National Park Service
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Natural Resources Program Center

Water Resources Foundation Report
Bandelier National Monument

Natural Resource Technical Report NPS/NRPC/WRD/NRTR—2007/060

ON THE COVER

Photograph: Frijoles Canyon, Bandelier National Monument (Don Weeks - NPS Water Resources Division, 2007)

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Natural Resource Technical Report NPS/NRPC/WRD/NRTR—2007/060

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EXECUTIVE SUMMARY

> *This Water Resources Foundation Report is one of several planning products offered by the NPS Water Resources Division that assist national park units with achieving or maintaining water resource integrity.*

Following the 2004 Park Planning Program Standards, parks are to prepare a *Foundation for Park Planning and Management* document (Foundation Document), which describes its purpose, significance, primary interpretive themes and special mandates, identifying and analyzing those resources and values determined to warrant primary consideration (*Fundamental and Important Resources and Values*) in park planning and management. The Foundation Document may be developed as the first stage of a park's general management planning process or independently of a General Management Plan (National Park Service, 2004a).

This Water Resource Foundation Report is designed to support development of the Foundation Document for Bandelier National Monument (BAND) and extend as a reference for the General Management Plan, if necessary.

The primary objectives of this report are to:

1. Build from the national monument's purpose and significance statements and identify the *important* water resources critical to achieving BAND's purpose and maintaining its significance.
2. Provide background information for BAND's *important* water resources (current condition, related trends, and issues/threats).
3. Define the relevant water-related laws and policies that support management decisions, and identify stakeholder interest.

Some of the water-related strategies captured from current policies and referenced reports are summarized in this Executive Summary per request by the NPS Denver Service Center (DSC).

A workshop was held to generate *Purpose Statements* for BAND, which describes the specific reason(s) for establishing the national monument and *Significance Statements*, which define what is most important about the national monument's resources and values and are based on BAND's purpose.

The Purpose Statements that apply to natural resources for BAND are:

"*To conserve the ecosystem structures and functions of the Jemez Mountains found within Bandelier National Monument and to maintain wilderness resources and values*."

"To develop and implement research that contributes to the stewardship of cultural resources and integrated management of natural resources in the park with broader public education and resource management applications."

From these Purpose Statements, the following Significance Statements were developed:

"*The natural processes associated with a broad range of elevation and variety of landforms within the monument produces a variety of habitats and support high flora and fauna diversity*."

"The Bandelier Wilderness provides opportunities for visitors to easily access primeval conditions and experience viewsheds, air quality, night sky, natural soundscapes, solitude, and healthy ecosystems in the context of prehistoric cultural setting having thousands of archeological sites."

"Research at Bandelier continues to shape the practice and perspective in cultural and natural resource management and preservation."

What is the importance of BAND's water resources?

Building from the Purpose and Significance statements, water resources are identified as an "important resource" at BAND. The national monument was established to preserve what remains of the area's once thriving Ancestral Puebloan culture. Streams, springs, and riparian zones allowed these ancient agrarians to flourish in an otherwise harsh landscape. Thus, water is important at the national monument in interpreting the cultural resources of BAND.

The occurrence of water over a wide range of elevations and microclimates continues to support BAND's diverse assemblage of plants and animals, while providing a variety of visitor usage in the national monument (i.e., fishery, backcountry water supply, swimming, etc.). The 1916 Organic Act and 2006 NPS Management Policies mandates BAND to manage these natural resources "…in such a manner and by such means as will leave them unimpaired for future generations."

What is the adequacy of the existing water resources information?

The existing water-related information for BAND consist of discontinuous datasets from numerous studies and monitoring efforts by NPS staff and other agencies that range from a single sampling event to multi-year monitoring programs. Data collected since the 1960's includes; water quality, discharge, and benthic macroinvertebrate data, along with geomorphic, aquifer and flood-history assessments. These studies are summarized in this report. Relating wildfire influences on the national monument's water resources have evolved into a relatively large portion of the assessment work. Some data trends and current conditions can be inferred from these various sets of information.

There is still much to be learned about water resources within BAND's watershed. For ground water:

1. Individual zones of saturation beneath LANL have not been adequately delineated, and the "hydraulic interconnection" between these is not understood;
2. The recharge area(s) for the regional aquifer and intermediate perched zones have not been identified, and the effect of fracture-fault zones on recharge is unknown;
3. The ground-water flow direction(s) of the regional aquifer and intermediate perched zones, as influenced by pumping of production wells are unknown; and,
4. Aquifer characteristics cannot be determined without additional monitoring wells installed within the specific intervals of the various aquifers beneath the facility.

What are the current state or conditions and the related trends of these water resources?

Water Quality

Capulin and Frijoles creeks are listed as "impaired" based on the 2004 303(d) list for impaired water bodies in New Mexico. The listed impairment for Capulin Creek is "sedimentation/siltation". The listed impairment for Frijoles Creek is pesticides (DDT). Additional Frijoles Creek impairments listed by the U.S. Environmental Protection Agency (2007) included "water temperature, total and fecal coliform, and turbidity".

Bacteria contamination of Frijoles Creek rises during the warm summer months when visitation is high. A typical trend is relatively low bacteria upstream of the visitor center, with higher values downstream.

With a few exceptions, nitrate and ammonium values were typically low in both Frijoles and Capulin creeks.

Several contaminates have been detected in the alluvial and perched ground water systems (tritium, plutonium-239 and -240, americium-241 and strontium-90), as well as organic compounds and nitrates.

Geomorphology

Frijoles and Capulin creeks contain relatively high amounts of fine substrate and subsequent embeddedness, leading to a reduction of high-quality benthic macroinvertebrate habitat.

Over eight feet of incision was observed in the channel of Capulin Creek in response to the Dome Fire induced flooding.

Cochiti Reservoir

The sedimentation rate in the upper Cochiti Reservoir is estimated at 1,189 acre-feet per year. At the 1976-1998 rate of sediment accumulation, the design storage will be fully utilized by 2063.

Ground Water

Zones of perched ground water exist beneath most, if not all, of the wetter canyons of the Pajarito Plateau. The hydrogeologic systems below the Pajarito Plateau are very complex with faults, fractures, permeable and impermeable formations influencing flow velocity and direction.

What are the current and potential threats to water resources at BAND?

Fire Management

Nearly a century of fire suppression at BAND resulted in unnatural plant communities and fuel loading. The consequences of poor fire management practices were revealed in 1977, 1996, and 2000 as the La Mesa, Dome, and Cerro Grande wildfires burned over 70,000 acres within and adjacent to BAND. Elevated rates of watershed erosion are delivering excess sediment to BAND's streams, decreasing habitat diversity and covering spawning areas. Riparian areas sustained direct and indirect impacts associated with alteration of stream channels, banks, and floodplains. Wildfires can also increase stream temperatures by removal of shade and the direct heating of water surfaces. This can result in decreased dissolved oxygen concentrations and increased plant growth.

Water Quality

Along with influences from wildfires, sources of sediment include hiking trails, unpaved road surfaces, and road ditches within and upstream of BAND. Increased ungulate populations could also increase sediment yield in the higher elevations of the watershed by reducing vegetation, increasing soil compaction, and causing trail and gully development.

Elevated fecal coliform counts (in excess of 3,000 colonies/100 mL) have been recorded in Frijoles Creek around BAND's headquarters. Potential bacteria sources include sewage system failures, horse corrals, and pit toilets.

Extensive ground water contamination has been documented in all three ground water zones below LANL. Contaminates could be migrating through the Pajarto Fault zone into BAND. Natural stream processes have transported radionuclide-contaminated sediments from LANL canyons to BAND lands within the backwaters of Cochiti Reservoir.

The New Mexico Department of Transportation applies road salt and cinders to Highway 4 in the headwaters of Frijoles Creek. Spring runoff of salt could degrade water quality.

Fisheries

Past stocking with exotic salmonids may have eliminated native cutthroat trout and could be altering other elements of aquatic communities (e.g., macroinvertebrates) in BAND.

Cochiti Reservoir

Riparian areas along the Rio Grande River in BAND were badly damaged by flooding and sedimentation following the construction of the Cochiti Dam in the 1970's. Most of the native riparian vegetation has been replaced by exotics and weeding pioneer species.

Visitor Use

Documented recreational impacts have only been confirmed in the headquarters reach of Frijoles Creek. For example, trampling from heavy visitor traffic has produced stream banks devoid of vegetation, resulting in overwidening of the stream channel and increased embeddedness. Other visitor-impacted areas within BAND's watershed are likely.

Climate Change

As greenhouse gases continue to accumulate in the atmosphere, the effects of climate change on the environment will only increase. Ecological changes will range from the emergence of new ecosystems to the disappearance of others. The distributions of many species of plants and animals will likely shift across the American landscape, including BAND, independent of the borders of protected areas.

Who are the stakeholders who have an interest in BAND's water resources?

U.S. Department of Agriculture, Natural Resources Conservation Service (originally called the Soil Conservation Service) provides leadership in a partnership effort to help America's private land owners and managers conserve their soil, water, and other natural resources.

U.S. Environmental Protection Agency's mission is to protect human health and the environment.

U.S. Forest Service manages public lands in national forests within BAND's watershed.

U.S. Fish and Wildlife Service works with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats.

U.S. Geological Survey serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.

Los Alamos National Laboratory (LANL) has been involved in numerous large-scale U.S. Department of Energy research and development projects, including nuclear reactors and weapons. As a neighbor to BAND, LANL environmental assessments provide some of the latest understanding of ground water quality and flow dynamics in the immediate area.

New Mexico Environmental Department promotes a safe, clean, and productive environment for New Mexico. Programs include: surface water quality, ground water quality, air quality, drinking water, hazardous waste, pollution prevention, radiation control, and solid waste).

New Mexico Game and Fish provides programs to manage wildlife habitat, restore and manage populations, provide outreach programs and information materials, conserve at-risk species, develop regulations, and provide necessary law enforcement to ensure all of these resources remain healthy and available.

Northern New Mexico Citizens' Advisory Board is a community advisory group chartered in 1997 to provide citizen input to the U.S. Department of Energy on issues of environmental monitoring, remediation, waste management, and long-term environmental stewardship at the LANL.

Which laws and policies apply to BAND's water resources, and what guidance do the laws and policies provide?

Select legislation and management policies that support water resource management at BAND are presented below. Additional water-related legislation and management policies are included in this report.

Proc. No. 1322 (1916) 49 Stat. 1764 is the authorizing proclamation establishing Bandelier National Monument stating, "certain prehistoric aboriginal ruins….are of unusual ethnologic, scientific, and educational interest, and it appears the public interests would be promoted by the proper reserving these relics of a vanished people, with as much land as may be necessary for the proper protection thereof." In addition, the proclamation stipulated that forest operation should not impact the national monument by mandating "the National Monument hereby established shall be the dominate reservation, and any use of the land which interferes with its preservation or protection as a National Monument is hereby forbidden."

The *National Park Service Organic Act* of 1916 created the NPS and includes a significant management provision stating that the NPS *shall promote and regulate the use of the federal areas known as national parks, monuments, and reservations by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for future generations*.

The *National Parks Omnibus Management Act* of 1998 outlined a strategy to improve the ability of the NPS to provide high-quality resource management, protection, interpretation and research in the national park system.

The 1972 *Federal Water Pollution Control Act*, also known as the *Clean Water Act*, strives to restore and maintain the integrity of U.S. waters.

2006 *NPS Management Policies* provide NPS management requirements for natural resources, including water resources (water quality, floodplains, wetlands, watershed and stream processes, water rights).

Executive Order 11990: *Wetlands Protection* requirements for the NPS.

Executive Order 11988: *Floodplain Management* requirements for the NPS.

Construction and operation of Cochiti Dam and reservoir is authorized by PL 86-645 (*1960 Flood Control Act*) and PL 88-293 (1964).

What planning decisions exist for BAND's water resources?

The 1977 *Memorandum of Understanding* (MOU) between the NPS and the U.S. Army Corps of Engineers, which permits a maximum flood-pool contour of 5,465.5 feet for Cochiti Reservoir, allowing approximately 350 acres of national monument lands to be submerged.

The BAND *Water Resources Management Plan* (Mott, 1999) provides a very comprehensive and technical summary of water resources, issue analysis, and recommendations for future actions and studies.

LANL has developed a comprehensive *Hydrogeologic Workplan* (Los Alamos National Laboratory, l998). This document describes activities to be performed by LANL to characterize the hydrogeologic setting beneath the laboratory, and enhance the laboratory's groundwater monitoring program. The planning was completed with close oversight from the New Mexico Environmental Department.

Strategies

Although not typically included in a Water Resources Foundation Report, some of the water-related strategies captured from current policies and existing reports referenced in this document are listed below, per request of the NPS Denver Service Center. These broad strategies should be considered in the future, during development of BAND's Resource Stewardship Strategy (RSS):

Based on the *2006 NPS Management Policies* for water resources (National Park Service 2006a):

- BAND will avoid, whenever possible, the pollution of waters by human activities occurring within and outside of parks.
- BAND will manage watersheds as complete hydrologic systems, and minimize human disturbance to the natural upland processes that deliver water, sediment, and woody debris to streams.
- BAND will manage wetlands in compliance with NPS mandates and the requirements of Executive Order 11990 (Wetland Protection), the Clean Water Act, and the Rivers and Harbors Appropriation Act of 1899, and the procedures described in D.O. 77-1. The service will 1) provide leadership and take action to prevent the destruction, loss, and degradation of wetlands; 2) preserve and enhance the natural and beneficial values of wetlands; and 3) avoid direct and indirect support of new construction in wetlands unless there are not practicable alternatives and the proposed action includes all practicable measures to minimize harm to wetlands. The NPS will implement a "no net loss of wetlands" policy.
- BAND will 1) manage for the preservation of floodplain values; 2) minimize potentially hazardous conditions associated with flooding; and 3) comply with the NPS Organic Act and all other federal laws and executive orders related to the management of activities in flood-prone areas, including Executive Order 11988 (Floodplain Management), NEPA, applicable provisions of the Clean Water Act, and the Rivers and Harbors Appropriation Act of 1899.

The NPS Southern Colorado Plateau Inventory and Monitoring Network (SCPN) is composed of 19 NPS units, including BAND, with the following strategies (National Park Service, 2006b):

- inventory the natural resources and park ecosystems under National Park Service stewardship to determine their nature and status;

- monitor park ecosystems to better understand their dynamic nature and condition, and to provide reference points for comparisons with other, altered environments;

- establish natural resource inventory and monitoring as a standard practice throughout the National Park system;

- integrate natural resource inventory and monitoring information into National Park Service planning, management, and decision making;

- share accomplishments and information with others and form partnerships for reaching common goals and objectives.

The following strategies were presented in BAND's Water Resources Management Plan (Mott, 1999):

- Determine the effects of prescribe fire on surface hydrology.
- Restore degraded stream and stream corridor within BAND.

- Assess potential sewage leakage at BAND.
- Assess flooding potential above developed areas in BAND.
- Coordinate interagency native fish restoration program at BAND.
- Conduct stream flow gain/loss studies to assess potential for ground water contamination.
- Assist with nomination of Outstanding Natural Resource Waters at BAND.
- Properly manage hazardous materials stored within BAND for operations.
- Reconcile its future water needs with existing water rights to determine if additional rights should be secured or if any existing rights are needed.

INTRODUCTION

Bandelier National Monument (BAND) was established in 1916 to preserve one of the largest concentrations of precontact (prior to Spanish explorers) Indian dwellings in the American Southwest. Since then, lands have been added to the national monument bringing the total acreage to almost 35,000, of which 23,267 acres are designated wilderness.

Water helped carve the rugged landscape we see today at BAND. A landscape that attracted the Pueblo people, who came into the region 10,000 to 12,000 years ago. Springs and streams allowed these ancient agrarians to flourish in an otherwise harsh landscape. Ancestral Pueblo groups occupied the Bandelier area for more than 400 years, where they farmed the land and supplemented their diet with the diverse native plants and animals in the region (National Park Service, 2004a).

