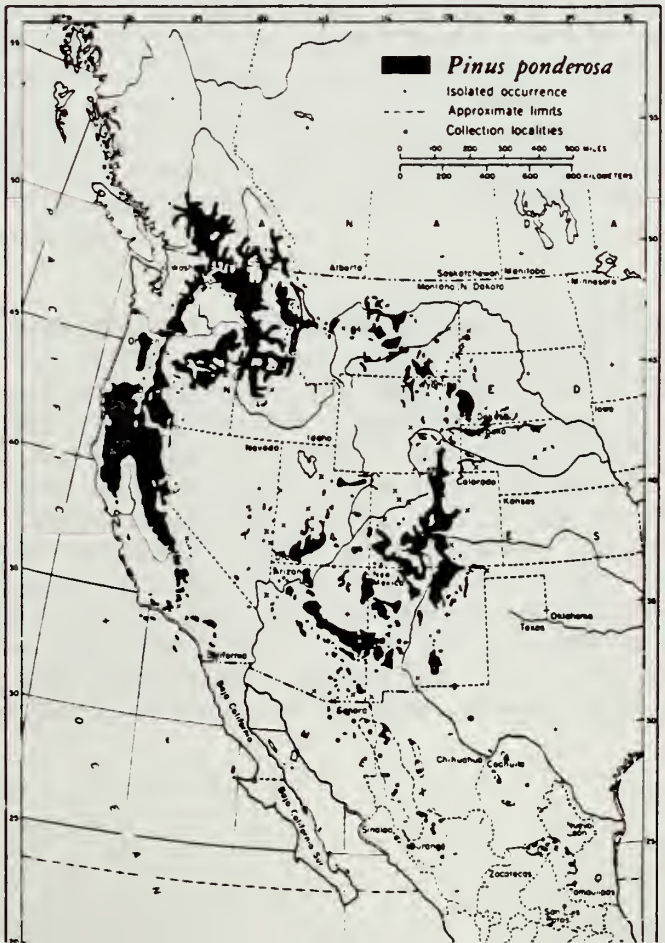
The program proposed here is an attractive model for the NPS to consider as a prototype for long-term ecological monitoring throughout the NPS system. The coniferous forest types monitored in the Upper Rio Grande LTEM parks represent important, widespread ecosystems which are dominant components of many NPS units. Piñon-juniper woodlands and ponderosa pine forests respectively cover about 19 and 11 million hectares in the western U.S. (Figure 1), with mixed conifer forests of various types covering additional millions of hectares. The potential exists for developing an expanded cooperative LTEM network among other NPS units with similar ecosystems in the Four Corners area. A sampling of "nearby" NPS units which could be linked with the Upper Rio Grande LTEM include Great Sand Dunes, Capulin Volcano, Chaco Canyon, Mesa Verde, Sunset Crater, Wupatki, Petroglyphs, and Grand Canyon.

Our basic program design contains a number of unique and attractive elements which could be adopted by other NPS units. The focus on a university-based, multi-park, "eco-swat team", with lesser emphasis on use of park-based staff, is a logistically efficient way to collect large amounts of field data, as it sequentially concentrates the necessary number of people at each park for the intensive collection of pulses of data without unneeded, expensive redundancy of scarce technical staff at each park. This university-based team approach also maximizes the scientific credibility of the results and improves linkages between researchers and resource managers.

Thus this program is an appealing model for small NPS units which individually may be below the threshold of being able to develop and implement a viable monitoring program, as it links

Figure 1. Distribution of Piñon-Juniper Woodlands (*top*) and Ponderosa Pine Forests (*bottom*) in Western North America.





them to the critical mass of technical expertise and overall program resources needed to implement a high-quality monitoring program. Utilizing identical methodologies across a spatial array of parks increases the interpretive power and clarity of monitoring results. By directly interacting with a LTER network site the NPS accesses the accumulated expertise of the best scientific personnel available, including their peer-reviewed experience with cutting edge sampling and data management methods which have been developed over years with many millions of dollars. Contracting with outside scientists to collect, analyze, interpret, and report on the data insures that **all** of these essential activities occur annually. Involving the faculty of a local university provides additional opportunities to promote the use of the parks as study sites for resource management purposes and public education, as well as for "the sake of science".

This program monitors a wide variety of ecosystem components in great detail, providing a broad-based overview of keystone park resources. Most of the elements of this monitoring program are applicable with only minor modifications to a broad spectrum of NPS units. While the overall program design and the specific monitoring methodologies are scientifically state-of-the-art, the approach and methods are conceptually straightforward and can be directly implemented elsewhere without expensive equipment.

However, the successful implementation of this program does require access to, and efficient utilization of scarce, highly skilled, human resources. One strength of our monitoring program design is that it facilitates the application of the needed types and quantities of human resources to multiple parks while minimizing the time lost by NPS staff to the bureaucratic overhead associated with federal government hiring and supervision requirements. When the efficiency of the multi-park team approach and the quantity/quality of data collected are considered in conjunction with the savings associated with delegating most hiring, supervision, procurement, and payroll functions to UNM, this program certainly demonstrates a cost-effective overall design.

PARK INFRASTRUCTURE AND PROGRAM ORGANIZATIONAL STRUCTURE:

The proposed NPS LTEM program takes advantage of existing infrastructure owned and operated by UNM for its LTER program. Office space will be available for LTEM employees in the UNM Biology Department buildings on campus in Albuquerque. New laboratories, offices, and housing are available and will be utilized for this program at the Sevilleta LTER Field Station. Fiber-optic computer network links are already well-established between the UNM campus and the SEVI field station, with access available to the NPS units through existing phone/computer equipment. Because the NPS LTEM staff will largely operate out of UNM facilities the individual parks do not need extraordinary amounts of on-site infrastructure to implement this LTEM program.

The Museum of Southwestern Biology, located on the UNM campus, will house one set of voucher specimens. This academic museum is emerging as the major regional repository of specimens for past and future work by the USFWS and National Biological Survey. A second set of voucher specimens will be provided to the NPS for storage at the respective parks, or elsewhere, as appropriate.

All three NPS units have the resource management staffs, adequate on-site infrastructure, and the active support of their superintendents needed to support this LTEM program. Bandelier has had a Resource Management Division since 1980, currently composed of a GS-12 Chief, GS-11 Archeologist, GS-9 Curator, GS-5 Museum Technician, GS-9 Natural Resource Specialist (2 M.S. degrees), GS-11 Ecologist (Ph.D.), GS-7 Biological/Data Management Technician, graduate coop student Biological Technician, two GS-5 Biological Technician fire monitors (six month positions, currently staffed with M.S. and Ph.D. degrees), and several summer seasonal positions. The Ecologist, coop student, and one seasonal will be transferred to the NBS on October 1st, forming the charter members of the "Bandelier Field Station" of the National Ecology Research Center of the NBS. This NBS field station will continue to support long-term ecological monitoring and research at BAND.

BAND has the infrastructure necessary to support the proposed LTEM program. One or two trailers are available to serve as office and laboratory space. The Resource Management Division currently has a number of personal computers (two with 486 microprocessors, three 386's, and two 286's), with extensive software resources and telecommunications links to message and database services. In addition, BAND's GIS is currently running on a Sun workstation in the park. The park curatorial staff maintain on-site collections of cultural and natural resource materials in four separate buildings as well as the visitor center museum. These collections include an excellent herbarium facility which completely documents the known flora of 732 species. The park's arthropod reference collection is currently being updated by UNM as part of ongoing arthropod monitoring. Other facilities and equipment on hand range from microscopes and a mirror stereoscope to water quality sampling equipment. A wide assortment of expertise and equipment are also available on loan from adjoining Los Alamos National Laboratory.

El Malpais has a Resource Management and Visitor Services Division, with the division chief devoting 30% of his duties to resource management (400+ hours of natural resource management training). The division has a GS-9 Resource Management Specialist whose duties are 90% resource management. In addition, the two District Rangers conduct resource management as 35% of their duties (approximately 300+ hours of natural resource management training total). The resource management program is augmented by a Ranger Activities Clerk for support services, and a field Ranger with a degree in wildlife management. In addition, ELMA maintains a coop student position which emphasizes

natural resource management activities.

El Malpais presently maintains two sets of offices: a headquarters in Grants and a field office in the Bandera Crater District. The offices in Grants accommodate 13 permanent employees, including one from the Chaco Protection Sites Program. The GIS runs on a 386 computer system at the headquarters. A request is currently being processed by GSA to expand the present office space to include another building. The Bandera office accommodates two permanents with space for a third. ELMA is able to provide office space for the LTEM program at either the headquarters area or the Bandera office. Flora and arthropod reference collections are near completion by UNM under the current inventory work, including a 1500-specimen herbarium.

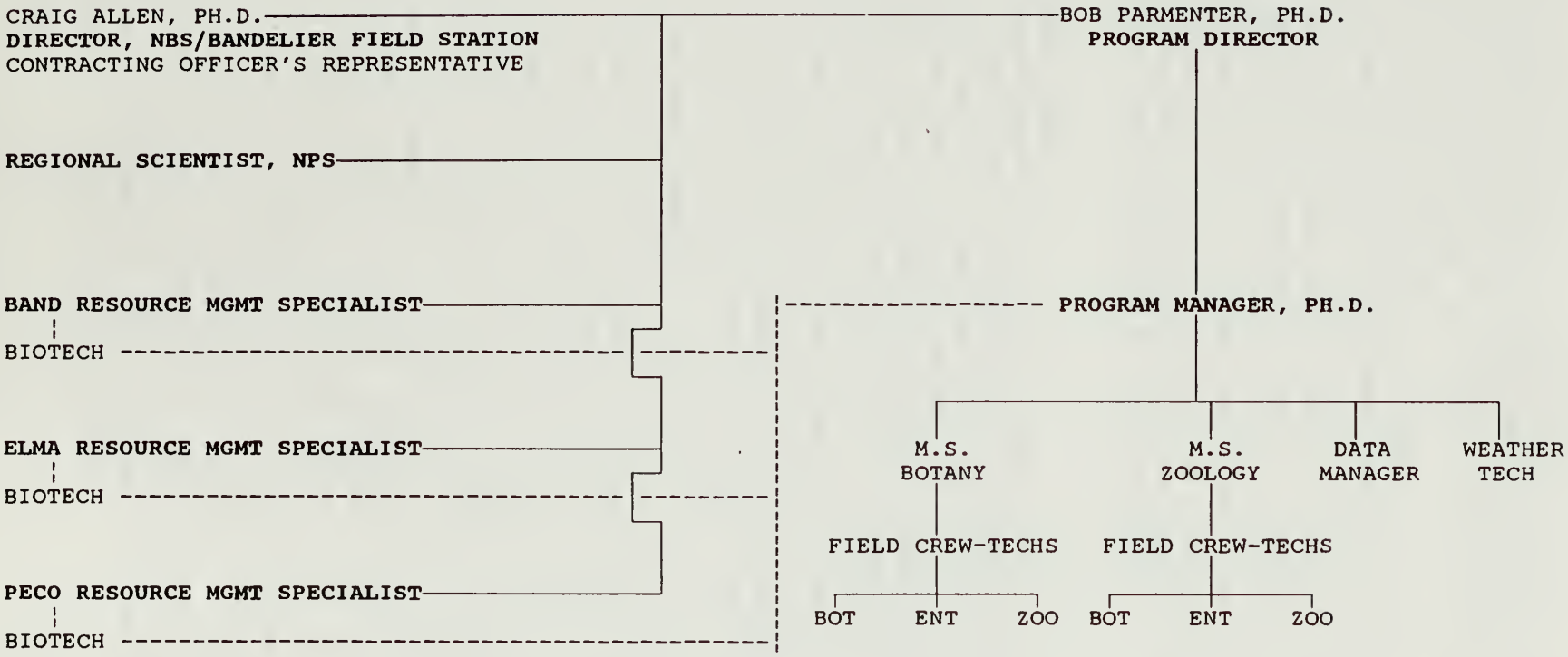
Pecos National Historical Park has a Division of Natural Resource Management and Visitor Protection with a GS-11 Division Chief, a GS-9 branch chief of Natural Resource Management (who expects to hire a permanent GS-7 biotech and a GS-5 seasonal technician in FY 1994), a GS-9 branch chief of visitor and resource protection overseeing two GS-5 patrol rangers. In addition, there is a separate Division of Cultural Resource Management with a GS-11 archeologist supervising a seasonal archeologist and a 5-person, ruins stabilization crew. The management of this new, expanded park has strongly supported efforts to immediately collect baseline ecological information and establish an ecological monitoring program.

Park infrastructure includes the fully utilized headquarters area as well as a number of buildings inherited from the former ranch which would easily allow PECO to provide on-site office and work space for LTEM workers. Flora and arthropod reference collections are being developed through the current inventory work, which includes the creation of a comprehensive on-site herbarium.

Upper Rio Grande Basin LTEM Program Organizational Structure Chart and Description

Figure 2 displays the organizational structure for our LTEM program. Craig Allen (Bandelier Field Station of the NBS) will serve as the contracting officer's representative and oversee the program for the NBS by interacting closely with the resource management specialists at each of the NPS units, the NPS Regional Scientist, the LTEM Program Director, and the LTEM Program Manager. Bob Parmenter (LTEM Program Director) will hire the LTEM program staff and supervise the LTEM Program Manager, and generally insure that the LTEM program is running smoothly and that all of the contractual requirements of the cooperative agreement are fully implemented. The LTEM Program Manager will supervise the rest of the LTEM staff and will oversee the details and daily operations of the LTEM program. The two M.S. level positions would supervise the seasonal field crews. The three NPS, 6-month, biotech positions would be hired and supervised by the resource managers in their respective parks, although they would receive training from the UNM LTEM staff and would work

Figure 2. Upper Rio Grande Basin LTEM Program Organizational Structure. Members of the LTEM program coordinating committee are indicated in bold text.



with those field crews when they were in-park (thus the dashed line connecting the NPS biotechs to the LTEM Program Manager). Craig Allen, Bob Parmenter, and the LTEM Project Manager will work closely with the NBS to evaluate the monitoring protocols and overall program design.

A LTEM Program Coordinating Committee will be formed to oversee the program, insure close communications among participants (especially information transfer from the LTEM staff to NPS managers), review and discuss monitoring results, and make concensus decisions regarding overall changes in program direction or methods. The LTEM Program Coordinating Committee will be chaired by Craig Allen and consist of the NPS Southwest Regional Scientist (or his designated representative), the resource management specialists of each of the three NPS units, Bob Parmenter, and the LTEM Program Manager.

