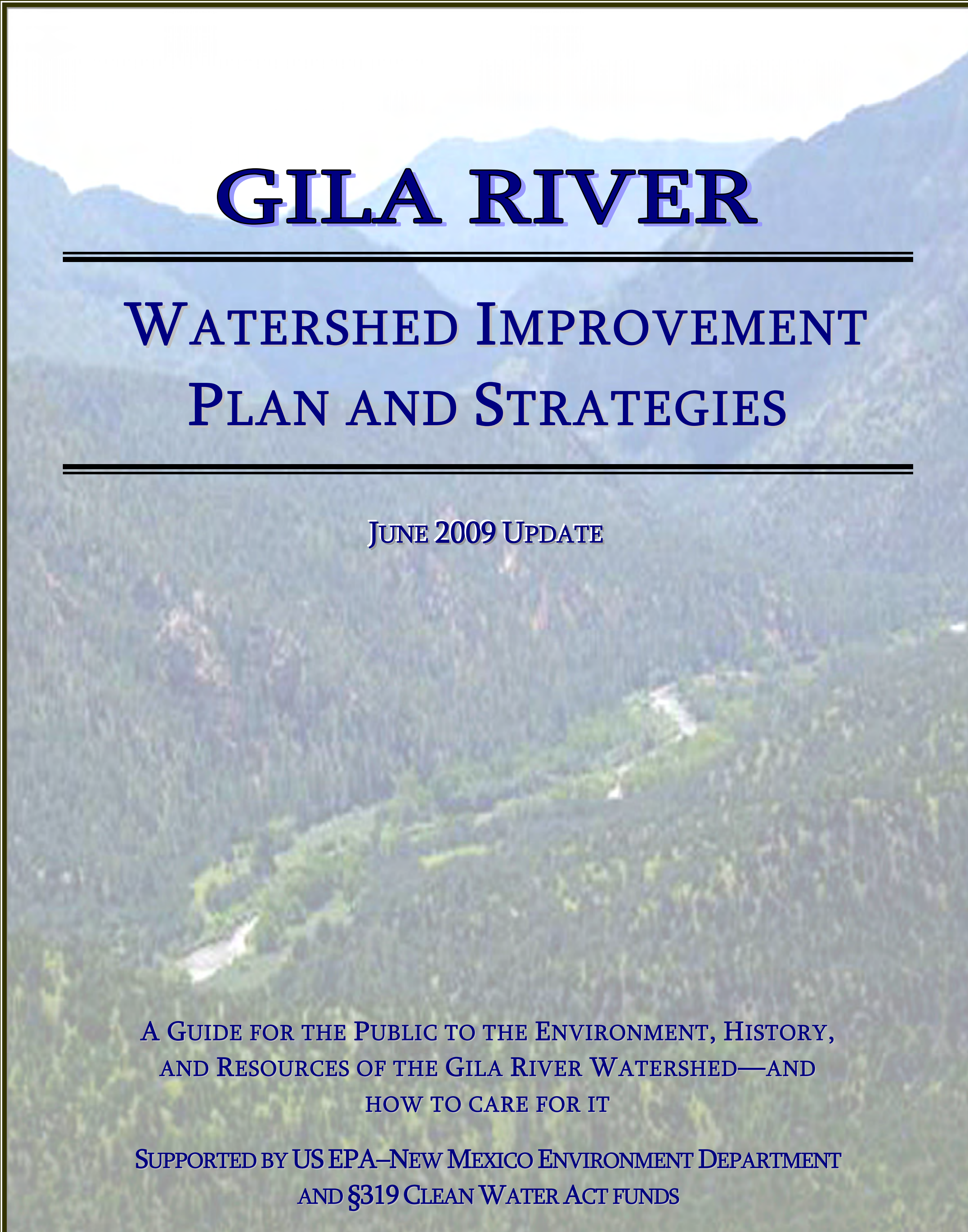

GILA RIVER

WATERSHED IMPROVEMENT PLAN AND STRATEGIES

JUNE 2009 UPDATE

A GUIDE FOR THE PUBLIC TO THE ENVIRONMENT, HISTORY, AND RESOURCES OF THE GILA RIVER WATERSHED—AND HOW TO CARE FOR IT

SUPPORTED BY US EPA–NEW MEXICO ENVIRONMENT DEPARTMENT AND §319 CLEAN WATER ACT FUNDS

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GILA RIVER

WATERSHED IMPROVEMENT PLAN AND STRATEGIES

JUNE 2009 UPDATE

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FREE additional copies of this document are available upon request by e-mail to Gary.King@state.nm.us, by telephone at (505) 827-2928, or by fax at (505) 827-0160. Requests can also be mailed directly c/o Gary King, Surface Water Quality Bureau, Water & Waste Management Division, New Mexico Environment Department, Harold Runnels Building N2206, 1190 S. St. Francis Drive, Santa Fe, New Mexico USA 87502. This document was originally created in Microsoft® Office Word 2003 (11.8327.8221). Individual chapters can be freely downloaded from the Internet as Adobe® Acrobat® 9.1.0 (saved as Adobe® 6) files beginning at:

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Acknowledgments

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The *WIPS* could not have been completed without help from the many agencies responsible for watershed lands. We especially thank Joe Encinas, Carolyn Koury, Mike Natharius, and Bill Wells on the Gila National Forest, and District Rangers Pat Morrison and Russell Ward, who offered opportunities to review on-the-ground planning and remediation work. Tim Herfel of EPA's Region 6 office gave helpful guidance and illuminated earlier collaborative efforts on the watershed. Special recognition is also due to other agency staff, including Gary Garrison of NRCS and Rich Olson of the Black Range RC&D. NMED's SWQB Water Protection Section provided stakeholder training in sampling protocols and opportunities to participate in sampling work, and their Wetlands office is an inspiration for more focused attention on these areas. Dave Menzie of the Silver City SWQB office provided many of the photos and descriptions included in the *WIPS*. Personal thanks from Ellen Soles to NAU for flexibility in allowing travel time for trips to New Mexico.

These acknowledgments would be incomplete without recognition of the many researchers, practitioners, and land stewards who are working to understand and protect the ecosystems of the Southwest's watersheds. Successful efforts to improve these resources would not be possible without them.

SECTION 1

Why a *WIPS*?, and How to Use It

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PREFACE

This *Watershed Improvement Plan and Strategy (WIPS)* is an inventory and data resource in support of a science-based approach to watershed resource planning. Watershed remediation work to improve deteriorated conditions is often supported by federal funds made available through Section (§)319 provisions of the Clean Water Act (CWA). This *WIPS* is a required component in New Mexico to securing §319 non-point source pollutant grant funding through the U. S. Environmental Protection Agency (EPA) and New Mexico Environment Department (NMED; 2006b). The CWA requires each state to identify surface waters within its boundaries that are not meeting, or expected to meet, water quality standards. In 1998 a statewide task force identified 21 out of 83 New Mexico watersheds as Category I, "in need of restoration." The Gila River is designated as a Category I watershed (NMED, 1999).

Figure 1. Gila River watershed at Wilderness boundary, Gila National Forest. September, 2006. Photo courtesy NMED, Silver City.

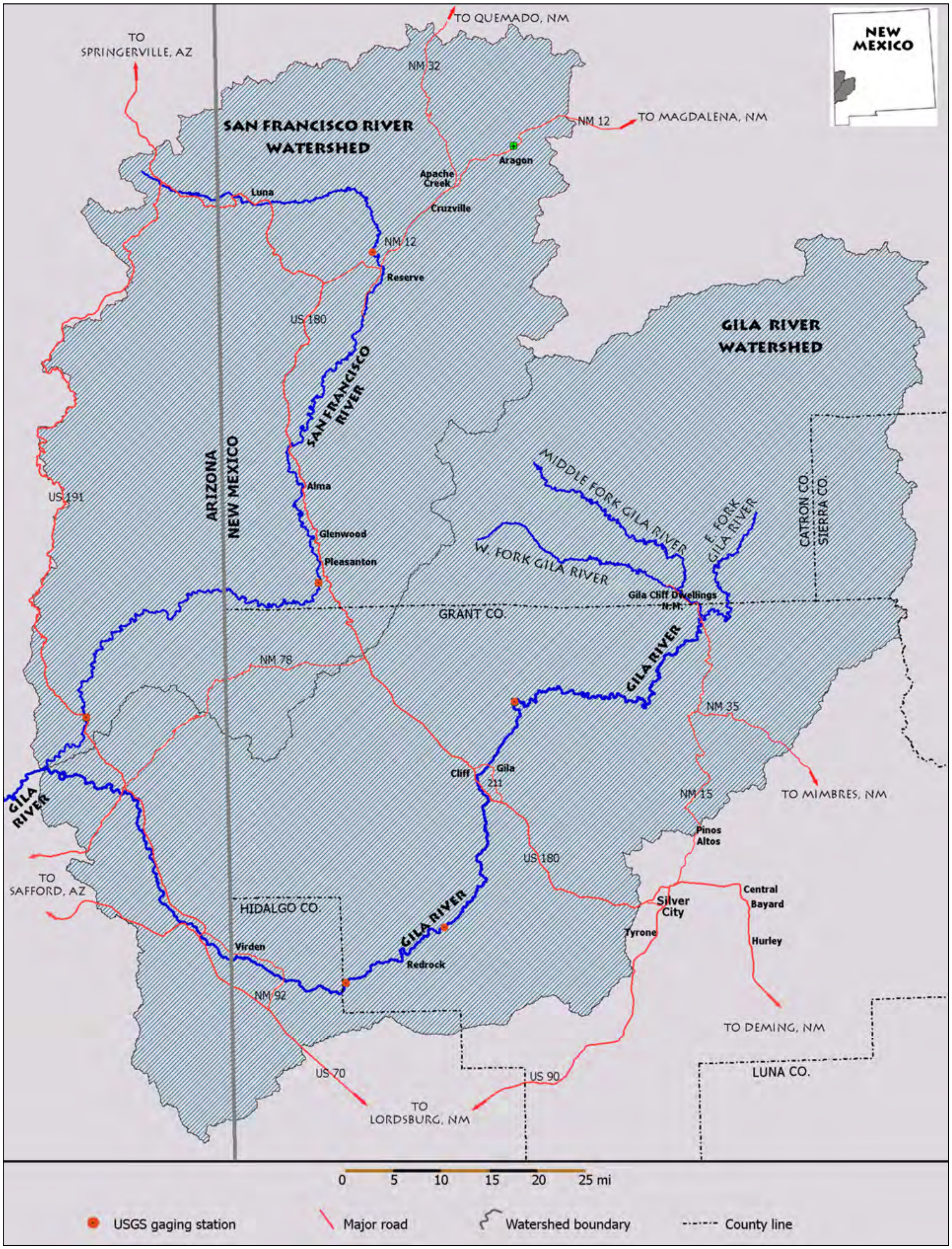
The Gila River flows 600 miles from its headwaters in the mountains of southwestern New Mexico to its confluence with the Colorado River near Yuma, Arizona. The origins of its name are unknown, although different authors postulate varying theories for it. Corle (1951) traced it back to one used by the Yuma people near the Colorado River confluence, who told Spanish explorers in 1539 their name for it: *Hah-quah-sa-eel*. In New Mexico, the river and its tributaries occupy one of the more remote and beautiful corners of the southwestern U.S.

The three forks of the Gila River flow through the forested mountains of the Gila Wilderness (Figure 1) to join just south of the Gila Cliff Dwellings National Monument, a site where the most striking evidence of this region's prehistoric human presence is preserved (Figure 2). The river's course continues through deep canyons and alluvial valleys across 100 miles of New Mexico landscape before it reaches the Arizona state line. One of the Gila's most significant tributaries is the San Francisco River. From its headwaters in Arizona, the San Francisco crosses into New Mexico and flows for about 90 miles near the state line before topography sends it back toward its confluence with the Gila in Arizona, about 40 miles to the west of the border between the two states (Map 1). At their confluence, the two rivers drain a total of about 6,840 sq. mi.. Nearly 80% of this total area (5,340 sq. mi.) lies within their New Mexico basins. Most of the land traversed by the San Francisco River and higher elevation reaches of the Gila River is part of the Gila National Forest, where their watersheds are similar in many ways. This is reflected by the work of most of the groups and agencies active on these watersheds, whose efforts encompass both of these rivers and their tributaries.

Figure 2. Site at Gila Cliff Dwellings National Monument, 2005. Photo courtesy NMED, Silver City.

Evidence of human habitation here dates back at least 20,000 years. In this semi-arid region, humans have always recognized the value of these streams. Their flows create and are sustained by a landscape that helped to inspire the U.S. Forest Service in 1924 to designate the upper watershed as the first wilderness area in the country. Today, they provide significant water supply, recreation, economic, and aesthetic benefits for the watershed's inhabitants. Because their natural flow regimes in New Mexico remain mostly—and uniquely—unaltered, they support one of the largest remaining riparian ecosystems in the Southwest.

These rivers are the region's most precious resource, and this is the most fundamental reason to be concerned with the health of their watersheds. Excessive rates of sediment runoff or erosion, loss of wetlands and riparian cover, and dense forest cover prone to high-intensity wildfire are conditions present both on mainstem river segments and within the subwatersheds tributary to them. Such conditions frequently result in impairments to water quality. River flows are not constrained by the political and legal boundaries of land management responsibility or ownership, and the effects of impaired watershed health may extend far downstream of their source.



Map 1. Watersheds of the Gila and San Francisco Rivers at their confluence in Arizona, including major roads, political boundaries, communities, and USGS streamflow gaging station locations.

WHY A *WIPS*?

A watershed planning document like this one is often referred to as a *Watershed Restoration Action Strategy*, or *WRAS*, and the initial draft of this document (*Gila River WRAS*, October 2005) followed this convention. In the ecological sciences, however, "restoration" can refer specifically to "an attempt to create an ecosystem exactly like the one that was present prior to disturbance" (Briggs, 1999). There are a number of difficulties with this approach (see Baker, 2000; Stromberg & Chew, 1999), but among the most profound is a lack of knowledge about what conditions were actually *like* prior to disturbance, the selected time period over which disturbances have occurred, and how to categorize "natural" versus "human" (i.e., reparable) disturbances. This document therefore aims less at returning watershed conditions to some previous state than at supporting and improving conditions of hydrologic and ecosystem resilience on the watershed. To this end, the *WIPS* provides an inventory of current conditions on the watershed, suggested actions to improve them, and a means of documenting the measurable results of those actions. Specific goals and their benefits are numerous and include, but are not limited to: increasing public knowledge and input regarding specific improvements to enhance riparian structure, form and function; improving water infiltration and soil moisture storage throughout the watershed; improving wildlife habitat; providing new opportunities for sustainable economic use; and enhancing recreational opportunities for residents and visitors.

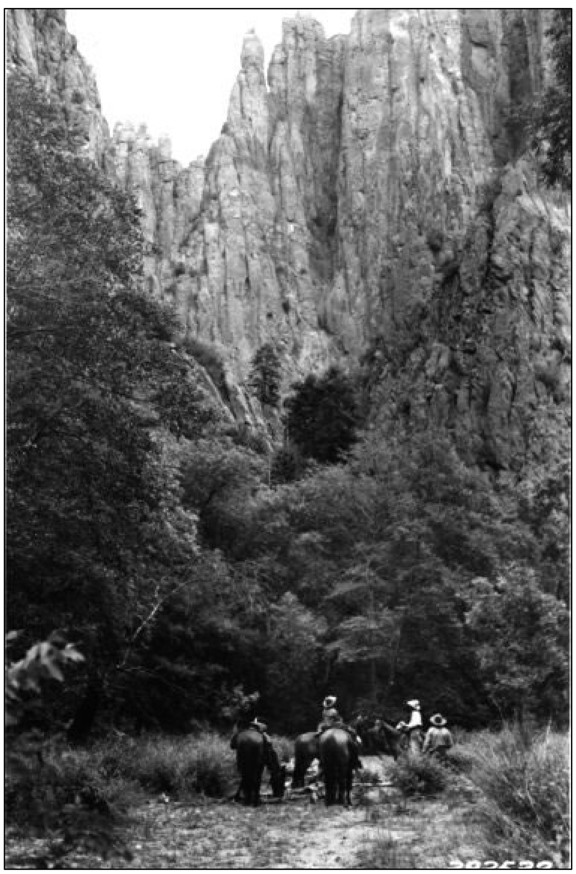


Figure 3. Horseback riders, 1922, on what became the Gila Wilderness two years later. Photo courtesy USDA Forest Service.

Development of the *WRAS* and its revision as the *WIPS* were supported by §319 funding from EPA and NMED. In revising the document, we have relied on guidelines from EPA's *Handbook for Developing Watershed Plans* (2005). A *WRAS* is typically designed to support water quality improvements by implementing measures aimed at reducing contaminant loads to acceptable levels (known as Total Maximum Daily Loads, or TMDLs). The *WIPS* retains a focus on water quality issues, and particularly on subwatersheds identified by NMED to be of special concern. However, watershed planning can go beyond strategies for attaining TMDLs to consider the larger watershed context (EPA, 2005). Other issues directly connected to watershed health include land use history, climate effects, economic sustainability, reduced minimum flows, water transfers, wetland modification, habitat protection, and synergistic effects among these. The *WIPS* is intended to support all actions that are aimed at improving watershed function within the Gila River basin.

HOW TO USE THE *WIPS*

The geographic area encompassed by the Gila River watershed in New Mexico is enormous and diverse. In any given year, strategies designed to improve watershed functioning can typically be implemented only on a small proportion of the watershed. Detailed planning and careful evaluation of results can greatly enhance the effectiveness of this work. The *WIPS* and its ancillary components are intended to provide a foundation for such efforts. It is generally recognized that the most effective watershed planning recognizes the interactions among all of the factors—vegetation and soil types, topography, climate, and land use, for instance—that ultimately influence stream hydrology and water quality. Planning should ideally include measures to enhance the functioning of the entire watershed, from uplands to the stream channel itself. On the scale of the entire Gila watershed, this is an impossible task. However, establishing specific geographic limits within which sets of improvement strategies can be implemented makes detailed planning and evaluation of results more manageable. We use the term *subwatershed* to describe these limits, as the land area from which water reaches any particular point on a stream. It is intended as a flexible concept whose extent depends only on the stream location selected.

We strongly encourage stakeholders to develop detailed plans at the subwatershed scale. Developing and implementing a detailed, effective subwatershed plan depends on coordinated work among willing landowners, management and liaison agencies, and practitioners. Any watershed plan will incorporate a number of improvement practices, and hundreds of technical and financial sources are available to assist in implementing these practices. The *WIPS* helps stakeholders locate and use these resources. Applications for funding assistance are increasingly judged by whether or not they address watershed issues on a holistic basis, including the formation of partnerships between private and public entities. EPA supports watershed planning efforts with funding and technical assistance that includes a template for coordinated watershed plan development (EPA, 2005). The *WIPS* and EPA's planning template can help landowners and others who want to develop integrated, coordinated watershed plans and to locate technical and financial support for project implementation.

Table 1 summarizes the planning template. The *WIPS* sections shown in the table provide information on potential partners, proposal development support, data, technical or financial resources, and methods for measuring results from improvement practices. Different users will find some sections of the *WIPS* more pertinent than others. For projects supported with §319 funding (see *WIPS* Sections 4 and 5), EPA *requires* additional, specific components, referred to as "Nine Key Elements" for watershed planning. These elements are highlighted in the table as boxed tasks: items a through i. Not all of the steps and tasks described in the table are necessarily sequential, and most will benefit from iterative development. For example, stakeholders who join the process after initial steps are complete may have access to additional information that could help guide the planning effort.

Each of these steps and tasks is covered in detail in the EPA (2005) *Handbook*. To request a copy, or to access individual chapters, go to: http://www.epa.gov/owow/nps/watershed_handbook/.

Table 1. Summary of watershed planning process suggested by EPA, including the nine key elements required for §319-funded practices, and sections in the *WIPS* containing relevant planning resources and data. Boxed items in the table are EPA's required "Nine Key Elements" for §319-funded planning and remediation projects.

PLANNING STEPS	TASKS	WIPS SECTION(S)
BUILD PARTNERSHIPS	Locate key stakeholders List issues of concern Establish initial goals Conduct public outreach	Section 7
CHARACTERIZE THE [SUB]WATERSHED	Gather existing data to compile into a subwatershed inventory Identify data gaps and collect additional data a) Identify causes and sources of pollution (biological, physical, and/or chemical) Identify other impairments to watershed function Estimate pollutant loads (NMED/SWQB data available)	Section 3 Section 4 Section 5
FINALIZE GOALS AND IDENTIFY POTENTIAL SOLUTIONS	Document management objectives b) Identify specific indicators and quantify targets, including pollutant load reductions Identify critical areas for implementation of practices c) Identify most effective management practices to achieve targets	Section 4 Section 5 Section 6
DESIGN YOUR IMPLEMENTATION PROGRAM	d) Develop an implementation schedule e) Identify interim "milestones" to be achieved (e.g., map all water sources; obtain clearances) f) Develop measurement criteria (what to measure) g) Outline a monitoring plan (how to measure) h) Develop an information component (to evaluate progress and communicate results) i) Outline technical and financial assistance needed for implementation of project components Assign responsibility for plan review and revision	Section 4 Section 5 Section 6 Section 7

Table 1, continued.

IMPLEMENT THE PLAN	Implement initial management practices Monitor results Document results Broadcast results	Results documented in *WIPS* and GIS provide an information resource to support other efforts
MEASURE PROGRESS AND MAKE ADJUSTMENTS	Review and evaluate progress Analyze monitoring results Document all progress and results in annual work plan Disseminate information Adapt future management practice details and begin implementation process	

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SECTION 2

Watershed Geography:
Geology, Topography, History, Economics, and Land Ownership/Management

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WATERSHED GEOGRAPHY

The physical and human geography of the Gila watershed—its topography, climate, land settlement patterns, and economic structure—reflect the interaction between events of the geologic past and the cultural traits of human groups who have occupied the region over the past centuries. The following sections describe these interactions and their ramifications for current watershed condition.

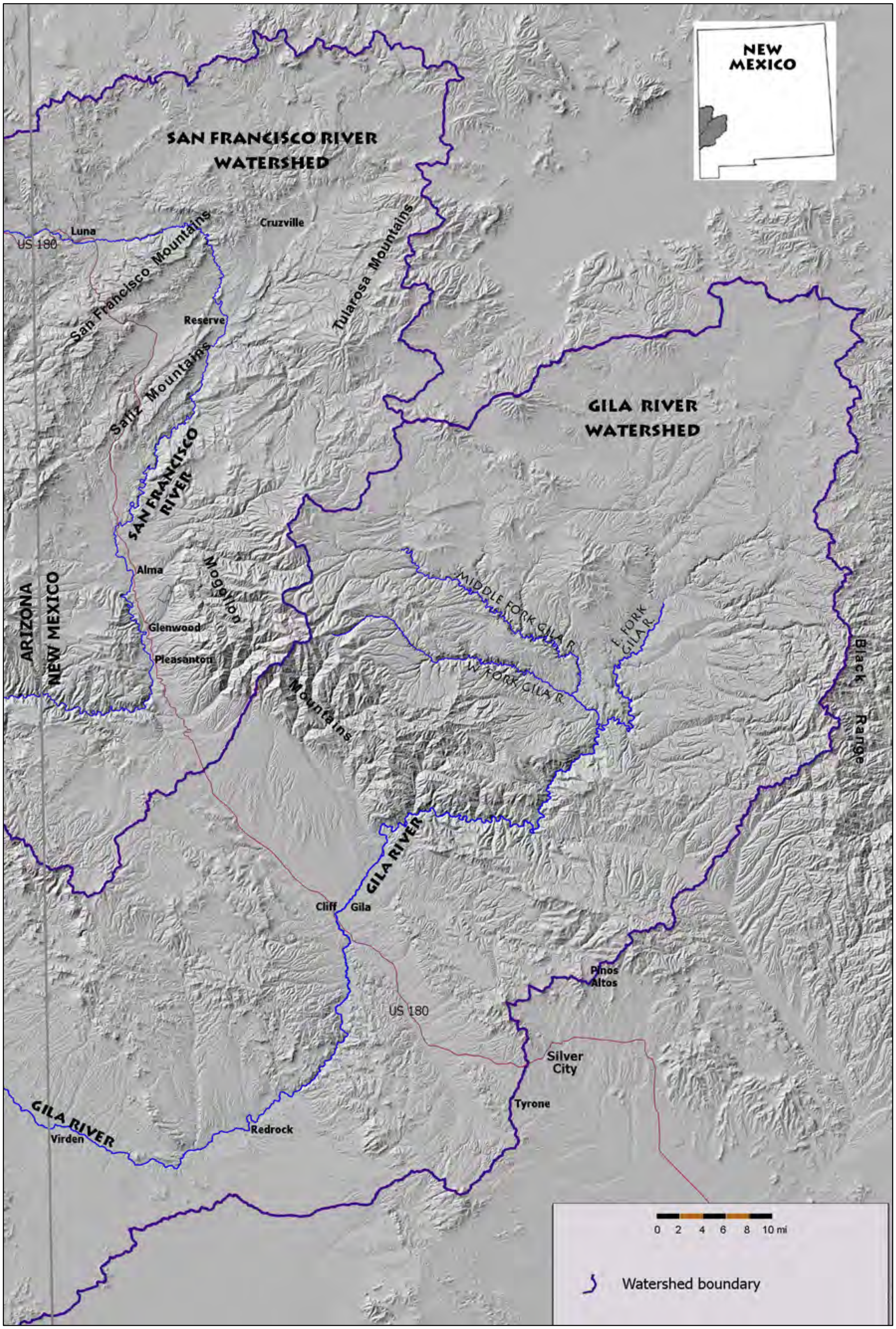
TOPOGRAPHY AND ITS INFLUENCE

Across the Gila watershed, different topographic and climatic zones are compressed over relatively short distances. This creates abrupt transitions from steep slopes, covered with higher-elevation tree species like Ponderosa pine and spruce, through gentler hills of Chihuahuan grassland, to near-arid deserts of cholla and saguaro cactus (Corle, 1951).

Much of the watershed lies with the Transition Zone between the Colorado Plateau and Basin and Range province, reflecting its complex geologic history, including relatively recent volcanic events (Trauger, 1972). The river's headwaters arise in complicated, mountainous terrain (Map 2). The 10,000-foot peaks of the Mogollon Mountains, near the western boundary of the Gila National Forest (GNF), create the divide between waters tributary to the Gila River in New Mexico and those that reach the San Francisco within the state. The Gila's western headwaters flow from the east-facing slopes of the Mogollons. To the northwest, the San Francisco and Tularosa Mountain ranges contain the San Francisco's headwaters. Near the eastern boundary of the GNF, the Black Range forms part of the Continental Divide that separates the Gila and Rio Grande watersheds. The southernmost New Mexico reaches of the river are entrenched in the aggraded desert plains of the Mexican Highlands, typified by generally low relief. However, the Gila River has cut sharply 300 to 500 feet into the plains and has developed a flat-bottomed inner valley up to a mile wide in the vicinity of Virden and Red Rock. (NM WQCC, 2004).

Daniel Conner traveled along the upper Gila in 1863 and was impressed by its unique character. Among other observations, he commented, "I will venture to assert that the Gila is the longest river of its size in the world and that it drains more country than any other stream of its width and depth and yet it has time to go dry in places" (1956, p. 45). The characteristics he noticed can all be considered as consequences of the geologic past. Until about 60 million years ago (MYA), the Gila River watershed was for millions of years part of a vast marsh extending across what is now southern New Mexico and Arizona. Until the Rocky Mountains began to form, this entire region was of relatively low relief that allowed the swamp-like conditions to prevail. The river flowed west, as it does today, from slightly higher terrain in western New Mexico and eastern Arizona toward seas whose outlines changed over time.

The uplift that created the Rocky Mountains began around 60 MYA, at the beginning of the Cenozoic era, and dramatically elevated the landscape encompassing the Gila and San Francisco headwaters. At their highest points, the headwaters now emerge at elevations above 10,000 feet. The steepened slopes of the river and its tributaries changed their character from slow, wandering streams to rapid torrents that incised the landscape, creating the canyons that characterize the region today.



Map 2. Shaded relief map of the Gila River watershed in New Mexico showing major watershed boundaries, mainstem rivers, towns, and US 180, the watershed's major highway. All data from NMED and USGS, 2005.

Other geologic changes forced the retreat of the shallow sea that once reached to southwestern Arizona, while the rise of the Sierra Nevada in California changed climate patterns throughout the region, capturing Pacific moisture on its western slopes and creating the rain shadow to the east that continues to enhance arid conditions into Arizona, Nevada, Utah, and New Mexico. As a consequence, it is altitude and its effect on average annual precipitation that exert the strongest influence on ecosystems or "life zones" here. In New Mexico, the Gila watershed traverses elevations ranging from over 10,000 feet to near 3,700 feet at the Arizona state line. This elevation and precipitation gradient supports a variety of forest and plant types ranging from the high elevation Canadian zone, or spruce-fir habitat, through a Transition zone of Ponderosa pine that grades into pinyon/oak/ juniper woodland, and into the shrubby Chaparral zone of mountain mahogany, buckthorn, and manzanita. The semi-desert habitat of remnant Chihuahuan grassland covers broad areas across the watershed's lowest elevations in New Mexico. This ecological diversity offers habitat for a wide array of species, including many species whose survival status is of concern.

HUMAN OCCUPATION

Humans have lived in the Gila region for more than 20,000 years; perhaps considerably more. Only scant evidence of the ancient populations remains, but the remnants of later occupation are more obvious. People of the Mogollon culture inhabiting the higher elevations of the watershed built pit houses and produced quality pottery and fine cotton fabrics. Their transition to building pueblo-type houses by about 1000 A.D. probably followed contact with peoples of the Anasazi culture to the north, whose structures at places like Chaco Canyon are renowned. The best-known of the Mogollon structures are at the Gila Cliff Dwellings National Monument (Map 1). The Mogollon people were hunters who relied on the atlatl, an ingenious invention that enabled them to hurl a spear fast and far, and only later adopted the bow and arrow. They were also agriculturists who grew maize, beans, and squash, constructing devices to spread and capture water in the process. Olmsted (1919) noted remnants of their stone and earthen dams and terraces throughout the areas they inhabited.

The Mogollon abandoned the region by about 1400 A.D., leaving it "open" for western Apache, an Athapascan people. Spanish sorties sent from Mexico, including Coronado's infamous 1540 expedition, avoided the upper Gila watershed and no written record exists of Apache presence in southwestern New Mexico before the 17th century.

It is nonetheless likely that they immigrated to the area between 1500 and 1600 (Spicer, 1992), and certain that they had acquired Spanish guns, knives, and horses by that time. They proved particularly adept at incorporating the horse into their culture, expanding their range and their threat to other tribes. By the late 1600s, Spanish missionary and settlement efforts had been extended into southern New Mexico. Fighting and raiding between the Spanish and virtually all of the native tribes developed throughout a 250-mile-wide corridor stretching north and south of the Gila River. The intensity

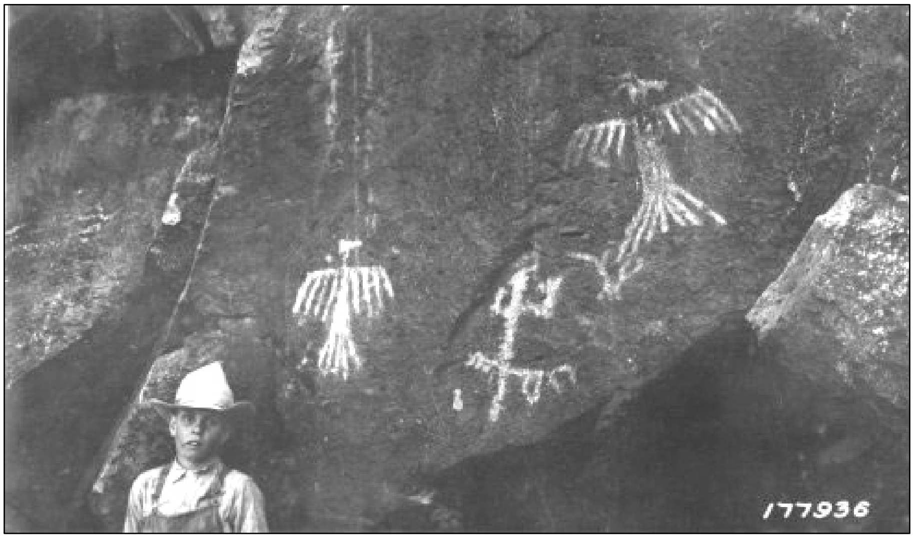


Figure 4. Pictographs on rocks near Tularosa Ranger Station, 1923. (Photo by USDA Forest Service.)

and frequency of the warfare eventually reached such levels that, between the late 1600s and the first Anglo arrivals around 1830, the Spanish for all purposes ceded the territory to the tribes inhabiting it, including the Apache. Over these decades, Spicer (1992) notes, the Apache honed the "lifestyle" that contributed to the friction between them and more settled inhabitants. He writes that they:

> perfected a way of life which...aimed merely at supplying their shifting camps in the mountains of southeastern Arizona and southwestern New Mexico by raids whenever they wished on the settlements of Spaniards, Opatas, and Pimas. They had come to desire the horses and cattle and other stock for food...and maintained themselves by quick raids in which they drove stock and plundered communities. They were not especially interested in killing people. Rather it was to their advantage that people continued to live in the Sonora settlements...This way of life was by 1785 well developed (p. 239).

Anglo settlement

The first contacts between Anglo travelers and the Apache people who lived on the watershed occurred shortly after 1826, when about 100 fur trappers obtained licenses from Santa Fe Mexican officials to trap along the Gila River. Other contacts occurred at the Santa Rita mines outside Silver City, leased by Anglos about the same time (Spicer, 1992). Between 1826 and the early years of the 20th century, the interactions between the soldiers, miners, settlers, and explorers who entered the watershed and its native inhabitants were as contentious, colorful, and downright murderous as anywhere else in the U.S. If it less well known outside the region than similar stories from elsewhere, it may be due to what remains the extremely remote character of much of the watershed. Vast areas remain roadless and unsettled, and even established communities are small, distant from one another, and limited by administrative boundaries or topography to particular areas.

In 1846 Mexican–American hostilities inspired the U.S. government to dispatch General Stephen Kearny, accompanied by Lieutenant William Emory, to "ascertain whether or not the Southwest was worth taking by force and, if so, whether or not it was worth keeping" (Calvin, 1946). Emory's account of the "reconnoissance," which took the group down the Rio Grande, west to the Mimbres River and Mangas Creek, and then down the Gila, became a classic. The Treaty of Guadalupe Hidalgo, ending the war, formalized New Mexico as a U.S. territory. But warfare between the U.S. military (and settlers) and the Apache accelerated, not ending until near the start of the 20th century (Spicer, 1992). Anglo settlement of much of the New Mexico portion of the watershed was slow and sporadic. At higher elevations on the watershed, settlement was concentrated in the valley bottoms where agriculture seemed possible. Early settlers, arriving in the mid- to late 1870s, must have seen great promise in farming these river bottoms, since contemporary accounts emphasize their constant fear of raiding and attack by the Apache.

For instance, an 1868 attempt by Missouri immigrants to settle in the Cliff-Gila Valley ended within six months when local Apaches "[ran] off every hoof of stock [leaving them] on the border of destitution" (Calvin, 1946). Farming at Alma, on the San Francisco River, began in 1879; the following year, 31 people were killed between Alma and Silver City during a series of raids and retaliations. (Alma hosted other colorful characters with a disposition to violence. Butch Cassidy and a number of the Wild Bunch took a break from their outlaw careers for employment as hands on the WS Ranch near Alma in the late 1800s. Ranch managers seemed happy with their work since cattle rustling apparently stopped during this interval. After some of them robbed a train near Folsom in 1899, however, the remaining members fled the area (Gibson, 2006; Stanley, n.d.).

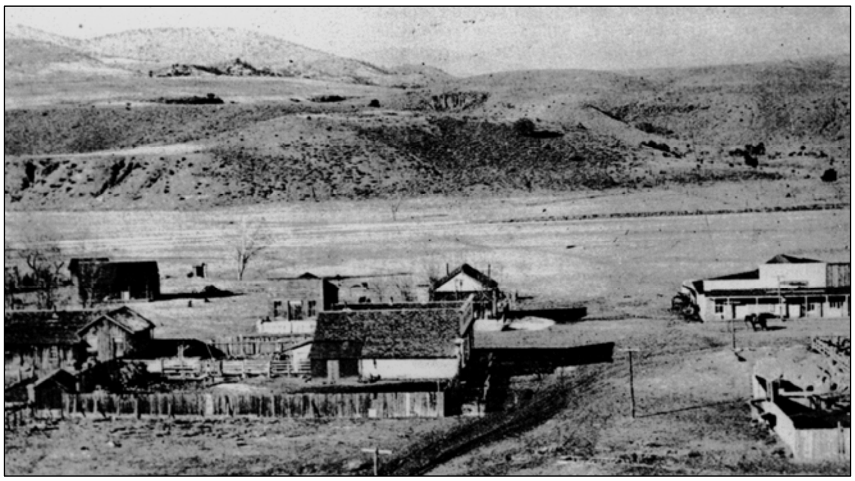


Figure 5. Alma, about 1913. The San Francisco River flows behind stores owned by Hugh McKeen (left) and the Jones Bros. (right). Courtesy Silver City Museum, all rights reserved.

Figure 6. Same view as in Figure 3, October 2006. The river's appearance has changed considerably since 1913. Photo courtesy NMED, Silver City.

Many settlers found early success in agriculture. Anglo settlers in the Cliff-Gila Valley established a foothold by 1875 and constructed their first irrigation works (which remain in use today); by 1880, wheat, oats and corn were being grown in the valley. In 1927, Black reported that "corn, alfalfa, garden truck, melons, and deciduous fruits" were produced from irrigated farms on nearly 3,000 acres there. Substantial corn and alfalfa crops were produced on Duck Creek through the early part of the 20th century (*Mogollon Mines*, 1916). In Alma, a settler wrote in 1882 that "every foot of irrigated land along the Frisco River is owned by somebody, and the owners are making ready to harvest big crops. Fruit trees and garden seeds are being ordered in vast quantities..." (Stanley, n.d.). By 1905, settlers had "patented" (claimed title to) virtually all of the region's available arable land and permanent water sources (Wooton, 1908). Local ore discoveries and mining booms boosted farmers' hopes for expanded markets. Copper mining began at Tyrone, in the Mangas Creek headwaters, in 1879. A short-lived silver and gold mining boom brought miners to the Mogollon Mountains between 1880 and about 1910. Valuable deposits were found near Mogollon, Cooney, (in the headwaters of Mineral and Mogollon Creeks) and Graham, on Whitewater Creek (Figure 7).

However, speculators and others who ventured into the territory between 1850 and 1880 quickly identified its potential for cattle and sheep production. Accounts from the period are filled with references to abundant grama grass and "good water." The scale of these operations soon overshadowed farm production.

Setting the patterns of land management and ownership

When the U. S. acquired the territory comprising Arizona and New Mexico by treaty with Mexico in 1848, lands not already in private ownership or designated as Indian reservations became part of the public domain. Public lands were opened, under various laws, to settlement, purchase, and use. Railroads were a major beneficiary of the public land domain, and their construction provided the genesis of many present-day towns in the Southwest. Local forests generally supplied construction timbers, ties, and fuel. Construction of rail lines through the new territory was an early priority, and favored routes included one along the 32nd line of latitude, just south of the Gila River's course into Arizona. The Southern Pacific railway line from Yuma across southern Arizona and New Mexico met the existing line at El Paso in 1883.

To support railroad construction, the federal government typically gave away forty alternate sections (a square mile each) for every mile of track built. Railroads also often had rights to “lieu lands” in exchange for previously taken private holdings along their rights of way. As a result, they generally controlled, and sold, vast amounts of land. In fact, the Santa Fe Railroad was second only to the federal General Land Office (GLO) in land acreage sold in New Mexico (USDA Forest Service, 2006b). These land sales served their long-term financial interests: towns, farmers, and ranchers became their customers; access to rail shipment for cattle accelerated livestock production.

The GLO, which had jurisdiction over the Federal lands, was primarily interested in selling them. The minimum price was $1.25 per acre. Homestead laws were generous: settlers could claim 160 acres for each adult family member. In the half century before 1900, the population of Arizona and New Mexico increased from about 62,000 to 320,000 (USDA Forest Service, 2006b). The population growth represented, in part, a triumph of the national policy of encouraging Anglo land settlement of the Western territories. But the late 19th century marked something of a shift in Federal land management priorities and the policies shaped by them. The new policies were spurred to some extent by growing evidence of deteriorated land, water, and wildlife conditions. Lands designated as the first

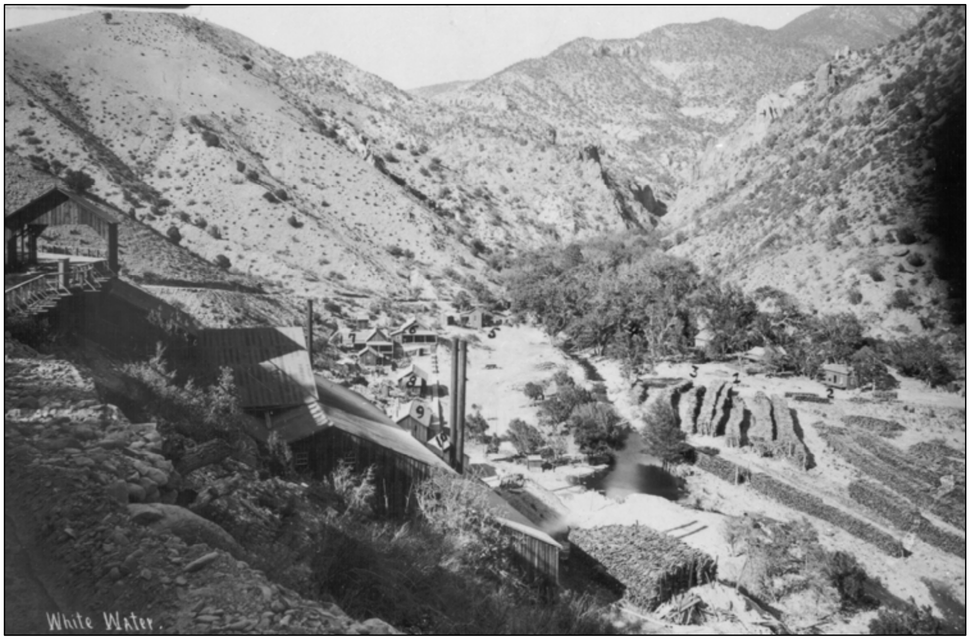


Figure 7. Upstream view on Whitewater Creek, ca. 1900. Silver mining in the canyon above was active for about 20 years. The mine mill is in left foreground; town of Graham on valley floor. Cords of wood at right were hauled in for mill operations. The pipeline transporting water from about 3 miles upstream to the town and mill is not visible through the dense vegetation along the creek. Compare hillslope vegetation cover with Figure 8 below. (Photo courtesy GNF.)

Figure 8. Same view as Figure 7, July 2006. The parking lot serves visitors to the Gila National Forest Catwalk recreation area. Traces of the mill are still evident, but they are hidden by dense juniper in this photo. (Photo courtesy NMED, Silver City.)

Figure 9. Part of a herd of 5,000 sheep near Glenwood about 1911. Photo courtesy Silver City Museum, all rights reserved.

national parks, forests, and wildlife refuges were withdrawn from settlement and reserved for public ownership during this period (BLM, 2005). The tension between these two impulses—on the one hand, to put lands to direct economic use; on the other, to restrict such uses in favor of protecting an area's other resource values—remains a potent force.

In 1891, Presidential authority to create forest reserves was granted by Congress—and then restricted, in 1897, to specific purposes such as preserving timber and protecting watersheds. The Gila National Forest (or Gila River Forest Reserve, as it was originally named) was established in 1899. Parts of what later became the Apache National Forest were designated at about the same time. Today, almost 70% of the Gila watershed is on lands managed by the US Forest Service (Map 3 and Table 2). "Multiple use" of Forest Reserve lands was an early-established principle, but designation of specific Forest Reserve lands was also intended as a means of managing that use. Regardless, early use of Forest Reserve lands for grazing and other private economic purposes remained generally unconstrained by all but topography (USDA Forest Service, 2006b). The tradition of public land use for production was already well established. Private landowners retained de facto control of adjoining public lands. In the Southwest, those who owned lands with springs or perennial surface water in effect controlled large tracts of adjacent dry land.

The introduction in 1905 of grazing fees and restrictions on the use of Forest lands encountered widespread resentment. Still, private landowners continued to benefit from adjacent public lands. In New Mexico, about 30 million acres of farm and ranch land were privately owned in 1945, while 74 million acres of public lands were available for grazing (USDA Forest Service, 2006b).

However, special designations for a particular use of federal lands have also limited other uses. Wilderness designations are probably the prime example of these on the Gila watershed. Aldo Leopold (1887–1948) is generally credited as the founder of designated wilderness in the U.S. Famously, Leopold's support for wilderness developed from a change in his views on the role of predators in the ecosystem. He published his first proposal for wilderness establishment on the Gila in 1922, proposing some 500,000 acres of the Gila Forest as official wilderness without roads and only minimum trails. The proposal became reality in 1924, when the Gila Wilderness was designated, joined later by the Aldo Leopold Wilderness and the Blue Range Primitive Area. More than a quarter of USFS lands on the watershed are now designated as wilderness.

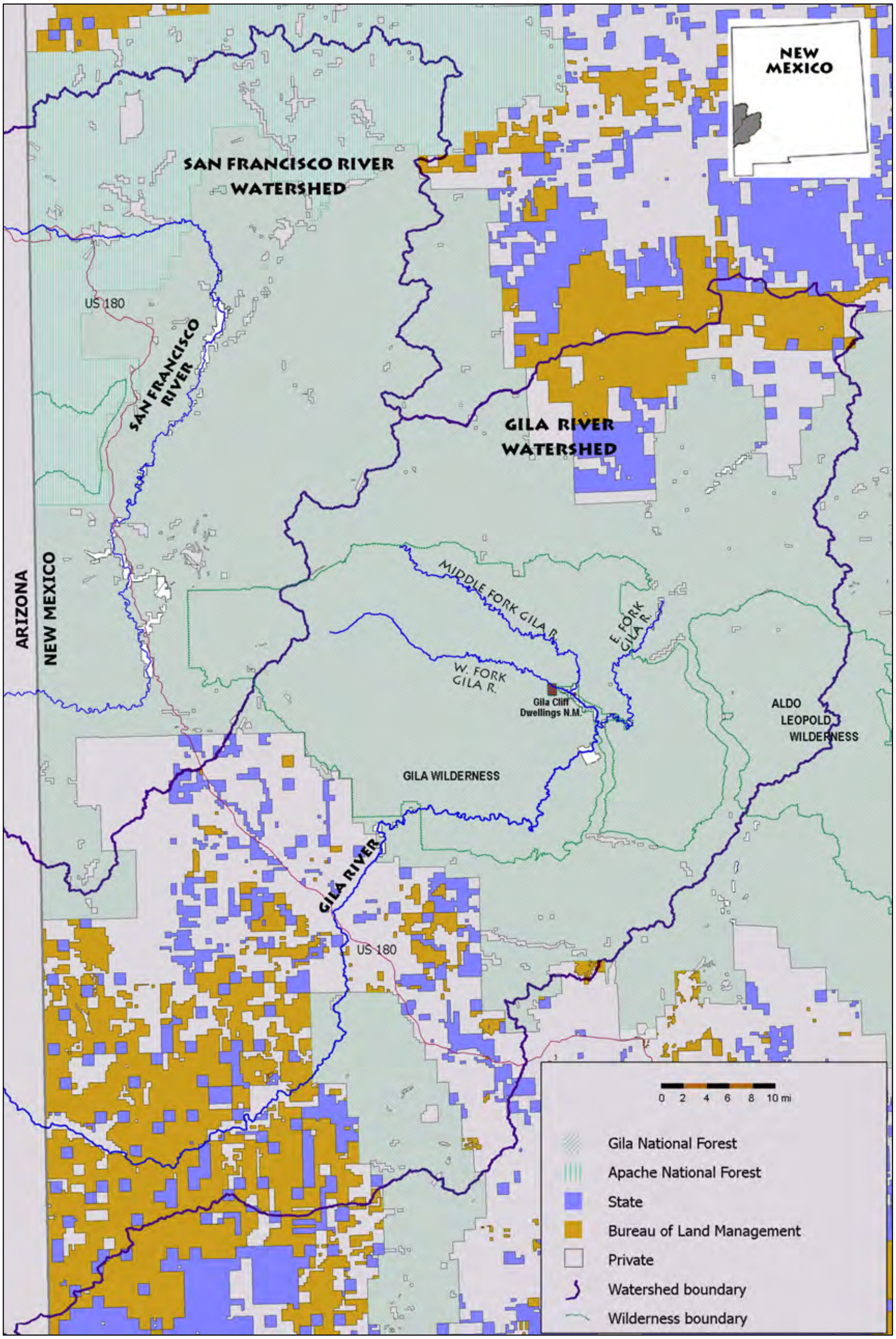
Like other forested lands in the Southwest, those now known as the Apache and Gila National Forests occur on the highest elevations, where annual rates of precipitation are enough to sustain timber

Figure 10. A herd of 450 cattle owned by the Heart-Bar Cattle Company trailing to market near Pinos Altos in 1928. (Photo courtesy of USDA Forest Service.)

growth. But lower elevations offered plenty of public land as well. On the Gila watershed in New Mexico, these were typically located in the Chihuahuan grassland and chaparral zones, around elevations of 3000 to 5000 feet. These areas seemed to offer vast promise as grazing rangeland or farm land, but usually contained less surface water than the mountainous region. As a general rule, the public rangelands purchased by private landowners from the GLO were those with the best availability of surface or near-surface water sources.

Figure 11. The Gila River Lower Box, on land managed by the BLM between Virden and Redrock. December 2005.

The resulting pattern appears on Map 3. Although smaller streams like Duck, Mangas, and Mule Creeks are not delineated on the map, their general locations are nonetheless evident. Most of the private lands outside of National Forest boundaries occupy accessible lands around the Gila River and these creeks, which generally traverse the large block of mostly private land across the south-central part of the watershed. Most of these lands probably went into private ownership prior to 1934, when the Taylor Grazing Act was passed. The Act, a response to the environmental devastation of the Dust Bowl era, closed most of the remaining public grasslands to homesteading. The system of Soil & Water Conservation Districts, made



Map 3. Land management status map, Gila River watershed in New Mexico. All data from USGS and Gila N.F., 2005.

up of local livestock producers, was established to manage them as a public grazing resource (Worster, 1979). The Act also created the federal Grazing Service. In 1946, the GLO and Grazing Service were merged to create the Bureau of Land Management (BLM; 2005).

Other federal lands were ceded to new territories and states, typically to provide revenue to support their public schools. It took 62 years, from 1850 to 1912, for New Mexico to move from Territory status to statehood. Legislation in 1898 and 1910 granted the Territory what were known as “school sections”: Sections 16 and 36 and 2 and 32, respectively, in every public lands township. (Land sales and exchanges have modified this pattern somewhat over the decades.) Later legislation also provided mineral estate royalties to the state from school lands. Authority to manage the lands and the royalties generated from them was given to the State Land Office. Revenue from each acre of state trust lands is designated in support of a particular institution. Particularly today, these lands form a substantial part of state revenues. In the 2006 fiscal year, state land revenues, generated from 9 million acres of surface land and 13 million oil, gas, and mineral acres, totaled nearly $415 million (New Mexico SLO, 2006). State trust lands comprise about 5% (160,000 acres) of the Gila watershed in New Mexico.

Table 2. Approximate current distribution of management and ownership of Gila and San Francisco Rivers watershed lands within New Mexico (data from US Geological Survey, 2005).

Management agency or owner	Gila, mi^2 (% of total)	San Francisco, mi^2 (% of total)	Total (mi^2)
US Forest Service	1966 (56%)	1709 (92%)	3675
Bureau of Land Management (BLM)	538 (15%)	<1 (< 1%)	539
State	245 (7%)	5 (<1%)	250
Private	736 (21%)	141 (7%)	877
National Park Service	1 (<1%)	--	1
Total	3486	1856	5342

It took only about 60 years to set the watershed's present land ownership and management patterns in place, but they can profoundly influence watershed condition and practices aimed at its improvement. For example, many river bottom lands are irrigated for pasture or for alfalfa or crop production: these small-scale irrigation withdrawals from the Gila and San Francisco River basins total about 50,000 acre-feet (a-f) annually, nearly all from surface flows (Wilson, 1998). Such small diversions for irrigation have been constructed on the Gila watershed for centuries. However, no major dams have been constructed on its mainstem rivers or tributaries. (A current proposal to divert an average of 14,000 acre-feet of water from the Gila and San Francisco Rivers as part of the Arizona Water Settlement Act is under study, with a recommendation due to the Secretary of the Interior by 2014. See New Mexico OSE/ISC, 2006 for more details.)

The greatest hydrologic alteration to streamflows may therefore come in the form of shallow groundwater withdrawals.To date, there are no large towns or extensive developments anywhere on the watershed. Yet the area's remoteness and beauty have attracted and continue to attract new residents. Private lands in small river valleys occupy some of the watershed's most biologically productive zones;

they are also among the most aesthetically desirable. As elsewhere in the western U.S., these could become the areas where subdivision and development are most likely to occur. Groundwater withdrawals from alluvial aquifers consequent to increased development could be significant; where domestic wells are concentrated, they can stress groundwater supplies and cause significant depletions in stream flow (OSE, 2006).

In addition, the varying land management designations across the watershed create a patchwork of stewardship responsibilities. About 84% of the Gila watershed is on public lands. BLM and state lands often occur in non-contiguous parcels spottily interspersed among private lands; private lands within National Forest boundaries are predominantly located in stream valleys (Map 3). These legal boundaries often do not correspond with the topography that describes the limits of each subbasin within the greater watershed. It is generally recognized that the most effective practices for improving watershed function are holistic, in recognition of the interconnections among all the components of the watershed landscape. Yet even on small watersheds, coordinating improvement strategies across the variety of owners and managers responsible for their stewardship can represent a major challenge—or opportunity—for successful implementation.

Figures 12 and 13. View upstream through the valley of Reserve. Top, in 1923. Bottom, 2006.

ECONOMICS AND DEMOGRAPHICS

The history of the watershed is partly reflected in its present-day economic base, employment structure, and demographics. Parts of four New Mexico counties are within the Gila watershed: Catron, Grant, Hidalgo, and Sierra counties (see Map 1). This corner of New Mexico is remote and largely rural in character; even the larger towns on the watershed have fewer than 1000 residents. New Mexico's population increased 33% between 1990 and 2004. Population changes in these four counties during the same period varied from an increase of 34% in Catron County to a decrease of 13% in Hidalgo County, as shown in Table 3 (all data from US Census Bureau, 2006a, 2006b).

Table 3 and Figure 14 also reflect something of a changing age structure within the four county area. Between 1990 and 2000, the percentage of residents above the age of 54 increased in all but Sierra County (which had a far larger proportion of those residents in 1990 than the other three counties). This shift was especially evident in Catron County, where 10% more residents were over the age of 54 in 2004 than in 1990. In New Mexico as a whole, the percentage of the population aged 20–54 probably increased by more than 1% between 1990 and 2000 (an exact comparison is not possible with these figures since the U.S. Census Bureau began including 20 year-olds in this category only as of 2000). Only Grant and Sierra counties on the Gila watershed saw similar increases in this age category. In the state and in three of the four counties, the number of people less than 20 (21) years old declined during the decade; only in Sierra County was the percentage the same in 2000 as in 1990.

Table 3. Population, 1990 and 2004, and demographics 1990 and 2000, in New Mexico and the four New Mexico counties of the Gila watershed.

	Catron County	Grant County	Hidalgo County	Sierra County	New Mexico
Population					
1990 population	2,563	27,676	5,958	9,912	1.5 million
2004 population	3,428[1]	29,363[1]	5,173[1]	12,948[1]	2.0 million
Population change	34%	6%	-13%	31%	33%
Demographics					
1990: < 21 years old	29.6%	34.9%	37.1%	22.0%	34.0%
2000: < 20 years old	22.8%	29.0%	34.4%	22.0%	31.1%
1990: 21-54	43.8%	41.6%	42.9%	32.0%	47.2%
2000: 20-54	40.6%	43.5%	42.7%	36.4%	48.5%
1990: > 54 years old	26.6%	23.5%	20.0%	46.0%	18.8%
2000: > 54 years old	36.6%	27.5%	22.9%	41.6%	20.4%

Unless otherwise shown, all data are from US Census Bureau (2006a, 2006b). [1] Data from Bureau of Economic Analysis, U.S. Department of Commerce, 2006.

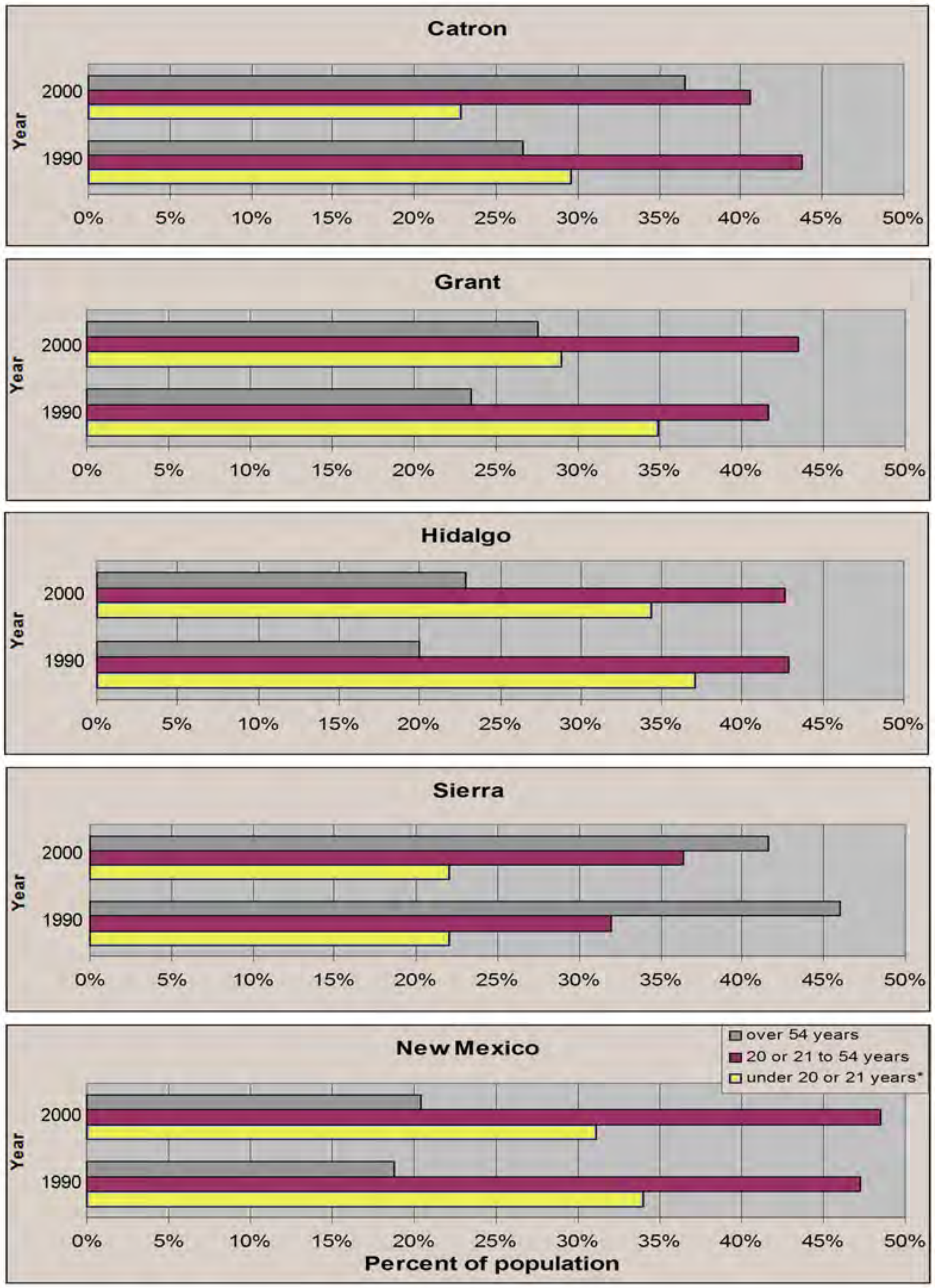


Figure 14. Demographic changes in the four New Mexico counties on the Gila River watershed and in New Mexico, 1990–2000 (see also Table 3). * In 2000, the U.S. Census Bureau began including 20 year-olds in this age group; they were excluded in 1990.

Table 4 shows general information from 2004 on job categories and wage sources for the four counties. According to the Bureau of Economic Analysis (2006), per capita income in the four-county area rose eight to ten percent between 2003 and 2004. Per capita income remains well below the state average, however. Generally, the economic activities within the small communities of the watershed are mostly in agriculture, services, retail trade, and construction; Unsworth et al. (2005) cited tourism and a growing retirement population as the primary drivers of the last three. The Gila National Forest is a significant destination for hikers, hunters, and other recreationists; a recent study estimated 1.3 million visits to the GNF in 2001 (Unsworth, 2005). Government jobs provide the predominant source of wages in the four counties, although in Catron County, a substantial proportion of economic activity is based on livestock production. Most livestock operations in the three counties for which livestock income provided more than half of agricultural income (Catron, Grant, and Sierra) are of relatively small scale, according to data from the USDA (2002; cited by Unsworth, 2005). In each of the three counties, slightly more than half of operators reported running fewer than 50 head in 2002. In Catron County, about 10% of operations were with more than 500 head; in Grant County, about 7%, and in Sierra County, about 8% (USDA, 2002).

Table 4. Income and jobs in the four counties on the Gila watershed in New Mexico, 2004.

	Catron County	Grant County	Hidalgo County	Sierra County	New Mexico
Income[1]					
Per capita income 2004	$17,504	$21,084	$18,882	$19,402	$26,184
Net agric. income	-$1,351,000	-$3,311,000	$1,294,000	$2,258,000	Not obtained
Agric. income from livestock	> 99%	> 99%	34%	81%	Not obtained
Total wages and salaries	$16,341,000	$259,480,000	$40,238,000	$68,941,000	Not obtained
Percent and total wages from agriculture	5.0% $812,000	0.4% $1,031,000	8.6% $3,458,000	2.7% $1,864,000	Not obtained
Jobs					
Total jobs 2004	1,525	13,708	2,362	4,698	Not obtained
Government: Fed, state, local (% of total)	346 (23%)	3,776 (28%)	520 (25%)	975 (21%)	Not obtained
Agric. jobs (% of total)	307 (20%)	439 (3%)	341 (13%)	362 (8%)	Not obtained
All other non-govt jobs	872 (57%)	9,493 (69%)	1,501 (62%)	3,361 (71%)	Not obtained

[1] **Data from Bureau of Economic Analysis, U.S. Department of Commerce, 2006.**

Mining industry jobs also account for a substantial proportion of employment on the watershed, although exact numbers are not available. The service industries employed 11% (Catron County) to 23% (Sierra County) of workers; 6% (Catron County) to 13% (Grant County) of employment was in the wholesale and retail trades. Construction jobs accounted for 5% to 7% of jobs in the four counties (Bureau of Economic Analysis, 2006).