In 2007, BAND started a new planning process, following the National Park Service (NPS) 2004 Park Planning Program Standards, to address some of the new information and understanding about the monument's resources and values. This new NPS planning format begins with development of a *Foundation for Park Planning and Management* document. As a guide, the Foundation Document (also referred to as the Foundation Statement) ensures that the most important objectives that are critical to achieving the national monument's purpose and maintaining its significance are accomplished.

The first BAND Foundation Document workshop (June 2007) produced *Purpose Statements* and *Significance Statements* for the national monument. The purpose statement communicates why Congress established the national monument as a unit of the National Park System. The significance statements tier off the purpose statement, defining what is most important about the park's resources and values and is based on the purpose of why the national monument was created. Below are the most recent draft purpose statements and significance statements related to BAND's natural resources:

Purpose Statements

"*To conserve the ecosystem structures and functions of the Jemez Mountains found within Bandelier National Monument and to maintain wilderness resources and values*."

"To develop and implement research that contributes to the stewardship of cultural resources and integrated management of natural resources in the park with broader public education and resource management applications."

Significance Statements

From these Purpose Statements, the following Significance Statements were developed:

"*The natural processes associated with a broad range of elevation and variety of landforms within the monument produces a variety of habitats and support high flora and fauna diversity*."

"The Bandelier Wilderness provides opportunities for visitors to easily access primeval conditions and experience viewsheds, air quality, night sky, natural soundscapes, solitude, and healthy ecosystems in the context of prehistoric cultural setting having thousands of archeological sites."

"Research at Bandelier continues to shape the practice and perspective in cultural and natural resource management and preservation."

The next workshop objective was to identify *fundamental* and *important resources* and *values* at BAND. These resources warrant primary consideration during planning and management because they are critical to achieving BAND's purpose and maintaining its significance. From that exercise, "water" was listed as an *important resource*. This report provides the justification for that designation, along with presenting the current understanding of the national monument's water resources and associated issues that impact these resources.

Water Resources Planning

This Water Resources Foundation Report is designed to support development of the Foundation Document for BAND's planning process. This section outlines the individual elements of the NPS planning framework (National Park Service, 2004b), including the Foundation Document, and better describes how this report fits into the framework.

Changes in the NPS general planning (2004 *Park Planning Program Standards*) and resources planning (draft *Director's Order 2.1: Resource Stewardship Planning*) required programmatic revision to the existing NPS Water Resources Planning Program to assure that its products continue to support the NPS planning framework within which planning and decision-making are now accomplished. Within this new planning framework, six discrete elements of planning are captured in six planning-related documents (Figure 1).

The *Foundation for Planning and Management* (Foundation) document defines the legal and policy requirements that mandate the park's basic management responsibilities, and identifies and analyzes the resources and values that are fundamental to achieving the park's purpose or otherwise important to park planning and management.

The *General Management Plan* (GMP) uses information from the Foundation document to define broad direction for resource preservation and visitor use in a park, and serves as the basic foundation for park decision-making, including long-term direction for *desired conditions* of park resources and visitor experiences.

The *Program Management Plan* tiers off the GMP, identifying and recommending the best strategies for achieving the desired resource conditions and visitor experiences presented in the GMP. Program planning serves as a bridge to translate the qualitative statements of *desired conditions* established in the GMP into measurable or objective indicators that can be monitored to assess the degree to which the *desired conditions* are being achieved. Based on information obtained through this analysis, comprehensive strategies are developed to achieve the *desired conditions*. The Program Management Plan component for natural and cultural resources is the Resource Stewardship Strategy (Figure 1).

The *Strategic Plan* tiers off the Program Management Plan identifying the highest-priority strategies, including measurable goals that work toward maintaining and/or restoring the park's *desired conditions* over the next 3 to 5 years.

Implementation Plans tier off the Strategic Plan describing in detail (including methods, cost estimates, and schedules) the high-priority actions that will be taken over the next several years to help achieve the *desired conditions* for the park.

The *Annual Performance Plan and Report* measures the progress of projects from the Implementation Plan with objectives from the Strategic Plan.

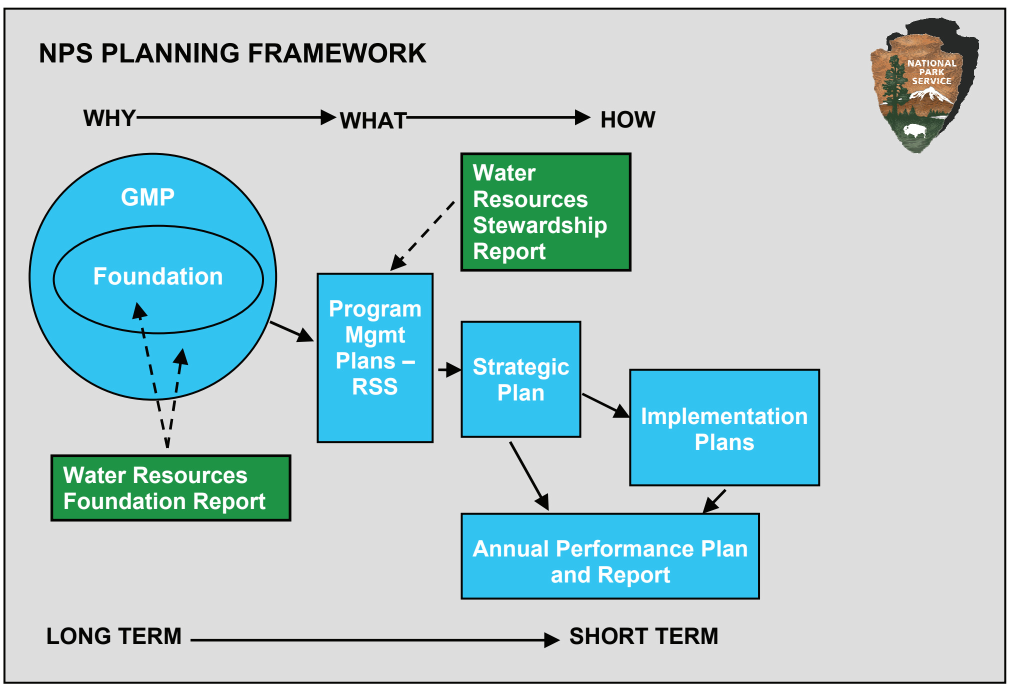

Figure 1. The NPS framework for planning and decision making (blue boxes). Green boxes represent WRD planning products. RSS = Resource Stewardship Strategy.

The *Water Resources Foundation Report* and the *Water Resources Stewardship Report* will support this new planning framework. The Water Resources Foundation Report (Figure 1) addresses the needs of either the Foundation Document or phase one of the GMP. The Water

Resources Stewardship Report (Figure 1) is designed specifically to address the water resource needs in a park's Resources Stewardship Strategy.

<u>Water Resources Foundation Report Objectives</u>

The primary objectives of this *Water Resources Foundation Report* are to; 1) provide an overview of BAND's important water resources, 2) identify issues impacting these water resources, and 3) identify BAND's watershed stakeholders and laws and management policies that protect water resources. The water-related information contained in this report is designed to better assist BAND with development of the Foundation Document, which can also support the preparation of a new park General Management Plan, if warranted.

It should be noted that the majority of this report references heavily from BAND's *Water Resources Management Plan* (Mott, 1999), since little has changed since the plan was completed (Jacobs, pers. com., 2007). The primary author of that plan, David Mott (former NPS Hydrologist) produced the very comprehensive report, which included recommendations for the issues elevated in the report. Mr. Mott, now the Watershed and Air Program Manager for the U.S. Forest Service in Juneau, Alaska, approved referencing from his 1999 plan, as needed, for this water resources planning product. It is recommended that the 1999 *Water Resources Management Plan* be referenced for specifics that extend beyond the scope of this report.

Location and Demography

BAND is located in north central New Mexico, consisting of two noncontiguous units (Figure 2). The small Tsankawi unit (800 acres) is not discussed in this report because of its limited water resources (ephemeral washes being the most predominant). The main unit (32,827 acres) comprises 70 percent of the Monument's 47,100-acre watershed. BAND' s headquarters is within the lower Frijoles Canyon near Los Alamos, New Mexico.

BAND's most intensely developed neighbor is Los Alamos National Laboratory (LANL) to the north (Figure 3), encompassing 27,520 acres. LANL has been involved in numerous large-scale research and development projects, including nuclear reactors and weapons. LANL is almost exclusively outside the Monument's surface watersheds.

The northwestern and western boundaries adjoin the 88,900-acre Valles Caldera Preserve, previously the Baca cattle ranch, which incorporates most of the Valles Caldera (Figure 3). The preserve takes in portions of the Monument's uppermost watersheds. The National Park Service purchased a private tract in this same area, Elk Meadows.

BAND's largest neighbor is the Santa Fe National Forest. National Forest lands include 13,900 acres of the national monument's western watersheds and the headwaters of four streams (Figure 3). The Santa Fe National Forest also borders the national monument to the north and along the length of the Rio Grande. National monument lands adjacent to the Rio Grande include an easement granted to the U.S. Army Corps of Engineers, which permits "flooding and inundation as is required for the operation of Cochiti Reservoir (NPS and U.S. Army Corps of Engineers, 1977)." The southern boundary is contiguous to lands owned by the University of New Mexico. These lands are entirely downstream from the national monument.

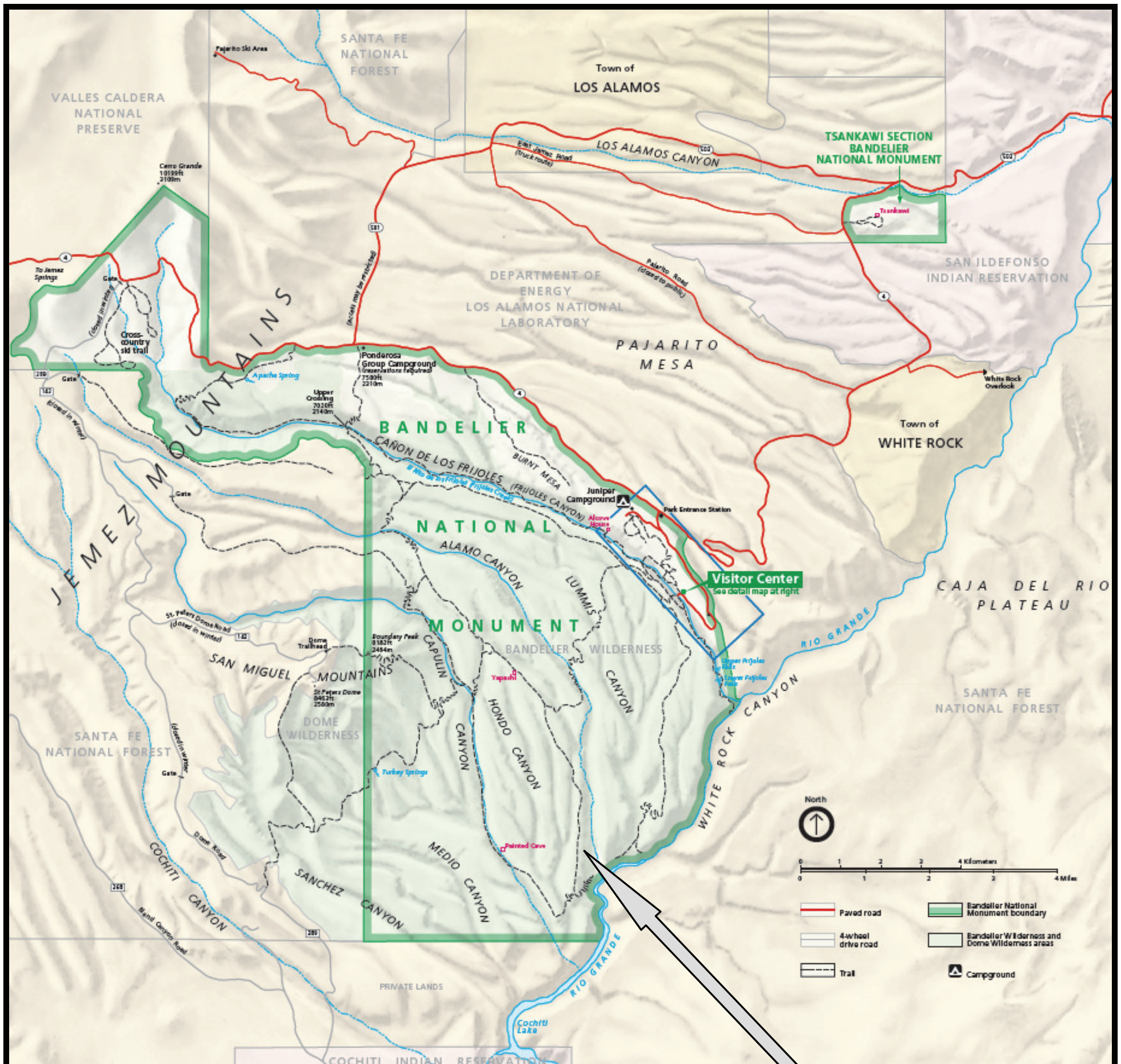

Figure 2. Location map for Bandelier National Monument (National Park Service, 2007a).

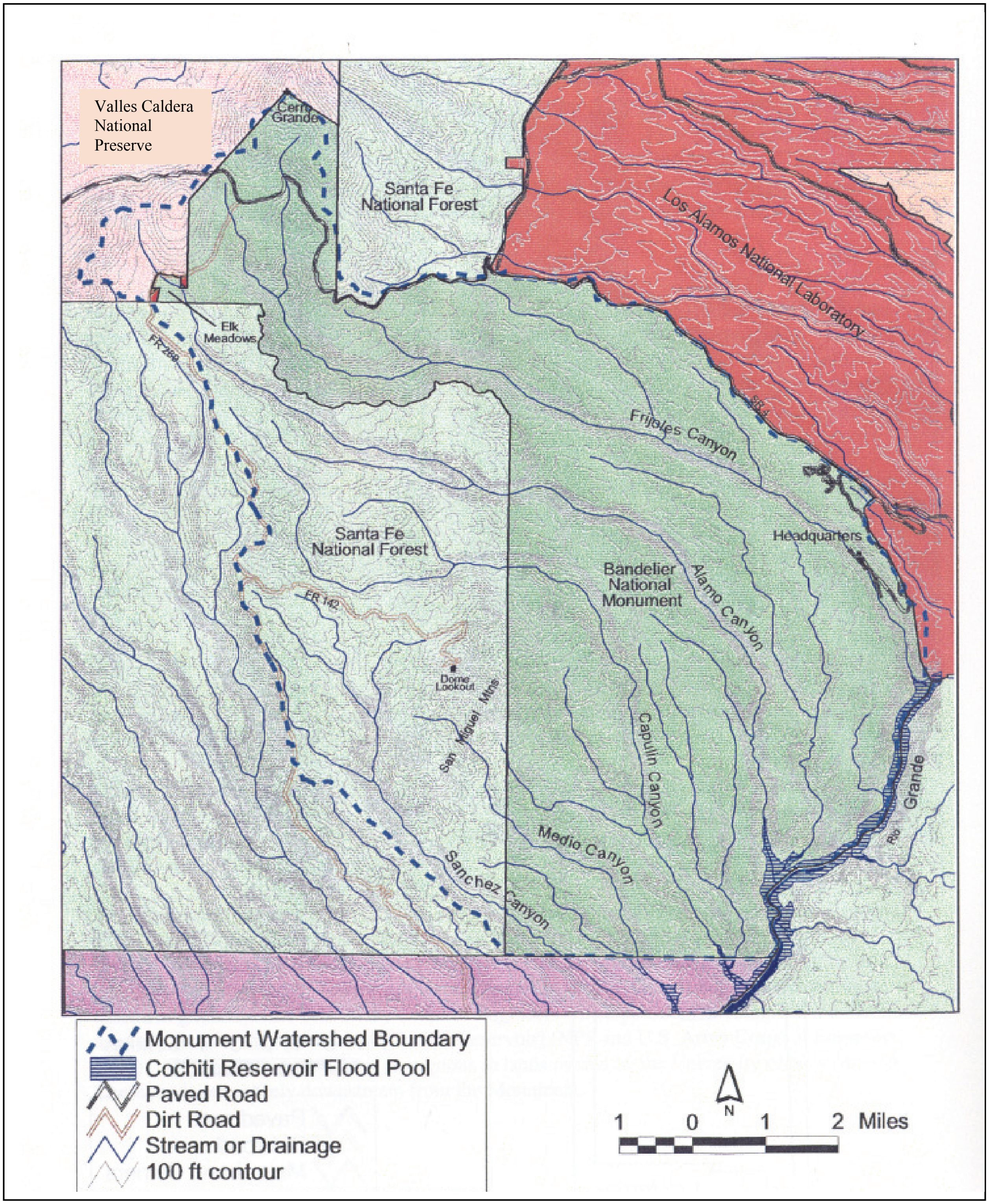

Figure 3. Bandelier National Monument's adjacent landowners (Bandelier National Monument – GIS).