DATA MANAGEMENT PLAN:

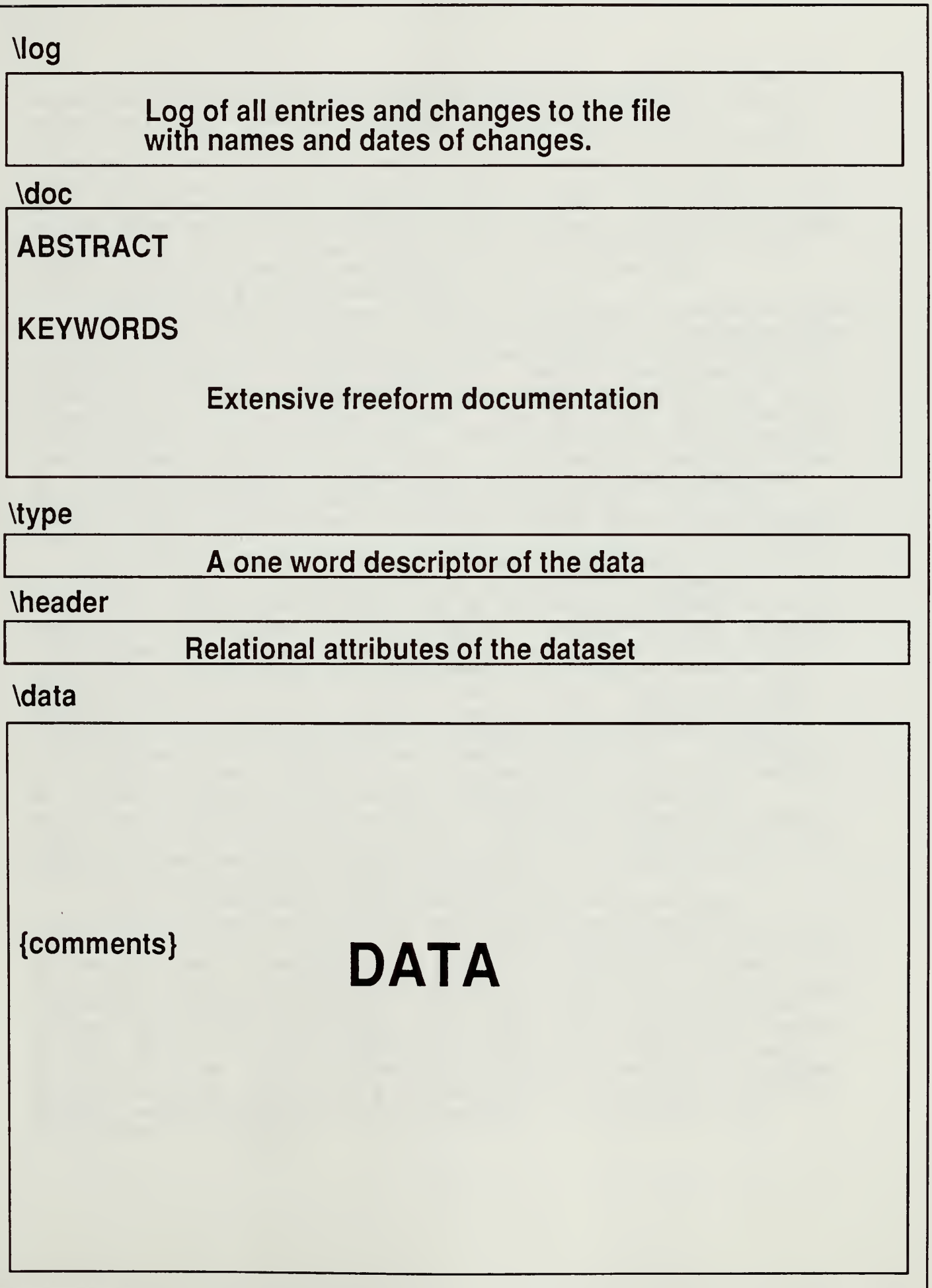
Data management for the NPS LTEM program will be coordinated through the Sevilleta Information Management System (SIMS). LTER network experience has demonstrated that the management of long-term ecological data at the project level can help programs achieve their goals through integrated computational services that provide access to relational data base operations, statistical and numeric operations, and technical text support. As one component of SIMS, these operations are collectively supported as a DataBase Management System (DBMS).

The design for the research data management system for the Sevilleta LTER is built around an archive datafile format. This format provides a computer data structure that contains full documentation and comments (Figure 3). The file, called the "Intersite Archive Datafile (IAF), is a generic data structure that can be used on any hardware and software system, and that can be sent on any electronic network or file transfer system. The IAF structure has been adopted by a number of LTER sites as a **defacto** standard to facilitate intersite communication, and provides a mechanism for an orderly approach to the design and implementation of a project research data management system.

The basic structure is a generic ASCII file that contains the data and categories of information that define the data. While the more complex issue of managing geographic data as they apply to geographic information systems (GIS) will not be addressed in detail here, suffice it to state that for the archival storage of imagery the IAF structure has been expanded to allow for more flexible storage and retrieval.

In any long-term monitoring project the incorporation of minimum documentation standards is crucial. The test of adequate documentation is that data should stand alone, and contain sufficient information so that a future investigator who did not participate in collecting the data can use the information for some management or scientific purpose.

Figure 3. Intersite Archive File Structure.



In keeping with the "practical" approach, the SIMS DBMS is developed around the file handling capabilities that already exist in todays operating systems such as DOS and UNIX. Using shell and C programming for application and database programs eliminates the overhead of maintaining a commercial DBMS. According to some practitioners, this system is known as a "Data File Management System" (DFMS) and not a DBMS. The capabilities of the DFMS are available to meet all the requirements of a DBMS without the cost. For network access or impromptu analytical applications, it may be necessary to use the indexing capabilities of a commercial DBMS.

Data collected on these projects are stored in archive files in specific areas of the hierarchical directory structure of the computer system, with analytical and management tools stored in discipline specific areas (Figure 4). Certain areas of the directory structure are used for data entry, manipulation, and construction of the archive files. Once complete, the files are transferred to the archive area. The archive file then becomes the reference version of the data. All subsequent work is done to the archive file or copies made from it and then replaced. This helps to control the problem of "offspring" files that contain different versions of the data which tend to proliferate through time.

Much data will be directly entered in the field on palmtop PC's (e.g., HP-95's used since 1992 at BAND) or notebook computers, while some information (e.g., meteorological data) is continuously recorded by data loggers. Computerization of data from paper data forms, or data entry, is achieved by the use of text editors, and data entry programs. The use of data entry programs allows for the verification of field inputs with the documentation for those fields. Range checks, look-up tables, and choice lists are provided via these programs which cuts post-processing for quality assurance substantially. The data are double entered, checked by a computer error checking program, or visually checked, with summary analyses produced for additional quality assurance checks. Data are rekeyed if error rates are found to be more than 5%. With the use of filters the data are then translated into the archive file format and submitted for archival storage (Figure 5).

Once the data are in the archive area they are then accessible to the NPS and collaborating investigators via electronic network. Access is provided through an interface that allows the user to download the data in a variety of formats compatible with the analytical tools available, for example, data would be available in Digital Line Graph (DLG) format for GIS layers and Abstract Data Type (ADT) format for satellite imagery. In most cases, data are archived on-line, most image data are stored off-line. The on-line data are copied and saved to tape or optical disk and put in 2 places off the premises to protect against natural and un-natural disasters. This process is documented in Figure 5.

Figure 4. Directory Structure Location of Archive Files.

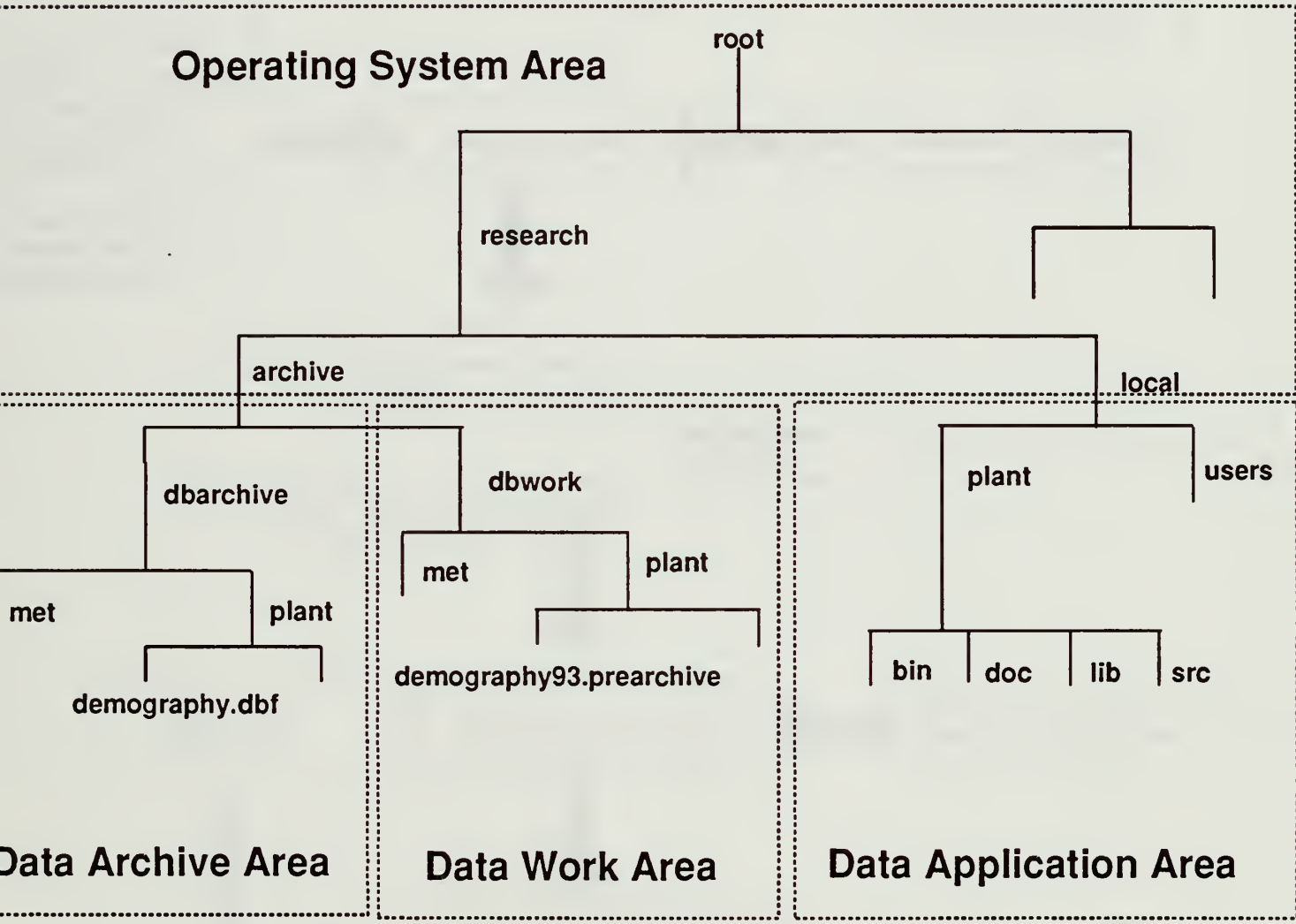
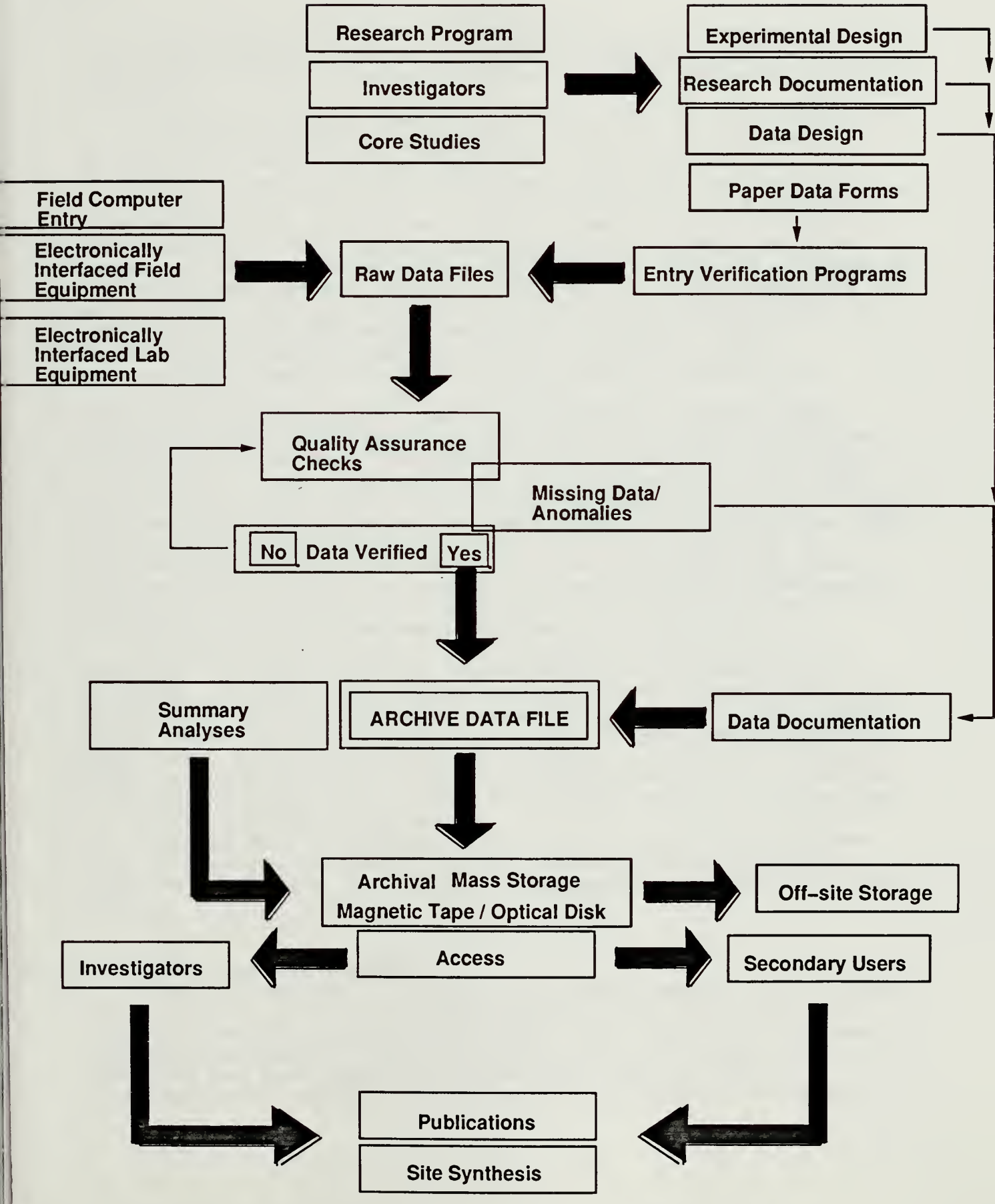


Figure 5. Data Management Flow Chart.



For certain sensitive data sets (e.g., the locations of endangered species) access to computer databases will be restricted through a password system to insure the security of the data.

LTEM data will be summarized and analyzed at least annually by the permanent LTEM program staff. The bulk of the data analysis will occur during the winter, when less fieldwork is conducted, as part of the annual report preparation process.