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SECTION 3

Watershed Conditions

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CLIMATE

As across much of the Southwest, the climate of the Gila watershed exhibits high intra- and interannual variability. Streams in these regions, even under pristine conditions, are prone to greater instability than those in regions with more regular climate patterns (Graf, 1988; Nanson, 1986; Wolman & Gerson, 1978).

Rainfall across the watershed varies from an annual average of 12 inches in the low desert elevations to 36 inches in the high-elevation headwaters. Snow in the mountains has been recorded at depths of 165 inches and can contribute large amounts of runoff in the spring melt (NRCS, 2004). Typically, the greatest amounts of precipitation fall in the monsoon season of July and August; monsoon rainfall is often highly localized. The highly variable climate regime is partly responsible for the region's unpredictable and sometimes extreme runoff events.

Widespread drought has been the rule during the last few years in this region. The region's climatic variability was well demonstrated this year by Palmer Drought Severity Index maps for the periods ending June 17 and August 26, 2006 (Figure 15: NOAA, 2006).

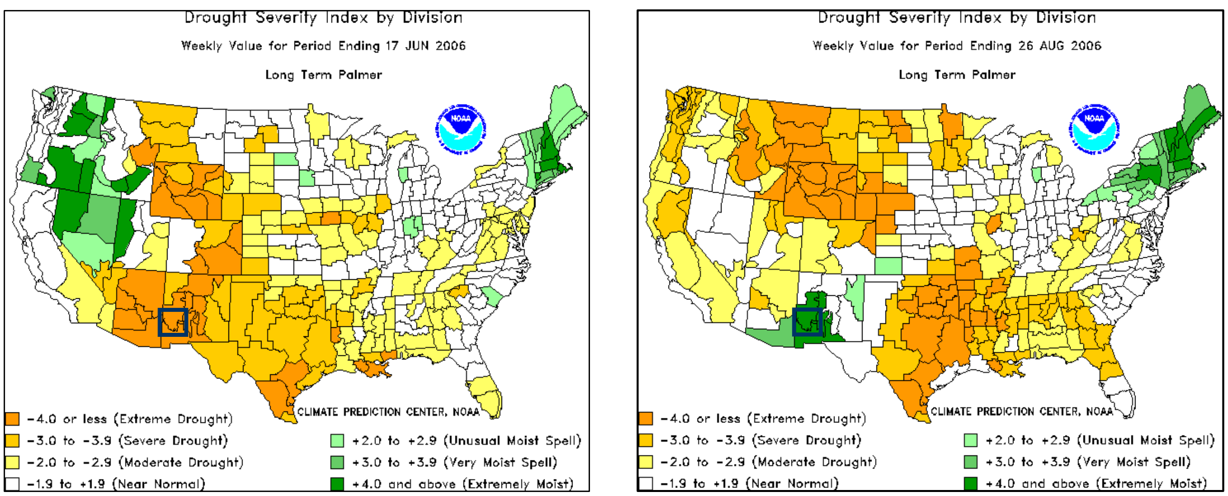


Figure 15. Palmer Drought Severity maps for June 17 and August 26, 2006. An intense monsoon season reversed the watershed's short-term rating from "extreme drought" to "extremely moist" over this nine-week period. Blue square outlines approximate extent of the Gila watershed in New Mexico.

Even with record-setting amounts of precipitation received during the 2006 monsoon, however, NOAA (2006) points out,

> the degree to which drought-related impacts would continue to be a concern would depend on what time scale a given class of impacts responds to. Obviously, in this situation, wildfire danger would decline sharply, at least for the immediate future...topsoil moisture would be substantially recharged if the precipitation lasted long enough, thereby providing at least a temporary respite for

non-irrigated agriculture. On the other hand, reservoir stores might increase only slightly, having been depleted by a few years of precipitation failing to keep up with demand, and ground water levels and/or well water depth, if they were low, might be barely (or at best belatedly) affected by the heavy short-term rains, since much of the water was likely dispersed by swollen streams or absorbed by parched topsoil.

Much of the rainfall received during the 2006 monsoon did become surface runoff, eventually creating widespread flooding across the watershed. US Geological Survey (USGS) stream gaging stations (Map 1) reported numerous record-setting daily mean streamflows during the period (USGS, 2006). Substantial changes in channel morphology, whether the result of deposition, erosion, or both, occurred in many places. The effects of extreme erosion were evident on some streams (Figure 16).

Figure 16. Damage to Pueblo Creek bridge, GNF, during monsoon rains in 2006. Pueblo Creek is a tributary of the San Francisco River. Photo courtesy C. Koury, GNF.

HISTORIC CHANGES IN CONDITION

Current conditions on the Gila watershed and in its streams reflect the cumulative interactions of climatic patterns with historic and ongoing land use activities. Along with the extreme climatic variations demonstrated by the current drought and the 2006 monsoons, much of the watershed is characterized by easily erodible soils and steep slopes. These are capable of delivering large sediment loads to streams. The combination of factors makes parts of the watershed highly susceptible to vegetation or soil loss and delivery of water contaminants to stream channels. Inappropriate land use practices that contribute to high rates of surface runoff, sedimentation, and floodplain instability exacerbate these effects, particularly during periods of drought or epsiodes of high-intensity precipitation. Historic changes in condition of the watershed include altered runoff, sediment transport, and flow discharge regimes; disrupted floodplain function, and major changes in stream channel morphologies.

The return of hydrologic and riparian systems to a previous condition can be slow in this region—and in some places may be impossible over anything approaching human time scales. Current conditions on the watershed may therefore continue to reflect the effects of some anthropogenic impacts that date back nearly two centuries, as well as more recent activities. In addition to the recent (and perhaps continuing) regional drought, there were long-term droughts in the late 19th and mid-20th centuries. Conversely, above average precipitation in some years between 1980 and 1995 caused a series of major, low-frequency flood events and considerable morphological change in many channels, as did more recent flooding in February 2005 and during the summer of 2006. In short:

- Land management decisions are often forced to balance economics with not only the effects of current climate and land use practice but with the long-term consequences of earlier activities.
- An extensive literature related to the causative factors for changes in watershed condition in this region exists. The factors are complex and variable. Research and monitoring to clearly establish the most effective means of improving watershed condition are primary needs. Previous work suggests that the results of some remediation practices (e.g., prescribed thinning) are often quite site-specific (for example, see Belsky, 1996). Some suggested monitoring protocols are addressed in Section 6.

Forest and herbaceous cover

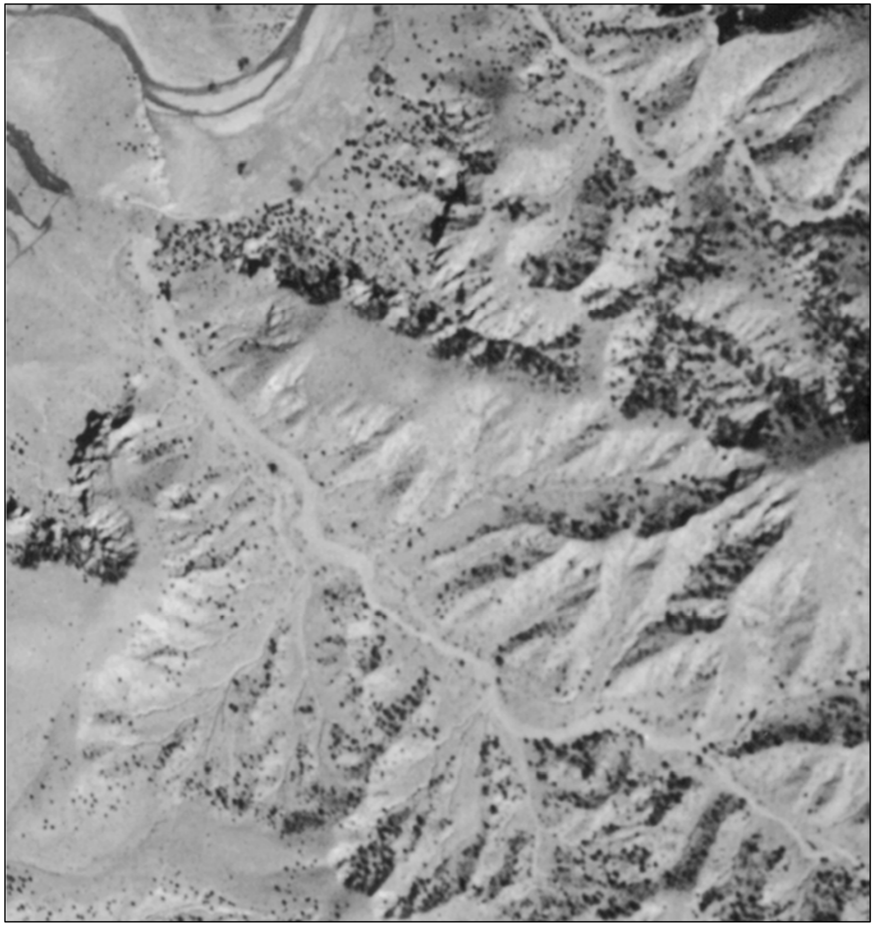
Woodlands and forests occupy a greater percentage of the western landscape than they did a century ago. A tremendous expansion in ponderosa forest and pinyon-juniper woodland area and density has occurred in this region over the past 100 years (Miller & Wigand, 1994). Periodic expansion and contraction of vegetation range are nothing new (Swetnam & Betancourt, 1998), but scientists refer to this one as "unprecedented" (e.g., Belsky, 1996; Wilcox, 1996). Dense tree stands now occupy many areas described as "open, park-like forest" 150 years ago, and woodlands have expanded into former meadows and grasslands. These changes are linked to losses in native ground cover, including grasses, as the root systems of trees outcompete those of grasses for water and nutrients. Inverse relationships between canopy cover and herbaceous cover have been found; Jameson (1967) derived a series of equations describing these relationships with data from ponderosa pine and pinyon–juniper stands in northern Arizona.

Figures 17 and 18. Top, the landscape from the Pinos Altos Ranger Station, established in 1907, ca. 1915 (courtesy USDA Forest Service). Bottom, the view today.

On the Gila watershed, Miller (1999) examined vegetation changes between 1935 and 1991 on about 22,000 acres of the Negrito Creek subwatershed, near Reserve. Elevations ranged from approximately 5600 to 9900 feet. Historic grazing, climate, and fire patterns for the period were typical of many Gila National Forest lands. Relatively uncanopied area (grassland, savanna, and open woodland) decreased from about 50% to 18% of the area during the 56-year period. Grassland area alone decreased by 90% (from 10% to 1%); more than a third of 1935 grassland was occupied by relatively dense woodland or forest by 1991. These changes were evident both on "gently sloping mesas" and on steeper slopes. In areas where mixed pinyon-juniper stands have replaced open savanna, Miller and others (e.g., Hill et al., 1992; Potter 1957) conclude that pinyon is likely to become the eventual dominant vegetation type. At higher elevations, ponderosa pine canopy is also denser than a century ago. Boucher at al. (2000) cite a number of studies that describe pre-20th century conditions on what is now the Gila Wilderness as a near-continuous herbaceous understory, composed predominantly of Arizona fescue, mountain muhly, and screwleaf muhly, beneath an open-structured forest canopy cover. Miller found that a majority of previously "open" ponderosa forest changed to relatively closed canopy type between 1935 and 1991. Extensive Ponderosa pine incursions into higher-elevation grass stands are also documented (Miller, 1999; Arnold, 1950).

At lower, drier elevations, the increasing density and extent of woody species like mesquite are also documented: Hennessy et al. (1983) reported that honey mesquite attained "complete dominance" on study transects in the Jornada Experimental Range between 1935 and 1980. Bahre and Shelton (1993) reviewed 20 papers published between 1891 and 1991 that examined vegetation changes in semi-arid southeastern Arizona at elevations of 3000–5000 feet, analogous to the lower elevations of the Gila watershed in New Mexico. Nineteen papers reported an increase in woody species and 18 reported a corresponding decrease in grass species. Mesquite particularly tends to successfully colonize badly degraded sites. Grass cover is often inversely related to mesquite density. Glendening and Paulsen (1955) found mesquite seedling establishment was 16 times greater on bare soils than in "vigorous stands of perennial grasses," perhaps due to seedling shading by grass (cited in Bahre & Shelton, 1993).

Probable causes. A combination of changed fire frequencies, grazing history, and drought are most often implicated in meadow-to-forest conversion and loss of native grass cover across the Southwest. Interactions among these and other factors are complex, however. In the Black Hills, Shinneman and Baker (1997) found detailed 1899 descriptions of extensive patches of extremely dense ponderosa forest, and concluded that "climatic and topographical differences were likely responsible for variations in ponderosa pine forest densities" (p. 1284). Dense tree stands were generally concentrated in protected ravines and canyon bottoms, and intense ("stand-replacing") fires sometimes burned large areas under these conditions. Open, "park-like" forest types were more common on warmer, drier, more exposed sites; these probably experienced fire more frequently and at less intensity. Likewise, research on the Gila National Forest shows that on drier sites, natural fires burned on 2- to 12-year cycles; on moister (mesic) sites, at about 15-year intervals (Swetnam, 1990; Covington & Moore, 1994; both cited in Boucher et al. 2000).



1935

1996

Figures 19 and 20. Typical expansion in tree cover range and density during the 20th century on parts of the Gila watershed. The area shown is just south of Bear Creek near its confluence with the Gila River, at an elevation of about 5000 feet. Left, 1935; right, 1996. Bear Creek is visible in the upper left of each image. The area shown covers approximately ½ square mile (adapted from Soles, 2003).

To further complicate matters, Dobyns (1981) notes historical (ca. 1830 to 1870) evidence on the Gila watershed of hunting with the use of large-scale fire drives by Western Apache. He believes that these fires were set on a nearly annual basis during the dry season and burned extensive areas, and concludes that they were likely to have suppressed shrub and tree growth across much of the region. Numerous researchers report that fire effectively suppresses mesquite recruitment, killing up to 60% of mesquite less than ½ inch in diameter (13 mm) in several studies reviewed by Bahre & Shelton (1993). Betancourt et al. (1993), citing evidence of widespread woodland depletion by Anasazi cultures around 900 A.D., also point out that it is possible that "current [pinyon-juniper] 'invasions' represent recovery from impact only two to three tree generations ago."

Although the interactions are complex, research strongly implicates changes in land use, fire regime, and climate in the region's historic and widespread decline in herbaceous cover (Belsky, 1996; Boucher, 2000; Miller, 1999). Frequent natural fire is known as a "disturbance regime," and in this region forests have adapted to its presence over the course of millennia. Beschta et al. (2004) call it "arguably" the most important of the disturbance regimes in this area, as a primary influence on seedling survival, soil productivity, tree mortality, and other factors.

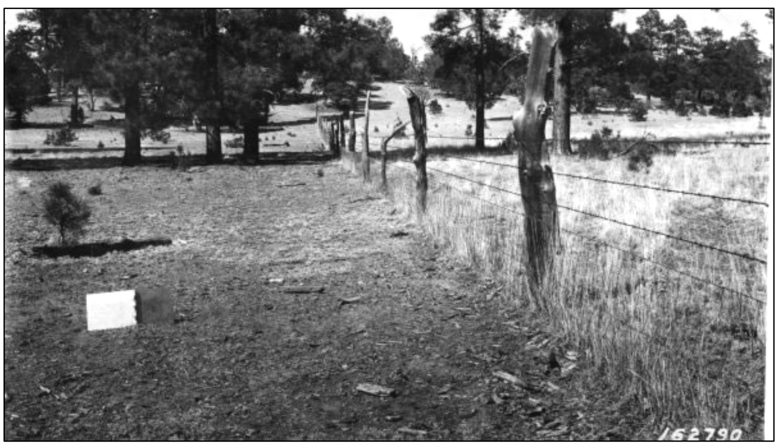


Figure 21. A 1921 GNF photo documenting the "difference in utilization of forage inside and immediately adjoining a lambing pasture." Courtesy USDA Forest Service.

Intensive grazing reduces the effectiveness of natural surface fire by removing fine surface fuels (Bahre & Shelton, 1993; Cable, 1967; Miller, 1999; Savage, 1991). By the late decades of the 19th century, stocking rates of both sheep and cattle were extremely high. Historic sources report that between 1875 and 1882, up to 60,000 sheep were grazed annually on present-day GNF lands (Cooper (1960; cited in Miller, 1999). Wooton (1908) estimated stocking rates of 10 to 16 head of cattle per section in the area, in addition to the large numbers of sheep. An early report on *Forest Conditions in the Gila River Forest Reserve* notes the economic importance of grazing in the region, but observes that it had exacted a heavy toll on the land and "required careful attention and supervision to prevent the almost inevitable result—the total destruction of the grass roots by overstocking" (Rixon, 1905). Grazing effects were heightened by drought conditions that prevailed in the region between 1860 and 1896; drought overlapped the period of peak stocking rates between 1889–1890. During World War I, another rapid increase in stocking rates occurred, as the Forest Service supported increased cattle and sheep production for the war effort. But a 1919 drop in prices continued through much of the 1920s, and ranchers were unable to profitably sell their animals. Planned reductions in stocking rates were delayed (USDA Forest Service, 2006).

The natural fire regime on the Gila was of course also affected more directly by federal policy aimed at suppressing fire on federal lands. As a consequence, the role of natural fire on the watershed was lost for most of the 20th century. Swetnam and Dieterich (1985) examined fire histories in pure stands of ponderosa pine on and near the Gila Wilderness and found an abrupt decrease in fire frequency after 1900: prior to that time, fires generally burned areas within their study region every 4 to 8 years (with some fire-free intervals of up to 22 years, corresponding to wetter-than-usual periods). Between 1949 and 1992, less than 5% of Miller's (1999) Negrito Creek study area burned, resulting in a fire cycle (the amount of time required to burn the entire area) of more than 1,000 years. The fire ecology literature strongly supports the idea that the widespread practice of total fire suppression operated to the detriment of herbaceous cover and diversity by enhancing dense tree growth. Arnold (1950) studied herbaceous cover in five grazing exclosures established in 1912 in a heavily logged ponderosa forest area near Flagstaff, Arizona. Favorable conditions for ponderosa regeneration occurred in 1919, producing a dense crop of seedlings. Grass cover within the exclosures declined substantially beginning in 1925, despite the lack of grazing. Arnold concluded that shading and competition for water and nutrients from what had become a dense ponderosa sapling thicket were responsible.

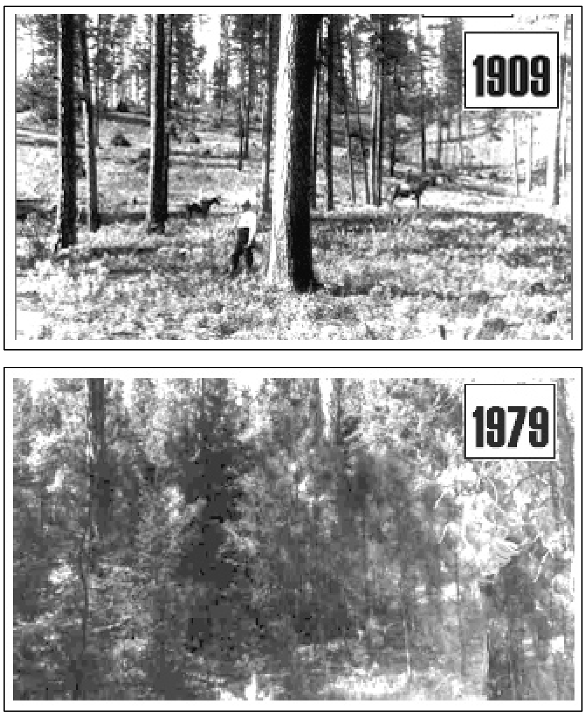


Figure 22. Photographs showing the relative densities of ponderosa forest cover in 1909 and 1979 (from the *Taylor Creek WRAS,* 2005).

Watershed implications. Increased tree or shrub canopy and concurrent loss in herbaceous cover has several implications for watershed condition. The roots of grasses and forbs create passageways that allow water to pass into soils, and their foliage reduces rainfall impact on soils. When bare ground replaces native herbaceous cover, surface water runoff is accelerated. Reduced soil water infiltration and increased rates of sheet erosion accompany this effect (Wilcox et al., 1988; Wilcox et al., 1996) to varying degrees, depending on the influence of other variables like slope, soil depth, and litter or rock cover. A number of studies of the effects of tree thinning or clearing on water yield have reported increased *streamflow*, although the results were generally 1) dependent on average levels of precipitation (in conifer forests, areas where average annual precipitation was greater than 40 inches showed the greatest response); and 2) typically short-lived (Bosch & Hewlett, 1982; Davis, 1984; also see Schumann's 2005 review). However, increased streamflow that results only from higher rates of surface runoff reflects no net increase in soil moisture storage and probably indicates increased sediment delivery to streams. Canopy cover effects on rates of snow sublimation (direct conversion of snow to water vapor), are unclear, but research shows that snow intercepted by the tree canopy can be subjected to much higher rates of evaporation than snow on the ground (Satterlund & Adams, 1992), also reducing potential soil moisture. The increased rates of surface runoff that accompany loss of herbaceous cover, in addition to anecdotal evidence, also implicate high tree densities in reduced base flow from local springs and seeps. Yet controlled long-term studies of this relationship are lacking.

The roots of native grass and forb species bind the soil, and their loss makes soil more vulnerable to erosion. Where herbaceous cover loss occurs in conjunction with soil disturbance, exotic and/or invasive woody species tend to colonize these areas. These species often form deep tap roots that are less suited to sod formation than the dense root mats formed by many native grass species. On lower-elevation sites, woody or shrub species like rabbit brush now dominate large expanses of disturbed soils; Wooton (1908) reported that snake weed and Russian thistle had replaced grass cover on "thousands of acres" of New Mexico rangeland by the early years of the 20th century. This vegetation creates conditions less vulnerable to surface erosion than bare soils, but the exposed ground between plants is often lost during runoff events, leaving the plants' roots clutching a "pedestal" of soil. In 1954, a report on erosion in the Gila River watershed by the Soil Conservation Service also noted the loss of herbaceous cover that had previously "protected the surface soils and created optimum infiltration conditions" (p. 4).

Among the most profound implications of increased tree canopy density for water quality is increased risk for catastrophic wildfire. Dense canopy cover creates conditions more conducive to crown fire. Ponderosa average a 33% needle loss each year, and this tends to accumulate around the base of the tree, along with bark and twigs, forming debris piles that burn or smolder at very high temperatures (Boucher et al., 2000). Intense wildfire can destroy the seed sources that allow recovery of herbaceous groundcover: Griffis et al. (2001) found that in ponderosa pine forests of northern Arizona, regrowth of native grass species after intense wildfire was much less than after any other treatment. Complete loss of vegetation and canopy cover in areas that experience high-intensity burns leaves soils highly vulnerable to erosion (see Robichaud, 2000).

Figure 23. Gilita Creek, GNF, August 2006. The Bear Wildland Fire burned across more than 51,000 acres. Fire intensity in some areas was extreme. [Photo courtesy C. Koury, GNF.]

Parts of the Gila watershed experienced the combined results of wildfire and heavy rainfall during the summer of 2006. More than 80,000 acres of the GNF burned, in some places at very high intensity, shortly before the arrival of monsoon rains (USDA GNF, 2006). When heavy rains fall on recently burned areas, particularly in steep topography, extremely high rates of surface runoff, erosion, and transport of fine-grained sediments and ash into stream channels result (Figure 23). Streambed sedimentation and degradation of water quality may follow. High rates of surface runoff entering stream channels from barren surfaces can also create extremely erosive conditions within stream channels, further degrading water quality with sediment eroded from the stream's banks and bed.

Research into global-scale effects on southwestern forests and grasslands may increase the urgency for implementing management measures directed at reducing forest density and the potential for high-intensity, large-scale fire. Increasing atmospheric CO_2 levels have been implicated in woody species encroachments into former grasslands (Betancourt, 1996; Polley et al., 1996). Research correlating warmer spring and summer temperatures and earlier snowmelt dates with greater wildfire frequency over a longer fire season suggests that an increased potential for these fires may be with us for some time (Westerling et al., 2006).

Floodplains, stream channels, and gully formation

Evidence from historic maps, anecdotal accounts, and aerial photography show that stream channels on the Gila watershed experienced substantial and widespread changes in form (morphology) during the 20th century. The changes include incision, widening, and extreme lateral movement. Extensive gully formation through valley bottoms and wet meadows has also occurred since the 1800s. The consequences of these changes are loss of floodplain soils, lowered water tables, changes in vegetation types and density, increased rates of soil loss, and continued channel instability.

Probable causes: Interactions among climate and a variety of abruptly-imposed changes in land use are most often cited for historic channel incision and gullying effects. Agricultural lands on the watershed, including irrigated pasture, are generally located in stream valley bottoms. Nineteenth-century settlers recognized that these generally provided the most expansive areas for agriculture, and were among the most accessible and best-watered lands available. Past centuries of flooding left deep deposits of fine-grained soils and dense vegetation created networks of roots that held the soil in place.

Wooton (1908) described unfarmed river valleys of New Mexico that were still occupied by bunch grass and other sod-forming grasses, or by sedge and rush species where the alluvial water table was high enough (p. 14). These vegetation species increase soil structure development, infiltration rates, soil organic components, and water retention capacity. Intensive stocking rates removed streamside vegetation and compacted floodplain soils. As elsewhere, 19th century plowing techniques destabilized floodplain soils, leaving them highly vulnerable to flood erosion. In some valleys, more than 90% of arable floodplain lands were eroded in less than three decades (Dobyns, 1981). Rich (1911) summarized a bleak account of the effects of cultivation and "sodding" techniques on the valley of the Blue River, a 600-sq. mi. Arizona tributary of the San Francisco:

> The floor of the canyon of Blue River...was in 1885 covered with grama grass, hardwood trees, and pine. The stream had many trout. In 1900 floods began to cut an ever-widening channel and active erosion was in full swing by 1906. In 1921 the bottom of the canyon was ruined for agriculture and pasturage. The forty-five ranches with three hundred inhabitants that existed in 1900 were decreased to twenty-one ranches and ninety-five people in 1921.

Roads and trails also played an important role in changing stream channel conditions and gully formation. Duce (1918) wrote a detailed description on the tendency of hoof compaction to maximize the erosive effects of the surface runoff that converged on these trails, labeling them "miniature torrents" during rainstorms. Swift, in 1926, described cattle trails that were "well-defined" but ungullied in 1900, "soon formed into small arroyos," and eventually into major ones. Chamberlin, traveling through the Gila watershed in 1849, observed many instances in which his party discovered a "good [hard-packed] trail" which they supposed to be Kearney's 1846 route (Bloom, 1945). A number of early reports (e.g., Leopold 1921; Rixon 1905) noted that roads were typically constructed in valley bottoms, as these provided the easiest routes for wagons through rugged terrain.

Figure 24. A streamside road in the GNF, 1932. The original caption notes that "willows have come in along a creek after it was fenced." Courtesy USDA Forest Service.

Rixon’s 1905 report of conditions on the Gila River Forest Reserve was particularly detailed in relation to historic logging activities. In 1903, Rixon surveyed each township within the Reserve to document the amounts of “merchantable timber” that had already been removed, and what remained. Rixon documented about 5 million board feet of timber that had been logged “in a desultory manner” from the Reserve, most of it in parts of only seven townships (less than about 250 square miles). Steep slopes and extremely difficult road access limited logging through much of the watershed. Noting the difficulty of transporting logs by road, Rixon suggested that railroads would have to be constructed through the steep canyons of the watershed and numerous sawmills constructed to provide adequate lumber processing capacity near logged areas (Figure 25). He described most of the trees he noted on lower hillslopes and mesa tops as “scattered timber” of oak, pinyon, or juniper; nearby settlers generally cut these trees for their own use.

Figure 25. Hauling out logs from the Black Range, 1912. (Photo courtesy USDA Forest Service.)

The most extensive logging occurred in streamside areas. Rixon’s report notes repeated cases across the watershed in which logging operations were “confined to the timber standing immediately along the edges of the creek bottom[s].” Much of this logging was conducted to provide power for mining and ore processing operations. Most of the few areas in which Rixon noted extensive hillslope logging had occurred were near mines, suggesting that more easily accessible timber within the canyon bottom had already been removed. These operations would have contributed to compacting and destabilizing stream banks and increased sediment runoff from skidding areas and road construction. Permanent downcutting of streambeds may have accompanied these effects along some stream channels. Current logging activities are of limited extent on the Gila National Forest and watershed. One consequence of the increased forest density described earlier in this section has been to focus attention on logging techniques and economic uses for small-diameter trees.

The region's geologic history created large deposits of various valuable minerals, including gold, silver, and copper. Significant deposits were found in the Mogollon, Black Range, and Burros Mountains. Mining in the area declined before World War I, but resumed at increased production levels after the war. Mining operations varied greatly in scope and type, from the large-scale activities of the Tyrone copper mine south of Silver City, to individual prospectors working a single claim. Copper mining at Tyrone, in the Mangas Creek headwaters, began in 1879, generating "thousands of tons of high grade oxides," and construction of a town and large smelting plant before 1900 (Mogollon Mines, 1916). The large volumes of water required for ore processing can flush significant amounts of sediment, often containing heavy metals or other toxins, into streams and rivers. Tyrone remains the largest mining operation in the Gila watershed, and extensive reclamation of the site is currently underway. The details of the reclamation plan, particularly as related to stockpiles and potential groundwater contamination issues, are still being resolved (GRIP, 2006; NM EMNRD, 2005). Numerous smaller mining operations were also established, especially in the Mogollon Mountains. Most of these smaller mines were abandoned by 1905, but open pits, unreclaimed tailings, and mining adits remain. Many may still contribute to accelerated rates of localized erosion and sedimentation containing relatively high concentrations of contaminants. The roads constructed to transport equipment and to haul ore away for processing or sale were often marvels of human determination, but they also created concentrated zones of accelerated surface runoff.

Figure 26. Heavy equipment destined for the gold mill on Whitewater Creek, ca. 1893. The original caption notes that “loads like this one required teams of up to 40 horses to cross the national forest.” (Courtesy USDA Forest Service.)

Watershed implications. In addition to increased volume and rates of surface runoff, direct impacts to stream systems are created through grazing and/or trampling of riparian herbaceous and tree cover on creek banks, particularly under heavy grazing pressure (Holechek, Baker, & Boren, 2005) or when grazing occurs year-round (Chaney, Elmore, & Platts, 1993). Native riparian herbaceous species, as well as emergent cottonwood and willow, are highly palatable to herbivores. Loss of vegetation and their root structure tends to destabilize stream banks and consequently to increase sediment inputs to the stream (Belsky, Matzke, & Uselman, 1999; Groeneveld & Griepentrog, 1985). Developed soil structure and vegetation diversity on floodplains was destroyed by some historic farming practices and equipment that broke up and overturned sod; many of these former floodplains today are characterized by dry, infertile soils. Willows and other early-seral stage vegetation frequently re-colonize these zones first (Campbell & Green, 1968; Stromberg et al, 1997). Levees constructed in some places to protect farmland were often built of material excavated from the floodplain, destabilizing channel banks, introducing additional sediment loads, and sometimes leading to channel incision (e.g., USDI Bureau of Reclamation, 2004).

Lowered groundwater tables or lack of seed sources may inhibit the return of the vegetative diversity represented by other species like sedges, rushes, and grasses. Stream channel sedimentation and decreased streamflow depth increases stream temperatures, potentially exacerbated by lack of shade cover. Sediment delivery to stream channels is increased, affecting water quality during runoff events and possibly leading to sedimentation of aquatic habitat and subsequent impacts to the species that depend on these habitats, especially fish species. Native fish species may have difficulty adapting to increased sediment loads; sediment interferes with breathing and reproduction and can suffocate fish eggs and insect larvae (Klapproth & Johnson, 2000). (However, a number of researchers point out that careful studies of cause-and-effect between land use activities, particularly grazing, and fish species native to much of the Gila watershed, are lacking—for example, see Holechek et al., 2005; Medina & Rinne, 1999; Rinne, 1985).

Figure 27. Typical gully on the Gila watershed, 2006. Courtesy SWQB, Silver City.

In conjunction with other impacts, high rates of surface runoff over exposed soils can lead to stream channel widening, or to rill and gully formation, particularly where incision has created a drop in the base level control imposed by the main stream channel. Gully networks may result, like those described by Wooton (1908): "They all say that years ago the ground was level enough to drive over with a wagon where it is now almost impassable for a horseman" (p. 19). Gully networks effectively drain groundwater tables throughout the affected area. Vegetative cover loss is exacerbated. Surface soil loss in gullied landscapes can be much greater than simple sheet erosion from ungullied regions (Moir, Ludwig, & Scholes, 2000). The effects on watershed soil conditions were well-documented by mid-century. In 1959, the Grant SWCD described the general range and hydrologic conditions as poor. The Soil Conservation Service (precursor of the NRCS) produced a number of evaluations of regional soil conditions, reporting in 1954, for instance, that 73 percent of the Gila watershed was affected by moderate to severe erosion.

Even earlier, the federal government had employed the Civilian Conservation Corps in efforts to improve soil condition and alleviate gullying on the watershed. The CCC, which employed jobless young men and older World War I veterans to reconstruct "the nation's environmental infrastructure" (Helms, 1985), is among the better-known of the 1930s New Deal programs. In New Mexico, more than 32,000 men worked in CCC camps (Bingaman, 2006), including at least 15 camps that operated in and near the watershed between 1933 and 1941 (CCC Alumni, 2000). Camps were established from near the Arizona state line to Beaverhead, including sites like Glenwood, Apache Creek, Reserve, Gila, Buckhorn, Mangas, and Redrock. Most, but not all, of the work took place on federal and state-owned lands. CCC efforts followed USDA soil erosion control guidelines, limiting work to "controlling gullies by means of soil-saving dams, forest planting and vegetation" (Helms, 1985). On the Gila and nearby watersheds, workers constructed tens of thousands of sediment control structures ranging from one-rock dams and water spreaders to more elaborate efforts. An historic map of structures built in the Little Walnut drainage near Silver City shows a density of almost 1500 per section (USDA GNF, 2005a). Many structures failed due to design or construction, but hundreds continue to perform their sediment-capture function. Some of these are quite evident. Close observation often reveals others that are now hidden under captured sediment and the vegetation that has established on it.

Figure 28. Historic erosion-control structure in the Burro Mountains, 2005. The channel and floodplains above and below the structure are intact, stable, and well-vegetated with a diversity of species.

Effects from roads and trails are often linked to the historic tendency to construct them through valley bottoms, parallel with the creek channel. During flood or runoff events, the compacted or rutted surfaces of these roads capture and funnel water. Under some conditions, the valley floor may erode to such an extent that the roadbed is "captured," leading to loss of entire floodplain surfaces and stream channel widening. Under others, the previous channel is abandoned and the incised roadbed simply becomes the new and actively eroding channel. Where this has occurred, the historic channel may remain visible as a meandering swale, while the active channel is deeply incised into higher-elevation ground on the former floodplain. Road crossings, where vegetation was frequently removed or destroyed, banks broken down, and stream beds compacted, can cause instability that typically leads to channel widening and/or lateral movement, while creating significant localized sediment sources. Heavy use further compacts soils, destroys vegetation, and destabilizes stream banks, contributing additional stream sediment loads. The resilience of riparian systems and their ability to successfully regenerate is reduced under these conditions, inhibiting recovery.

Figure 29. At this road crossing, a trolley transported vehicles across the Gila River until construction of Iron Bridge south of Cliff in 1916. Historic maps show the trolley crossing in the same location as the present-day Highway 211 bridge. Courtesy Silver City Museum, all rights reserved.

Roads and trails continue to affect watershed condition. Road construction and reconstruction on federal public lands has caused substantial ecological effects including stream sedimentation and other water contamination, introduction of nonnative plants, and fragmentation of wildlife habitat. These effects may persist for decades (USFS, 1999). Dense road networks cover parts of the GNF. Roads used for forest management, recreation, logging, grazing access, and other purposes cover a total of 7400 "inventoried" miles. Road density averages 1.54 mi per square mile (USDA GNF, 2003). The Forest analyzed condition, economic benefit, and potential hazards created by 724 miles of forest roads in late 2002 (USDA GNF, 2003). Among a number of indices assessed in the report are various parameters associated with the roads' potential effects on water quality and stream condition. The report notes that:

> Roads can have several effects on the hydrology of a watershed. These can include interception of rainfall directly on the road surface and cutbanks, expansion of the channel network, conversion of subsurface flow to surface flow, concentrating of flows, [and] diversion of water from normal flow paths...Road-stream crossings have the potential to directly and indirectly affect local stream channels and water quality. These crossings can be a major source of sediment to streams...Higher volumes of traffic and an increased density of non-paved roads, additionally, add to the negative impacts that sedimentation may cause to water quality and fish and macro-invertebrate habitat. [34-36]
>
> Loss of trees and woody riparian species, within the road corridor and adjacent to streams, can potentially reduce shade coverage, expose surface waters to more sunlight, and increase water temperatures. [p.38]

The report concluded that more than 200 road segments totaling nearly 300 miles (of the 724 miles analyzed) demonstrated high risk for hindering attainment of state water quality standards. Some of these roads and trails will be closed when the GNF completes its travel management planning process, currently underway. Initial efforts were focused in the Burro Mountains region (USDA Gila National Forest, ca. 2004). Planning is now forest-wide; proposals for the designated travel system will be submitted by Forest Districts in spring, 2007 and GNF expects to publish final maps of the system by 2009 (USDA Forest Service, 2006).

Wetlands

Bryan, in 1926, wrote that "early settlers in the region can remember the time when many of these valley flood plains were intact and the floods spread widely. At that time, meadows, belts of cottonwood or willow trees, and even swamps characterized the floors of valleys that now support only scattered sage, greasewood, or mesquite."

Figure 30. Gilita Creek flowing through a wet meadow in 1931. (Courtesy USDA Forest Service.)

Rixon (1905) documented perennial springs on the San Francisco watershed, and Wooton (1908) noted that "not infrequently in the mountainous regions [of New Mexico] there occur relatively small basin-like areas, into which considerable of the water of the surrounding slopes drains. Small marshy or swampy areas are thus formed..." Wooton described the vegetation species of these areas as various sedges and water-loving grasses. However, he notes, many of these wetlands were being transformed as "generally such places are enclosed, partly drained, and the crop cut for hay" (p.13). Substantial wetland area throughout the watershed was probably lost by early in the 20th century. Various wetland types occupy different zones in this region (Minckley & Brown, 1982), and former wetlands are often evident in streambank soils revealed during channel incision, or in historic wet meadows fed by headwater springs. Both often show remnants of characteristic wetland soils and vegetation (Lyon, 1993); some historic wetlands are well documented.

Mangas Creek is a significant tributary to the Gila River in the Burro Mountains (see Map 5, Section 4). In 1848, Emory reported that the ground around Mangas Creek a few miles from the Gila was so "miry" that even very thirsty mules would not get near it; a soldier who took the wrong trail and "got on the wrong side of the treacherous creek" had to backtrack two or three miles to ground firm enough to allow him to cross the creek (Emory, 1848/1951; p. 99). Rich (1911; cited in Bryan, 1926) identified the 1881–1891 period for the initiation of stream channel "trenching" (incision) in tributaries to Mangas Creek. The latter date is probably more accurate. In 1883, a shallow lake covered about 1 ½ miles of the floor of Mangas Valley; settler James K. Metcalf noted that "nearly 1,000 springs" fed the lake. He stocked it (along with five artificial ponds) with German carp. The lake and surrounding wetland were gone by 1908.

Residents of the nearby communities of Cliff and Gila also recall accounts from the early years of the 20th century that described the Gila River and Duck Creek valleys around their confluence as an extensive marsh, inhabited by ducks and geese (Soles, 2003). The Gila River–Duck Creek confluence today supports a substantial growth of woody riparian vegetation, but the wetland no longer exists. Duck Creek now occupies a deeply incised ephemeral gully throughout its 20-mile course from the gentle hills northwest of Cliff to its confluence with the Gila.

Figure 8. Mangas Valley, Near Mangas Springs. Cut Out in One Night as Result of An Ordinary Rain of About Two Hours' Duration.

Figure 31. Mangas Valley, ca. 1905. One example of the early results of runoff, resulting in lateral and vertical incision that drained the water table supporting this former grass- and sedge-dominated wetland. Much of the erosion creating the present-day gully through Mangas Valley occurred before 1905, leaving a channel "75 feet wide and 18 to 20 feet deep" (Wooton, p. 22).

Probable causes. Incision and gullying of wet meadows and marshes caused much of the loss of historic wetlands. A number of historic factors are probably responsible. Wooton (1908) attributed the massive incision and draining of the water table that previously supported an "abundant" growth of grasses and sedges entirely to poor grazing management. "[R]emoval of the grass and other small herbage will cause the run-off of a region to change from a gentle seeping into and through the soil to a surface flow, which becomes in the end rapid, violent, and destructive..." (p. 23). He observed that in his conversations with "stockmen of the Territory [including] a number of the 'oldest inhabitants...the almost invariable reply to questions as to the past condition of a range was a statement that much damage has been done to the range by overstocking...The arroyos show where trails have been and where not only the grass but even the soil is gone as the result of the overstocking" (19-20).

The floodplain-destabilizing effects of historic farming practices, described earlier, may have contributed to near-channel wetland losses, exacerbated by drought during the 2nd half of the 19th century. The Lyons and Campbell Cattle Company headquarters was established on Duck Creek around 1882, about 12 miles upstream of its confluence with the Gila River. The *Mogollon Mines* boasted in 1916 that Lyons was among "the greatest corn growers in the State." His corn and alfalfa crops, grown on hundreds of acres along Duck Creek and the Gila River, were irrigated from a reservoir constructed on Duck Creek that impounded "several hundred acres" of water. By 1927, 2,900 acres were irrigated and farmed in the Cliff-Gila Valley (Black, 1927).

Figure 32. Duck Creek near its confluence with the Gila River, May 1999. Dense riparian growth lines the creek’s banks, but the channel is deeply incised into its former floodplain. Marsh conditions and vegetation types historically present in the area are gone.

Earlier impacts may also be implicated in gullying and subsequent wetland loss. Dobyns (1981) speculates that Anglo horses and cattle only heightened trailing and gullying effects begun prior to 1840 by large Apache horse herds. He suggests that grazing by these herds (which he estimated at more than 30,000 on the Gila watershed) may have "diminished the biomass, and especially the grasses, sufficiently to weaken vegetative cover...[so that] the large flocks and herds of the 1870s and 1880s constituted merely the final blow" leading to "regional erosion on a grand scale" (88-89).

A significant and less frequently mentioned factor in historic wetland loss is the effect of intensive trapping on the watershed’s beaver populations between 1830 and 1850. Accounts from the 1820s through mid-1830s chronicle very high densities of beaver on streams and rivers throughout the watershed (Clarke, 1966; Dobyns, 1981; Scurlock, 1998). As on other streams across the western U.S., they were nearly eliminated by 1850.

Beaver are perhaps the most widely acknowledged example of a “keystone species,” one whose activities have disproportionately large effects on the surrounding environment. Beaver dams form ponds and low-velocity backwater areas that substantially reduce the potentially erosive effects of floods. Where extensive series of dams have been constructed along a stream, each pond captures and slows water moving downstream during a flood. Since beaver ponds raise local water table elevations, they support increased vegetative biomass along stream banks and overflow channels, another inhibition to erosive effects from floods (Apple, 1985; Parker et al., 1985). Beaver also significantly modify the composition of streambank vegetation communities (Naiman, et al., 1988), in part by thinning cottonwood and other palatable tree species, reducing canopy cover, and allowing increased sunlight to penetrate to the floodplain.

Extensive beaver populations can enhance perennial flow throughout a watershed with their dam-building and ponding activities. The elevated water tables around beaver ponds increase the amount of water surface in contact with streambanks, improving infiltration and streambank storage and creating new zones for wetland vegetation establishment. This can sometimes present difficulties for livestock, however, if they venture into an area and are unable to escape after becoming mired in saturated soils (Parker et al., 1985). Beaver dams are susceptible to flood damage (Riece, Wissmar, & Naiman, 1990). While beaver will rebuild damaged dams (personal observations, 1999-2006), they were so thoroughly trapped out of the Gila watershed by the 1840s that flooding after that date is likely to have permanently removed entire series of dams throughout its stream systems.

Watershed implications. Profound consequences for hydrologic condition accompany extensive wetland desiccation. Wetlands absorb hydraulic forces during flooding and can mitigate forces that might otherwise result in stream channel widening and incision. When wetland loss reduces streambank water storage, long-term baseflow declines. Baseflow during dry periods may be reduced, and historically perennial stream reaches below former wetlands and beaver ponds may become ephemeral. For example, studies comparing western streams with and without beaver populations consistently report substantial effects of beaver dam construction on wetland extent and alluvial water storage (Westbrook et al., 2006). By helping to store water and recharge alluvial aquifers, wetlands provide habitat that is particularly important during drought periods and in degraded stream systems (NMED, 2006a).

Wetlands, including off-channel backwater zones and beaver ponds, are effective sediment traps, providing new substrate conducive to colonization by a diversity of aquatic and hydrophytic vegetation types (McKinstry, et al., 2001). Wetland vegetation is an extremely effective filtration mechanism. It buffers and improves water quality by capturing and filtering sediment and nutrients from stream flow and overland runoff.

Figure 33. A small beaver dam on the Gila River elevates the local water table, supporting a community of wetland and mesic vegetation that extends 200 yards upstream of the dam. Cliff-Gila Valley, 1999.

Species composition

Changes in species composition comprise another set of factors influencing watershed condition, although the relationships between these changes and hydrologic or water quality condition may not always be easily discernible. A few of the more notable changes are described below.

The introduction of non-native species that are well-adapted for colonizing disturbed landscapes often results in their rapid occupation of areas where climate effects, human activities, or other perturbations have depressed the populations or resilience of native species. Introduced vegetation, for instance, may come to dominate an area to the extent of establishing a near-monoculture, reducing diversity and available habitat for native vegetation and animal species. This is the case on some floodplains within the watershed where historic farms were abandoned and dense growths of Russian thistle (tumbleweed) and other introduced species adapted to disturbed soils are now dominant. Many of the nonnative vegetation species now present on the watershed's uplands, riparian zones, and grasslands are considered invasive or noxious. Of the riparian species, three tree species introduced to the Southwest are frequently cited as the most ecologically and economically damaging: tamarisk (salt cedar), Russian olive, and Siberian elm (*Tamarix* ssp, *Elaeagnus angustifolia*, and *Ulmus pumila*). All were introduced by the mid-20th century for ornamental or streambank stabilization purposes. They are prolific spreaders and can create extremely dense, near-monotypic stands to the detriment of understory cover and diversity (Parker et al., 2005). All are present on the Gila watershed; dense tamarisk thickets cover many square miles of floodplain along lower reaches of the Gila River, particularly in Arizona. In New Mexico, however, these species are mostly distributed only locally, in "pockets" on the San Francisco River and some tributaries, and on the East Fork, Middle Fork, and mainstem of the Gila River (Whiteman, 2003). Tree of Heaven (*Ailanthus altissima*) is a fourth introduced riparian tree species with high invasive potential; it is particularly evident in some areas of the San Francisco River watershed.

Figure 34. Solitary tamarisk on Sapillo Creek, July 2006.

The populations of a number of animal species native to the watershed have been reduced or eliminated (NM Department of Game & Fish, 2006). Of these, the loss and recent re-introduction of the Mexican wolf have generated the greatest attention and the strongest opinions. Intensive predator reduction campaigns eliminated wolves from the watershed by early in the 20th century, about the same time that Rocky Mountain elk were introduced to replace the extirpated native species, Merriam's elk (Eldridge, 1955; Ligon, 1927 [cited in Treadaway et al., 2006]). Elk numbers on the watershed have greatly increased; on the GNF they are estimated at approximately 20,000 (Unsworth et al., 2005). Mexican wolves were reintroduced at various sites on the GNF in Catron, Grant, and Sierra counties beginning in 1998. The possible economic and ecological impacts of elk and wolves are complex, potentially affecting local income derived from hunting, tourism, and livestock production. Wolf depradations of livestock are a particularly significant potential cost to producers. At the same time, highly concentrated elk populations can have negative effects due to intensive grazing that results in the loss of both herbaceous and riparian cover (Treadaway et al., 2005), and Mexican wolves are a primary elk predator. Wolf re-introduction, on the Gila watershed and elsewhere, is a relatively recent development, and research into its economic and environmental consequences is likewise in its early stages. Some of the work available is reported in Kroeger et al., 2006; Montana State University, 2006; Penn State University, 2006; Ripple & Beschta, 2005; Schoenecker & Shaw, 1997; Soule et al., 2003; and Unsworth et al., 2005.

Among the animal species introduced to the Gila watershed during the past century is the crayfish. Exactly when crayfish (particularly the species *Orconectes virilus*) were introduced is unknown. Their current densities in some reaches of the Gila River mainstem and some of its perennial tributaries are very high (personal observations, 2001-2006). Crayfish are omnivores whose feeding behaviors can significantly modify their environments (Dorn & Mittelbach, 1999). Crayfish eat other aquatic animals and their eggs; they also destroy macrophyte (aquatic vegetation) beds through grazing and fragmentation (Lodge, Kershner, & Aloi, 1994). This behavior results in the loss of juvenile fish habitat, and reduces the instream filtration capacity provided by aquatic vegetation. Crayfish activity tends to increase with water temperature. Temperature impairments on perennial waters may therefore support a feedback mechanism enhancing crayfish populations and their effects on stream conditions, including water quality. The rate at which crayfish feed has been shown to increase in the absence of predator-sized fish (Hill & Lodge, 1995, 1998; cited in Dorn & Mittelbach, 1999), and O. *virilus* tends to grow to considerably larger size than most native fish species. In general, crayfish control by chemical means has proven difficult, and its predators in this region are limited. River otter is the most likely significant predator, since crayfish is among its two most important food sources (Hansen, 2003). River otter were extirpated from the watershed by the mid-20^{th} century (Corrigan, 2005), but the New Mexico Department of Game and Fish plans to re-introduce them to the Gila River by late 2007.

SECTION 4

The Clean Water Act:
Implementation on the Gila Watershed

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THE FEDERAL CLEAN WATER ACT: NONPOINT SOURCE POLLUTION

The federal Clean Water Act (CWA) was originally adopted in 1948. In 1967, the New Mexico state legislature approved the state's Water Quality Act, creating a Water Quality Control Commission (WQCC) and establishing the authority to adopt water quality standards consistent with the CWA.

Major changes to the CWA in 1987 included a requirement that the states develop management programs to address nonpoint source water pollution. Nonpoint source pollution of surface waters occurs when rain or snowmelt moving over and through the ground carries natural and human-made pollutants into lakes, rivers, streams, wetlands, or groundwater. Atmospheric deposition and hydrologic modification are other sources of nonpoint pollution (NMED, 2006c). Nonpoint source pollution is the leading cause of water quality degradation in New Mexico. Efforts designed to reduce nonpoint source pollution under provisions of the CWA are known as Section (§) 319 programs; in New Mexico, NMED Surface Water Quality Bureau (SWQB) is responsible for administering §319 programs in coordination with US EPA Region 6.

The state's approach to water quality management has evolved partly as a consequence:

> New Mexico's approach to water quality planning and management has evolved substantially over the last three decades, largely in response to the changing federal and state statutory mandates. Although the State currently conducts water quality planning on a statewide level, these efforts are evolving toward more of a watershed level focus in the context of the statewide planning efforts... That is, planning and management are moving toward a holistic strategy to protect or attain the desired beneficial uses and levels of water quality within a watershed, including, where appropriate, protection of human health and aquatic ecosystems. A successful watershed protection approach must be founded on cooperative interaction between the federal, state, and local levels of government, and between the public and private sectors (WQCC, 2003).

The New Mexico WQCC defines the state's water quality goals in the *Surface Water Quality Standards* (WQS; 2005, 2006) by designating uses for waterbodies, setting criteria to protect those uses, and establishing provisions to preserve existing water quality ("antidegradation" standards). To support these tasks, NMED SWQB has established a network of water quality monitoring and sampling sites across the state (see Maps 4 through 6 for sites on the Gila watershed). Intensive water quality monitoring is conducted on a rotating schedule throughout the state.

Biannually, the state documents the health of its surface waters in a two-part report. Under §305(b) of the CWA, the state must report the results from all assessments of surface waters; §303 requires a list of all surface waters that fail to meet state water quality standards. Waters not meeting state water quality standards are designated as "water quality limited" or "impaired," and are also often referred to as "listed" stream segments. New Mexico documents both its complete list of assessed waters and the evaluations that resulted in water-quality impaired designations in its combined §305(b)/ §303(d) Report (NM WQCC, 2004). Table 5 summarizes the combined §305(b)/ §303(d) Report for the Gila watershed.

Table 5. Combined 2004–2006 303(d)/305(b) listing for Gila and San Francisco River watersheds in New Mexico (from NMED, 2004a). The 305(b) list includes an assessment of water quality for all identified stream segments. 303(d) units are water quality limited segments, each requiring identification of wasteload and load allocations and development of a total maximum daily load; in the table, 303(d) items are those for which a TMDL parameter is shown. See final page of table for definitions.

Assessment unit	Reach length (mi.)	AU dbase ID	8-digit HUC	De-list parameter	TMDL parameter	Date to EPA or TMDL scheduled	Impairment category	Non-supported uses
Black Canyon Cr. (EF Gila River to headwaters)	25.2	NM-2503_21	15040001		Temperature	Nov-01	4A	HiQ coldwater
Canyon Cr. (MF Gila River to headwaters)	14.2	NM-2503_43	15040001		Plant Nutrients	Dec-01	4A	HiQ coldwater
ditto					Turbidity	Dec-01		
Diamond Creek (EF Gila River to headwaters)	25.6	NM-2503_43	15040001		NA[2]		2	
Gila River (EF)	26.2	NM-2503_20	15040001		Al chronic	Nov-01	4A	HiQ coldwater
Gila River (MF)	36.6	NM-2503_40	15040001		NA[3]	2011	5/5A	HiQ coldwater
Gila River (Mogollon Cr. to Gila Hot Springs)	43.5	NM-2502.A_30	15040001	Turbidity		Dec-01	2	
Gila River (WF abv. Cliff Dwellings)	31.4	NM-2503_30	15040001				3	
Gila River (WF blw. Cliff Dwellings)	4.9	NM-2503_10	15040001		NA[3]	2011	5/5A	HiQ coldwater
Gilita Creek (MF Gila River to Willow Cr.)	6.3	NM-2503_45	15040001		NA[3]	2011	5/5A	HiQ coldwater
Gilita Creek (perennial reaches abv. Willow Cr.)	6.6	NM-2503_48	15040001				3	
Hoyt Creek (Wall Lake to headwaters)	20.0	NM-2503_26	15040001				3	
Iron Creek (MF Gila River to headwaters)	12.7	NM-2503_44	15040001				2	
Lake Roberts	68.4 ac[1]	NM-2504_20	15040001		NA[3]	2017	5/5A	Coldwater
Mogollon Cr. (Perennial reaches abv USGS gage)	12.6	NM-2503_02	15040001		Al chronic	Nov-01	4A	HiQ coldwater
ditto				Pb chronic		Nov-01		
ditto				SBD		Nov-01		
Sapillo Cr. (Gila River to Lake Roberts)	11.9	NM-2503_04	15040001		Turbidity	Dec-01	4A	HiQ coldwater
ditto				TOC		Dec-01		
ditto				Bio impair.		Dec-01		
Snow Canyon Cr. (Gilita Cr. to Snow Lake)	3.1	NM-2503_46	15040001	SBD		Dec-01	1	
Taylor Cr. (Beaver Cr. to Wall Lake)	2.6	NM-2503_23	15040001		Al chronic	Nov-01	5/5A	HiQ coldwater
ditto					Temperature	Nov-01		
ditto				Turbidity		2011		
Taylor Cr. (perennial reaches abv. Wall Lake)	19.8	NM-2503_24	15040001		NA[3]	2011	5/5A	HiQ coldwater
Turkey Cr. (Gila River to headwaters)	16.9	NM-2503_03	15040001		NA[3]	2011	5/5A	HiQ coldwater
Wall Lake	14.3 ac[1]	NM-2504_10	15040001		NA[3]	2017	5/5A	Coldwater
Willow Cr. (Gilita Cr. to headwaters)	7.7	NM-2503_47	15040001	Nutrients			2	

Table 5 (continued).

Assessment unit	Reach length (mi.)	AU dbase ID	8-digit HUC	De-list parameter	TMDL parameter	Date to EPA or TMDL scheduled	Impairment category	Non-supported uses
Bear Cr. (Gila River nr Cliff to headwaters)	31.7	NM-2503_01	15040002	Al acute	NA[2]	Dec-01	1	
ditto				Zn acute		Dec-01		
ditto				Cu acute		Dec-01		
Bill Evans Lake	1.5 ac[1]	NM-2502_B00	15040002				2	
Carlisle Cr. (Gila River to headwaters)	15.0	NM-2502.A_02	15040002	Al acute	NA[2]	Dec-01	1	
ditto				Cu acute		Dec-01		
ditto				Cd acute		Dec-01		
ditto				Zn acute		Dec-01		
Gila River (AZ border to Red Rock)	24.6	NM-2501_00	15040002	SBD		Dec-01	2	
ditto				Turbidity		Dec-01		
Gila River (Mangas Cr. to Mogollon Cr.)	14.0	NM-2502.A_10	15040002	SBD		Dec-01	2	
ditto				Turbidity		Dec-01		
Gila River (Red Rock to Mangas Cr.)	21.1	NM-2502.A_00	15040002	SBD		Dec-01	2	
ditto				Turbidity		Dec-01		
Mangas Cr. (Gila River to Mangas Springs)	6.2	NM-2502.A_21	15040002	SBD		Dec-01	4A	Marginal coldwater
ditto					Nutrients	Dec-01		
Mangas Cr. (Mangas Springs to headwaters)	17.8	NM-2502.A_22	15040002				2	
Apache Canyon (Tularosa R. to Hardcastle Cnyn.)	8.7	NM-2603.A_44	15040004	Conduct.	NA[2]	Dec-01	1	
Centerfire Cr. (San Fran. R. to headwaters)	16.1	NM-2603.A_50	15040004		Conduct.	Nov-01	5/5A	HiQ coldwater
ditto					Nutrients	Dec-01		
ditto					NA[3]	2009		
Mineral Cr. (San Fran. R. to headwaters)	19.6	NM-2603.A_20	15040004	Temperature	NA[2]	Dec-01	1	
Mule Cr. (San Fran. R. to Mule Springs)	10.5	NM-2601_01	15040004				2	
Negrito Cr. (South Fork)	14.5	NM-2603.A_43	15040004		Temperature	Nov-01	4A	HiQ coldwater
Negrito Cr. (Tularosa R. to NF/SF)	12.4	NM-2603.A_42	15040004		NA[3]	2009	5/5A	HiQ coldwater
San Fran. R. (AZ border to Dry Cr.)	15.7	NM-2601_00	15040004				2	
San Fran. R. (Centerfire Cr. to AZ border)	14.9	NM-2602_20	15040004		Nutrients	Nov-01	4A	Coldwater
ditto					Temperature	Nov-01		
ditto				Turbidity		Nov-01		
San Fran. R (Dry Cr. to Whitewater Cr.)	8.7	NM-2601_10	15040004				2	
San Fran. R (Largo Cnyn. to Centerfire Cr.)	19.8	NM-2602_10	15040004				2	
San Fran. R (Whitewater Cr. to Largo Cnyn.)	43.5	NM-2601_20	15040004	SBD		Nov-01	2	

Table 5 (continued).

Assessment unit	Reach length (mi.)	AU dbase ID	8-digit HUC	De-list parameter	TMDL parameter	Date to EPA or TMDL scheduled	Impairment category	Non-supported uses
Silver Cr. (Mineral Cr. to headwaters)	9.6	NM-2603.A_21	15040004	Conduct.	NA[2]	Dec-01	1	
ditto				Turbidity		Dec-01		
Trout Cr. (San Fran. R. to headwaters)	15.3	NM-2603.A_60	15040004		NA[2]		1	
Tularosa River (Apache Cr. to headwaters)	17.6	NM-2603.A_41	15040004				2	
Tularosa River (San Fran. R. to Apache Cr.)	22.0	NM-2603.A_40	15040004		Conduct.	Nov-01	4A	HiQ coldwater
Whitewater Cr. (San Fran. R. to Whitewater Campgrd)	6.9	NM-2603.A_10	15040004		Turbidity	Nov-01	4A	HiQ coldwater
ditto				Al chronic		Nov-01		
ditto				SBD		Nov-01		
Whitewater Cr. (Whitewater Campgrd to headwaters)	14.2	NM-2603.A_12	15040004		Al chronic	Nov-01	4A	HiQ coldwater

EF: East Fork; MF: Middle Fork; WF: West Fork; San Fran.: San Francisco; Nutrients: plant nutrients; SBD: streambed deposits; TOC: total organic carbon; Conduct.: conductivity. Chronic: at levels that create "a stimulus that lingers or continues for a relatively long period relative to the life span of an organism. Chronic effects include, but are not limited to, lethality, growth impairment, behavioral modifications, disease and reduced reproduction." Acute: at levels that create "a stimulus severe enough to induce a response in 96 hours of exposure or less" (both from State of New Mexico, 2002).
AU dbase ID: for identification purposes only. 8-digit HUC: Hydrologic Unit Code assigned by USGS. De-list parameter: Stream segment de-listed for this parameter since earlier TMDL was developed. TMDL parameter: exceeded pollutant value. Pb: lead; Al: aluminum; Zn: zinc; Cu: copper; Cd: cadmium.

Impairment categories: 1:Attaining the water quality standard for all existing and designated uses. 2: Attaining some of the designated or existing uses based on parameters that were tested, and no reliable monitored data are available to determine if remaining uses are attained or threatened, 3: No reliable monitored data to determine if any designated or existing use is attained. 4A: Impaired for one or more designated uses, but all necessary TMDLs have been developed that once implemented are expected to result in full attainment of the standard. 5/5A: Impaired for one or more designated uses and a TMDL is underway or scheduled.
All non-supported uses in the Gila watershed are for aquatic life. HiQ: High quality.