DESCRIPTION OF NATURAL RESOURCES

Climate

BAND's climate is characterized as a semi-arid, continental mountain climate, with significant climate variability within the monument boundaries. The area's elevation gradients range from 5,300 to 10,199 ft (msl). With a mile of elevation change and variances in slope, aspect, and topography, significant differences in precipitation and temperature exist within BAND (Allen, 1989).

Recognizing that one climate station will not capture the climate variability within the national monument's boundaries, Figure 4 presents climate data for Los Alamos, New Mexico, which is in the middle of the elevation range at 7411 ft (msl). At this station, the annual average precipitation is 18.7 inches (World Climate, 2007). Typically, July and August are the wettest months (4.4 inches), when the intensive convective storms occur during the "monsoon" season. These summer thunderstorms have been responsible for the most extensive surface erosion and highest flood peaks on record (Reneau *et al*., 1996). A dry period usually extends from late April through the end of June (Allen, 1989). Average monthly air temperatures range from 28.6° F (-1.9 º C) in January to 67.8° F (19.9º C) in July (Figure 4) (World Climate, 2007).

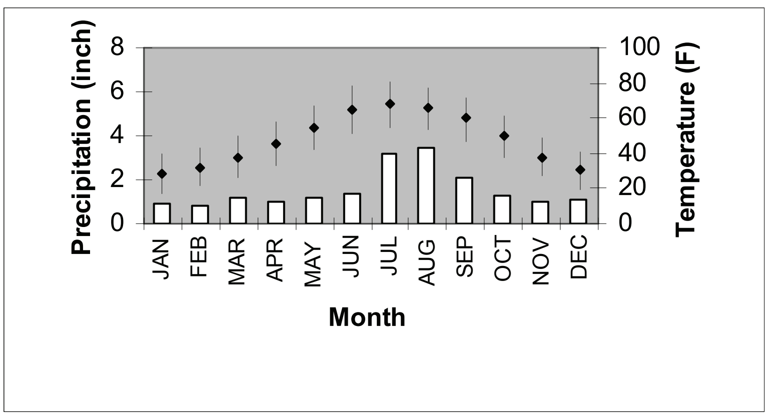

Figure 4. Monthly mean precipitation (bars) (1961-1990) and 24-hr average air temperature (diamonds) (1919-1989), Los Alamos, New Mexico (World Climate, 2007).

Physiography

Bandelier lies on the southeast flank of the Valles Caldera, the central feature of the Jemez Mountains. The Jemez Mountains are a complex volcanic pile at the intersection of two regional geologic features: the eastern rim of the Colorado Plateau to the west, and the Rio Grande rift to the east (Christensen, 1980). The Sierra de los Valles are the mountains encircling the caldera's rim. Streams draining the caldera form a radial drainage pattern. BAND's drainage patterns include: dendritic drainage pattern in the headwaters; parallel drainage pattern across the Pajarito Plateau; and trellis drainage pattern within individual canyons (White and Wells, 1984).

The highest elevations within Bandelier coincide with the eastern rim of the Vales Caldera. The national monument encompasses a portion of the eastern slopes of the Sierra de los Valles; the extreme southwestern part of the Pajarito Plateau (also referred to as "Pajarito Mesa") and its canyons; and, extends down the west wall of White Rock Canyon to include the Rio Grande River's west bank and riparian zone. Elevations generally decrease in a southeasterly direction across the monument, with the exception of highlands comprising the San Miguel Mountains (Figure 3).

Geology

BAND lies within an area with a long history of volcanism; consequently, its surficial geology is predominantly volcanic extrusives. Sedimentary rocks are found on the east edge of the San Miguel Mountains and in the bottom of Capulin Canyon. Quaternary gravels (alluvium) occur in lower reaches of the canyons and along the Rio Grande River (Figure 5). East of the Rio Grande are a group of cinder cone vents forming the Cerros del Rio. These cones erupted 3 million years ago filling ancient valleys with basalt (Mott, 1999).

The Jemez Mountains are the remnants of a large, collapsed volcano that underwent massive eruptions 1.4 and 1.1 million years ago. The six-mile wide Valles Grande (central crater) was formed by an explosion believed to have been 600 times as powerful as the Mt. Saint Helens eruption (Barry, 1990). Lava and ash from these eruptions covered the older basalt to a depth of 1,000 feet in some places and formed the Pajarito Plateau. The Rio Grande has cut through the tuff and into underlying units to form White Rock Canyon (Mott, 1999).

Ash fall, pumice, and rhyolite tuff comprise the Pajarito Plateau and its cliff forming units, and together are referred to as the Bandelier Tuff. Most of the national monument's elongated mesas are comprised of this tuff which is over 1000 ft thick in the western part of the Plateau and thins to about 260 feet eastward near the Rio Grande River. To the west, the tuffs overlap onto the Tschicoma Formation, which consist of older volcanics that form the Jemez Mountains (Los Alamos National Laboratory, 1995).

Major faults along the western boundary of the national monument resulted from crustal adjustments associated with the Rio Grande rift (Purtymun and Adams, 1980). The Pajarito fault system, a system of normal faults, extends from north to south across the central portion of the monument, a mapped distance of 65 miles (Figure 5). The fault system traverses multiple canyons within the monument, watershed boundaries on the north and south, and has been mapped into LANL lands. Vertical displacement across the fault is 400 feet or greater, with the down-dropped wall to the east (LANL, 1998).

Seismic hazard studies indicate the Pajarito fault system could produce maximum earthquakes with a Richter magnitude of about seven. Other work indicates additional faulting underlying and pre-dating the Bandelier Tuff (U. S. Department of Energy, 1998).

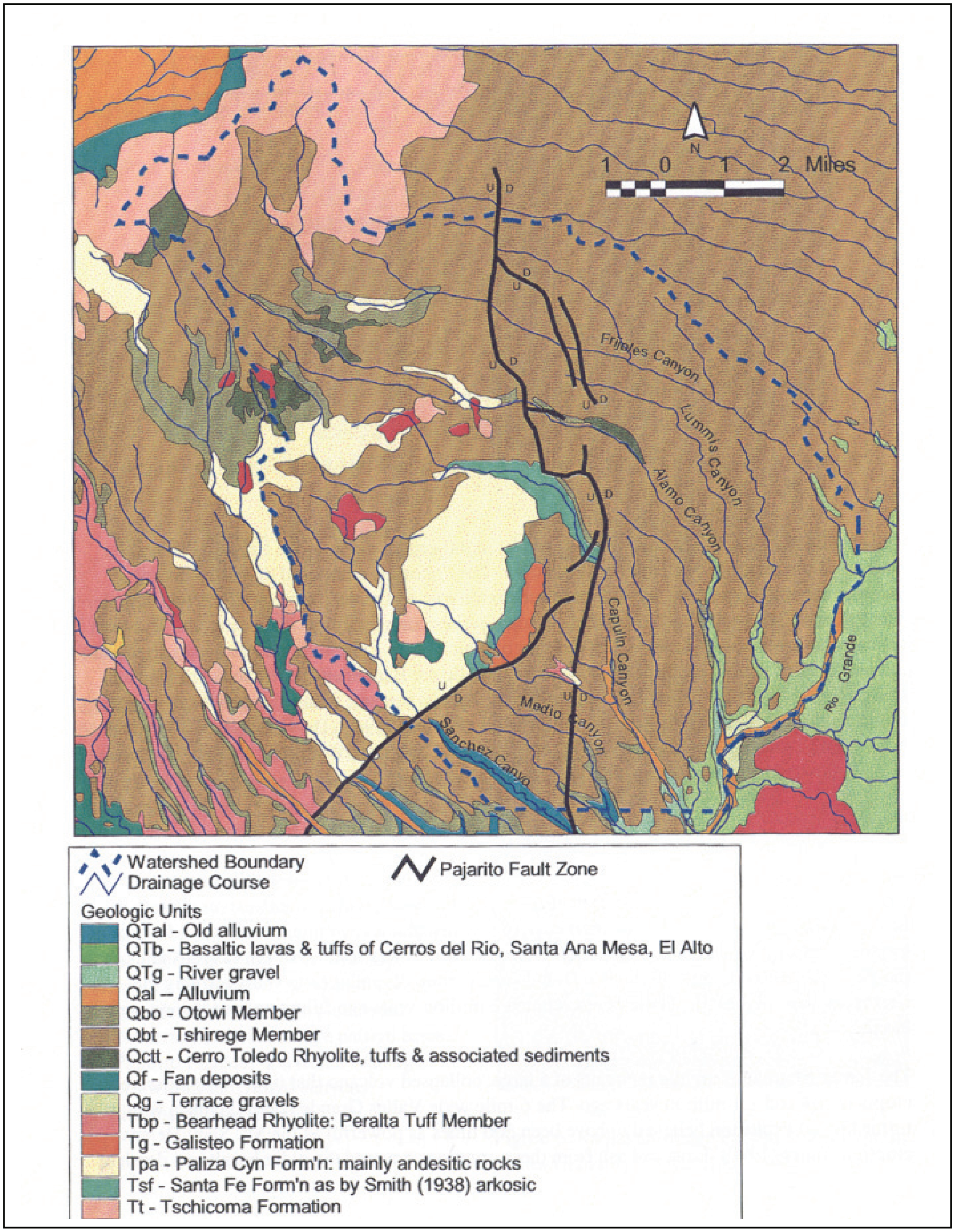

Figure 5. Surficial Geology at Bandelier National Monument (Bandelier National Monument – GIS).

Soils

Several distinct soils have developed as a result of interactions between bedrock, topography, and localized climatic conditions. Soil orders found at BAND include Entisols, Inceptisols, Alfisols, Mollisols, and Aridisols (Allen, 1989).

The two most important properties of soils at the watershed scale are their infiltration rate and erodability. Soils in the area generally have a moderate to high infiltration rate due to the widespread occurrence of pumaceous and other highly porous parent material. Erosion hazard ranges from moderate to severe depending on soil characteristics, slope, effective ground cover, and overstory vegetation conditions (Cassidy *et al*., 1996).

Most areas in BAND have degraded soils (Swan, 2005). Soil loss at the national monument has been estimated at nearly one inch per decade; an unsustainable rate given soil depth in piñon-juniper woodlands is only one to three feet to bedrock (National Park Service, l995a). Piñon-juniper woodlands have replaced the grazed grasslands and savanna communities over the past century, covering 40 percent of BAND. High erosion rates are apparently related to this degraded state (Allen, 1989). At least 80 percent of BAND's archeological sites within the piñon-juniper zone are being damaged by accelerated erosion (National Park Service, 1995b). Accelerated soil erosion can negatively influence water quality and habitat in the national monument's aquatic environments.

Hydrology

Watersheds

According to the NPS Management Policies, the NPS will manage watersheds as complete hydrologic systems, and will minimize human disturbance to the natural upland processes that deliver water, sediment, and woody debris to streams (National Park Service 2006a).

Watersheds are delineated by the U.S. Geological Survey using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 subregions, 352 accounting units, and 2,262 cataloguing units. A hierarchical hydrologic unit code (HUC) consisting of 2 digits for each level in the hydrologic unit system is used to identify any hydrologic area. The 6-digit accounting units and the 8-digit cataloguing units are generally referred to as basin and sub-basin, respectively. HUC's serve as the backbone for the country's hydrologic delineation. Within the HUC classification system, BAND is located in the *Rio Grande – Santa Fe* sub-basin (13020201) of Region 13, *Rio Grande*, (see Figure 6).

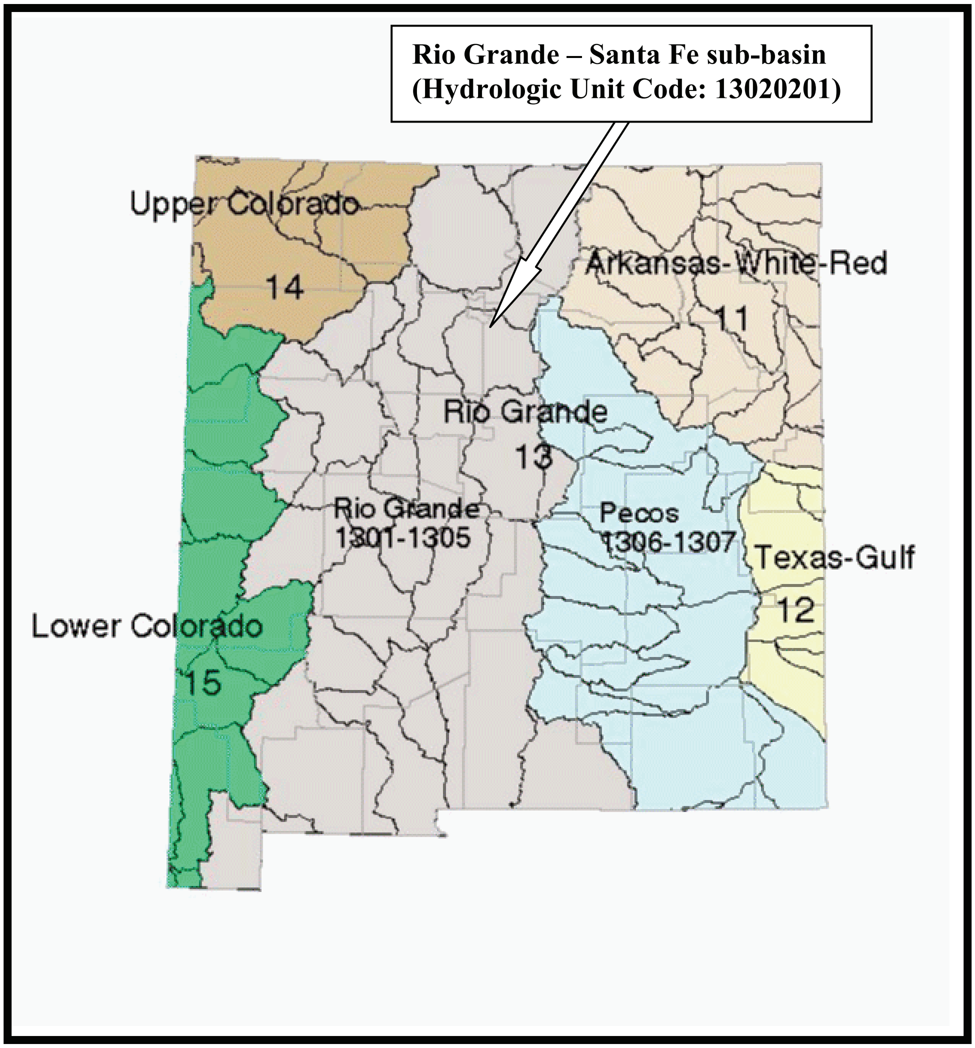

Figure 6. Location of the Rio Grande – Santa Fe sub-basin (13020201), which includes BAND (New Mexico Water Resources Research Institute, 2007).