Equipment investments to support this level of DFMS for a long term project must be made with a great deal of forethought and commitment. The system described above is implemented on a cluster of UNIX workstations, a UNIX file server, and a number of associated DOS and MAC computers (Figure 6). These computers are all connected through a common ethernet based network which is connected to the UNM campus LAN and to "Internet" and are accessible by modem. The file server is used for most non-graphical applications including e-mail and data entry.

LTEM Data administration: Data management for the NPS LTEM Program will be coordinated through SIMS personnel. Part-time funding for these data management tasks is essential to support this project. The LTEM personnel, in collaboration with SIMS managers, will be responsible for the development of the NPS LTEM data network. The LTER data management team will train the LTEM personnel and associated NPS staff. This training will familiarize them with the entire LTER network, enabling them to archive data collected at each site, facilitate data flow among NPS personnel at UNM and various parks, and help with the synthesis of diverse datasets required by this project.

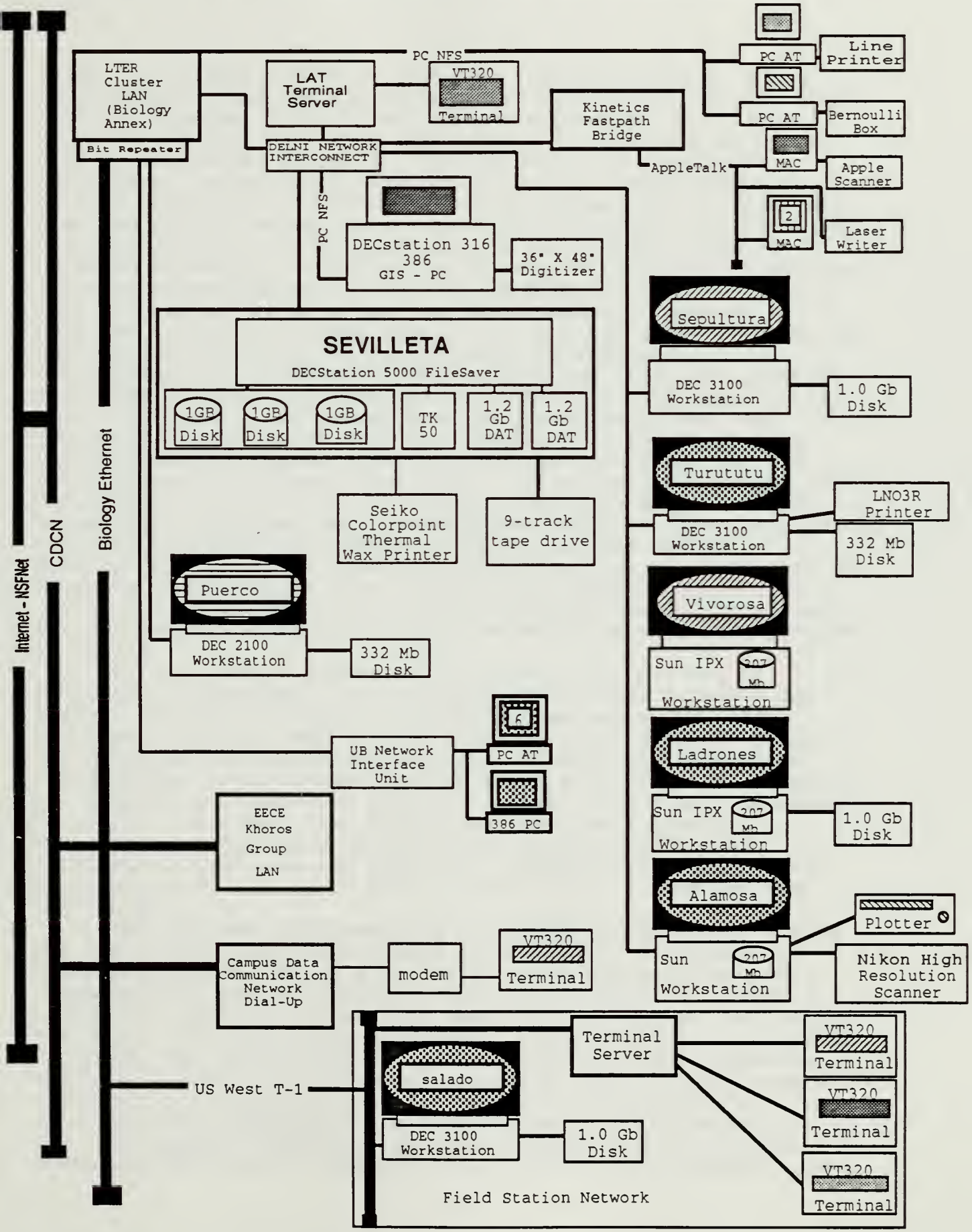
As data are archived by the LTEM data manager they will immediately become available to the NPS through computer linkages. In addition, archive copies of the raw data files will be provided to each of the NPS units every year with the written annual report. General data such as GIS themes, meteorological data, etc., will be available to the entire scientific community. Other requests for data from individual projects will be handled on a case-by-case basis, guided by policies mutually agreed upon by the NPS and LTER programs.

Data files for specimens submitted as voucher collections will be produced following the NPS Museum Handbook protocol. These Museum Record data files will be maintained at each of the parks.

) GIS SUPPORT AND INTEGRATION:

GIS will be used to support this LTEM program, building upon the solid base of past activities at all three NPS units and links to the SEVI LTER program. BAND, ELMA, and PECO each have a functional GIS system with adequate to excellent data bases. Bandelier has been operating a GIS since 1988 to support landscape-level research and management activities (Allen 1989,

Figure 6. Hardware Linkages of the Sevilleta Data File Management System.



Allen - in press). BAND is currently running GRASS on a Sun workstation, while both El Malpais and Pecos are operating EPPL7 on DOS platforms. All three parks have the basic data layers (complete Digital Elevation Model files at 1:24,000, complete Digital Line Graph files at 1:24,000, and park boundaries). Vegetation, soils, roads, trails, hydrology, and hypsography maps at this same scale are available at all three parks. Each park also has several unique data layers; for example, the Bandelier GIS contains over 2,000 archeological sites and associated detailed database, the locations of rare or threatened plants and animals, extensive and varied data on historic and prehistoric fire occurence, historic land use and vegetation changes, detailed ecological survey data (e.g., the GIS image in Plate 2), geology, scanned 1991 aerial stereophotographs and orthophotographs (scales 1:4800, 1:7200, and 1:24,000), digital elevation data at a 10 foot contour interval resolution for the entire park and 2 foot resolution for portions of the park (courtesy of Los Alamos National Laboratory), and other data. LANDSAT Thematic Mapper data from 1990 are available for all three areas, at 30 meter resolution. Also available is the state GAP analysis data set which includes land ownership, land use, vegetation, distribution of vertebrates from the state data base, and selected other attributes. These state GAP data are continuous between the three NPS areas, so they can be linked by a common regional data base. Other land management agencies (USFS, BLM, BIA) are also rapidly developing new GIS datalayers for surrounding lands which can be accessed by this LTEM program if needed.

All three parks either have or are in the process of training GIS operators, and all three have color printers for graphic output. In addition, ELMA has scanner and plotter equipment on-site. BAND is currently in the process of having large numbers of photographic slides of permanent vegetation plots scanned into CD-ROM formats, which will allow the images to be analyzed and digitally archived. BAND hired a GS-7 technician in 1992 to work half-time on GIS and other data management activities; organizing inventory and monitoring data and integrating them into the GIS (e.g., through digitizing of all permanent plot locations) is a primary focus of this position's activities.

BAND has been collaborating with a GIS group at Los Alamos National Laboratory (LANL) since 1988 which is currently demonstrating the use of a GIS which links various types of computer data through a single, spatially organized, software interface, allowing the user to seamlessly access and manipulate GIS maps, text, graphics, databases, or spreadsheets. This LANL group has expressed interest in demonstrating these impressive, state-of-the-art, GIS integrative capabilities in a different context - a funded Upper Rio Grande Basin LTEM program would be an attractive candidate for a LANL demonstration program.

GIS support for all three parks is available at the NPS Southwest Regional GIS Support Center (RGSC) in Albuquerque, New

Mexico. The RGSC, established in 1991, has a permanent staff of 4 persons, with expertise in GRASS, EPPL7, and a variety of other software packages. The RGSC archives and maintains operational copies of the GIS data from each park in a "regional master database". The center has a 36-inch scanner, appropriate software to convert scanned raster maps into vectors, and the ability to output color maps 36 inches wide and of any length. The RGSC is physically located with UNM's Technology Applications Center (TAC), and the expertise and hardware (e.g., numerous digitizing tablets) of TAC are available to the NPS under cooperative agreement.

The RGSC also operates a Trimble Community Base Station for support of field Global Positioning System (GPS) units. The Base Station operates 12 hours per day, 7 days a week, and base station files are available over a 14K baud telephone modem or can be obtained from CC Mail or in person upon request. All three parks are within 100 air miles of Albuquerque, and thus all three park units can use the base station for differential correction of rover locations to obtain a positional accuracy of one meter. The data base of Pecos, for example, was constructed using GPS units from the beginning, and BAND and ELMA have owned and operated multiple GPS units since 1992. Classes in GPS use are offered once or twice a year at the RGSC. Staff at the RGSC are available by telephone to field areas or they can travel to any of the parks to assist in special applications or problem solving.

The SEVI program utilizes georeferenced data to organize much of its LTER data, as landscape-level spatial questions are inherent in the design of this program. Thus the SEVI utilizes a full-time GIS coordinator for the LTER program and interacts intensely with TAC. SEVI primarily utilizes ARCINFO and GRASS for GIS applications, thus data transfer techniques between these software packages (and between EPPL7 as well) have been well developed by TAC. SEVI staff are actively exploring the use of sophisticated image processing techniques for monitoring ecological variables, such as vegetation cover, which may soon become applicable to the NPS LTEM program.

.) LINKAGES AND LEVERAGING:

This NPS LTEM program is tightly linked with inventory and monitoring efforts on local surrounding lands, as well as more generally linked to a variety of regional efforts. For example, at BAND this program is closely linked to inventory and monitoring efforts at adjoining Los Alamos National Laboratory (LANL), with whom collaborative projects include: monitoring of local chorus frog populations (LANL is funding a graduate student project working on both lands); monitoring the effects of the La Mesa Fire (similar plots on both lands, with time donated by LANL for the original PI and a field crew to collect data on BAND and LANL); a variety of GIS activities, ranging from LANL funding of new aerial stereo and orthophotos of BAND (hardcopy and digital)

and the associated development of high resolution digital topography for the park (ten foot and two foot contour intervals) to LANL support of efforts to scan in (and geographically rectify into orthophotos) all historic aerial photographs of BAND and interpret them for landscape change; a joint fungal inventory of LANL and BAND (primarily funded by LANL); and intensive monitoring of runoff and erosion in the BAND Frijolito watershed (funded by LANL). BAND has also been working collaboratively on landscape-wide ecological inventory, monitoring, and research efforts with the surrounding Santa Fe National Forest, which has provided $26,000 to BAND in the past three years to support projects like mapping (in a GIS) and databasing all known observations of threatened and endangered species in our joint landscape, mapping all old-growth forests in this landscape, and development of a high-quality vegetation interpretation of LANDSAT imagery for this area.

In the ELMA area there is interest in establishing monitoring programs among all the surrounding land managers, including BLM, Cibola National Forest, and several native American tribes (Acoma, Zuni, and Ramah Navajo). The ELMA, BLM, and the USFS are all using the same GIS database, and efforts to establish cooperative data sharing are underway. Similarly, at PECO cooperative monitoring and data sharing efforts have been initiated between the NPS, several State of New Mexico agencies, and the Santa Fe National Forest.

The significant benefits of closely linking the NPS LTEM program with the National Science Foundation's LTER network have been discussed in detail elsewhere in this proposal. We believe that this direct linkage is a major strength of our proposal. This linkage has also been fostered by collaboration between BAND, ELMA, and SEVI on a proposal for global change research (Allen and Carlton 1990).

In addition, the NPS LTEM program will also contribute to numerous resource management activities in New Mexico. President Clinton has recently listed the Rio Grande Basin as one of the nation's four Ecosystem Management Programs, designed to demonstrate to the nation how cooperative programs among federal agencies, state agencies, Indian nations, universities, and private interest groups, can address current and future resource management issues. The inclusion of this NPS LTEM program (which would have three study areas within the Rio Grande Basin) in this initiative will provide both high visibility to the NPS, and potentially increased Congressional budget allocations for implementing and enhancing collaborative programs on natural resource issues.

The LTEM program will also collaborate with the Rio Grande Basin Consortium, which is composed of numerous Federal agencies (BLM, USFS, BIA, USGS, BuRec, USFWS), State Government agencies (from Colorado, New Mexico, and Texas) and private interest groups. The Consortium deals with management problems within the Rio Grande corridor, and has a great deal of public respect and cooperation in the region.

Data collected from the LTEM Program will also assist in regional development plans by the Pueblo Nations. For example, the Zuni Indian Tribe, located near ELMA, has prepared a Sustainable Resource Development Plan which concentrates on the biological, hydrologic, and soils resources on the Pueblo lands. Data from ELMA on erosion and biological responses to disturbances and climate dynamics will be of use to the Pueblo in implementing their future management plans. Similarly, BAND has close ties with the neighboring pueblos of Cochiti and San Ildefonso which will lead to sharing of the results of our work and possibly collaborative activities.

Funding from a variety of sources has been cobbled together to establish the baseline data and framework of collaborative relationships outlined in this LTEM proposal, and we expect that securing funds devoted to LTEM work would allow us to leverage significant additional resources into this program. For example, the Centers for Disease Control would collaborate at no cost with our LTEM program to monitor Hantavirus infection rates in the rodents of these three NPS units. Park base funds at all three NPS units have been allocated for resource management staff devoted to monitoring, particularly at BAND where an ecologist and associated biological technician positions were created from a fixed park base by rearranging park priorities. PECO is currently hiring two new biological technician positions to work on inventory and monitoring issues. Regional office science base funding has gone into all three parks in recent years to support the collaborative inventory and monitoring work with UNM. ELMA receives NPS regional office support for a natural resources coop student position which currently works on grazing impacts and revegetation monitoring. ELMA's superintendent sits on the board of the natural resource program of the Southwest Indian Polytechnic Institute and is able to direct student projects toward our three NPS areas. Federal Highways revegetation project funding has been utilized at BAND to supplement the ecological inventory work in piñon-juniper woodlands. Southwest Parks and Monuments Association and the Friends of Bandelier have supported inventory and monitoring work at BAND through funding capitalized equipment (e.g., two GPS units and a binocular dissecting microscope), a seasonal biological technician, and Student Conservation Association interns. As noted above, BAND has also secured significant direct and indirect funding support for ecological monitoring activities from Los Alamos National Laboratory and the Santa Fe National Forest.