[1]Non-stream surface water body area shown in acres. [2] Not applicable: De-listed due to ephemeral or intermittent nature. [3] Not applicable, but one or more parameters now show non-support; scheduled for TMDL review at date shown.

Designated uses

Determinations of impairment by NMED are made in relation to the "designated uses" assigned to each stream segment. Designated uses are documented in the New Mexico WQCC *Standards for Interstate and Intrastate Surface Waters* (2005a, 2006d). The designation of use for each stream segment is important in setting water quality standards. If a designated use is inaccurate, water quality standards may be set unrealistically high or low. For example, temperature standards for warm-water fisheries are less stringent than those applied to coldwater fisheries. When more than one designated use applies to a stream reach, the more stringent criteria are used to determine impairment.

Other Provisions of Water Quality Standards

Triennial review. Water quality standards are reviewed every three years, in a process known as Triennial Review. New Mexico completed its last Triennial Review in July 2005 (NMED, 2006d). The review process allows the public an opportunity to participate in setting water quality standards. The WQCC publishes advance notice of hearings during which data and commentary are sought from interested members of the public, reviews public input during the following months, and then issues revisions to the WQS (WQCC, 2005).

Antidegradation. The state's Water Quality Management Plan also includes an "antidegradation" clause to protect existing water quality. Generally, the clause ensures that surface water quality will be maintained and protected where it exceeds standards, and that, at least for existing uses, will not be allowed further deterioration even where it does not meet an applicable criterion (WCQQ, 2003, p.19). Waters designated by the WQCC as "Outstanding National Resource Waters" are also protected from degradation; these are nominated for designation by WQCC and may include surface waters in national or state monuments, parks, wildlife refuges, or waters of "exceptional recreational or ecological significance" (see WQCC 2006b).

Clean Water Act terminology: a brief primer

- §319: Section of the Clean Water Act that targets nonpoint source pollution and provides support for improvement measures.
- Listed: Included on New Mexico's 303(d) list of surface water bodies that fail to support designated uses because of water quality impairments.
- Designated uses: Surface water bodies are used for specific purposes like fisheries, irrigation, domestic supply, or livestock watering. Specific standards for water quality apply to each designated use.
- NPS: Nonpoint source pollution; contaminants that enter surface waters from generalized sources rather than specific points, such as a pipe. NPS may include surface runoff of precipitation or inputs from stream bank erosion, for example.

Delisting. An impaired stream segment is removed from the 303(d) list ("de-listed") when sampling indicates its water quality, on average, is capable of supporting its designated uses, or when sampling becomes impossible due to lack of perennial flow. The rationale for water quality impairment designations and de-listings are documented for the historic record in the *Record of Decision* (NMED, 2004a). As shown in Table 5, a number of stream segments on the Gila watershed (e.g., Silver Creek) have been delisted in recent years due to lack of perennial flow during the 2002 sampling visits. Some of these sites may have been historically ephemeral or intermittent; others may be reflecting only the current regional drought. In either case, re-classification as ephemeral or intermittent affects a stream's designated uses, and therefore the water quality standards applied to it, as described below.

“Ephemeral” waters flow only in direct response to precipitation or snowmelt in the immediate locality. Their streambeds are always above the water table of the adjacent region. Designated uses include livestock watering, wildlife habitat, limited aquatic life, and secondary contact. See WQS Section 20.6.4.97 for designated uses; Section 20.6.4.900 for water quality criteria.

“Intermittent” streams contain water only at certain times of the year, such as when flow enters them from springs, melting snow, or precipitation. Designated uses include livestock watering, wildlife habitat, aquatic life, and secondary contact. See WQS Section 20.6.4.98 for designated uses and Section 20.6.4.900 for water quality criteria.

"Unclassified" perennial surface waters are those not specifically identified in the WQS (for instance, some headwater reaches of San Francisco River tributaries downstream of Whitewater Creek may fall into this category) See WQS Section 20.6.4.99 and Section 20.6.4.900 for designated uses and water quality criteria, respectively.

The *WIPS:* §319(h) and then some

NMED's nonpoint source (NPS) program utilizes a voluntary approach to water quality improvement that focuses on watershed plan development and support for building watershed group formation and partnering efforts. Incentives for voluntary implementation of remediation efforts include technical support and competitive funding through §319(h) of the CWA for state and local agencies, nonprofit groups, and citizen watershed groups working to improve watershed health (NMED, 2006c). While §319(h) project funding in New Mexico is designed to target watershed improvement work for very specific surface waters—i.e., stream segments identified on the 303(d) list for water quality impairments—NMED's "ultimate goal is to manage a balanced program that both addresses existing impairments...*and prevents future impairments*" (NMED, 2006c; emphasis added).

The *WIPS* aims to support this goal by documenting as completely as possible both existing conditions and "the analyses, actions, participants, and resources related to development and implementation" (EPA, 2005) of improvement strategies not only on listed reaches, but watershed-wide. Specific reasons for this approach include:

- Identified water quality impairments often reflect generally poor watershed condition. Successful remediation strategies directed at reducing nonpoint source runoff will also tend to improve overall hydrologic condition.
- Some stream reaches, although themselves not technically "impaired," contribute pollutants to downstream listed reaches. Management practices designed to improve water quality on similar listed reaches are also applicable to these stream segments.

Go to Section 5 for information specific to §319 listed stream reaches, including:

- Detailed maps
- Links to TMDL documents
- Land management information
- Suggested management strategies
- Ongoing remediation planning and implementation
- Photos

- Because water quality standards pertaining to sporadic flow in intermittent stream channels are considerably less stringent than those for perennial waters, intermittent streams are less likely to be eligible for §319 funding. Nonetheless, watershed conditions that eventually contribute to water quality degradation in downstream perennial waters exist in areas where only intermittent flow now occurs—perhaps in part due to the deteriorated conditions themselves.

- In some areas, conditions may threaten existing water quality. The *WIPS* provides one means for those most familiar with these areas (landowners or management agency staff, for example) to locate the resources for developing preventative integrated remediation plans.

- Providing a watershed-wide information source can assist stakeholders interested in participating in the water quality triennial review process.

- Many identified impairments are exacerbated by reduced base (minimum) streamflow, because contaminant concentrations increase under these circumstances. Improvement strategies that work to sustain higher baseflow levels will have corollary water quality benefits.

- Supporting and documenting the results of remediation projects and strategies provides a science-based means of evaluating the most effective ways to enhance the ecological integrity that will ultimately produce the greatest benefits for water quality.

WIPS development and resources availability

A watershed plan like the *WIPS* is typically the creation of a group of individuals who agree to collaboratively identify shared goals and strategies for watershed improvement. Efforts over the course of more than a decade to create a watershed-wide group on the Gila watershed of New Mexico have repeatedly faltered. Discussions during the past year with stakeholder groups indicated no consensus on a current need for such a group, although this may change with time. The initial draft of this watershed planning document, published in October 2005, was developed from preliminary information gathered by the NMED SWQB and the watershed information coordinator. It was made available to all known watershed groups and agencies, and comments were requested for incorporation into this second edition.

Although no formal watershed-wide group accompanies the development of this WIPS, funding for its development also made available to stakeholders a variety of technical and data resources, proposal development assistance, and liaison capacity with agencies, funding sources, and other watershed groups (see Section 7, Resources). To describe the forum through which these resources are offered, we have continued to use the name adopted for the purposes of information dissemination and stakeholder engagement in the first draft of the planning document, the *Gila Watershed Partnership of New Mexico* (GWP). The name links New Mexico watershed improvement efforts to those of a collaborative group in Arizona, the *Gila Watershed Partnership of Arizona,* which offered to share the name and logo for a potential New Mexico coalition of groups interested in watershed protection and improvement efforts that may transcend the state border.

A major GWP goal is maintaining the *WIPS* as a "living document" for stakeholder reference to information on water quality and other geographic-based data, financial and technical resources, or documented results from implemented management practices as a planning tool for future work and outreach. The comment sheet in Appendix A is included to allow interested readers to submit specific information for future editions of the *WIPS.* This information might include, but is not limited to, identification of subwatersheds of concern, suggested remediation practices, or descriptions of projects that were inadvertently excluded from this edition.

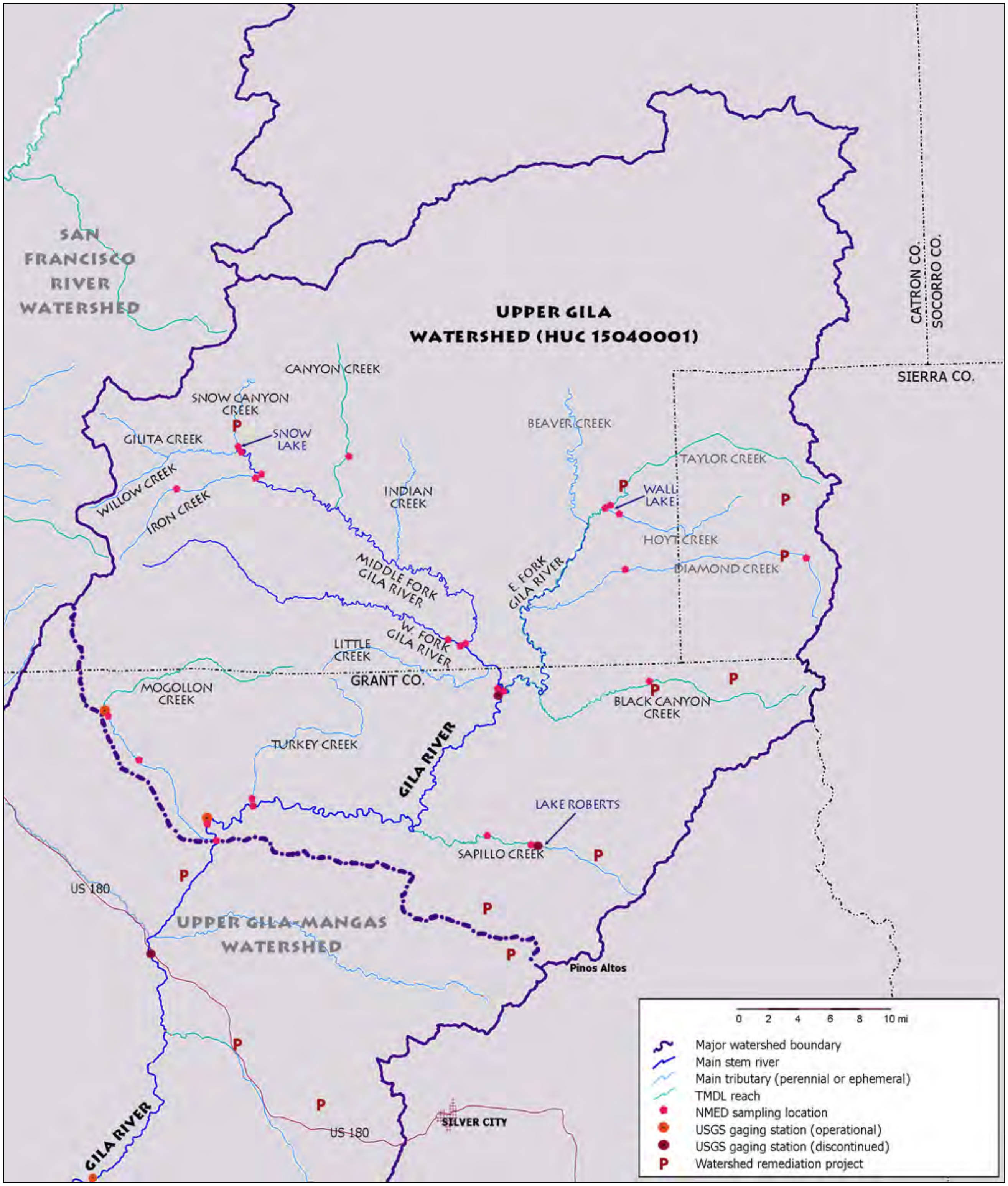
HUC maps and GIS data availability

The US Geological Survey (USGS) identifies watershed drainage areas, or "hydrologic units," by numeric codes, abbreviated as HUCs. Loosely stated, the number of digits within the code is inversely related to the size of the watershed delineated. For example, a 14-digit code might designate one small subwatershed, while an 8-digit code delineates the greater Upper Gila watershed. As shown in Table 5, the three mainstem river segments tributary to the Gila River at its confluence with the San Francisco include HUC 15040001 (Upper Gila); HUC 15040002 (Upper Gila-Mangas); and HUC 15040004 (San Francisco).

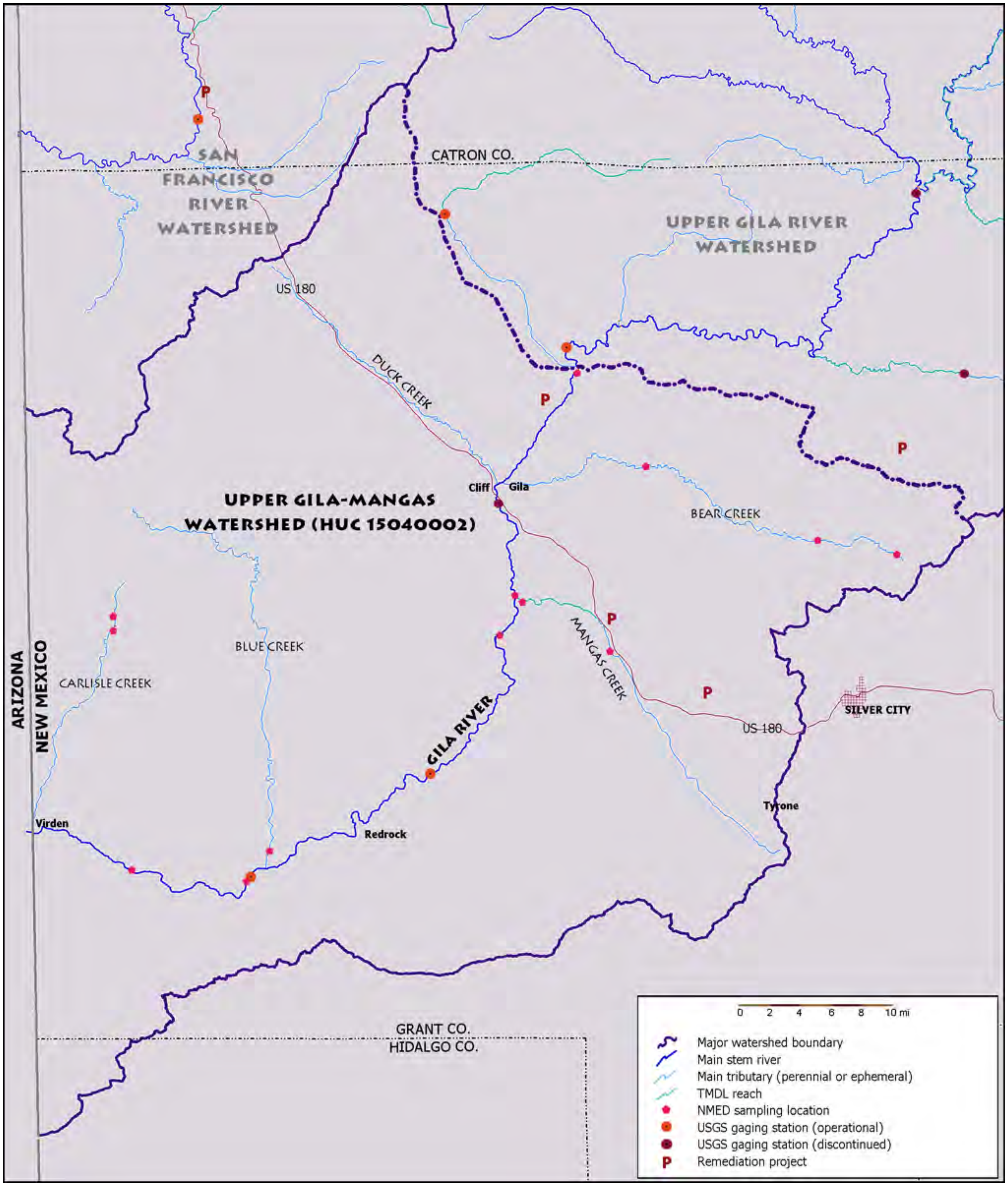
The maps on the following three pages delineate the major HUC boundaries within the New Mexico Gila watershed. For user reference, they include all sites at which water quality sampling is conducted or supervised by NMED (sampling or monitoring by volunteers at some sites occurs under *Quality Assurance Protection Plans* developed by NMED staff). Listed reaches are shown, as well as other major tributary channels, whether perennial or intermittent. The general locations of known remediation projects are also shown.

Additional details about all monitored stream reaches are contained in Appendix B of the *303(d)/305(b) Report* (WQCC, 2004), at: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/index.html

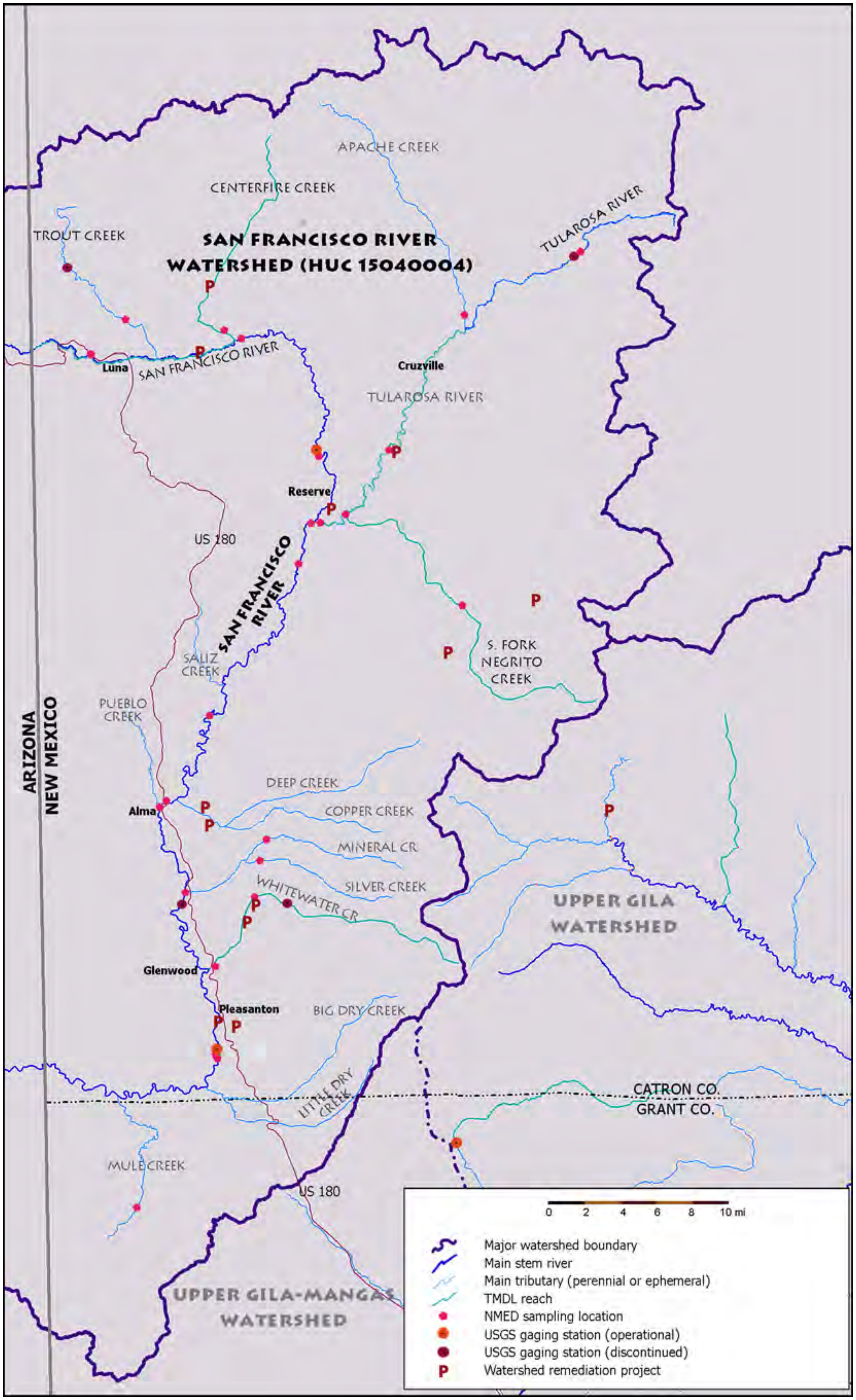
Like the other maps in the *WIPS*, these are intended to be viewable in paper format as well as digitally; they are therefore unable to depict in detail all of the data that are available through GWP to practitioners and managers. The Santa Fe office of NMED, however, is working to establish a GIS platform based on the mapped and other data, to be accessible to watershed stakeholders via Internet. The site is planned as an adjunct to the *WIPS* to provide straightforward data access for watershed-based planning and implementation efforts. During GIS project development, these data will be available through the watershed information coordinator at the contact information shown on the inside cover. See Section 6 for a listing of currently available data.



Map 4. Upper Gila watershed (HUC 15040001), including major tributary drainages, listed reaches, all NMED sampling sites, USGS streamflow gaging stations, and the general locations of known watershed improvement projects (excluding most GNF projects, too numerous to depict). See TMDL maps in Section 5 for more detail on listed reaches.



Map 5. Upper Gila-Mangas watershed (HUC 15040002), including major tributary drainages, listed reaches, all NMED sampling sites, USGS streamflow gaging stations, and the general locations of known watershed improvement projects (excluding most GNF projects, too numerous to depict). See TMDL maps in Section 5 for more detail on listed reaches.



Map 6. San Francisco watershed in New Mexico (HUC 15040004), including major tributary drainages, listed reaches, all NMED sampling sites, USGS streamflow gaging stations, and the general locations of known watershed improvement projects (excluding most GNF projects, too numerous to depict). See TMDL maps in Section 5 for more detail on listed reaches.

IDENTIFIED WATER QUALITY IMPAIRMENTS ON THE GILA WATERSHED

NMED SWQB's 2003 *Annual Report* identified eight principal causes of nonpoint source contamination of New Mexico surface waters: erosion from rangelands, agricultural activities, construction, silviculture, resource extraction, land disposal, unsurfaced roads, and recreation. They also noted the potential impacts of hydromodification works, including diversion of surface flow, channelization projects, and dredge-and-fill work (NMED, 2004b).

The New Mexico WQCC (2004) listed a number of possible factors of concern for water quality on the Gila basin, including historical degradation of the riparian community, habitat alteration, destabilization of streambanks, and forest management practices such as fire suppression. Other concerns included the presence of pathogens, sediment-laden runoff from forest roads, and recreational impacts caused by off road vehicles, camping and streamside trails, hydromodification, and silviculture projects. Levels of all contaminants identified on the Gila watershed may be elevated by localized NPS inputs, general watershed impacts, or some combination of the two. Whether of local or regional origin, most nonpoint source contamination in New Mexico waters tributary to the Gila River is derived from overland sediment runoff. Consequently, these water quality issues may apply to all surface waters on the Gila watershed, whether they are listed for impairments of designated use or not. Descriptions of identified contaminants and their potential implications follow.

Aluminum. The rock units of some parts of the Gila watershed are naturally abundant in aluminum. These include quaternary age basalt (16.8% Al_2O_3) and basaltic andesite (17% Al_2O_3). High aluminum concentrations in streams flowing through areas where the geologic composition includes aluminum can most likely be linked to naturally occurring sediment transport. However, many streams that exhibit exceedances of aluminum also show elevated turbidity levels, suggesting an increased rate of overland sediment delivery to the stream. Increased rates of sediment runoff often result from loss of native ground cover due to drought, intensive grazing, gullying, historic farming practices on floodplains, or encroachment of woody species, like pinyon-juniper, into former meadow areas. Ground disturbances due to mining activities also frequently result in increased aluminum concentrations where natural background sources exist. High chronic levels of dissolved aluminum are toxic to fish, benthic invertebrates, and some single-celled plants. The *Record of Decision* for the 2004–2006 §303(d)/§305(b) list notes that, on the Gila watershed, aluminum and other metals in surface waters are most often transported via suspended sediments. This mode of transport is less biologically damaging than the release of dissolved metals into surface waters, a less common occurrence typically linked to areas where mining wastes are high in sulfides. The common pH range in such situations is extremely low, from 2.0 to 5.0, with metal loading varying from small traces to extremely high values.

Conductivity. Conductivity is the ability of water to pass an electrical current. In surface water, conductivity is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions or sodium, magnesium, calcium, iron, and aluminum cations. The law of electroneutrality states that for a solution to be electrically neutral, the total charge on all positive ions (cations) must equal the total charge on all negative ions (anions). These ions move through a water column under the influence of an externally applied electric field (conductivity meter). The electric current that flows through the water is proportional to the concentration of dissolved ions in the water – the more ions, the more conductive the water, resulting in a higher electrical current. Conductivity is affected by temperature; warmer water will measure relatively higher conductivity results. Conductivity is used as a measure of stream water quality as this measure tends to have a relatively constant range within a stream.

Plant Nutrients. Aquatic vegetation is normal in streams. However, an increase in plant nutrient levels—especially of nitrogen and phosphorous—creates excessive amounts of aquatic vegetation. Aquatic vegetation, chiefly algae and macrophytes, may increase dissolved oxygen above saturation during warm, sunny afternoons. These supersaturated levels can be harmful to fish in some instances, causing gas-bubble disease. Plants and algae also consume carbon dioxide, causing pH to rise. Nitrogen released during decomposition produces ammonia, and the amount of ammonia that is converted to the toxic un-ionized form is directly related to pH. Decomposition of aquatic vegetation reduces available dissolved oxygen, a potential limiting factor for other aquatic species. An increase in plant nutrients can come from a variety of point and non-point sources. Nutrients, primarily phosphorous and nitrogen fertilizers, are sometimes applied to the surface for vegetative growth. Soluble nutrients may reach surface or ground water through runoff, seepage, and percolation. Insoluble forms may be absorbed on soil particles and reach water by direct wash-off of debris and recently applied fertilizer. Other sources include animal waste, storm water runoff (carrying lawn fertilizer or pet waste), surface runoff transport of background nutrients bound to sediment, or septic tanks that are poorly installed or placed close to ground water. Concentrations of plant nutrients will also increase as stream base flow declines, one of the consequences of decreased floodplain and bank water storage. An excess of nutrients in stream waters causes eutrophication, or excessive aquatic plant growth. An excess of aquatic vegetation can affect water quality by depleting the stream of dissolved oxygen, reducing its capacity to support fish and other dependent species (US EPA, 1995).

Temperature. Thermograph measurements indicate above average temperatures for 4 out of 13 reaches for which TMDLs have been established on the watershed. Water temperature influences the metabolism, behavior, and mortality of fish and other aquatic organisms. Factors that impact water temperature are 1) hill slope and stream bank failure, which may increase the stream's width-to-depth ratio, causing more water surface to be exposed to solar radiation; 2) other changes in channel morphology, often the result of high-intensity flow events; 3) lack of riparian vegetation, resulting in reduced effective shade cover and thus increasing solar radiation; 4) decreased floodplain water storage, resulting in lower base flows; and 5) elevated sediment loads, which increase the amount of solar energy absorbed by the water. Temperature impairments may therefore be both an indicator and a result of deteriorated watershed and floodplain conditions.

Turbidity. Turbidity is a measurement of the reduction of the penetration of light through natural waters caused by the presence of suspended particles. Suspended solids include clay, silt, ash, plankton, and organic materials. Exceedances of suspended particles in the water can inhibit the normal growth, function, and reproduction of aquatic life. When these particles settle to the channel bottom, they may impact aquatic life forms. Increased turbidity may result from natural runoff after heavy rainfall. Anthropogenic factors that may increase turbidity levels include accelerated runoff from exposed soil, improperly maintained or poorly designed roads, or activities that result in stream bank destabilization, removal of riparian vegetation, or inhibition of riparian regeneration. Road crossings, use of stream channels by motorized traffic, or poorly designed culverts may also increase the amounts of fine sediments in stream channels. Wetlands and beaver ponds tend to act as sediment traps, and the numbers of both on the Gila watershed have declined over the past 150 years.

Other contaminant sources:

Pesticides. Pesticides, if applied during vegetative management activities, may be soluble or insoluble. Pesticides in surface or ground water may result in toxicity problems, affecting water quality and food sources for aquatic life.

Debris. Silviculture or brush control practices can introduce elevated organic pollutant loads from tree limbs, tree tops, and other waste materials. They reach streams through direct pushing or felling into water drainages, and washout during storms. Decomposition of large volumes of organic material may place oxygen demands on surface waters, reducing available oxygen for aquatic life forms.

Milestone Measures

The concept of "milestones" is useful in watershed improvement planning. Milestones are used to define the control actions being implemented and their relative effectiveness. Interim milestones measure progress toward an ultimate goal; achieving an ultimate milestone is equivalent to reaching a desired condition established during watershed planning. For water-quality impaired stream reaches, attainment of TMDL standards is an ultimate milestone. The milestones listed here may be useful in watershed planning as a means of outlining management strategies and identifying the most effective ways to achieve them.

Quantifiable measures provide the most useful basis for evaluating progress toward achieving desired condition, and may help to reveal problems or conflicts among the strategies being implemented. (Protocols and references for monitoring techniques that can help managers obtain these measurements are in Sections 6 and 7.) Quantifiable, interim measures for overall water quality improvement can include:

- Percent restored riparian buffers: improved bank stability, filtration capacity, and shade cover
- Increase in length, density, and effectiveness of vegetative buffers between streams and agricultural activities or roads
- Decrease in sediment runoff from upland areas
- Decrease in volume of sediment inputs from ephemeral stream tributaries, including gullies
- Expansion of herbaceous cover (woody species thinning; improved grazing methods; wildlife management)
- Percentage of seasonal or permanent closures of poorly designed/unauthorized roads and stream crossings
- Historic wetland acreage rehabilitated

For specific water quality pollutants identified on the Gila watershed, target criteria may include:

Aluminum

- Measured increase in vegetated streambank length and vegetation density (filtration of metal-transporting sediments)
- Increase in wetland areas to filter and reduce metals concentrations found in streams
- Measured decrease of aluminum concentrations in water samples

Conductivity

- Measured increase in vegetated streambank length and vegetation density (vegetative uptake of ionic compounds)
- Measured reduction in total dissolved solids

Plant Nutrients

- Measured reductions in nitrogen and phosphorous contributions
- Measured reductions in aquatic plant production
- Moderation in diurnal fluctuations of dissolved oxygen and/or pH
- Measured increase in buffer zones between agricultural areas and stream banks

Temperature

- Measured reduction in total suspended solids and peak turbidity
- Reductions in temperature exceedances over the standard for designated use
- Percent increase in stream shade cover
- Measured change in channel dimensions (increased depth)

Turbidity

- Decrease in measured turbidity
- Decrease in excessive aquatic plant production
- Measured increase in vegetated streambank length, vegetation density, and extent of wetland areas (sediment filtration)

Implementation results, project completions, and improvements in water quality will be periodically documented in the *WIPS* as they become available, and targeted milestones may be adjusted as a consequence. NMED SWQB has established procedures for evaluating changes in water quality (Section 6); these will also be documented in updates to the *WIPS*.

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SECTION 5

The Clean Water Act:
§319 and TMDLs on the Gila Watershed

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THE FEDERAL CLEAN WATER ACT: TMDLS

Section (d)303 of the CWA requires the states to prioritize their listed waters for development of total maximum daily loads (TMDLs). The TMDL of a pollutant is the greatest loading or amount of the pollutant that may be introduced into a stream reach from all sources without resulting in a violation of water quality standards. A TMDL sets an "allowable budget" by determining the amount of pollutants that can be assimilated without causing a waterbody to exceed water quality standards set to protect its designated uses (e.g., fishery, irrigation, etc.). Once this capacity is determined, sources of the pollutants are considered (NM Water Quality Control Commission [WQCC], 2003).

Both point and nonpoint sources must be included. A "point source" is simply described as a discrete discharge of pollutants as through a pipe or similar conveyance (e.g., a ditch). All other pollutant inputs—sheet flow from pastures or sediment runoff from steep forest slopes, for example—are defined as "nonpoint sources." Once all sources are accounted for, the pollutants are then allocated, or budgeted, among the sources in a manner which will describe the limit (the total maximum load, or TMDL) that can be discharged into the river without causing the stream standard, or budget, to be exceeded (NM WQCC, 2003).

On stream segments for which TMDLs are developed for nonpoint contaminants, water quality does not meet or is not expected to meet applicable water quality standards even after point source discharges achieve the effluent limitations required by §301 and §306 of the CWA. TMDLs are established for these segments on a pollutant-by-pollutant basis (taking into account seasonal variability). Identification of a watercourse segment as water quality limited and still requiring TMDLs means that the state is to:

- Calculate a TMDL for the segment;
- Develop more stringent effluent limitations and wasteload allocations (WLAs), if necessary, for point sources on the segment;
- Identify nonpoint sources of pollution and if possible quantify and assign load allocations (LAs) to them; and
- Identify management practices (MPs), where appropriate, to mitigate nonpoint source pollution. Improvement practices are defined as schedules of activities based on approved or proven actions or stratagems, including design and selection that exhibits efficiency and effectiveness towards decreasing a measured resource problem that ultimately achieves control of sources of water pollutants.

Normally, the bulk of the work is done by NMED and submitted to the State's WQCC for their consideration. WQCC in turn compiles the identified water quality limited segments in the §303(d) list and submits them to EPA on April 1st of each even-numbered year. If the State does not set TMDLs to the EPA's satisfaction, then EPA is required to do so (see CWA §303(d)). Public notice is issued and there is opportunity for public comment on proposed lists (NM WQCC, 1998, 2004).

The §303(d) list for 2004–2006 as approved by EPA was used in development of the *WIPS*. TMDLs have been developed for 13 water-quality impaired stream segments on the Gila watershed in New Mexico, as listed in Table 6. (The complete §305(b)/§303(d) listing appears in Table 5, Section 4.) Figure 35 shows the number of stream segments affected by each identified contaminant within the Upper Gila/Gila-Mangas and San Francisco HUCs.

Table 6. Current water-quality impaired reaches on the 2004–2006 303(d) list for the Gila and San Francisco watersheds (from New Mexico WQCC, 2004).

Assessment unit	Reach length (mi.)	TMDL parameter	Impairment category	Non-supported uses
HUC 15040001 (Gila mainstem and tributaries at and upstream of the confluence with Mogollon Creek)				
Black Canyon Cr. (EF Gila River to headwaters)	25.2	Temperature	4A	HiQ coldwater
Canyon Cr. (MF Gila River to headwaters)	14.2	Nutrients	4A	HiQ coldwater
ditto		Turbidity		
Gila River (EF)	26.2	Al chronic	4A	HiQ coldwater
Mogollon Cr. (Perennial reaches abv USGS gage)	12.6	Al chronic	4A	HiQ coldwater
Sapillo Cr. (Gila River to Lake Roberts)	11.9	Turbidity	4A	HiQ coldwater
Taylor Cr. (Beaver Cr. to Wall Lake)	2.6	Al chronic	5/5A	HiQ coldwater
ditto		Temperature		
HUC 15040002 (Gila mainstem and tributaries from the AZ–NM line upstream to the confluence with Mogollon Cr.)				
Mangas Cr. (Gila River to Mangas Springs)	6.2	Nutrients	4A	Marginal coldwater
HUC 15040004 (San Francisco and tributaries)				
Centerfire Cr. (San Fran. R. to headwaters)	16.1	Conduct.	5/5A	HiQ coldwater
ditto		Nutrients		
Negrito Cr. (South Fork)	14.5	Temperature	4A	HiQ coldwater
San Fran. R. (Centerfire Cr. to AZ border)	14.9	Nutrients	4A	Coldwater
ditto		Temperature		
Tularosa River (San Fran. R. to Apache Cr.)	22.0	Conduct.	4A	HiQ coldwater
Whitewater Cr. (San Fran. R. to Whitewater Campgrd)	6.9	Turbidity	4A	HiQ coldwater
Whitewater Cr. (Whitewater Campgrd to headwaters)	14.2	Al chronic	4A	HiQ coldwater

EF: East Fork; MF: Middle Fork; San Fran.: San Francisco; Nutrients: plant nutrients; Conduct.: conductivity. Chronic: at levels that create "a stimulus that lingers or continues for a relatively long period relative to the life span of an organism. Chronic effects include, but are not limited to, lethality, growth impairment, behavioral modifications, disease and reduced reproduction" (from New Mexico WQCC, 2005).
8-digit HUC: Hydrologic Unit Code assigned by USGS. TMDL parameter: exceeded pollutant value. Al: aluminum. Impairment categories: 4A: Impaired for one or more designated uses, but all necessary TMDLs have been developed that once implemented are expected to result in full attainment of the standard. 5/5A: Impaired for one or more designated uses and a TMDL is underway or scheduled.
All non-supported uses in the Gila watershed are as habitat for aquatic life; HiQ: High quality.

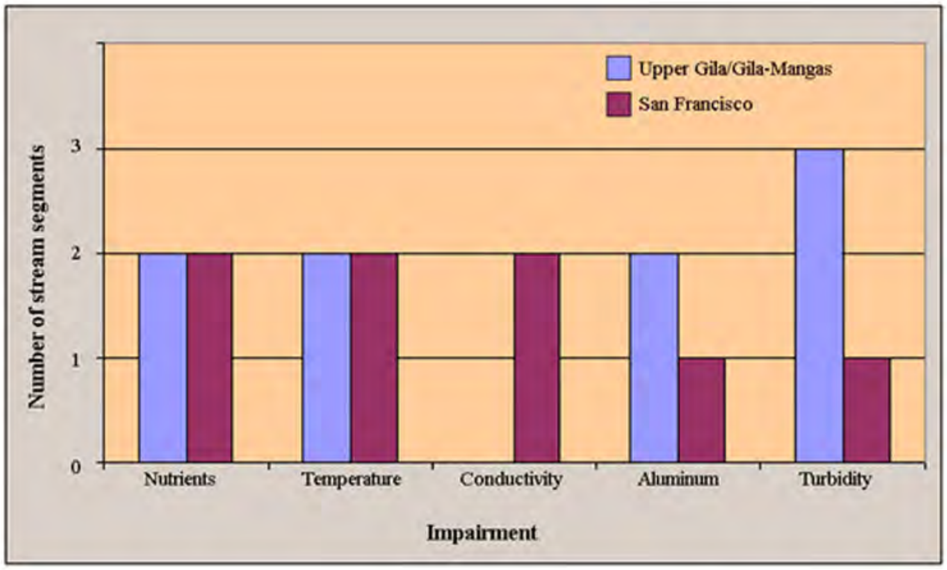

Figure 35. Number and type of NPS water-quality impaired stream segments for which NMED SWQB has developed TMDLs on the Upper Gila/Gila–Mangas and San Francisco HUCs in New Mexico.

All of the completed TMDLs for the Gila watershed were prepared by NMED and accepted by EPA as of August 2002. In general, re-assessment or development of TMDLs for a particular watershed is scheduled on an 8-year cycle. Assessments for potential TMDL development of many surface waters not listed in Table 6 have been scheduled or re-scheduled for future years. Refer to Section 4 for more information on these stream segments.

TMDL SUBWATERSHEDS

Impaired surface waters for which TMDLs have been developed are grouped by HUC: 15040001 (Upper Gila); 15040002 (Upper Gila-Mangas); and 15040004 (San Francisco). Reach descriptions within each HUC are in downstream-to-upstream order. The map for each HUC shows listed stream reaches and the contributing subwatershed area for the reach (the TMDL drainage area). The maps within this section are best viewed digitally. All data used to construct the maps are available through the watershed information coordinator. All NMED SWQB sampling locations are shown; non-listed stream segments with sampling sites are identified on the maps in Section 4.

Since designated uses reflect the particular attributes of each drainage basin, each reach description includes a link to the WQCC *Standards* (2006) and identifies the pertinent section within the *Standards* that describes its assigned water quality standards. Links are also included to the original TMDL documents, which describe potential contaminant sources and derivation of the TMDL in greater detail. Potential management strategies to reduce NPS contaminant loads are outlined with a links to the original TMDL documents (NMED, 2001) for each listed subwatershed. Management practices are described in Section 6; financial and technical resources are listed in Section 7.

Ideally, watershed planning is a holistic, adaptive, and iterative process integrated with other planning efforts and geographically defined by watershed divides rather than legal boundaries. The interim results of remediation practices should result in quantifiable positive trends in water quality or its likely indicators: e.g., arrested gully development or improved ground cover (EPA, 2005). On a watershed of the geographic scale of the Gila River, the best results from improvement practices will be achieved at the subwatershed level, when multiple, complementary projects are designed and implemented in an integrated fashion. (This approach can have corollary benefits in leveraging funding support from varied sources, as well.) Achieving this sort of integration is dependent on the landowners, management agencies, and watershed groups who are working on or can be engaged in watershed planning and implementation of improvement practices.

Table 7. General schedule for identification, planning, and implementation of remediation projects on the Gila watershed.

Implementation Actions	Year 1	Year 2	Year 3	Year 4
Public outreach and initial data collection	X	X	X	X
Establish milestones		X	X	X
Secure/leverage funding		X	X	X
Implement Management Practices (MPs)		X	X	X
Data collection (monitoring)		X	X	X
Evaluate effectiveness of MPs				X
Begin new cycle				

Table 7 is a general schedule for the steps involved in planning and implementing on-the-ground projects. Additional planning, including data collection or documentation of contaminant sources, is still needed for many subbasins. The implementation schedules provided for each subwatershed are guidelines that will be adjusted over time depending on 1) engagement among management agencies, advisory groups (e.g., SWCDs), and private landowners to identify contaminant sources within the watershed; 2) prioritization of the effectiveness and efficacy of management strategies; 3) completion and funding of work plans to put strategies into on-the-ground practice, 4) effectiveness monitoring within a landscape-model approach, and 5) adaptation and implementation of additional measures.

UPPER GILA RIVER WATERSHED

(HUC 15040001)

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UPPER GILA (HUC 15040001)

The Gila River mainstem from the confluence with Mogollon Creek to the headwaters, and all tributaries upstream of and including Mogollon Creek.

Designated uses by reach within HUC 15040001

Gila mainstem, from the confluence with Mogollon Creek upstream to the confluence of West and East Forks of the Gila River: industrial water supply, irrigation, livestock watering, wildlife habitat, warmwater and marginal coldwater aquatic life, primary contact.

WQS Section **20.6.4.502**

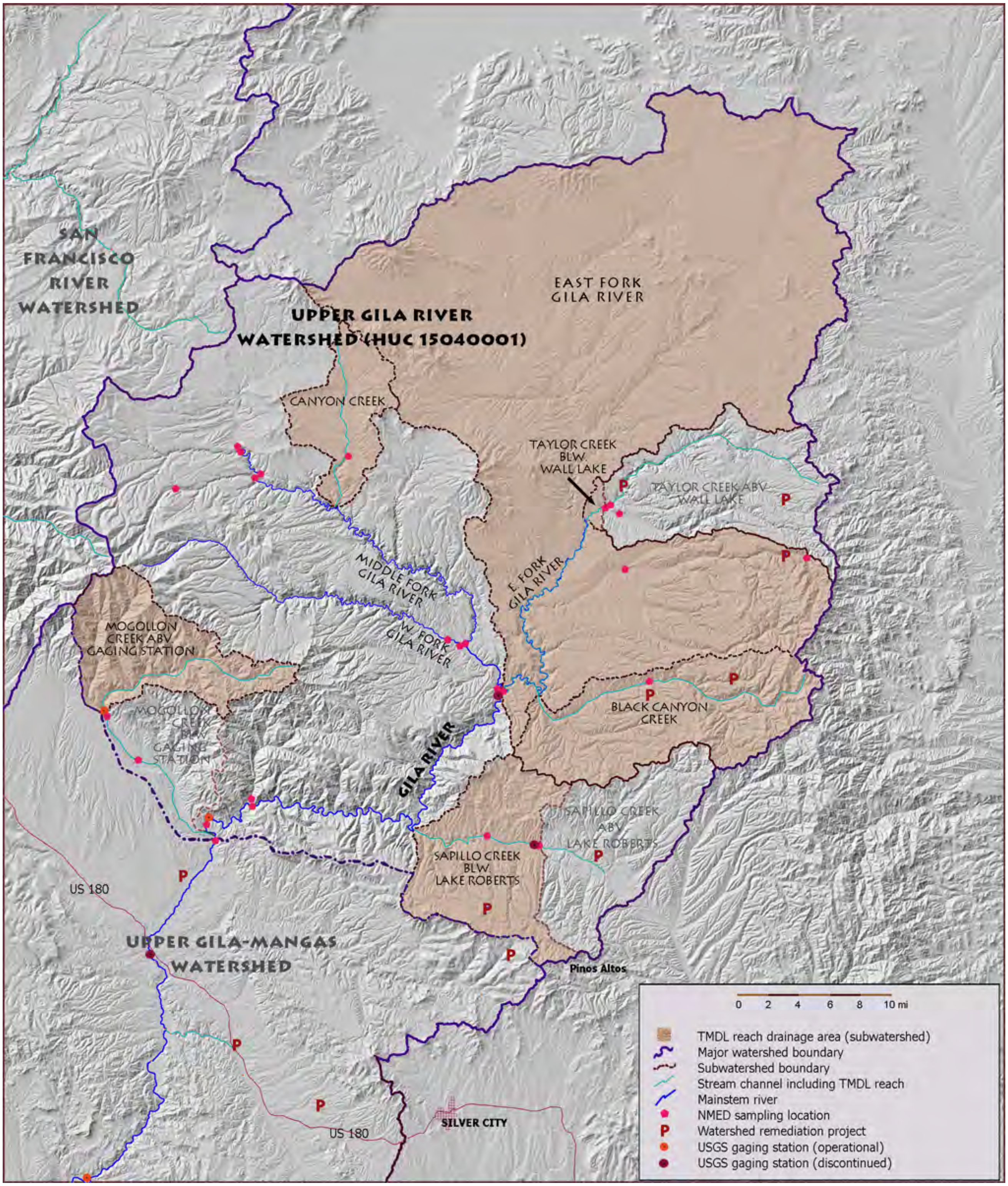
All perennial tributaries [including the East and West Forks, Gila River] upstream of and including Mogollon Creek: domestic water supply, irrigation, high quality coldwater aquatic life, wildlife habitat, livestock watering, secondary contact.

WQS Section **20.6.4.503**

Lake Roberts, Snow Lake, and Wall Lake: irrigation, coldwater aquatic life, wildlife habitat, livestock watering, and secondary contact: coldwater aquatic life, irrigation, livestock watering, wildlife habitat, and secondary contact.

WQS Section **20.6.4.504**

Link to WQS: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf



Map TMDL-01. Subwatersheds for water-quality impaired (TMDL) stream segments on the Upper Gila watershed (HUC 15040001). All NMED water-quality sampling sites are shown; see Map 4 for stream segments not named here. Locations of USGS gaging stations for current or historic streamflow data are also shown. On some streams, water quality data indicate that contaminant loads significant enough to impair designated uses occur only on particular segments (e.g., Mogollon Creek, Taylor Creek). In these cases, the entire stream reach appears on the map, and the subbasin draining directly to the water-quality impaired reach (the TMDL drainage area) is distinguished from the remainder of the stream's watershed. The tables for each TMDL subwatershed in this section include information on remediation projects shown on the map.

BLACK CANYON CREEK SUBWATERSHED (EAST FORK GILA RIVER TO HEADWATERS)

TMDL reach length: 25.2 mi; **Subwatershed area:** 113 sq. mi.
Elevation range: 5700–9000 ft.
Watershed cover: 95% forested; 5% rangeland
Watershed management: >99% USFS (Wilderness RD); <1% private
Wilderness: ~102 sq. mi. (93%)
Counties [SWCDs]: Grant [Grant], Sierra [Sierra]
TMDL: http://www.nmenv.state.nm.us/swqb/Temperature_TMDL_in_Black_Canyon_Creek_11-05-01.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.503)**

TMDL parameter exceeded: Temperature

Current exceedance: 37% of readings exceeded 20° C standard

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	Action (identification of MPs)	Possible MPs
Loss of riparian shade cover Inhibited riparian regeneration Reduced base flow due to increased floodplain evaporation/infiltration rates Grazing* and silviculture (historic fire suppression); consequent reduction in herbaceous cover; increased sediment runoff to channel Extreme runoff events after catastrophic fire (e.g. 1995, 1996) causing increased width–depth stream morphology *No livestock grazing is currently permitted on the upper 75% of the watershed, and no term permit will be issued before ~ 2017.	Proposed, October 2006: Evaluate trail and road impacts Evaluate herbaceous cover Evaluate stream banks and morphology Design/implement fish barrier improvements Other: Evaluate grazing activities in lower 25% of watershed (ongoing by The Nature Conservancy/Headwaters Ranch) Evaluate road and recreation impacts, including in-stream vehicular traffic & campground (GNF & partners in travel planning)	Proposed, October 2006: Near-channel pole/post/herbaceous plantings In-channel structures (decrease width-depth ratios) Fish barrier improvements Other: Fencing (elk) Grazing management (Sapillo allotment) Prescribed burning to increase herbaceous cover (NEPA under development by Trout Unlimited, GNF) Road realignment; culvert and trail improvements; OHV closures Brush layer, filter strip; other floodplain remediation

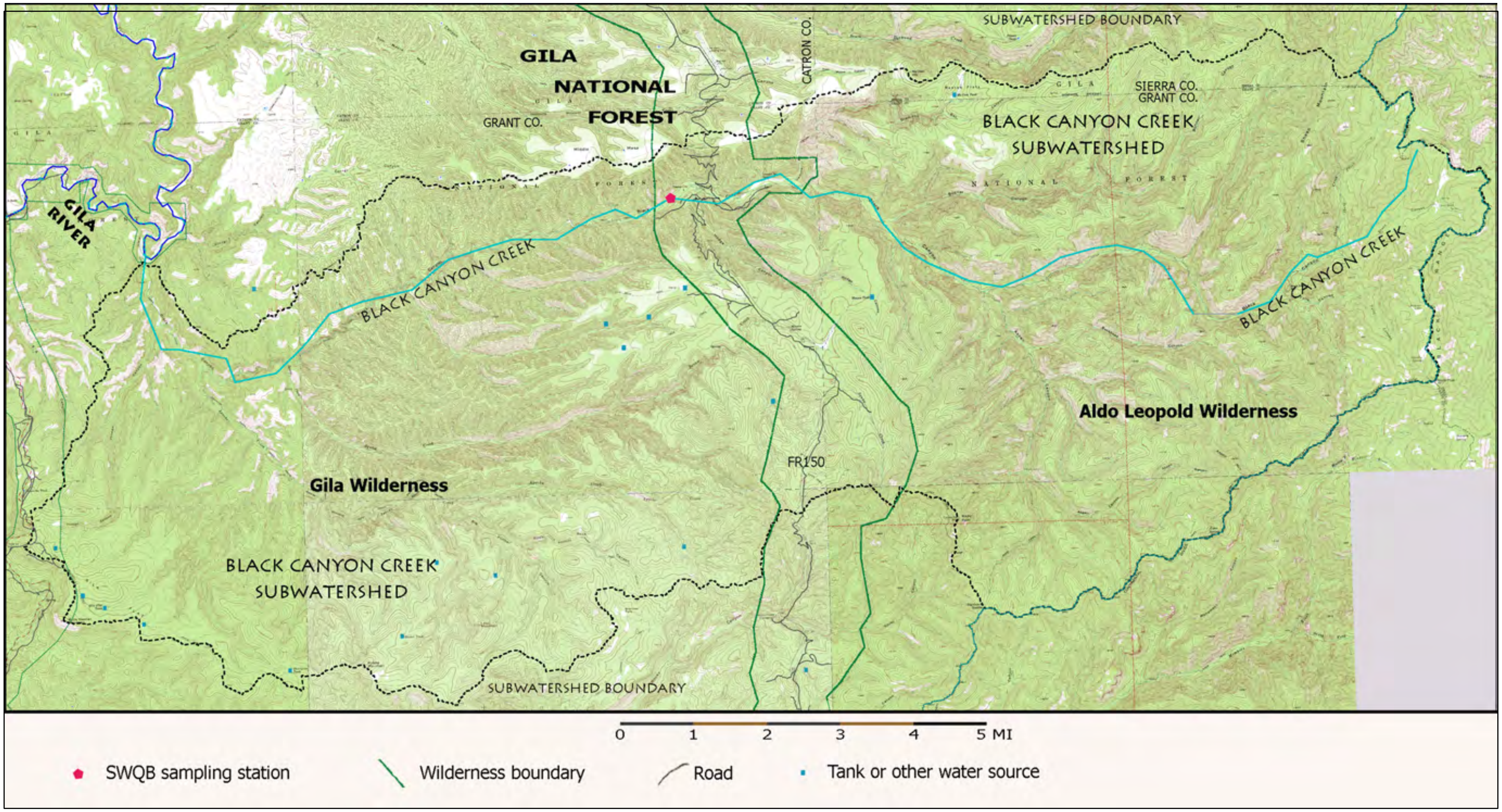
BLACK CANYON CREEK SUBWATERSHED (EAST FORK GILA RIVER TO HEADWATERS)—continued

Milestones	**Schedule**	**Target criteria**
Develop and submit initial work proposal (GWP) Obtain funding; complete initial project work; establish monitoring protocols Document existing canopy; vegetative cover; road, trail, vehicle, and campground impacts NEPA for silviculture improvements in place (GNF, TU) Prescribed burning plan complete Travel management planning finalized (GNF & partners) Future work plans developed: burning, road improvements/closures Costs and funding sources ID'd	2006 2007 2007 2009 GNF, USFWS schedule 2008? Dependent on above Dependent on above	Increase stream shade canopy from 60% to 75% Increase total vegetative cover on streambanks by 20% Decrease width-depth ratio by 40% Increase herbaceous cover on treated forested areas by 30% Reduce temperature exceedances to < 10%

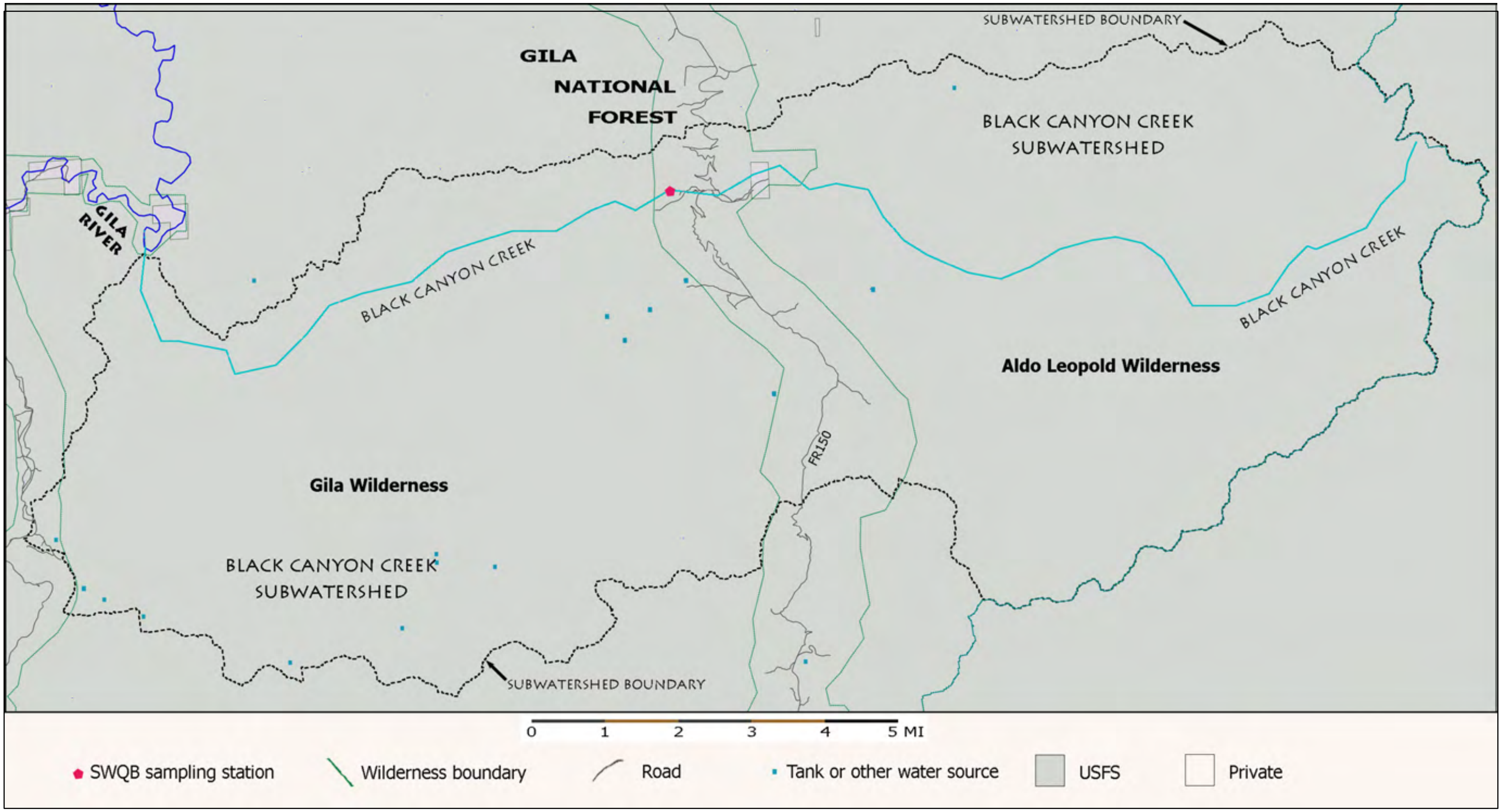
Monitoring (suggested monitoring protocols are described in Section 6):

- Regular NMED/SWQB monitoring and sampling at established stations
- Riparian cover density measured over three years; photo points; channel morphology baseline and changes
- Prescribed burning: protocols for tree cover density, line-point intercept for herbaceous cover
- Road management: HEM, RUSLE
- Long-term volunteer monitoring programs under development to document riparian condition, water quality, nonpoint source contributions

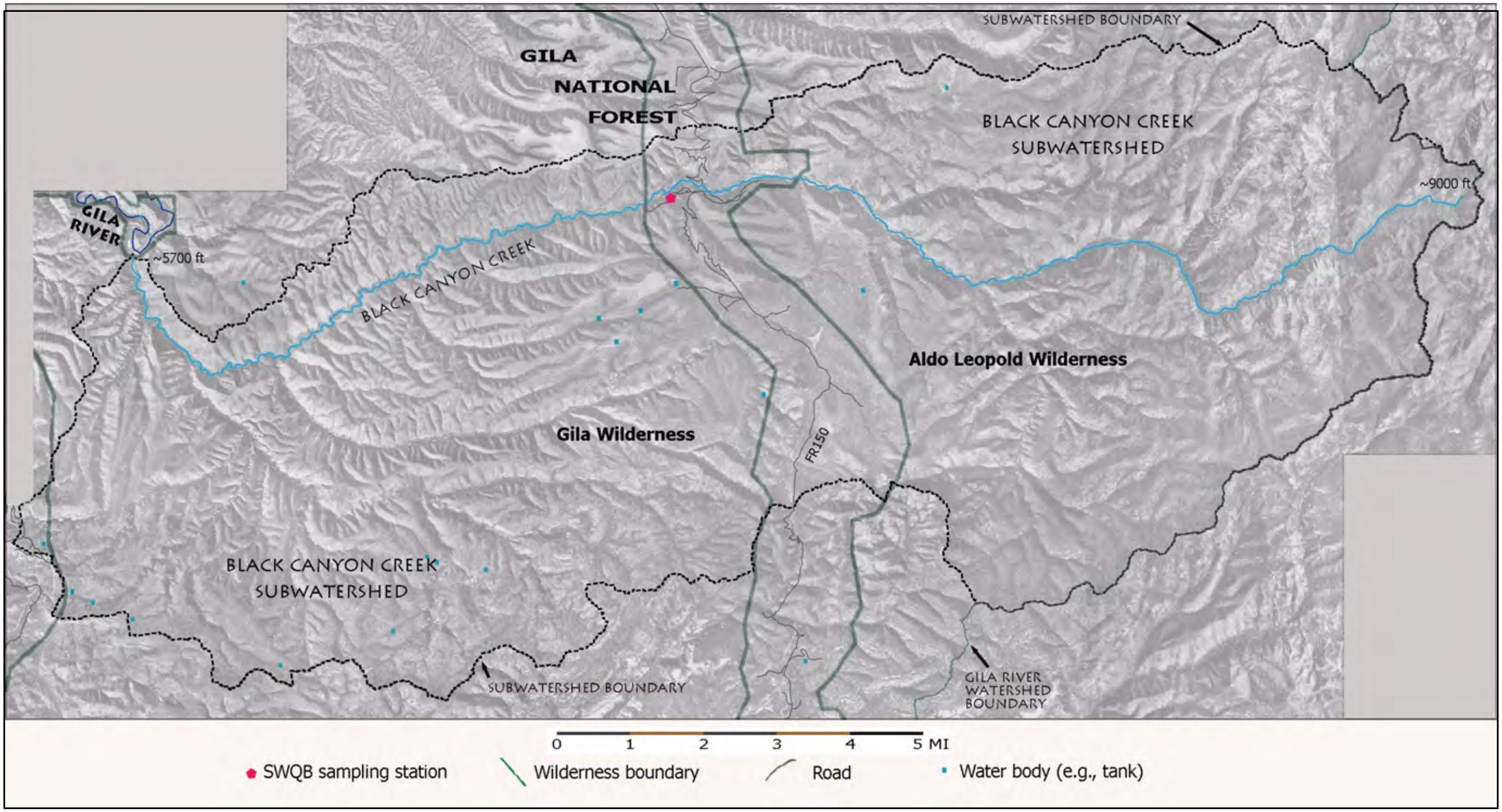
Note. Gila trout, a listed species, have been reintroduced to Black Canyon Creek.



Map TMDL-02. Topographic map, Black Canyon Creek subwatershed. Base image from USGS 1: 24000 quads. All data from USGS, NMED, and USFS Gila National Forest.



Map TMDL-03. Land management status map, Black Canyon Creek subwatershed. All data from NMED, USGS and USFS Gila National Forest.



Map TMDL-04. Aerial photography relief map, Black Canyon Creek subwatershed. Base image: 1996-2002 USGS digital orthophotoquads. All data from NMED, USGS and USFS Gila National Forest.

BLACK CANYON CREEK—continued

Black Canyon Creek photos. Clockwise from upper left: Downstream from FR150, June 2006; at campground, June 2006; road through campground, April 2001. 2001 photo courtesy NMED, Silver City.