Fire Management

Fire management is the single most important component of watershed management at BAND. Stream hydrographs undergo significant responses to the widespread intense wildfires (Mott, 1999). According to Neary (1995), wildfire in southwestern environments affects the quantity of water derived from a watershed by reducing interception, storage, transpiration, and infiltration, and increasing overland flow, and surface storm flow. Watershed response to storm events is greater with shortened time to peak-flow and a greater susceptibility to flash floods. Total water yields from burned watersheds are higher. The magnitude of measured water yield increases the first year after the fire disturbance and can vary greatly at one location or between locations depending on the fire intensity, climate, precipitation, geology, soils, watershed aspect, tree species, and proportion of the forest vegetation burned. Watershed recovery can vary from a few years to decades. Wildfires generally produce higher sediment yields than other forest disturbances. After fires, turbidity can increase due to the suspension of ash and soil particles. The increased erosion and peak flows can also increase bed loads, which can destroy stream habitat. Ammonium-based fire retardant can produce short-term mortality in some aquatic organisms. Non-ionized ammonia is the principal toxic component to aquatic species. Wildfires can also increase stream temperatures by removal of shade and the direct heating of water surfaces. This can result in decreased dissolved oxygen concentrations and increased plant growth (Mott, 1999).

<u>Surface Water</u>

Rivers and Streams

Streams draining from topographic highs dissect the relatively soft tuff and form the narrow canyons and valleys of BAND. Flowing water downcuts as much as 1,000 feet into the tuff, and in places, up to 200 feet into the underlying basalt and sedimentary strata (Barry, 1990).

The entire national monument drains to the Rio Grande (Figure 2) and Cochiti Reservoir. The Rio Grande is the master stream in north central New Mexico and south central Colorado, with a drainage area above Otowi of 14,245 mi^2. The discharge at Otowi for 94-years of record (1902-1996) ranged from 60 cfs in 1902 to 24,400 cfs in 1920, with the average flow being 1,530 cfs (U.S. Geological Survey, 1998). The eastern boundary of the national monument is defined as the west bank of the Rio Grande (Mott, 1999). Flooding along the Rio Grande, primarily associated with spring snowmelt, was formerly critical for the successional patterns in the riparian zone. The river valley provided the majority of Bandelier's nesting and foraging habitat for migrating shorebirds and waterfowl, along with cover for grazing species. However, the Rio Grande's flow has long been modified, even before the filling of Cochiti Reservoir. Diversions, most notably the Abiquiu project on the Rio Chama in northern New Mexico, modified the natural hydrograph. Reduced peak flows, altered sediment regimes, and other factors changed the Rio Grande's fluvial dynamics and floodplain ecology (Mott, 1999).

Several canyons dissect Bandelier's portion of the Pajarito Plateau in a northwest to southeast alignment (Figure 3). These canyons support various base flows, which originate from springs and seeps along the mountain/plateau interface. The two most prominent streams, Capulin and Frijoles, have average base flows of approximately 0.5 and 1.0 cfs, respectively. Only Frijoles

Creek maintains perennial flow to the Rio Grande (Mott, 1999; Stephens, 1982). Stream information for BAND's canyons is summarized in Table 1.

Table 1. Stream information for Bandelier National Monument's Canyons (compiled by Mott (1999) from Purtymun and Adams (1980)).

Name	***Location of Headwaters***	***Drainage Area (mi^2)***	***Perennial Reaches ****	***Average Gradient * (ft/mi.)***
Chaquhui Canyon	Pajarito Plateau	1.8	M	all = 475
Frijoles Canyon	Sierre de los Valles	19.8	U,M,L	U=397, M, L=158
Lummis Canyon	Pajarito Plateau	7.6	None	all = 211
Alamo Canyon	Sierra de los Valles	19.1	U,M,L_p	U=397, M, L=211
Capulin Canyon	San Miguel Mountains	19.6	U,M,L_p	U=317, M, L=211
Medio Canyon	San Miguel Mountains	6.6	U	U=686, M, L=211
Sanchez Canyon	San Miguel Mountains	7.7	M	U=422, M, L=211

* U = Upper, M = Middle, L = Lower, L_p = Portion of Lower

Purtymun and Adams (1980) noted that stream flow increased in Frijoles Canyon from the springs to the crossing of the Pajarito fault line (upper crossing of trail). They attributed this increased flow to return flow from thinning alluvium, seepage from colluvium at the base of the canyon walls, and movement of water through brecciated zones associated with the faults. Surface flow decreased from the fault line to the confluence with the Rio Grande River. They also reported intermittent reaches of Frijoles Creek during some summers.

Based on the mean monthly flows the Frijoles gauge operated (1963-1969), April and May produce the highest average flows in spite of the "dry period from late April through the end of June" reported by Allen (l989). This stream gage was located 3,600 feet upstream from BAND Headquarters with flow data collected by the U.S. Geological Survey. High flows in spring result from snowmelt passing down the canyon. Average stream flow drops until August when recurrent thunderstorms (monsoon) produce runoff events.

Cochiti Reservoir

The Middle Rio Grande Conservancy District (MRGCD) constructed four major diversion dams by 1935, including Cochiti. The Cochiti diversion was subsequently included in flood/sediment control efforts for the Rio Grande Valley through the 1960 Flood Control Act *(P.L. 86-645).* In 1964, P.L. 88-293 authorized the Secretary of the Interior to provide a permanent pool at the Cochiti dam site for the development of "fish and wildlife resources, conservation and recreation purposes." An enlarged dam, designed to support the multi-purpose mandate, was completed in 1973. The dam is located about six miles downstream of BAND (Bullard and Wells, 1992).

Before the construction of Cochiti Dam, the Rio Grande near BAND was a transitional reach within the lowest section of White Rock Canyon. Within the canyon, the river was a relatively high-energy, high-gradient, fast flowing stream, confined by canyon walls and colluvium and relatively stable. Below White Rock Canyon the river was aggrading and had many channels separated by bars and islands composed of course gravel and cobbles (Bullard and Wells, 1992).

Cochiti Dam holds Rio Grande flood waters, primarily during spring runoff events, and annually drowns the entire reach of the Rio Grande adjacent to BAND and up to 350 acres of the national monument lands (National Park Service, 1995b). This flooding is allowed under a Memorandum of Understanding (MOU) signed March *25,* 1977, between the National Park Service and the U.S. Army Corps of Engineers, which permits a maximum flood-pool contour of 5,465.5 feet.

Cochiti Reservoir's mandated recreation pool extends about 6.5 miles upstream from the dam, while the flood pool extends 20 miles upstream and inundates several riparian landholders. A total of 9,621 acres of flood easement was acquired for project purposes from the U.S. Forest Service (8,236 acres), Atomic Energy Commission (345 acres), National Park Service (361 acres), University of New Mexico (540 acres), and private concerns (139 acres) (U.S. Army Corps of Engineers, 1995).

A wedge of sediments is accumulating in upper Cochiti Reservoir. The average sedimentation rate is 1,189 acre-feet per year (Gallegos, 1998). Approximately 27,341 acre-feet of sediment had accumulated by 1998, utilizing 27 percent of the reservoir's 105,000 acre-feet sediment reserve. At the 1976-1998 rate of sediment accumulation, the design storage will be fully utilized by 2063. U.S. Army Corps of Engineers estimates predict this reservoir will be completely filled with sediment in about 500 years (Allen, 1989).

Potter (1981) stated most of BAND's native high quality riparian areas were effectively buried by sedimentation within Cochiti's backwaters. The Rio Grande's cottonwood trees died because they are adapted to only a limited amount of submergence in their normal role as a riparian tree. Receding silt-laden water coated woody vegetation such as cholla and junipers about a quarter of an inch thick. Burial of a floristicly diverse spring at the mouth of Frijoles Canyon apparently caused the direct extirpation of six plant species from the national monument (Allen, 1989). The apparent death of all herbaceous and woody vegetation in the inundated area produced an unattractive, desolate appearance. Deposition of layers of river sand and silt provided a favorable medium for pioneer plant succession, including a variety of introduced agricultural weeds and riparian exotics.

Riparian/Floodplain

Floodplains and riparian zones occur along intermittent and perennial streams in BAND's canyons. Riparian vegetation is maintained where phreatophytes have access to a dependable supply of alluvial ground water. Jacobs (1998) provided the following description of the canyon-bottom, vegetative community:

> <u>Canyon bottom complex</u>: a narrow riparian zone that includes overstory elements from the adjacent canyon slope along with floristic elements requiring enhanced moisture regimes. Some common species associated with this riparian zone include narrowleaf cottonwood, boxelder, mountain maple, gambel oak (tree form), alder (two species), beech, cherry and New Mexico Olive. Most of BAND's sensitive plants are associated with the perennial moisture found in the upper canyon areas. This is a fairly intact community in most areas where the historic use was limited to seasonal grazing. Exotic perennial grasses or invasive native shrubs can dominate areas developed for more intensive uses, such as Frijoles Canyon between Long House and the Stable (i.e.

agriculture, housing, and, visitor use). Fire regimes for canyon bottom areas are comparable to the adjacent community. Desired conditions for this complex are comparable to the adjacent community, but include reduction of exotic perennials and maintenance of existing hydrologic conditions necessary for current riparian vegetation.

Some of BAND's historic structures are located within floodplains and can be at risk to damage from flooding. In managing floodplains, the NPS will (1) manage for the preservation of floodplain values; (2) minimize potentially hazardous conditions associated with flooding; and (3) comply with the NPS Organic Act and all other federal laws and executive orders (i.e., Executive Order 11988: Floodplain Management, 2006 Park Management Policies) related to the management of activities in flood-prone areas (National Park Service, 2006a).

When it is not practicable to locate or relocate development to a site outside the floodplain, the NPS is instructed to prepare and approve a statement of findings in accordance with procedures described in Director's Order 77-2 (Floodplain Management). Requirements for development in floodplains are contained in Executive Order 11988 (National Park Service, 2006a).

Flood frequency data derived from U.S. Army Corps of Engineers (COE) regionalized graphs, along with cross-sections developed by NPS staff, were used to estimate 10-year, 50-year, 100-year, and 500-year floodplain elevations for Frijoles Creek near BAND headquarters. Water surface elevations were predicted using the COE's HEC-2 computer program (U.S. Army Corps of Engineers, 1987). The 100-year and 500-year floodplains for Frijoles Creek were delineated on a 1935 topographic map constructed by the NPS with a contour interval of 10 feet. Past review of this map by park staff indicated that a 100-year flood would inundate the picnic area and its restrooms, along with the backcountry parking lot, and the lower parking lot at the visitor center. A 500-year flood would reach the visitor center (restroom wing), museum, maintenance facility (wood/welding shop, oil house, and lumber storage), and the search and rescue and fire cache. Maximum flood depths in the vicinity of the headquarters infrastructure area would be 12.2 feet with a maximum width of 320 feet for the 100-year flood, and 13.6 feet and a maximum width of 364 feet for the 500-year flood. The farthest downstream cross-section that was modeled was completed near the same location as the USGS gauging station. The largest flood on record at this gauge (3,030 cfs) attained a maximum stage height of 6.34 feet. The 100-year and 500-year flows from the COE study were 2,750 cfs and 6,500 cfs, respectively. So with a predicted stage height (12.2 feet) for the modeled 100-year flood (2,750 cfs) that is over twice the actual stage height observed during a 3,030 cfs event (Mott, 1999), re-evaluation of the HEC-2 model for Frijoles Creek is warranted.

Wetlands

Wetlands represent transitional environments between terrestrial and aquatic systems where the water table is at or near the surface or the land is covered by shallow water (Cowardin *et al.*, 1979). Flora within these systems exhibit extreme spatial variability, triggered by very slight changes in elevation.

The sediment deposited at the head of Cochiti Lake is forming a vast delta and associated wetlands. Wetlands comprised 199 acres in the delta area in 1991. The growing delta wetlands are ecologically valuable due to the widespread destruction of wetlands in the Rio Grande corridor and throughout the southwest. Allen *et al*. (1993) believe that with proper management, the Cochiti delta can develop into one of the most ecologically significant wetlands in New Mexico, with great benefits for local wildlife, migratory waterfowl, several threatened and endangered species, fisheries, and human enjoyment (Mott, 1999).

Important wetlands associated with springs and seeps exist at BAND and are much smaller than the Cochiti Lake wetland. These small but important wetland environments can potentially be missed in park inventories. A few of these wetlands in BAND have been identified through the U.S. Fish and Wildlife's National Wetlands Inventory (NWI). Additional wetland inventories within the monument are needed, building from the NWI, so BAND can better manage these important aquatic environments.

There are four federal government agencies responsible for identifying and delineating wetlands: the U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and Natural Resources Conservation Service.

<u>Ground Water</u>

Ground water beneath the Pajarito Plateau occurs in three zones: the shallow alluvium of canyons; perched on relatively impermeable strata; and in the main aquifer (Los Alamos National Laboratory, 1995). The main, or regional, aquifer is the only viable water source on the Pajarito Plateau (Rogers *et al*., 1996b).

The only aquifer capable of producing large-scale municipal water is referred to as the regional, or main aquifer, the surface of which rises westward from the Rio Grande within the Santa Fe Group and into the lower portion of the Puye Formation. The presence of numerous basalt flows interbedded in the Santa Fe Group may account for confining conditions noted in portions of this aquifer. Near the top of the Santa Fe Group and underlying the center of the Pajarito Plateau appears to be a late Miocene trough 3 to 4 miles wide and extending 7 to 8 miles from the northeast to southwest. It is filled with up to 1500 feet of gravels, cobbles, and boulders and produces the area's only high-yield, low-drawdown water supply wells (Los Alamos National Laboratory, 1998).

Christensen (1980) proposed that springs and seeps providing base flow to BAND streams are recharged from perched water in the Tschirege member of the Bandelier Tuff, or within the underlying Tschicoma formation. These perched bodies are found in fractured or jointed rock, or in a pumice bed at the base of the Tschirege. Recharge is thought to occur on the southeast flank of the Sierra de los Vales. Information on springs and seeps within the national monument is presented in Table 2.

Table 2. Selected spring and seep information at Bandelier National Monument (compiled by Mott (1999) from Purtymun and Adams, 1980).

Name	*Location*	*Average Flow (gpm)**	*Character*	*Comments*
Doe Spring	Upper Chaquehui	small	large seep	forms pools
Turkey Spring	Capulin Canyon	22.2	spring	perennial flow
Spring (at head of canyon)	Frijoles Canyon	231	spring	perennial flow
Apache Spring	Frijoles Canyon	0.96	spring	perennial flow
Spring (at mouth of canyon)	Frijoles Canyon	1.38	spring	silted over
Alamo Spring	Alamo Canyon	small	seep	silted over

* gpm = gallons per minute

Water Quality

The pollution of surface waters and ground waters by point and non-point sources can impair the natural function of aquatic and terrestrial ecosystems and diminish the utility of NPS waters for visitor use and enjoyment. According to the NPS Management Policies, the NPS will determine the quality of BAND water resources and avoid, whenever possible, the pollution of park waters by human activities occurring within and outside park boundaries (National Park Service, 2006a).

Within BAND, natural water quality conditions should be maintained "unimpaired" under the National Park Service Organic Act (1916, 16 USC 1). Water quality standards relative to BAND are guided by the Clean Water Act as promulgated by the State of New Mexico (New Mexico Water Quality Control Commission, 2007) and declare:

> *"Perennial tributaries to the Rio Grande in Bandelier National Monument and their headwaters..."*
>
> <u>Designated Uses</u>*:* domestic water supply, high quality cold water aquatic life, irrigation, livestock watering, wildlife habitat, municipal and industrial water supply, secondary contact and primary contact.
>
> <u>Standards</u>*:* In any single sample: specific conductivity shall not exceed 300 µmhos, pH shall be within the range 6.6 to 8.8, and temperature shall not exceed 20°C (68 °F). Other use specific standards apply and natural background occurrences of some parameters may exceed these standards.
>
> The monthly geometric mean fecal coliform bacteria shall not exceed 126 cfu/100 mL; single sample 235 cfu/100 mL or less.
>
> The dissolved oxygen for "high quality cold water" systems shall be equal or exceed 6.0 mg/L.