) REPORTING SYSTEM:

We propose a straightforward reporting system comprised of the following components. Fufillment of the cooperative agreement between the NBS/NPS and UNM would require that the UNM LTEM project staff prepare: a) quarterly written progress reports; and b) an annual written report which presents annual and cumulative summaries and analyses of the various datasets.

The M.S. level botanist and zoologist would work through the data in their respective specialty areas, and the LTEM Program Manager would synthesize their information, along with data from other components of the program, into a single report. The annual reports would be suitable for publication in either a NPS or NBS technical report series. The quarterly and annual reports would be distributed to the entire LTEM Program Coordinating Committee (see Figure 2), as well as to any other levels of the NPS and NBS which has an interest or need for the information.

Upon completion of the annual report (late winter) the three full-time LTEM staff would hold an annual meeting with the LTEM Program Coordinating Committee, either at UNM or rotated around the various parks, to present the report results in person and discuss any needed program modifications for the coming year. An additional annual meeting of the full LTEM Coordinating Committee is envisioned for each fall, to insure ongoing, interactive feedback between all participants.

The LTEM Program Manager will be expected to submit an article annually to **Park Science**. In addition, Bob Parmenter, Craig Allen, the LTEM Program Manager, and other UNM LTER collaborators (Appendix E) would certainly utilize the data to generate peer-reviewed publications.

) PARK THREATS:

All three of the NPS units in this cluster park proposal have documented concerns over the resource threats of diminished ecosystem integrity, altered air, altered water, alien species, and effects of park operations and visitor activities. In addition, urban encroachment is a problem at PECO. The Upper Rio Grande Basin LTEM Program proposed here will provide some managerially useful information with regard to each of these threats. However, this LTEM proposal is primarily focused upon addressing the complex issue of how to determine the status and trends of overall ecosystem health (integrity). We believe that the multi-faceted, holistic approach to long-term ecosystem monitoring which is proposed here will provide a scientifically credible basis for detecting and understanding ecological changes in park resources, as well as a socially defendable basis for management action, where needed.

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Program Description

THE SEVILLETA LONG-TERM ECOLOGICAL RESEARCH PROGRAM

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Summary

The University of New Mexico's Sevilleta Long-Term Ecological Research Program (LTER) in the central Rio Grande Basin is part of a National Science Foundation network of research sites that examines the responses of ecosystems to environmental changes. The Sevilleta LTER Program is located primarily at the Sevilleta National Wildlife Refuge (Socorro County, NM), but researchers also utilize areas in Cibola National Forest, Bosque del Apache National Wildlife Refuge, El Malpais National Monument, Bandelier National Monument, and Kirtland Air Force Base. These varied study sites include a wide range of ecosystem types, including Chihuahuan Desert, Great Plains Grassland, Great Basin Shrub-Steppe, Piñon-Juniper Woodland, Bosque Riparian Forests and Wetlands, Ponderosa Pine Forests, Mixed-Conifer Montane Forests, and Subalpine Forests and Meadows. The dominant theme of the Sevilleta LTER Program is to examine long-term changes in ecosystem attributes (e.g., population dynamics of plants and animals, nutrient cycling, hydrology, productivity, species diversity) as a result of both natural and man-made disturbances (e.g., global warming, acid rain, grazing, wildfires, droughts, and the "El Niño–Southern Oscillation" (ENSO)). Through these long-term studies, scientists will improve their understanding of the natural dynamics of ecosystems in the heterogeneous landscape of central New Mexico.

Introduction

The Sevilleta LTER Program is conducted by the University of New Mexico's Department of Biology in close collaboration with the U.S. Fish and Wildlife Service. The LTER is funded by a major grant from the National Science Foundation. The Sevilleta LTER is part of a coordinated network of 18 LTER sites that span North America (including two sites in Antarctica). The Sevilleta LTER Program concentrates its research efforts on the Rio Grande Basin in central New Mexico. Four dedicated research areas comprise the core sites for the field research activities. These are the Sevilleta National Wildlife Refuge (100,000 ha), the Bosque del Apache National Wildlife Refuge (25,300 ha), the Sierra Ladrones Wilderness Study Area (28,390 ha) and the Magdalena Mountains Research Area (15,000 ha) in Cibola National Forest. Additional studies are being conducted at Bandelier National Monument near Los Alamos, at the El Malpais National Monument near Grants, and at Kirtland Air Force Base in Albuquerque.

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The Sevilleta research region spans the Rio Grande Basin. In the Socorro County area, study site elevations range from 1,350 m at the Rio Grande to 2,195 m in the Los Pinos Mountains in the east, to 2,797 m at Ladone Peak in the northwest, and to 3,450 m in the Magdalena Mountains to the southwest. Other important regional features include the San Agustin Plains to the west, and the Jornada del Muerto ("Journey of Death") valley to the south. The San Agustin Plains is an ancient lakebed, which has had a number of paleoecological studies that have characterized the long-term vegetation changes in the region; it is also the site of the Very Large Array Radio-telescope funded by NSF. The Jornada del Muerto extends southward some 125 km, and is largely uninhabited except for military personnel at the White Sands Missile Range, site of the first atomic bomb test. The Jornada del Muerto area is the northward extension of habitats characteristic of the Jornada LTER.

Variations in elevation, parent material and geomorphic setting have combined to produce a variety of soils and habitats ranging from thin and rocky residual soils to deep alluvium. For example, in the Sevilleta NWR outside of the floodplain, there are 3 orders, 6 suborders, 10 great groups, 17 subgroups, and 38 named series of soils represented. In the floodplain are additional Entisols and Vertisols. The variability attributed to topography, geology, and soils over a number of scales contributes directly to the variety of gradients in the region. There are wide ranges of variation in soil properties such as texture, depth, presence of argillic and calcic horizons, A-horizon organic matter content, temperature and moisture regimes, and salinity.

The imposition of climatic dynamics in combination with diverse microsite characteristics presents numerous, excellent opportunities for research on species and ecosystem dynamics. Climatic dynamics occur over a range of time and space scales and the research region offers an opportunity to examine many of them. There is a rich set of "behaviors" in response to the dynamics of climate. At one end of the spectrum, areas as large as the Sevilleta or Magdalena Mountains can be viewed as a single pixel and will show variations in spectral reflectance from seasonal to annual time-scales and longer. At another point in the spectrum, species are subject to genetic change and demonstrate an evolutionary response to climate dynamics, at both fine and broad scales. In between these examples is a rich diversity of biological and ecological features that can be studied. The current research ranges from studies of genes to landscapes.

Although the dedicated research areas form the core of the site research, there are excellent opportunities to evaluate management influences on species or landscapes. Intensive grazing occurs outside the boundaries of the research areas and fence-line contrasts have been studied frequently. The Rio Grande provides irrigation water, and floodplain agriculture also has been studied. The juxtaposition of reserved and managed areas also allows studies of, for example, species' refuges, dispersal factors, the influence of exotics, and disturbed-land restoration.

LTER in a Biome Transition Zone

Topography, geology, soils, and hydrology, interacting with major air mass dynamics, provide a spatial and temporal template that has resulted in the region being a transition zone for a number of biomes. The region contains communities representative of, and at the intersection of, Great Plains Grassland, Great Basin Shrub-steppe, Chihuahuan Desert, Interior Chaparral, and Montane Coniferous Forest. The elevational gradient of the Magdalena Mountains provides further

transitions for Interior Chaparral, Piñon-Juniper Woodland, Montane Conifer Forest, Subalpine Conifer Forest, and Subalpine Grassland (Brown 1982). The Magdalena Mountains represent the northeastern limit of Interior Chaparral and are unique in having both Subalpine Conifer Forest and Interior Chaparral on the same mountain range.

The regional location at the junction of a number of biomes is critical for quantifying (1) gradient relationships with distance, (2) the scale-dependent or independent nature of spatial variability, (3) how steep gradients influence system properties, (4) integrated responses across the region, and (5) biome responses to climate change (Gosz and Sharpe 1989).

Biodiversity

The size of the area, the heterogeneous topographic and geological features, and the characteristics of a biome transition zone have resulted in a rich diversity of species. At least 104 families, 1,201 species and 208 varieties of plants occur within the study region, and many species are at their distributional limits. For example, 54 plant species terminate their geographic distributions within the Sevilleta NWR. Some of these species represent major life forms and physiologies, such as the C_3 perennial grasses (*Oryzopsis*). The terrestrial vertebrate fauna includes 89 species of mammals, 353 birds, 58 reptiles, and 15 amphibians (Findley et al. 1975, Hubbard 1970, Snell unpubl.). A substantial proportion of these species have a geographic distribution boundary within the region. Reptiles provide the most dramatic example, as 47 of the 58 species end their distributions in the vicinity of the Sevilleta (33 of these are northern limits of desert species). In addition, a high diversity of ground-dwelling arthropods, with distinctive habitat-specific assemblages, has been documented in recent (Crawford 1988) and ongoing studies.

An important feature of the biodiversity of this region is the number of examples of sympatric swarms of closely related species. This sympatry affords opportunities for studying the evolutionary differentiation of species. For example, six species of mice in the genus *Peromyscus* occur on the Sevilleta (a seventh may also occur), of which five have been found coexisting on a one hectare plot. Four species of *Bouteloua* grasses can be found in the same habitat, and seven species of lizards in the genus *Cnemidophorus* are present. Six of these seven lizard species are found in Sevilleta shrubland habitats, and all seven are present in the shrubland/piñon-juniper transition.

The LTER Program as an "Ecological VLA"

At a regional scale, the central New Mexico landscape is composed of a mosaic of biome types, many of which are represented by study sites in the Sevilleta LTER. The study region also straddles the boundary between major seasonal air masses (e.g., the "Arctic express" on the Great Plains influences Sevilleta's eastern edge; Great Basin polar air masses extend to Sevilleta's northern edge; the Bermuda High generates summer convective storms over the mountains, which track northeast across Sevilleta's lowlands). Superimposed on these spatial patterns are the temporal dynamics of the ENSO phenomenon. These climate phenomena are a function of orographic effects of the southern Rocky Mountains and the New Mexico basin-and-range topography.

Given the reasonably large latitudinal, longitudinal and elevational gradients found in the Sevilleta study region, Sevilleta LTER researchers have access to many representative biome

"patches" that lie close to the edges of their continental distributions. The LTER capitalizes on this "biome diversity" to scale-up the population, community and ecosystem studies, and address biotic responses to climate change on a regional basis. To accomplish this, we have developed an ecological analog to NSF's Very Large Array Radiotelescope (VLA). The VLA is composed of a series of scattered, individual dish-antennae, that, when monitored simultaneously, reveal high-resolution data on obscure astronomical objects. As a rule, signal resolution increases with greater antennae numbers and spread-diameters.

In line with this approach, the LTER Program established a number of research sites (VLA antennae analogs) in various habitats ranging from Rio Grande riparian forest through grassland, shrub-steppe, desert shrubland, piñon-juniper woodland, mixed-conifer subalpine forest, and sub-alpine meadow. In combination with the Sevilleta LTER Program, the studies at Bosque del Apache NWR, Cibola National Forest, Kirtland Air Force Base, and the Bandelier and El Malpais National Monuments are becoming important components of the New Mexico "Ecological VLA." With this network of sites, that spans a two-fold gradient in precipitation amount (VLA spread-diameter analog), we can address problems that require simultaneously-measured, multi-biome data. Such topics include the role of drought or wet cycles on (1) primary production, decomposition and nutrient cycling budgets at a regional scale, (2) species diversities and trophic structures of biotic assemblages across landscapes, and (3) population dynamics and demographics of plants and animals with multi-biome distributions. The benefit of this approach is enhanced greatly by the fact that all these regional research sites are subjected to the same regional climate dynamics; e.g., a drought year for one site is a drought year for all. With the ecological VLA approach, the LTER Program can conduct a "natural experiment," examining proportionate or disproportionate responses of biome types under a similar climatic "treatment."

Description of Hypotheses Addressed by the LTER Program

The LTER Program addresses a number of ecological questions, including: 1) How do the El Niño/La Niña climate dynamics influence ecological processes, such as nutrient cycling and energy flows, as well as the population abundances and spatial/temporal distributions of plants and animals; 2) What effects do climate dynamics have on the species compositions and trophic structures of the various biome types; 3) Across the central New Mexico landscape mosaic, are there similar or disproportionate responses among communities in various biome types when subjected to a common, regional climate change (e.g., drought); 4) Are patterns of plant and animal demographics, density/abundance, survivorship, and reproduction associated with habitat-specific variables (e.g., primary production, precipitation, soil moisture, temperature); 5) How does the heterogeneity of habitat mosaics, in concert with their ecotones, influence floral and faunal distributions, and which species might be poised for habitat invasion/retreat following abrupt or long-term climate changes?

Project Description

The following pages provide provide a conceptual description of the Sevilleta research program's present status and future direction, based largely on current trends and national funding priorities in ecological research. Following this section is a more detailed projection of the long-term future of the Sevilleta LTER Program.

The primary values of the research region include: (1) the four dedicated research areas occupying a large area (150,000 ha), (2) the location at transitions spanning a number of biomes,

and (3) the high biological and environmental diversity. The transitions can express themselves in a number of ways, as various gradients of soils, geology, and topography change through space and time. Climate change will also express itself over a range of time and space scales and the ecological transitions of the Sevilleta region represent an opportunity to examine many of them. We anticipate that the area will demonstrate a wide range of "behaviors" in response to the dynamics of climate. For example, the 1950's drought caused marked vegetation boundary movement in much of the region. The 1988-89 La Niña event produced a strong winter drought that prevented spring production of C_3 grasses. Other wet years in the 1980's caused increased production and expansion of C_3 perennial grasses (*Oryzopsis*). The area is expected to provide a rich set of ecological "tools" capable of quantifying the range of responses to environmental dynamics.

The high biodiversity is related to the large area, heterogeneous habitats and the transitional area for so many biomes. This offers excellent possibilities to understand the factors that contribute to the high diversity, including the high degree of sympatry for closely related species. Population studies are focusing on the interaction between climate change and evolutionary change. Climate change may both stretch the limits of response and change the process of evolution through climate-induced changes in population structure. The effects of a dynamic and heterogeneous environment are expected to be magnified for species at the margins of their ranges. Such species, near the limits of physiological tolerance, are most likely to be affected by short time scale changes, and their population dynamics may reflect the rapid environmental changes typical of this region.

Disturbance patterns and frequencies are important forcing functions for the ecology of the area. "Disturbance" is viewed and studied across many scales that range from antelope hoof-marks in the soil crust between plants, to individual plant mortality (gap dynamics), to mammal mound activity, to frequency and intensity of flooding/scouring in ephemeral streams, to the grassland and forest fires that are increasing in frequency in the protected areas, and to decadal patterns of climate dynamics.