CANYON CREEK SUBWATERSHED (MIDDLE FORK GILA RIVER TO HEADWATERS)

TMDL reach length: 14.2 mi; **Subwatershed area**: 47 sq. mi.
Elevation range: 6700–8200 ft.
Watershed cover: 36% forested; 64% rangeland
Watershed management: 99% USFS (Reserve and Wilderness RDs); 1% private
Wilderness: 5.5 sq. mi. (~12%)
Counties/SWCDs: Catron (San Francisco SWCD)
TMDL: http://www.nmenv.state.nm.us/swqb/Plant_Nutrients_TMDL_for_Canyon_Creek_12-18-2001.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.503)**

TMDL parameter exceeded: Plant nutrients

Current exceedance: Aquatic productivity exceeds standard by 2.58 lbs/day (75%)

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	**Action (identification of MPs)**	**Possible MPs**
Natural nitrogen sources (springs) Loss of riparian vegetation and subsequent reduction in filtration and nutrient uptake capacity Grazing management: animal waste inputs to stream Road condition, including road crossings: nutrient transport in sediment runoff Streamside livestock trampling; increased nutrient transport to channel Reduced baseflow from loss of streambank storage Loss of high-elevation and/or near-channel wetlands	Evaluate local spring sources of nitrogen Evaluate animal waste levels, compaction, and grazing impacts near riparian zone Evaluate stream bank vegetative cover density Evaluate potential for increased bank storage through natural or bioengineering techniques Evaluate potential sediment inputs from road crossings, road design, and recreation impacts, including in-stream vehicular traffic (GNF & partners travel planning)	Riparian exclosures (to decrease cattle/elk floodplain compaction effects and in-stream animal waste) Filter strip, and/or pole plantings to increase vegetation filtration capacity and nutrient uptake In-stream structures to enhance floodplain/bank water storage, increase base flow Road realignment; culvert improvement; seasonal or OHV closures Reclamation of meadows, wetlands

CANYON CREEK SUBWATERSHED (MIDDLE FORK GILA RIVER TO HEADWATERS)—continued

TMDL reach length: 14.2 mi; **Subwatershed area:** 47 sq. mi.
Elevation range: 6700–8200 ft.
Watershed cover: 36% forested; 64% rangeland
Watershed management: 99% USFS (Reserve and Wilderness RDs); 1% private
Wilderness: 5.5 sq. mi. (~12%)
Counties [SWCDs]: Catron [San Francisco]
TMDL: http://www.nmenv.state.nm.us/swqb/Turbidity_TMDL_for_Canyon_Creek_12-13-2001.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.503)**

TMDL parameter exceeded: Turbidity

Current exceedance: Turbidity (as total suspended solids) exceeds standard by 263 lbs/day (61%)

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	Action (identification of MPs)	Possible MPs
Loss of riparian vegetation and subsequent reduction in filtration capacity Road condition, including road crossings: sediment runoff Streambank destabilization Herbaceous cover loss: reduced upland infiltration rates; increased overland sediment delivery to channel Tributary channel gullying; increased sediment input during runoff events Loss of high-elevation and/or near-channel wetlands; reduced filtration capacity	Evaluate animal floodplain compaction and grazing impacts in riparian zone Evaluate stream bank vegetative cover density Evaluate potential sediment inputs from road crossings, road design, and recreation impacts, including in-stream vehicular traffic (GNF & partners in travel planning) Identify other streambank stability impacts Evaluate potential for thinning/burning to improve herbaceous cover	Riparian exclosures (to decrease cattle/elk floodplain compaction effects; enhance riparian vegetation survival) Filter strip, and/or pole plantings to increase vegetation filtration capacity In-channel structures to improve bank stability Road realignment; culvert improvement; seasonal or OHV closures Prescribed thinning/burning Reclamation of meadows/wetlands

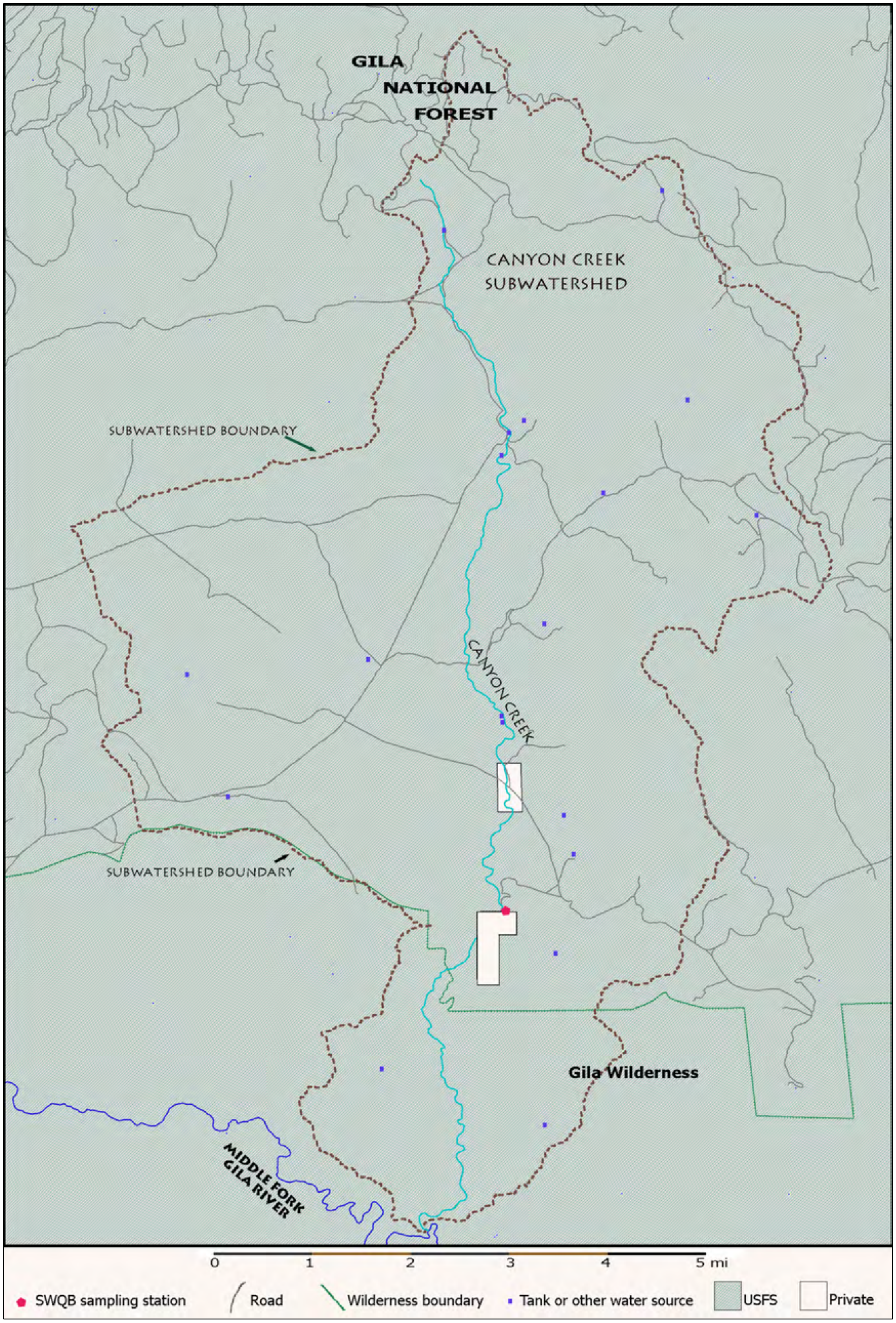
CANYON CREEK SUBWATERSHED (MIDDLE FORK GILA RIVER TO HEADWATERS)—continued

Milestones	**Schedule**	**Target criteria**
Agency/landowner liaison to establish working group/plan	2007-2008	Filter strips and/or exclosures constructed on 20% of most heavily impacted floodplain areas
Document existing canopy; vegetative cover (GNF planning)	Dependent on GNF scheduling	Increase streambank vegetative cover by 20% Increase upland herbaceous cover by 20%
Document road and vehicle impacts (travel management planning)	2007?	Reduce aquatic vegetation productivity by ~25%, from 3.45 lbs/day to 2.6 lbs/day
Travel management planning finalized (GNF & partners)	2008?	Reduce nitrite level from 0.25 mg/L; nitrate from 0.21 mg/L, and phosphorus from 0.078 mg/L
Future work plans developed: silviculture, road improvements/closures; streambank and floodplain measures	GNF schedule	Reduce average turbidity levels by 25%, to 519 lbs/day
Costs and funding sources ID'd	Dependent on above	

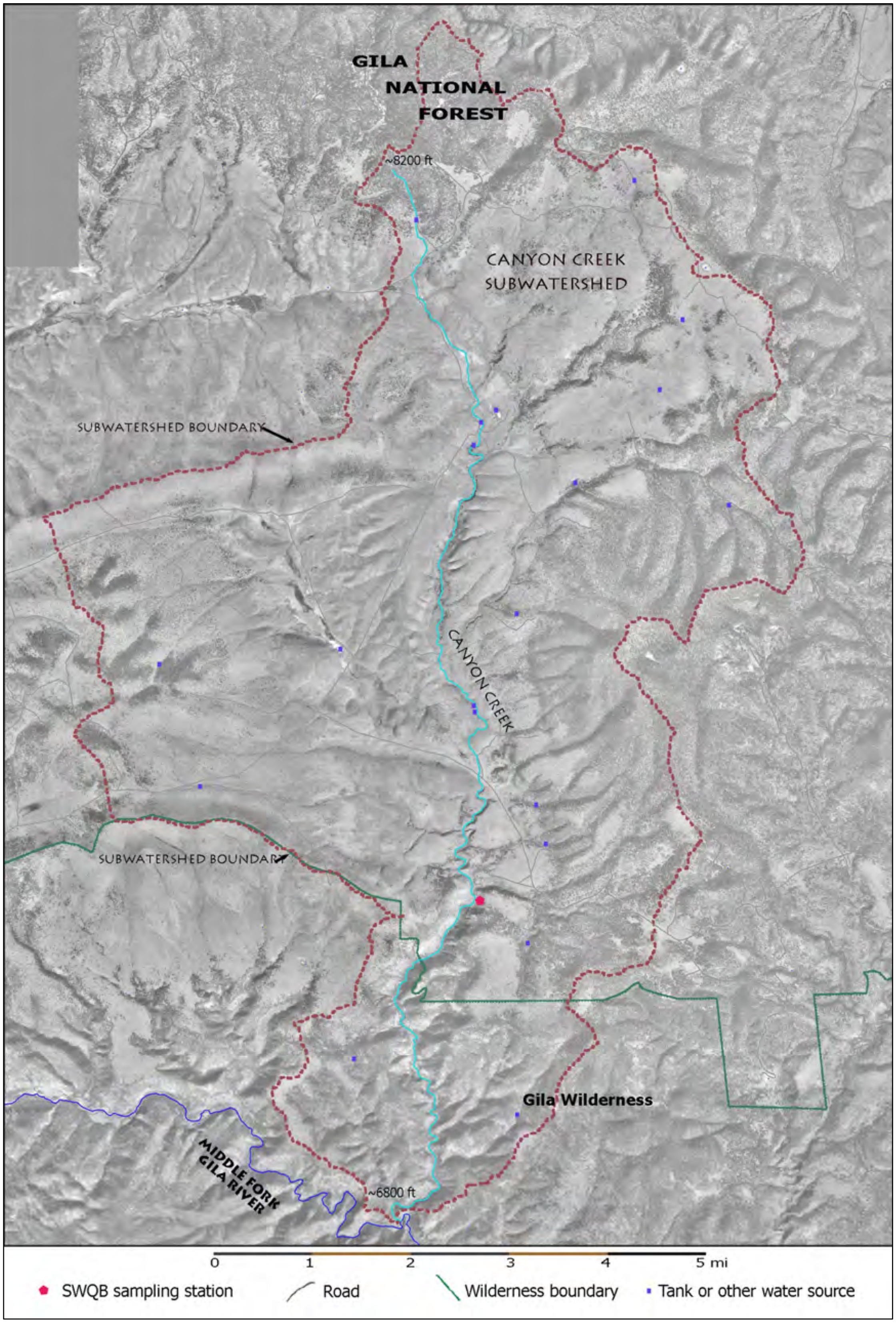
Monitoring (suggested monitoring protocols are described in Section 6):

- Canyon Creek is an extremely remote site. Ideally, local landowners/permittees would be engaged in planning and monitoring efforts.
- Appropriate monitoring protocols will depend on implemented MPs
- Regular NMED/SWQB monitoring and sampling at established stations
- Long-term volunteer monitoring programs under development to document riparian condition, water quality, nonpoint source contributions

Map TMDL-05. Topographic map, Canyon Creek subwatershed. Base image from USGS 1:24000 quads. All data from USGS, NMED, and USFS Gila National Forest .



Map TMDL-06. Land management status map, Canyon Creek subwatershed. All data from NMED, USGS and USFS Gila National Forest.



Map TMDL-07. Aerial photography relief map, Canyon Creek subwatershed. Base image: 1996-2002 USGS digital orthophotoquads. All data from NMED, USGS, and USDA Gila National Forest.

CANYON CREEK—continued

Canyon Creek photos. Clockwise from left: Downstream past NMED sampling site, May 2001; FR 142 and culvert near sampling location, May 2001; NMED/SWQB staff in dense aquatic vegetation at sampling site, June 2001. All photos courtesy NMED, Silver City.

EAST FORK GILA RIVER SUBWATERSHED

TMDL reach length: 26.2 mi; **Subwatershed area:** 798 sq. mi. (excluding Taylor and Black Canyon Creek watersheds); 1013 sq. mi. total
Elevation range: 5700–9000 ft.
Watershed cover: 70% forested; 29% rangeland; 1% agriculture. Most rangeland is in the northern half of watershed.
Watershed management: 64% USFS (Reserve, Black Range, and Wilderness RDs); 14% BLM; 10% private; 12% state
Wilderness: ~290 sq. mi. (29%)
Counties [SWCDs]: Catron [San Francisco], Grant [Grant], Sierra [Sierra]
TMDL: http://www.nmenv.state.nm.us/swqb/Chronic_Aluminum_TMDL_in_East_Fork_of_Gila_River_and_Taylor_Creek_11-05-01.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.503)**

TMDL parameter exceeded: Chronic aluminum

Current exceedance: Aluminum standard exceeded by 551 lbs/day (371%)

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	Action (identification of MPs)	Possible MPs
Natural sources (basalts) Inhibited riparian regeneration; reduced streambank filtration Loss of high-elevation meadows and wetlands; reduced filtration capacity Poorly drained or damaged roads; road crossings; culverts Sediment runoff from trails (recreational or livestock) Grazing and silviculture (historic fire suppression) management; consequent reduction in herbaceous cover and increased sediment runoff Gullying and loss of tributary channel vegetation; increased sediment input during runoff events	Evaluate streambank vegetative cover, particularly in historically farmed areas Evaluate grazing impacts, particularly in upper elevation areas of watershed on non-USFS lands (modification of grazing plans by GNF has already occurred) Evaluate road and recreation impacts, including in-stream vehicular traffic & campground (GNF& partners in travel planning) Identify gully sites and evaluate for remediation Evaluate historic meadow, wetland sites and springs for remediation potential	Gully remediation Grazing management Prescribed burning/thinning Road realignments; culvert and trail improvements; OHV closures Brush layer, filter strip; other floodplain remediation including re-seeding or re-planting Near-channel pole/post/herbaceous plantings; exclosures from grazing by livestock or elk Meadow and/or wetland reclamation In-channel structures to improve channel morphological resistance to erosion during moderate flow events

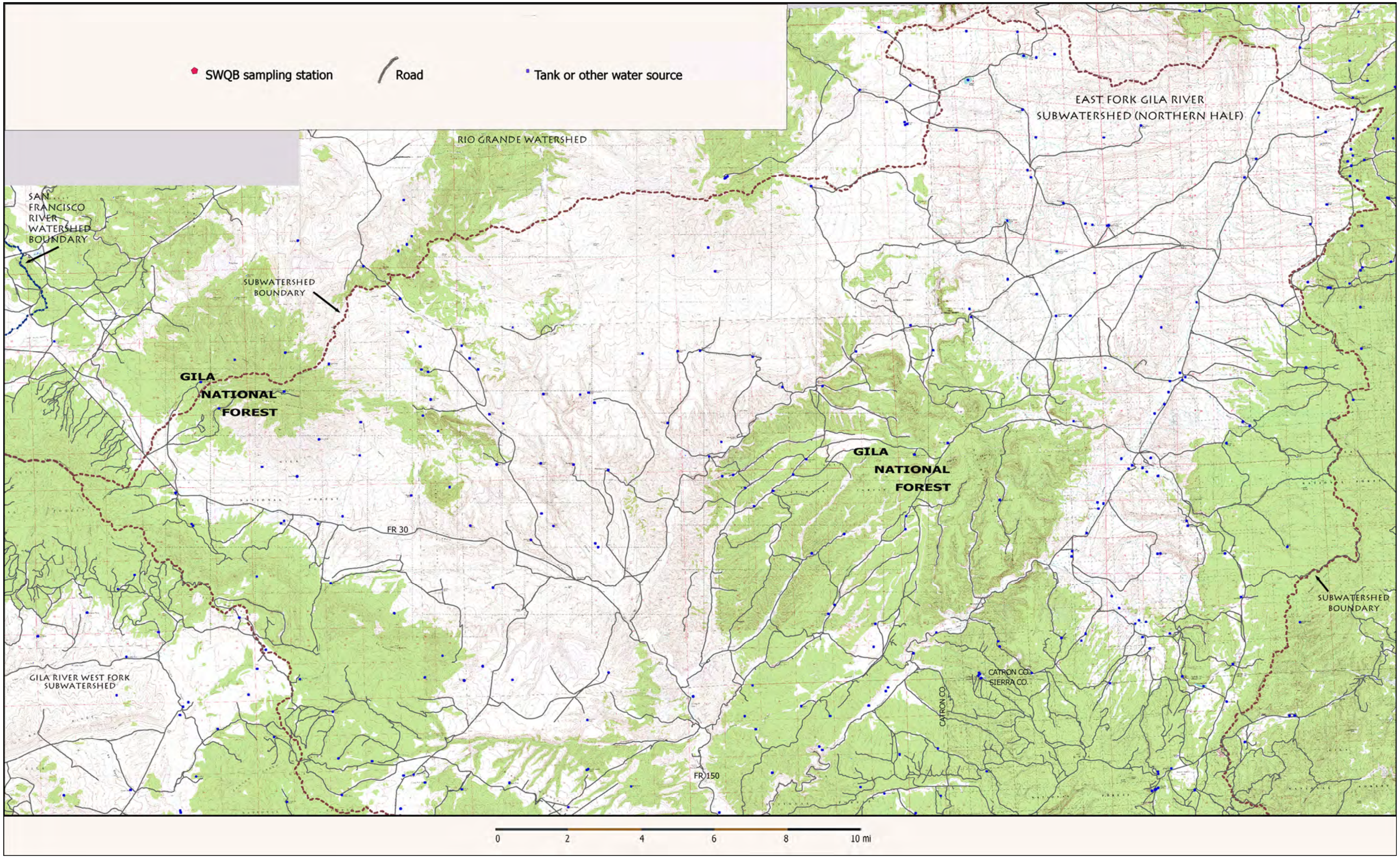
EAST FORK GILA RIVER SUBWATERSHED—continued

Milestones	Schedule	Target criteria
Establish/improve liaisons with private landowners, all management agencies to identify and document existing vegetative cover; road/vehicle, historic agricultural impacts and gullying sites Identify potential meadow/wetland remediation sites Travel planning complete Target subwatersheds and develop management strategies in conjunction with existing management plans Identify costs and leveraged funding sources Develop proposals First-round implementation of management measures Initial monitoring	2007-2009 2007-2008 2008? As scheduled with GNF, other stakeholders Based on above Based on above Based on above	Increase vegetative cover on targeted streambank reaches by 20% Implement remediation practices on 100 acres of meadow or wetland Thinning/burning of 10% of uplands Reduce sediment runoff inputs on targeted subwatersheds by 5% Reduce aluminum concentration by 50%, to 350 lbs/day

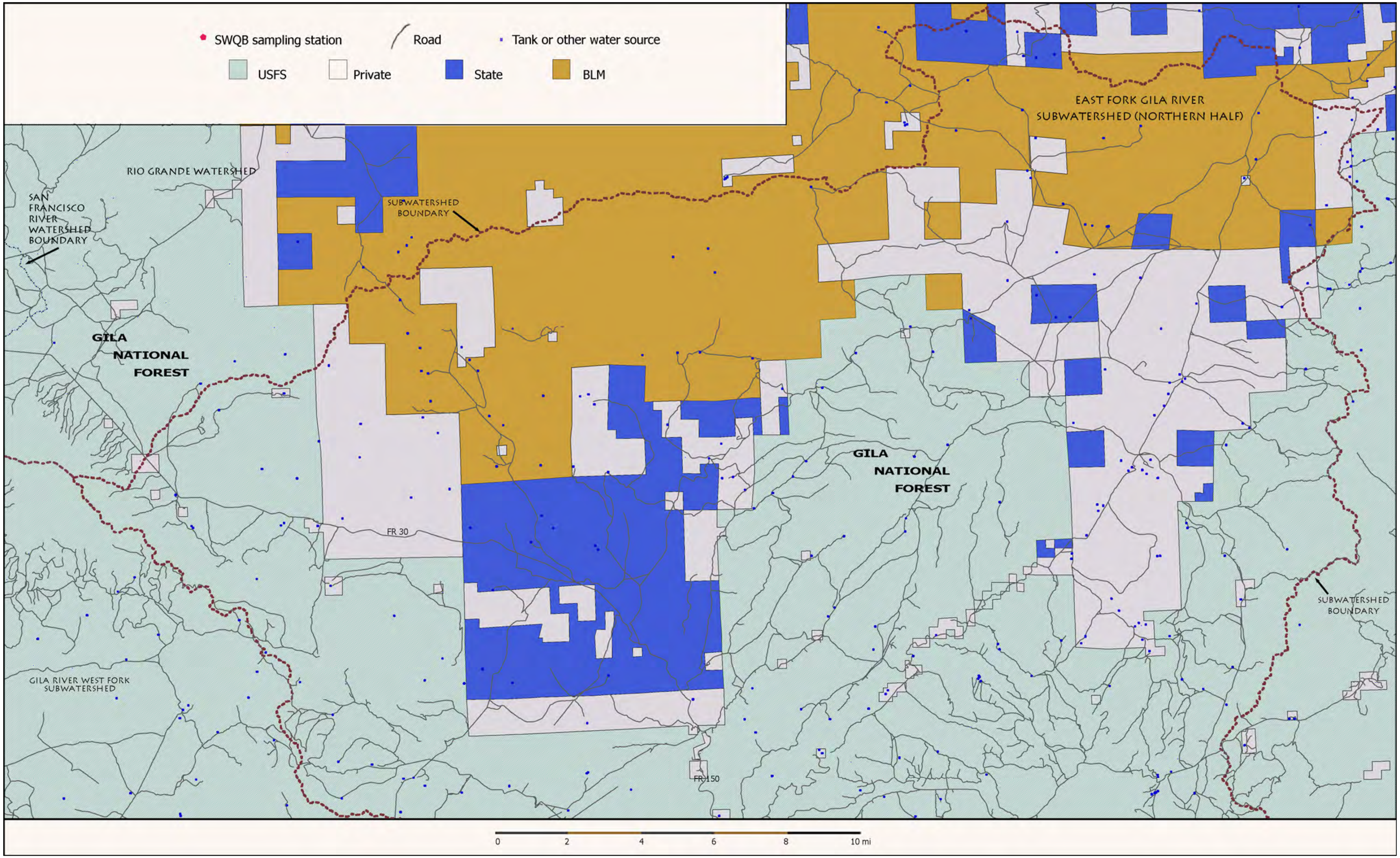
Monitoring (suggested monitoring protocols are described in Section 6):

- Appropriate monitoring protocols will depend on implemented MPs
- Regular NMED/SWQB monitoring and sampling at established stations
- Long-term volunteer monitoring programs, ideally involving watershed landowners, are under development to document riparian condition, water quality, nonpoint source contributions

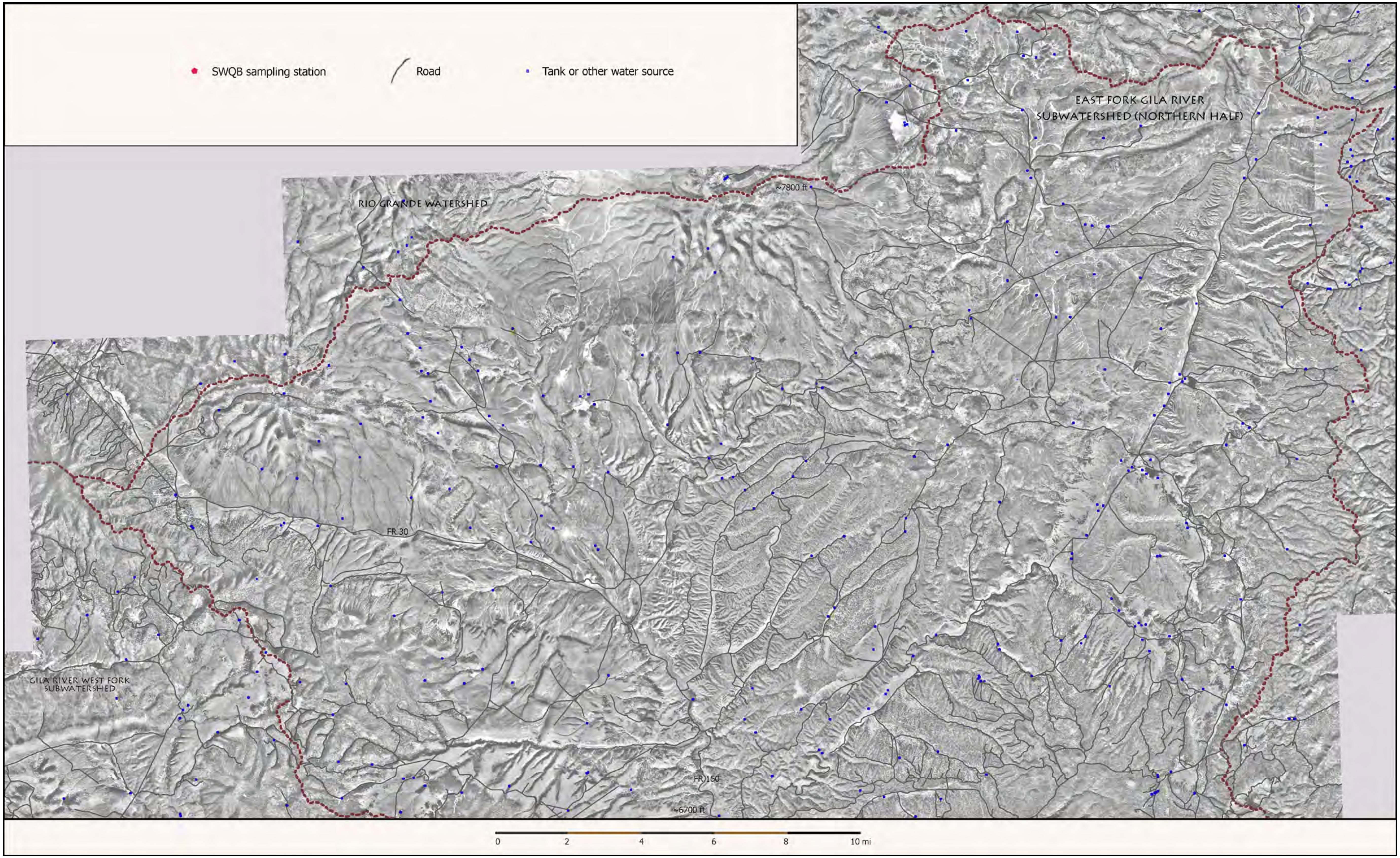
Note. The 2001 TMDL was established only for a 7.5 mile reach, from the mainstem confluence upstream to Taylor Creek, but a later revision in the *ROD* is for the 26.2-mile reach extending from the confluence upstream through Beaver Creek. This table and accompanying maps therefore reference the entire East Fork watershed. The Taylor Creek and Black Canyon subwatersheds are described in more detail in separate TMDL sections.



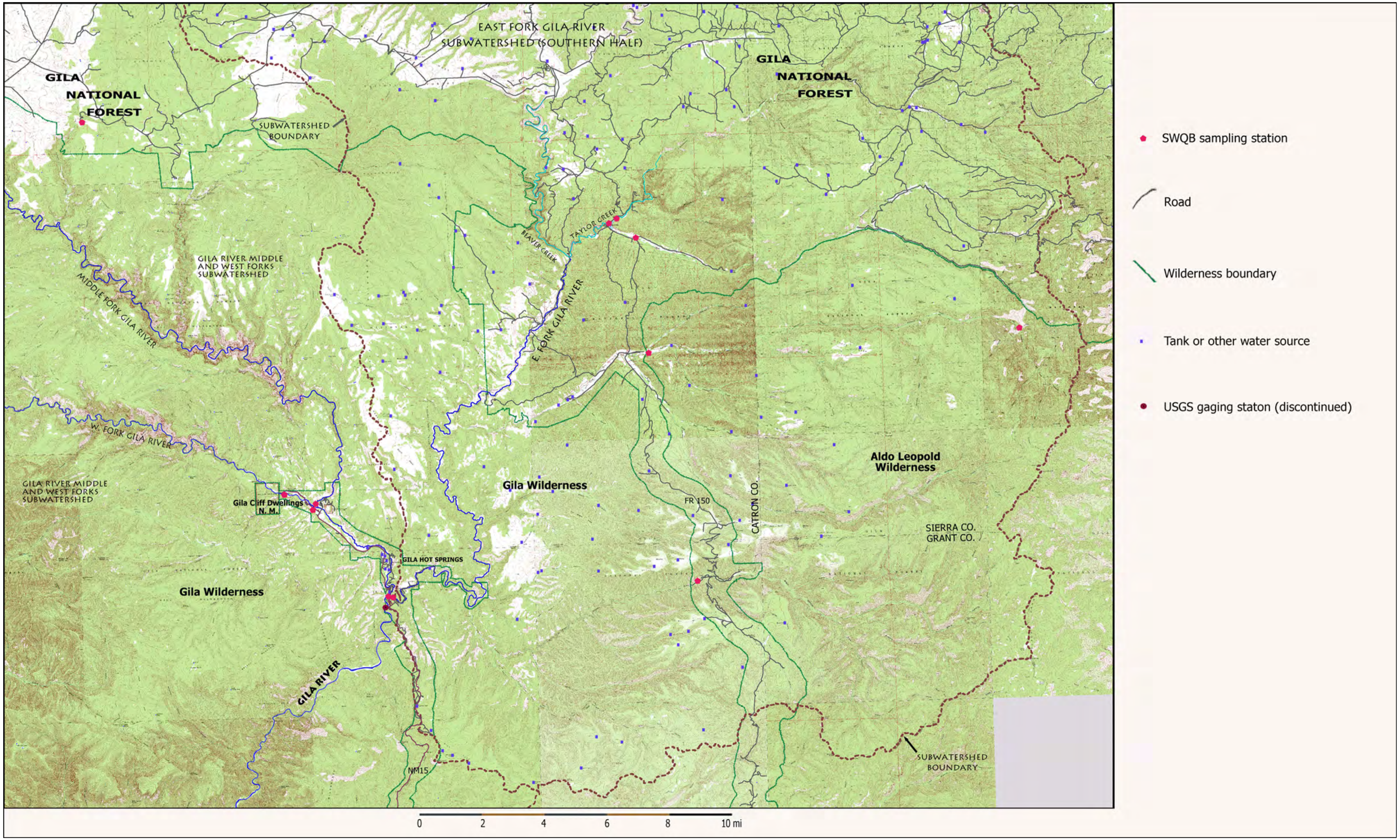
Map TMDL-08. Topographic map, Gila River East Fork subwatershed (northern half). There are no SWQB sampling stations on this portion of the watershed. Base image: USGS 1:24000 quads. All data from USGS, NMED, and USDA Gila National Forest. Refer to separate TMDL sections for more detail on the Taylor Creek and Black Canyon Creek subwatersheds, both tributary to the East Fork.



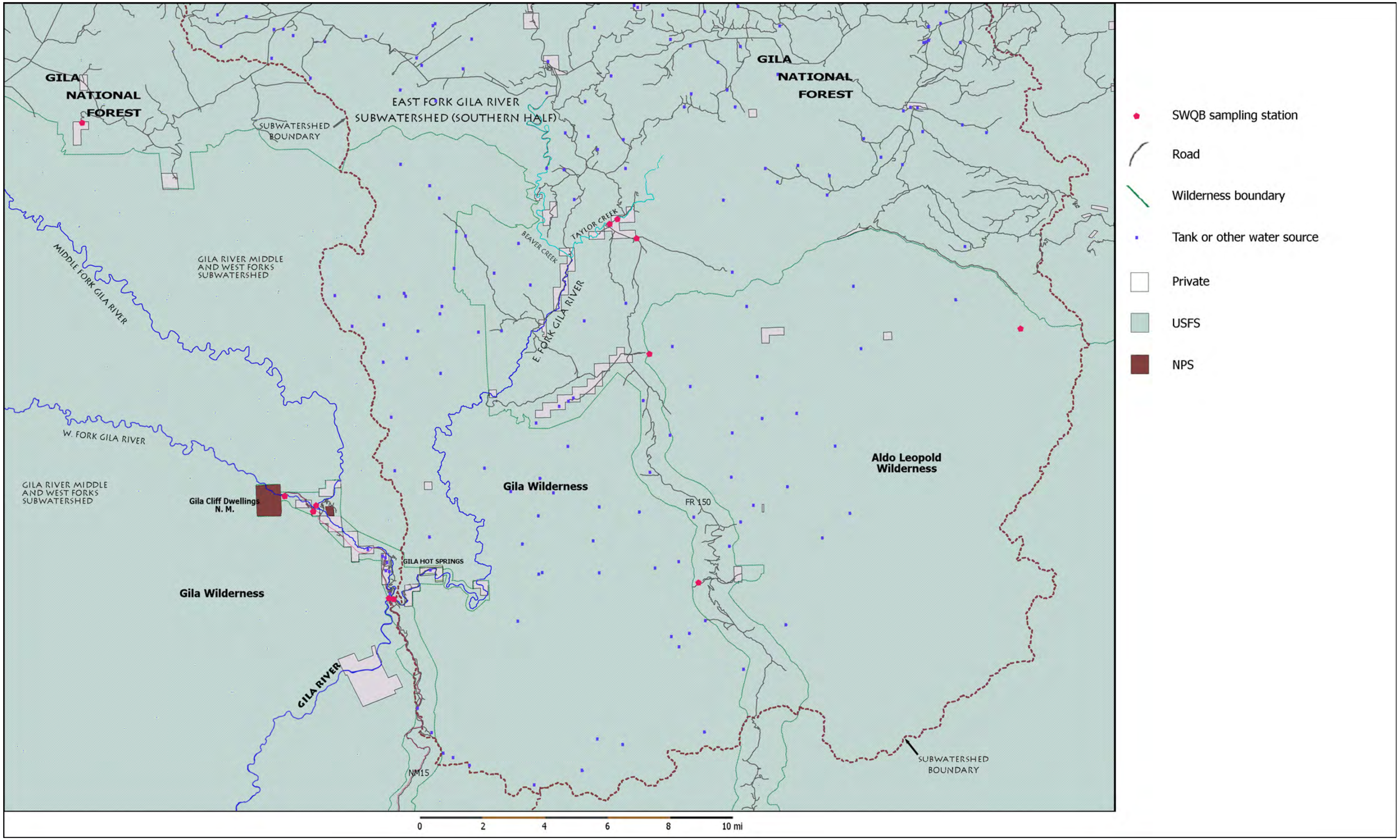
Map TMDL-09. Land management status map, Gila River East Fork subwatershed (northern half). All data from USGS, NMED, and USDA Gila National Forest.



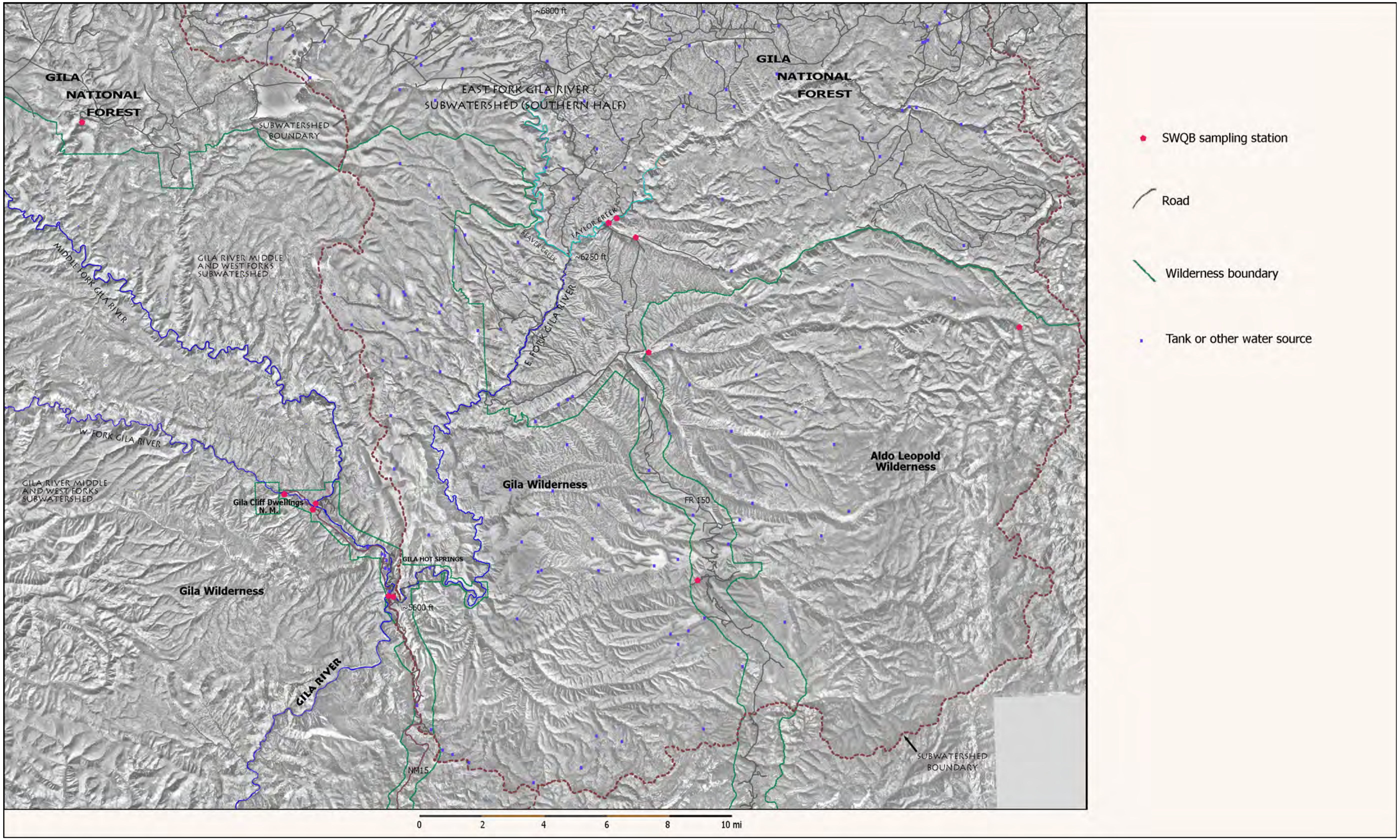
Map TMDL-10. Aerial photography relief map, Gila River East Fork subwatershed (northern half). Base image: 1996–2002 USGS orthophotoquads. All data from USGS, NMED, and USDA Gila National Forest.



Map TMDL-11. Topographic map, Gila River East Fork subwatershed (southern half). Base image: USGS 1:24000 quads. All data from USGS, NMED, and USDA Gila National Forest.



Map TMDL-12. Land management status map, Gila River East Fork subwatershed (southern half). All data from USGS, NMED, and USDA Gila National Forest.



Map TMDL-13. Aerial photography relief map, Gila River East Fork subwatershed (southern half). Base image: 1996–2002 USGS digital orthophotoquads. All data from USGS, NMED, and USDA Gila National Forest.

EAST FORK GILA RIVER—continued

East Fork Gila River photos. Clockwise from top left: Road crossing on Diamond Creek, a tributary to the East Fork, April 2001; East Fork at NMED/SWQB sampling station near mainstem confluence, April 2003; Hoyt Creek, a tributary of Taylor Creek and the East Fork, April 2001; NRCS remediation work site on the East Fork just downstream of confluence of Beaver and Taylor Creeks, June 2006. All 2001 and 2003 photos courtesy NMED, Silver City.

MOGOLLON CREEK SUBWATERSHED ABOVE USGS GAGING STATION

TMDL reach length: 12.6 mi; **Subwatershed area:** 73 sq. mi. (above gaging station); 124 sq. mi. total
Elevation range: 4600–8000 ft.
Watershed cover: 69% forested; 30% rangeland; <1% agriculture; <1% barren
Watershed management: 90% USFS (Wilderness and Glenwood RDs); <10% private; <1% state. Nearly all private land is downstream of the listed reach.
Wilderness: ~108 sq. mi. (87%)
Counties [SWCDs]: Catron [San Francisco], Grant [Grant]
TMDL: http://www.nmenv.state.nm.us/swqb/Chronic_Aluminum_TMDL_in_Mogollon_Creek_11-05-01.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.503)**

TMDL parameter exceeded: Chronic aluminum

Current exceedance: Aluminum standard exceeded by 31 lbs/day (91%)

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	Action (identification of MPs)	Possible MPs
Natural sources (basalts) Acid mine drainage from abandoned mines and tailings Surface disturbance from mining activity; increased sediment runoff Historic fire suppression, subsequent increases in forest density, and loss of upland herbaceous cover Conversion of meadow areas; loss of wetlands: decreased filtration capacity Grazing management	Identify abandoned mine sites and evaluate for nonpoint source contribution, particularly in Rain Creek drainage Identify potential sites for re-construction of wetlands Evaluate historic forest encroachment and potential for thinning treatments in conjunction with GNF planning efforts Evaluate stream bank vegetative cover density Evaluate grazing plans	Mine and tailings reclamation Constructed wetlands (filtration) Diversion of storm-induced flows near unreclaimed mines to infiltration areas Prescribed burning/thinning of woody species Modified grazing management

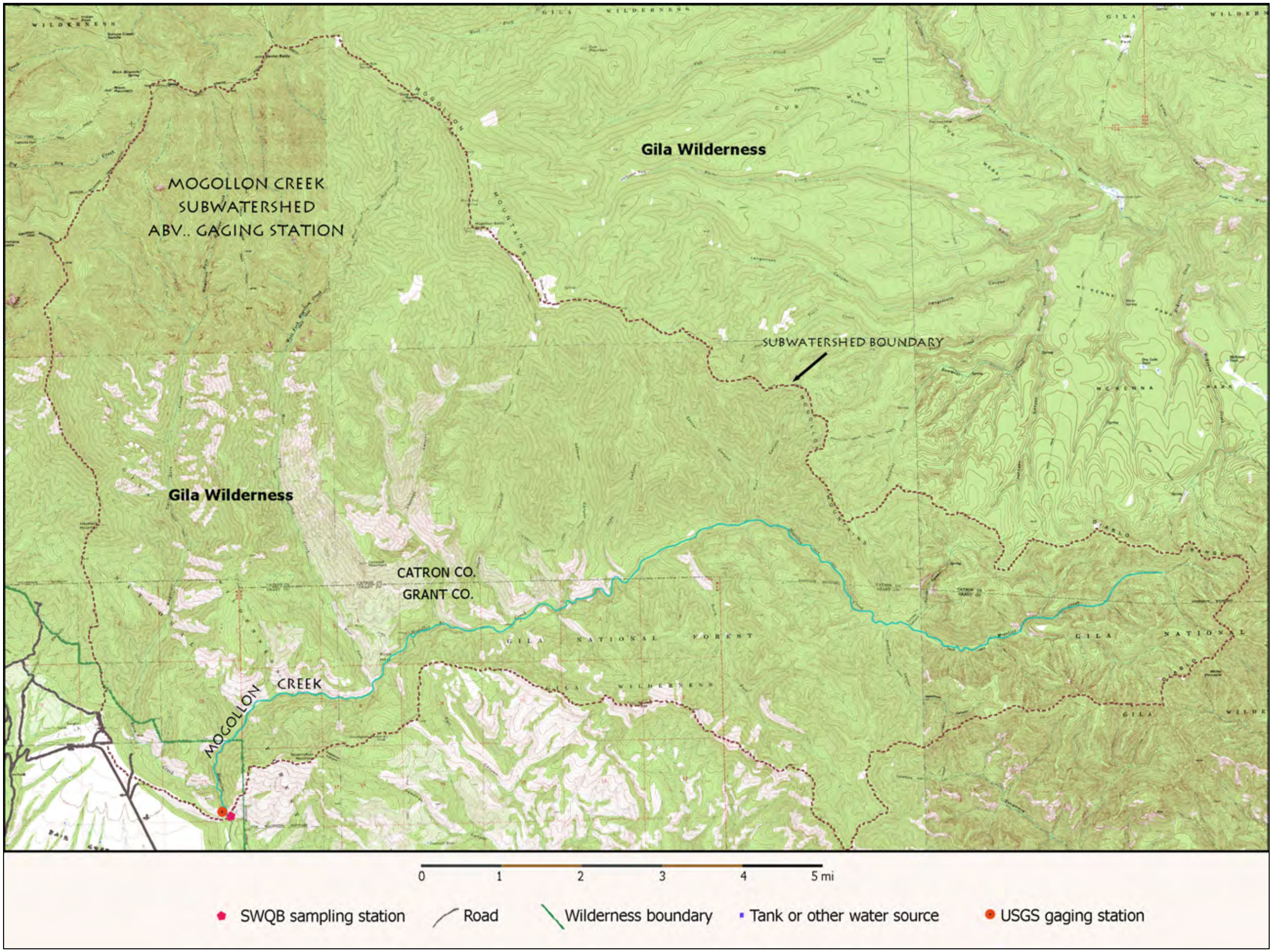
MOGOLLON CREEK SUBWATERSHED ABOVE GAGING STATION—continued

Milestones	**Schedule**	**Target criteria**
Abandoned mines and tailings mapped and evaluated	2007-2008	Two mining reclamation sites targeted and plans developed
Identification of historic meadows /potential wetlands completed	2007-2008	Potential wetland, meadow, and runoff diversion sites identified
Liaison with agencies (GNF, SWCDs, NRCS) and permittees re: forest and grazing plans	2007-2008	Wetland remediation plans developed 10% increase in herbaceous cover in targeted areas (managed fire; reseeding)
Most effective management measures identified; work plan established with GNF and other partners	2008	Reduce aluminum concentration by 25%
Identify costs and funding sources		
Develop proposals	As scheduled with GNF, other stakeholders	
First-round implementation of management measures		
Initial monitoring		

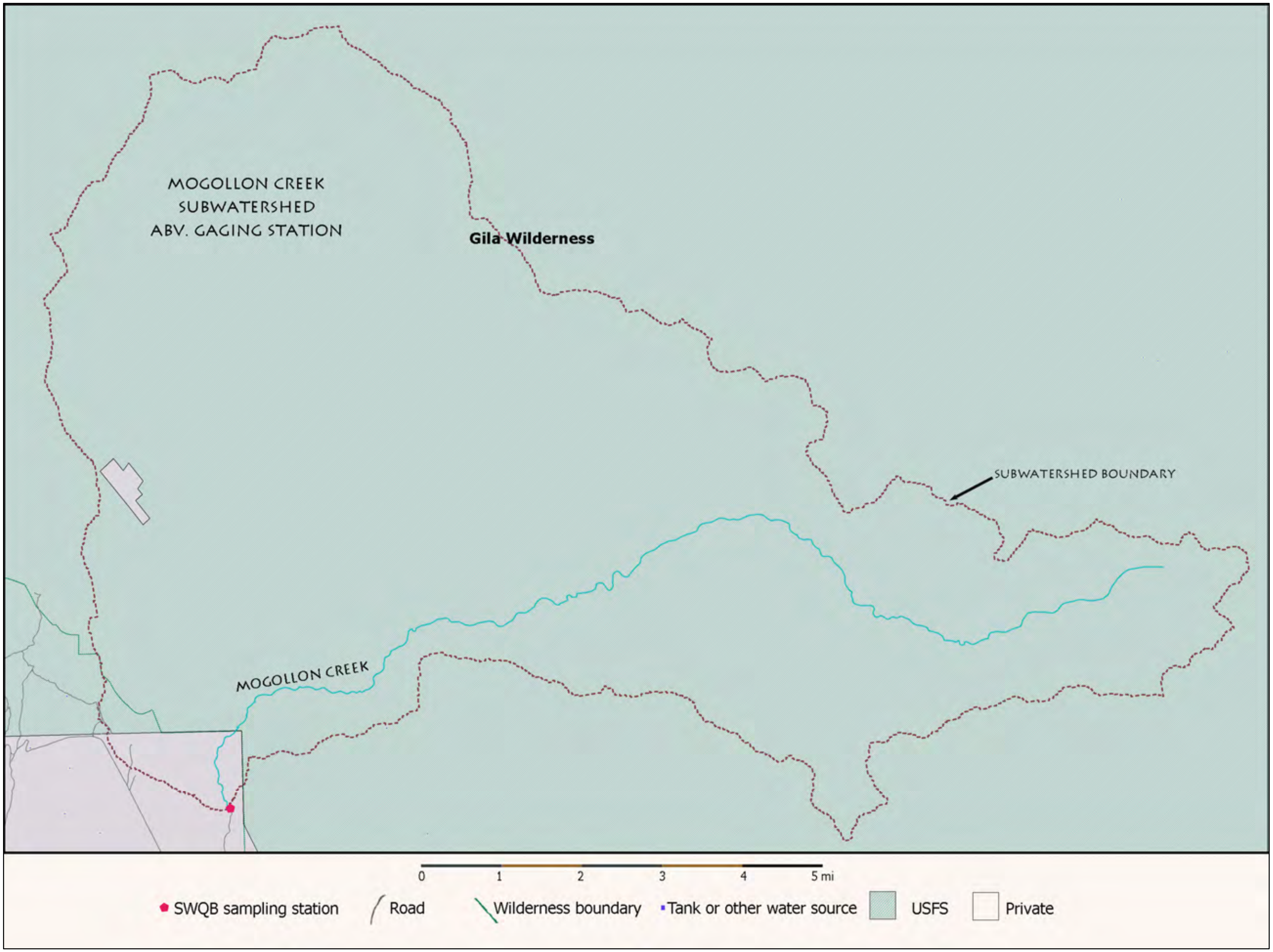
Monitoring (suggested monitoring protocols are described in Section 6):

- Regular NMED/SWQB monitoring and sampling at established stations
- Appropriate monitoring protocols will depend on implemented MPs and could include protocols to measure tree cover/herbaceous cover; HEM, RUSLE to monitor mine reclamation efforts
- Long-term volunteer monitoring programs under development to document riparian condition, water quality, nonpoint source contributions

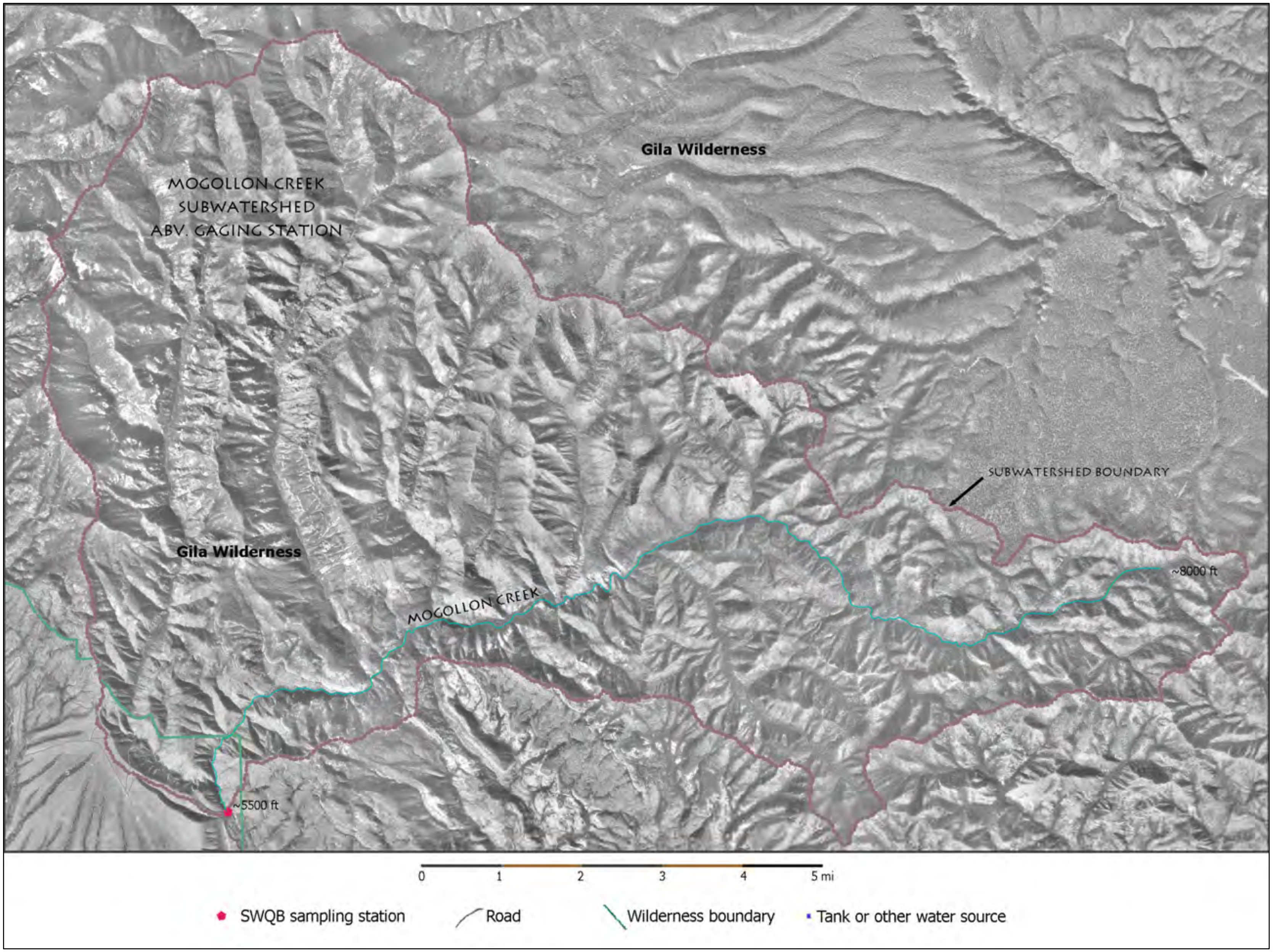
Note. Gila trout, a listed species, are present in perennial reaches of Mogollon Creek.



Map TMDL-14. Topographic map, Mogollon Creek subwatershed above USGS gaging station. Base map from USGS 1:24000 quads. All data from USGS, NMED, and USFS Gila National Forest.



Map TMDL-15. Land management status map, Mogollon Creek subwatershed. All data from NMED, USGS and USFS Gila National Forest.



Map TMDL-16. Aerial photography relief map, Mogollon Creek subwatershed upstream of gaging station. Base image: USGS 1996–2002 digital orthophotoquads.

MOGOLLON CREEK—continued

Mogollon Creek photos. Clockwise from upper left: NMED/SWQB sampling site near gaging station, January 2001; from Rain Creek Mesa, May 2001; in flood near confluence with Gila River, July 2006; view of upper watershed, May 2001. All 2001 photos courtesy NMED, Silver City.

SAPILLO CREEK SUBWATERSHED BELOW LAKE ROBERTS

TMDL reach length: 11.9 mi; **Subwatershed area:** 87 sq. mi. (to Lake Roberts); 174 sq. mi. total
Elevation range: 5200–6600 ft.
Watershed cover: 80% forested; 15% rangeland; 3% agriculture; 2% water
Watershed management: 98% USFS (Wilderness and Silver City RDs) ; < 2% private
Wilderness: ~65 sq. mi. (37%)
Counties [SWCDs]: Grant [Grant]
TMDL: http://www.nmenv.state.nm.us/swqb/Turbidity_TMDL_for_Sapillo_Creek_12-14-2001.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.503)**

TMDL parameter exceeded: Turbidity

Current exceedance: Turbidity (as total suspended solids) exceeds standard by 625 lbs/day (31%)

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	Action (identification of MPs)	Possible MPs
Septic leach or runoff from developed lands downstream of Lake Roberts Sediment transport through Lake Roberts during runoff events Road or gully runoff Loss of native ground cover by grazing impacts, historic agriculture, or clearing for construction Historic fire suppression and subsequent decline in upland herbaceous cover Conversion of meadow areas; loss of wetlands: decreased filtration capacity Channel earth-moving work (property protection)	Evaluate potential for wetland reclamation or construction Evaluate sediment reduction potential in Lake Roberts Evaluate stream bank vegetative cover density Evaluate road and recreation impacts (GNF& partners travel planning underway) Evaluate historic forest encroachment and potential for thinning treatments in conjunction with GNF planning efforts Evaluate grazing plans (underway on Sapillo allotment by The Nature Conservancy) Evaluate tributary drainages for gullying or other erosion effects	Constructed wetlands (filtration) Filter strips, brush mats, herbaceous or pole/post plantings on streambanks Silt fencing or other protection on construction sites Meadow reclamation Road and/or culvert realignment; closures Lake Roberts sediment reduction structures Prescribed burning/thinning of woody species (current 319/CFRP projects ongoing) Improved grazing management Gully or other treatments to reduce sedimentation from tributary channels

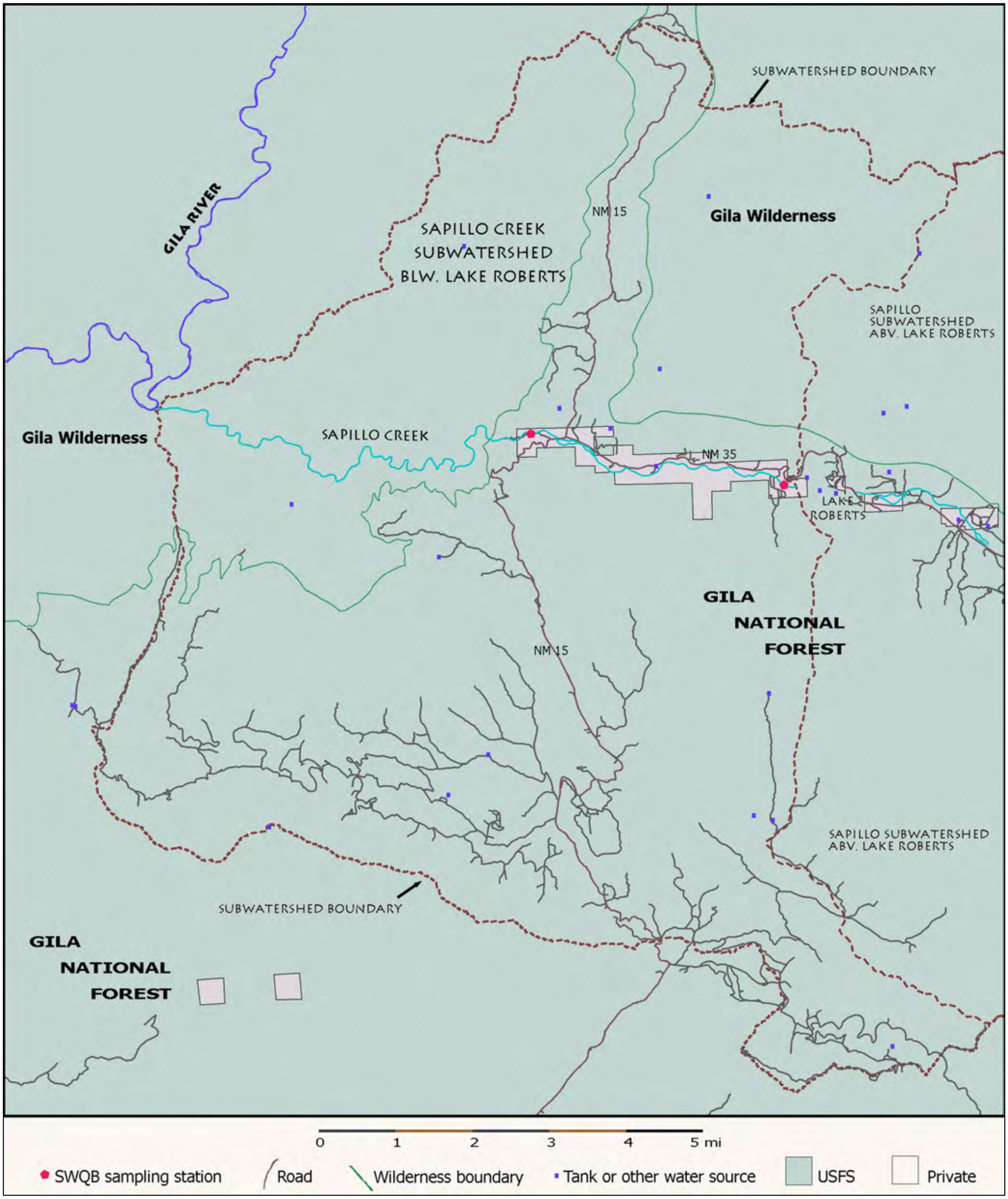
SAPILLO CREEK SUBWATERSHED (LAKE ROBERTS TO GILA RIVER)—continued

Milestones	Schedule	Target criteria
Initial contacts with landowners; development of remediation strategies Potential wetland sites identified Travel management planning complete Liaison established with pertinent Lake Roberts stakeholders to develop remediation strategies Coordination with GNF on remediation plans Most effective management measures identified; work plan established with GNF and other partners Identify costs and funding sources Develop proposals First-round implementation of management measures Initial monitoring	2006 2007-2008 2008? 2007-2008 2007-2008 2008-2009 Dependent on GNF scheduling	Proposal developed for abatement of sediment contributions from tributary drainage (GWP) Wetland reclamation: 5 acres Road improvement or closure reduces road sediment runoff by 10% on targeted sites Remediation of Lake Roberts sediment issues Native ground cover restored on 10% of currently bare ground or duff Thinning/prescribed burning plan in place for upper watershed Cessation of in-channel earth-moving projects Turbidity (as TSS) reduced 20%

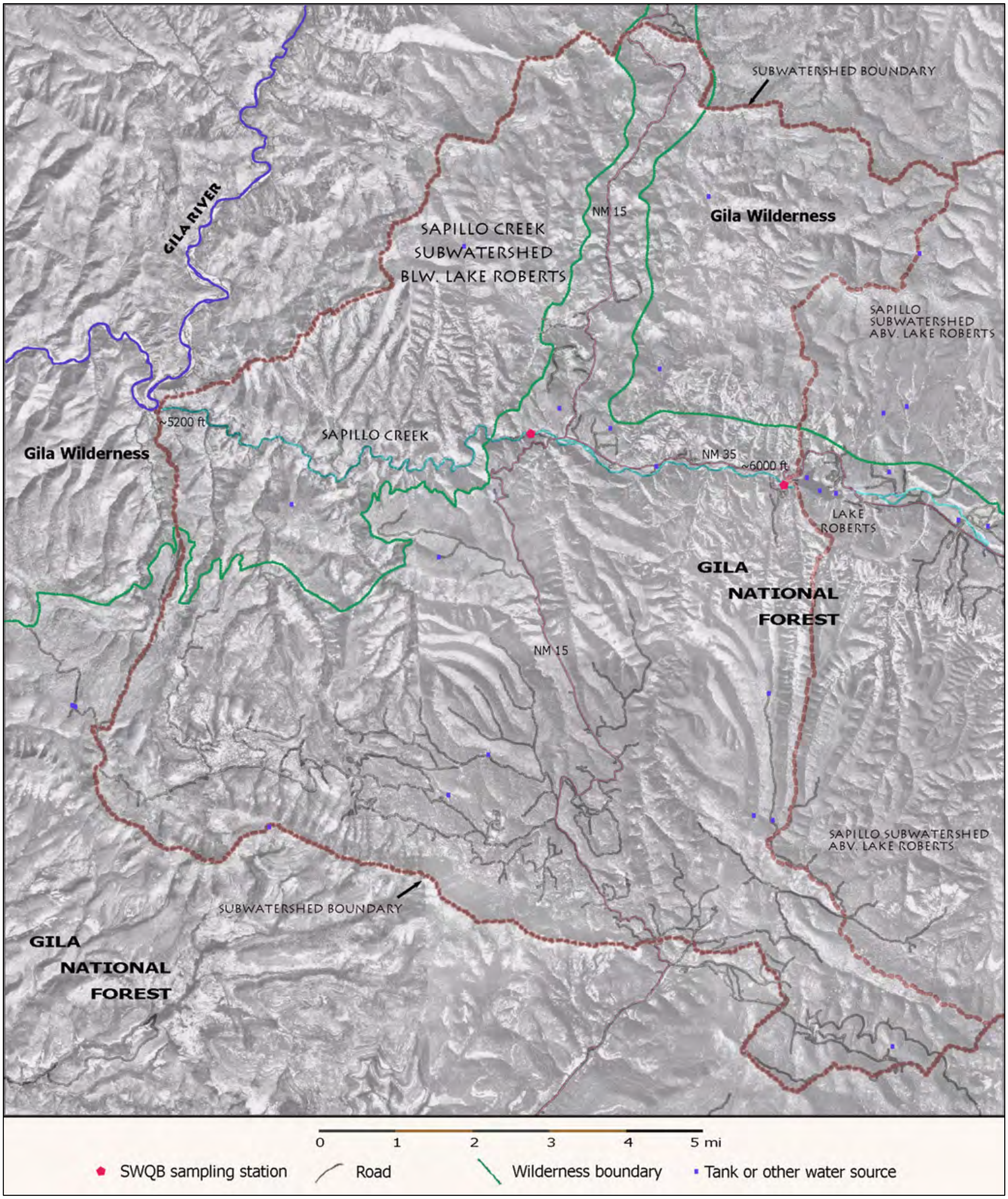
Monitoring: Monitoring (suggested monitoring protocols are described in Section 6):

- Regular NMED/SWQB monitoring and sampling at established stations
- GNF monitors RASES site within impaired reach; data collection on Skates fire effects to be incorporated
- Current data collection underway on 319 thinning project
- Tree cover/herbaceous cover; HEM, RUSLE to monitor road improvement or closure effects; results of upland thinning projects
- Long-term volunteer monitoring programs under development to document riparian condition, water quality, nonpoint source contributions

Map TMDL-17. Topographic map of the Sapillo Creek subwatershed downstream of Lake Roberts. Base image: USGS 1:24000 quads. All data from NMED, USGS, and USFS Gila National Forest.