The NPS Water Resources Division completed a comprehensive summary in 1997 of existing surface water quality data for BAND, the *Baseline Water Quality Inventory and Analysis, Bandelier National Monument* (National Park Service, 1997). This document presents the results of surface water quality data retrievals for BAND from six of the United States Environmental Protection Agency's (EPA) national databases: (1) Storage and Retrieval (STORET) water quality database management system; (2) River Reach File (RF3); (3) Industrial Facilities Discharge (IFD); (4) Drinking Water Supplies (DRINKS); (5) Water Gages (GAGES); and (6) Water Impoundments (DAMS). The National Park Service (1997) used Environmental Protection Agency and NPS Water Resources Division screening criteria to evaluate these water data. This screening found the metals copper, lead, and zinc exceeded EPA acute freshwater criteria in lower Frijoles Creek.

Sampling in the headquarters reach of Frijoles Creek occasionally found fecal coliform levels in excess of 3,000 colonies per 100 milliliters (col/100mL), suggesting intermittent sewage system failures. Historical documentation of other potential sources of coliform contamination (i.e., visitor use, pit toilets, horse corrals, paved and dirt parking lots, picnic areas, wildlife) is more problematic (Mott, 1999).

The U. S. Geological Survey's National Ambient Water Quality Assessment Program (NAWQA) measured water chemistry, bed sediment, fish tissue and stream flow from a reach of Frijoles Creek just below the visitor center over a three-year interval beginning in April, 1993. The water sampled was a well-oxygenated, sodium calcium magnesium bicarbonate type. The median specific-conductance value was 108 µmhos/cm, the median pH value was 7.8, and the median dissolved oxygen saturation was 98 percent. Dissolved solids and most major constituents were in the low group as compared to other sites in the Rio Grande study unit, chloride was in the middle group, and silica was in the high group. In fact, the minimum silica concentration detected in Frijoles Creek was equal to the maximum observed from all of the other sites combined. These large silica concentrations are probably the result of weathering of volcanic tuff in the drainage basin (Healey, 1997).

Nitrogen species median values reported through NAWQA were below detection limits. Total phosphorus was also very low and dissolved phosphorus and orthophosphate were in the middle group. Dissolved iron concentrations were in the high group, much larger than expected for well-oxygenated surface waters (Healey, 1997). Because of the extent of mineralization in the Rio Grande basin, relatively high arsenic, cadmium, copper, lead, mercury, selenium, and zinc concentrations in water and bed-sediment samples probably represent natural conditions (Carter, l997a). Trace element concentrations in bed sediment at Frijoles Creek were within the range observed for all Rio Grande basin NAWQA study sites, and below USGS-determined background concentrations with the exception of beryllium. Beryllium had the maximum concentration of 4 µg/g. This maximum value is not considered to be significantly different from other sites, and it is noted that beryllium in fish tissue was less than the detection limit at this same site (Carter, 1997b).

Air Quality

The NPS is responsible to preserve, protect and enhance air quality and air quality related values of the National Park System units under both the Organic Act (16 U.S.C. 1, 1a-1) and the Clean

Air Act (National Park Service, 2006a). Air quality is linked to many natural processes (i.e., soil and water nutrients, photosynthesis, acidification of lakes and streams).

Both local and distant air pollutant sources can influence air quality in the monument. Large power plants and several gas processing facilities in nearby San Juan and McKinley counties are the largest nearby point sources of both sulfur dioxide and nitrogen oxides. Vehicles in the Santa Fe and Albuquerque metropolitan areas are also significant sources of nitrogen oxides. Emissions from these sources result in deposition of nitrogen and sulfur compounds in the monument; in addition, nitrogen oxides sources contribute to the formation of ozone that may affect air quality in the monument (National Park Service, 2007b).

BAND met the National Ambient Air Quality Standard for fine particulate matter in 2006 and therefore met the USDI ambient air quality standards goal (1a3B) for Class I areas. In addition, air quality was found to be stable or improving from 1996-2005, so BAND also met the long-term NPS air quality goal (1a3). The air quality condition for visibility was rated moderate, based on 2001-2005 data (National Park Service, 2007c).

Atmospheric releases of hazardous and radioactive contaminants from LANL have occurred. Perimeter sampling has not indicated problems and current releases are reported to be low. Review of rainwater chemistry data indicates no decrease in pH or increases in nutrients. These data did show a statistically significant downward trend for sulfate (Mott, 1999).

Biological Resources

Water resources are critical to the sustenance of BAND's populations of flora and fauna. Biological resources are intimately linked to hydrological systems. For example, riparian habitat is closely tied to the health of both wetlands and streams, influencing stream fish assemblages. Characteristics of riparian habitat structure such as the ratio of edge to interior, the degree of canopy complexity within riparian strata (e.g., herb/forbs, shrubs, sub-canopy tree, and overstory tree), and the degree of fragmentation is highly associated with amount and type of wildlife use.

The purpose of this section is to begin exposing some of the biological concerns where water resources are found to be an important habitat requirement. This section includes some of the listed species in or in close proximity of the national monument.

Flora

Major vegetation types vary with increasing elevation, including juniper savannas, piñon-juniper woodlands, canyon-wall shrub lands, ponderosa pine forests, riparian forests, mixed conifer forests, and montane grasslands. A general vegetation inventory for the monument has been completed and records can be accessed through a species database (Jacobs, 1989).

Livestock grazing was officially discontinued at Bandelier when the NPS assumed control in 1932. At that time, "the whole area was heavily grazed," with 15 or more corrals, watering tanks, drift fences and other facilities to encourage grazing (Allen, 1989). Trespass cattle continue to have access to the Rio Grande corridor and the lower reaches of Bandelier's canyons. Large populations of mule deer and elk within Bandelier may also be a management concern due to potential over-browsing of the vegetation.

Piñon-juniper woodland systems have colonized millions of acres of western grazing lands since ca. 1850, including BAND, transforming former grassland and savanna communities into woodlands, and encroaching into the understories of upland forests. A poor understanding of this dynamic vegetation type has limited the success of management initiatives to improve watershed, wildlife, and range conditions, protect cultural resources, and mitigate impending wildlife hazards (Jacobs *et al*., 2002).

Re-establishment of herbaceous ground cover in degraded piñon-juniper woodland areas is extremely difficult due to soil movement, soil loss, unreliable precipitation and an inadequate seed source. Major factors limiting restoration include: 1) restrictions on methodology as imposed by cultural, natural and wilderness values; 2) poor site conditions characterized by sparse vegetative cover, organic and nutrient poor soils prone to frost heave and high rates of erosion, depleted soil seed bank and limited seed source; 3) unreliable growing season precipitation or protective winter snow pack; and, 4) heavy utilization of existing herbaceous vegetation by wildlife ranging from ants to elk (National Park Service, 1995b).

Endangered, Rare and Sensitive Species

Potentially present federally listed endangered or rare and sensitive plant species include the Wood Lily (*Lilium philadelphicum L. var. andinum*), Yellow Lady's Slipper Orchid (*Cyprepedium calceolus L. var. Pubescens*), and the Helleborine Orchid (*Epipactis gigantean*) (Mott, 1999).

Fauna

The Jemez Mountain elk population exhibited exponential population growth over the past three decades. From the 1961 estimate of 200 animals, the population grew to an estimated 1989 level of 6000 to 8000 individuals. The estimated annual growth rate for this herd is 13 percent, with a doubling time of *5.7* years. Elk were especially drawn to Bandelier after the 1977 La Mesa Fire, with winter use increasing from 100 animals in 1978 to around 1500 by 1992. The dramatic increase was due in part to the creation of about 14,820 acres of grassy winter range by the fire (Allen, 1996). Similar increases are expected in response to grassy range created by the 1996 Dome Fire (Mott, 1999).

Rare. Threatened, and Endangered Species

Potentially present federally listed threatened and endangered species include the peregrine falcon *(Falco peregrinus),* whooping crane *(Grus americana),* Mexican spotted owl *(Strix occidentalis luck/a),* and southwest willow flycatcher *(Empidonax traillii extimus).*

Additional federal candidate and state-listed or otherwise sensitive animals found in the Bandelier area include: northern goshawk *(Accipiter gentilis);* ferruginous hawk *(Buteo regalis);* zone-tailed hawk *(Buteo albonotatus);* prairie falcon *(Falco mexicanus);* golden eagle *(Aquila* *chrysaetos);* gray vireo *(Vireo vicinior);* swift fox (*Vulpes velox);* and, Jemez Mountains salamander *(Plethodon neomexicanus)* (National Park Service, 1995b).

The bald eagle (*Haliaeetus leucocephalus*), although recently delisted from the endangered and threatened status (August 2007), continues to receive protection under the 1940 Bald Eagle Protection Act (16 U.S.C. 668-668d) and the 1972 Migratory Bird Treaty Act (16 U.S.C. 703-712).

On August 19, 1994, the USFWS listed the Rio Grande silvery minnow *(Hybognathus amarus)* as an endangered species. Once occupying the reach of the Rio Grande adjacent to Bandelier and possibly utilizing the lower reach of Frijoles Creek, this species currently survives in only five percent of its historic range. The minnow’s decline is attributed to river channelization, modified flow regimes, and the introduction of non-native predatory species (National Park Service, 1995b).

IMPORTANT WATER RESOURCES

It is important for NPS units to identify the resources and values critical to achieving the park's purpose and maintaining its significance. The reasons for identifying fundamental and other important resources and values are:

1. To define and understand the most important resources and values that support the park's purpose and significance. If these resources and values are degraded or eliminated, they then jeopardize the park's purpose and significance.
2. To ensure that the planning team and public understand the key elements that sustains the park's purpose and significance.
3. To help planning and management activities focus on larger issues and concerns regarding protection of the resources and values that support the park's purpose and significance.
4. To allow the planning team to test out alternatives and estimate how they will influence the fundamental and important resources and values of the park.
5. To become the building blocks in creating a future vision and management strategy for the park while being responsive to the park's needs.

Identifying the fundamental and important resources and values at BAND helps ensure that all planning is focused on what is truly most significant about the park. As presented earlier in this report, "water" was listed as an *important resource* at BAND.

The following sections follow a format currently used by the NPS Denver Service Center (DSC) Planning Division for the national monument's *fundamental* and *important resources and values*. This includes the following seven questions that are answered for water resources at the park:

1. Who are the stakeholders who have an interest in BAND's water resources?
2. Which laws and policies apply to BAND's water resources, and what guidance do the laws and policies provide?
3. What is the importance of these water resources?
4. What is the adequacy of the existing water resources information at BAND?
5. What are the current state or conditions and the related trends of these water resources?
6. What are the current or potential threats to these water resources?
7. What planning decisions exist for BAND's water resources?

For water resources, these questions are answered from existing technical references provided to the author.

Watershed Stakeholders and Water Resources Legislation and Management Policies

1. *Who are the stakeholders who have an interest in BAND's water resources?*

U.S. Department of Agriculture, Natural Resources Conservation Service (originally called the Soil Conservation Service) provides leadership in a partnership effort to help America's private land owners and managers conserve their soil, water, and other natural resources.

U.S. Environmental Protection Agency's mission is to protect human health and the environment.

U.S. Forest Service manages public lands in national forests within BAND's watershed.

U.S. Fish and Wildlife Service works with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats.

U.S. Geological Survey serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.

Los Alamos National Laboratory (LANL) has been involved in been involved in numerous large-scale DOE research and development projects, including nuclear reactors and weapons. As a neighbor to BAND, LANL environmental assessments provide some of the latest understanding of ground water quality and flow dynamics in the immediate area.

New Mexico Environmental Department promotes a safe, clean, and productive environment for New Mexico. Programs include: surface water quality, ground water quality, air quality, drinking water, hazardous waste, pollution prevention, radiation control, and solid waste).

New Mexico Game and Fish provides programs to manage wildlife habitat, restore and manage populations, provide outreach programs and information materials, conserve at-risk species, develop regulations, and provide necessary law enforcement to ensure all of these resources remain healthy and available.

Northern New Mexico Citizens' Advisory Board is a community advisory group chartered in 1997 to provide citizen input to the U.S. Department of Energy (DOE) on issues of environmental monitoring, remediation, waste management, and long-term environmental stewardship at the Los Alamos National Laboratory.

2. *Which laws and policies apply to BAND's water resources and what guidance do the laws and policies provide?*

The management of BAND's water resources is guided by many federal and state laws and policies summarized below.

Park-specific

Proc. No. 1322 (1916) 49 Stat. 1764 is the authorizing proclamation establishing Bandelier National Monument stating, "certain prehistoric aboriginal ruins….are of unusual ethnologic, scientific, and educational interest, and it appears the public interests would be promoted by the proper reserving these relics of a vanished people, with as much land as may be necessary for the proper protection thereof." In addition, the proclamation stipulated that forest operation should not impact the national monument by mandating "the National Monument hereby established shall be the dominate reservation, and any use of the land which interferes with its preservation or protection as a National Monument is hereby forbidden."

Proc. No. 1991 (1932) 47 Stat. 2503 transfers the administration of the National Monument to the National Park Service. It should be noted that the western boundary separating BAND and the Santa Fe National Forest remained a straight north-south line cutting across watersheds. Resource extraction and other multiple-use activities occurring in these headwaters under U.S. Forest Service direction have impacted BAND's streams. Attempts to transfer these headwaters to NPS administration have been made in the past. To date, only the Elk Meadow area (approx. 90 acres) has been acquired by the NPS (Mott, 1999).

Boundary adjustments in 1959, 1963, and 1977 brought all but about 100 acres of the Rito de los Frijoles watershed into the national monument (Mott, 1999).

Public Law 94-567 (1976) applied wilderness designation to 23,267 acres of the national monument.

Federal

Management of BAND's water resources is also guided by many additional federal laws and NPS policies.

- The *National Park Service Organic Act* of 1916 created the NPS and includes a significant management provision stating that the NPS *shall promote and regulate the use of the federal areas known as national parks, monuments, and reservations by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for future generations*. The Organic Act also authorizes the NPS to *regulate the use* of national parks and develop rules, regulations and detailed policies to implement the broad policies provided by Congress. Rules and regulations for the national park system are described in the *Code of Federal Regulations* (Title 36).

- The *General Authorities Act* of 1970 strengthened the 1916 *Organic Act*, stating that lands in all NPS units, regardless of title or designation, shall have a common purpose of preservation. All water resources in the national park system, therefore, are equally protected by federal law. It is the primary duty of the NPS to protect those resources unless otherwise indicated by Congress.

- The *Redwood National Park Act* of 1978 amended the *General Authorities Act* of 1970, identifying the *high public value and integrity of the national park system* as reason to manage and protect all park system units. The act further stated that no activities should be allowed that will compromise the *values and purposes for which these various areas have been established*, except where specifically authorized by law or provided for by Congress.

- The *National Parks Omnibus Management Act* of 1998 outlined a strategy to improve the ability of the NPS to provide high-quality resource management, protection, interpretation and research in the national park system by:

    - Fostering the collection and application of the highest quality science and information to enhance management of units of the national park system;
    - Authorizing and initiating cooperative agreements with colleges and universities, including but not limited to land grant schools, along with creating partnerships with other Federal and State agencies, to construct cooperative study units that will coordinate multi-disciplinary research and develop integrated information products on the resources in national park system units and/or the larger region surrounding and including parks;
    - Designing and implementing an inventory and monitoring program of national park system resources to collect baseline information and to evaluate long-term trends on resource condition of the national park system, and;
    - Executing the necessary actions to fully and properly apply the results of scientific study to park management decisions. Additionally, all NPS actions that may cause a significant adverse effect on a park resource must conduct unit resource studies and administratively record how study results were considered in decision making. The trend in resource condition in the national park system shall be a critical element in evaluating the annual performance of the NPS.

- The 1972 *Federal Water Pollution Control Act*, also known as the *Clean Water Act*, strives to restore and maintain the integrity of U.S. waters. The Clean Water Act grants authority to the states to implement water quality protection through best management practices and water quality standards. Section 404 of the act requires that any dredged or fill materials discharged into U.S. waters, including wetlands, must be authorized through a permit issued by the U.S. Army Corps of Engineers, which administers the Section 404 permit program. Additionally, Section 402 of the act requires that pollutants from any point source discharged into U.S. waters must be authorized by a permit obtained from the National Pollutant Discharge Elimination System (NPDES). All discharges and storm water runoff from major industrial and transportation activities, municipalities, and certain construction activities generally must be authorized by permit through the NPDES program. NPDES permitting authority typically is delegated to the state by the U.S. Environmental Protection Agency.