Landscape dynamics also receive significant attention. The hundreds of square kilometers surrounding the Sevilleta Field Station provide a natural laboratory for studying the interplay between temporal environmental variation and the spatial patterning of habitat. Viewed from afar, the extensive landscape exhibits repeating patterns of low-elevation grassy plains punctuated by ascending topography that may be viewed as a superstructure upon which environmental gradients are arrayed. As precipitation and temperature vary temporally, we expect to see spatially correlated shifts in the distributions of habitats, and consequently species distributions may be envisioned as ever expanding and contracting mosaics constrained by the shifting habitats. An interesting analogy between the landscape dynamics and the annealing of alloys provides a theoretical framework for the envisioned fluctuations (B. Milne, pers. comm.). Annealing is the process of repeated heating and cooling of mixtures. Heating excites the component molecular species to seek new configurations that result in minimized free energy levels upon cooling. Variation in annual precipitation constitutes an "excitation" of the system, thereby allowing the entire collection of species to seek new "free energy levels" which may be characterized by such measures as genetic similarity, species richness (per area), primary production, or by multivariate vectors of community composition. The free energy achieved depends on the organismal, demographic, community, and ecosystem level interactions of the populations involved.

Restoration biology also is an area of intense interest in the region. The grassland and desert shrub areas of most of New Mexico were heavily grazed for centuries. The research areas allow experiments and studies of natural succession and recovery. Species reintroductions also are being planned, such as the native Desert Bighorn Sheep in the Sierra Ladrones and pronghorn antelope on the Sevilleta NWR west of the Rio Grande. The riparian cottonwood forest along the Rio Grande also has been greatly altered by harvesting, river control from impoundments, and invasion by exotics. UNM and FWS ecologists have initiated a new research program at Bosque del Apache NWR that examines aspects of cottonwood forest restoration, focusing particularly on flood manipulations of the Rio Grande and the effects on riparian forest ecosystem processes.

Summary of "Core" Program Studies

The Sevilleta LTER Program is an integral part of the regional research effort, and has already proven to be a tremendous asset to both resident and visiting research scientists. The "long-term" nature of the LTER funding schedule (6-yr intervals) contributes a large degree of continuity and stability to the region's research program, ensuring consistent collections of important "core" data sets. The following sections summarize the various ecological research programs that continually accumulate these "core" data sets, all of which are accessible to any interested scientist. The existence of these ongoing projects greatly enhances the data bases available to scientists during all phases of project implementation, from hypothesis development and experimental design through data analysis and interpretation. The LTER "core" projects take advantage of the region's large size and valuable characteristics as a biome transition zone. The approaches are designed to emphasize a variety of scales and levels, including landscapes, phenotypic plasticity, and evolution. Numerous other ongoing studies in geology, anthropology, hydrology and geomorphology will not be discussed because of space limitations.

Meteorological Studies

The Sevilleta NWR has been instrumented with 7 fully-equipped meteorological stations and data-loggers, over 50 rain gauges, and an additional 20 collectors for precipitation chemical analysis. The Langmuir Laboratory and the Bosque del Apache riparian forest site are also equipped with meteorological stations. Historical weather records (100+ yr) for the region are available from the Socorro, NM, weather station. The LTER also acquires lightning strike data (frequencies and locations) for the entire central New Mexico region. All weather data are archived in the Sevilleta Information Management System (SIMS), and are available on request.

Vegetation Assemblage Studies

The principal, large-scale environmental gradients are related to the north-south and east-west characteristics of meteorologic dynamics and topography. Major transects 3 km wide, 30 to 50 km long are designed to traverse the transitions between biome types as well as maximize or minimize environmental gradients (e.g., temperature and precipitation) and elevation. Transects of this scale allow remote sensing analyses from aircraft and satellite to be coordinated with balloon photography and ground truthing to identify gradients in spectral reflectance, species distributions, and substrates. Within the transects, 1 km^2 plots concentrate traditional plant (as well as animal) measurements and permanent photography quadrats.

Watershed Studies

The justifications for including a watershed approach within the region are: (1) water courses amplify variation in precipitation, especially in arid and semiarid regions where there is a nonlinear relationship between variation in precipitation and variation in runoff. Hence, biological responses (demographic, functional, etc.) to changes in mean climate will be magnified along ephemeral watercourses; (2) drainage networks have a natural, hierarchical organization and scale by both size and dynamical behavior, with the smallest watersheds flowing at high frequency and low magnitude and large watersheds at low frequency and high magnitude (Yair 1983, Yair and Shachak 1982); (3) watershed studies have, as a central focus, movement of water across the landscape (the focal constraint in the region's ecology), and represent especially steep, spatially predictable, gradients in water availability; and (4) watershed-based analyses allow comparative studies with other research environments. The watershed studies are based on a conceptual view of watershed processes developed in the Negev Desert (Noy-Meir 1973, 1981). The focus is on biotic responses to the hydrologic redistribution of water as a consequence of interaction between scale, climate, local geology, and microtopography. These interactions result in spatially predictable patterns of average runoff intensity and frequency. Currently, 8 ephemeral stream sites nested within the Rio Salado drainage are studied with watershed areas spanning several orders of magnitude (4 at about 22 ha, 2 at 240 ha, 1 at 3,000 ha, 1 at 300,000 ha). The hydrologic data of U.S.G.S. for the Rio Puerco (1 million ha) and the Rio Grande (5.5 million ha) provide long-term, broad scale results. Recent studies of El Niño/La Niña effects in the region also identify temporal predictability at certain scales. The watershed studies (1) form a model for studies of other constraints which change across scales in other landscapes, and (2) form an empirical basis in attempts to link ecological studies to regional and global biogeospheric studies.

Plant and Animal Population Studies

For plant population studies, the ideas focus on the interaction between climatic change and evolutionary change. Climate change may both stretch the limits of response and change the process of evolution through climate-induced changes in population structure. For long-lived species, it is crucial to understand the limits of phenotypic response. For shorter lived species, genetic change is possible. The effects of short term climatic change on the evolutionary process is being studied by investigating the effects of La Niña and El Niño conditions on gene flow and reproduction in current populations.

Plant productivity responses to environmental dynamics may change beyond simple responses to climate due to enhanced susceptibility to herbivores. Monitoring specific interactions between a plant species and its herbivores show at what levels plants react initially to climate change. Genetic variation of spatially separated populations and changes in response to changing environment as well as altered herbivore interactions are hypothesized to control landscape patterns of species.

For animal populations, movement of individuals is being quantified, as well as dynamics of populations, abundance and distribution of species, and trophic and taxonomic composition of assemblages of rodents, large herbivorous mammals, birds, reptiles, and surface-active arthropods. Patterns and rates of genetic change (in isozymes and mitochondrial DNA clones) are monitored in rodents and lizards. These measurements are made over a sufficient range of spatial and temporal scales: (1) to document the response to heterogeneity across the entire region; and (2) to assess

the detailed response of individuals and local populations to both natural environmental change and any experimental manipulations. Specimens are sorted and recorded using the Museum of Southwestern Biology (MSB) computerized information retrieval system.

Fertilization Studies

The abundance of plants from many different biomes suggests intriguing questions of nutrient limitation. Ecosystem nutrient limitation has been noted in many studies while others clearly indicate that each species responds individually to resource availability in relation to its requirements (Chapin and Shaver 1985, Gutierrez and Whitford 1987, Tilman 1982). The ability to predict strong El Niño or La Niña events offers additional capabilities to study nutrient limitation. During wet springs associated with El Niños, cool season plants are expected to be limited by nutrients rather than moisture. The warm season grasses also would be nutrient limited during an El Niño year because of nutrient immobilization by spring growth of cool season grasses. In La Niña years both cool and warm season grasses should be more water limited than nutrient limited (Lauenroth and Sims 1976). Fertilization experiments on Sevilleta grasslands have been initiated to evaluate these hypotheses.

Wildfire Studies

Natural fires have become more common on the grassland areas of the protected research areas (no cattle grazing). The studies of these natural fires shows that the influence of fire is very species specific because perennial grasses with large, belowground root systems (e.g., Blue Grama of the Great Plains flora) survive while Chihuahuan Desert species (e.g., Black Grama, desert shrubs) are depleted. Thus, in the tension zone between Chihuahuan and other biomes, fire may be a primary agent in controlling species movement due to climate dynamics. In areas where the desert species have been established for a longer period (i.e., more like desert habitat than transition habitat), the grass component has been greatly reduced and fires are rare or nonexistent. The natural fires allow studies of species and the effects on subsequent ecosystem processes. Factorial experiments have begun that relate burning and herbivore (large ungulates) activity to plant and animal community composition and ecosystem processes.

Future Research Potential

Based on current research activity in the Sevilleta region, as well as on the research activity projections considered internally and with potential visiting researchers, several major avenues of future research are anticipatedq. First are ecosystem- and community-level studies addressing the effects of climate change on biotic systems. These will include both seasonal, annual, decadal (and longer time scales) fluctuations and trends in climatic variables, and the eventual responses in ecosystem structure and function among the various biomes represented in the Sevilleta region.

Second, a dramatic increase in population- and organism-level studies can be expected in response to the increasing concern about world-wide patterns of declining biodiversity. Included in this category of research are studies concerning the genetic variability of existing plant and animal species, and the historical implications. As mentioned above, the Sevilleta is an extemely

species-rich region, and many species therein occur near the boundaries of their range distributions. As such, they are subjected to environmental conditions that, for them, may be extreme. In some cases, e.g., a species of desert millipede, the region contains only isolated, relict populations that are widespread elsewhere (Crawford et al. 1987). Comparisons of genetic similarity among these and other species populations that, over time, have colonized marginal habitats in the Rio Grande Basin, will be of prime importance in LTER studies.

Third, an increase in the number of studies concerning the relationship between ecosystem restoration and biodiversity is anticipated. The Rio Grande Basin as a whole has been overexploited in a number of ways, particularly in the past century. Currently, however, much discussion and some research has centered on restoration of the region's semi-arid grasslands and on the marshes and gallery forests associated with the Rio Grande itself. The Sevilleta NWR contains extensive grasslands that have been free of livestock grazing for nearly two decades. Studies of the effects of livestock removal on the diversity of grassland biotas are underway and more are planned. The Rio Grande Valley has lost most of the marshland that made it one of North America's most important migration routes for birds. The introduction of salt cedar and Russian olive trees in this century has greatly compounded that loss in terms of habitat alteration. Significant strides to correct these alterations have been made by the Fish and Wildlife Service at the Bosque del Apache NWR, where federal and UNM biologists have begun collaborative studies on restoration of the original wetlands.

Fourth, a number of current and planned research projects on the Sevilleta concern the research and development of new technologies for use in ecological studies, and the application of current technologies to field research. For example, the development of field FTIR (Fourier-Transform Infra-Red) technology to measure trace atmospheric gas production over km^2 areas of natural ecosystems has been and continues to be an active program on the Sevilleta. In addition, Sevilleta researchers are developing a 3-dimensional, advanced image processing system that will calculate plant biomass from stereoscopic photographs of permanent study plots. An example of integration of existing technologies is the collaborative effort between UNM and NMIMT to correlate lightning activity during thunderstorms with realized precipitation. A 20 km^2 grid of 25 tipping-bucket rain gauges, each gauge instrumented with a data logger, provides rainfall timing and distribution data that are integrated with temporal and spatial lightning data collected simultaneously by Langmuir's Lightning Detection System. As future technology is made available for scientific use, Sevilleta LTER researchers will continue to develop practical applications of technology for ecological research.

Finally, Sevilleta researchers are developing program interactions with several Federal Government agencies and their respective Global Change initiatives. Collaborative efforts are underway with the National Park Service's Global Change Program at the El Malpais National Monument and Bandelier National Monument, and with the U.S. Air Force (Kirtland AFB) under the auspices of the DOD Legacy Program. The Bureau of Indian Affairs is considering a cooperative agreement with Sevilleta researchers to use satellite imagery and GIS analyses to extend the Sevilleta vegetation transects from the Rio Grande valley into other parts of New Mexico, Arizona, Colorado and Utah. These developing regional databases will permit considerable increases in the scale and detail of analyses on ecosystem changes in the southwestern United States.

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APPENDIX B. THE MOST IMPORTANT MONITORING PROJECT STATEMENT FROM BAND'S RESOURCE MANAGEMENT PLAN

BAND-N-003.001: INVENTORY AND MONITOR; BIOTIC RESOURCES

SYSTEMWIDE ISSUES:
N17 Loss of biological diversity
N20 Lack of basic data: insufficient understanding of park ecosystems and threats to them

PROBLEM STATEMENT:
Basic inventories of the biotic resources of Bandelier are essential to sound planning and management of the park. Presence/absence inventories have been conducted for some prominent biological groups, such as vertebrates, insects, and vascular plants, although little information has been collected on the distribution and population status of individual species in these groups. For other taxa, such as fungi, essentially no data exist. Long-term monitoring is ongoing for a few prominent species, but the status and trend of many keystone species and ecosystem parameters remain unknown. Lack of a comprehensive natural resources inventory and monitoring program at Bandelier is incompatible with the park's legislative purpose and NPS policies and guidelines.

In 1991, a collaborative effort was begun with the University of New Mexico's Long-Term Ecological Research (LTER) group to establish multiple-purpose, long-term, inventory and monitoring data collection methods for vascular plants in piñon-juniper woodlands, and in 1992 ground-dwelling arthropods and small mammals were added at piñon-juniper and mixed conifer sites. Methodologies for data collection and data management mirror those developed by the LTER group. A variety of plots have been established and some initial inventory work has been accomplished - however, even for the target groups the inventories remain incomplete and this work has not yet been institutionalized as monitoring.

RECOMMENDED PROGRAM:
Implementation of a comprehensive, long-term, inventory and monitoring (IM) program is recommended. This program would include: 1) development of IM methodologies, including selection of ecological components, selection of IM sites, and development of handbooks with the protocols for IM; 2) establishment of data management procedures to insure that collected data are properly recorded, archived, and analyzed; and 3) establishment of procedures for reporting results and modifying IM methods in light of new results and/or technologies.

Specific IM needs at Bandelier include:

- inventory of all non-vascular plants (fungi, mosses, algae, lichens, and microphytic crusts);
- inventory all invertebrate species (including insects, arachnids, annelids, mollusks, and gastropods);
- inventory and monitor the distribution and abundance of sensitive vascular plants and animals, including all amphibian species; and
- institutionalize and begin the long-term **monitoring** of various target ecosystem components in the following descending order of priorities (funding dependent): vegetation, avifauna, soils, arthropods, and small mammals.

Proposed work in FY 1993:
Develop a Biotic Resources Inventory and Monitoring Plan. Further develop the collaborative work with the University of New Mexico's LTER group to set up long-term inventory and monitoring apparatus for vascular plants, invertebrates, and small mammals in ponderosa pine forests. Also, monitoring plots would be established for woody plants in the piñon-juniper zone. Begin to monitor previously established inventory sites. Funding needs for FY '93 is $10,000.

Interact with local and regional educational institutions to solicit graduate student work for needed inventories.