Map TMDL-18. Land management status map, Sapillo Creek subwatershed downstream of Lake Roberts. All data from NMED, USGS and USFS Gila National Forest.



Map TMDL-19. Aerial photography relief map, Sapillo Creek subwatershed downstream of Lake Roberts. Base image: 1996-2002 USGS digital orthophotoquads. All data from USGS, NMED, and USFS Gila National Forest.

SAPILLO CREEK—continued

Sapillo Creek photos. Clockwise from upper left: ash from the June 2006 Skates fire transported downstream and deposited on banks below FR 15, July 2006; SWQB sampling site just upstream of Wilderness boundary, July 2001; Lake Roberts community ~1/2 mile downstream of Lake Roberts (Sapillo Creek flows across the center of the photograph), July 2001. Photos from 2001 courtesy NMED, Silver City.

TAYLOR CREEK SUBWATERSHED BELOW WALL LAKE

TMDL reach length: 2.6 mi; **Subwatershed area:** 3.2 sq. mi. (to Wall Lake); 102 sq. mi. total
Elevation range: 6200–9000 ft.
Watershed cover: 99% forested; <1% rangeland; <1% agriculture
Watershed management: 99% USFS (Black Range RD); < 1% private
Wilderness: ~9 sq. mi. (9%)
Counties [SWCDs: Catron [San Francisco]; Sierra [Sierra].
TMDL: http://www.nmenv.state.nm.us/swqb/Temperature_TMDL_for_Taylor_Creek_11-05-01.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.503)**

TMDL parameter exceeded: Temperature

Current exceedance: 52% of readings exceeded 20°C standard

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	Action (identification of MPs)	Possible MPs
Warming and evaporative effects due to Wall Lake impoundment Increased sediment inputs from Wall Lake during overtopping events; effects on channel width–depth ratios downstream of reservoir Loss and inhibited regeneration of riparian shade cover; encroachment of upland species onto floodplain Reduced base flow due to increased floodplain evaporation/infiltration rates Grazing/silviculture practices (historic fire suppression); consequent reduction in herbaceous cover; increased overland sediment runoff Campground recreation/road impacts	Proposed in the Taylor Creek WRAS*: Evaluate stream bank vegetative cover density, upland encroachment; bank stability Evaluate road and recreation impacts (travel management planning) Evaluate historic forest encroachment and potential thinning treatments in conjunction with GNF planning efforts Evaluate grazing plans Evaluate sediment reduction potential via Wall Lake dredging	Filter strips, brush mats, herbaceous or pole/post plantings on streambanks Stream barbs/bioengineering techniques Road realignments and/or drainage improvements, including campground Continuation of GNF thinning/prescribed burning projects (particularly in conjunction with biomass use projects) Meadow reclamation; native ground cover re-seeding Livestock/elk grazing management strategies Wall Lake dredging

TAYLOR CREEK SUBWATERSHED (WALL LAKE TO BEAVER CREEK)—continued

TMDL reach length: 2.6 mi; **Subwatershed area:** 3.2 sq. mi. (to Wall Lake); 102 sq. mi. total
Elevation range: 6200–9000 ft.
Watershed cover: 99% forested; <1% rangeland; <1% agriculture
Watershed management: 99% USFS; < 1% private
Wilderness: ~9 sq. mi. (9%)
Counties [SWCDs: Catron [San Francisco]; Sierra [Sierra].
TMDL: http://www.nmenv.state.nm.us/swqb/Chronic_Aluminum_TMDL_in_East_Fork_of_Gila_River_and_Taylor_Creek_11-05-01.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.503)**

TMDL parameter exceeded: Chronic aluminum

Current exceedance: Aluminum standard exceeded by 331 lbs/day (719%)

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	Action (identification of MPs)	Possible MPs
Increased sediment inputs from Wall Lake during overtopping events Wetland and riparian loss; reduced uptake of solutes by root systems Grazing/silviculture practices (historic fire suppression); consequent reduction in herbaceous cover; increased overland sediment runoff Campground recreation/road impacts	Proposed in the Taylor Creek WRAS*: Target areas for improved stream bank vegetative cover density and bank stability measures, reduction in upland species encroachment Evaluate historic forest encroachment and potential thinning treatments in conjunction with GNF planning efforts Evaluate grazing plans Evaluate road and recreation impacts (travel management planning) Evaluate sediment reduction potential via Wall Lake dredging Other: Evaluate wetland potential for increased filtration of sediments	Filter strips, brush mats, herbaceous or pole/post plantings on streambanks Stream barbs/bioengineering techniques Road realignments and/or drainage improvements, including campground Continuation of GNF thinning/prescribed burning projects (particularly in conjunction with biomass use projects) Meadow reclamation; native ground cover re-seeding Livestock/elk grazing management strategies Wall Lake dredging Wetland reclamation or construction (filtration)

TAYLOR CREEK SUBWATERSHED (WALL LAKE TO BEAVER CREEK)—continued

Milestones	**Schedule**	**Target criteria**
Collaborative project development among private and agency stakeholders	Complete/ongoing	Temperature: Post-dredging increase in Wall Lake water depth
Floodplain vegetation thinning (upland species)	Ongoing	Increase of 10% in riparian canopy cover
Reseeding of abandoned agricultural areas	Ongoing	Decrease of 5% in sediment runoff from treated areas
Initial streambank stabilization, plantings complete	Complete	Average water temperature reduction of 20%
Pasture fencing and additional watering devices constructed (grazing management)	2009-2012	Aluminum: Decrease of 5% in sediment runoff from treated areas
NEPA and other planning complete for prescribed burning measures	GNF scheduling	Increase of 10% in riparian vegetation density (herbaceous and/or woody)
Most effective management measures for road/recreation impacts identified	Ongoing	Potential wetland remediation sites identified
Identify costs and funding sources; develop proposals	Ongoing (travel management planning)	Average load reduction of 25%
	2007-2015	

Monitoring:

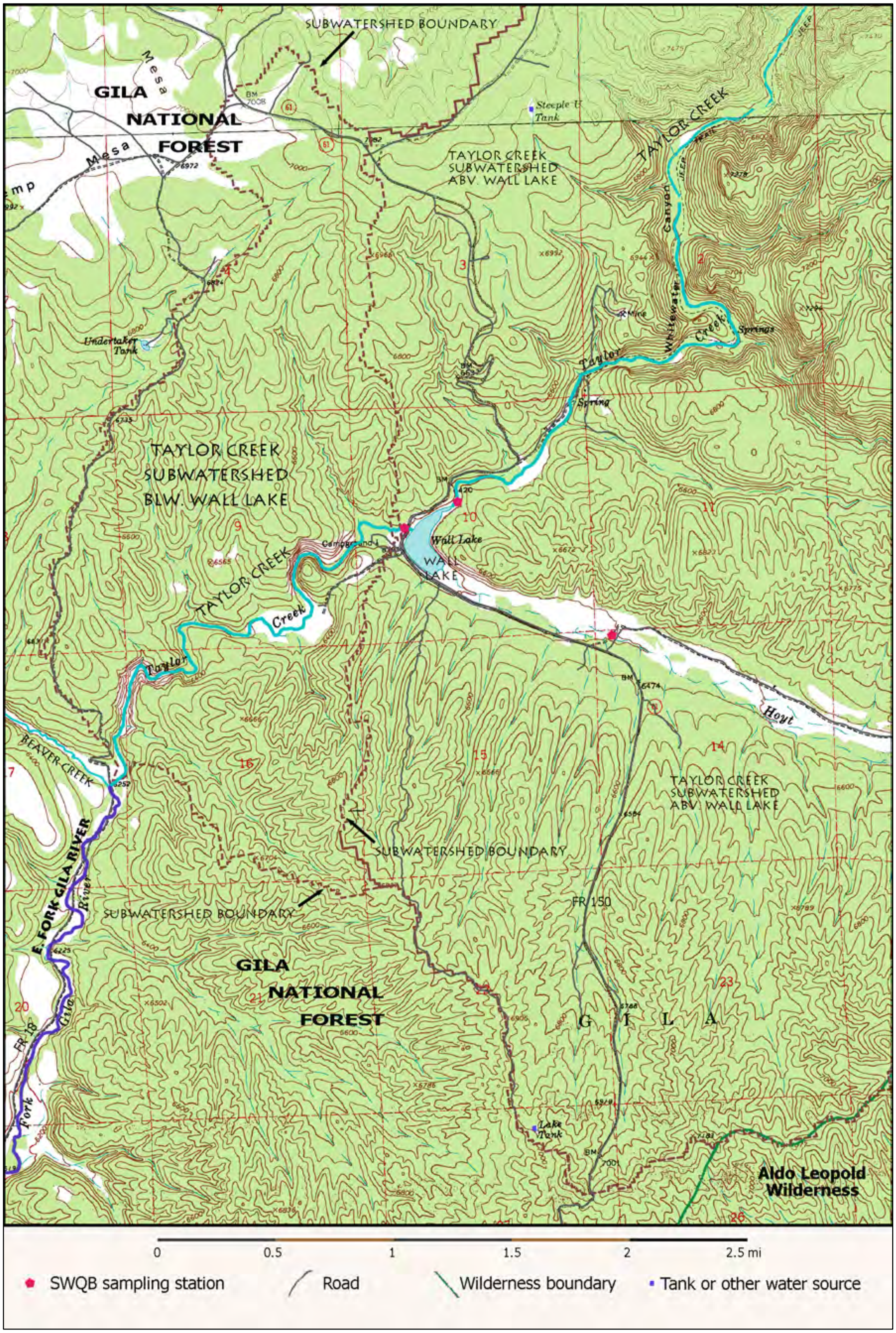
Programs in place:

- Beaverhead Terrestrial Ecosystem Survey (TES) and PSIAC surveys: assist in evaluating potential sediment yield/runoff
- Range/allotment assessments by GNF
- GNF Fire Regime Condition Class (FRCC) mapping of vegetation conditions
- NM Extension Service riparian grazing trials
- Standard NMED/SWQB water quality monitoring/sampling

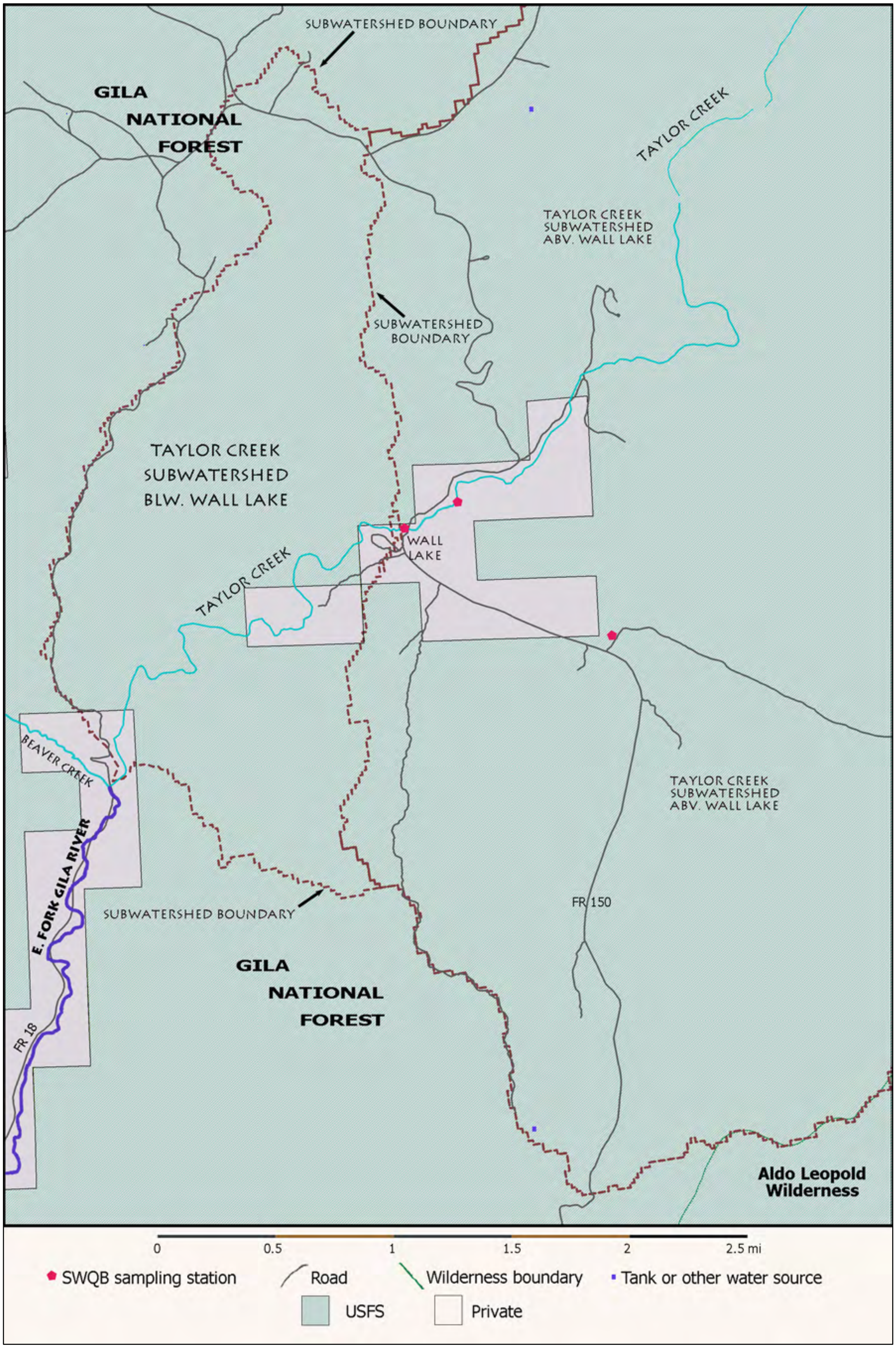
Additional monitoring components:

- Stakeholder/volunteer monitoring via photo points and temperature thermographs
- HEM/RUSLE modeling
- Vegetative cover baseline/change measurements

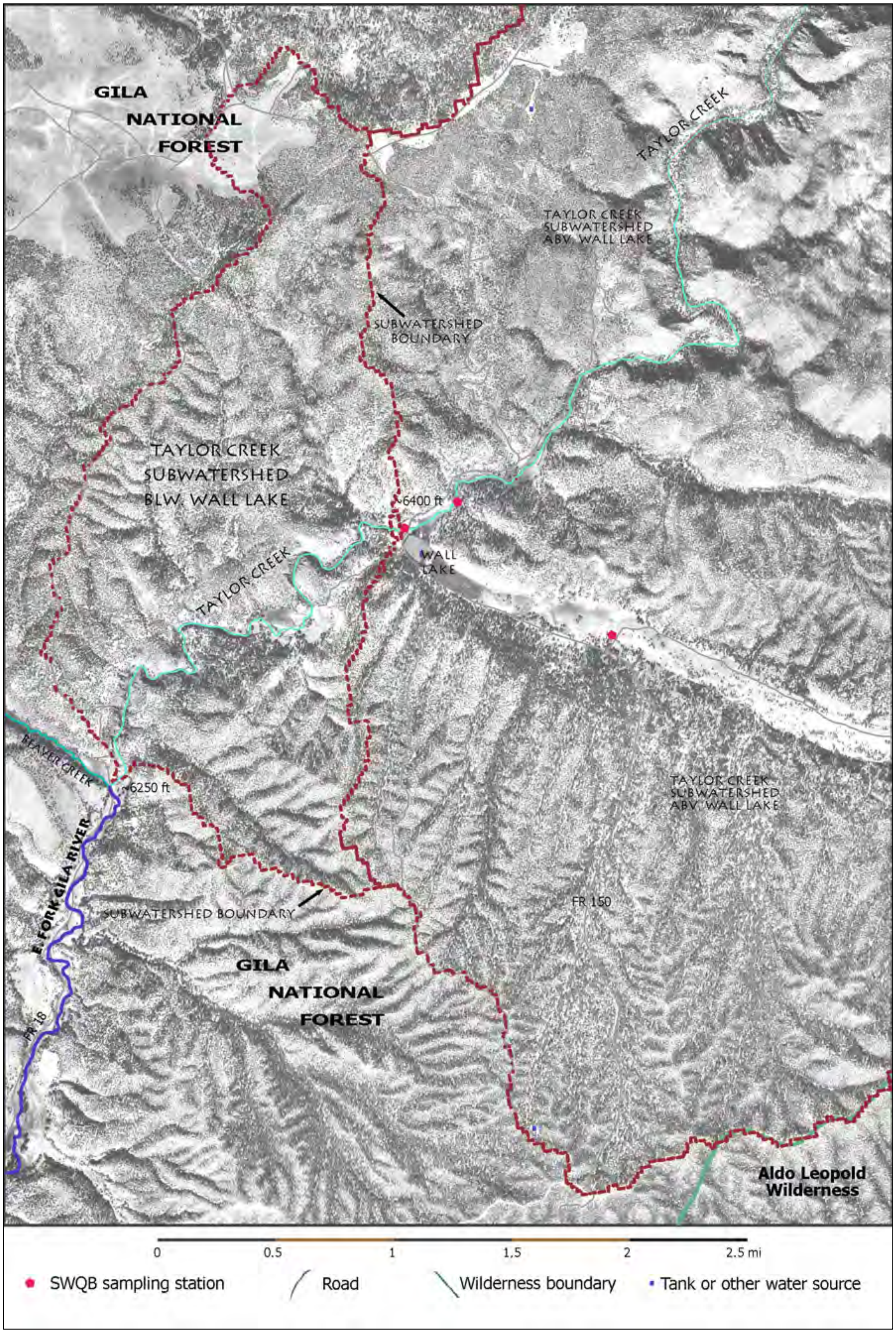
[*] The Taylor Creek Watershed Committee *WRAS* (July 2005), can be accessed at:
http://www.nmenv.state.nm.us/swqb/wps/WRAS/Taylor_Creek_15040001_WRAS_July_2005.pdf



Map TMDL-20. Topographic map, Taylor Creek subwatershed below Wall Lake. Base image: USGS 1:24000 quads. All data from NMED, USGS, and USFS Gila National Forest.



Map TMDL-21. Land management status map, Taylor Creek subwatershed below Wall Lake. All data from NMED, USGS, and USDA Gila National Forest.



Map TMDL-22. Aerial photography relief map, Taylor Creek subwatershed below Wall Lake. Base image: 1996–2001 USGS digital orthophotoquads. All data from NMED, USGS, and USDA Gila National Forest.

TAYLOR CREEK—continued

Taylor Creek photos: Top row, left to right: Taylor Creek before (left) and after (center) installation of stream barbs, September 1999; deposition of fines and stream bank vegetation recovery at barb site after floods in August 2004 (right). Bottom left: Taylor Creek immediately downstream of Wall Lake spillway at FR 150, June 2006. Bottom right: Wall Lake at FR 150, June 2006. Top row photos courtesy NRCS (2005).

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UPPER GILA–MANGAS WATERSHED

(HUC 15040002)

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UPPER GILA–MANGAS (HUC 15040002)

The Gila River mainstem from the Arizona state line upstream to the confluence with Mogollon Creek, and perennial reaches of tributaries downstream of Mogollon Creek.

Designated uses by reach within HUC 15040002

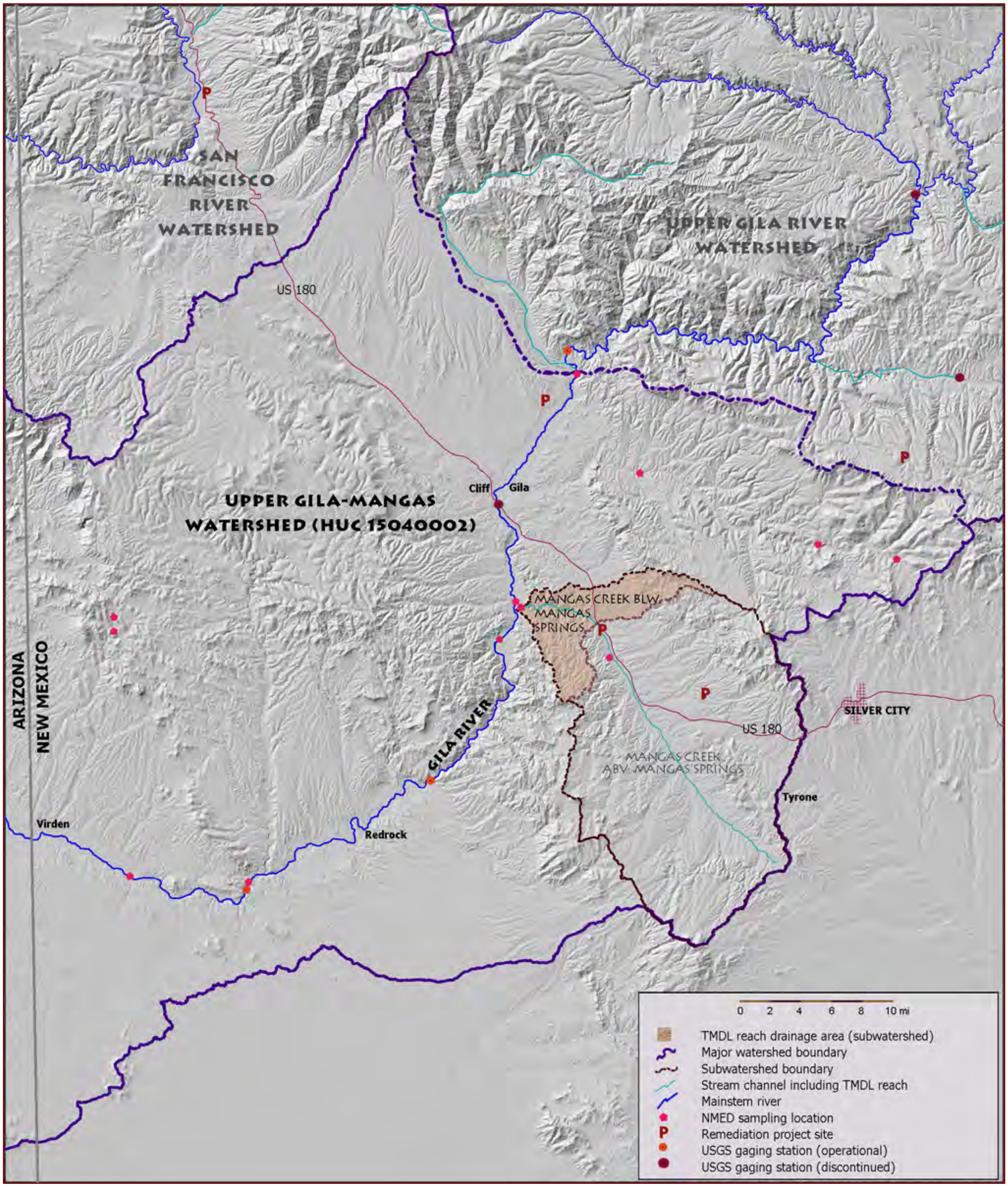
Gila mainstem, from the New Mexico–Arizona line upstream to Redrock Canyon and perennial reaches of streams in Hidalgo County: irrigation, livestock watering, wildlife habitat, marginal warmwater aquatic life, primary contact.

WQS Section **20.6.4.501**

Gila mainstem, from Redrock Canyon upstream to the confluence with Mogollon Creek and perennial reaches of tributaries downstream of Mogollon Creek: industrial water supply, irrigation, warmwater and marginal coldwater aquatic life, wildlife habitat, livestock watering, and primary contact.

WQS Section **20.6.4.502**

Link to WQS: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf



Map TMDL-23. Subwatersheds for water-quality impaired (TMDL) stream segments on the Gila–Mangas watershed (HUC 15040002). All NMED water-quality sampling sites are shown; see Map 5 for stream segments not named here. Locations of USGS gaging stations for current or historic streamflow data are also shown. Water quality data indicate that contaminant loads significant enough to impair designated uses occur only on the downstream segment of Mangas Creek. The entire stream reach appears on the map, and the subbasin draining to the sampling site where impairments were identified (the TMDL drainage area) is distinguished from the remainder of the creek's watershed. The TMDL subwatershed table in this section includes information on remediation projects shown on the map.

MANGAS CREEK SUBWATERSHED FROM MANGAS SPRINGS TO THE GILA RIVER

TMDL reach length: 6.2 mi; **Subwatershed area:** 27 sq. mi. (to springs); 204 sq. mi. total
Elevation range: 4400–6300 ft.
Watershed cover: 49% rangeland; 47% forested; 2% barren; 1% agriculture; 1% water
Watershed management: 45% private; 38% USFS (Silver City RD); 13% state; 4% BLM
Wilderness: None
Counties [SWCDs]: Grant [Grant].
TMDL: http://www.nmenv.state.nm.us/swqb/Plant_Nutrients_TMDL_for_Mangus_Creek_12-18-2001.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.502)**

TMDL parameter exceeded: Plant nutrients

Current exceedance: Aquatic productivity exceeds standard by 4.2 lbs/day (323%)

Unsupported use: marginal coldwater aquatic life

Possible mechanisms	Action (identification of MPs)	Possible MPs
Background sources Loss of streambank vegetation Inhibited riparian regeneration Loss of herbaceous ground cover allows excess nutrient delivery via sediments Sediment runoff from roads, ORV trailing Animal waste Fertilizers	Evaluate herbaceous cover Evaluate stream bank condition and vegetative cover Evaluate nitrate sources Evaluate gullying effects for sediment–nutrient delivery to Mangas Creek Evaluate road/trail sediment runoff (GNF and partners in travel planning)	Brush layer, filter strip: streambank filtration Streambank pole/post plantings Fencing; seasonal grazing (cattle) Prescribed thinning or burning in uplands; re-seeding (ongoing) Improved fertilizer application methods Gully remediation (ongoing) Road/trail closures, improvements

MANGAS CREEK SUBWATERSHED (MANGAS SPRINGS TO THE GILA RIVER)—continued

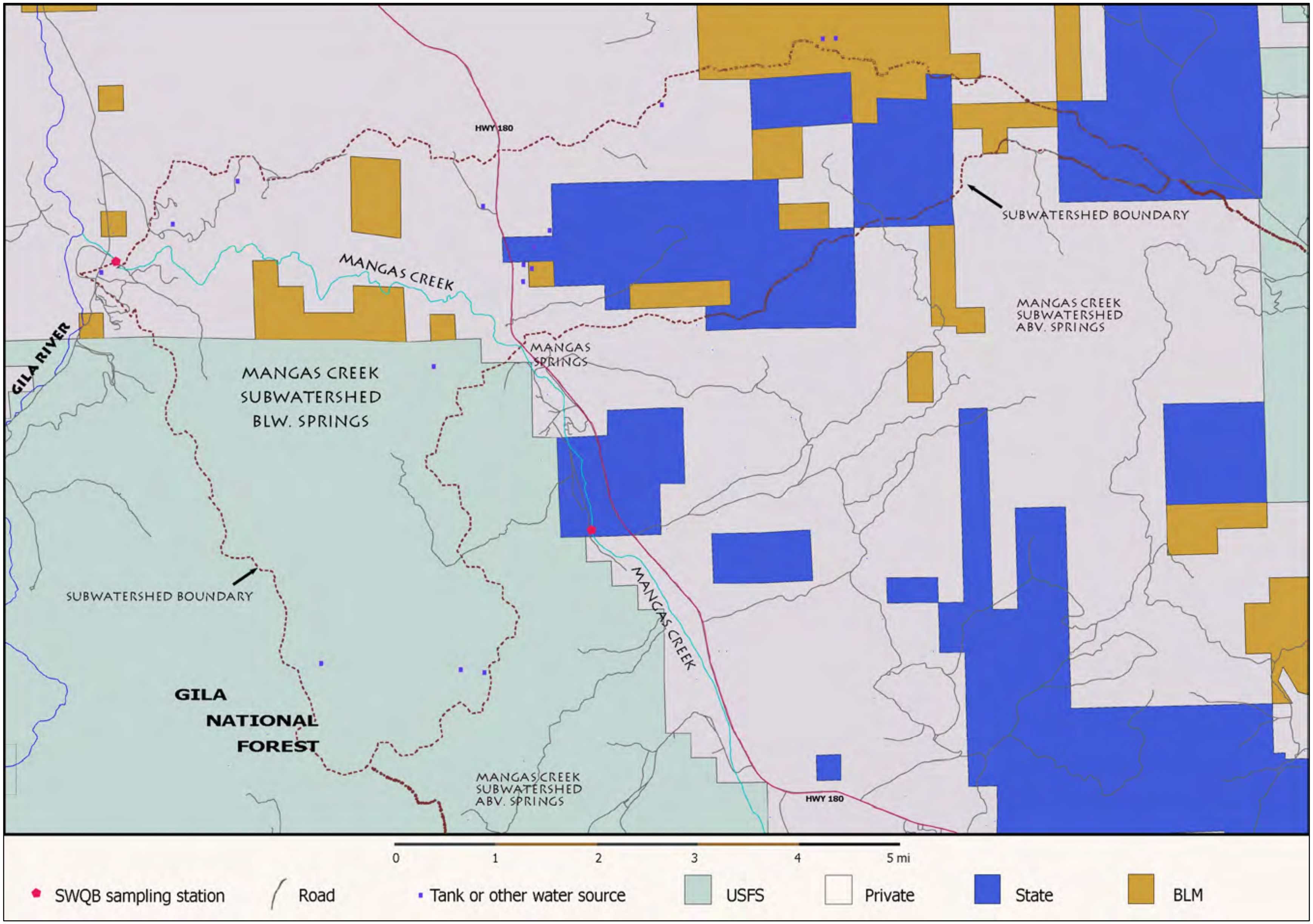
Milestones	Schedule	Target criteria
Streambank pole plantings Liaison with private landowners (Grant SWCD) Develop prescribed burning plan Obtain funding; conduct burns and establish monitoring sites and protocols Develop and implement gully remediation plan Document vegetative recovery and evaluate sediment runoff response via monitoring (burn & gully remediation sites) Travel management planning finalized (GNF & partners) Future work plans developed: silviculture treatments; road improvements/closures Stream bank cover evaluated for potential MPs Costs and funding sources ID'd	Complete Complete Complete 2001-2007 2004-2007 2006-2007 2008? Dependent on monitoring results; GNF travel planning 2008 Dependent on above	20% increase in streambank vegetation Increase of 15% in herbaceous cover at burn vs. control site Increase of 30% in herbaceous cover at gully remediation sites Positive trends in measured sediment output at burn vs. control sites; ~30% reduction in output Long-term positive (downward) trends in measured aquatic vegetation productivity 2010 target: 25% reduction in aquatic vegetation productivity, from 1.9 mg/L dry weight to 1.4 mg/L

Monitoring (suggested monitoring protocols are described in Section 6):

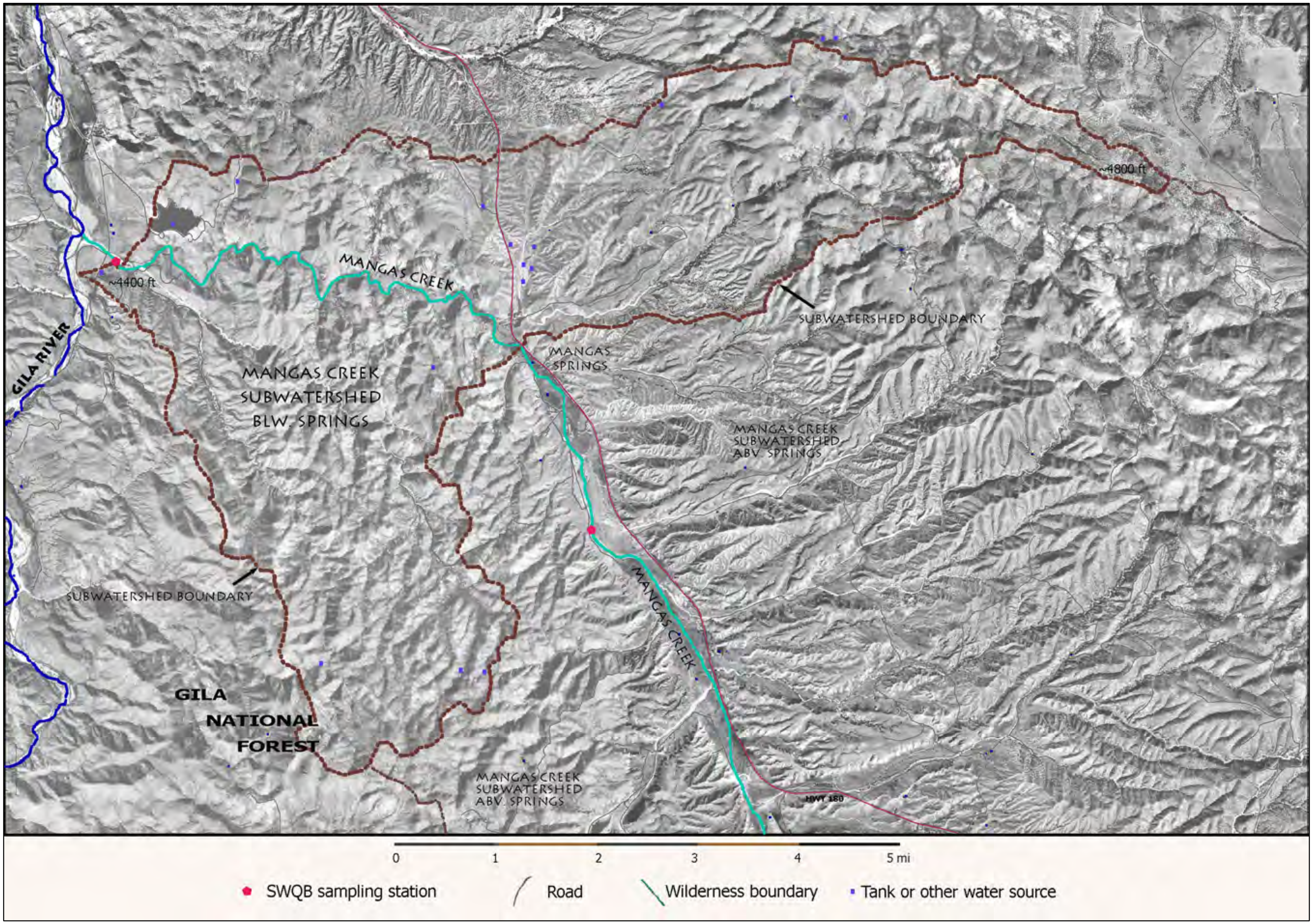
- Regular NMED/SWQB monitoring and sampling at established stations
- Herbaceous cover: line-point intercept; sediment runoff: erosion bridge/HEM (recording rain gauge installed near site)
- Repeat photography, especially at gully sites
- Monitoring continues over 3 year period

Note. Loach minnow were present in Mangas Creek in 1999.

Map TMDL-24. Topographic map, Mangas Creek subwatershed below Mangas Springs. Base image from USGS 1: 24000 quads. All data from USGS, NMED, and USFS Gila National Forest.



Map TMDL-25. Land management status map, Mangas Creek subwatershed below springs. All data from NMED, USGS and USFS Gila National Forest.



Map TMDL-26. Aerial photography relief map, Mangas Creek subwatershed below springs. Base image: 1996-2002 USGS digital orthophotoquads. All data from NMED, USGS and USFS Gila National Forest.

MANGAS CREEK—continued

Mangas Creek photos (all photos courtesy NMED, Silver City).

NMED sampling site near confluence with Gila River, April 2001.

Mangas Creek approximately 1 mile above confluence with Gila River, below Bill Evans Lake, June 2001.

Fifteen-foot entrenchment of the Mangas Creek channel above the springs dates back to ~1900. June 2001.

Mangas Creek near springs, June 2001.

Floodplain vegetation re-establishment within incised cutbanks near springs, June 2001.

SAN FRANCISCO WATERSHED

(HUC 15040004)

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SAN FRANCISCO (HUC 15040004)

In New Mexico, the San Francisco River mainstem and all tributaries.

Designated uses by reach within HUC 15040004

The San Francisco River mainstem from the New Mexico–Arizona line upstream to State Highway 12 at Reserve, and perennial reaches of Mule Creek: irrigation, marginal warmwater and marginal coldwater aquatic life, wildlife habitat, livestock watering, and secondary contact.

WQS Section **20.6.4.601**

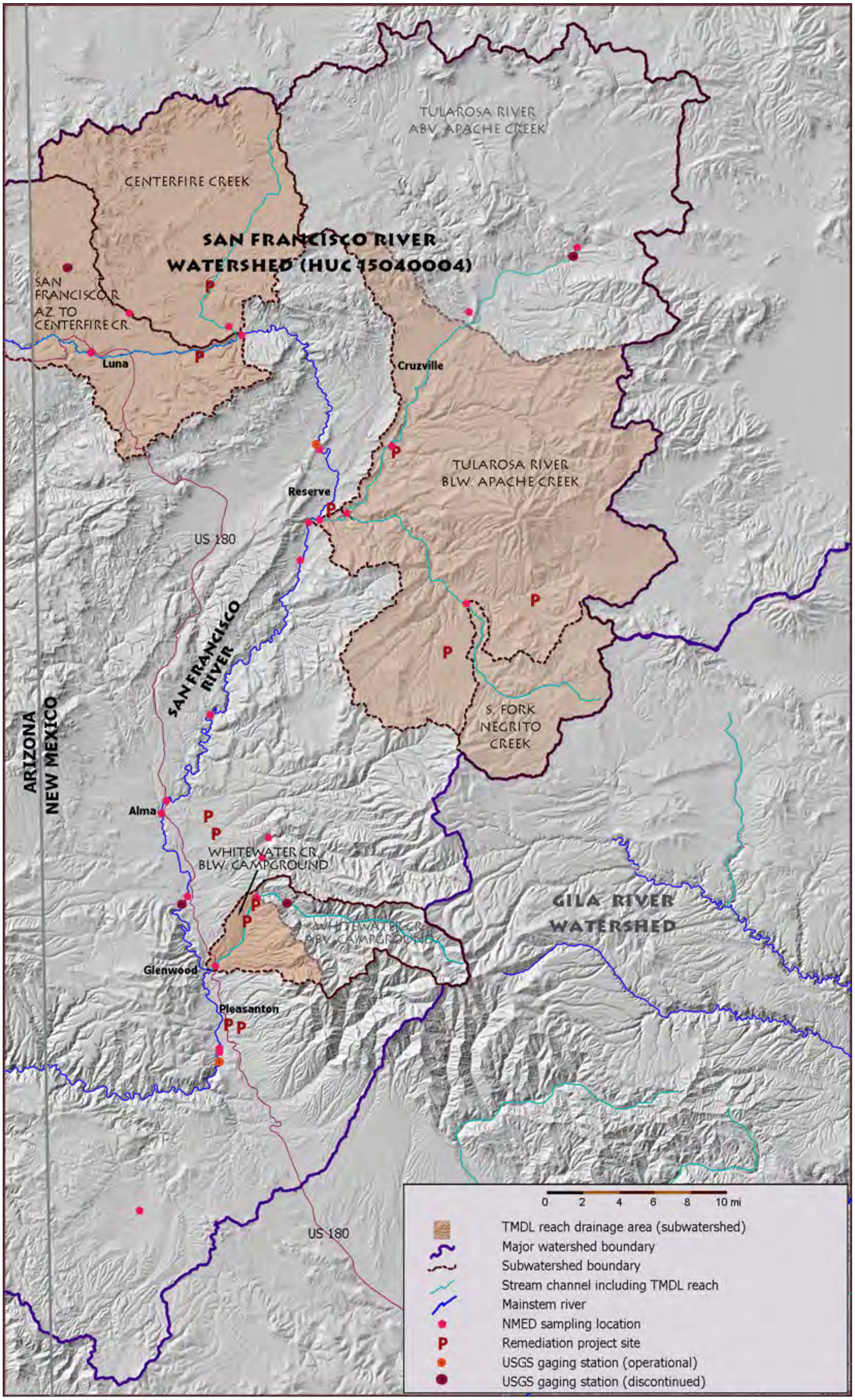
San Francisco mainstem from State Highway 12 at Reserve upstream to the New Mexico-Arizona line: irrigation, coldwater aquatic life, wildlife habitat, livestock watering, and primary contact.

WQS Section **20.6.4.602**

All perennial reaches of tributaries to the San Francisco River from the confluence of Whitewater Creek, including Whitewater Creek: domestic water supply, irrigation, fish culture, high quality coldwater aquatic life, wildlife habitat, livestock watering, and secondary contact.

WQS Section **20.6.4.603**

Link to WQS: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf



Map TMDL-27. Subwatersheds for water-quality impaired (TMDL) stream segments on the San Francisco watershed (HUC 15040004). All NMED water-quality sampling sites are shown; see Map 6 for locations of those not labeled on this map. Locations of USGS gaging stations for current or historic streamflow data are also shown. On some streams, water quality data indicate that contaminant loads significant enough to impair designated uses occur only on particular segments (e.g., Tularosa River). In these cases, the entire stream reach appears on the map, and the subbasin draining to the sampling site where impairments were identified (the TMDL drainage area) is distinguished from the remainder of the stream's watershed. The tables for each TMDL subwatershed in this section include information on remediation projects shown.

CENTERFIRE CREEK SUBWATERSHED (SAN FRANCISCO RIVER TO HEADWATERS)

TMDL reach length: 16.1 mi; **Subwatershed area:** 138 sq. mi.
Elevation range: 6700–9000 ft.
Watershed cover: 75% forested; 25% rangeland; <1% wetland
Watershed management: 90% USFS (Quemado RD); 10% private (primarily in valley bottom)
Wilderness: none
Counties [SWCDs]: Catron [San Francisco]
TMDL: http://www.nmenv.state.nm.us/swqb/Conductivity_TMDL_in_Centerfire_Creek_11-05-01.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.603)**

TMDL parameter exceeded: Conductivity

Current exceedance: Conductivity as total dissolved solids exceeds standard by 690 lbs/day (23%)

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	Action (identification of MPs)	Possible MPs
Streambank destabilization, channel widening and incision of fine-grained soils Loss/inhibited regeneration of streambank vegetation (filtration) Roads: sediment runoff effects Reduced base flow due to increased floodplain evaporation/infiltration rates Grazing effects (livestock and elk) Historic agricultural practices and fire suppression; consequent reduction in herbaceous cover; increased sediment runoff to channel Watershed gullying Wetland dessication	Evaluate riparian grazing effects, particularly by elk, for potential fencing projects Evaluate stream bank condition; vegetative cover Evaluate potential sites for water projects (grazing management) Evaluate current condition of Spur Ranch project (depositional enhancement) Evaluate trail and road impacts, particularly road crossings Evaluate upland herbaceous cover and forest densities Identify potential gully remediation sites Evaluate tributary wetland conditions	Streambank filter strips or near-channel pole/post/herbaceous plantings (with fencing: substantial elk depradation of prior plantings has occurred) Channel deposition enhancement (2-phase project completed) Bridges or improved design and construction of low-water crossings Prescribed burning/thinning to improve native ground cover (some projects completed) Grazing management: water projects or herding Road realignment; culvert and trail improvements; OHV closures Wetland and floodplain remediation to improve base flow conditions

CENTERFIRE CREEK SUBWATERSHED (SAN FRANCISCO RIVER TO HEADWATERS)—continued

TMDL reach length: 16.1 mi**; subwatershed area:** 138 sq. mi
Elevation range: 6700–9000 ft.
Watershed cover: 75% forested; 25% rangeland; <1% wetland
Watershed management: 90% USFS (Quemado RD); 10% private (primarily in valley bottom)
Wilderness: none
Counties [SWCDs]: Catron [San Francisco]
TMDL: http://www.nmenv.state.nm.us/swqb/Plant_Nutrients_TMDL_for_Centerfire_Creek_12-13-2001.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.603)**

TMDL parameter exceeded: Plant nutrients

Current exceedance: Aquatic productivity exceeds standard by 7.7 lbs/day (248%)

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	Action (identification of BMPs)	Possible BMPs
Animal waste (elk, livestock) Loss of filtration mechanisms: wetland dessication, inhibited streambank regeneration, lost upland herbaceous cover Direct floodplain and streambank destabilization from historic farming practices and gullying effects (nutrient transport via bank and gully sediments) Sunlight: lack of riparian vegetation may increase aquatic plant productivity Increased plant nutrient concentrations due to reduced baseflow	Evaluate riparian grazing effects, particularly by elk, for potential fencing projects Evaluate stream bank condition; vegetative cover Evaluate potential sites for dispersed water projects (grazing management) Evaluate current condition of Spur Ranch project (potential for riparian recruitment) Evaluate upland herbaceous cover and forest densities Identify potential gully remediation sites Evaluate wetland conditions in upper watershed for potential baseflow improvements	Brush layer, filter strip; streambank plantings to provide filtration; riparian exclosures Wildlife dispersion practices Prescribed thinning; burns in uplands (projects underway) Additional channel deposition enhancement (2-phase project completed) Prescribed burning/thinning to improve native ground cover (some projects completed) Grazing management: water projects or herding Wetland and floodplain remediation to improve base flow conditions

CENTERFIRE CREEK SUBWATERSHED—continued

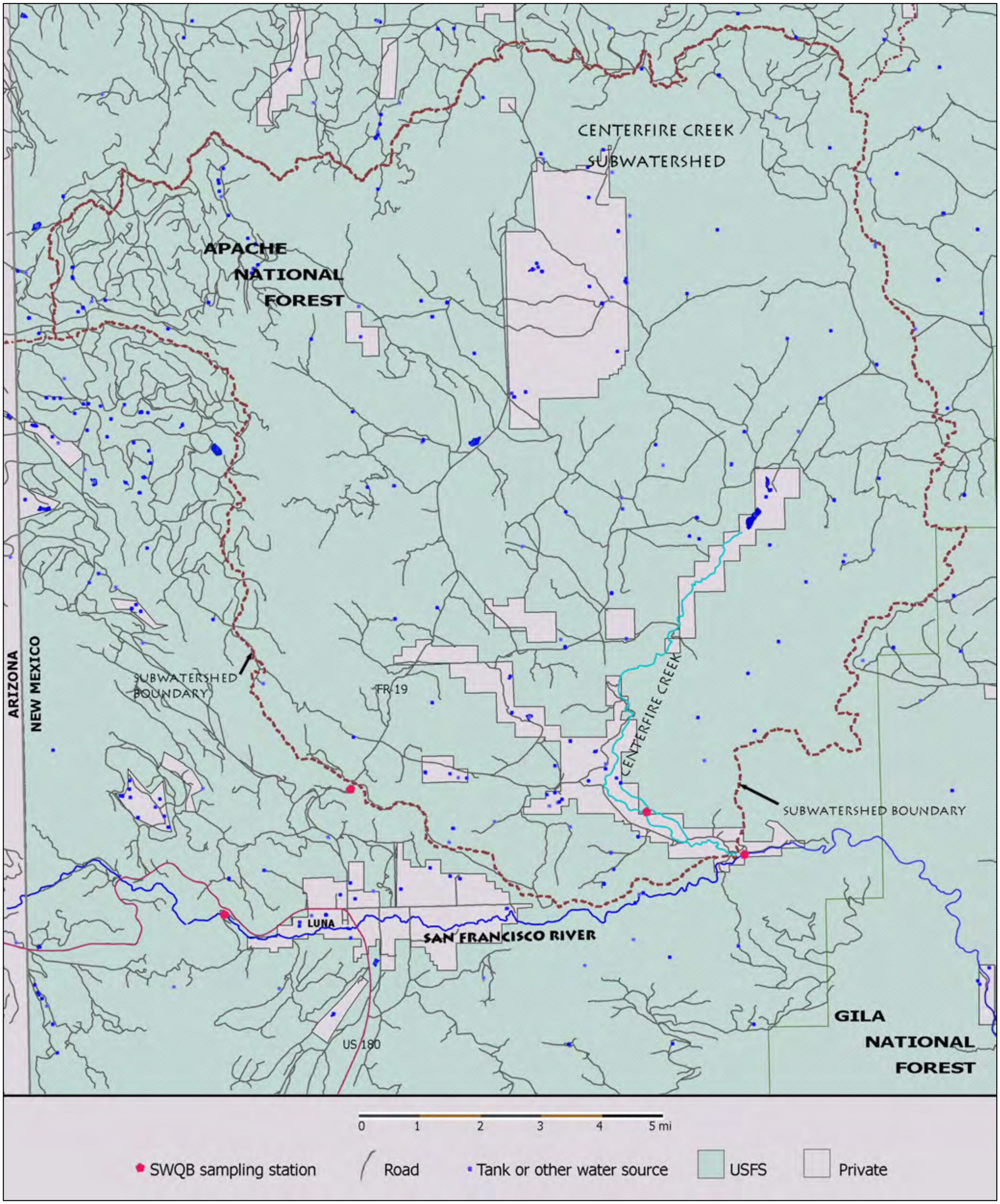
Milestones	Schedule	Target criteria
Measurable aggradation in sediment retention basin Filter or bank planting sites targeted Re-establishment of 10% floodplain vegetation near existing project site Riparian exclosures Prescribed thinning on uplands to enhance herbaceous cover (NM State Forestry & partners) Other wildlife dispersion measures in place Wetland and floodplain remediation to improve base flow conditions Additional potential wetland reclamation sites identified	2005 and continuing 2005 and continuing 2010 Partial, 2005; continuing Partially complete, 2005; continuing 2010 GNF project complete, 2001 2008	Conductivity: Riparian buffer establishment on 10% of floodplain zone 20% increase in terrace herbaceous cover 2010 target: Reduce total dissolved solids by 20% to 275 mg/L (approx. 3,000 lbs/day) Additional 2-acre wetland reclamation complete Plant nutrients: Riparian buffer establishment on 10% of floodplain zone 20% increase in terrace herbaceous cover 2010 target: Reduce aquatic vegetation productivity by ~25%, from 3.7 mg/L dry weight to 2.8 mg/L (~8 lbs per day)

Monitoring (suggested monitoring protocols are described in Section 6):

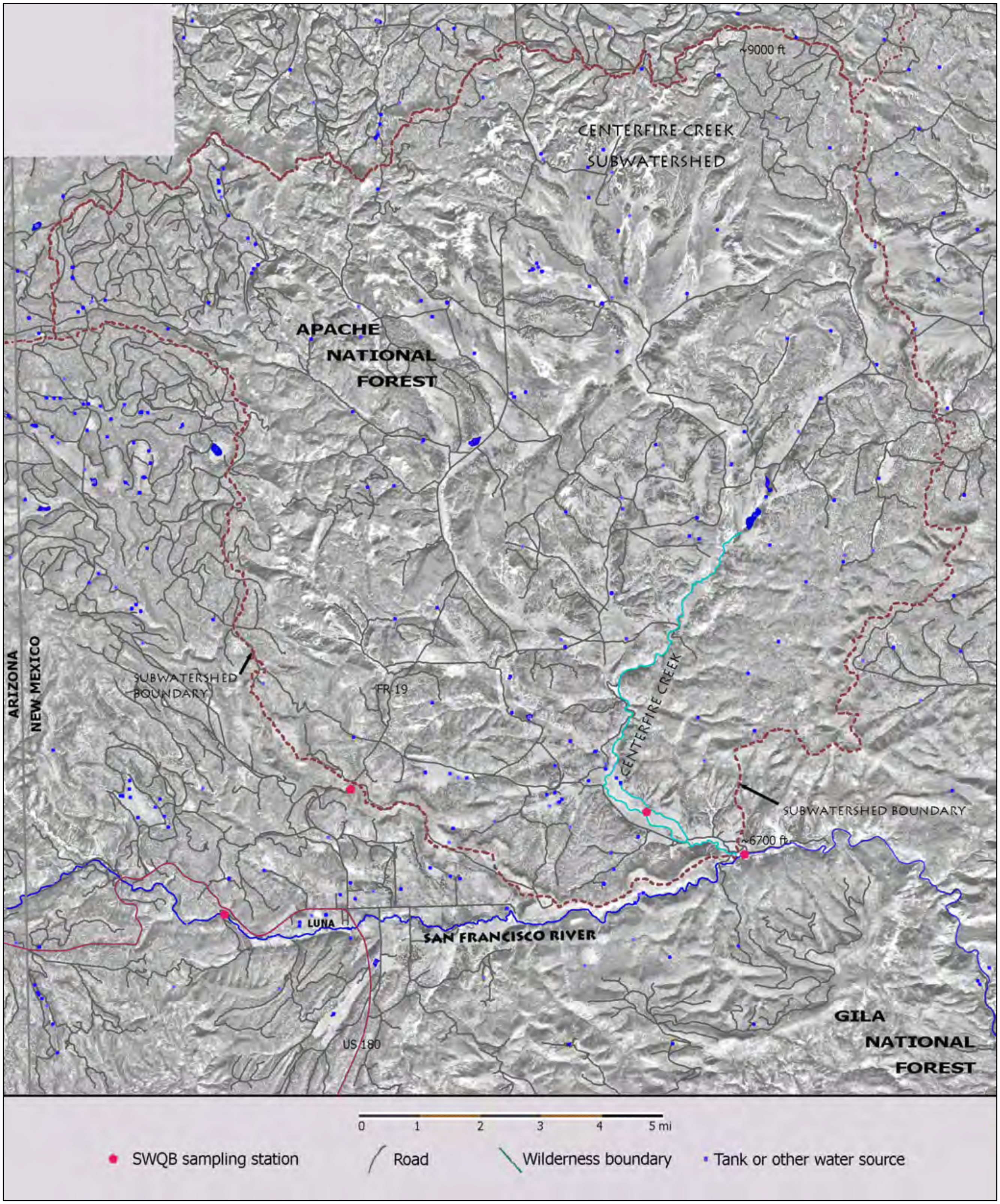
- SF SWCD currently monitors water quality on the San Francisco mainstem just downstream of the Centerfire Creek confluence under a QAPP developed by NMED, in addition to regular NMED/SWQB monitoring and sampling at established stations..
- Prescribed burning: protocols for tree cover density, line-point intercept for herbaceous cover
- Photo points

Note. A Safe Harbor Agreement is in place between USFWS and a private landowner for a number of species, including loach minnow.

Map TMDL-28. Topographic map, Centerfire Creek subwatershed. Base image from USGS 1: 24000 quads. All data from USGS, NMED, and USFS Gila National Forest.



Map TMDL-29. Land management status map, Centerfire Creek subwatershed. All data from NMED, USGS and USFS Gila National Forest.



Map TMDL-30. Aerial photography relief map, Centerfire Creek subwatershed. Base image: 1996-2002 USGS digital orthophotoquads. All data from NMED, USGS and USFS Gila National Forest.

CENTERFIRE CREEK— continued

Centerfire photos, clockwise from top left: View south across Centerfire Creek valley approx. 3 mi. upstream of San Francisco River confluence, June 2001; tour of Centerfire Creek §319 project by landowner, October 2005; Gila N. F. wetlands project on Arroyo Grande, a significant, ephemeral Centerfire Creek tributary, June 2001; typical cutbank on creek, October 2005; sampling station at project site , March 2001. All 2001 photos courtesy NMED, Silver City.