- *Safe Drinking Water Act* (42 USC 3001 et seq.) applies to developed public drinking water supplies. It sets national minimum water quality standards and requires testing of drinking water.

    2006 NPS Management Policies: The NPS will determine the quality of park surface and ground water resources and avoid, whenever possible, the pollution of park waters by human activities occurring within and outside of parks.

    - ❖ Work with appropriate governmental bodies to obtain the highest possible standards available under the Clean Water Act for the protection of park waters.
    - ❖ Take all necessary actions to maintain or restore the quality of surface waters and ground waters within the parks consistent with the Clean Water Act and all other applicable federal, state, and local laws an regulations; and
    - ❖ Enter into agreements with other agencies and governing bodies, as appropriate, to secure their cooperation in maintaining or restoring the quality of park water resources.

    2006 NPS Management Policies: The NPS will manage watersheds as complete hydrologic systems, and will minimize human disturbance to the natural upland processes that deliver water, sediment, and woody debris to streams. The NPS will achieve the protection of watershed and stream features primarily by avoiding impacts to watershed processes to proceed unimpeded.

- *Executive Order* 11990: *Wetlands Protection* requires the NPS to 1) exhibit leadership and act to minimize the destruction, loss, or degradation of wetlands; 2) protect and improve wetlands and their natural and beneficial values; and 3) to refrain from direct or indirect assistance of new construction projects in wetlands unless there are no feasible alternative to such construction and the proposed action includes all feasible measures to minimize damage to wetlands.

    NPS 2006 Management Policies: The NPS will manage wetlands in compliance with NPS mandates and the requirements of Executive Order 11990 (Wetland Protection), the Clean Water Act, and the Rivers and Harbors Appropriation Act of 1899, and the procedures described in D.O. 77-1. The service will 1) provide leadership and take action to prevent the destruction, loss, and degradation of wetlands; 2) preserve and enhance the natural and beneficial values of wetlands; and 3) avoid direct and indirect support of new construction in wetlands unless there are not practicable alternatives and the proposed action includes all practicable measures to minimize harm to wetlands. The NPS will implement a "no net loss of wetlands" policy.

- *Executive Order* 11988: *Floodplain Management* has a primary objective *...to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative*. For non-recurring actions, the order requires that all proposed facilities must be located outside the boundary of the 100-year floodplain. Barring any feasible alternatives to construction within the floodplain, adverse impacts are to be minimized during the design phase of project planning. NPS guidance for this executive order can be found in D.O. 77-2.

    2006 NPS Management Policies: In managing floodplains on park lands, the NPS will 1) manage for the preservation of floodplain values; 2) minimize potentially hazardous conditions associated with flooding; and 3) comply with the NPS Organic Act and all other federal laws and executive orders related to the management of activities in flood-prone areas, including Executive Order 11988 (Floodplain Management), NEPA, applicable provisions of the Clean Water Act, and the Rivers and Harbors Appropriation Act of 1899. Specifically the NPS will:

    - ❖ Protect, preserve, and restore the natural resources and functions of floodplains;
    - ❖ Avoid the long-and short-term environmental effects associated with the occupancy and modifications of floodplains; and
    - ❖ Avoid direct and indirect support of floodplain development and actions that could adversely affect the natural resources and functions of floodplains or increase flood risks.

- The *Clean Air Act* of 1970 (as amended in 1990) regulates airborne emissions of a variety of pollutants from area, stationary, and mobile sources. The amendments to the act were added primarily to fill gaps in earlier regulations pertaining to acid rain, ground level ozone, stratospheric ozone depletion and air toxics, and also to identify 189 hazardous air pollutants. The act directs the U.S. Environmental Protection Agency to study these pollutants, identify their sources, determine the need for emissions standards and develop and enforce appropriate regulations.

- The *National Environmental Policy Act* (NEPA) of 1969 requires that any action proposed by a federal agency that may have significant environmental impacts shall *utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making which may have an impact on man's environment*.

- The *Endangered Species Act* of 1973 requires the NPS to identify all federally listed endangered, threatened and candidate species that occur within each park unit and promote their conservation and recovery. The act requires that any activity funded by federal monies that has the potential to impact endangered biota must be consulted through the Secretary of Interior. It requires agencies to protect designated critical habitats upon which endangered and threatened species depend. Although not required by law, it also is NPS policy to identify, preserve and restore state and locally listed species of concern and their habitats.

- *Invasive Species* (Executive Order 13112): enhances and furthers the existing authority of the federal government to assist in preventing and controlling the spread of invasive species.

Construction and operation of Cochiti Dam and reservoir is authorized by PL 86-645 (*1960 Flood Control Act*) and PL 88-293 (1964). The facility regulates Rio Grande flows for flood damage reduction and sediment management. Approximately 350 acres of BAND lands are inundated annually (typically during the spring runoff events). This flooding is allowed under a 1977 Memorandum of Understanding (MOU) between the NPS and U.S. Army Corps of Engineers, which permits a maximum flood-pool contour of 5,465.5 feet (Mott, 1999).

<u>State of New Mexico</u>

Water quality standards relative to BAND are guided by the Clean Water Act as promulgated by the State of New Mexico (New Mexico Water Quality Control Commission, 2007). Details to these standards were provided earlier in this report.

Restoration plans called *Total Maximum Daily Loads* (TMDLs) are prepared for impaired waters in New Mexico. The objective of the TMDLs is to restore impacted waters to where they meet their respective state designated uses. Waters listed as impaired in BAND are Capulin and Frijoles Creek. The specific impairments of these two creeks are discussed later in this report.

The New Mexico Environmental Department (NMED) entered into an agreement with the U.S. Department of Energy in October (1990) to provide guidance regarding applicable state environmental laws and regulations. These include air quality, surface and ground water quality, and hazardous and radioactive materials issues. In January 1995, a separate NMED bureau (LANLJDOE Oversight Bureau) was created to handle these functions.

Executive Order 05-033 (2005) established the New Mexico Climate Change Action Council and the New Mexico Climate Change Advisory Group (CCAG). The CCAG shall review and provide recommendations to the Governor's office regarding climate change policy.

<u>Water Rights</u>

New Mexico water law follows the doctrine of prior appropriation. The right to use water is established by placing it to beneficial use and is maintained as long as water use continues. Rights established earlier in time are senior to, and must be satisfied before, those rights established later. State law requires a permit for any water use other than small domestic or stock wells or small stock reservoirs. Bandelier has two prior appropriation water rights. License number 820 allows diversion of 45 acre-feet from Frijoles Creek to irrigate an historic orchard in Frijoles Canyon with a 1915 priority date. License number 2470 allows diversion of 11 acre-feet from Frijoles Creek for domestic uses with a priority date of 1943 (Mott, 1999).

When the government reserves land for specific purposes, it also reserves an amount of water, from that amount unappropriated at the time of the reservation, to fulfill the purposes of the reservation. These rights associated with federal reservations vest, or have a priority date as of the time of the reservation. Consistent with this legal interpretation, there exists a federal reserved water right for consumptive uses and instream uses at BAND with a priority date that is the proclamation date, 1916. The quantity of this reserved water right is undetermined until such time as the United States brings a court action or is joined in a McCarran adjudication (43 USC 666). Neither of these actions is anticipated at this time.

Currently, all potable water used at the national monument is supplied by the County of Los Alamos. Natural flow regimes in park streams and springs are critical for many instream and riparian resources such as fish, macroinvertebrates, riparian vegetation, etc. In turn, these instream aquatic resources support many species of mammals and birds. Additionally, a free flowing stream is important to interpreting the cultural resources of BAND because a source of water was a critical element to human inhabitation of the canyon.

BAND should reconcile its future water needs with existing water rights to determine if additional rights should be secured or if any existing rights are not needed. Water rights are real property and must be managed accordingly (Mott, 1999).

Important Water Resources

Finally, in looking at the important water resources (streams, rivers, wetlands, groundwater), we answer the remaining five questions posed by the DSC Planning Team that provide the justifications for why these resources are important to BAND, along with the issues that threaten these important resources.

2. What is the importance of these water resources?

Water was essential for human inhabitation of the national monument's canyons. Springs, streams, wetlands, and riparian areas in BAND allowed the ancient Puebloan culture to flourish in an otherwise harsh landscape. Thus, water is important at the national monument in interpreting the cultural resources of BAND.

The occurrence of water over a wide range of elevations and microclimates continues to support BAND's diverse assemblage of plants and animals, while supporting a variety of visitor usage in the national monument (i.e., fishery, backcountry water supply, swimming, etc.).

Based on the *2006 NPS Management Policies* for water resources (National Park Service, 2006a):

- BAND will avoid, whenever possible, the pollution of waters by human activities occurring within and outside of parks.
- BAND will manage watersheds as complete hydrologic systems, and minimize human disturbance to the natural upland processes that deliver water, sediment, and woody debris to streams.
- BAND will manage wetlands in compliance with NPS mandates and the requirements of Executive Order 11990 (Wetland Protection), the Clean Water Act, and the Rivers and

Harbors Appropriation Act of 1899, and the procedures described in D.O. 77-1. The service will 1) provide leadership and take action to prevent the destruction, loss, and degradation of wetlands; 2) preserve and enhance the natural and beneficial values of wetlands; and 3) avoid direct and indirect support of new construction in wetlands unless there are not practicable alternatives and the proposed action includes all practicable measures to minimize harm to wetlands. The NPS will implement a "no net loss of wetlands" policy.

- BAND will 1) manage for the preservation of floodplain values; 2) minimize potentially hazardous conditions associated with flooding; and 3) comply with the NPS Organic Act and all other federal laws and executive orders related to the management of activities in flood-prone areas, including Executive Order 11988 (Floodplain Management), NEPA, applicable provisions of the Clean Water Act, and the Rivers and Harbors Appropriation Act of 1899

4. *What is the adequacy of the existing water resources information at BAND?*

The existing water-related information for BAND consists of numerous studies and monitoring efforts by NPS staff and other agencies that range from a single sampling event to multi-year monitoring programs. For example, park-based water quality monitoring at BAND has been attempted intermittently in the past, mostly during the ten-year period from 1982-1992 (Mott, 1999). The following is a select summary of historic and current efforts to collect water resources information at BAND.

<u>General</u>

Water quality, discharge, and benthic macroinvertebrate data were collected from the Frijoles and Capulin watersheds for two years (Stevens, 1996) prior to the outbreak of the Dome Fire. Ongoing research (MacRury, 1997; National Park Service, 1996) is designed to examine the effects of a large-scale disturbance (fire) on an aquatic ecosystem. Changes in stream hydrology, water chemistry, and benthic macroinvertebrate communities in Capulin will be compared before and after the fire, and with the adjacent unburned Frijoles watershed, utilizing data and experimental studies conducted over a 3-year period.

A U.S. Geological Survey - NAWQA fixed site was established on Frijoles Creek where stream flow, water chemistry (including trace elements), and organic pesticide levels (in fish, aquatic invertebrates, and bed sediments) were collected. Ecological surveys of stream and riparian habitat were also included with benthic, algae, and vascular plant communities assessed. The site was active from 1993 to 1996.

Los Alamos National Lab (LANL) continues to collect a broad range of water quality baseline data at the Frijoles gauge site for its annual perimeter surveillance efforts (radiochemical analysis is sometimes included). Sediments are occasionally monitored within the wetland area at the head of Cochiti Reservoir. A massive, multi-million dollar ground water assessment program is currently being implemented by LANL and its contractors.

The NPS Southern Colorado Plateau Inventory and Monitoring Network (SCPN) is composed of 19 NPS units, including BAND, with the following goals (National Park Service, 2006b):

- inventory the natural resources and park ecosystems under National Park Service stewardship to determine their nature and status;
- monitor park ecosystems to better understand their dynamic nature and condition, and to provide reference points for comparisons with other, altered environments;
- establish natural resource inventory and monitoring as a standard practice throughout the National Park system;
- integrate natural resource inventory and monitoring information into National Park Service planning, management, and decision making;
- share accomplishments and information with others and form partnerships for reaching common goals and objectives.

The water resource vital signs selected by the SCPN for hydrology are; 1) depth to ground water and 2) stream flow. The water resource vital signs for water quality are; 1) water quality of streams and springs, 2) aquatic macroinvertebrates, and 3) spring, seep, and tinaja ecosystems. This effort has been in the protocol development with site selections and implementation just starting for some of the NPS units (National Park Service, 2006b).

Water Quality

The National Park Service (1997) completed a comprehensive summary of existing surface water quality data for BAND. According to this baseline water quality report (National Park Service, 1997), water quality has been sampled from a total of 34 stations within Bandelier, with 20 of these sites on Frijoles Creek. Thirteen sites have long-term records consisting of multiple observations dating as far back as 1957. Some specifics to the historic and current sampling efforts are listed below:

> Park-based water quality monitoring has been attempted intermittently in the past, mostly during a ten-year period from 1982 to 1992. Parameters were sampled at nine to 16 stations and included: pH, conductivity, air and water temperature, dissolved oxygen, alkalinity, organic carbon, and turbidity. Biological parameters including total fecal coliform counts, fish tissue and bed sediment analyses for organics, and aquatic invertebrate surveys were occasionally performed. Discharge measurements were not taken; however, gauging stations located on Frijoles and Capulin Creeks provide stage height records for two of the water quality stations (National Park Service, 1995a). Stage data at the Frijoles station have subsequently been converted to flow by the U.S. Geological Survey as part of the National Park Service funded NAWQA efforts.

Park-based sampling attempted to develop a baseline water quality dataset, assess potential external impacts, and determine if backcountry recreation or headquarters development (sewage system, horse corral, picnic area, pit toilets, maintenance compound, etc.) were impacting water quality. Probably the most sensitive parameter related to these goals is fecal coliform bacteria. Fecal coliform measurements were made every two weeks from six stations along the developed portion of Frijoles Creek during 1976 to 1978, 1982 to 1985, and 1993 to 1994 (National Park

Service, l995b).

Hydrology

The U.S. Geological Survey installed a water stage gauge near Upper Crossing of Rito de los Frijoles in 1960, moved it above the intake (or orchard irrigation ditch) in 1963, and operated this gauge from 1964-69 and in 1978 (Allen, 1992). The USGS retains these flow data (and some associated sediment data). In 1979, the USGS built the current gauging station (located on the right bank of the stream 800 ft. downstream from Monument Headquarters under contract with the NPS (Allen, 1992). According to Swan (2005), it is unclear who currently monitors this system. Data summaries can be found in yearly LANL reports (station number 08313350) (Shaull, Alexander *et al*., 2001 and 2002).

A Parshall flume was constructed at Base Camp in 1983. Discontinuous records exist beginning in 1983 (Allen, 1992).

A flood-history for Frijoles Canyon was reconstructed using flood-scarred trees (McCord, 1996). This chronology extends back to the 17th century. Flood scar evidence suggests that there have been at least four floods over this timeframe comparable to the 1970 floods brought on by the La Mesa fire (Swan, 2005).

Staff with the U. S. Geological Survey has been involved with hydrologic monitoring of Capulin Creek and its watershed. The main purpose of these studies is to quantify post-fire peak flows for comparison with pre-fire flows, quantify gross channel responses to floods, assess the potential for debris flows and landslides in Capulin and its tributary canyons, and assess the potential flood hazards posed to visitors and BAND personnel.

Geomorphological changes in the Rio Grande upstream of the Cochiti Dam were assessed in a German thesis (Oberhofer, 1998). The thesis includes an abstract that compares the geomorphology of the channel from 1935 to 1991 and GIS files, unfortunately the entire document has not been translated to English (Swan, 2005).

Wetlands

The wetlands in the region have been identified through the U.S. Fish and Wildlife National Wetland Inventory (NWI). It should be noted that some wetlands were missed in this inventory since the aerial surveys typically miss small wetlands (<0.5 acre) without field confirmation.