COSTS:

	Funded				Unfunded			
	Source	Activity	Budget	FTE	Source	Activity	Budget	FTE
Year 1:	PKBASE-NR	MON	4.40	0.1	NRPP	RES	100.00	4.0
Year 2:	PKBASE-NR	MON	4.40	0.1	NRPP	RES	100.00	4.0
Year 3:	PKBASE-NR	MON	4.40	0.1	NRPP	RES	100.00	4.0
Year 4:	PKBASE-NR	MON	4.40	0.1	NRPP	RES	100.00	4.0

Explanation: Funding for this activity covers the 0.1 FTE of natural resource staff time. A full-scale I&M program (unfunded) could take up to 4.0 FTE and $100,000+ per year for several years.

COMPLIANCE:
EXCL Categorical Exclusion

Explanation: 516 DM2 App. 2, 1.6:
"Non-destructive data collection, inventory (including field, aerial and satellite surveying and mapping), study, research and monitoring activities."

APPENDIX C. THE MOST IMPORTANT MONITORING PROJECT STATEMENT FROM ELMA'S RESOURCE MANAGEMENT PLAN

PROJECT NUMBER: **ELMA-N-001.000**

TITLE: **MONITOR NATURAL RESOURCES**

FUNDING STATUS: FUNDED: 0.00 UNFUNDED: 300.00

SERVICEWIDE ISSUES:
N20 BASELINE DATA
N17 BIODIVERSITY

PROBLEM STATEMENT:
If long term natural resource management is to be directed by science as opposed to guesswork, the monitoring of the park's most environmentally sensitive natural resources must be established in a timely manner. We have started to identify trends in resource conditions, and the source and nature of environmental impacts on park resources. Where needed, management actions have started to mitigate or eliminate problems. This is partially the result of resource basic inventory of flora, fauna, and geology that will be completed at the end of FY 93.

Cyclic and non-cyclic variations are occuring continuously in El Malpais' ecosystems. Climatic trends impose environmental conditions which lead to the replacement of species or to the alteration of a biotic communities. Although biotic damage or change may be readily apparent in an area subject to extreme human land use pressures, such as intensive grazing, areas receiving less human impact may be undergoing more subtle changes. Quantitative measurements of ecosystem components or population characteristics are needed to detect these changes.

The establishment of this natural resource monitoring program and its implementation will enable managers to comply with the mandates of relevant laws and policies, and the park's enabling legislation.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY:
Establish a comprehensive Natural Resource Monitoring Program in FY 1994, FY 1995 and FY 1996. Data collection methods will be those specified in NPS-77 and the Natural Resource Inventory/Monitoring Data Collection System developed in N-018 and other physical science data.

The purpose of the Natural Resource Monitoring Program is to identify those natural resources that are most sensitive to natural and/or human induced environmental change and to devise

scientifically sound methods to provide for the longterm monitoring of those resources.

The following natural resource monitoring list is presented to give an idea of the number and type of sensitive natural resources that will require monitoring in the park (additions may be made in the future):

	FLORA	SEASON	FREQUENCY	METHODS
1.	stressed mixed conifer vegetation	summer	TBA	
2.	stressed Ponderosa pine vegetation	summer	TBA	
3.	stressed pinyon-juniper vegetation	summer	TBA	
4.	cave dependent algae community	june and august	TBA	
5.	ice/cave dependent lichen communities	june and august	TBA	
6.	ice/cave dependent moss communities	june and summer	TBA	
7.	ice/cave dependent fern communities	june and summer	TBA	
8.	ice/cave dependent sedge communities	june and september	TBA	
9.	riparian communities	august	TBA	
10.	Malpais fire area	august	TBA	
11.	Collapse fire area	august	TBA	
12.	Hoya fire area	august	TBA	
13.	invasion pinyon-juniper site(s)	summer	TBA	
14.	logged area site(s)	summer	TBA	
15.	grazing exclosure sites	june and august	TBA	
16.	ungrazed primary	june and	TBA	

	kipukas	august	
17.	ungrazed secondary kipukas	june and august	TBA
18.	T&E plant species	summer	annual

	FAUNA	SEASON	FREQUENCY
1.	bat population, Calderon bat cave	july	TBA
2.	bird observations	summer	visitors/ staff
3.	wildlife observations	all year	visitors/ staff
4.	cave invertebrates	summer	TBA
5.	kipuka invertebrates	summer	TBA
6.	ice cave dependent fauna	June	TBA
7.	T&E animal species	TBA	TBA

	PHYSICAL RESOURCES		
1.	ice cave air temperatures at 4 cave sites (automated)	all year	daily
2.	weather readings (automated)	all year	daily
3.	air quality (automated teleradiometer at BLM facility near park)	all year	daily
4.	selected ice cave water samples	bi-annual	B/C ranger

	VISITOR USE IMPACTS		
1.	intensive use area impact assessment, designated site(s)	annual	BD ranger

2. backcountry use impact assessment, designated site(s)	annual	B/C ranger	
3. cave use impact assessment, designated site(s)	annual	RMSpec.	
4. backcountry use (permit system)	annual	B/C ranger	

In short, the development of the park's Natural Resource Monitoring Plan will identify those resources that are the most sensitive to ecosystem shifts and disturbance. The plan will also develop and implement the on-the-ground methods that are most conducive to specifically monitoring each of the identified natural resources in a manner that is compatable with the system developed in N-018, including the time of year monitoring should take place and its duration.

BUDGET AND FTEs:

FUNDED

	Source	Act Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:				
Year 3:				
Year 4:				
		Total:	0.00	0.0

UNFUNDED

	Source	Act Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:	NRPP	MON	100.00	0.5
Year 3:	NRPP	MON	100.00	0.5
Year 4:	NRPP	MON	100.00	0.5
		Total:	300.00	1.5

(OPTIONAL) ALTERNATIVE ACTIONS/SOLUTIONS AND IMPACTS:

NO ACTION Alternative: the park would not establish a Natural Resource Monitoring Program.

Natural resource management's vital linkages to long term scientific monitoring data from environmentally sensitive park resources would be largely severed. Resource management at the park would be forced to adopt a passive "let nature take its course" orientation in which park management would become essentially a custodial function.

A passive approach to land management would preclude the park from actively striving to mitigate or eliminate through appropriate management actions the negative effects of past land use practices (e.g., domestic livestock grazing, fire control, extirpation of desert bighorn sheep, etc.). This would result in the delay or preclusion of environmental rehabilitation/restoration at the national monument. Passive management could also result in the perpetuation of natural resource management errors and the ecological disruption or elimination of sensitive park resources.

COMPLIANCE CODE(s): EXCL

EXPLANATION: 516 DM6 App. 7.4 B(4)

Proposal Date: 91

APPENDIX D. THE MOST IMPORTANT MONITORING PROJECT STATEMENT FROM PECO'S RESOURCE MANAGEMENT PLAN

PECO-N-003.000: ESTABLISH LONG TERM ECOLOGICAL MONITORING

SYSTEMWIDE ISSUES:
N17 Loss of biological diversity
N20 Lack of basic data: insufficient understanding of park ecosystems and threats to them

PROBLEM STATEMENT
As of May 18, 1993 Pecos National Historical Park amended it's physical boundaries to include 5,500 additional acres. This newly acquired land includes an a unique riparian community along the Pecos River. Terrestrial and aquatic invertebrates, mammals, flora, amphibians, reptiles, avian, macrobenthics, soils and fish inventories are currently being, or have been conducted to date.

Establishment of a solid monitoring program is fundamental to understanding and management of the natural resources. Currently this information is not available to the General Management Planning team. A scientific assessment of the status of the system is vital to the construction of prudent and visionary policy. Without long-term ecological monitoring in place, management has no temporal measure of the health of the system.

Current impacts or threats to Pecos NHP resources include:
1) Lack of information on the status of the ecosystem
2) Terrero Mine contamination of the Pecos River
3) Accelerated erosion (previous grazing impacts)
4) Conflicting adjacent property use (water treatment facility)
5) Visitor use impacts (this will become more important as visitor use regulations are established in the GMP and this protected/new parcel is opened up to the public)
6) Exotic vegetation and feral animal displacement of native species
7) Effects of Highway 63 and Interstate 25 traffic on animal movement and ultimately species population stability
8) Unprotected water flow rate for the Pecos River and Glorieta Creek

Without monitoring it is impossible to determine the level of impacts, and subsequently prescribe and justify protection measures. Substantive information based on solid research methodology is imperative to effectual management of the resources we are mandated to protect.

PROBLEM SOLUTION
To document the level of impact from the above mentioned threats monitoring of the significant ecosystem components below are

recommended:

Monitor Resident & Transient Avian Populations	(PECO-N-003.003)
Establish Air Quality/Meteorological Baseline	(PECO-N-008)
Monitor Small Mammals	(PECO-N-003.001)
Monitor Large Mammals	(PECO-N-003.002)
Monitor Pecos River Fish Population	(PECO-N-003.004)
Monitor Glorieta Creek Fish Population	(PECO-N-003.005)
Monitor Temporal Vegetation Composition Change	(PECO-N-017.000)
Conduct Intensive Soil Survey	(PECO-N-019.00)
Study Pecos River Riparian Biodiversity	(PECO-N-020.000)
Monitor Rate of Erosion along Pecos River and Glorieta Creek	(PECO-N-021.00)
Water Quality Study	(PECO-N-04.000)

A comprehensive examination of these primary components will provide a picture of how the system is responding to the perceived impacts. With this data to support management, future actions (both internal and external) will have a baseline from which to measure. Success or failure of projects will be more objectively evaluated. Essentially this type of monitoring will provide us with the necessary tools to legally protect our resources.

Park management has already established a cooperative research alliance with the University of New Mexico's Long Term Ecological Research (LTER) program. The five year old Sevilletta field site has a laboratory currently funded by the National Science Foundation which is equipped with the computers and laboratory items necessary for monitoring analysis and data management. Monitoring should be designed and implemented by the same Sevilleta LTER team who conducted the initial inventories to increase the overall consistency and ultimately the managerial benefit.

Long Term Ecological Research methodologies were favored due to the high standard, world class peer review and the National Science Foundation endorsement. Recent inventories of both terrestrial and aquatic invertebrates and small mammals were conducted in accordance with LTER protocol. LTER data collected is readily transferrable to the EPPL7 data format used by the existing park GIS system.

Monitoring of this nature will provide a picture of the stability and resilience of individual populations. Ultimately the assimilation of the results will provide the park with an indication of the health of the overall ecosystem. This approach will also provide a mechanism for monitoring the fluctuations of biodiversity within the system.

Similar studies are being proposed at Bandelier National Park, and El Mapais National Monument. LTER techniques will be mirrored and monitoring results will be shared with these parks. This approach will render critical site-specific information as well as provide a greater regional perspective by combining the results. Expanding the spatial coverage by coordinating research efforts with Bandelier and El Malpais will multiply the overall benefits derived from the monitoring results.

BUDGET AND FTEs:

FUNDED

	Source	Act Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:				
Year 3:				
Year 4:				
		Total:	0.00	0.0

UNFUNDED

	Source	Act Type	Budget ($1000s)	FTEs
Year 1:				
Year 2:	NRPP	MON	100.00	1.0
Year 3:	NRPP	MON	100.00	1.0
Year 4:	NRPP	MON	100.00	1.0
		Total:	300.00	3.0

APPENDIX E. STAFF LIST FOR UNM'S LTER PROGRAM. The twenty-one principal investigators and collaborators listed below form the core of the UNM Biology Department's ecology faculty, and are the major researchers working on the Sevilleta LTER Program. The research interests of the LTER faculty encompass a wide range of topics, yet are coordinated under the common theme of the LTER.

Research Topic	UNM Faculty Member
Ecosystem Processes/Nutrient Cycling	James R. Gosz
Landscape Ecology	Bruce T. Milne
Geographical Information Systems	Brad Musick
Remote Sensing	Brad Musick
Watershed Dynamics	Cliff Dahm, Manuel Molles
Plant/Animal Community Ecology	James Brown, Robert Parmenter
Plant Population Ecology	Diane Marshall Plant
Evolutionary Ecology & Genetics	Ann Evans, Diane Marshall
Plant Systematics	Timothy Lowrey
Mammal/Avian Population Ecology	James Brown, James Findley
Reptile/Amphibian Population Ecology	Howard Snell
Invertebrate Population Ecology	David Lightfoot, Cliff Crawford
Parasitology	Donald Duszynski
Microbiology	Gordon Johnson
Evolutionary and Population Genetics	Ann Evans, Diane Marshall, Terry Yates
Vertebrate Systematics	Terry Yates
Paleoecology	Glenna Dean, Richard Holloway
Meteorology	James Gosz
Soil & Precipitation Chemistry	Carl White
System Data Management	James Brunt

Professional Resume

ROBERT R. PARMENTER

Associate Professor of Research, Department of Biology, University of New Mexico, Albuquerque
Program Director, Sevilleta Long-Term Ecological Research Program
Station Manager, Sevilleta Field Research Station
Coordinator, Sevilleta Research Experiences For Undergraduates (REU) Site Program
Coordinator, Sevilleta Minority-Undergraduate Research Program

Education:	Ph.D.	Utah State University	1982	Biology/Ecology
	M.S.	University of Georgia	1978	Zoology
	B.S.	Colorado College	1974	Biology

Research Interests:

Research interests include (1) ecosystem disturbance and succession, (2) nutrient cycling dynamics, (3) community and population ecology of vertebrates and arthropods, (4) plant-animal interactions, and (5) biodiversity issues. In addition to the NSF-sponsored LTER research, I currently conduct research projects for the National Park Service at Bandelier National Monument, Pecos National Historic Park, and El Malpais National Monument, as well as ecosystem surveys and analyses for the Department of Defense (U.S. Air Force).
Pending projects include additional NSF and DOD research, as well as a long-term cooperative research agreement with Sandia National Laboratory for ecological field studies.

Scientific Publications:

Zak, D. R., D. Tilman, R. R. Parmenter, C. W. Rice, F. M. Fisher, J. Vose, D. Milchunas, and C. W. Martin. In Review 1993. Plant production and the biomass of soil microorganisms in late successional ecosystems: a continental-scale study. Submitted to Ecology.

Parmenter, R.R., S. L. Brantley, J. H. Brown, C. S. Crawford, D. C. Lightfoot, and T. L. Yates. In Press. Diversity of animal communities on southwestern rangelands: Species patterns, habitat relationships, and land management. In: West, N. E. (ed.). Biodiversity of Southwestern Rangelands. Oregon State University Press, Corvallis.

Parmenter, R.R. In Press. The diversity, spatial variability and functional roles of vertebrates in the desert grassland. In: M. McClaran and T. Van Devender (eds.). The Desert Grassland. University of Arizona Press, Tucson.

Parmenter, R.R. and J. A. MacMahon. In Press. Ecosystem restoration: Faunal interactions in post-disturbance environments. In: E. Allen and Z. Naveh (eds.). Principles of Restoration Ecology: An Integrated Approach. Springer-Verlag.