SOUTH FORK NEGRITO CREEK SUBWATERSHED (NORTH FORK CONFLUENCE TO HEADWATERS)

TMDL reach length: 14.5 mi; **Subwatershed area:** 50 sq. mi.
Elevation range: 5800–8000 ft.
Watershed cover: 84% forested; 15% rangeland; 1% agricultural
Watershed management: 98% USFS (Reserve RD); 2% private
Wilderness: none
Counties [SWCDs]: Catron [San Francisco]
TMDL: http://www.nmenv.state.nm.us/swqb/Temperature_TMDL_in_South_Fork_of_Negrito_Creek_11-05-01.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.603)**

TMDL parameter exceeded: Temperature

Current exceedance: 33% of readings exceeded 20°C standard

Unsupported use: high-quality coldwater aquatic life

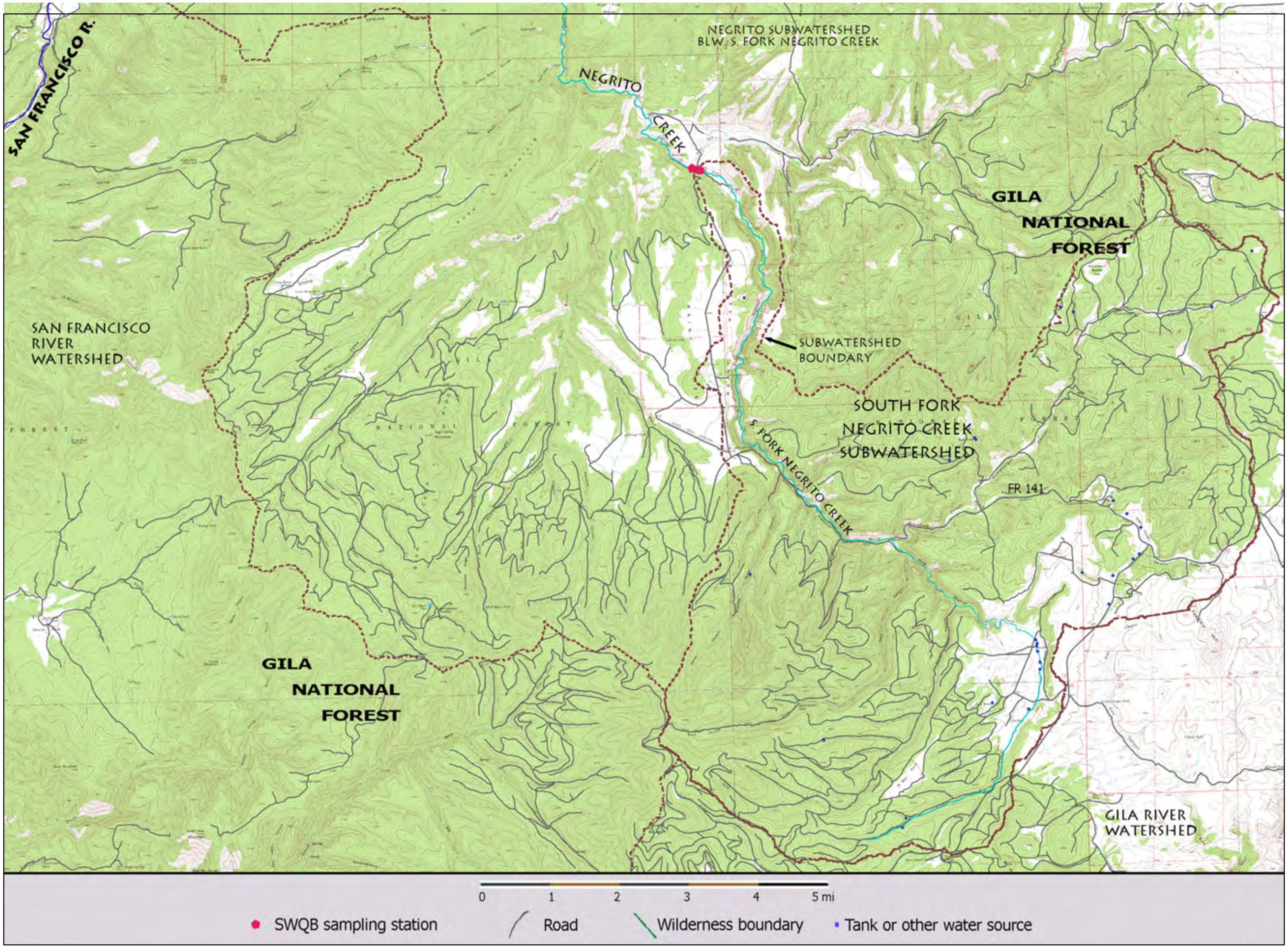
Possible mechanisms	Action (identification of MPs)	Possible MPs
Streambank destabilization and channel widening: increased width-depth ratios Loss/inhibited regeneration of streambank vegetation (shade cover; streambank effects) Roads: sediment runoff effects Reduced base flow due to increased floodplain evaporation/infiltration rates Historic fire suppression and drought effects: increased tree densities, reduced herbaceous cover, increased sediment runoff to channel	Evaluate stream bank condition; vegetative cover Evaluate stream channel morphology Evaluate trail and road impacts, including stream crossings (GNF & partners travel management planning underway) Evaluate upland herbaceous cover and forest densities for thinning projects (Negrito Creek ecosystem project underway)	Streambank filter strips or near-channel pole/post/herbaceous plantings (with protective fencing In-channel structures to decrease width-depth ratio Road closures; road or culvert improvements Prescribed burning/thinning to improve native ground cover (some projects completed)

SOUTH FORK NEGRITO CREEK SUBWATERSHED—continued

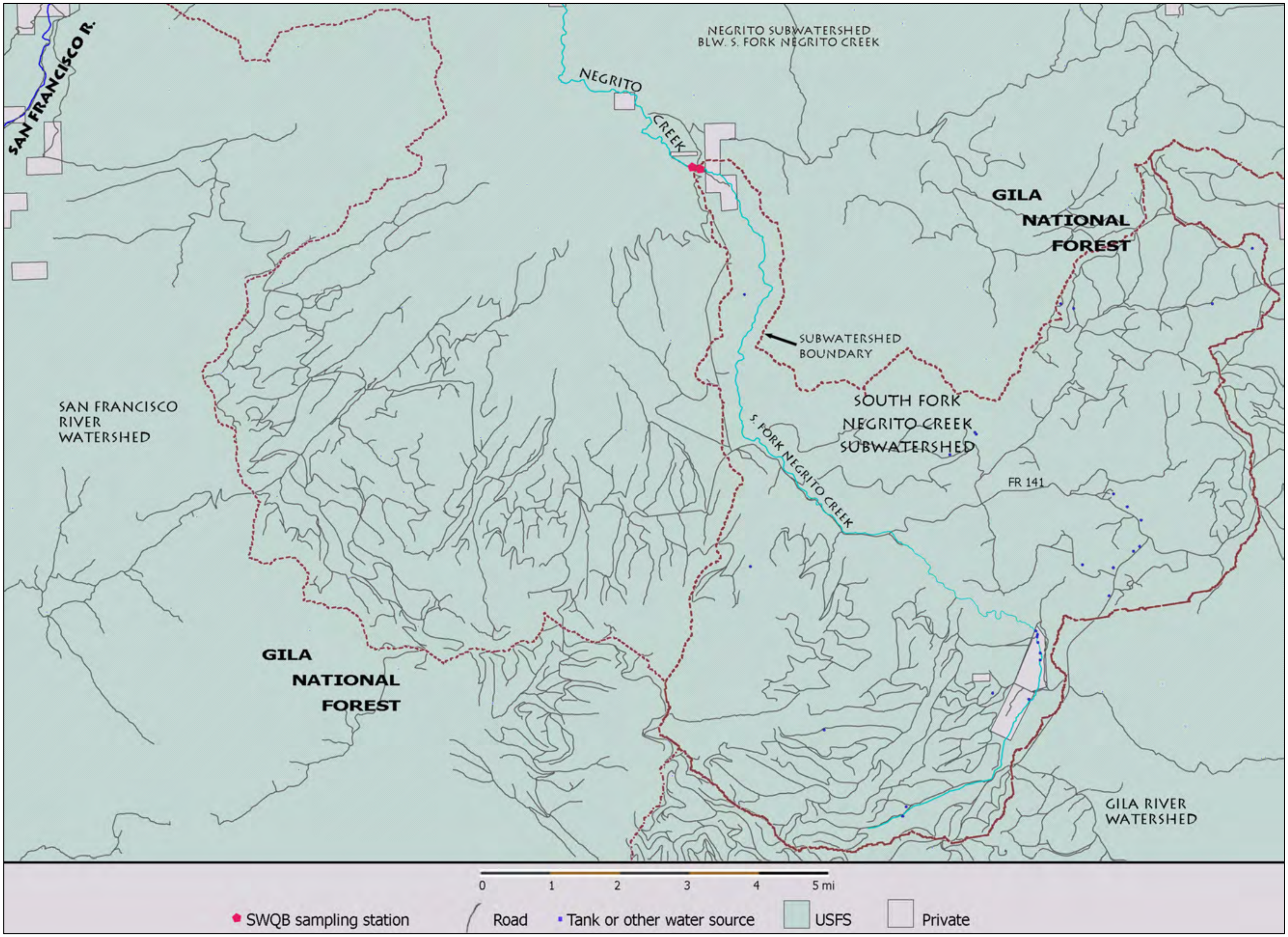
Milestones	**Schedule**	**Target criteria**
Potential streambank planting sites identified and workplan developed in conjunction with GNF, other partners	Dependent on GNF scheduling	Riparian canopy cover increased 25 to 50% through selected reach
Ditto: in-channel structures	Dependent on GNF scheduling	Reduction in width-depth ratio of 20%
Roads identified for closure/improvement	2008?	Percent reduction in sediment inputs from roads to be based on planning results
Negrito thinning project complete (per goals outlined by GNF and partners)	2007-2008	See scoping details per GNF 2012 target: Temperature exceedances reduced to <15%

Monitoring (suggested monitoring protocols are described in Section 6):

- Regular NMED/SWQB monitoring and sampling at established stations
- Photo points
- Monitor riparian tree canopy at selected locations
- Establish and monitor channel morphology cross-sections at selected intervals
- GNF monitoring plan developed in conjunction with the Negrito Ecosystem project for thinning work



Map TMDL-31. Topographic map, South Fork Negrito Creek subwatershed. Base image from USGS 1: 24000 quads. All data from USGS, NMED, and USFS Gila National Forest.



Map TMDL-32. Land management status map, South Fork Negrito Creek subwatershed. All data from NMED, USGS and USFS Gila National Forest.

Map TMDL-33. Aerial photography relief map, South Fork Negrito Creek subwatershed. Base image: 1996–2002 USGS digital orthophotoquads. All data from NMED, USGS, and USFS Gila National Forest.

SOUTH FORK NEGRITO CREEK—continued




South Fork Negrito Creek photos, clockwise from upper left: At FR 141, May 2001; at USFS campground, May 2001; mesa off FR 141, May 2001; USFS grade control at road intersection, May 2001; at NMED sampling station, April 2001. All photos courtesy NMED, Silver City.

SAN FRANCISCO RIVER SUBWATERSHED, CENTERFIRE CREEK TO ARIZONA BORDER

TMDL reach length: 14.9 mi; **Subwatershed area:** 151 sq. mi.(Centerfire Creek to headwaters in AZ)
Elevation range: 6700-8800 ft.
Watershed cover: 86% forested; 7% rangeland; 6% agricultural; <1% wetland; <1% urban
Watershed management: 93% USFS (Quemado RD); 7% private
Wilderness: none
Counties [SWCDs]: Catron [San Francisco]
TMDL: http://www.nmenv.state.nm.us/swqb/Temperature_TMDL_in_San_Francisco_River_11-05-01.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.602)**

TMDL parameter exceeded: Temperature

Current exceedance: 6% of readings exceeded 25°C standard

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	Action (identification of MPs)	Possible MPs
Loss and inhibited regeneration of streambank vegetation (shading) Increased sediment runoff and delivery to channel: uplands, unstable banks, or roads Sediment loading from eroding banks Increased width-depth ratio Upstream impoundment Recreational use, including OHVs and campgrounds Reduced base flow from loss of riparian cover or impacts to upstream spring sources	Evaluate streambank and channel morphology condition for potential rehabilitation sites Evaluate campground and road effects, including crossings (travel management planning underway; GNF & partners) Evaluate potential for thinning or prescribed burn projects (Apache/Gila NFs) Measure riparian bank cover Investigate historic wetland/spring sources for potential impacts	Pole/post plantings for shade canopy, sediment filtration; riparian exclosures In-channel structural controls Brush layer or filter strips Road/culvert realignment or paving; seasonal or OHV closures Thinning/burning/seeding to improve herbaceous upland cover Wetland/spring reclamation

SAN FRANCISCO RIVER SUBWATERSHED (CENTERFIRE CREEK TO ARIZONA BORDER)—continued

TMDL reach length: 14.9 mi; **Subwatershed area:** 151 sq. mi. (to headwaters in AZ)
Elevation range: 6700–8800 ft.
Watershed cover: 86% forested; 7% rangeland; 6% agricultural; <1% wetland; <1% urban
Watershed management: 93% USFS (Quemado RD); 7% private
Wilderness: None
Counties [SWCDs]: Catron [San Francisco]
TMDL: http://www.nmenv.state.nm.us/swqb/Plant_Nutrients_TMDL_for_San_Francisco_River_12-18-2000.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.602)**

TMDL parameter exceeded: Plant nutrients

Current exceedance: Aquatic productivity exceeds standard by 1.3 lbs/day (684%)

Unsupported use: coldwater aquatic life

Possible mechanisms	**Action (identification of MPs)**	**Possible MPs**
Loss and inhibited regeneration of streambank vegetation (shading)	Evaluate riparian grazing effects (including elk)	Pole/post plantings to provide filtration; riparian exclosures (elk); filter strips
Nutrients bound to sediments delivered to stream through excess sediment runoff (roads, campgrounds, uplands)	Evaluate road/vehicle/campground impacts (roads are under evaluation by GNF)	Road/culvert/low water crossing realignment or paving; seasonal or OHV closures
	Evaluate stream bank condition and measure riparian vegetative cover	In-channel brush layers or willow fascines
Septic tank leaks (identified in Luna Lake, Alpine, AZ, by ADEZ)		Thinning/burning/seeding to improve herbaceous upland cover
Grazing practices (AZ; per ADEQ)	Follow-up with ADEQ	Detention basin or wetland reclamation
		As determined by ADEQ for AZ impacts

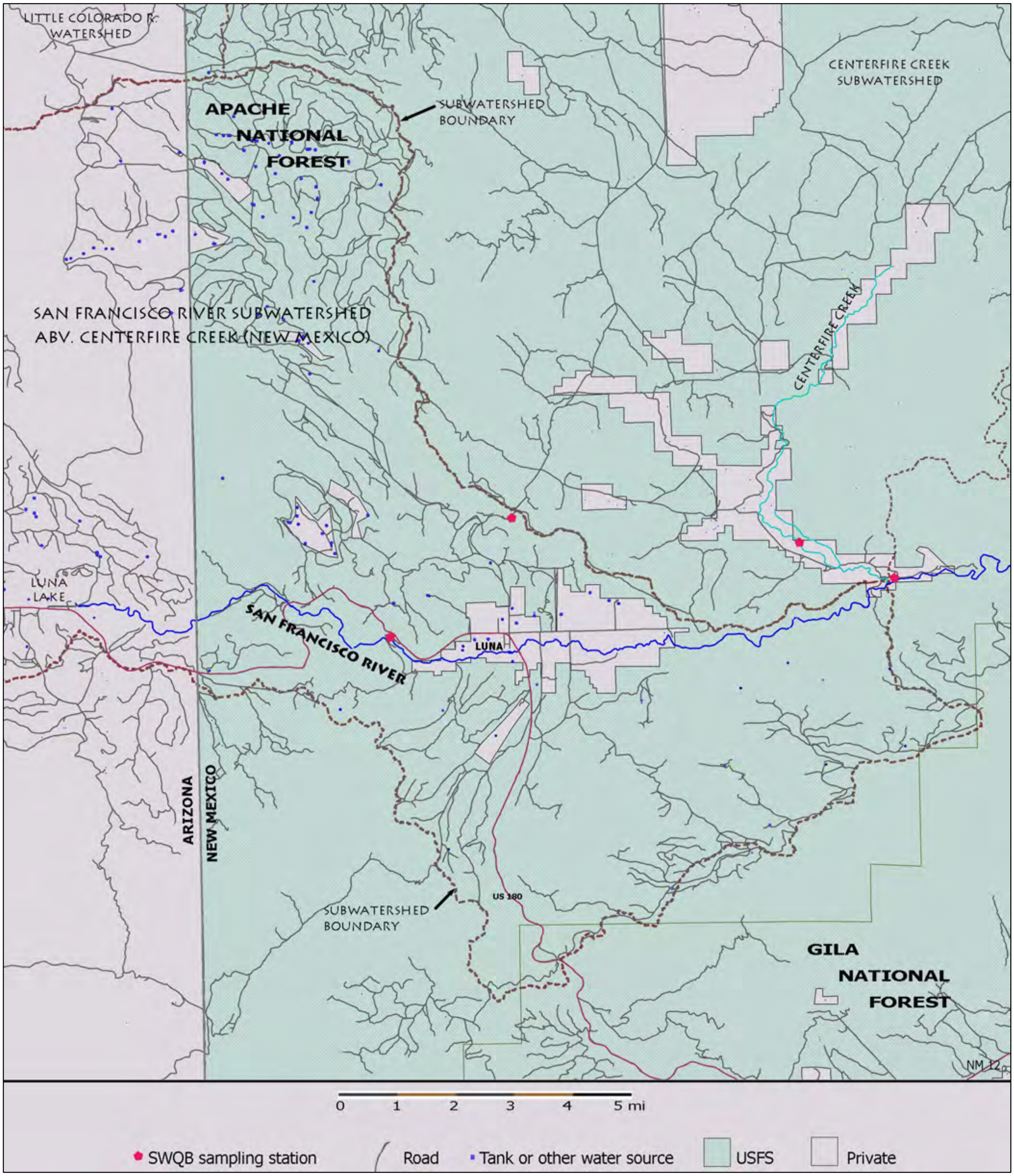
SAN FRANCISCO RIVER SUBWATERSHED (CENTERFIRE CREEK TO AZ BORDER)—continued

Milestones	**Schedule**	**Target criteria**
Filter or bank planting; channel remediation sites targeted Completion of forest travel management planning complete Evaluation of potential thinning projects completed Potential wetland reclamation sites identified	2008 2008? Dependent on USFS schedules 2008-2009	Temperature: Create buffer/filter strip on 25% of targeted reach; increase canopy cover by 4-10% Sediment delivered from roads/campgrounds identified; road closures or improvements completed 10% increase in herbaceous cover for project areas 2012 target: Reduce temperature exceedances to 0% Plant nutrients: Improve buffer/filter strip; increase bank vegetation cover by 10% 2012 target: Reduce aquatic vegetation productivity by ~25%, from 3.7 mg/L dry weight to 2.8 mg/L (~1.2 lbs/day)

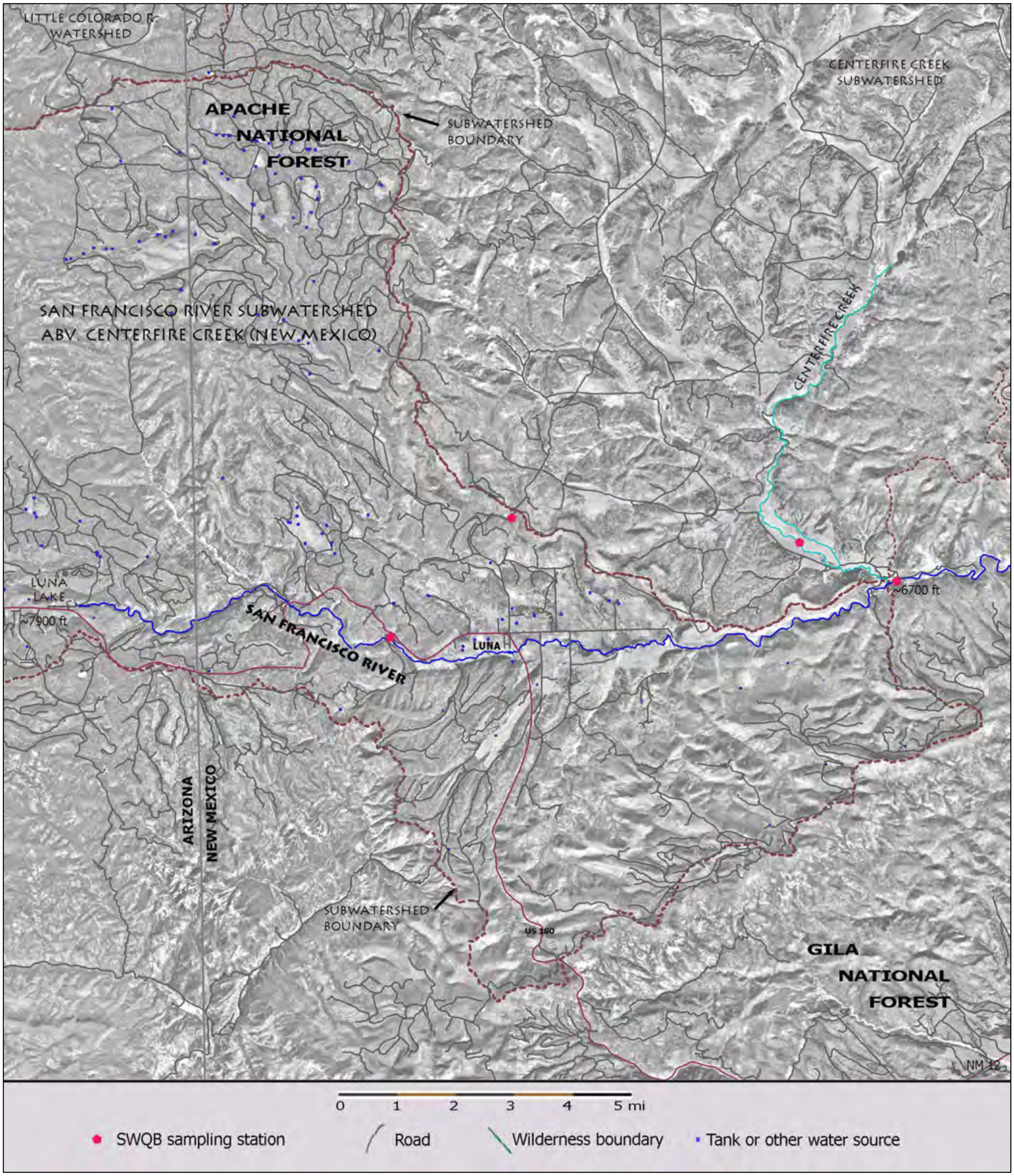
Monitoring (suggested monitoring protocols are described in Section 6):

- SF SWCD currently monitors water quality on the San Francisco mainstem just downstream of the Centerfire Creek confluence under a QAPP developed by NMED, in addition to regular NMED/SWQB monitoring and sampling at established stations..
- Photo points
- Monitor riparian tree canopy at selected locations
- Establish and monitor channel morphology cross-sections at selected intervals
- Coordinate with ADEQ to obtain results on Luna Lake monitoring

Map TMDL-34. Topographic map, San Francisco River subwatershed, Centerfire Creek to Arizona state line. Base image: USGS 1:24000 quads. All data from USGS, NMED, and USFS Gila National Forest.



Map TMDL-35. Land management status map, San Francisco River subwatershed, Centerfire Creek to Arizona state line. All data from NMED, USGS, and USFS Gila National Forest.



Map TMDL-36. Aerial photography relief map, San Francisco River subwatershed, Centerfire Creek to Arizona state line. Base image: USGS 1996–2002 digital orthophotoquads. All data from USGS, NMED, and USFS Gila National Forest.

SAN FRANCISCO RIVER—continued

San Francisco River above Centerfire Creek photos. Clockwise from upper left: between Luna Lake, AZ and Luna, NM; NMED sampling site upstream of Luna; flowing from spillway at Luna Lake; headwaters at Alpine, AZ. All photos from June 2001; courtesy NMED, Silver City.

TULAROSA RIVER SUBWATERSHED, SAN FRANCISCO RIVER TO APACHE CREEK

TMDL reach length: 22 mi; **Subwatershed area:** 336 sq. mi (to Apache Creek); 640 sq. mi total
Elevation range: 6400 ft to 7600 ft.
Watershed cover: 75% forested; 25% rangeland; <1% wetland
Watershed management: 98% USFS (Reserve RD); 2% private
Wilderness: none
Counties [SWCDs]: Catron [San Francisco]
TMDL: http://www.nmenv.state.nm.us/swqb/Conductivity_TMDL_in_Tularosa_Creek_11-05-01.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.603)**

TMDL parameter exceeded: Conductivity

Current exceedance: Conductivity as total dissolved solids exceeds standard by 86 lbs/day (< 2%)

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	Action (identification of MPs)	Possible MPs
Loss and inhibited regeneration of streambank vegetation (filtration) Direct grazing impacts in riparian zone, including soil compaction Road/OHV impacts, especially at low water crossing Sediment loading from destabilizaed streambanks, gullying in upper watershed Historic silviculture practices (loss of upland herbaceous cover)	Evaluate riparian grazing effects (including elk) for potential exclosures Quantify existing streambank vegetation; identify likely remediation sites Evaluate road/vehicle impacts; identify road crossings contributing heaviest sediment loads (GNF & partners in travel management planning) Establish forest thinning plan (Negrito Ecosystem Project underway) Locate and map gullies	Seeding/plantings; brush filters, filter strips to provide filtration; riparian exclosures Road/culvert/low water crossing realignment or paving; seasonal or OHV closures Forest thinning; seeding to improve herbaceous cover Gully remediation

TULAROSA RIVER SUBWATERSHED (SAN FRANCISCO RIVER TO APACHE CREEK)—continued

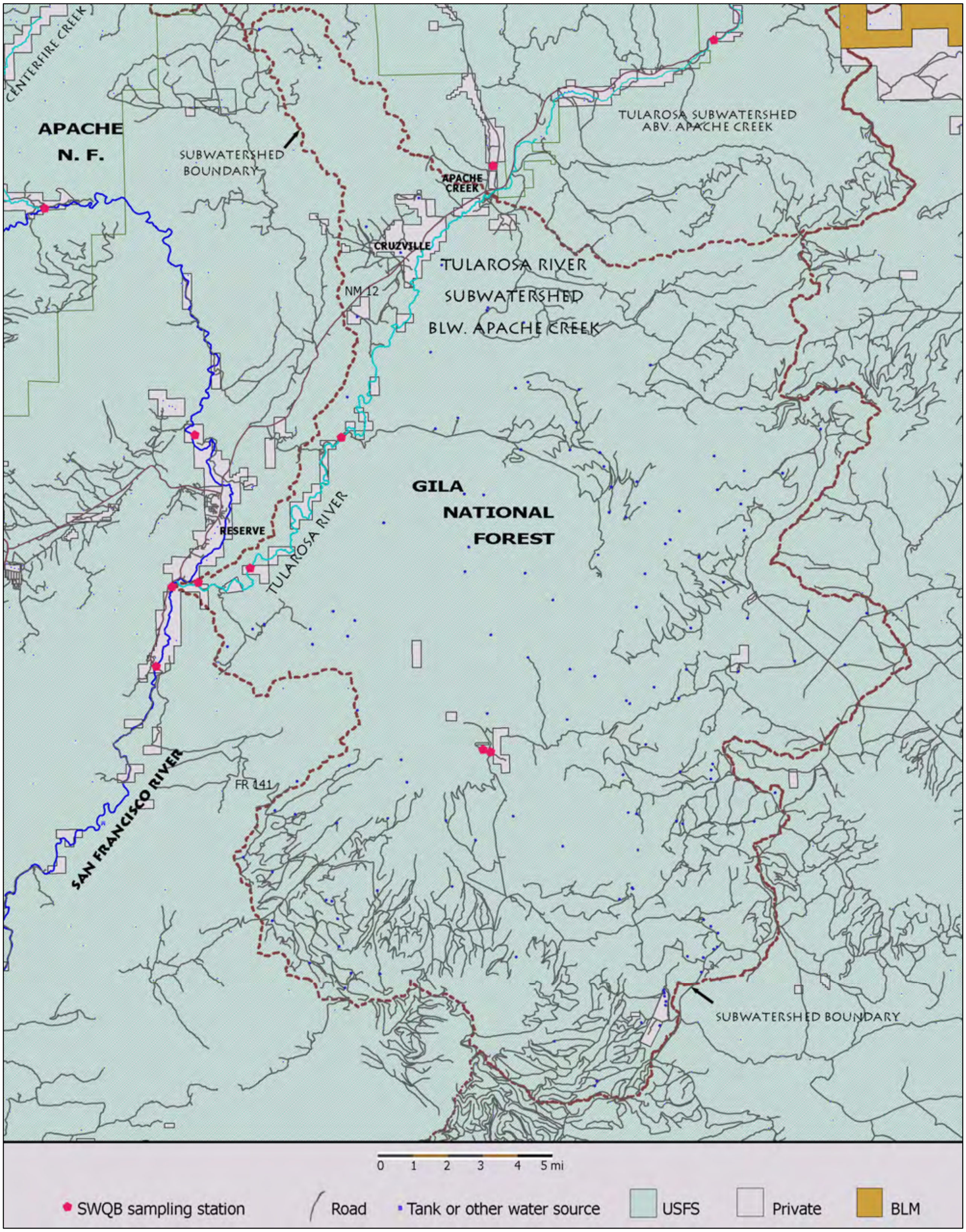
Milestones	**Schedule**	**Target criteria**
Filter or bank planting sites targeted Low water crossing projects identified (FR 233 is a GNF/TU joint project) Negrito Creek thinning completed; monitoring established (GNF planning) Travel management plan completed (GNF & partners) Liaison with NRCS, SWCD to develop gully remediation plan developed Travel management plan implemented and minimum of two additional road crossings targeted for improvement	2008 2006-2010 2007-2009 2008? 2008-2009 Dependent on all of above	Detectable positive (downward) trend in sediment runoff from uplands and targeted roads Riparian buffer/filter strip/seeding implemented on 20% of targeted reaches 10% increase in upland herbaceous cover on thinning project sites 2012 target: Reduce total dissolved solids by 8% to 300 mg/L (approx. 4,800 lbs/day)

Monitoring (suggested monitoring protocols are described in Section 6):

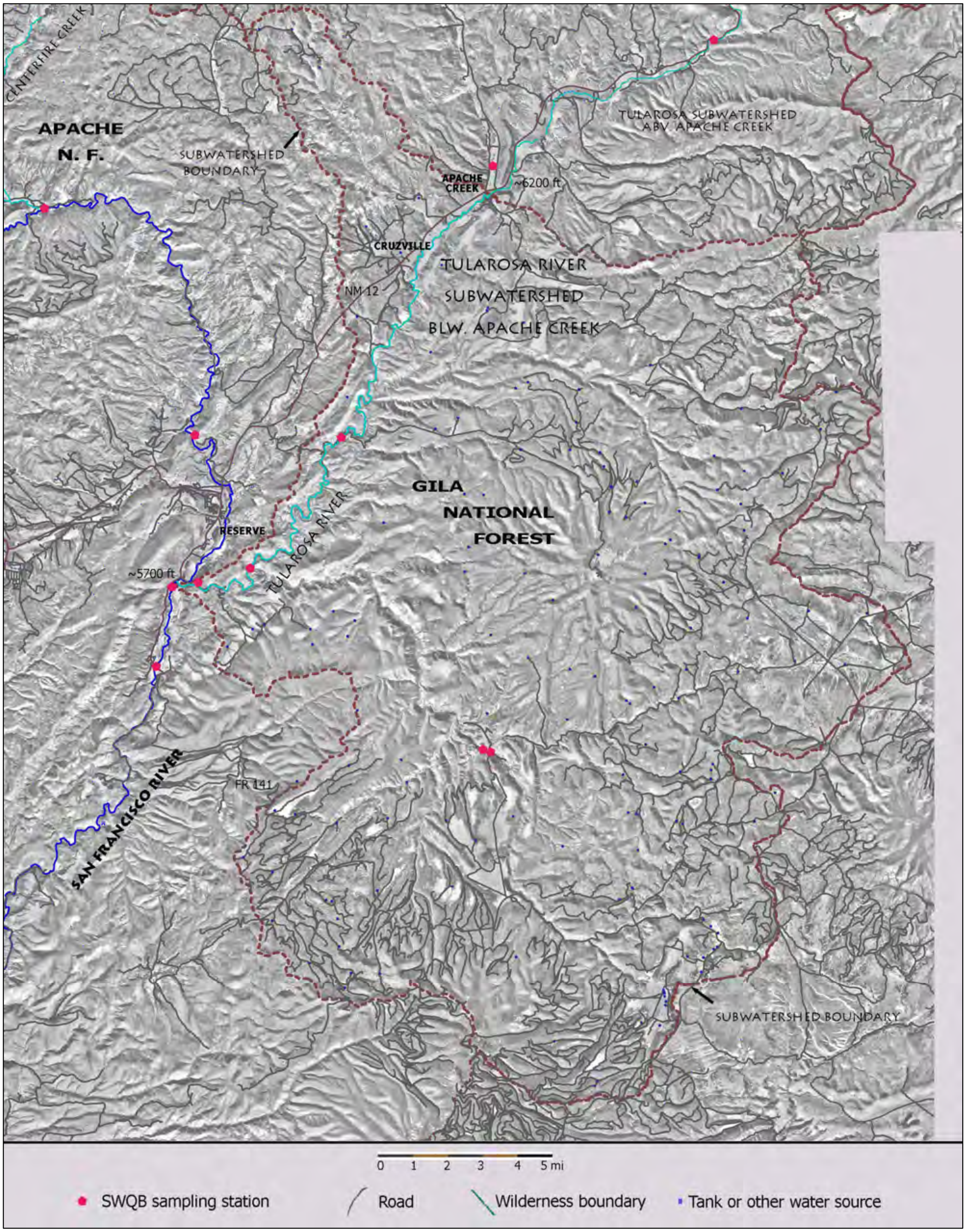
- SF SWCD currently monitors water quality on the San Francisco mainstem just downstream of the San Francisco River confluence under a QAPP developed by NMED, in addition to regular NMED/SWQB monitoring and sampling at established stations..
- Photo points
- Sediment runoff quantification/modeling
- Monument streambank/floodplain monitoring sites; quantify cover; revisit annually

Notes: Tularosa River subwatershed below Apache Creek includes the Negrito Creek watershed, detailed separately in this section.
Loach minnow are present in Tularosa Creek near the FR 233 crossing.

Map TMDL-37. Topographic map, Tularosa River subwatershed below Apache Creek. Base image: USGS 1:24000 quads. All data from USGS, NMED, and USFS Gila National Forest. Note that Negrito Creek is tributary to this reach of the Tularosa; Negrito Creek is addressed in a separate TMDL table. Also see Map TMDL-31.



Map TMDL-38. Land management status map, Tularosa River subwatershed from the San Francisco River to Apache Creek. All data from NMED, USGS, and USFS Gila National Forest. Also see Map TMDL-32, the Negrito Creek subwatershed.



Map TMDL-39. Aerial photography relief map, Tularosa River subwatershed from the San Francisco River to Apache Creek. Base image: USGS 1996–2002 digital orthophotoquads. All data from USGS, NMED, and USFS Gila National Forest. Also see Map TMDL-33, the Negrito Creek subwatershed.

TULAROSA RIVER—continued

Tularosa River photos, clockwise from top left: NMED staff and volunteer monitor trainees, September 2006; from Highway 32, October 2001; sampling site near FR 233, October 2001; upstream end of Tularosa wetlands near Highway 12, October 2001; road crossing near FR 233 sampling site, October 2001. All 2001 photos courtesy NMED, Silver City.

<u>WHITEWATER CREEK SUBWATERSHED</u>: SAN FRANCISCO RIVER TO CAMPGROUND

TMDL reach length: 6.9 mi; **Subwatershed area:** 18.2 sq. mi (to campground); 55 sq. mi total
Elevation range: 4700 ft to 10000 ft. (total)
Watershed cover: 70% forested; 27% rangeland; 3% agriculture; <2% water or urban
Watershed management: 95% USFS (Glenwood RD); 5% private (16% private owned to campground)
Wilderness: 67% of entire watershed
Counties [SWCDs]: Catron [San Francisco]
TMDL: http://www.nmenv.state.nm.us/swqb/Turbidity_TMDL_on_Whitewater_Creek_11-05-01.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.603)**

TMDL parameter exceeded: Turbidity

Current exceedance: Turbidity (as total suspended solids) exceeds standard by 663 lbs/day (106%)[1]

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	Action (identification of MPs)	Possible MPs
Hydromodification (levees); bank destabilization Loss and inhibited regeneration of streambank vegetation (filtration) Road/low water crossing impacts Historic fire suppression and loss of herbaceous cover; increased sediment inputs	Evaluate channel modification potential in consultation with landowners, NM DOT, USFWS, ACOE, etc. Quantify existing vegetative cover and potential for recovery Identify potential revegetation sites Evaluate low water crossing impacts (GNF and TU project underway) Evaluate thinning projects potential	Road/culvert/low water crossing realignment Pole/post plantings; brush filters, filter strips to provide filtration; riparian exclosures Seeding; thinning of upland woody species to improve herbaceous cover Channel revegetation/modification measures including levee deconstruction (SF SWCD/SFRA project underway)

<u>WHITEWATER CREEK SUBWATERSHED</u>: CAMPGROUND TO HEADWATERS

TMDL reach length: 14.2 mi; **Subwatershed area:** 36.7 sq. mi. (above campground; 55 sq. mi. total)
Elevation range: 4700–10000 ft. (total)
Watershed cover: 70% forested; 27% rangeland; 3% agriculture; <2% water or urban
Watershed management: ~100% Gila NF (Glenwood RD); <<1% private (campground to headwaters)
Wilderness: 88% (32 sq. mi. above campground)
Counties [SWCDs]: Catron [San Francisco]
TMDL: http://www.nmenv.state.nm.us/swqb/White_Water_Creek-Metals_TMDL.pdf
Record of Decision: http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB/2004-2006ROD.pdf
WQS reference: http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf (Section **20.6.4.603)**

TMDL parameter exceeded: Chronic aluminum

Current exceedance: Aluminum standard exceeded by 0.003 lbs/day (70%)

Unsupported use: high-quality coldwater aquatic life

Possible mechanisms	Action (identification of MPs)	Possible MPs
Natural sources (basalts) Increased sediment runoff delivery to channel: trails, historic fire suppression Loss of upland herbaceous cover Runoff from mine tailings	Evaluate stream bank vegetative cover density and potential planting sites (filtration) Evaluate wildland fire potential in upper watershed (wilderness): GNF planning Locate and map any mine tailings	Riparian buffer zones for filtration Burning/thinning of woody species Reseeding of herbaceous species Trail stabilization Tailings reclamation

WHITEWATER CREEK SUBWATERSHED:
SAN FRANCISCO R. TO CAMPGROUND AND CAMPGROUND TO HEADWATERS—continued

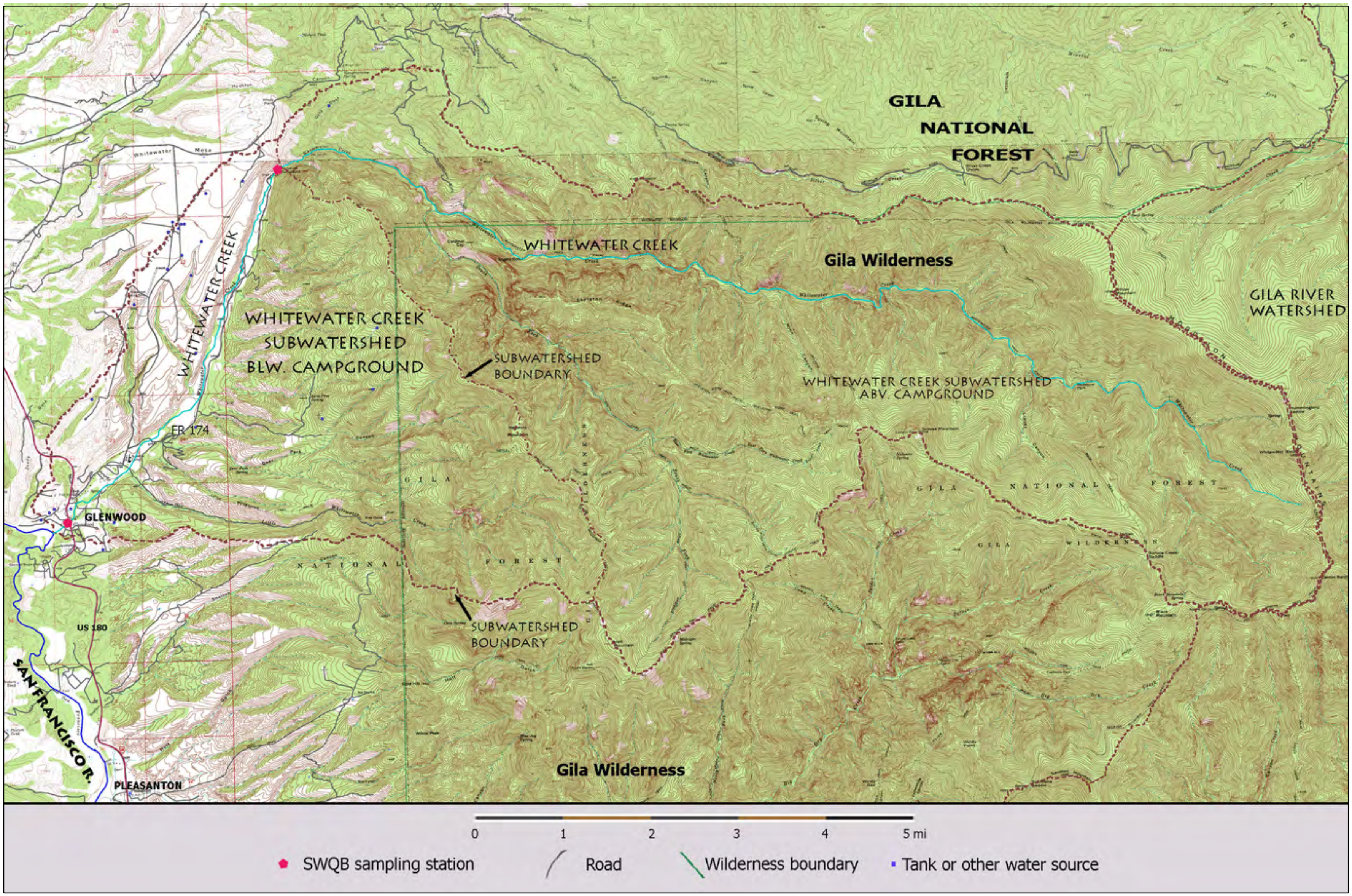
Milestones	**Schedule**	**Target criteria**
Filter or bank planting sites targeted Low water crossing projects and funding sources identified Liaison with private landowners, NRCS, GNF, working groups Channel re-design plan complete and funding obtained Potential revegetation sites identified Trail reconstruction plan complete Potential for thinning/prescribed or wildland fire identified	2005 (GNF, SFRA) 2006 (GNF, TU) Ongoing 2005 Data collection ongoing 2006 Per GNF planning schedule (extent of wilderness makes thinning unlikely)	Turbidity: Clear downward trend in turbidity measured at monitoring sites post-implementation, to 75% of current levels Bankside vegetation established on 25% of target sites Post-fire: 10% increase in measured herbaceous cover Aluminum: Reduce aluminum concentration by 25%, to 0.006 lbs/day

Monitoring (suggested monitoring protocols are described in Section 6):

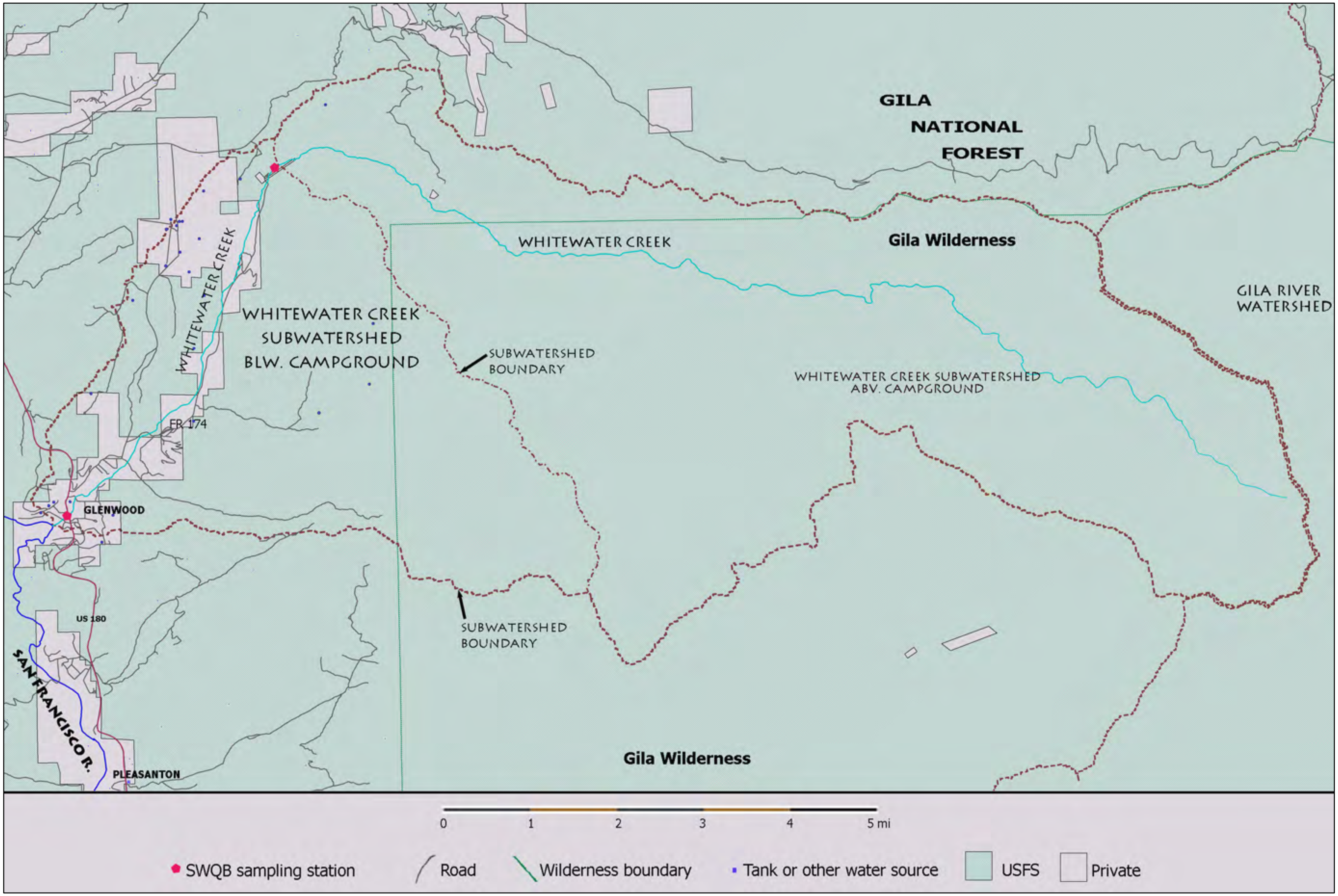
- SF SWCD currently monitors water quality on the San Francisco mainstem downstream of the Whitewater Creek confluence, and on Whitewater Creek at the campground, under a QAPP developed by NMED. The regular NMED/SWQB monitoring site on Whitewater Creek is located immediately upstream of the San Francisco River confluence.
- Herbaceous cover via line-point intercept; channel/floodplain cross-sections to monitor deposition of fines post-project
- Photo points
- Groundwater levels for plant re-establishment

NOTE. Loach minnow are present in Whitewater Creek.

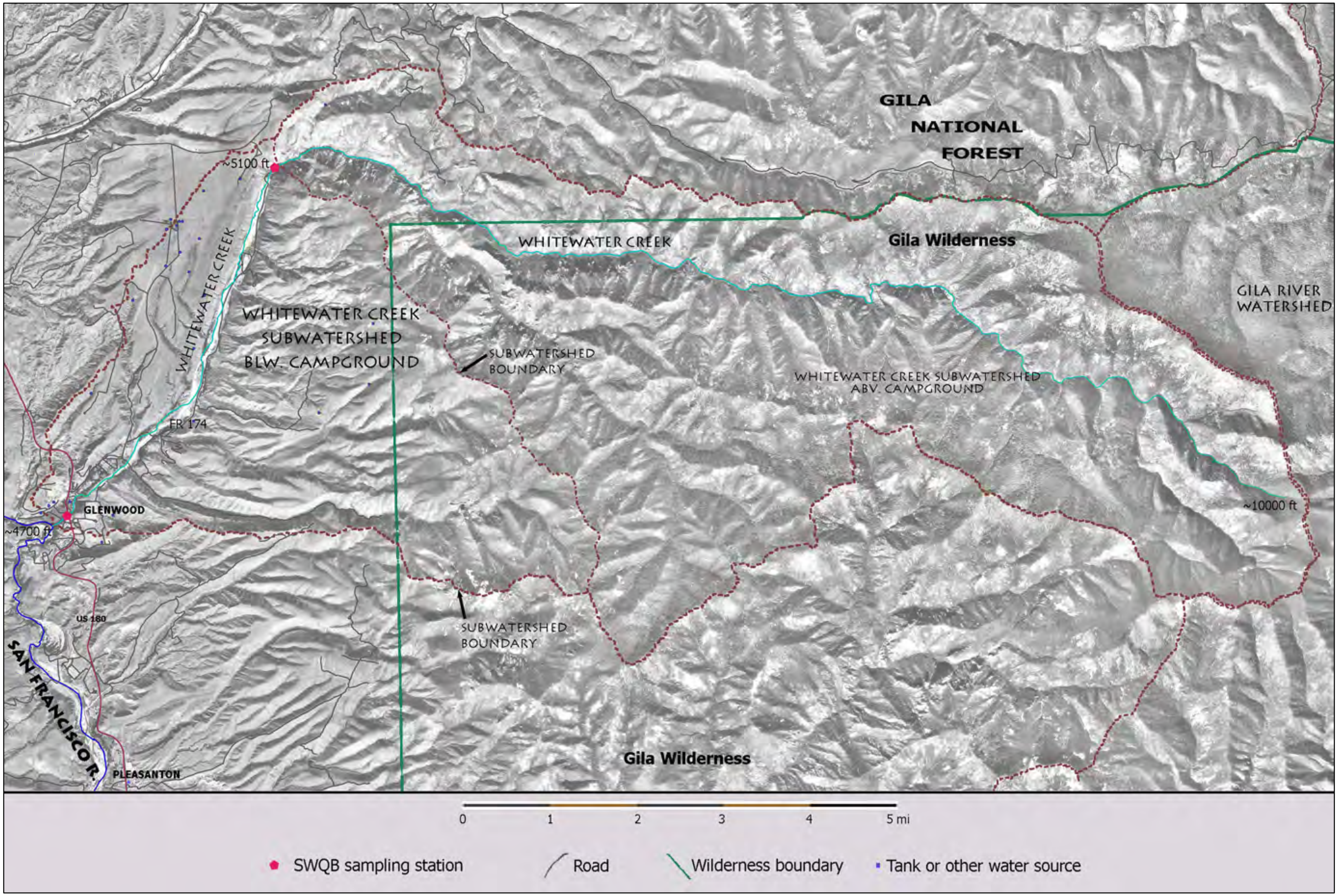
[1]Excluding the NM Fish Hatchery, a point source permitted to discharge 334 lbs/day. Total exceedance is 997 lbs/day.



Map TMDL-40. Topographic map, Whitewater Creek subwatershed. Base image from USGS 1: 24000 quads. All data from USGS, NMED, and USFS Gila National Forest.



Map TMDL-41. Land management status map, Whitewater Creek subwatershed. All data from NMED, USGS and USFS Gila National Forest.



Map TMDL-42. Aerial photography relief map, Whitewater Creek subwatershed. Base image: 1996–2002 USGS digital orthophotoquads. All data from NMED, USGS, and USFS Gila National Forest.

WHITEWATER CREEK—continued

Whitewater Creek photos, clockwise from upper left: Downstream near Catwalk campground toward picnic area, March 2001; From Highway 180 bridge in Glenwood, March 2001; NMED demonstration of sampling techniques for local residents, May 2001; part of more than 2 leveed miles of the creek downstream of the Catwalk (levee runs from center left edge of photo toward the road), March 2001. All photos courtesy NMED, Silver City.

SECTION 6

Watershed Planning,
Strategies for Improvement, and Monitoring of Results

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WATERSHED PLANNING

Defining desired future condition is an important early step in watershed improvement planning. An achievable desired condition will partly depend on the scale of the watershed, ecological and economic constraints on rehabilitation, and land management goals. One goal of watershed rehabilitation is to make land more useful and valuable by assisting in the recovery of ecosystem function and processes. Rehabilitation does not necessarily aim to recreate a predisturbance condition, but it does mean "establishing geological and hydrologically stable landscapes that support the natural ecosystem mosaic" (Federal Interagency Stream Restoration Working Group, 1998). One of the most critical tasks in achieving improvement is to halt, decrease, or mediate the disturbance activities that cause degradation or prevent recovery of the watershed ecosystem (Federal Interagency Stream Restoration Working Group, 1998). The effort and expense required to implement more active remediation measures will yield far greater benefits when this occurs than otherwise, and their success or failure may depend on it.

Integrated planning work will involve a number of factors. These include land management or ownership status, seasonality, projects already under development or underway, funding availability, and the level of interest among landowners, watershed groups, and management agency staff.

Land management/ownership status implications. A coordinated approach to watershed planning and identification of appropriate Management Practices greatly facilitates work on subwatersheds for which multiple agencies and/or landowners share responsibility. For example, identifying willing landowners when subwatersheds are divided between private and public lands may best be accomplished through interested liaison agency staff. In addition, federal lands require development of Decision Memos, Categorical Exclusions, or NEPA clearances. Planning and implementation can proceed more quickly for areas where these requirements have already been met or budget prioritizes the affected area and agency staff can help to identify these areas. In other cases, Biological Assessments will be required where sensitive species are present; in- or near-channel earth-moving work must be coordinated with the Army Corps of Engineers and NMED; archaeological clearances are often required for work on both public, state and private lands. Planning includes knowledge of which of these tasks have already been completed, or takes into account the time and budgets needed to accomplish them.

Season of year. The timing of funding decisions has implications for project development. For instance, if scheduled tasks must be accomplished during a dry season, as with instream work, funding that becomes available only after the onset of monsoon season in July can delay implementation for many months.

Existing project work. Where ever possible, planning should be integrated with existing project work. For work on public lands, communication and coordination with agency staff who are familiar with or responsible for subwatershed lands can often be the best means for identifying and contacting the groups or individuals engaged in such work.

Funding availability. A wide variety of funding is available for watershed improvement work (see Resources, Section 7). Each funding source has its own requirements for matching dollars, the types of work and groups or agencies eligible for funding, and proposal requirements. Leveraging funding sources by developing partnerships, thoroughly researching funding possibilities, and developing coordinated management plans helps to optimize support dollars and the use of in-kind services as match.

IDENTIFYING AND IMPLEMENTING MANAGEMENT PRACTICES

Management practices (MPs) are voluntary actions aimed at improving hydrologic conditions on the watershed. They are often referred to as "Best Management Practices," but since the best measures for achieving these goals may vary substantially among sites on a watershed of the scale of the Gila’s, we avoid using that term.

Soil and water are the most fundamental requirements for watershed health. The land steward's job is to enhance the processes that help to retain soil and water, or, in more scientific terms, the "degree to which the integrity of the soil, vegetation, water, and air...and the ecological processes of the ecosystem are balanced and sustained” (adapted from the Task Group on Unity in Concepts and Terminology, 1995). MPs are a means of accomplishing this goal.

As used here, MPs are actions specifically designed to reduce nonpoint source pollution of surface waters. They are practical methods for protecting surface waters from the potentially adverse effects of resource use and natural events such as long-term drought. Pollutants on the Gila watershed are generally introduced to surface waters by excessive rates of erosion and sediment runoff. To successfully improve these conditions, MPs must work to conserve soils, improve alluvial and soil moisture storage, and sustain vegetative cover. Moreover, finding ways to support landowners and land managers in achieving these goals is probably the best way to enhance long-term economic sustainability on the watershed.

The MPs suggested here can assist landowners and other land managers in improving or protecting waters from nonpoint source pollution. Whether educational, structural, or nonstructural, MPs typically function to prevent or reduce the movement of sediment, nutrients, and other pollutants from the land to surface or ground water. MPs must be "economically achievable actions" (US EPA, 2005);

Rapid soil and water loss occur under the conditions shown in the top image. Fundamentally, MPs are aimed at supporting the self-sustaining conditions of the lower image, where native vegetation holds and improves the soil, soils retain more moisture, soil moisture enhances plant vigor, and so on.

that is, they must achieve a balance between water quality protection and the limitations imposed by nature and economics. Nonpoint sources are a diffuse and widespread form of pollution. They occur naturally to some extent. Although the volume of pollutant (or sediment) generated from any particular spot may be small and insignificant, the total volume from all sources across the landscape can create substantial water quality problems. It is unrealistic to expect that all nonpoint source pollution can be eliminated, but MPs can minimize their impacts.

The most common form of surface water pollutant created by land use activities is sediment. Soil loss, of both mineral soils and organic matter, contributes substantially to the total sediment load that enters surface waters. Excessive sediment inputs can upset balanced stream ecology by smothering bottom dwelling organisms in the water, interfering with photosynthesis by reducing light penetration, inhibiting fish reproduction, altering stream flow, and widening and reducing the depth of stream channels.

Adoption and use of MPs will assist practitioners in attaining these water quality goals:

- enhancing the integrity of stream courses;
- reducing the volume of surface runoff originating from an area of management disturbance and running directly into surface water;
- minimizing the movement of pollutants (e.g., pesticides, nutrients, petroleum products) and sediment into surface and ground water;
- stabilizing exposed mineral soils through natural or artificial revegetation means
- intercepting pollutants before they reach surface waters.

MANAGEMENT PRACTICES: BY LAND USE CATEGORY

Management practices can be categorized in different ways. NMED's *New Mexico Nonpoint Source (NPS) Management Program* (1999) and EPA's watershed planning guide (2005) group suggested remediation practices by their potential for reducing the contaminants likely to be generated by various activities. Within each activity category, the actions that will be most effective in reducing nonpoint contamination will depend on site-specific factors.

MPs: Agriculture/grazing practices

- Soil loss and sediment runoff: stubble mulching, terracing
- Nutrient movement: fertilizer management
- Irrigation management: tailwater recovery, land leveling and spreading techniques; drip irrigation; infiltration galleries
- Grazing management: deferments; pasture rotation; management of riparian use through exclosures and water developments; supplemental feed and water developments to increase livestock or wildlife distribution
- Gully abatement: reestablishment of bank vegetation, rock and brush dams, grade stabilization; gully plugs
- Restoration of vegetative cover: planting/seeding in critical areas; mulching; brush management (thinning or burning)

- Reclamation of wetland buffer systems
- Filtration enhancement: revegetating
- Water harvesting techniques

MPs: Impervious cover/construction

- Infiltration basins
- Wetland reclamation
- Revegetation
- Temporary silt fencing

MPs: Mining activities

- Erosion control: reclamation/revegetation of mined areas; runoff controls
- Toxics: treatment of acid mine runoff
- Tailings: stabilization, relocation, diversions of runoff to avoid tailings; revegetation; wetland reclamation

MPs: Recreation activities or road construction/maintenance

- Runoff control: dips, improvements in culvert design
- Road closure; ripping/seeding
- Gully plugs and other sediment control structures
- Improved stream crossing design and construction

MPs: Timber/forest management

- Stream protection
- Erosion control
- Prescribed thinning/burning; fuel load management

MANAGEMENT PRACTICES: EXAMPLES

A good understanding of MPs and flexibility in their application are important in selecting those that will provide the most effective control of nonpoint source pollution under the conditions of a particular subwatershed or stream reach. Criteria for good MPs should include their ability to stand the test of time and climate, with relatively low maintenance, as they "mature" into the ecosystem. More than one correct MP for reducing or controlling nonpoint source pollution will probably apply; the best planning will identify all of the likely causes for nonpoint source pollution within the subwatershed and incorporate MPs to address as many of the causes—from uplands to stream channels—as possible. MPs are numerous. The *WIPS* provides only a few of many examples, and we expect stakeholder knowledge and inspiration to suggest additional valuable and innovative practices.

The resources available to assist landowners and others in identifying and implementing MPs are almost endless. Most of these practices are eligible for funding assistance through programs offered by the Natural Resource Conservation Service (NRCS), for instance; local SWCD offices and the district NRCS office will work with landowners to obtain this funding. Other agency offices offering assistance with the MPs described in this section include USFS, BLM, US Fish & Wildlife Service, NMED, SWCDs, and state offices of Forestry and Game & Fish, among others (Section 7).

Examples of MPs that follow include:

Stream channel remediation practices

- Sediment retention structures
- Stream barbs, weirs, and other structures
- Revetment fencing
- Riparian buffers: vegetative or bioengineered
- Irrigation diversion structures
- Wetland reclamation

Soil and surface runoff conservation practices

- Gully reclamation
- Road/culvert/trail construction and management (including stream crossing designs)
- Silt fencing
- Road improvements and reclamation
- Water harvesting techniques
- Small mining sites reclamation
- Mulching
- Grazing management

Woody species reduction practices

- Forest thinning
- Prescribed burns
- Seeding for native ground cover
- Herbicide use

Education and outreach

Go to Section 7, Resources, to find links and other reference materials for:

- Detailed information on management practices
- Watershed group and agency information and contact
- Data availability listings
- Sources of technical support
- References and links for monitoring protocols
- Information and links to financial assistance resources for watershed projects

Stream channel remediation

All of the techniques and structures shown here for capturing sediment and restabilizing stream channels share the ultimate goal of improving conditions for streambank and floodplain vegetation. Vegetation appropriate to site conditions is the most effective means of capturing sediment and arresting excessive rates of erosion. These are targeted practices best implemented in conjunction with others that address, where ever possible, the underlying causes for channel instability. We encourage landowners to consult with a variety of resources to discuss needs and site conditions; see Section 7.

Sediment Retention Structures

Drawdown tower and dam at Spur Ranch on Centerfire Creek.

Drawdown tower designs reduce stream sediment loads by maintaining water level in a ponding area created by dam construction. , allowing sediment to settle in the bed of a deeply incised channel. Water is released slowly downstream through ports in the tower during flow events. Stair-stepped dam designs help dissipate the energy of overtopping floods. Reduced sediment loads downstream improve water quality, and eventually, the fine sediments deposited upstream of the dam will provide suitable substrate and improved soil moisture to enhance the survival of bank and floodplain vegetation. Vegetation helps to stabilize stream banks and dissipate the flood energy that eroded the channel to the depth and width seen here.

Structures like this are costly to design and build, and they work most effectively in conjunction with other watershed improvement measures. At this site, the landowner's commitment to the project has resulted in concurrent efforts to enhance native herbaceous cover by thinning work in upland ponderosa pine stands and removal of dense woody brush growing on the former floodplain. Riparian vegetation will be planted and exclosed from grazing (mainly by elk) in targeted locations. Many agencies are engaged in these efforts. Workshops are conducted at the project site to share results with other landowners and managers.

Stream barbs, weirs, and other structures

When channel incision or lateral erosion is caused by bank instability, techniques designed to dissipate or deflect concentrated flows and reduce erosive forces can be effective. Measures to improve vegetative cover are one means of addressing excessive rates of surface and streambank erosion, and these are addressed later in this section. Rill erosion or gully headcutting caused by focused surface runoff can also be remediated by placement of simple water spreading devices: rock or brush lines, straw wattles, or mulch.

A number of simple, effective techniques exist for reducing erosion and enhancing deposition in channels, with minimal stream disturbance. Depending on watershed area, many can be constructed manually, using local materials like rock, willow, and juniper. These can include weirs, vanes, baffles, low dams, layered rock flow "interrupters," or stream barbs. Each is designed to enhance deposition or redirect erosive stream flows to achieve a specific aim.

Simple stream barb constructed of local rock on Taylor Creek. Photo on left shows eroding bank immediately after barb construction; on right, there was no damage from two large floods in August 2004 that deposited fine-grained material throughout the reach. Emergent vegetation grows on the sediment deposited at the barb and on banks during the floods.

Stream barbs and other structures are often constructed of rock or wood post sills. Stream barbs project out from a streambank and across the stream's thalweg (low point) to redirect streamflow away from an eroding bank; other structures, like weirs or flow dissipaters, may be constructed in the stream bottom. Typically, a series of barbs or other devices is constructed, with their specific spacing and alignment dependent on stream conditions. These structures work by minimizing or arresting specific points of erosion, while creating conditions that encourage the stream to deposit sediment during flood events.(In some cases, vegetative amendments alone may accomplish these goals and should be considered prior to adding structural methods.) The new sediment creates good conditions for vegetation recruitment and growth. Vegetation helps to slow water velocity and filters and deposits additional fine-grained sediments. Fine sediments further enhance vegetation survival by capturing moisture that can otherwise drain rapidly from coarse streambed and bank materials (alluvium). As a further benefit, increasing the water storage capacity of alluvial material during high flow events helps to sustain stream base flow, when the stored water is slowly released back into the stream channel during dry periods (refer to Whiting, 1998, for more information).