Ground Water

In response to documented ground water contamination and the need to answer basic ground water questions, LANL has developed a comprehensive *Hydrogeologic Workplan* (Los Alamos National Laboratory, l998). This document describes activities to be performed by Los Alamos National Laboratory to characterize the hydrogeologic setting beneath the laboratory, and enhance the laboratory's groundwater monitoring program. The planning was completed with close oversight from the New Mexico Environmental Department stated four issues that the Department considered unresolved:

1. Individual zones of saturation beneath the Laboratory have not been adequately delineated, and the “hydraulic interconnection” between these is not understood;
2. The recharge area(s) for the regional aquifer and intermediate perched zones have not been identified, and the effect of fracture-fault zones on recharge is unknown;
3. The ground-water flow direction(s) of the regional aquifer and intermediate perched zones, as influenced by pumping of production wells are unknown; and,
4. Aquifer characteristics cannot be determined without additional monitoring wells installed within the specific intervals of the various aquifers beneath the facility.

Biology

In 1974, soil types were delineated and characterized roughly, with little field data for lower elevation portions of the monument (Earth Environmental Consultants Inc., 1974). This report also includes some discussion of erosivity of the various soil types and gives characteristic range vegetation for the sites (Swan, 2005).

Pippin and Pippin (1981) studied the aquatic invertebrates of Capulin Creek. A total of 65 taxa were collected from the creek.

Stevens (1996) sampled macroinvertebrate communities above and below horse corrals near Frijoles Creek (headquarters area, following pollution control implementation) and Capulin Creek (Base Camp area), using full and rapid assessment techniques.

MacRury (1997) expanded on earlier macroinvertebrate studies by re-sampling both Frijoles and Capulin to determine the impacts of the Dome Fire on these communities and track their recovery. MacRury collected samples from a wide variety of sites and habitat types on both streams, and other streams draining the Pajarito Plateau, including Capulin’s headwaters on U.S. Forest Service land.

In early 1997, mechanical thinning and slash mulching treatments were applied in BAND to one of two, paired, 40 ha watersheds, where piñon-juniper woodlands have encroached the area. Response to treatment was quantified using both biotic and abiotic measures. At three years post-treatment, total herbaceous plant cover had increased three-fold over pre-treatment and control levels, while soil erosion rates were significantly reduced relative to control (Jacobs *et al*., 2002).

Ongoing prescribed fire and vegetation restoration programs should also have positive affects on water resources as discussed in the issues section. A major elk research project is underway to determine such things as density, distribution, and impacts on native vegetation.

5. *What are the current state or conditions and the related trends of these water resources?*

Water Quality

Based on the 2004 303(d) list for impaired water bodies in New Mexico, Capulin and Frijoles creeks are listed as “impaired” (New Mexico Environmental Department, 2003). The listed impairment for Capulin Creek is “sedimentation/siltation”, which impacts the cold-water fishery. Sources listed for the impairment include: watershed runoff from past fire-impacted lands and silviculture. The listed impairment for Frijoles Creek is pesticides (DDT), with possible sources listed as “spills and land disposal”. The U.S. Environmental Protection Agency (2007) included “water temperature, total and fecal coliform and turbidity” as additional impairments for Frijoles Creek.

One of the first intensive water quality studies (Purtymun and Adams, 1980) focused on post-fire water quality perturbations and indicated a slight increase in calcium, bicarbonate, chloride, fluoride, and TDS in the base flow of Frijoles Creek. Storm flow samples showed elevated suspended sediment, barium, calcium, iron, bicarbonate, manganese, lead, phenol, and zinc concentrations. Phenol is attributed to the decay of vegetation. Other constituents can be attributed to runoff from the burned area, or in the case of lead, possibly from automobile emissions. Base-flow water quality returned to normal 3 to 5 years after the fire (Mott, 1999).

Purtymun *et al.* (1987) reported on radionuclides in river sediments of the Rio Grande, including one site on the Rio Grande below the confluence with Frijoles Creek. Data interpretation was lacking in this report, but a cursory review of data tables did not reveal any notably high concentrations (Mott, 1999). Environmental surveillance conducted by Los Alamos National Laboratory in 1990 (Los Alamos National Laboratory, 1992) included radiochemical analysis of sediments from Frijoles Creek at Bandelier headquarters. The highest total uranium concentration (5.2 µg/g) and gross gamma counts (4.7 counts/min/g) of 36 sites sampled were reported from Frijoles Creek. The total uranium values are below the EPA Primary Drinking Water Standards (20 µg/L) and surface water samples collected later were even lower in total uranium (1.0 µg/L). All other radionuclide parameter concentrations were low and the uranium concentrations found in the sediments could also be due to natural sources (Los Alamos National Laboratory, 1996). A detection of contaminant derived from high explosives was reported in Frijoles Creek at low levels by LANL researchers in 1996 (Gallaher, 1998).

Bracker (1995) interpreted the results of bacteria samples collected from Frijoles Creek on 27 recording dates between December 7, 1993 and December 5, 1994. Samples were collected at eight different sampling stations; the upstream site was at the Wilderness Boundary above Ceremonial Cave, and the downstream site was below the horse corral. These samples were tested for fecal coliform and fecal streptococcus bacteria. Bracker concluded:

- Bacterial contamination of the stream rises markedly during the warm summer months when visitation is highest. Unfortunately, turbidity was not measured. When turbidity and fecal coliform bacteria exhibit a positive correlation, it provides evidence that adsorbed bacteria is either being re-suspended with stream sediments (i.e. from visitors wading in the stream above the sampling station) or washed in from nonpoint sources. When a correlation between turbidity and bacteria is weak, it indicates the bacteria are in solution and probably result from point sources or ground water.

- There is an erratic tendency for Frijoles Creek to become more contaminated as it flows through the heavily used part of the canyon. In some cases there is a marked increase in bacteria counts at a specific point. This may indicate that discrete events (spills at the lift station, spillovers at the corral due to heavy rain, etc.) are being observed. In other cases, there is a slow steady degradation in water quality throughout this portion of the stream.

- A characteristic pattern seems to be low readings at stations above the visitor center and high at stations below the visitor center. This pattern is most evident when the overall contamination is fairly low. On one occasion, there was a fairly abrupt rise between stations above and below the visitor center.

- After two days of rain, bacteria counts are consistently high, and spike very high at stations next to the horse corral. Runoff of manure-laden water into the creek was suspected. The yearly highs seem to fall in July when summer rains typically begin. After August, the trend is dramatically downward (as is visitation).

Stevens (1996) sampled macroinvertebrate communities above and below horse corrals near Frijoles Creek (headquarters area, following pollution control implementation) and Capulin Creek (Base Camp area), using full and rapid assessment techniques. Stevens did not detect any difference in physicochemical or biological parameters in either stream resulting from the corrals. The major difference detected between the two streams was one of functional groups, with Frijoles being dominated by collector-gatherers and Capulin being dominated by scrapers.

Stevens (1996) found general agreement with previous water quality monitoring in Frijoles and Capulin Creeks. Nitrate concentrations were typically very low in both streams, with 50 percent of the samples below the detection limit of 0.01 mg/L in Frijoles Creek and 80 percent of the samples below 0.01 mg/L in Capulin Creek. Nitrates were relatively high at all three sites on Frijoles Creek (0.280, 0.280, and 0.333 mg/L) in December 1996. Ammonium samples were always below the detection limit of 0.001 mg/L, except at all six sampling locations of both streams in August, when concentrations jumped to 0.6 mg/L.

The 2006 air quality condition for atmospheric deposition in BAND was reported (National Park Service, 2007c). According to this report, wet sulfur deposition was rated as good, that is, less than one kilogram per hectare per year (kg/ha/yr). Wet nitrogen deposition was rated as moderate, between 1-3 kg/ha/yr.

<u>Cochiti Reservoir</u>

P.L. 88-293 requires maintenance of an open-water permanent pool of 1200 surface acres (Cochiti Reservoir) behind Cochiti Dam. A wedge of sediments is accumulating in the upper Cochiti Reservoir. This is the result of upstream sediments transported down by the Rio Grande and deposited once entering the low-energy reservoir. Because the expanding sediment delta consumes open-water surface area, pool levels must be routinely adjusted upward.

From a regional perspective, aggradation of sediments in the Rio Grande channel and adjacent floodplain was formerly a natural phenomenon that combined with multiple, meandering stream channels and non-diverted water flows to provide a variety of wetland environments in the riparian zone. Most of the Rio Grande's native wetland habitats have been lost through such human activities as: diversion of water, alteration of the river channel, regulation of river flows and sediment loads with dams, and degradation of the river channel downstream from reservoirs due to the interruption of natural sediment loads.

The U.S. Army Corps of Engineers staff indicated that the rate of sedimentation should be slowing due to construction of upstream reservoirs and better land use management in the contributing watershed. This was not supported by the data evaluated from Gallegos (1998) by Mott (1999).

The ecological character of the flooded portions of BAND is continually changing as Cochiti Reservoir fills with sediment. The growing delta has the potential to become a valuable wetland habitat, thus offsetting a portion of the regional wetlands loss (Allen, 1989). The delta currently attracts thousands of migrating waterfowl each year. Threatened and endangered species also use the area including bald eagles and peregrine falcons, and the delta may also be used by whooping cranes during their spring and fall migrations (Allen *et al*., 1993). However, the irregular flooding regime of Cochiti Reservoir, sometimes including 100-foot rises above the former river level and almost year round duration, reduces the potential productivity of this area as wildlife habitat (National Park Service, 1995b).

Stream Geomorphology

Stevens (1996) looked at a limited number of physical habitat parameters on Frijoles and Capulin creeks. Both streams contained relatively high amounts of fine substrate and subsequent embeddedness, leading to a reduction in the amount of overall high-quality, benthic macroinvertebrate habitat. The level of embeddedness combined with low ionic content (particularly nutrients) and alkalinity in these streams could contribute to low overall abundance and diversity.

Close scrutiny of geomorphic parameters in Frijoles reveals physical habitat alterations still exist in some of its reaches 20 years after the La Mesa Fire (Mott, 1999). The most obvious physical alteration within Capulin Creek is entrenchment, which results in the stream channel being down-cut and widened so that subsequent flood flows are confined to a vertically-walled trench and no longer spread out upon adjacent floodplains. The process of regaining a stable channel type is impeded by the inability of post-fire bank-full discharges to redistribute the available bedload and form a stable channel cross-section and new floodplain.

Mott (1999) observed incision of over eight feet within the Capulin channel, upstream from Capulin Base Camp, in response to the Dome Fire induced flooding. In other reaches, cobbles and boulders excavated by the floods were re-deposited, burying the preexisting channel.

Current and abandoned roads and trails can be focal points for accelerated erosion throughout the watersheds. The infiltration capacity of road and trail surfaces is low, and little precipitation is required to generate runoff. This runoff is often channeled down the surface of the road or trail, or within road ditches, at erosive velocities (Mott, 1999). Studies reviewed by Castro and Reckendorf (1995) reveal the density and extent of a basin's drainage are increased because the roads and trails act as ephemeral tributaries, creating a more efficient sediment delivery system.

Floodplain

In compliance with Executive Order 11988, a flood hazard survey was completed for Frijoles Canyon in 1987 (National Park Service, 1995b). Flood frequency data derived from U.S. Army Corps of Engineers regionalized graphs, along with cross-sections developed by NPS staff, were used to estimate 10-year, 50-year, 100-year, and 500-year floodplain elevations for Frijoles

Creek near Monument headquarters. Water surface elevations were predicted using the COE's HEC-2 computer program. Maps and tables were produced showing the area inundated and maximum depth of flow for each event (U.S. Army Corps of Engineers, 1987). Unfortunately the U.S. Army Corps of Engineers' predicted stage height (12.2 feet) for the modeled 100-year flood (2,750 cfs) is over twice the actual stage height observed during a 3,030 cfs event (Mott, 1999).

Ground Water

Almost everything that is known about the area's ground water comes from investigations conducted by or for Los Alamos National Laboratory. Despite the millions of dollars and years of effort spent on sampling, modeling, and quantifying subsurface waters, these systems remain a conundrum (Mott, 1999).

Purtymun and his associates (Purtymun and Cooper, 1969; Purtymun and Johansen, 1974; Purtymun and Adams, 1980; Purtymun, 1984; Purtymun *et al*., 1989) conducted much of the early ground water investigations in the area. This work resulted in a conventionally acceptable model of ground water recharge and flow that had the following premises:

> 1) Water in canyon alluvium is recharged by perennial, intermittent, or ephemeral stream flow. Once in the alluvium, it moves down canyon and is depleted mainly through evapotranspiration;
>
> 2) Springs in the upper canyons arise from perched water bodies. Perched ground water beneath the Pajarito Plateau is recharged from the eastern slopes of the Valles Caldera;
>
> 3) Water in the main aquifer is under water table conditions in the western and central part of the plateau and under artesian conditions in the eastern part and along the Rio Grande. Major recharge to the main aquifer is from the intermountain basin of the Valles Caldera in the Jemez Mountains west of Los Alamos. The water table in the Caldera is near land surface. The underlying lake sediments and volcanics are highly permeable and contribute to the recharge of the aquifer through the Tschicoma Formation interflow breccias and the Tesuque Formation;
>
> 4) Ground water flow within the main aquifer is toward the Rio Grande River. Water levels in the aquifer are higher than the river level north of the mouth of Frijoles, and about 20 springs and seeps discharge to the river within this gaining section of the Rio Grande River. Downstream from the confluence with Frijoles Creek the water table drops below the channel of the Rio Grande resulting in a losing reach;
>
> 5) The rate of water movement within the main aquifer is estimated to be about 393 ft/yr. Depth to the top of the main aquifer at BAND headquarters is estimated to be 354 ft;
>
> 6) The main aquifer is isolated from the alluvial and perched waters by 350 to 620

feet of dry tuff and volcanic sediments. Thus, on the Pajarito Plateau, there is little hydrologic connection or potential for recharge to the main aquifer from alluvial or perched water; and,

7) The hydrologic characteristics of the unsaturated tuff forming the Pajarito Plateau can retain or arrest the movement of water-soluble contaminants originating from liquid or solid wastes stored in the tuff.

While the above description of subsurface water remains generally valid, the details regarding recharge and hydraulic connectiveness among the three zones of ground water, and between surface infiltration and these zones, have been significantly altered by subsequent researchers. Reevaluation was triggered by the detection of contaminants in each of the three ground water bodies (Los Alamos National Laboratory, 1998). Mott (1999) listed some of these relevant modifications, which are numbered to correlate with the above discussion:

1) Zones of perched water exist beneath most, if not all, of the wetter canyons of the Pajarito Plateau. These perched bodies are recharged by intermittent and perennial stream flow loss to alluvial sediments and, ultimately, underlying volcanics (Los Alamos National Laboratory, 1995; Los Alamos National Laboratory, 1998);

2) Drilling at the western boundary of LANL did not detect a laterally extensive perched ground water zone. Fracture transmission may be responsible for recharge to the springs, with the actual source of this water remaining unknown (Los Alamos National Laboratory, 1998);

3), 4) and *5)* Blake *et al*., (1995) concluded that the Valles Caldera is not the source of recharge to the Los Alamos well field. They concluded most aquifer recharge comes from the Espanola Basin or other regions to the north. Stable isotope analysis (Goff and Sayer, 1980; Vuataz and Goff, 1986) and age dating of main aquifer water (Rogers *et al*., 1996b) indicates that part of the aquifer is recharged from the Sangre de Cristo Mountains, and that a ground water divide lies west of the Rio Grande. Analysis of spring water geochemistry within White Rock Canyon along the Rio Grande shows the presence of numerous constituents commonly found in explosives and trace levels of depleted uranium, and may be related to intermediate perched water (Los Alamos National Laboratory, 1998) as opposed to recharge from the main aquifer;

6) and 7) Ground water sampling summarized by the U.S. Department of Energy (1998) documented a myriad of contaminants in alluvial and perched ground water, many of which exceed EPA or New Mexico water quality criteria. Even in the main aquifer, tritium, plutonium-239 and -240, americium-241, and strontium-90 have been detected, as well as organic compounds and nitrates. Because these products were originally discharged to canyon streams or buried on mesa tops, as opposed to injected directly to ground water bodies, their presence in monitoring and production wells confirms vertical migration through unsaturated deposits. Mechanisms allowing this vertical migration are described by Rogers *et al*. (1996a) and Turin and Rosenberg (1996) and involve fracture, fault, joint, surge

bed and other permeable unit through-flow under canyons or mesas during the wetter seasons.