Brantley, S.L., M.R. Mesch, J.A. MacMahon, and R.R. Parmenter. In Press. Successional patterns of arthropod communities: spider recolonization of surface coal mines in a sagebrush-steppe ecosystem. Journal of Arachnology.

Parmenter, R.R., J. W. Brunt, D. I. Moore, and S. Ernest. 1993. The Hantavirus epidemic in the Southwest: Rodent population dynamics and the implications for transmission of Hantavirus-associated Adult Respiratory Distress Syndrome (HARDS) in the Four Corners Region. Report to the Federal Centers for Disease Control and Prevention, Atlanta, GA.

Parmenter, R.R. and J.A. MacMahon. 1992. Faunal community development on disturbed lands: An indicator of reclamation success. In: J. C. Chambers and G. L. Wade (eds.). Evaluating Reclamation Success: The Ecological Consideration. U.S. Forest Service General Technical Report NE-164.

Gosz, J. R., R. R. Parmenter and D. L. Marshall. 1992. Ecological Indicators in a Desert/Grassland Transistion. In: McKenzie, D. H., D. E. Hyatt and V.J. McDonald Eds. Ecological Indicators, Volume 1. Elsevier Applied Science, New York. pp. 739-763.

Parmenter, R.R., and V. A. Lamarra. 1991. Nutrient cycling in a freshwater marsh: The decomposition of fish and waterfowl carrion. Limnology and Oceanography, 36:976-987.

Parmenter, R.R., J.A. MacMahon, and C.A.B. Gilbert. 1991. Early successional patterns of arthropod recolonization on reclaimed Wyoming strip mines: the grasshoppers (Orthoptera: Acrididae) and allied faunas (Orthoptera: Gryllacrididae and Tettigoniidae). Environmental Entomology, 20:135-142.

Parmenter, R.R., and H.W. Avery. 1990. The feeding ecology of the slider turtle. In: J.W. Gibbons (ed.). The Natural History of the Slider Turtle, *Trachemys scripta*. Washington, D.C.: Smithsonian Institution Press.

Parmenter, R.R., J.A. MacMahon, and D.R. Anderson. 1989. Animal density estimation using a trapping web design: Field validation experiments. Ecology, 70:169-179.

MacMahon, J.A., R.R. Parmenter, K.A. Johnson, and C.M. Crisafulli. 1989. Small mammal recolonization on the Mount St. Helens volcano: 1980-1987. American Midland Naturalist, 122:365-387.

Parmenter, R.R., C.A. Parmenter, and C.D. Cheney. 1989. Factors influencing microhabitat partitioning in arid-land darkling beetles (Tenebrionidae): Temperature and water conservation. Journal of Arid Environments, 17:57-67.

Parmenter, R.R., C.A. Parmenter, and C.D. Cheney. 1989. Factors influencing microhabitat partitioning among coexisting species of arid-land darkling beetles (Tenebrionidae): Behavioral responses to vegetation architecture. Southwestern Naturalist, 34:319-329.

Parmenter, R.R., and J.A. MacMahon. 1988. Factors influencing species composition and population sizes in a ground beetle community (Coleoptera; Carabidae): Predation by rodents. Oikos, 52:350-356.

Parmenter, R.R., and J.A. MacMahon. 1988. Factors limiting populations of arid-land darkling beetles (Coleoptera: Tenebrionidae): Predation by rodents. Environmental Entomology, 17:280-286.

Parmenter, R.R., and J.A. MacMahon. 1987. Early successional patterns of arthropod recolonization on reclaimed strip mines in southwestern Wyoming: The ground-dwelling beetle fauna (Coleoptera). Environmental Entomology, 16:168-177.

Parmenter, R.R., M.R. Mesch, and J.A. MacMahon. 1987. Shrub litter production in a sagebrush-steppe ecosystem: Rodent population cycles as a regulating factor. Journal of Range Management, 40:50-54.

Kelrick, M. I., J. A. MacMahon, R. R. Parmenter, and D. V. Sisson. 1986. Native seed preferences of shrub-steppe rodents, birds and ants: the relationships of seed attributes and seed use. Oecologica, 68:327-337.

Parmenter, R.R., J. A. MacMahon, M. E. Waaland, M. M. Steube, P. Landres, and C. M. Crisafulli. 1985. Reclamation of surface coal mines in western Wyoming for wildlife habitat: a preliminary analysis. Reclamation and Revegetation Research, 4:93-115.

Parmenter, R.R., and J. A. MacMahon. 1984. Factors influencing the distribution and abundance of ground-dwelling beetles (Coleoptera) in a shrub-steppe ecosystem: The role of shrub architecture. Pedobiologia, 26:21-34.

Parmenter, R.R., J. A. MacMahon and S. B. Vander Wall. 1984. The measurement of granivory by desert rodents, birds and ants: a comparison of an energetics approach and a seed-dish technique. Journal of Arid Environments, 7:75-92.

Parmenter, R.R., and J.A. MacMahon. 1983. Factors determining the abundance and distribution of rodents in a shrub-steppe ecosystem: the role of shrubs. Oecologia, 59:145-156.

Parmenter, R.R. 1981. Digestive turnover rates in freshwater turtles: the influence of temperature and body size. Comparative Biochemistry and Physiology, 70A:235-238.

Schubauer, J.P., and R. R. Parmenter. 1981. Winter feeding by aquatic turtles in a southeastern reservoir. Journal of Herpetology, 14:444-447.

Parmenter, R.R. 1980. Effects of food availability and water temperature on the feeding ecology of pond sliders (*Chrysemys s. scripta*). Copeia, 1980:503-514.

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1994.

BUDGET CATEGORY	UNIT COST	EXTENDED COST
PERSONNEL:		
Program Director (0.5 month/year) (Dr. Robert R. Parmenter)	$ 3,672/mo	$ 1,836
Project Manager (Full-time, 6 months in FY94) (Ph.D., UNM Research Faculty)	$ 2,800/mo	$ 16,800
Biologists (Full-time, 6 months in FY94) (2 M.S.-level field biologists for biological sample collections and identifications)	$ 2,200/mo	$ 26,400
Technician (2.5 months/year) (Weather station maintenance and meteorological data management)	$ 2,000/mo	$ 5,000
Data Manager (2 months/year) (Coordination and management of data sets)	$ 2,100/mo	$ 4,200
Summer Temporary Field Technicians (3 Park Service 6-month Temporary Employees, 1 employee at each NPS Unit)	$ 1,500/mo	$ 27,000
Temporary Technicians for Field Crews (6 months/yr) (2 Botany, 2 Entomology, 2 Vertebrate)	$ 1,500/mo	$ 54,000
Salary Benefits		
UNM Faculty/Staff (22.5% of $108,236)	$ 24,353/yr	$ 24,353
U.S. Nat. Park Serv. (7.65% of $27,000)	$ 2,066/yr	$ 2,066
TOTAL PERSONNEL		$ 161,655

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1994, Continued.

BUDGET CATEGORY	UNIT COST	EXTENDED COST
MATERIALS AND SUPPLIES		
Laboratory Analyses (18 precipitation samples in FY94)	$ 100	$ 1,800
NWQAP Sample Analyses	$ 3,000	$ 3,000
Office supplies, copying, Long-distance phone, mail, etc.	$ 2,000	$ 2,000
Data Management (Computer maintenance, software licenses, printer supplies)	$ 2,000	$ 2,000
Field Supplies		
Plant Studies Meter tapes, meter sticks, flagging, rebar stakes, tags, etc.	$ 2,000	$ 2,000
Vertebrate Studies 500 Rodent live-traps Bait, scales, rulers, meter tapes, etc.	$ 6,300 $ 1,000	$ 6,300 $ 1,000
Arthropod Studies Pitfall traps, nets, insect pins, storage drawers, propylene glycol	$ 3,000	$ 3,000
Meteorological Studies Upkeep supplies for weather stations	$ 2,000	$ 2,000
Soil Erosion Studies Rebar stakes, paint, etc.	$ 500	$ 500
Wood Decomposition Studies Chain-saw chains, misc. tools, scales	$ 500	$ 500
TRAVEL		
Project Truck #1		
Mileage, fuel, oil	$ 4,000	$ 4,000
Truck Maintenance	$ 1,500	$ 1,500
Project Truck #2		
Truck rental (4x4 suburban, 6 months/yr) (Cost includes unlimited mileage and fuel)	$ 40/day	$ 7,200
TOTAL MATERIALS, SUPPLIES, TRAVEL COSTS:		$ 36,800

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1994, Continued.

BUDGET CATEGORY		UNIT COST	EXTENDED COST
EQUIPMENT			
Truck -- One (1) 1994 4X4 Chevrolet Suburban, 3/4 Ton, Automatic Transmission, Roof-rack, Winch, Spotlights, Trailering Package.		$ 26,000	$ 26,000
Meteorological Stations (See appended detailed list)			
3	Wet/Dry Precip. Collectors	$ 2,150	$ 6,450
1	Pecos Station	$ 5,568	$ 5,568
3	Bandelier	$ 6,577	$ 19,731
1	El Malpais	$ 5,568	$ 5,568
1 Set	Emergency Standby Component Set	$ 2,658	$ 2,658
5 Sets	Extra Sensors (5 Year Supply)	$ 2,050	$ 10,250
TOTAL EQUIPMENT			$ 76,225
INDIRECT COSTS University of New Mexico Indirect Costs IDC rate is normally 44.9%, but will be reduced to 15% of Direct Costs. No IDC is charged on Equipment ($76,225) or NPS Temporary Employee Salaries/Benefits ($29,066). Total Direct Costs subject to IDC = $169,389 x 0.15 =			$ 25,408
TOTAL BUDGET			$ 300,088

BUDGET SUMMARY		
	SALARIES:	$ 161,655
	SUPPLIES/TRAVEL:	$ 36,800
	EQUIPMENT:	$ 76,225
	INDIRECT COSTS:	$ 25,408
TOTAL BUDGET		$ 300,088

Details of Meteorological Stations

Pecos Station

No.	Campbell Cat. No.	Item	Cost per sta.
1	CR10	CR10	$1090.00
1	CR10KD	Display	$275.00
1	PS12-LA	Power Supply	$250.00
1	ENC12/14	Enclosure	$180.00
1	207	Temp. R.H. Probe	$235.00
1	014A	Wind speed Sensor	$300.00
1	024A	Wind Dir. Sensor	$440.00
1	41004-5	12 Gill radiation Shield	$165.00
1	107B	Temperature probe (with 50' lead)	$49.50
1	108B	Temperature probe (with 50' lead)	$54.50
2	227	Soil Moisture Block (50' leads)@$60	$120.00
1	CM10	Tripod	$275.00
1	019ALU	Cross Arm	$70.00
1	MSX10	Solar Panel (10 Watt)	$205.00
1	LI200S	Pyranometer	$215.00
1	LI2003S	Pyranometer Base and Leveling Fixture	$44.00
1	015	Pyranometer Mounting Arm	$70.00
1	385	AC heated ppt collector	$995.00
1	380B	Mounting Base	$65.00
1		Power Line	$100.00
1	SM192	Storage Module	$370.00
		TOTAL COST	$5568.00

3 Bandelier Weather Stations (2 with power, 1 without power)

No.	Campbell Cat. No.	Item	Cost per station	Extended Cost (no. of sta's)
1	CR10	CR10	$1090.00	$3270.00 (3)
1	CR10KD	Display	$275.00	$275.00 (1)
1	PS12-LA	Power Supply	$250.00	$750.00 (3)
1	ENC12/14	Enclosure	$180.00	$480.00 (3)
1	207	Temp. R.H. Probe	$235.00	$705.00 (3)
1	014A	Wind speed Sensor	$300.00	$900.00 (3)
1	024A	Wind Dir. Sensor	$440.00	$1320.00 (3)
1	41004-5	12 Gill radiation Shield	$165.00	$495.00 (3)
1	107B	Temperature probe (with 50' lead)	$49.50	$148.50 (3)
1	108B	Temperature probe (with 50' lead)	$54.50	$163.50 (3)
2	227	Soil Moisture Block(50' leads)@$60	$120.00	$3600.00 (3)
1	CM10	Tripod	$275.00	$825.00 (3)
1	019ALU	Cross Arm	$70.00	$210.00 (3)
1	MSX10	Solar Panel (10 Watt)	$205.00	$615.00 (3)
1	LI200S	Pyranometer	$215.00	$215.00 (1)
1	LI2003S	Pyranometer Base and Leveling Fixture	$44.00	44.00 (1)
1	015	Pyranometer Mounting Arm	$70.00	$140.00 (1)
1	260-378	Propane heated collector	$1995.00	$1995.00 (1)
and		Propane Tank and plumbing	150.00	150.00 (1)
OR				
1	385	AC heated ppt collector	$995.00	$1990.00 (2)
1	380B	Mounting Base	65.00	130.00 (2)
		Power cabling	$100.00	200.00 (2)
1	SM192	Storage Module	$370.00	$1110.00 (3)
		w/ AC	$5,568.00	$19,731.00
		wo/AC	$6,553.00	

El Malpais Weather Station

No.	Campbell Cat. No.	Item	Cost per station
1	CR10	CR10	$1090.00
1	CR10KD	Display	$275.00
1	PS12-LA	Power Supply	$250.00
1	ENC12/14	Enclosure	$180.00
1	207	Temp. R.H. Probe	$235.00
1	014A	Wind speed Sensor	$300.00
1	024A	Wind Dir. Sensor	$440.00
1	41004-5	12 Gill radiation Shield	$165.00
1	107B	Temperature probe (with 50' lead)	$49.50
1	108B	Temperature probe (with 50' lead)	$54.50
2	227	Soil Moisture Block(50' leads)	$119.00
1	CM10	Tripod	$275.00
1	019ALU	Cross Arm	$70.00
1	MSX10	Solar Panel (10 Watt)	$205.00
1	LI200S	Pyranometer	$215.00
1	LI2003S	Pyranometer Base and Leveling Fixture	$44.00
1	015	Pyranometer Mounting Arm	$70.00
1	385	AC heated ppt collector	$995.00
1	380B	Mounting Base	65.00
1		Power Cable	100.00
1	SM192	Storage Module	$370.00
			$5,568.00

Weather Stations -- Standby Emergency Components

No.	Campbell Cat. No.	Item	Cost per station
1	CR10	CR10	$1090.00
1	SM192	Storage Module	$370.00
1	207	Temp. R.H. Probe	$235.00
1	014A	Wind speed Sensor	$300.00
1	024A	Wind Dir. Sensor	$440.00
1	107B	Temperature probe (with 50' lead)	$49.50
1	108B	Temperature probe (with 50' lead)	$54.50
2	227	Soil Moisture Block(50' leads)	$119.00
1	LI200S	Pyranometer	$215.00
			$2658.00

Repair and Replacements for Met stations

		per yr.	5 yr.	All
RH chip	annual	100	500	2,500
Anemometer	every 2 yrs	100	500	2,500
Vane	every 2 yrs	150	750	3,500
Soil moisture blocks	every 2 yrs	60	300	1,500
				$10,250

Wet/Dry Precipitation Collectors (one at each NPS Unit)

3	Model 301 Automatic Wet/Dry collector	$1,695.00	$5,085
3	Solar Panel	$205.00	$615
3	Battery	$100.00	$300
3	Extra Buckets @ $10 ea.	$100.00	$300
3	Misc installation materials	$50.00	$150
	Total	$2,150.00	$6,450

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1995.