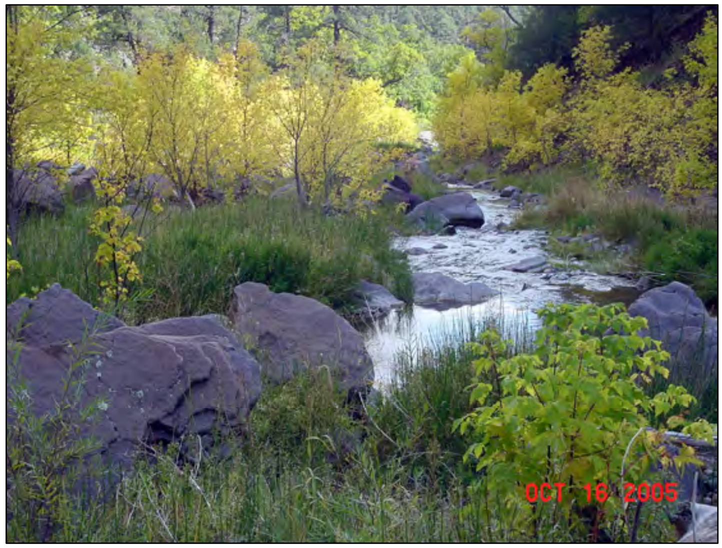
Revetment fencing

Floods in this region typically exhibit steep hydrographs: that is, streamflow during the beginning and ending stages of the flood may rise and fall very abruptly. Flood erosion, particularly during long-duration events, frequently occurs during the late stages of a flood due to the rapid recession of water from wetted streambanks and floodplains. Fine-textured field soils are at high risk during such events. Revetment fencing is a useful tool for restabilizing streambanks under conditions where lateral erosion or stream widening are so severe that standard revegetation techniques are impractical. In such cases the distance between stream banks is often more than sufficient to allow stream meandering, but extreme channel widening has been induced by earlier river bottom practices or watershed conditions that result in faster surface runoff. These conditions should also be addressed in the planning process, because they will continue to contribute to extensive agricultural field loss when flood flows capture and erode additional fine-grained field soils.

Newly installed revetment fencing on the Gila River near Virden. Top, immediately prior to floods in February 2005. The cutbank in the photo foreground is 6 to 8 feet high. Bottom, from a different angle, just after February 2005 floods. The fences are the dark lines extending at an angle away from the camera and draped in lightweight flood debris. Approximately four feet of sediment deposited during the flood is ready for planting.

Revetment fencing is installed on pipe stem embedded into the streambed at the existing bank and angled into the stream channel, like the stream barbs described above, to produce backwater areas for sediment capture during floods. The fresh sediment provides a nursery site for re-establishment of vegetation. Planting should be conducted after each flood deposits more sediment. Selection of appropriate vegetation species is important and will depend on depth and variability of groundwater levels, soil type, and region; suitable vegetation may range from herbaceous or woody riparian species to more xeric species like rabbit brush and Apache plume.

Riparian buffers: vegetative



San Francisco River Box above Reserve, NM.

Sediment runoff impacts streams directly and by transporting contaminants, where they are present on the landscape, into stream channels (see Klapproth & Johnson, 2000). Near-channel vegetation helps traps overland runoff before it enters a stream, and captures sediment transported during high flows when flood water overtops the stream's banks. Riparian plants also increase the infiltration capacity of soils (thus decreasing surface runoff) through creation of passages by root systems and by loosening soils. Aquatic vegetation in the channel directly filters sediments transported in surface waters. Where barren floodplains exist or aged, monotypic forest canopy precludes groundcover establishment, stream sedimentation from both overland sources and eroding streambanks is increased. Rehabilitation of appropriate vegetative stream buffers in these areas can be a highly effective means of improving water quality and ecosystem function.

Both woody and herbaceous riparian cover can effectively trap sediment from shallow overland sheet flows. Herbaceous cover is typically better at collecting very fine particles like clay and silt, while woodier species like willow tend to trap higher volumes of sand and gravel-sized particles. Generally, the wider the buffer zone between the stream and upland, the more effectively fine particles like clay and silt are trapped (Wilson, 1967). Local hydrology, controlled by geology, topography, and soils, is an important control on the effectiveness of riparian buffers and on the suitability of various forms of vegetation for specific sites. Properly identifying the most suitable species for re-vegetation efforts is important in defining realistic goals for riparian remediation. Unrealistic goals create unrealistic expectations and potential disenchantment when the expectations are unfulfilled (Federal Interagency Stream Restoration Working Group, 1998).

Successful planning for riparian re-vegetation efforts includes:

- Recognizing site limitations (soil texture, depth to groundwater, potential loss from scouring floods)
- Meeting watering/mulching requirements for planted stock or seed

- Preparation for effects of potential weed competition
- Identifying and locating sources for a suitable structural diversity of vegetation types

Riparian buffers: bioengineering

Other methods of arresting or mitigating erosion on streambanks can be applied alone or in conjunction with direct replanting or reseeding efforts, depending on site conditions. Bioengineering treatments use live plant materials to provide erosion control, slope and stream bank stabilization,

Brush mattress installation to reduce accelerated streambank erosion.

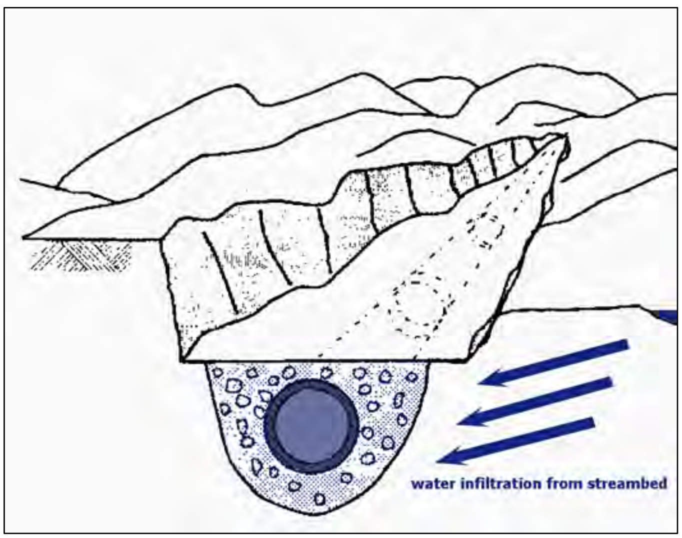
Willow clumps installed in trench between rock stream barbs.

Willow clumps with juniper revetment at the toe of a resloped bank.

landscape rehabilitation, and wildlife habitat. These techniques are used alone or in conjunction with conventional "hardened" engineering techniques. For instance, in some situations “laying back” vertical incised banks to flatten their slope allows normal floods to overtop the streambanks. The flatter slope increases streambank biomass, and enhances the bioengineering methods used.

Bioengineering methods are generally less costly and require less disturbance of existing conditions by heavy equipment than conventional approaches—an important consideration in riparian remediation. Appropriate plant species should be used; many species are readily available and are well adapted to local climate and soil conditions. Transplanting local native plants and using locally harvested seed can provide additional savings. Soil bioengineering projects may be installed during the dormant season of late fall, winter, and early spring. Bioengineering is often useful on sensitive or steep sites where use of heavy machinery is not feasible. One significant advantage to these applications is that they grow stronger as vegetation becomes established. Even if the plants die, roots and surface organic litter continues to play an important role for establishment of other plants. Once vegetation is established, its root systems reinforce the soil mantel and remove excess moisture from the soil profile, often key to long-term soil stability.

Irrigation diversion structures



Simple off-channel design for an infiltration gallery.

Numerous irrigation diversions and ditches supply surface water to pastures and fields on the Gila River and its tributaries. Most diversions are in the form of push-up berms that pond water high enough to enter a gravity-flow ditch. Flooding necessitates periodic reconstruction of the berms, creating sedimentation problems through disturbance of the streambed and often, the stream bank used for heavy equipment access to the berm.

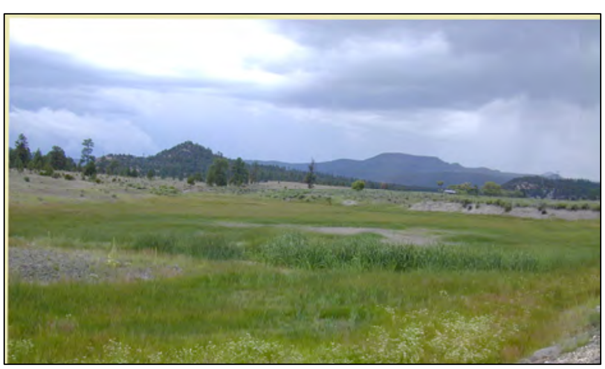
An infiltration gallery is a sub-surface groundwater collection system, typically shallow in depth, constructed of perforated or screened pipe. Off-stream placement of an infiltration gallery induces infiltration through permeable alluvial materials from an adjacent surface water body. A gallery consists of well screen and filter pack material installed in a trench excavated perpendicular to the direction of water flow (in the case of off-channel installation, this generally means parallel to the streambed). The gallery is connected by pipe to the irrigation system and reburied. In permeable floodplain substrate, they can be installed in a trench backfilled with fine gravel or other filtering material. The length of the gallery will depend on the amount of water required and the hydraulic characteristics of the water-bearing sediments. When properly designed and installed, galleries resist clogging by finer materials, but they can also be maintained by backwashing with water or compressed air. Their placement out of the streambed is their advantage for water quality, since it ends the need for in-channel diversion maintenance. In appropriate sites, and if installed far enough upstream of the irrigation point, gravity flow into the irrigation system can be maintained. The town of Safford, Arizona, has relied on an infiltration gallery and gravity-fed system for its water needs since 1939; it currently supplies more than 19,000 users (Town of Safford, 2006).

Cross-vane weir. Point of diversion is at center bottom of photo.

Like standard diversion berms, cross-vane weirs function to divert water into a gravity-fed irrigation ditch. Under the proper conditions, they offer an alternative means of reducing stream bed disturbance from berm maintenance. They can divert stream flow while maintaining sediment movement downstream, and enhance fish passage that is otherwise restricted by traditional berms. Well-constructed weirs may be much less likely to be destroyed by floods than standard diversion berms, as they are designed to allow higher-stage flows to pass unimpeded. Careful design, particularly in consideration of typical low flow stage, is important (see Barkdoll et al, 1997, for a review of some structural details). Construction can entail significant disturbance to the stream channel and floodplain, and damage to the ecological functioning of these adjacent areas can eventually lead to failure of the structure itself.

Wetland remediation

There are many definitions of what constitutes a wetland, but they all involve characteristic soils, hydrology, and plant types. Simply stated, a wetland is an area that remains saturated for long enough during the growing season to support certain plant types, known as "hydrophytic" vegetation (NMED, 2000). Wetlands enhance water quality and storage by dampening flood effects, capturing water and slowly releasing it to enhance long-term baseflow, and filtering sediments. Many hydrophytic plants absorb contaminants contained in water and sediments. Wetlands are often found in oxbows (cut-off river channels), abandoned irrigation ditches, near high-elevation springs and seeps, in riverine backwater areas, and around beaver ponds.



High-elevation wetland on the Centerfire Creek subwatershed.

Ongoing national and state interest is focused on protecting and enhancing wetland areas, and NMED's Wetlands Office has targeted the Gila watershed for development of a mapping and rehabilitation program. Much of the riparian remediation work described earlier will enhance wetland creation or protection. Wetland reclamation may include investigations of soil types, groundwater–surface water relationships, re-vegetation techniques, and enhancement of natural flow or ponding patterns (see Brinson & Rheinhardt, 1996). Re-establishing native wetland plant communities is often best accomplished through a combination of hydrologic improvement strategies and transplants of remnant wetland soils with intact native seed banks; these sites are sometimes found near abandoned river channels or historic irrigation ditches (see Brown & Bedford, 1997). Watercourses altered with stock tanks also have potential for reclamation as retention basins to promote groundwater recharge in former wetland zones. Although wetland remediation can offer significant benefits to private landowners, concerns about listed species implications may also dampen their enthusiasm for investigating its possibilities. A variety of federal assurance programs have been created to support landowners in this situation. We encourage landowners and land managers interested in learning more about the potential for wetland remediation, its benefits, and assurance programs to contact NMED or the watershed information coordinator for more information. See Section 7, Resources.

Wetland established on abandoned irrigation ditch, Gila River.

Soil and surface runoff conservation

Gully reclamation

The best approaches for rehabilitating gullies are site-specific and highly dependent on the landowner/user/manager and secondly on the particular mechanisms responsible for the formation and development of the gully. The shape of the channel often gives clues about the mechanisms involved in erosion. For instance, channels where erosion is caused mostly by the effects of concentrated surface flows often form a "V" shape; whatever their size, they are technically known as *rills* (see below).

Reshaping the form or pattern of a gully or rill can help to slow water velocity, encourage vegetative growth on banks, and lessen erosive potential.

A deep bed of coarse material in the bottom of a gully prohibits transport of collapsed material downstream and helps protect steep-sided walls from additional collapse.

True gullies tend to form in the shape of a "U," with nearly vertical walls. Although gullies often initially form where surface flows concentrate (as in old trails or roads along valley bottoms), their continued erosion is often more likely caused by groundwater seepage than overland flow. This effect typically begins when vertical incision reaches a water-bearing soil layer (see Higgins et al., 1990).

The characteristic steep sides and head wall (scarp) of gullies often indicate this source of erosion, known as a "sapping" or "piping" effect. The erosion, in other words, occurs from within the gully's banks rather than from the top down. The pressure of water seeping through the gully banks weakens their structure, typically causing large blocks of bank material to collapse into the bottom of the gully. The same effect usually occurs at the face of the headcut, particularly when vegetation or a more resistant layer are present on the surface (Leopold et al, 1964). This is why headcut retreat is often most active where a gentle slope exists above the headcut (enhancing subsurface water infiltration), and why actively forming gullies in certain soil types so often leave "bridges" across parts of their incised channels.

In this situation, the main erosive function of surface flow within the gully is to transport the collapsed material downstream, allowing additional material to collapse into gully bottom. Structures

When well-designed and constructed, gully plugs can slow water velocities, enhance water infiltration and sediment deposition within the gully, and help provide nursery sites for revegetation efforts. Photo at right is pre-treatment gully in the Mangas Creek watershed, February 2002.

Gully plug and sloped banks engineered to watershed specifications, after construction, July 2002.

that are designed to increase water infiltration on the land surface *above* the gully (typically, on the valley floor) are perversely likely to enhance gully growth, causing the collapse of new large blocks of bank and head scarp material and maintaining their vertical structure.

Under these conditions, gullies naturally "heal" themselves by incising upstream, a process known as headcut migration, until the gully's bottom slope intersects the valley slope. When this happens, material carried downstream will begin to deposit in a fan around the bottom end of the gullied reach, lessening the overall gully slope and impeding further transport. Avoiding the loss of soil and water storage that results from continued headcut migration—which can lead to the formation of extensive gully networks—is the goal of gully remediation. Remediation techniques work by enhancing the processes that inhibit transport of collapsed material downstream.

For example, when surface runoff falls over the face of the headcut and undermines its base, headcut migration is exacerbated. A bypass ditch to reroute water from above the headcut to a re-entry point farther downstream can be used in this situation to help stop headcut migration. Within the gully, grade control structures that incorporate re-vegetation techniques increase channel roughness and slow the velocity of water moving downstream. Straw bale dams, log mats, or cut trees can be used in the

As of September 2003, ground cover at the gully site shown above was becoming re-established and site hydrology had improved.

gully bottom to provide grade control, protected areas for vegetation recruitment, and sediment capture. Gully plugs are also designed to accomplish these goals. Series of alternating gully plugs have been used to effectively increase the distance that water in the gully bottom must travel, which has the effect of decreasing its slope and slope length. The plugs slow water velocity, facilitate water infiltration within the *bottom* of the gully, and therefore support vegetation survival and the capture of additional sediment. Conservative design and rest will enable many gullies to stabilize and revegetate. The design and construction of gully structures is critical, however: blow-outs of under-designed structures are likely to have consequences worse than the original gullying they were meant to address.

Historic gully control efforts offer another remediation tactic. The thousands of gully-control and sediment-capture structures constructed in the 1930s throughout the watershed by CCC workers were often constructed of local rock. Many have been damaged or failed during the decades since. Often, their design allowed them to be undermined by flood flows. In other cases, insufficient capacity remained in the channel to allow flows to pass over the structure, leading to erosion of the surrounding bank and eventual failure. However, examples of these structures that continue to perform their function are also visible throughout the watershed. Under the proper conditions, reconstruction of remnant structures provides another potential tool for gully or rill reclamation. Surviving structures provide a source of reference for the siting, design, and construction techniques that perform best over time.

Road construction and management

A well-planned and maintained road system is essential to reducing erosion and sedimentation in areas requiring vehicular or equipment access. Roads on national forest lands and other back country areas are managed to provide adequate access for timber and livestock management, fire suppression, wildlife habitat improvement, and a variety of dispersed and developed recreational activities. Often, these are low volume roads that must carry heavy loads for short periods of time. Particular potential for adverse impacts from roads exists in steep terrain, in areas with erodible or easily compacted soils, and

Culvert and road design enhance the wetland characteristics of a high-elevation meadow on the San Francisco River watershed, mitigating potential erosion downstream of the road crossing.

where roads approach or cross water courses (see Ward & Seiger, 1983). Roads are one of the most costly investments made by landowners and land managers, but poorly designed or constructed roads also represent a major conduit for water and soil loss. Good road design and construction results in lower maintenance and operating costs, safety, longer operating periods, and minimal impacts to water quality. Major water quality objectives in building, rehabilitating, or closing roads are to avoid creating erosive potential that eventually results in deteriorated road condition and high rates of sediment runoff, and to protect water courses from the potential compaction, vegetation removal, and sedimentation effects of roads.

Practices for constructing good roads or improving bad ones include:

- Avoid locating roads in riparian buffer zones except where there is no feasible alternative and access to a water crossing is crucial. Minimize the number of stream crossings. A road near any riparian buffer zone must be designed and located to minimize adverse effects on fish habitat and water quality; in-slope roads to provide drainage away from the stream channel. Cross streams at right angles to the stream channel. Avoid wetland areas.
- Properly orient, design, and maintain stream crossings
- Design bridge installations with a margin of safety proportional to the importance of the road and the protected resources. Culverts must be well-engineered and placed to minimize changes in natural stream beds during high water. Culverts or fish passages on perennial streams should be installed low enough to allow passage of aquatic life during low water.
- Provide drainage where surface and groundwater cause slope instability. Avoid diverting water from natural drainage ways.
- Locate roads to fit the topography and minimize alterations to the natural features.
- Avoid construction activities during wet periods to avoid soil compaction and disturbance.
- Disperse subsurface drainage from cut and fill slopes. Construct stable embankments, and further stabilize them during construction to reduce erosion and road deterioration.

Temporary sediment control practices, like properly installed silt fencing, provide protection during road or other construction and can allow time for designing long-term remediation strategies.

This may require mesh or other materials in addition to planting, seeding, or structural measures.

- Road grades should be kept at less than 10%, except where terrain requires short, steep grades.
- Divert flows around construction sites
- Reclaim unnecessary or temporary roads with ripping and seeding techniques. Use local, native seed materials; heavy equipment treads can be used to work seed into the road surface.
- Use seasonal closures to restrain use of unpaved roads during seasonal wet periods if possible.
- Provide culverts, dips, water bars, and cross drainages to minimize road bed erosion. Dips, water bars, and cross drainage culverts should be placed above stream crossings so that water can be filtered through vegetative buffers before entering streams.

Water bars should be located to take advantage of existing wing ditches and cross drainage, and constructed at an angle of 30 to 45 degrees to the road. Water bars should be periodically inspected and damage or breeches should be promptly corrected. Install water bars at recommended intervals. Recommended water bar spacing appears below, although water bars may need to be more closely spaced depending on soil type and rainfall.

Road Grade	**Distance Between Water Bars**
2%	250 ft.
5%	135 ft.
10%	80 ft.
15%	60 ft.
20%	45 ft.
25%	40 ft.
30%	35 ft.
40%	30 ft.

Off-road vehicle (ORV) trails create an additional network of roads. The GNF and numerous partners are currently engaged in a travel management planning process that will address all roads and ORV trails on the Forest. When the process is complete, travel will be allowed only on roads and trails officially designated as open, essentially reversing current policy. The criteria to be used in designating open, closed, or restricted roads and trails include resource protection and seasonal constraints.

Water harvesting

Enhancing the soil's capacity to store moisture below the surface is one of the best investments land managers can make. Any practice that functions to accomplish this goal can reduce surface erosion and rates of loss to evaporation, enhance base flow in springs and seeps, and facilitate vegetation survival and vigor. Most of these practices are surprisingly simple, low-cost measures that can be implemented with locally available materials. Each individual practice may be small in scale, but utilizing a number of these structures across the landscape can result in significant improvements in soil moisture storage and vegetation recruitment. Miniature catchments, formed by shallow depressions behind low mounds, provide good sites for herbaceous cover re-establishment. Rural roads often create special opportunities for water harvesting through the use of rolling dips, cross drains, and lead-out ditches. Constructed swales, and rock lines, felled trees, or straw wattles on hill slopes slow or capture runoff and create opportunities to use water that otherwise forms surface runoff and exacerbates erosive conditions.

Small mining site reclamation

Historic mining activities were widespread throughout the Gila watershed. Small mining operations were often abandoned; many remain unreclaimed and may contribute to water quality impairments. Numerous abandoned mining sites remain. Surface runoff through abandoned tailings or unstabilized heaps near mine adits can contribute to sedimentation and excessive concentrations of metals in surface waters. Depending on site conditions, reclamation of these smaller sites can incorporate a number of the methods described above for reducing erosion in stream channels, sediment filtration with vegetative buffers, temporary silt fencing, and stream channel remediation for channelized flow. Appropriate remediation techniques will be site-specific. Depending on the extent of the area affected by mining activities, re-introduction of herbaceous cover in conjunction with micro-catchments can be an effective means of stabilizing and capturing runoff. At some sites natural topography may lend itself to the creation of sediment detention basins to capture surface runoff. Many hydrophytic plants uptake and store contaminants and metals; the site's wetland reclamation potential can be evaluated as a means of both improving local hydrologic condition and decreasing contaminant runoff.

Using a rocker to extract gold in 1934 from tailings left at the abandoned Whitewater Creek mill site (courtesy USDA Forest Service).

Mulching

Applying a protective cover of plant residue or other suitable material helps to retard sheet, rill, and wind erosion, conserves soil moisture, lowers rates of evaporation from bare soils, and can help to control weed infestations. It is a useful technique for enhancing recovery of many disturbed areas, including construction sites and reclaimed areas. By reducing soil moisture loss, mulch tends to increase plant survival and vigor.

Mulch can be composed of small rock or pebble material, manufactured erosion cloth, or organic material. Use of organic mulches benefits soil by providing additional soil nutrients and provides a use for biomass products generated during wood thinning projects. Trees cleared locally (e.g., juniper or pinyon) can also be piled and used as soil protective cover, but the piles should be arranged to allow light and air to penetrate to avoid inhibiting herbaceous species growth. If erosion or other another manufactured mulching cloth will be used, investigate the potential effects of the various forms available. For instance, clear and infra-red transmissible (IRT) plastics have the greatest warming potential. Black fabrics are less effective at warming soils, since they transfer energy only by conduction, but they may provide the best weed control. In addition, organic mulch compounds can introduce unwanted seed sources; certified weed-free mulch is available.

Grazing management

Grazing management practices essentially help herbaceous cover and other forage plants to retain their vitality and diversity while being used as an ungulate food source. Successful management strategies take into account not only the direct effects of plant consumption, but others like trampling, soil compaction, and trail development that can lead to gullying effects. A vast literature on recommended grazing practices for our region—seasonal, rotational, high-intensity, short-duration, riparian or upland, and so forth—is available. Financial assistance for landowners seeking to rest heavily used areas or to restore soil health and native herbaceous cover to degraded lands, whether through vegetative or structural means, is offered through a number of different agencies. References are supplied in Resources, Section 7.

Instinctual ungulate foraging behavior is based on water availability and on expending the least effort for the maximum energy gain (see Treadaway, et al., 2006). Under typical conditions, livestock tend to utilize a higher percentage of riparian than upland vegetation. Riparian exclosure and water development practices are designed to disperse grazing concentrated in riparian areas by, respectively, controlling access or attracting animals to other areas. Riparian fencing exclosures can be costly and time-consuming to maintain, but in some cases may be the most effective means of accomplishing short duration or seasonal use. For water breaks, swing panels within the stream channel (constructed of pipe, heavy chain, wood slats, or corrugated metal) are more resistant to flood damage than standard fencing (Leonard et al., 1997). Water feeders, trick tanks and other rain harvesting devices, and solar-powered pumps are all means of providing water to livestock and wildlife away from streams or other riparian zones. For riparian and stream condition, water access control and other grazing management strategies will probably be only as successful as allowed by the conditions created by managers upstream. A coordinated approach that encompasses as much contiguous stream corridor and adjacent upland area as possible has the best chance of demonstrating measurable improvements in water quality, stream condition, and ecosystem productivity.

Running fence line on the watershed in 1953. Photo courtesy NRCS.

Woody species reductions

The most economically and ecologically sustainable practice for control of sediment runoff is rehabilitation and maintenance of native sod-producing cover, where productive conditions exist naturally or can be restored. Many of the treatment strategies outlined previously are aimed at this objective. Potential treatments should be weighed according to site specific conditions, because in places, extreme grades and shallow, rocky soils may preclude establishment of dense herbaceous cover. However, across much of the Gila watershed densities of upland woody species exceed those considered optimal under the conditions that should prevail within a healthy ecosystem (see Section 3). Overly dense stands of trees or woody shrubs are linked to a decline in native herbaceous cover. Successful use of MPs designed to reduce woody species cover and enable re-establishment of soil-building ground cover can reduce rates of surface water and sediment runoff and may enhance soil moisture infiltration.

Forest and brush treatments: thinning

Thinning treatments have two major objectives: rehabilitation of watershed and ecosystem function, and reductions in tree stand density to reduce the risk of high-intensity wildfire. Plans for thinning treatments are enhanced by partnerships with federal, state, and local agencies engaged in land management planning, or by incorporating them into community wildfire protection (Wildland-Urban Interface, or WUI) strategies.

These objectives are supported by the federal Community Forest Restoration Act and its Collaborative Forest Restoration programs in New Mexico. Local organizations and firms have significant experience in thinning work conducted under CFRP (see Section 7), with diverse goals that include improved functioning of forest ecosystems and enhanced biodiversity; reducing unnatural densities of small-diameter trees; improved communication and shared problem-solving; identifying economically viable strategies for the use of small diameter trees; supporting sustainable communities and forests; and developing, demonstrating, and evaluating ecologically sound forest restoration techniques.

Forest thinning projects can be controversial. In an effort to avoid delays in restoration work in New Mexico, a team representing a broad spectrum of management agencies, industry, science, and conservation groups identified what they called "a zone of agreement," and drafted them into a set of recommended restoration principles in 2006 (USDA Forest Service, 2006a).

Gila WoodNet Collaborative Forest Restoration project near Silver City.

Recommended practices include the use of low impact logging techniques to minimize sedimentation, disruption of surface runoff, and other detrimental ecosystem effects. For example, removing felled trees through “skidding” can result in extensive soil disturbance and compaction; equipment is available to remove trees without skidding. Equipment and techniques should be managed according to soil and water conservation “best management practices” applicable to site-specific soil types, physiography and hydrological functions. Prioritization for project areas includes fire risk and proximity to developed areas and important watersheds. Projects should strive for no net increase in road density. Reconstruction and maintenance of existing roads to correct for poor hydrologic alignment and drainage condition can greatly reduce soil loss and sedimentation rates.

Thinning treatments should consider the forest understory, including shrubs, grasses, forbs, snags, and down logs. The understory, including soil organisms like mycorrhizal fungi, is an important forest component that directly affects tree regeneration patterns, fire behavior, watershed functioning, wildlife habitat, and overall patterns of biodiversity. A healthy forest understory provides a restraint on tree regeneration and it is essential for carrying surface fires. The issue of re-seeding practices following thinning treatments is complex; generally, it seems best to allow native herbaceous vegetation to re-establish over time, unless there is potential for significant soil erosion or for occupation of the site by non-native invasive plants. Where efforts to increase herbaceous vegetation are needed, especially for road closures and recovery, locally sourced native seed or individual transplants from nearby areas into treatments are recommended. In addition, post-treatment planning should include early actions to protect the new community of herbaceous fine fuels from possible encroachment by aggressive woody or weedy species.

Forest and brush treatments: prescribed burns

The goals of prescribed burning treatments are the same as those for thinning treatments: improved watershed and ecosystem function, and reduced risk of high-intensity wildfire. In Wilderness areas on National Forests, prescribed or wildland fire use burns are often the only viable large-scale treatments possible. The following management practices, recommended for wildfire control and reclamation (USDA Forest Service, 2005b), also apply to prescribed burns. Fireline construction is essential, but a number of control practices can be implemented during construction to prevent unnecessary erosion. Fireline management practices should incorporate minimum impact strategies that meet land and resource management objectives. Firelines should follow the guidelines established for logging trails and skid trails with respect to waterbars and wing ditches.

Firelines should be stabilized and, if necessary, revegetated, and other erodible areas altered by suppression work should be repaired and revegetated as necessary (see below). Access road surfaces should be repaired and stabilized as necessary. Whenever possible, avoid using fire suppression chemicals over watercourses and prevent their runoff into watercourses. Do not clean application equipment in watercourses or locations that drain into watercourses. Provide advance planning and training for firefighters that considers water quality impacts when fighting wildfires.

Prescribed burn in the Burro Mountains.

Carefully plan burning to adhere to time of year, weather, topography, and fuel conditions that will help achieve the desired results and minimize impacts on water quality. With proper planning, prescribed fires should not cause excessive sedimentation due to the combined effect of removal of canopy species and the loss of soil-binding ability of subcanopy and herbaceous vegetation roots in streamside vegetation, small ephemeral drainages, or on very steep slopes. Intense prescribed fire for site preparation should be conducted only if it achieves desired results with minimum impacts to water quality.

Include rehabilitative practices as part of suppression and post-suppression tactics and strategies to mitigate non-point source pollution. First priority for revegetation should be given to banks of surface water bodies to enable re-establishment of riparian buffer zones. Beschta et al (2004) point out that the best recovery prescription following wildland fire is often to reduce pre-fire impacts (e.g., soil compaction, intensive grazing, road use) to a minimum until after initial site recovery. Avoiding soil compaction is particularly important: research links post-fire mechanical disturbance with accelerated rates of erosion (McIver & Starr, 2000; cited in Beschta et al., 2004). Post-treatment, it appears to be generally desirable to allow native herbaceous vegetation to recover incrementally, unless there is potential for serious soil erosion or establishment of non-native invasive plants (Beschta et al., 2004).

Re-seeding should use only native seed types; it is crucial to avoid introducing exotic weed species. If enhancement of herbaceous vegetation is needed, especially for road closures and recovery, using certified or weed free seeds to reduce the risk of contamination by non-native species or varieties is best.

Herbicide use

The purpose of an herbicide or pesticide application is to promote the establishment, survival, and growth of a desired species or condition by managing or eliminating undesirable species of vegetation, insects, or diseases. If herbicides or pesticides must be used to control exotic or woody species invasions, careful planning is an essential first step. Planning should go beyond removal of unwanted vegetation. It must include considerations for herbicide selection and use (see below) and an evaluation of the steps needed to promote the re-establishment of desired vegetation species. Recovery of desired vegetation may occur through natural recruitment, or it may require more active interventions such as soil improvements, reseeding, or follow-up methods to remove new incursions. Particularly in cases where historic or ongoing soil disturbance is a factor, simply removing the “problem” species will not necessarily result in improved site conditions. Even poorly adapted, invasive weed species may provide better soil protection than no vegetation at all.

Considerations in herbicide use.

When selecting an herbicide, evaluate the following:

- Effectiveness against the target species.
- Toxicity to birds and mammals, humans, aquatic species, and to other non-target
- organisms (including algae, fungi, and soil organisms).
- Application considerations and safety.
- Mechanisms of dissipation (persistence, degradation, and likelihood
- of movement via air or water to non-target organisms).
- Behavior in the environment (in soils, water, and vegetation).

Planning should allow for efficient application of the herbicide with minimal adverse impacts on the environment. Use herbicides that target the weed species, and are the least likely to drift or to persist (see below). At times, a single application that kills the weed species, even if of a more toxic or persistent chemical, may be preferable to a less persistent or toxic compound requiring repeated application. Consider accessibility, proximity to open water, depth to groundwater, sensitive species, and potential disturbance to the site during application.

Environmental contamination. Herbicidal contamination of the environment occurs when herbicides become volatilized during or after application, evaporate from soil and plant surfaces, leach through soils into groundwater, or become suspended in surface/subsurface runoff. Three main characteristics affect an herbicide's potential to contaminate surface or ground water. They are solubility, adsorption and breakdown (degradation) rate.

Solubility

Solubility is the ability of a compound to dissolve in water. The greater the solubility, the greater the chance that the chemical will leach to ground water. An herbicide's spread through the environment is probably most determined by its solubility: water-soluble herbicides are typically highly mobile (Tu, 2001).

Adsorption

Adsorption is the inherent ability of a chemical compound to bind with soil. Some stick very tightly to soil while others are easily dislodged. Herbicides may be immobilized by adsorption to soil particles or uptake by non-susceptible plants. These processes isolate the herbicide and prevent it from moving in the environment, but both adsorption and uptake are reversible, and adsorption can slow or prevent the permanent breakdown of an herbicide. Adsorption typically increases as soil organic matter and clay content increase, and decreases with increasing pH and temperature.

Rate of breakdown or degradation

Breakdown rate is the time a chemical compound takes to decompose to smaller component compounds, and eventually to inert components through photochemical, chemical, or biological processes. Half-life is specifically the time it takes for half of the compound to dissipate. An herbicide's half-life is substantially influenced by soil characteristics, weather (especially temperature and soil moisture), and local vegetation. It does provide a means of comparing the relative persistence of herbicides, however. Pesticides that do not break down quickly can be hazardous when they move into groundwater or surface water. Sunlight can decompose some chemical compounds. Microbes present in soils also serve as agents of decomposition; optimum soil conditions for chemical degradation include warmth, moisture, and high organic content. Chemical breakdown occurs during hydrolyzation (typically a reaction with the hydrogen in water), oxidation, or disassociation—the loss of some other chemical group from the herbicide's molecules(Tu et al.,2001).

Protecting water quality must be an important consideration in all aspects of herbicidal treatment planning. In a given situation, herbicides with the highest water solubilities, greatest persistence, lowest affinities for adsorption to organic matter and other soil components, and highest application rates have the greatest potential for movement in surface water or into groundwater. To prevent contamination of water bodies, management plans must carefully consider the hydrology of the system that is being treated, including potential leaching into shallow aquifer systems. Evaluate potential paths for runoff and take appropriate measures (such as buffer zones) to block them. Consider minimizing potential herbicide movement by selecting a non-broadcast application technique for the same herbicide to reduce the amount of the chemical applied directly to the soil. Total rainfall during the first few days after application mostly determines the amount of leaching and/or runoff that occurs; one of the simplest measures to avoid environmental contamination by herbicides is checking the weather forecast and avoiding application during times when rainfall is most likely (e.g., monsoons).

Education and outreach

The effectiveness of every implementation practice is amplified when it is used as a tool to engage public support and participation in efforts to protect and improve watershed health. Whenever possible, planning for management implementation should include strategies to engage volunteers in project workshops and monitoring efforts. Broadcasting the results of project implementation is often most effectively accomplished through workshops and site tours, where interested landowners and land managers can see on-the-ground results and apply the lessons learned in previous efforts to their own planning. Watershed groups, agencies, and landowners involved in the planning and implementation of improvement projects play an active role in generating public support and participation. Local SWCDs, watershed groups, and agencies like NRCS and the Black Range Resource Conservation & Development office can assist with these outreach efforts. Many of these organizations conduct monthly or quarterly meetings which themselves provide good learning opportunities for others seeking information on improvement strategies, partnerships, or participation in ongoing work.

Local landowners provide among the best outdoor "classrooms" available for area residents. USFS, NRCS, NMED, NM State Forestry, and SWCDs are among the agencies that can assist in project implementation and provide support for tours of project sites.

U. S. Geological Survey staff teach Silver City students how to measure streamflow at one of many learning stations during the annual Children's Water Festival.

Local schools and organizations are dedicated to educating children on the economic and ecological services provided by watersheds. Regional high school students participate in remediation and monitoring work, and an annual and highly popular children's water festival is hosted and staffed by regional school districts, NMED SWQB, and a number of local groups and agencies. Approximately 500 area fourth and fifth grade students learn elements of river ecology, chemistry, biology, and stream physical characteristics through professional indoor and outdoor classroom instruction every year.

The *WIPS* and its corollary GIS offer additional support for educational and outreach opportunities. It is disseminated to the broadest possible audience of watershed stakeholders, and can be used to locate and build potential partnerships, find project resources and suggestions, and to reference project results that may benefit future remediation work. The stages involved include:

- Initial *WIPS* (*WRAS*) development and dissemination
- Input and revision
- Liaison work with agencies, organizations, private landowners
- Documentation of priority sites, technical and financial support, initial project/proposal development
- Support for regional public educational events
- Continued data collection, documentation, technical and liaison support
- *WIPS* and GIS updated and disseminated

MONITORING AND EVALUATION

Monitoring to evaluate the effectiveness of MPs begins the adaptation process. It emphasizes the importance of making adjustments to the design. A monitoring plan should determine goals, acceptable or unacceptable results, and potential contingencies for addressing unacceptable results. Documented results provide invaluable information for land managers engaged in other planning efforts. On many projects, monitoring offers a “win-win” solution for simultaneously meeting match requirements and providing proof of work results.

A monitoring and assessment plan should be part of all subwatershed and project planning. Ideally, plans will include maps showing monitoring and assessment sites in order to clearly demonstrate their relevance for evaluating project results. However, finding the means to design and carry through a good monitoring program is not always easy. GWP will offer any support possible to landowners and other stakeholders to help expand monitoring programs on the watershed, including 1) technical assistance for developing monitoring procedures, such as templates for data collection; 2) links to relevant data sources or research; 3) on-the-ground identification of existing SWQB monitoring sites for relevant water quality data; 4) assistance in obtaining technical support or funding to establish additional water quality monitoring/sampling sites; and 5) dissemination of data, results, and project documentation provided by willing participants. The long-range goals in establishing these assessment and monitoring programs are:

- Targeting areas where the greatest reductions in sediment and other pollutant contributions can be achieved through implementation of MPs
- Tracking trends in reducing sediment loads, decreasing stream temperatures, and improving general hydrologic function—including soil moisture and alluvial water storage

Data gathered to evaluate the effectiveness of MPs can include both *qualitative* and *quantitative* measures. Qualitative monitoring is based on observation; quantitative monitoring on numeric measurement of selected indicators. We encourage quantitative monitoring where possible, but the most important consideration for a good monitoring program is that the information collected is directly related to determining whether or not progress is being made toward the objectives established for the implemented practice(s). When models are used to evaluate project results, they should be relevant, credible, and usable (EPA, 2005). Suggested monitoring strategies and models include:

- Seek and/or collect existing data on baseline conditions
- Establishing monitoring sites and collecting additional baseline data
- Inventories and maps of significant features: e.g., riparian density, gullies and other high-priority erosive areas, evidence of in-stream vehicular use; exclosures; water sources
- Photo documentation from established photo points
- Collection of climate data, especially local precipitation
- Measurements of stream channel geometry
- Monitoring surface water–groundwater relationships
- Vegetative cover measurements

- Water quality and habitat measures (NMED Water Protection Section protocols)
- Sediment runoff/erosion measurements, including slope, and models

Suggested monitoring tools and practices are outlined below. Detailed descriptions of the procedures and equipment required are available elsewhere, and we have included only a limited number of them here. Contact the information coordinator, or see Resources (Section 7), for links to detailed protocol descriptions, sources of additional information, technical support, and other monitoring tools.

IDENTIFYING EXISTING DATA SOURCES

Although many sources for data relevant to developing watershed plans and monitoring strategies are available, locating them can be surprisingly difficult at times. Geographically-referenced data collected during ongoing *WIPS* development will become available through the NMED SWQB website as the GIS component is completed, or at any time through either of the contact addresses on the cover. Much of this information was compiled and made available by the GNF or other agencies.

Data currently available through GWP that may be useful for planning, proposal development, or evaluation of project results include:

- Watershed delineations (for stakeholder-defined subwatersheds of any scale)
- Identified TMDL reaches and subwatersheds
- Topographic quadrangles (1:24000 and 1:100000 scale)
- Aerial photography
- Digital elevation models
- Land ownership/management
- Soils (Terrestrial ecosystem survey data for Gila N.F. and other soils data as available)
- Roads/trails (Gila/Apache N.F.s)
- Fire history (Gila N.F.)
- Vegetation class (Gila N.F.)
- Water sources (tanks; springs; wells)
- Stream channels
- Weather station sites and records
- Water quality sampling sites and sampling results
- Streamflow data collection sites (USGS) and records
- Known remediation project sites and available project details
- Project monitoring sites and available monitoring results
- Land cover
- Ecoregions
- Political/management boundaries

Federal, state, and local agencies can provide a wide variety of other information. In addition, an enormous literature base of research exists on relevant topics, most of it peer-reviewed. See Resources in Section 7; the information coordinator can assist in locating these and other data sources.

ESTABLISHING MONITORING SITES AND BASELINE CONDITIONS

Selecting the best site(s) for monitoring work obviously depends on the hoped-for goals of the management practices selected. Other issues to be considered include accessibility and the site's suitability for representing conditions within the watershed or some portion of it. If data have previously been collected at a suitable site, re-locating that site offers the opportunity for extending the period of time over which data have been collected and for comparing current results with earlier ones.

When establishing a site, plan to enable someone 50 years from now to re-locate it. Identify its geographic location—by GPS or topographic map—preferably to within about 10 feet (about 1/10th second for latitude/longitude). It is important to record the reference system (graticule, UTM, State Plane, etc.) and datum in which the coordinates are being reported. Monumenting the site, if possible, with a labeled T-post or other system can be helpful. Use photographs with dates and descriptions as additional documentation. Photographs that show identifiable topographic features like ridgelines, in addition to nearby detail, are the most useful over the long term.

Collecting baseline data before implementing any management measures is a crucial step. Not only will this establish conditions at the start of work, it helps in identifying initially unresolved issues in monitoring protocols (in what units are measurements obtained? how many samples will be collected? does the time of day when monitoring is conducted matter?). Thoroughly document, in the greatest detail bearable, the data collection forms to be used and each step of the monitoring or sampling procedure. One of the most useful educational tools available is training others on data collection techniques—and, as a bonus, using volunteer assistance for monitoring can also help to meet in-kind match requirements. Documenting procedures and forms helps to ensure quality control in data collected by different people or groups.

NMED staff conducting water quality monitoring and sample collection on the Gila River near Virden, November 2005.

If an established USGS or NMED SWQB water quality sampling station is within the subwatershed, data collected by these agencies should be used in evaluating the results of implemented practices on water quality. The locations of established SWQB sampling sites are shown on Maps 4, 5, and 6. SWQB utilizes a rotating basin system approach to water quality monitoring. In this system, a select number of watersheds are intensively monitored each year, with an established return frequency of seven to eight years; supplementary data are also collected. See the Water Quality monitoring section below for information on establishing project-oriented monitoring procedures.

INVENTORIES AND MAPS

Creating an inventory and mapping potential sources of water quality impairments in relation to significant topographic, vegetative, and other features can be a key step in developing both an implementation plan and a suitable monitoring strategy. For example, where poor road condition is a potential contributor to stream sedimentation, documenting and mapping sites where improved culvert design, water bar installation, or improved drainage are likely to reduce road runoff will help in estimating project costs and selecting good locations for monitoring the effects of improvements on water quality. Mapped relationships among potential impacts are often easier to discern than written descriptions alone. Even a careful sketch map of the project area is an aid in deciphering field notes, planning remediation work, and interpreting data collected during monitoring. Drawing sketch maps also forces people to become better observers. Plan maps should include identification of monitoring or assessment sites. When funding or other assistance for improvement projects is needed, maps are invaluable for portraying project details to proposal reviewers, or for describing how the proposed MP will enhance previous work. In combination, maps and inventories provide the basis for a permanent record of implementation sites, monitoring locations, and project results.

PHOTO DOCUMENTATION AND PRECIPITATION DATA

Photo documentation is a useful tool for indicating qualitative trends, although it provides no quantitative data. (For example, changes in vegetative biomass cannot be calculated from photographic data alone.)

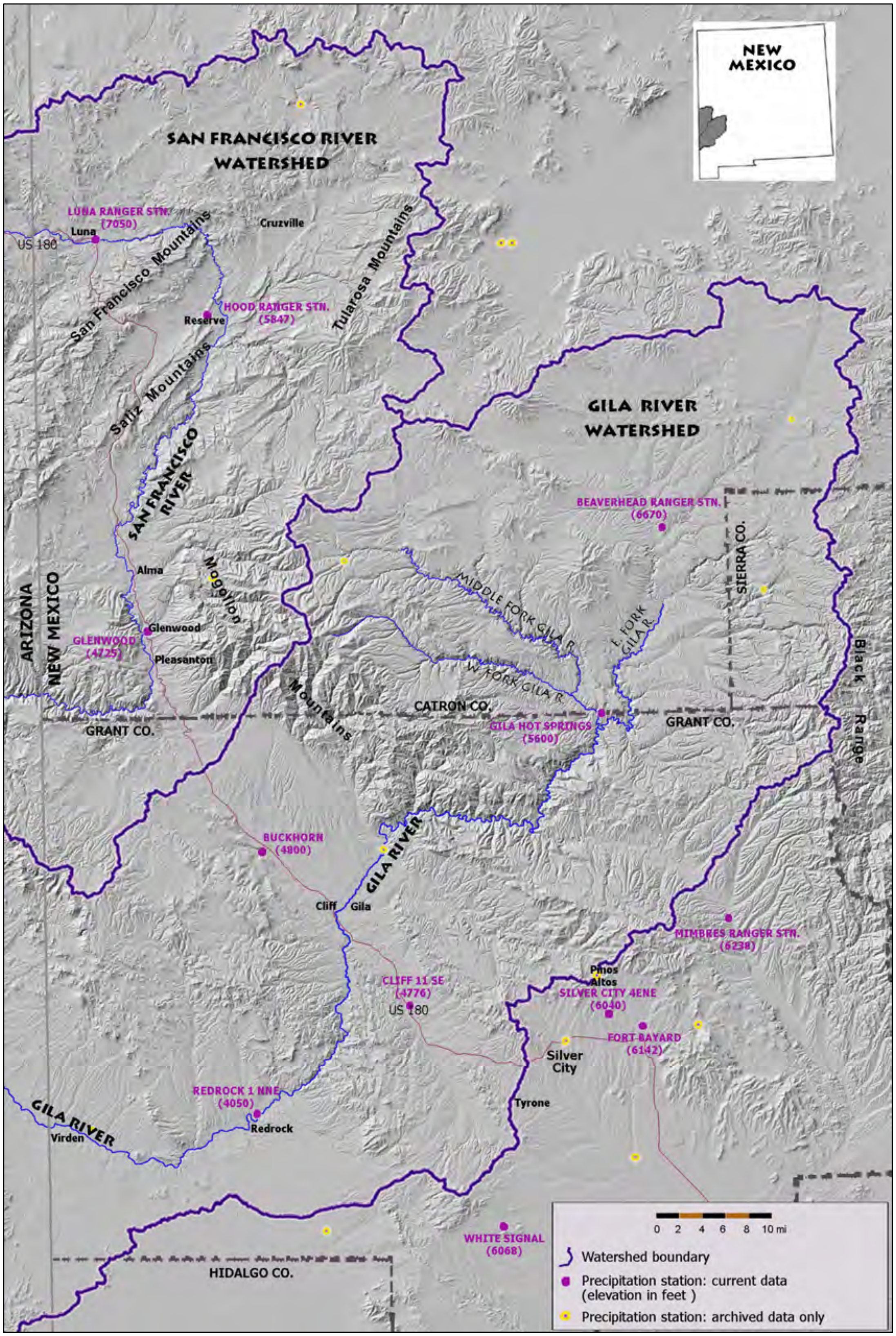
Suggested photo monitoring protocols:

- Monument photo points with firmly driven rebar. Slide a 5-ft section of PVC pipe over the rebar to ensure a constant camera elevation whenever photos are taken.
- Leave a 1-ft section of PVC over the rebar for safety and easier re-location between photo sessions.
- A dry-erase board can be used to record date, time, photo point identification, and photographer. Include the board in each photograph.
- Carry previous photos on each site visit to ensure good replication of the field of view.
- For riparian and stream channel photos, establish a monumented channel cross-section and take photos from left to right, right to left, and upstream and downstream from the center of the channel.

Since resulting conditions at a site may appear radically different after a year of drought than after a year of average or extreme precipitation, it is particularly important to collect local climate data (especially rainfall) when photo documentation is the primary means of monitoring project results. Given the region's highly variable and localized rainfall patterns, data collected from an on-site recording rain gage are preferred; these systems can be purchased for less than $200. They provide the best means of ensuring accurate precipitation data, and allow comparison of current rainfall with long-term trends at established weather stations. Table 8 provides a sample listing of established weather stations; their locations are shown on the following page. Note that only archived data are available from some stations, and the resolution of the data available (hourly or daily, for instance) varies. See Section 7 for more information.

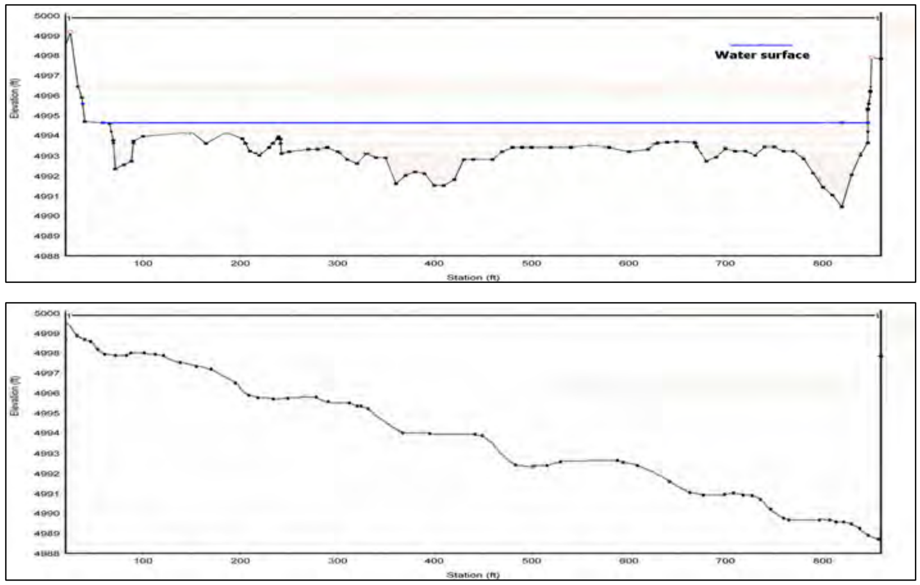
Table 8. Selected weather stations on and near the Gila watershed that provide current or historic (archived) precipitation data in digital format, per Western Regional Climate Center records. (See Map 7, next page.) WRCC lists no stations on the watershed in Hidalgo County. dd = decimal degrees.

Station number	Station name	Current/ Archive	Elevation (ft)	Latitude (dd)	Longitude (dd)
		Catron County			
290119	ADOBE RANCH	A	7418	33.5667	107.9
290818	BEAVERHEAD R S	C	6670	33.4333	108.1
293577	GLENWOOD	C	4725	33.3167	108.883
293969	HICKMAN	A	7894	34.5	108
294101 (297386)	HOOD (RESERVE) RANGER STN	C	5847	33.7167	108.783
294375	JEWETT WORK CENTER	A	7405	33.9833	108.633
295273	LUNA RS	C	7050	33.8167	108.95
295800	MOGOLLON	A	6804	33.3833	108.783
299760	WILLOW CREEK RANGER STN.	A	8107	33.4	108.583
299830	Y-RANCH	A	6926	33.8	108.317
299882	YORK RANCH	A	6804	33.8	108.333
		Grant County			
291252	BUCKHORN	C	4800	33.0333	108.717
291910	CLIFF 11 SE	C	4776	32.8333	108.5
293265	FORT BAYARD	C	6142	32.8	108.15
293528	GILA 6 NNE	A	4652	33.0333	108.533
293530	GILA HOT SPRINGS	C	5600	33.2	108.2
295754	MIMBRES RANGER STN	C	6238	32.9333	108.017
296854	PINOS ALTOS	A	7005	32.8667	108.217
297340	REDROCK 1 NNE	C	4050	32.7	108.733
298324	SILVER CITY	A	5920	32.7833	108.267
298325	SILVER CITY 4ENE	C	6040	32.8167	108.2
298819	THOMPSON CNYN RANCH	A	5200	32.55	108.633
299508	VIRDEN	A	3783	32.6833	108.983
299691	WHITE SIGNAL	C	6068	32.55	108.367
		Sierra County			
295532	MC CAULEY RANCH	A	6975	33.35	107.95



Map 7. Selected weather stations on the Gila watershed (see Table 8 above). Labeled stations are active; current precipitation data are available from these sites in digital format (see Resources, Section 7).

STREAM CHANNEL GEOMETRY

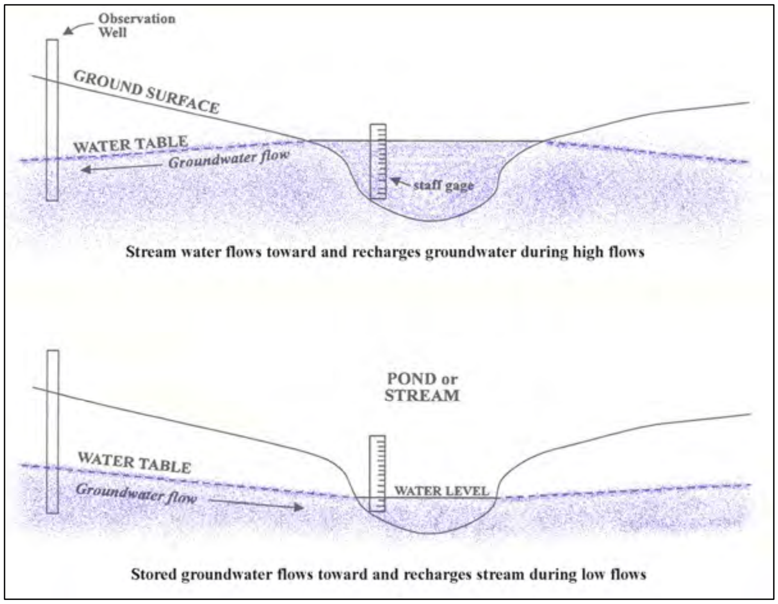


Top, a stream channel cross-section, measured by tape and laser level. Bottom, stream bottom profile measured by tape and rod.

Monitoring changes in stream channel geometry (in plan form, bottom profile, or cross-section) provides a graphical, quantifiable, and repeatable means of assessing the effects of remediation work and natural changes. It can be especially useful in monitoring post-installation response (stream barbs, weirs, or other channel structures), results from re-vegetation or bio-engineering strategies, or gully remediation work. The data collected can also be used for hydraulic or hydrologic modeling work, or in analyzing changes in alluvial water storage (see below). Channel geometry measurements can be obtained with very simple tools—a measuring tape, line level, and measuring rod—or by more sophisticated methods requiring the use of a surveyor's level, laser level, or even detailed mapping by total station. The technique used will depend on the desired outcome of the selected MP(s), on the available budget, and on the experience and training of the people who will be available to perform monitoring over the longer term. Regardless of the method used, cross-sections or the beginning and ending points of plan or profile surveys should be monumented to enable re-locating them for repeat surveys. Geographically referencing and mapping their locations (typically by GPS) provides a means for assessing changes in the stream channel relative to significant local factors like topography, changes in land use, or other remediation practices.

SURFACE WATER–GROUNDWATER RELATIONSHIPS

The primary or secondary aim of a variety of MPs is increasing the water storage capacity of streambanks and floodplains. Water stored in these alluvial materials during high flow events and from precipitation is later released, during drier periods, as base flow. Establishing baseline data and recording changes in groundwater elevations relative to surface streamflow after MP implementation provides much-needed information on the effects of these remediation practices. A simple and practical method for quantifying the relationship between groundwater elevations and surface flows



Generalized interactions between surface flows and groundwater in alluvial storage (adapted from The Nature Conservancy, 1996).

uses piezometers or observation wells and simple t-post gages. A piezometer or well is a simple device constructed of a screened well point attached to PVC or galvanized pipe. The well point and pipe are driven deeply enough into the floodplain to penetrate the alluvial water table, preferably to a depth 5 or 6 feet below the top of the water table. Groundwater enters through the well screen and rises within the pipe to match the surrounding water table elevation. In floodplains composed of sand or gravel, manual installation using a post pounder or augur is relatively simple. Coarser materials like cobble may require well-drilling machinery for installation. Typically, a minimum of two piezometers are used, one on either side of the stream channel. Piezometers can be constructed for less than $200. By driving a T-post into the streambed and surveying piezometers and T-post to a common reference elevation, the relationship between surface water and groundwater elevations is known. Simple measurements can be made using a standard measuring tape—and making these measurements are a great educational opportunity for students and volunteers. Electronic dataloggers are also available for continual data collection, although they are expensive: about $600. Properly installed piezometers are amazingly resistant to flood damage. Collecting data at regular intervals over a substantial period of time allows long-term relationships between streamflow, groundwater responses, and the results of management strategies to be correctly interpreted.

VEGETATION MEASUREMENTS

Selecting a suitable method for monitoring vegetation response to treatment depends on the treatment and its goals. There is an extensive variety of reference material and protocols available, to say the least, and links to a selection of those materials are provided in Section 7. Two examples are given below: vegetation monitoring for ponderosa forest cover, and the line-point intercept method for herbaceous and other cover.

Ponderosa forest cover

In 2003, USFS Region 3 and five partners produced a series of monitoring manuals for forest restoration projects in Ponderosa-type forests (USDA Forest Service, 2003). Among their objectives was to create "a framework and guidelines for multiparty monitoring and assessment...that will provide useful information at the project level and facilitate regional interpretation." The manuals include monitoring guidelines for a broad spectrum of indicators, from economic impacts to ecosystem effects. The sample indicators below, adapted from Chapter 1, are recommended for evaluating the results of thinning treatments relative to their potential for reducing risk from large-scale, high-intensity wildfire.

Sample Goal	Indicators to Monitor
Reduce risk of high-intensity fire	Canopy closure Tree stem density/area Ground-to-tree cover height Surface fuels cover/depth Canopy closure/break distribution

A suggested data collection form (see Appendix IV of the manuals) follows. Refer to the monitoring manuals for details and more information; links to them and other strategies for forest monitoring are in Section 7.

Sample Ecological Monitoring Data Sheet

Adult Tree and Sapling Density
and
Adult Tree Size and Basal Area

Site Name:__________________________ Date:_____________________

Observer:___________________________GPS Location:______________

Transect #:__________________________Elevation:__________________

Adult Trees							Saplings	
Plot #	Slope	Aspect	Tree #	Species	Tree Diameter (in.)	Tree Basal Area (in.)	Species	Sapling Tally Marks

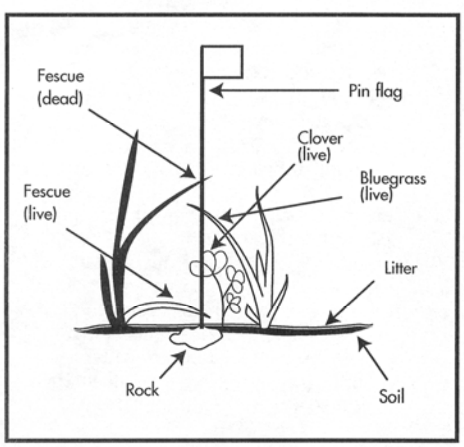
Herbaceous cover

The line-point intercept method is a generalized vegetative monitoring tool, typically used with "clip plots" that enable measurements of vegetation density in weight per area. Line-point intercept monitoring measures both canopy and basal cover, based on three assumptions: 1) that although increases in canopy cover are associated with increased resistance to degradation, 2) basal cover, being less sensitive to variations in precipitation and use, is the more reliable indicator, and 3) that an increase in bare ground area nearly always indicates an increased risk of runoff and soil erosion. The two figures below illustrate the general concepts and use of the method; all are taken from Herrick et al., 2005. (A somewhat different technique, the Daubenmire method, is described in the section on surface and sediment runoff below.)

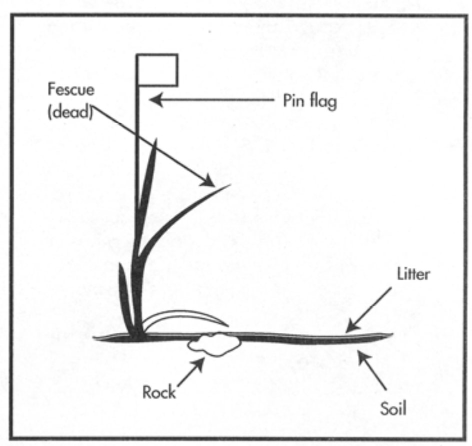
Table 2. Sample data form for examples illustrated below. Points 1 and 2 show the first two points on a line. In Point 1, the pin flag is touching dead fescue, live bluegrass, clover, live fescue, litter and a rock. Record fescue only once, even though it intercepts the pin twice. In Point 2, the flag touches fescue, then touches litter and finally the fescue plant base. Table 2 shows how to record these two points on the data form.

		Lower canopy layers			
Pt.	Top canopy	Code 1	Code 2	Code 3	Soil surface
1	Fescue	Bluegrass	Clover	L	R
2	Fescue	L			Fescue
3	Fescue	L			S
etc.					

Figure 8. Area defined as plant base and included as basal cover.



Point 1



Point 2

The "points" in the method are evenly spaced along a tape (the "line") stretched between pre-determined endpoints. "Intercepts" are determined by lowering a pin flag or thin metal rod perpendicular to the ground surface from each point on the line.

Line-point intercept indicator calculations

Canopy cover (as calculated here) does not include bare spaces within a plant's canopy.

1. Percent canopy (foliar) cover

Rules

1.1 Count the total number of canopy intercepts in the "Top canopy" column and record this number in the blank provided.

1.2 Canopy intercepts include all points where a plant is recorded in the "Top canopy" column. Do not include points that have a "NONE" in the "Top canopy" column.

1.3 Multiply the number of canopy intercepts (from 1.1) by 2* and record your "% canopy cover" in the blank provided.

2. Percent bare ground

Rules

2.1 Count the total number of points along the line that have bare ground and record this number in the blank provided.

2.2 Bare ground occurs **only** when:

A. There are no canopy intercepts (NONE is recorded in the "Top canopy" column).

B. There are no litter intercepts ("Lower canopy layers" columns are empty).

C. The pin only intercepts bare soil ("S" recorded in the "Soil surface" column).

2.3 Multiply the number of bare ground hits (from 2.1) by 2* and record your "% bare ground" in the blank provided.

3. Percent basal cover

Rules

3.1 Count the total number of plant basal intercepts in the "Soil surface" column and record this number in the blank provided.