This demonstrates the complexity of the hydrogeologic systems below the Pajarito Plateau and alludes to the widespread occurrence of contaminants beneath LANL. Also captured is the evolving nature of the scientific understanding of these systems and their contaminant attributes. Recent monitoring and assessment of ground water by Los Alamos National Laboratory and the state of New Mexico reveal laboratory management practices, especially past practices, relied too heavily on the area's hydrogeologic ability to assimilate, contain, or entrap contaminants (Mott, 1999).

6. *What are the current or potential threats to these water resources?*

<u>Water Quality</u>

Impacts from horse corrals were a potential threat to water quality in both Frijoles and Capulin creeks. BAND developed a strategy to mitigate contamination from the Frijoles horse corral and implemented it in 1995 (Mott, 1999). Mitigation included routing surface runoff from the drainage area above the horse corral around the corral, frequent clean-up and removal of waste, and boarding the horses outside the canyon when they are not needed for backcountry patrols. A follow-up study by Stevens (1996) investigated water quality above and below horse corrals on Frijoles and Capulin Creeks using benthic macroinvertebrates, fecal coliform, physical characteristics, and several water chemistry parameters. The objectives were to provide information on benthic macroinvertebrate community structure, assess potential impacts from the horse corrals, and examine the relationship between benthic macroinvertebrate community structure and physicochemical parameters (Stevens, 1996).

No significant differences were found in water chemistry or fecal coliform upstream and downstream of either horse corral. In general, there was an inverse relationship between fecal coliform counts and flow in Frijoles Creek, which is indicative of a point source. This relationship was not observed in Capulin Creek. Unfortunately, Stevens did not look at turbidity or total suspended solids, which should correlate highly with fecal coliform counts in a nonpoint setting. There were no single fecal coliform samples with over 2,000 colonies/100 mL (Stevens, 1996).

Sampling in the headquarters reach occasionally found fecal coliform levels in excess of 3,000 colonies per 100 milliliters (col/100mL), apparently documenting intermittent sewage system failures (Purtymun *et al*., 1988). Subsequent measurements appear to indicate rapid flushing of fecal coliform from the system. Purtymun *et al*. (1988) detected the compound *bis* (2-ethylhexyl) phthalate in Frijoles Creek at a level of 560 μg/L. Phthalates are common in surface waters receiving sanitary effluent and the Frijoles concentration is equivalent to levels measured below a sewage treatment plant in Los Alamos County (National Park Service, 1995b). Historical documentation of other potential sources of coliform contamination (i.e., visitor use, pit toilets, horse corrals, paved and dirt parking lots, picnic areas, wildlife) is more problematic (Mott, 1999).

Hoofed animals can negatively impact water resources by direct fecal contamination, destruction of streamside and riparian vegetation, trampling of stream banks, and promoting watershed erosion. At Bandelier, landscape carrying capacity is also a concern because of the highly erodible nature of the watershed (Mott, 1999).

Natural stream processes have transported radionuclide-contaminated sediments from LANL canyons to Bandelier lands within the backwaters of Cochiti Reservoir (Mott, 1999).

The New Mexico Department of Transportation applies road salt and cinders to Highway 4 in the headwaters of Frijoles Creek. Spring runoff of salt could be damaging soil properties, vegetative communities, and water quality (Mott, 1999).

Watershed

Excluding the Frijoles basin, all of Bandelier's upper watersheds are under U.S. Forest Service or private ownership. Multiple use management and private development have impacted downstream water resources within Bandelier. A U.S. Forest Service proposal would designate part of the headwaters as a grass bank for future intensive cattle stocking (Mott, 1999).

Overland runoff and sediment transport at BAND threaten the integrity of thousands of pre-historic cultural sites. Without focused management action to stabilize soils, significant losses of soils and cultural resources could occur within the next 100 years.

Sources of sediment include trails, unpaved road surfaces, and road ditches within and upstream of BAND. Roads and trails have the effect of extending an area's drainage network, allowing sediment laden storm flow to be delivered to streams more efficiently. Stream banks with decreased vegetative cover or bare soil produce sediment directly to the stream. Increased ungulate populations could also increase sediment yield in the higher elevations of the watershed by reducing vegetation, increasing soil compaction, and causing trail and gully development (Mott, 1999).

The piñon-juniper woodlands of BAND are experiencing accelerated erosion. Earlier studies suggest that causes of these rapidly eroding woodlands are related to the unprecedented rapid transition of ponderosa pine savanna to piñon-juniper woodlands as a result of cumulative historical effects of overgrazing, fire suppression, and severe drought (Hastings *et al*., 2003).

Ground Water

Extensive ground water contamination has been documented in all three ground water zones below LANL. Of particular concern to Bandelier is contamination of perched ground water. Recent hydro-stratigraphic mapping and interpretation indicate perched water could be migrating toward Bandelier and recharging Frijoles or Alamo Canyons. Perched water and associated contaminants could also be migrating through the Pajarito Fault zone (Mott, 1999).

Radioactive and hazardous waste has been generated and disposed at LANL since its inception in 1943. More than 2,000 potentially contaminated sites or solid waste management units were recognized by LANL in 1995 (Stone, 1996). In 1979, it was estimated that about three million pounds of solid radioactive waste were buried in trenches and shafts dotting LANL's mesas (Stephens, 1982). Abrahams (1963) stated that radioactive wastes from Los Alamos have been released into the air, onto the surface, and into the subsurface in unknown quantities.

Abrahams' early work recognized that while most buried plutonium was retained in the tuff, isolated areas existed where water carried the "activity" through joints to greater depths (Abrahams, 1963). Dale (1996) reports that historically, LANL disposed of some liquid radioactive waste by discharging to canyons, underground storage tanks, and absorption beds. Previous studies and ongoing work reported by Dale showed radionuclides, in both the suspended and dissolved phase, were detected in storm runoff and moved off-site, although total quantities are unknown.

Riparian Areas and Wetlands

Riparian areas along the Rio Grande in BAND were badly damaged by flooding and sedimentation following the construction of the Cochiti Dam in the 1970's. Most of the native riparian vegetation was killed by the long-term inundation and heavy silt deposits, and have been replaced by exotics and weeding pioneer species (Swan, 2005; Mott, 1999).

As discussed earlier in this report, a wetland has established on the sediment delta formed in upper Cochiti Reservoir. Unfortunately, continual pool adjustments due to sedimentation to maintain the reservoir's 1200-acre surface area recurrently submerge these wetlands. For example, permanent pool adjustment in 1992 inundated one quarter of the developing wetland (Mott, 1999).

Fire Management

Nearly a century of fire suppression at BAND resulted in unnatural plant communities and fuel loading. The consequences of poor fire management practices were revealed in 1977, 1996, and 2000 as the La Mesa, Dome, and Cerro Grande wildfires burned out of control. The 1977 La Mesa fire burned 15,000 acres, including roughly one-third of the national monument; the 1996 Dome Fire burned over 16,516 acres in BAND and the adjacent Santa Fe National Forest; and the 2000 Cerro Grande fired burned over 40,000 acres and destroyed over 250 homes in Los Alamos. These were the most widespread fires to occur in the watershed since at least 1899 (Allen, 1989; Reneau *et al*., 1996).

Elevated rates of watershed erosion are delivering excess sediment to BAND's streams, especially during post-fire conditions. Excess sediment negatively impacts streams by decreasing habitat diversity, covering spawning areas, increasing turbidity, and other factors that ultimately reduce biological diversity (Mott, 1999).

The first study of aquatic invertebrates in Bandelier was conducted on Frijoles Creek in 1978 after the La Mesa Fire (Pippin and Pippin, 1980). The most dramatic decreases in aquatic invertebrate numbers followed periods of heavy flooding resulting from the 1977 La Mesa fire. There was considerable damage noted in the stream channel below the burned area, and a corresponding decrease in the number (up to 98 percent reduction) and diversity of insect communities. However, above the area of major burning, flooding was not a factor that affected aquatic insect populations (Pippin and Pippin, 1980).

In both Frijoles and Capulin canyons, a series of damaging flash floods occurred during the three summer monsoon seasons following fires. Riparian systems sustained direct and indirect impacts associated with alteration of stream channels, banks, and floodplains. Wholesale loss of riparian plants occurred in some cases either by erosion or sedimentation (burial). The pre-fire stream channel was variably down-cut many feet to bedrock, significantly widened, and/or banks were undercut. Large rocks and boulders were transported and deposited in clusters, establishing new stream morphologies. In some instances, entirely new channel sections replaced the old ones, either through abandonment or sedimentation (National Park Service, 1996).

After the massive Cerro Grande wildfire, a Burned Area Emergency Rehabilitation Team (BAER) was assigned to assess the damage and to implement a rehabilitation plan to reduce further natural resource damage. During July 2000, approximately 7000 hydromulching and hydroseeding flights were carried out on 1,600 acres (6.5 km^2) of the burned area to reduce erosion and speed revegetation. Flooding was a concern in areas downstream of the burned zone. The town of Los Alamos, the national laboratory, and the lower parts of the burned area are all sited on the Pajarito Plateau, an area of extensive canyons and mesas which surface runoff tends to concentrate in the canyon bottoms. This tendency was exacerbated in Cerro Grande's aftermath by the fact that the soil in the burned areas had become hydrophobic, reducing infiltration of water and increasing water flow in the canyon streams that existing streambeds may not have been able to handle. Fortunately the monsoon season of 2000 was not particularly intense, and damage from flooding was generally minimal.

<u>Fish Management</u>

Area fisheries biologists believe the regionally native Rio Grande cutthroat trout was endemic to Frijoles and Capulin creeks. Past stocking with exotic salmonids would have eliminated native cutthroat and could be altering other elements of aquatic communities (e.g. macroinvertebrates). Monument managers are concerned that chemical extermination of exotic fish would affect other stream organisms, and that unauthorized restocking by a disgruntled angler might jeopardize restoration efforts (Mott, 1999).

In the 1950s and 1960s, BAND used DDT and other chlorinated hydrocarbons to control “pests” near Monument headquarters. In 1975, the State of New Mexico discovered high levels of DDT contaminants in Frijoles Creek and subsequent studies showed high concentrations in sediment and fish tissue. A ban was placed on fish consumption and remedial investigations and clean-up have been implemented (Mott, 1999).

<u>Visitor Use</u>

BAND receives over 250,000 visitors each year, with a peak of over 400,000 visitors in 1997 (National Park Service, 2007d). Development and promotion of visitor access in discrete areas has the potential to degrade the resources the NPS was mandated to protect. Intensive visitor access and concomitant sewage, hazardous waste, and floodplain issues characterize the heavily developed reach of Frijoles Canyon near BAND’s headquarters (Mott, 1999).

Unconstrained social usage near Cottonwood picnic area has resulted in the trampling of Frijoles Creek’s stream banks and channel. Trampling has produced stream banks devoid of vegetation, an overwidened stream channel, decreased sediment size, and increased embeddedness. Changes in these physical attributes cause reduced habitat quality (Mott, 1999). Reduced habitat values can take many forms, including filling of pools, reduction of pool volume, increased shallow runs, loss of cobble and gravel substrate which provides cover from predators, spawning areas, and protection from flooding, and shifting substrate which increases turbidity and decreases periphyton (attached aquatic plant) production. Because habitat value is diminished, aquatic communities typically show reduced biological diversity and a shift toward more tolerant species in geomorphically degraded reaches (Mott, 1999).

Water quality monitoring has indicated that sewage is possibly leaching into Frijoles Creek from the headquarters sewage system. Direct spills of sewage from the lift station to this stream have been observed in the past. The proximity of maintenance facilities, housing, concessions operations, and management offices to Frijoles Creek also highlights the need for competent management of hazardous materials stored or utilized in these areas (Mott, 1999).

Some of the headquarters infrastructure is within Frijoles Canyon's mapped 100-year floodplain and has been flooded in the past. In historic times, large magnitude floods have only been documented during post-fire periods (Mott, 1999). With the recent wildfires in BAND's watershed, the potential for floods impacting popular visitor use areas (i.e., Frijoles Creek) is increased.

Documented recreational impacts have only been confirmed in the headquarters reach of Frijoles Creek. Designation of the Jemez Mountains Recreation Area near BAND's watersheds could bring increasing recreational pressure to the national monument and surrounding lands (Mott, 1999).

Climate Change

As greenhouse gases continue to accumulate in the atmosphere, the effects of climate change on the environment will only increase. Ecological changes will range from the emergence of new ecosystems to the disappearance of others. Few natural ecosystems remain in the United States and the NPS is steward of some of the most intact representatives of these systems, including BAND. However, changes in climate that are now being driven by human activities are likely to alter national parks as we know them. Some iconic species are at high risk of extinction. The distributions of many species of plants and animals will likely shift across the American landscape, independent of the borders of protected areas. As such, our national parks, preserves, seashores, and monuments may change dramatically. For example, the glaciers in Glacier National Park are expected to melt by 2030 (Hall and Fagre, 2003).

Therefore, as stewards of our most precious natural resources, we should evaluate what can and should be done to minimize the effects of climate change on BAND's resources, and to maximize opportunities for wildlife, vegetation, and the processes that support them to survive in the face of climate change.

Recognizing the profound implications that global warming and climate variation could have on the economy, environment, and quality of life in the southwest, New Mexico Governor signed *Executive Order 05-033* (2005) establishing the New Mexico Climate Change Action Council and the New Mexico Climate Change Advisory Group (CCAG).

The Climate Change Action Council shall review and provide recommendations to the Governor's office regarding climate change policy. The Council will be chaired by the Secretary of the Environment and will have representatives from the Departments of Agriculture; Economic Development; Energy, Mining, and Natural Resources; General Services; Health; Indian Affairs; and Transportation. The State Engineer, Director of Game and Fish, and the Governor's Advisor on Energy and Environment will also serve on the Council. Drawing on its own expertise and the perspectives of the CCAG members, the Action Council will find meaningful solutions that fit New Mexico's unique needs and circumstances.

The New Mexico CCAG is a diverse group of stakeholders from across New Mexico. The Governor has charged the CCAG with providing:

- Proposals for reduction of GHG emissions to reduce New Mexico's total greenhouse gas emissions to 2000 levels by the year 2012, 10% below 2000 levels by 2020 and 75% by 2050.
- An inventory of existing and planned actions that contribute to GHG emissions reductions.
- Consideration of costs and benefits of proposals.
- An inventory of historical and forecasted GHG emissions in New Mexico.
- Findings on initiatives to create meaningful regional and national policy to address climate change.

7. *What planning decisions exist for BAND's water resources*?

The 1977 *Memorandum of Understanding* (MOU) between the NPS and the U.S. Army Corps of Engineers, which permits a maximum flood-pool contour of 5,465.5 feet for Cochiti Reservoir, allowing approximately 350 acres of national monument lands to be submerged.

The BAND *Water Resources Management Plan* (Mott, 1999) provides a very comprehensive and technical summary of water resources, issue analysis, and recommendations for future actions and studies.

LANL has developed a comprehensive *Hydrogeologic Workplan* (Los Alamos National Laboratory, l998) that describes activities to be performed by LANL to characterize the hydrogeologic setting beneath the laboratory, and enhance the laboratory's groundwater monitoring program. The planning was completed with close oversight from the New Mexico Environmental Department that stated four issues and questions that the Department considered unresolved:

1. Individual zones of saturation beneath the Laboratory have not been adequately delineated, and the "hydraulic interconnection" between these is not understood;
2. The recharge area(s) for the regional aquifer and intermediate perched zones have not been identified, and the effect of fracture-fault zones on recharge is unknown;
3. The ground-water flow direction(s) of the regional aquifer and intermediate perched zones, as influenced by pumping of production wells are unknown; and,

4. Aquifer characteristics cannot be determined without additional monitoring wells installed within the specific intervals of the various aquifers beneath the facility.

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