BUDGET CATEGORY		UNIT COST	EXTENDED COST
PERSONNEL			
Project Director (Dr. Robert R. Parmenter)	(0.5 month/year)	$ 3,856/mo	$ 1,928
Program Manager (Ph.D., UNM Research Faculty)	(Full-time)	$ 3,150/mo	$ 37,800
Biologists (2 M.S.-level field biologists for biological sample collections and identifications)	(Full-time)	$ 2,310/mo	$ 55,440
Technician (Weather station maintenance and meteorological data management)	(2.5 months/year)	$ 2,100/mo	$ 5,250
Data Manager (Coordination and management of data sets)	(3 months/year)	$ 2,205/mo	$ 6,615
Summer Temporary Field Technicians (3 Park Service 6-month Temporary Employees, 1 employee at each NPS Unit)		$ 1,575/mo	$ 28,350
Temporary Technicians for Field Crews (6 months/yr) (2 Botany, 2 Entomology, 2 Vertebrate)		$ 1,575/mo	$ 56,700
Secretary	(2 months/year)	$ 1,575/mo	$ 3,150
Salary Benefits			
UNM Faculty/Staff (22.5% of $166,883)		$ 37,549/yr	$ 37,549
U.S. Nat. Park Serv. (7.65% of $28,350)		$ 2,169/yr	$ 2,169
TOTAL PERSONNEL			$ 234,951

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1995, Continued.

BUDGET CATEGORY	UNIT COST	EXTENDED COST
MATERIALS AND SUPPLIES		
Laboratory Analyses 36 precipitation samples/year	$ 105/ea	$ 3,780
NWQAP Sample Analyses	$ 6,000	$ 6,000
Office supplies, copying, Long-distance phone, mail, etc.	$ 1,100	$ 1,100
Data Management (Computer maintenance, software licenses, printer supplies)	$ 2,150	$ 2,150
Field Supplies		
Plant Studies Meter tapes, meter sticks, flagging	$ 1,100	$ 1,100
Vertebrate Studies 500 additional rodent live-traps Bait, scales, rulers, meter tapes, etc.	$ 6,615 $ 1,100	$ 6,615 $ 1,100
Arthropod Studies Pitfall traps, nets, insect pins, storage drawers, propylene glycol	$ 2,150	$ 2,150
Meteorological Studies Upkeep supplies for weather stations	$ 2,150	$ 2,150
Soil Erosion Studies	$ 525	$ 525
Wood Decomposition Studies	$ 525	$ 525
TRAVEL		
Project Truck #1		
Mileage, fuel, oil	$ 4,200	$ 4,200
Truck Maintenance	$ 1,575	$ 1,575
Project Truck #2		
Truck rental (4x4 suburban, 6 months/yr) (Cost includes unlimited mileage and fuel)	$ 42/day	$ 7,560
TOTAL MATERIALS, SUPPLIES, TRAVEL		$ 40,530

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1995, Continued.

INDIRECT COSTS	
University of New Mexico Indirect Costs	
IDC rate is normally 44.9%, but will be reduced to 15% of Direct Costs.	
No IDC is charged on NPS Temporary Employee Salaries/Benefits ($30,519).	
Total Direct Costs = $244,962 x 0.15 =	$ 36,744
TOTAL:	$ 312,225

BUDGET SUMMARY		
	PERSONNEL SALARIES:	$ 234,951
	SUPPLIES/TRAVEL:	$ 40,530
	INDIRECT COSTS:	$ 36,744
TOTAL BUDGET		$ 312,225

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1996.

BUDGET CATEGORY		UNIT COST	EXTENDED COST
PERSONNEL			
Project Director (Dr. Robert R. Parmenter)	(0.5 month/year)	$ 4,048/mo	$ 2,024
Program Manager (Ph.D., UNM Research Faculty)	(Full-time)	$ 3,308/mo	$ 39,696
Biologists (2 M.S.-level field biologists for biological sample collections and identifications)	(Full-time)	$ 2,426/mo	$ 58,224
Technician (Weather station maintenance and meteorological data management)	(2.5 months/year)	$ 2,205/mo	$ 5,513
Data Manager (Coordination and management of data sets)	(3 months/year)	$ 2,315/mo	$ 6,945
Summer Temporary Field Technicians (3 Park Service 6-month Temporary Employees, 1 employee at each NPS Unit)		$ 1,654/mo	$ 29,772
Temporary Technicians for Field Crews (6 months/yr) (2 Botany, 2 Entomology, 2 Vertebrate)		$ 1,654/mo	$ 59,544
Secretary	(2 months/year)	$ 1,654/mo	$ 3,308
Salary Benefits			
UNM Faculty/Staff (22.5% of $175,254)		$ 39,432/yr	$ 39,432
U.S. Nat. Park Serv. (7.65% of $29,772)		$ 2,278/yr	$ 2,278
TOTAL PERSONNEL			$ 246,736

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1996, Continued.

BUDGET CATEGORY	UNIT COST	EXTENDED COST
MATERIALS AND SUPPLIES		
Laboratory Analyses (36 precipitation samples/year)	$ 110	$ 3,960
NWQAP Sample Analyses	$ 1,000	$ 1,000
Office supplies, copying, Long-distance phone, mail, etc.	$ 2,205	$ 2,205
Data Management (Computer maintenance, software licenses, printer supplies)	$ 3,308	$ 3,308
Field Supplies		
Plant Studies Meter tapes, meter sticks, flagging	$ 2,808	$ 2,808
Vertebrate Studies Bait, scales, rulers, meter tapes, etc.	$ 3,308	$ 3,308
Arthropod Studies Pitfall traps, nets, insect pins, storage drawers, propylene glycol	$ 4,650	$ 4,650
Meteorological Studies Upkeep supplies for weather stations	$ 4,150	$ 4,150
Soil Erosion Studies	$ 551	$ 551
Wood Decomposition Studies	$ 551	$ 551
TRAVEL		
Project Truck #1		
Mileage, fuel, oil	$ 4,410	$ 4,410
Truck Maintenance	$ 1,654	$ 1,654
Project Truck #2		
Truck rental (4x4 suburban, 6 months/yr) (Cost includes unlimited mileage and fuel)	$ 44/day	$ 7,920
TOTAL MATERIALS, SUPPLIES, TRAVEL		$ 40,475

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1996, Continued.

INDIRECT COSTS	
University of New Mexico Indirect Costs	
IDC rate is normally 44.9%, but will be reduced to 15% of Direct Costs.	
No IDC is charged on NPS Temporary Employee Salaries/Benefits ($32,050).	
Total Direct Costs = $255,161 x 0.15 =	$ 38,274
TOTAL:	$325,485

BUDGET SUMMARY		
	PERSONNEL SALARIES:	$ 246,736
	SUPPLIES/TRAVEL:	$ 40,475
	INDIRECT COSTS:	$ 38,274
TOTAL BUDGET		$ 325,485

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1997.

BUDGET CATEGORY		UNIT COST	EXTENDED COST
PERSONNEL			
Project Director (Dr. Robert R. Parmenter)	(0.5 month/year)	$ 4,250/mo	$ 2,125
Program Manager (Ph.D., UNM Research Faculty)	(Full-time)	$ 3,473/mo	$ 41,676
Biologists (2 M.S.-level field biologists for biological sample collections and identifications)	(Full-time)	$ 2,547/mo	$ 61,128
Technician (Weather station maintenance and meteorological data management)	(2.5 months/year)	$ 2,316/mo	$ 5,790
Data Manager (Coordination and management of data sets)	(3 months/year)	$ 2,431/mo	$ 7,293
Summer Temporary Field Technicians (3 Park Service 6-month Temporary Employees, 1 employee at each NPS Unit)		$ 1,736/mo	$ 31,248
Temporary Technicians for Field Crews (6 months/yr) (2 Botany, 2 Entomology, 2 Vertebrate)		$ 1,736/mo	$ 62,496
Secretary	(2 months/year)	$ 1,736/mo	$ 3,472
Salary Benefits			
UNM Faculty/Staff (22.5% of $183,980)		$ 41,396/yr	$ 41,396
U.S. Nat. Park Serv. (7.65% of $31,248)		$ 2,390/yr	$ 2,390
TOTAL PERSONNEL			$ 259,014

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1997, Continued.

BUDGET CATEGORY	UNIT COST	EXTENDED COST
MATERIALS AND SUPPLIES		
Laboratory Analyses 36 precipitation samples/year	$ 116	$ 4,176
NWQAP Sample Analyses	$ 1,000	$ 1,000
Office supplies, copying, Long-distance phone, mail, etc.	$ 2,315	$ 2,315
Data Management (Computer maintenance, software licenses, printer supplies)	$ 3,473	$ 3,473
Field Supplies		
Plant Studies Meter tapes, meter sticks, flagging	$ 2,998	$ 2,998
Vertebrate Studies Bait, scales, rulers, meter tapes, etc.	$ 3,473	$ 3,473
Arthropod Studies Pitfall traps, nets, insect pins, storage drawers, propylene glycol	$ 4,883	$ 4,883
Meteorological Studies Upkeep supplies for weather stations	$ 4,358	$ 4,358
Soil Erosion Studies	$ 579	$ 579
Wood Decomposition Studies	$ 579	$ 579
TRAVEL		
Project Truck #1		
Mileage, fuel, oil	$ 4,630	$ 4,630
Truck Maintenance	$ 1,736	$ 1,736
Project Truck #2		
Truck rental (4x4 suburban, 6 months/yr) (Cost includes unlimited mileage and fuel)	$ 46/day	$ 8,280
TOTAL MATERIALS, SUPPLIES, TRAVEL		$ 42,480

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1997, Continued.

INDIRECT COSTS	
University of New Mexico Indirect Costs	
IDC rate is normally 44.9%, but will be reduced to 15% of Direct Costs.	
No IDC is charged on NPS Temporary Employee Salaries/Benefits ($33,638).	
Total Direct Costs = $267,856 x 0.15 =	$ 40,178
TOTAL:	$341,672

BUDGET SUMMARY		
	PERSONNEL SALARIES:	$ 259,014
	SUPPLIES/TRAVEL:	$ 42,480
	INDIRECT COSTS:	$ 40,672
TOTAL BUDGET		$ 341,672

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1998.

BUDGET CATEGORY	UNIT COST	EXTENDED COST
PERSONNEL		
Project Director (0.5 month/year) (Dr. Robert R. Parmenter)	$ 4,464/mo	$ 2,232
Program Manager (Full-time) (Ph.D., UNM Research Faculty)	$ 3,647/mo	$ 43,764
Biologists (Full-time) (2 M.S.-level field biologists for biological sample collections and identifications)	$ 2,674/mo	$ 64,176
Technician (2.5 months/year) (Weather station maintenance and meteorological data management)	$ 2,431/mo	$ 6,078
Data Manager (3 months/year) (Coordination and management of data sets)	$ 2,553/mo	$ 7,659
Summer Temporary Field Technicians (3 Park Service 6-month Temporary Employees, 1 employee at each NPS Unit)	$ 1,823/mo	$ 32,814
Temporary Technicians for Field Crews (6 months/yr) (2 Botany, 2 Entomology, 2 Vertebrate)	$ 1,823/mo	$ 65,628
Secretary (2 months/year)	$ 1,823/mo	$ 3,646
Salary Benefits		
UNM Faculty/Staff (22.5% of $193,183)	$ 43,466/yr	$ 43,466
U.S. Nat. Park Serv. (7.65% of $32,814)	$ 2,510/yr	$ 2,510
TOTAL PERSONNEL		$ 271,973

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1998, Continued.

BUDGET CATEGORY	UNIT COST	EXTENDED COST
MATERIALS AND SUPPLIES		
Laboratory Analyses 36 precipitation samples/year	$ 122	$ 4,392
NWQAP Sample Analyses	$ 1,000	$ 1,000
Office supplies, copying, Long-distance phone, mail, etc.	$ 2,431	$ 2,431
Data Management (Computer maintenance, software licenses, printer supplies)	$ 3,647	$ 3,647
Field Supplies		
Plant Studies Meter tapes, meter sticks, flagging	$ 4,198	$ 4,198
Vertebrate Studies Bait, scales, rulers, meter tapes, etc.	$ 3,647	$ 3,647
Arthropod Studies Pitfall traps, nets, insect pins, storage drawers, propylene glycol	$ 5,127	$ 5,127
Meteorological Studies Upkeep supplies for weather stations	$ 4,575	$ 4,575
Soil Erosion Studies	$ 608	$ 608
Wood Decomposition Studies	$ 608	$ 608
TRAVEL		
Project Truck #1		
Mileage, fuel, oil	$ 4,862	$ 4,862
Truck Maintenance	$ 1,823	$ 1,823
Project Truck #2		
Truck rental (4x4 suburban, 6 months/yr) (Cost includes unlimited mileage and fuel)	$ 48/day	$ 8,640
TOTAL MATERIALS, SUPPLIES, TRAVEL		$ 44,558

National Park Service

LTEM Proposal

PROPOSED BUDGET, FY 1998, Continued.

INDIRECT COSTS	
University of New Mexico Indirect Costs	
IDC rate is normally 44.9%, but will be reduced to 15% of Direct Costs.	
No IDC is charged on NPS Temporary Employee Salaries/Benefits ($35,324).	
Total Direct Costs = $281,207 x 0.15 =	$ 42,181
TOTAL:	$339,369

BUDGET SUMMARY		
	PERSONNEL SALARIES:	$ 271,973
	SUPPLIES/TRAVEL:	$ 44,558
	INDIRECT COSTS:	$ 42,181
TOTAL BUDGET		$ 358,712

National Park Service

LTEM Proposal

SUMMARY PROPOSED BUDGET, FYS 1994-1998.*

BUDGET CATEGORY	1994	1995	1996	1997	1998
PERSONNEL SALARIES:	$ 161,655	$ 234,951	$ 246,736	$ 259,014	$ 271,973
SUPPLIES/TRAVEL:	$ 36,800	$ 40,530	$ 40,475	$ 42,480	$ 44,558
EQUIPMENT:	$ 76,225	$ 0	$ 0	$ 0	$ 0
UNM INDIRECT COSTS:	$ 25,408	$ 36,744	$ 38,274	$ 40,178	$ 42,181
	$ 300,088	$ 312,225	$ 325,485	$ 341,672	$ 358,712

* Annual budget increases are based on 5% cost-inflation per year

TOTAL BUDGET, 5 YEARS: $1,638,182