3.2 Plant basal intercepts occur anytime the pin intercepts a live or dead plant base (Species code recorded in "Soil surface" column).

3.3 Multiply the number of basal intercepts (from 3.1) by 2* and record your "% basal cover" in the blank provided.

*For 50 points per line. Multiply by 1 for 100 points per line. Multiply by 4 for 25 points per line.

Summary of calculations for monitoring changes in vegetative cover using the line-point intercept method.

WATER QUALITY MONITORING

NMED's SWQB Water Protection Section is responsible for the sampling and monitoring work that supports the state's water quality protection program (see Section 5). GWP is working to expand programs to monitor water quality and identify potential impairments on the Gila watershed by locating funds to support travel and training for voluntary monitoring efforts. Groups like the San Francisco SWCD, supervised by NMED staff, already provide volunteer assistance for water quality monitoring. Training and QAPP (Quality Assurance Project Plan) development is provided by NMED for these efforts. The eventual goals in developing a comprehensive voluntary monitoring program are three-fold: 1) to more thoroughly document impairment sources on the watershed as a means of obtaining assistance for landowners and land mangers interested in developing and implementing subwatershed improvement plans; 2) to ensure standardized, timely sampling and measurement for all surface waters of interest; 3) to educate interested residents on water quality and other watershed issues.

Project-specific monitoring work is also strongly supported. When watershed remediation projects affect a stream reach where NMED has an established monitoring site (see Maps 4,5, and 6), WPS data can be used in subwatershed planning to identify contaminants and establish baseline levels of water quality impairments. Follow-up data collected by the agency also provide one source of feedback on the results of management practice implementation. However, NMED's statewide monitoring responsibilities limit the frequency at which data can be collected at any given site.

Realistically assessing the effects of implementation on resulting condition therefore requires project-specific monitoring. Pre- and post-implementation monitoring can be included in §319 project costs. (Planners should consult the *Quality Assurance Project Plan for Water Quality Management Programs* (NMED, 2005a) or the Silver City SWQB office to coordinate scheduled monitoring work with their own assessments.) Other funding sources may cover these costs as well, or data collection efforts may be used to meet in-kind match requirements.

Volunteers learn water quality sampling and measurement methods during a training session hosted by NMED in August 2005.

Project-specific monitoring may incorporate any of the methods described elsewhere in this section in addition to specific water quality measurements. Water-quality monitoring plans should be developed with assistance from NMED WPS staff to assure compliance with the agency's protocols. Standard measurements include streamflow, dissolved oxygen, pH, conductance, temperature, stream bottom sediments (embeddedness), and riparian cover/habitat. The agency also has standardized methods for macroinvertebrate and aquatic vegetation assessments.

SURFACE AND SEDIMENT RUNOFF MEASUREMENTS AND MODELS

Although obtaining sediment runoff estimates can be complex, we strongly encourage practitioners to include this strategy in their monitoring plans. Reductions in sediment runoff are likely to signal a number of ecosystem improvements, and to have the greatest positive effect on nonpoint source pollution levels. Numerous methods and models to estimate surface runoff and overland sediment transport exist. Modeling techniques, however, are subject to large uncertainty because of the variability of conditions within even small watersheds. And as watershed size increases, so does the unreliability of results. Monitoring should therefore be designed to work in conjunction with modeling to help calibrate results, and the results obtained should be considered a means of assessing and quantifying *trends*, rather than absolute runoff values.

General methods for monitoring soil cover and erosion

Taken together, the five techniques described here provide a good overall method for monitoring response to vegetation treatments.

- photo plot
- Daubenmire method
- infiltration test
- bulk density test
- erosion bridge

Photo Plot

This method relies on close-up photos to show specific characteristics of an area, such as soil surface or the amount of ground surface covered by vegetation and organic litter. Close-up photos are taken periodically from permanently located photo points.

Equipment:

- 35mm or digital camera
- Hammer
- Two 72” folding tape measure
- Felt tip pin
- Photo identification label
- Fluorescent or brightly colored spray paint
- Four pieces of angle iron or rebar

Procedure:

- Using the 72” folding tape measure and 4 pieces of angle iron, form a 3 x 3 ft. square area. Paint the stakes a bright color to help in locating them during subsequent picture taking.
- Place a filled out photo identification label on the ground next to the photo plot.
- Stand on the north side of the plot about six to eight feet back from the center. Be sure the label is visible in the camera view finder before taking the picture(s).
- Mark the location of the photo plot on a map along with an arrow showing the direction in which the photo was taken.

Daubenmire Method

An alternative canopy-coverage method of vegetational analysis that can be used for gathering frequency and cover data in grassland vegetation.

Equipment:

- Hammer
- Fluorescent or brightly colored spray paint
- Two pieces of angle iron
- 100’ measuring tape
- 20cm x 50cm quadrant frame (PVC)
- Daubenmire forms

Procedure:

- Align a 100’ tape in a straight line by stretching it between two stakes
- Permanently mark the stakes with flagging or brightly colored paint.
- As the quadrant frame is placed along the tape at specified intervals, estimate the percentage of ground and canopy cover. Ground cover is generally described as bare soil, litter, basal area (shrub/tree or grass/forb), gravel, cobble, stone, and boulder. Canopy cover is also expressed as a percentage for shrub/tree or grass/forb.

Bulk Density Test

Soil bulk density is the weight of soil for a given volume. It is used to measure compaction. In general, the greater the density, the less pore space for water movement, root growth and penetration, and seedling germination.

Equipment**:**

- Hand sledge
- 3" diameter ring
- Wood block
- Garden trowel
- Flat-bladed knife
- Sealable bags and marker pen
- Scale (0.1g precision)
- 1/8 cup measuring scoop
- Paper cups
- Access to a microwave oven

Procedure:

- Using the hand sledge and block of wood, drive the 3” diameter ring to a depth of 3” into the soil. Take 4 measurements evenly spaced of the height from the soil surface to the top of the ring and calculate the average.
- Dig around the ring and with the trowel underneath it, carefully lift it out to prevent any loss of soil. Remove the excess soil from the sample with a flat-bladed knife. The bottom of the sample should be flat and even with the edges of the ring.
- Using the flat-bladed knife, push out the sample into a plastic sealable bag. Make sure the entire sample is placed in the plastic back. Seal and label the bag.
- Weigh and record the soil sample in its bag. Weigh an empty plastic bag to account for the weight of the bag.
- Mix the sample thoroughly in the bag by kneading it with your fingers. Take a 1/8-cup level scoop subsample of loose soil from the plastic bag and place it in a paper cup.

- Weigh and record the soil subsample in its paper cup. Weigh an empty paper cup to account for its weight.
- Place the paper cup containing the subsample in a microwave and dry for 4 minute cycles at full power. Repeat this step at least twice to insure the subsample is dry. Weigh and record the dry weight of the subsample.

Infiltration Test

Infiltration rate is a measure of how fast water enters the soil. Water entering too slowly may lead to ponding on level fields or to erosion from surface runoff on sloping fields.

Equipment**:**

- 6” diameter ring
- Plastic wrap
- 500mL plastic bottle
- Distilled water
- Stopwatch or timer

Procedure:

- Using the hand sledge and block of wood, drive the 6” diameter ring to a depth of 3”. Use your fingers to gently firm the soil surface only around the inside edges of the ring to prevent extra seepage.
- Line the soil surface inside the ring with a sheet of plastic wrap to completely cover the soil and ring.
- Fill the 500mL water bottle with distilled water and pour into the ring lined with plastic wrap.
- Remove the plastic wrap by gently pulling it out, leaving the water in the ring. Start the stopwatch and record the amount of time it takes for the volume of water to infiltrate the soil.

Erosion Bridge

An erosion bridge can be used to monitor sheet, rill and gully erosion. The bridge is designed to measure changes occurring over time to the soil surface and can be used as a means of calibrating results obtained from the Hillslope Erosion Model described below.

Equipment**:**

- 48” aluminum or wood masonry level machined to provide 10 to 20 vertical measuring holes, a slot on one end and a hole on the other for support
- Two steel support rods, each 5/8” in diameter, 2 to 4 feet long
- Sledge hammer
- Metal measuring rod, 3/16” in diameter, 2 to 4 feet long
- Measuring tape (metric or inches in tenths)
- Clipboard and appropriate forms

Procedure:

- The smaller diameter vertically aligned holes are equally spaced and drilled through both the top and bottom plates of the level. The larger end hole(s) and/or slot should only go through the bottom plate.
- At the selected site, one of the support rods is pounded vertically into the soil. The rod should be plumbed to insure proper placement and inserted at least 2’ into the ground. The 2nd rod is driven into

the ground using the same method and the distance between the two rods is determined by the distance between the two end holes in the level. Make necessary adjustments to the rods to insure that the level is level when placed upon the two support rods.

- The measuring rod is gently lowered through the vertically aligned holes on the bridge until contact is made with the soil.
- Obtain a measurement of the measuring rod by placing the measuring tape on top of the level and adjacent to the rod. The length from the bridge to the top of the rod is measured and recorded.

Models for estimating sediment runoff/erosion

We strongly urge land managers and other practitioners to collect data for estimates of sediment runoff. Two modeling examples are shown here, the Hillslope Erosion Model (HEM) and the Revised Universal Soil Loss Equations (RUSLE2). Both are appropriate to Gila watershed conditions, and provide a means of helping to validate the erosion and water quality improvement effects of management practices, particularly those aimed at improvements in upland condition. They generate estimates of sediment transported off-site by local rainfall. By monumenting your data collection site and periodically collecting these data after rainfall events, changes in vegetation cover and soil loss to erosion after treatment (thinning, burning, re-seeding, grazing changes, etc.) can be roughly quantified and evaluated. It is important to collect a baseline data set prior to starting the initial treatment.

Example Hillslope Model Input Values

Segment number	Cumulative Segment Length (m) from top of profile	Segment Slope (%) positive values	Canopy Cover (%)	Ground Cover (%)
1	5	2	10	25
2	10	6	25	50
3	25	3	60	75
4	50	1	60	75

Runoff Volume (mm) 10

Relative Soil Erodibility 2

Hillslope Erosion Model (HEM)

Use and application of the Hillslope Erosion Model is relatively straightforward. The HEM is an "event-based" model, and its best results will be obtained by collecting data after each significant rainfall event. We include a complete description of the HEM here as supporting material for the model. To help ensure consistency in data collection protocols and modeling results, please contact the SWQB office in Silver City or the Watershed Information Coordinator at the contact information on the front cover for assistance. The (free) model software can be found at

http://eisnr.tucson.ars.ag.gov/HillslopeErosionModel/

and it can be run from the website. An overview of the information needed to run the HEM is provided by one of the input screens, shown above, that users will find on the website. The most difficult aspect of the software for new users is the required runoff input. An explanation of this value and a link to a runoff estimating model follow.

Estimating runoff volume

Runoff is the total volume of water that flows over a particular area of the landscape. It can be determined from actual field measurements, or estimated by using models designed for the purpose. Runoff will be the total amount of precipitation received during a particular rainfall event, less the amounts that 1) evaporate; 2) infiltrate the ground surface; or 3) are taken up by vegetation. As used in the HEM, it is the surface water yield per unit area of the hillslope, expressed as an equivalent depth of water in mm or inches, per unit area represented by the entire hillslope profile. The instrumentation needed to obtain actual measurements of runoff is extensive, and estimating runoff with the use of modeling software is recommended instead. A generalized and relatively easy-to-use model is the TR-55 model developed by NRCS. Users can find and download the (free) software at

http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-wintr55.html

where NRCS also provides an extensive description of the model and instructions on its use. We recommend that users visit the website, review the documentation, and download the TR-55 software as the first step in collecting information needed to use the HEM.

The steps outlined below describe the process of collecting the remaining data needed for HEM use.

HEM field data collection for hillslope profiles (segments) and vegetation cover

Hillslope profiles are transects that follow the apparent flow path of water down a hillslope. Each profile is subdivided into a number of segments based on topographic slope breaks or natural barriers causing a change in flow direction or speed. The data collected along transects are the inputs to the HEM.

Equipment:

- 100m measuring tape
- Thin sampling rod
- Clinometer or laser level for representative hillslope profiles OR surveying equipment for precise measurement of hillslope profiles
- GPS unit
- Pin flags (plastic flagging on 50 cm steel rods i.e., standard flagging material)
- Camera/film or digital camera/diskettes
- Compass (optional for GIS layouts)
- 12” rebar and hammer (optional for permanently marking the transect)
- Rain gage (automatic recording type, if possible)

Procedures

1. Identify the hillslope profile to be used for erosion prediction.
   - Locate the top of the hill (called the base) or other obvious topographic break.
   - Hillslope profiles follow the path of overland flow.

- Identify the apparent water flow path down the hillslope to a natural barrier or change in flow path (an obvious change in slope or direction).
  - For permanent transects, mark the top and bottom of the profile with rebar.

2. Lay out the profile and hillslope segments.
   - Anchor a 100m measuring tape at the top of the profile (large screwdriver works well).
     - Photograph towards the bottom of the hillslope profile, record photo number.
     - Record GPS reading for latitude/longitude, UTM, elevation, and datum.
   - Determine each segment for the vegetation survey.
     - Walk downhill *along the apparent flow path* to the next change in vegetation community, vegetation density, soil type, or break in slope steepness.
     - There should be at least 3 segments per profile.
   - Stretch tape measure tautly along the segment and mark the segment with a red flag.
   - Determine length of survey increment for vegetation readings.
     - Read segment length from the tape and divide into a minimum of 20 increments i.e., for a 5m segment, divide by 20 to get twenty 0.25m increments → therefore take readings at every 0.25m for that segment.
   - Record the following for each segment on the data collection form:
     - Profile number
     - Segment number
     - Segment length (from 100m tape on the ground or by surveying)
     - Steepness percent (from surveying instrument or clinometer if only representative or sample estimates are needed)
     - Compass bearing (for GIS layouts only)
     - Survey increment in meters

3. Read the vegetation and ground cover data.
   - Leave tape measure in place, take vegetative canopy cover and surface ground cover data at each increment, and record on Vegetation Survey Data form.
   - At each increment, read and record the first vegetative life-form encountered by the rod as it is lowered perpendicular to the ground. If a tree or bush overhangs the rod, it is recorded as the vegetative cover for that point.
   - Vegetative cover is classified as grass, shrub, forb, tree, cactus, half-shrub, etc., or may be recorded simply as presence or absence of vegetative cover.
   - Ground cover is read and recorded as anything lying on the ground surface where the rod first touches the ground. Ground cover may be soil, litter, rock, gravel, cryptogram or plant basal area, or may be recorded as the presence or absence of ground cover (bare soil).
   - Repeat the readings for the entire length of the segment.

4. Read each segment until the bottom of the hill, gully, road, stream channel or other natural break is encountered. This is the end point of the profile.
   - Photograph uphill along the flags or towards the base point, record photo number.
   - Record GPS reading for latitude/longitude, UTM elevation, and datum.

5. Note the soil texture(s) along the profile. You will be asked to select among soil textures ranging from sand to clay when entering data into the HEM.

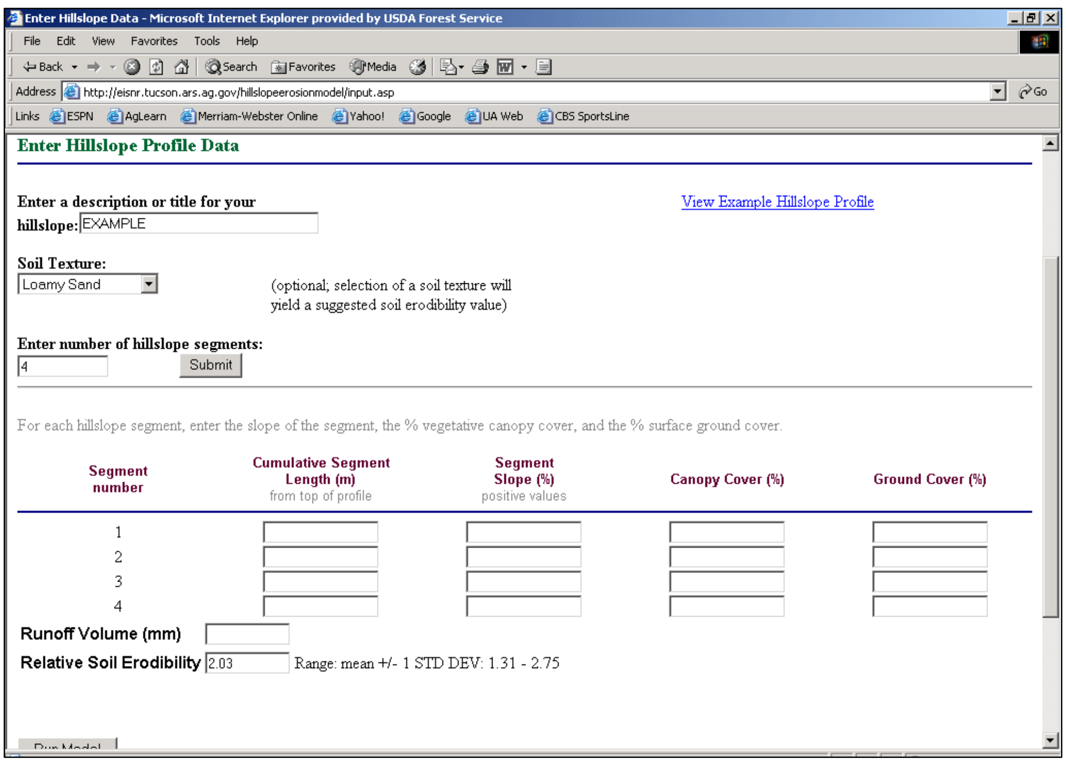
Input data reduction and entry to HEM

The model can be found at the website http://eisnr.tucson.ars.ag.gov/HillslopeErosionModel/

Vegetative and Ground Cover Data Reduction

- Calculate the percent vegetative cover and the percent ground cover for each segment.
  - For percent vegetative cover, divide all vegetative cover hits (presence of cover) by the number of increments in the segment.
  - For percent soil (bare ground), divide number of soil hits by the number of increments in the segment. For percent ground cover divide the number of hits that are not soil by the number of increments.

The data entry screen for the HEM.



Data entry

- Enter the first segment's length in meters. The lengths entered for following segments will be cumulative (i.e., if the first segment is 8 m long and the second segment is 10 m long, enter 18 m as the second segment length.
- Enter each segment's slope in percent, based on clinometer or other readings.
- Enter canopy and ground cover percentages for each segment based on the reduction calculations above.
- Select the profile's average soil texture based on field notes and the following table; the model will automatically enter the corresponding soil erodibility value.

Suggested soil erodibility values for soil texture classes

Soil Texture	Suggested Erodibility Value	Range
Sand	-	-
Loamy Sand	2.03	1.31 – 2.75
Sandy Loam	2.31	0.33 – 4.29
Loam	1.84	0.03 – 3.65
Silt Loam	1.74	1.18 – 2.30
Silt	2.26	-
Sandy clay loam	0.56	0.23 – 0.89
Clay loam	1.38	-
Silty clay loam	1.86	-
Sandy clay	-	-
Silty clay	3.34	0.92 – 5.76
Clay	1.41	0.23 – 2.59

Model results

The following definitions may be helpful in understanding results from the HEM, although its greatest value is enabling users to compare erosive soil losses from the treatment site over time in relation to practice implementation and local climate.

Concentration: The amount of material in a given amount of water by weight. As used in the HEM, sediment concentration is kilograms (Kg) of sediment per cubic meter of water. Expressed as a percentage, this is Kg of sediment per Kg of water times 100 (note that this is equivalent to pounds of sediment per pounds of water times 100).

Sediment yield: The total amount of eroded material that passes a downstream point. Sediment yield can be expressed as a total mass of sediment moving past a certain point (Kg) or as a mass per unit area (Kg/m2, Kg/ha, etc.).

Revised Universal Soil Loss Equations (RUSLE2)

To use RUSLE2, another free software model, users must download the software from this site:

http://www.ars.usda.gov/Research/docs.htm?docid=6010

One of RUSLE's advantages is that the only data that users are required to collect at the treatment site are terrain slope values; remaining data are built into the software on the basis of the site location and description. However, this means that users also need to download the appropriate data tables provided on the RUSLE site; instructions are provided. By dial-up, the download takes about 45 minutes. The information below is adapted from the website and provides an overview of the software, its use, data requirements, and results generated by the model.

Factors Affecting Erosion

The four major factors of climate, soil, topography, and land use determine rates of rill and interrill erosion. The user applies RUSLE2 to a specific site by selecting information from the RUSLE2 database to describe field conditions at the site for these four factors. RUSLE2 uses this field description to compute erosion estimates. However, RUSLE2 is "land use independent." It takes advantage of the fact that erosion rates are the result of the interaction between the forces applied to the soil by erosive agents and the soil's resisting forces, regardless of land use. Results from the model are therefore applicable for cropland, rangeland, disturbed forestland, mined land, construction sites, reclaimed land, landfills, parks, or any other land where mineral soil is exposed to the direct forces of waterdrop impact and surface runoff. The model is based on equations that describe how the rates of rill and interrill erosion are affected by basic features like plant yield, vegetative canopy and rooting patterns, surface roughness, mechanical soil disturbance, amount of biomass on and in the upper soil layers, and related factors.

Overview of Major Factors

Climate: The most important climatic variable used by RUSLE2 is rainfall erosivity, which is related to rainfall amount (how much it rains) and intensity (how hard it rains). Another important climatic variable is temperature because temperature and precipitation together determine the longevity of biological materials like crop residue and mulch applied to control erosion. Climate varies by location, and choosing a location in RUSLE2 chooses the erosivity, precipitation, and temperature values needed to apply RUSLE2 at a particular site.

Soils: Soils vary in their inherent erodibility as measured in a standard test involving a "unit plot." A unit plot is 72.6 ft (22.1 m) long on a 9% slope and is maintained in continuous tilled fallow (no vegetation) using periodic tillage up and down slope to leave a "seedbed-like" soil condition. The USDA-NRCS has assigned soil erodibility values for most cropland and similar soils across the U.S. RUSLE2 includes a procedure for estimating soil erodibility for highly disturbed soils at construction sites and reclaimed mined land. The RUSLE2 user typically selects a soil by soil-map unit name from a list of soils in the RUSLE2 database.

Topography: Slope length, steepness, and shape are the topographic characteristics that most affect rill and interrill erosion. Site-specific values are entered for these variables.

Land Use: Land use is the single most important factor affecting rill and interrill erosion because type of land use and land use condition are features that can be most easily changed to reduce excessive erosion. RUSLE2 uses the combination of cover-management (cultural) practices and support practices to describe land use.

Cover-management practices affect both the forces applied to the soil by erosive agents and the susceptibility of the soil to detachment. For a given land use like cropland, important features include the crops that are grown, yield level, and the type of tillage system such as clean, reduced, or no till. Important features on a construction site include whether or not the land is bare, the soil material is a cut or fill, mulch has been applied, or the slope has been recently reseeded. Important features on range and reclaimed land include native or seeded vegetation, production level, and degree of ecological maturity. The description of any cover-management practice is created, named, and stored in the RUSLE2 database. When RUSLE2 is run, the cover-management practice that fits the site-specific field condition is selected from the menu of choices. Changes can be made in key variables such as production (yield) level or mulch application rate so that the practice fits the local climate, soil, and other conditions.

Support practices include ridging (e.g., contouring), vegetative strips and barriers (e.g., buffer strips, strip cropping, fabric fence, gravel bags), runoff interceptors (e.g., terraces, diversions), and small impoundments (e.g., sediment basins, impoundment terraces). These practices reduce erosion primarily by reducing the velocity of surface runoff, causing sediment deposition. Support practices are selected from a list of these practices in the RUSLE2 database. Site-specific information, such as the location of a diversion on the hillslope, is entered as required for each practice.

Running RUSLE2

RUSLE2 is very easy to use. With the exception of topography, the RUSLE2 user describes the site-specific field conditions by selecting database entries from menus. When a menu selection is made, RUSLE2 “pulls” values stored in the RUSLE2 database and uses them as input values to compute erosion. The user enters site-specific values for slope length and steepness to represent topography. (The field techniques described above for the HEM can be used to obtain these measurements.)

RUSLE2 results/output

RUSLE2 estimates rates of rill and interrill soil erosion caused by rainfall and its associated overland flow or runoff. Detachment (separation of soil particles from the soil mass) by surface runoff erodes small channels or rills across the hillslope. Erosion that occurs in these channels is called rill erosion. Erosion on the areas between the rills, “interrill” areas, is called interrill erosion. Detachment on interrill areas is by the impact of raindrops and waterdrops falling from vegetation. The detached particles (sediment) produced on interrill areas is transported laterally by thin flow into the rills, where they are transported downslope to concentrated flow areas, or channels.

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SECTION 7

Resources

Links to the resources provided in this section are intended to promote stakeholder understanding of and involvement in state-led efforts to improve and protect water quality, and to support local implementation of management and monitoring strategies that will assist those efforts.

Technical and financial assistance for watershed improvement planning and implementation are provided by an array of local, state, and federal agencies and organizations, and data and monitoring support are available through GWP. Contact GWP through either of these addresses:

David Menzie, NMED SWQB
3082 32nd Street By-Pass Road – Suite D, Silver City, NM 88061
(575) 956-1548
David.Menzie@state.nm.us

Matthew Schultz, NMED SWQB
3082 32nd Street By-Pass Road – Suite D, Silver City, NM 88061
(575) 956-1550
Matthew.Schultz@state.nm.us

Most resources are provided as links to agency or organization websites (current as of June 2009). Many of the specific links included will also be found by navigating from the agency or organization's main website, but having spent more than a few hours ourselves exploring the vastness of cyberspace, we have also included direct links to as many pertinent resources as possible (e.g., NRCS datasets, which occupy a subset of the main NRCS page). For users without computer or internet access, please contact GWP at either address above, or refer to the list of watershed agencies, organizations, and groups for other contact information. This set of resources is by no means comprehensive but is intended to provide ideas and support—particularly for those wanting to know more about the health of their streams, or who may be new to watershed planning efforts.

WATER QUALITY INFORMATION RESOURCES:

NMED SWQB NONPOINT SOURCE PROGRAMS, DESIGNATED USES, IDENTIFIED WATER QUALITY IMPAIRMENTS, AND TMDL DEVELOPMENT

NONPOINT SOURCE POLLUTION

The State of New Mexico publishes a number of documents that explain its responsibilities and activities in tracking and reducing NPS pollution on the state's watersheds:

The New Mexico *Statewide Water Quality Management Plan*

http://www.nmenv.state.nm.us/swqb/Planning/Water_Quality_Management_Plan/index.html

- Summarizes CWA development, the state's water quality management system—including monitoring, data assessment, and reporting strategies—and the roles of major participants
- Describes TMDL development steps and provides links to TMDL documents for all impaired stream segments
- Summarizes effluent (point source), municipal, and industrial discharge limitations, in addition to the state's role in reviewing dredge-and-fill applications
- Details methods and event schedules for public input into water quality designations, evaluation, and protection

The state's *Nonpoint Source Management Program* (1999):

http://www.nmenv.state.nm.us/swqb/NPS_Management_Plan-1999.pdf

- Addresses surface water and groundwater NPS issues
- Identifies specific agencies and their strategies for managing nonpoint source pollution
- Describes WRAS development process and partnership efforts among SWQB, watershed groups, and land management agencies
- Defines impairment level designations, NPS categories, and MPs

DESIGNATED USES AND OTHER PROVISIONS OF WATER QUALITY STANDARDS

For complete information related to surface water quality standards for New Mexico, also known as ***Standards for Interstate and Intrastate Surface Waters,*** including their Triennial Review Process, please visit:

http://www.nmenv.state.nm.us/swqb/Standards.

Current updates to the *Standards* (as of August 2007) are available online at:

- http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.htm; or
- http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf.

  - The WQS is a reference for the most detailed information on the state's water quality programs; it provides definitions of all terminology used by the state in determinations and descriptions of water quality, impairments, and management strategies
  - Antidegradation policy and Outstanding National Resource Waters (ONRW) designation
  - Impairment criteria, sampling and analysis procedures
  - Designated use descriptions by stream segment, including designations for waters considered to be ephemeral, intermittent, or perennial. (Basin and stream segment designations in the *Standards* correspond to "WQS reference" designations in the §303(d)/§305(b) *Integrated Report.*)

Proposed revisions to the current *WQS* are underway as the focus of the 2009-2010 Triennial Review process. Hearings are currently scheduled to begin in December 2009. For more information concerning this upcoming review, please visit:

http://www.nmenv.state.nm.us/SWQB/Standards.

IDENTIFIED WATER QUALITY IMPAIRMENTS ON THE GILA WATERSHED

The most detailed information related to water quality impairments found on the Gila watershed appears in two documents published by the state:

New Mexico's 2008–2010 *Integrated Clean Water Act §303(d)/ §305(b) Report*:

http://www.nmenv.state.nm.us/swqb/303d-305b/2008-2010

- Information on the state's surface waters by basin, including physiographic characteristics, known impairments, and known remediation measures (Chapter 2).
- Information on the state's approach to and responsibilities for managing surface and groundwater quality (Chapters 3–5).
- For each stream segment, a list detailing designated uses, watershed area, future monitoring schedule, and current impairment category. For stream segments with identified impairments, a list of the impairment(s) and the probable causes as evaluated by SWQB (Appendix B).

The §*303(d)/* §*305(b) Report* is scheduled to be updated in late 2010.

The ***Record of Decision*** is the state's historical record of reasonings for stream reach listings, de-listings, and the sampling results that are used to develop the bi-annual §*303(d)/* §*305(b) Report*. The current version is the ***Record of Decision (ROD) for the 2008–2010 State of New Mexico Integrated List for Assessed Surface Waters***:

http://www.nmenv.state.nm.us/swqb/303d-305b/2008-2010/documents/303dROD.pdf

- Definitions of major terminology used in water quality and designated use determinations and summary explanations of parameters measured for determinations of surface water quality
- Stream segments are grouped by HUC, with summaries of bi-annual actions relating to each segment. The summaries include descriptions of results from intensive sampling and rationales for listing and de-listing decisions. See the example below from the 2004 ROD for Diamond Creek:

TMDL DEVELOPMENT

NMED SWQB's process for developing TMDLs, including public input, quantification of pollutant loads, and amendments to the *Water Quality Management Plan* are summarized at:

http://www.nmenv.state.nm.us/SWQB/TMDL/steps.html

A link to the TMDL developed for each listed reach on the Gila watershed appears on the TMDL table in Section 5 for that reach. For a list and links to TMDLs statewide, see:

Diamond Ck (East Fork Gila R to headwaters)
WQS: unclassified AU: NM-2503_43

Previously listed for temperature and total phosphorous. Values for both parameters are limited to one sample. Because of this limited data set the listing will be changed to Full Support, Impacts Observed based on 1/1 ratios at the stations.

1998 ACTION: The reach was removed from the 303(d) list and will be listed as Full Support, Impacts Observed on the 305(b) list.

2000 ACTION: None.

2002 ACTION: None. According to SWQB staff comments, this reach goes dry. Therefore, the only designated uses that apply are livestock watering and wildlife habitat.

2004 ACTION: None.

http://www.nmenv.state.nm.us/SWQB/TMDL/list.html

A statewide quality assurance plan (QAPP) governs and documents the sampling and data collection procedures followed by NMED SWQB's Monitoring and Assessment Section (MAS) for water quality assessments. The currently available version is the ***Quality Assurance Project Plan for Water Quality Management Programs:***

http://www.nmenv.state.nm.us/swqb/QAPP/index.html

- Responsibilities of SWQB's MAS for sampling plan development, data collection, and TMDL development
  - Monitoring/Assessment Section (MAS) integration with Water Protection Section (WPS)

- Quality control procedures and scheduling for sampling and data collection during intensive surveys of streams, lakes, reservoirs, playas
- Development of load limits for impaired reaches
- Relationship with USGS long-term water quality monitoring system

A series of assessment protocols documents SWQB's procedures for accepting, evaluating, and analyzing water quality and other data. The overview of these protocols can be found in the ***State of New Mexico Procedures for Assessing Standards Attainment for the Integrated 303(d)/ 305(b) Water Quality Monitoring and Assessment Report: Assessment Protocol*** (2008). Links to this document and the individual protocols can be found at:

http://www.nmenv.state.nm.us/swqb/Protocols/index.html

WATERSHED PLANNING AND PARTNERING RESOURCES

GENERAL WATERSHED PLANNING RESOURCES

EPA watershed planning tools	http://www.epa.gov/owow/nps/watershed_handbook/
EPA strategic plan for Region 6	http://www.epa.gov/region6/stratplan/
Gila National Forest	http://fs.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_RU4?ss=110306&navtype=forestBean&navid=091000000000000&pnavid=null&cid=null&ttype=main&pname=Gila%20National%20Forest%20-%20Home
Schedules of proposed actions	http://www.fs.fed.us/sopa/components/reports/sopa-110306-current.pdf
Links to all New Mexico *Watershed Restoration Action Strategies*	http://www.nmenv.state.nm.us/swqb/WPS/index.html
New Mexico's comprehensive *Forest and Watershed Health Plan*	http://www.emnrd.state.nm.us/FD/FWHPlan/FWHPlanMain.htm
Background research/reference:	
New Mexico Water Resources Research Institute (WRRI)	http://wrri.nmsu.edu/
Sustainability of Semi-Arid Hydrology and Riparian Areas (University of Arizona)	http://www.sahra.arizona.edu/
Treesearch (USDA Forest Service; links to Rocky Mountain Research Stations)	http://www.treesearch.fs.fed.us/

MAPPING RESOURCES

USGS geographic/geospatial data	http://edcsns17.cr.usgs.gov/EarthExplorer/
"Status map" of USGS data availability	http://statgraph.cr.usgs.gov/viewer.htm
National Geodetic Survey tools: data transformation, coordinate or projections conversion	http://www.ngs.noaa.gov/TOOLS/
To locate the name of a 7.5-min quad sheet	http://geonames.usgs.gov/domestic/index.html
Bureau of Land Management geographic/geospatial data (Geocommunicator)	http://www.geocommunicator.gov/GeoComm/index.shtm
US Forest Service Geodata Clearinghouse	http://svinetfc4.fs.fed.us/
NRCS geographic/geospatial data	http://datagateway.nrcs.usda.gov/
New Mexico geospatial data (note: "edge-matching" problems may be associated with some data from this site)	http://rgis.unm.edu/
USGS hydrographic data	http://gos2.geodata.gov/wps/portal/gos
Subwatershed delineations	
1) The NRCS watershed boundary dataset	http://www.ncgc.nrcs.usda.gov/products/datasets/watershed/
2) The National Hydrography Dataset	http://nhd.usgs.gov/
3) Elevation Derivatives for National Applications (currently, the most accurate)	http://edna.usgs.gov/

Many organizations and offices can assist in partnering and collaboration efforts; some offer funding for these efforts. This list provides only a small sample.

GENERAL PARTNERING RESOURCES

NMED SWQB's *Annual Reports*: descriptions of watershed projects and partners on the Gila and throughout the state. Both current and past issues are archived.	http://www.nmenv.state.nm.us/swqb/WPS/index.html
Statewide list (as of 1998) of watershed groups/contacts, compiled by NMED SWQB	ftp://ftp.nmenv.state.nm.us/www/swqb/WPS/ WatershedGroups.pdf
Amigos Bravos Resources page	http://www.amigosbravos.org/resources.php
Community-Based Collaborative Research Consortium	http://www.cbcrc.org/
Greater Flagstaff Forests Partnership	http://www.gffp.org/
National Forest Foundation (the nonprofit partner of USFS)	http://www.natlforests.org/
New Mexico Riparian Council links page	http://www.npariancouncil.org/
The Partnership Resource Center (collaboration with USFS)	http://www.partnershipresourcecenter.org/policy/index.php
Red Lodge Clearinghouse	http://rlch.org
The Society of American Foresters *Handbook for Preparing a Community Wildfire Plan* includes partnership suggestions useful for watershed-based planning	http://www.safnet.org/lp/cwpphandbook.pdf
Western Collaboration Assistance Network (collaboration coaching, mentoring, and "specialized technical assistance").	http://www.westcanhelp.org

LOCAL/REGIONAL PARTNERING AND TECHNICAL RESOURCES

There is a broad collection of agencies, organizations, and individuals on the Gila watershed whose work, directly or indirectly, affects watershed condition. The following pages provide contact and other information on federal and state agencies and local organizations to assist in planning and partnership efforts. Descriptions are taken from material published by each organization. See pp. 27–30 for more information on the federal and state agencies listed.

AGENCIES: FEDERAL

Agency and description	Phone	Website(s)
US Army Corps of Engineers (ACOE) Responsible for Section 404 permitting of dredging and discharge (or fill) work affecting surface waters.	(505)342-3283 (Albuquerque)	http://www.spa.usace.army.mil/reg/default.asp http://www.usace.army.mil (national)
USDA Farm Service Agency Farm Bill updates, conservation programs, drought programs, fact sheets	(505) 761-4900	http://www.fsa.usda.gov/FSA (national; links to state and county offices)
USDA Forest Service – Gila National Forest **Ranger Districts**: Black Range RD (T or C) Glenwood RD (Glenwood) Quemado RD (Quemado) Reserve RD (Reserve) Silver City RD (Supervisor's Office) Wilderness RD (Mimbres)	 (505) 894-6677 (505) 539-2481 (505) 773-4678 (505) 533-6232 (505) 388-8201 (505) 536-2250	http://fs.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_RU4?ss=110306&navtype=forestBean&navid=091000000000000&pnavid=null&cid=null&ttype=main&pname=Gila%20National%20Forest%20-%20Home (main site; links to Ranger District sites and all programs)

USDA Natural Resource Conservation Service (NRCS) Technical information, consultation, and financial assistance to farmers and ranchers. ▪ Silver City (Grant and San Francisco SWCDs) ▪ Lordsburg (Hidalgo SWCD) ▪ T or C (Sierra SWCD) Los Lunas Plant Materials Center Develops, tests and transfers native plants that can help solve conservation problems.	(505)388-1569 (505)542-9141 (505)894-2212 (505) 865-4684	http://www.nrcs.usda.gov (national) http://www.nm.nrcs.usda.gov (New Mexico) http://www.nm.nrcs.usda.gov/programs http://www.nm.nrcs.usda.gov/programs/pmc.html
Black Range RC&D (division of NRCS) A nonprofit organization serving Grant, Catron, Luna and Hidalgo counties. Locally elected volunteers plan and carry out projects for resource conservation and community development. NRCS provides technical and financial assistance and additional funding comes through developed projects.	(505)388-9566 x 5 (Silver City)	http://www.nm.nrcs.usda.gov/programs/rcd/blkrange.html http://www.rcdnet.org (national)
US EPA (Region 6) Responsible for coordinating CWA programs, including §319, through NMED SWQB	(800)887-6063 (Dallas)	http://epa.gov/region6/index.htm
US Fish & Wildlife Service (Region 2) Manages Partners for Wildlife, Safe Harbor, and other recovery/funding programs	(505)346-2525 (Albuquerque)	http://www.fws.gov/southwest/es/NewMexico/PFW_home.cfm (Ecological Services, Albuquerque) http://www.fws.gov/southwest (Region 2)
US Geological Survey Streamflow and irrigation diversion records; other data resources	(505) 830-7900 (Albuquerque)	http://waterdata.usgs.gov/nm/nwis/sw http://nm.water.usgs.gov
USDI Bureau of Reclamation (BOR)		http://www.usbr.gov/lc (Lower Colorado region)

AGENCIES: STATE/COUNTY/LOCAL

Agency and description	**Phone**	**Website(s)**
New Mexico Association of Counties		http://www.nmcounties.org
County governments/commissions		
Catron	(505)533-6423	https://mylocalgov.com/catroncountynm
Grant	(505)574-0021	http://www.grantcountynm.com
Hidalgo	(505)542-9428	http://www.hidalgocounty.org
Sierra	(505)894-5961	https://mylocalgov.com/sierracountynm
Local: communities of Alma, Apache Creek, Cliff, Gila, Glenwood, Luna, Pines Altos, Pleasanton, Red Rock, Reserve, Riverside, Virden		http://newmexico.hometownlocator.com/nm/catron
Town of Silver City	(505)538-3731	http://www.townofsilvercity.org
New Mexico Department of Agriculture Agriculture producer-consumer service and regulatory department, providing technical and administrative resources and planning assistance to SWCDs and the agricultural industry. Responsible for market expansion for New Mexico products, including livestock and processed foods.	(505)646-3007 (Las Cruces)	http://nmdaweb.nmsu.edu
New Mexico Department of Game and Fish –Santa Fe Wildlife management, including the Comprehensive Wildlife Conservation Strategy, Habitat Stamp and Sikes Fund program; funds used for habitat conservation and rehabilitation projects.	(505)476-8000	http://www.wildlife.state.nm.us
Las Cruces office	(505)532-2100	

New Mexico Energy, Minerals, and Natural Resources Department (EMNRD) Main (Santa Fe) State Forestry Division (NMSF) is responsible for wildfire suppression on all non-federal/non-municipal lands. NMSF provides technical advice on forest and resource management to private landowners.	 (505)476-3200 (505)476-3325 (Santa Fe) (505)662-1785	http://www.emnrd.state.nm.us/MAIN/Index.htm (EMNRD main) http://www.emnrd.state.nm.us/FD/index.htm (State Forestry)
NM Environment Department-Surface Water Quality Bureau Santa Fe (see Water Quality Resources section) Wetlands Office SWQB WPS, Silver City	 (505)827-0187 (505)827-0581 (505)388-0599	 http://www.nmenv.state.nm.us/swqb (main) http://www.nmenv.state.nm.us/swqb/Wetlands
New Mexico Department of Transportation Environmental Design Bureau	(505) 827-5100 (505)827-5223	http://nmshtd.state.nm.us (statewide) http://www.nmshtd.state.nm.us/main.asp?secid=14482
New Mexico Soil & Water Conservation Districts (SWCD) SWCDs provide local assistance to establish watershed management associations, develop watershed action plans, and provide water stewardship education to private landowners. National New Mexico Watershed SWCDs (with selected project information): Grant (§319 Mangas Creek/Burros rehabilitation) Hidalgo San Francisco (Long-Term Planning; Whitewater Creek improvement; NRCS Conservation Partnership Initiative) Sierra (§319 WRAS and project development, Taylor Creek)	 (202)547-6223 (505)981-2400 (505)388-1569 (505)542-9141 (505)539-2473 (505)894-2212	 http://www.nacdnet.org http://www.nacdnet.org/about/districts/directory/nm.phtml http://www.gilanet.com/sfswcd http://www.sierrasoil.org
New Mexico State Land Office (SLO) SLO is responsible for managing state trust lands and the derived mineral and lease royalties.	(505)827-5760	http://www.nmstatelands.org

Office of the State Engineer/Interstate Stream Commission The Office of the State Engineer is charged with administering the state's water resources. The State Engineer has power over the supervision, measurement, appropriation, and distribution of all surface and groundwater in New Mexico, including streams and rivers that cross state boundaries. The State Engineer is also Secretary of the Interstate Stream Commission.	(505)827-6120	http://www.ose.state.nm.us
Arizona Water Settlement Act and Gila-San Francisco Coordinating Committee		http://www.ose.state.nm.us/isc_colorado_gila_san fran_committee.html

NONPROFIT ORGANIZATIONS / SCHOOLS

Projects listed are local or watershed-specific and are provided for cross-reference; they are not necessarily comprehensive. To add an organization or additional information to this listing, contact the information coordinator, David Menzie: (575) 956-1548, David.Menzie@state.nm.us.

Organization, description, project work	Phone	Website(s) and/or location
Catron County Citizen's Group	(505) 539-2745	Glenwood, Reserve
Cattlegrowers' Association Beef/dairy cattle producers support	(505) 247-0584	www.nmagriculture.org (state) www.rcdnet.org (national)
Center for Biological Diversity (CBD) Protection of endangered species and habitats; CFRP	(520) 623-5252	www.biologicaldiversity.org
Continental Divide Trail Alliance (CDTA) Continental Divide trail improvement	(888) 909-2382	www.cdtrail.org/page.php
Environmental Education Association of New Mexico Network for improving and promoting state environmental education	(505) 883-3314	http://www.eeanm.org
Gila Conservation Coalition (GCC) Protection of Gila and San Francisco River flow; Gila River Festival; Arizona Water Settlement Act education Also see Gila Resources Information Project, Upper Gila Watershed Alliance, Center for Biological Diversity	(505) 388-3763	www.gilaconservation.org
Gila Conservation Education Center (GCEC) Natural resource conservation education and involvement; partnership facilitation among conservation groups, schools, and local citizens. Volunteer-supported natural resource trunk program for public schools, education/monitoring on CFRP and other projects; Children's Water Festival	(505) 388-8265 (505) 388-8266	http://gcecnm.org

Native Plant Society of New Mexico Gila Native Plant Society (Silver City) Conservation of the native flora of New Mexico	 (505) 538-5192	http://npsnm.unm.edu (state-wide) http://npsnm.unm.edu/gila.html
Gila Resources Information Project (GRIP) Public information/participation in resource use, including mining reclamation issues	(505) 538-8078	www.gilaresources.info
Gila Watershed Partnership of Arizona		www.water.az.gov/watershed/content/map/UppGil.htm Safford, AZ
Gila Watershed Partnership of New Mexico (GWP) SWQB, Silver City Watershed information coordinator §319 *WIPS* development and updates; technical, data, liaison resources; Black Canyon Creek Gila trout project	 (505) 388-0599 (928) 310-8955	--
Gila WoodNet (§319 and CFRP; small-diameter wood products; affiliated with Grant County Jobs & Biodiversity Coalition)	(505) 537-3250	www.gilawoodnet.com
Irrigation districts		Contact local SWCD for more information
New Mexico Chapter of The Nature Conservancy (TNC) SW New Mexico office Biodiversity preservation; §319 Gila Riparian BMP project	(505) 988-3867 (505) 538-9700	www.nature.org/wherewework/northamerica/states/newmexico
New Mexico Science Teachers Association Network for improving science education	(505) 883-3114	http://www.nmsta.org
New Mexico State University Cooperative Service NMSU Agricultural Extension education outreach branch: plant sciences; soil/water testing; certified weed-free forage/mulch program)	(505) 646-4511	http://aces.nmsu.edu/county (links to individual county extension offices)
New Mexico Volunteers for Outdoors	(505) 884-1991	www.nmvfo.org

New Mexico Wilderness Alliance New Mexico wilderness protection, restoration, designation	(505) 843-8696	http://nmwild.org
Quivira Coalition Networking/education capacity building centered on ecologically-based ranching; riparian/upland rehabilitation, grazing management	(505) 820-2544	www.quiviracoalition.org
River Source Enhancement of productive community–watershed relationships through education and networking support for watershed monitoring programs	(505) 660-7928	http://riversource.net/index.php?option=com_frontpage&Itemid=1
Rocky Mountain Elk Foundation Protection of enhancement of wildlife/elk habitat, funding for conservation education and stewardship, hunting heritage programs	(800) 225-5355	www.rmef.org
San Francisco River Association (SFRA) Native plant nursery; riparian rehabilitation; §319 Pleasanton/San Francisco River Restoration and Outreach; CFRP; Whitewater Creek rehabilitation; Conservation Partnership Initiative See also SF SWCD	505) 539-2033	Glenwood
Schools: Regional public school districts		
Cobre Consolidated	(505) 537-4011	
Reserve Independent	(505) 533-6241	
Silver Consolidated	(505) 956-2002	
Aldo Leopold (charter) High School	(505) 538-2547	http://www.aldoleopoldhs.org/index.shtml
Southwestern New Mexico Audubon Society Natural history public education, field trips, GCEC trunk program partner		http://www.swnmaudubon.org
Taylor Creek Watershed Committee §319 WRAS and remediation project development	(505) 894-2212	http://www.sierrasoil.org

Trout Unlimited CFRP (NEPA for prescribed burns; fish crossings)	703-522-0200	www.tu.org (national)
Upper Gila Watershed Alliance Watershed protection, community-based stewardship; §319 and CFRP projects; Burros Mountains riparian restoration, travel management planning, Gila River Festival	(505)535-2519	http://www.ugwa.org/index.shtml
The Volunteer Center of Grant County Mobilizes volunteers in support of Grant County community programs	(505)388-2988	www.volunteersofgrantcounty.org
Western New Mexico State University	505 538-6011	http://www.wnmu.edu

MANAGEMENT PRACTICE RESOURCES

The local and regional resources described above can provide technical planning and assistance in implementing management practices (MPs) appropriate for this region. The listing that follows provides additional resources and materials for MP design and implementation; resources are ordered to approximate their organization in Section 6.

General Management Practice Resources

Agency/organization, description	**Website(s)**
EPA Management Measures Guidance documents	www.epa.gov/owow/nps/pubs.html
Bureau of Land Management MPs	http://www.blm.gov/wo/st/en/prog/energy/oil_and_gas/best_management_practices/technical_information.html
NMED SWQB *Nonpoint Source Management Program* (1999); Appendix C contains an extensive bibliography of materials on NPS management practices	http://www.nmenv.state.nm.us/swqb/NPS_Management_Plan-1999.pdf
NRCS National Handbook of Conservation Practices	www.nrcs.usda.gov/technical/standards/nhcp.html
For specific MP details, see the Utah Department of Environmental Quality's website (TetraTech, 2004)	http://www.waterquality.utah.gov/TMDL/Sevier_River_TMDL_Appendix_A.pdf
NEMO Network Manual of Best Management Practices	http://www.srnr.arizona.edu/nemo/index.php?page=bmpmanual

Streams/Riparian Areas/Gullies/Wetlands

Association of State Wetland Managers: ASWM guides for nonprofits and the public	http://aswm.org http://www.aswm.org/propub/brochures2006.htm
Army Corps of Engineers (wetlands delineation and other manuals)	http://el.erdc.usace.army.mil/wetlands/wlpubs.html
Bureau of Land Management Advisory Riparian Service Team (technical assistance and onsite consultation) RESTORE - an aggressive partnership to restore our state's grasslands, woodlands and riparian areas to a healthy and productive condition.	 http://www.blm.gov/or/programs/nrst http://www.blm.gov/nm/st/en/prog/restore_new_mexico.html
Center for Watershed Protection wetlands information	http://www.cwp.org/wetlands
ECBar Ranch (Nutrioso, AZ)	http://www.ecbarranch.com/conservation.html
Environmental Law Institute (policy, practice, and wetlands resources)	http://www2.eli.org/nwa/nwaprogram.htm
EPA summaries of Section 404 permitting requirements	http://www.epa.gov/owow/wetlands/pdf/reg_authority_pr.pdf http://www.epa.gov/owow/wetlands/regs
Federal Interagency Stream Corridor Restoration Working Group: Stream Corridor Restoration handbook	http://www.nrcs.usda.gov/technical/stream_restoration
NRCS PLANTS database Los Lunas Plants Materials Center Patuxent Wildlife Research Center (trainings, assessments, resources)	 http://plants.usda.gov http://www.nm.nrcs.usda.gov/programs/pmc.html http://www.pwrc.usgs.gov

Quivira Coalition	
Management practice handbooks	http://quiviracoalition.org/Land_Health/Publications
New Ranch Network (MP resource and practitioner network)	http://www.newranch.net
Tamarisk Coalition	http://www.tamariskcoalition.org/tamariskcoalition
Tree New Mexico River Rescue	http://www.treenm.com
USDA Stream Systems Technology Center (technical resources and references)	http://www.stream.fs.fed.us
USFWS T&E Species System	http://ecos.fws.gov/tess_public
Landowner protections/assurances	http://www.fws.gov/endangered/landowner
Locally implemented assurances (e.g., Safe Harbor Agreements, Habitat Conservation Plans)	http://ecos.fws.gov/conserv_plans/servlet/gov.doi.hcp.servlets.PlanSelect
US FWS wetland data, assessment tools, plant lists	http://www.fws.gov/wetlands

Roads/Travel Management

Bureau of Land Management travel planning	http://www.fs.fed.us/recreation/programs/ohv/blm_strategies.pdf
Gila National Forest Travel management planning summary	http://fs.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_RU6?navtype=BROWSEBYSUBJECT&cid=stelprdb5035773&navid=180000000000000&pnavid=null&ss=110306&position=Project.Html&ttype=detail&pname=Gila%20National%20Forest-%20News
Quivira Coalition Management practice handbooks	http://quiviracoalition.org/Land_Health/Publications/index.html

Uplands/Herbaceous Cover/Weeds

Gila NF Range Management Project/Plans	http://www2.srs.fs.fed.us/r3/gila/projects/prorange.asp#docs
Global Invasive Species Initiative (TNC control tools and evaluations, outreach information, Weed Information Management system) Weed control handbook	http://tncweeds.ucdavis.edu/control.html http://tncweeds.ucdavis.edu/handbook.html
Malpai Borderlands Group	http://www.malpaiborderlandsgroup.org
New Mexico Department of Transportation Vegetation Management Program	http://www.nmshtd.state.nm.us/main.asp?secid=11414

New Mexico State University weeds site	http://weeds.nmsu.edu
Weed-free seed/mulch/forage certification, NMSU Extension Service	http://spectre.nmsu.edu/dept/academic.html?i=683
NRCS	
PLANTS database	http://plants.usda.gov
Los Lunas Plants Materials Center	http://www.nm.nrcs.usda.gov/programs/pmc.html
Quivira Coalition	
New Ranch Network (partnering and MP resource connections)	http://www.newranch.net
Society for Range Management publications	http://www.rangelands.org/publications.shtml
Archived papers available through U. of AZ link	
USFWS recommendations for spring development and livestock watering	http://www.fws.gov/southwest/es/NewMexico/SBC_NM_rec.cfm?pr=sdl
USGS Southwest Exotic Plant Information Clearinghouse	http://www.usgs.nau.edu/SWEPIC

Prescribed Thinning/Burning and Wildland Fire

Collaborative Forest Restoration	http://www.fs.fed.us/r3/spf/cfrp
Forest Guild Worker Safety Certification program (lowers Workers' Compensation insurance rates on thinning projects)	http://www.forestguild.org/index.htm
Gila NF Forest Management Projects and Plans	http://www2.srs.fs.fed.us/r3/gila/projects/proforest.asp
State and Private Forestry links from GNF	http://www.fs.fed.us/spf
USDA Economic Action, Forest Products, Landowner Assistance, and Urban Forestry Programs	http://www.fs.fed.us/r6/coop/index.htm

Bureau of Land Management Fire Program Analysis	http://www.fpa.nifc.gov
Firewise Communities (WUI planning)	http://www.firewise.org
Gila National Forest Wildland Fire/Wildland Fire Use	www.fs.fed.us/r3/gila
NACD Forest Resource committee Handbook for Preparing a Community Wildlife Protection Plan	http://forestry.nacdnet.org www.safnet.org/policyandpress/cwpp.cfm
National Fire Plan	http://www.fireplan.gov
National Wildfire Coordinating Group	http://www.nwcg.gov/teams/wfewt/biblio/index.htm
New Mexico Association of Counties (links to all state fire resources)	http://www.nmcounties.org/wildfire.html
NM State Forestry link to New Mexico Fire Plan	http://www.emnrd.state.nm.us/fd/FireMgt/Fire.htm

Education/Outreach

Ecological Restoration Institute curriculum for students engaged in CFRP multi-party monitoring	https://library.eri.nau.edu:8443/handle/2019/326
Natural Heritage New Mexico	http://nhnm.unm.edu/index.html
New Mexico Department of Game and Fish Project Wild	http://www.wildlife.state.nm.us/education/project_wild.htm
New Mexico Outdoor Education Initiative	http://outdoor.riversource.net/bin/view/Outdoor
NMSU/NMDGF Comprehensive Wildlife Conservation Strategy for New Mexico	http://fws-nmcfwru.nmsu.edu/cwcs/default.htm
New Mexico Watershed Watch	http://riversource.net/index.php?option=com_content&task=view&id=4&Itemid=98
Think New Mexico Strategic River Reserve	http://www.thinknewmexico.org/river.html
Tree New Mexico public training sessions	http://www.treenm.com/Programs.htm#Trainings

MONITORING/MODELING RESOURCES

General and riparian	
River Source statewide riparian QAPP/riparian monitoring tools Links to other monitoring programs and tools	http://riversource.net/index.php?option=com_frontpage&Itemid=1 http://riversource.net/index.php?option=com_weblinks&Itemid=4&catid=17
USDA Stream Systems Technology Center (monitoring software and technical resources)	http://www.stream.fs.fed.us/index.html
USFS Rocky Mountain Research Station riparian vegetation monitoring	http://www.fs.fed.us/rm/pubs/rmrs_gtr047.pdf
Hydrology/water quality	
EPA Technical Tools for Watershed Managers	http://www.epa.gov/owow/watershed/tools
NRCS water quality monitoring and modeling tools, databases, and other resources	http://www.nm.nrcs.usda.gov/technical/water/wq.html http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models.html
STORET database access	http://www.epa.gov/storet/index.html
USGS streamflow data, New Mexico	http://waterdata.usgs.gov/nm/nwis/nwis
Establishing a water quality monitoring program	Contact NMED SWQB, Silver City
Other vegetation cover	
CFRP Multiparty Monitoring guidelines handbooks	http://www.fs.fed.us/r3/spf/cfrp/monitoring

Forest Ecosystem Restoration Analysis (through NAU)	http://www.forestera.nau.edu
Bureau of Land Management *Interpreting Indicators of Rangeland Health* *Measuring and Monitoring Plant Populations*	 www.blm.gov/nstc/library/techref.htm http://www.blm.gov/nstc/library/techref.htm

Runoff/erosion models and supporting data

RUSLE documentation, training, software	http://www.ars.usda.gov/Research/docs.htm?docid=6010
Office of Technology Transfer RUSLE documents	http://www.ott.wrcc.osmre.gov/library/hbmanual/rusle.htm
NRCS TR-55 runoff model software/documentation NRCS WIN-20 runoff model software/documentation (watersheds > 25 sq. mi)	http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-wintr55.html http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-wintr20.html
National Climate Data Center Western Regional Climate Center station and data lists Snow information	http://www.ncdc.noaa.gov/oa/mppsearch.html http://www.wrcc.dri.edu/CLIMATEDATA.html http://www.wcc.nrcs.usda.gov/snotel/New_Mexico/new_mexico.html
NRCS soil survey mapping tools and database	http://websoilsurvey.nrcs.usda.gov/app http://soils.usda.gov
Hillslope Erosion Model (HEM)/references	http://eisnr.tucson.ars.ag.gov/HillslopeErosionModel

AGENCY AND PROGRAM DESCRIPTIONS

Program descriptions and NPS categories for which each program is best suited are excerpted from the *New Mexico Nonpoint Source Management Program* (NMED, 1999).

USDA Forest Service
NPS categories to be addressed: Rangeland and Grazing/Wildlife Management, Silviculture, Recreation, Construction, Resource Extraction.

USFS manages approximately 8.5 million acres in New Mexico. These lands include approximately 1,700 miles of the State's 2,000 miles of high quality mountain streams. USFS is a designated management agency for NPS control in New Mexico. Their responsibilities include control, abatement, and prevention of NPS pollution resulting from all activities conducted in National Forests. Water quality concerns identified in National Forests include sediment and nutrient inputs from grazing and foraging activities, road construction and maintenance, timber harvest, and mining. Recreation impacts, largely related to sediment and litter impacts, occur in virtually all easily accessible lakes and along many accessible streams.

USDA Farm Service Agency
NPS categories to be addressed: Agriculture

FSA is responsible for administering the federal Conservation Reserve Program (CRP) and Conservation Reserve Enhancement Program (CREP). CRP encourages farmers to protect their most fragile farmland and marginal pastureland by conserving and improving soil, water, and wildlife resources. Farmers and ranchers are eligible for cost-share assistance for conservation on agricultural land to convert highly erodible and other environmentally sensitive acreage devoted to production of agricultural commodities to long term approved cover. Producers enrolled in CRP are also offered annual rental payments and incentives for providing these conservation measures. Practices eligible for cost-share are those selected by farmer-elected County Committee members from a list approved by State FSA Committees and the Secretary of Agriculture. Converting highly erodible and/or environmentally sensitive cropland to permanent vegetative cover under the CRP has created significant improvements in water quality across the nation. According to the NRCS, each acre under CRP contract reduces erosion by an average of 19 tons of topsoil a year. This improves the quality of water in streams, lakes, and other bodies of water not only by reducing sediment, but also by reducing the amount of nutrients and pesticides swept into bodies of water along with topsoil. Producers who enroll acreage in CRP greatly reduce their application of pesticides and nutrients on these acres, thereby reducing runoff containing excess agricultural pesticides and nutrients.

USDA Natural Resources Conservation Service
NPS categories to be addressed: Agriculture, Rangeland and Grazing/Wildlife Management, Recreation, Resource Extraction

NRCS, through programs such as EQIP, Conservation Technical Assistance (CTA) and others, provides technical, educational, and financial assistance to landowners and operators to assist them in implementing practices for sound natural resource use and management. Assistance is provided for all types of land uses, which NRCS categorizes as follows: commercial/industrial; community services; cropland; farmstead or headquarters; hayland; native pasture; natural areas; pastureland; rangeland; recreation land; residential land; mined land; transportation services land; wildlife land; forest land; and other. Technical assistance, provided through local SWCDs, includes helping landowners develop conservation plans for implementation by the land owner/operator that include protection and enhancement of water quality through NPS control. The focus of NRCS activities is on voluntary action by landowners and managers to affect wise land use. Cost-share funds are often available for implementation of conservation practices through both NRCS and FSA.

USDI Bureau of Land Management

NPS categories to be addressed: Rangeland and Grazing/Wildlife Management, Resource Extraction, Recreation, Construction

The BLM is a designated management agency for NPS control in New Mexico. Their responsibility includes control, abatement, and prevention of NPS pollution resulting from activities conducted on over 13 million acres of lands managed by BLM in New Mexico. Of particular State concern, regarding NPS control on BLM lands, are development and implementation of BMPs for rangelands and riparian areas. Development of grazing BMPs on BLM land is accomplished through activity plans and site-specific NEPA analysis documents, such as EAs, on proposed actions that establish site-specific objectives and mitigation within the general objectives of a particular RMP. The riparian area management program is being developed and stresses improvement of water quality as a prime objective of the program. BLM is cooperating with other federal and State agencies and private groups to identify, restore, and manage important riparian areas on BLM lands in New Mexico.

U.S. Geological Survey Water Resources Division

SWQB has a contract with USGS, Water Resources Division, to collect data at numerous selected sites throughout the State. These data have been collected at the same sites, in some cases for decades, providing valuable baseline information on water quality and quantity. The data are uploaded into the STORET database, and also published regularly by USGS. SWQB uses these data in conjunction with its TMDL development program, as well as for NPS pollution management. USGS also acquires baseline data and conducts research on various water quality-related topics. USGS is involved in the National Water Quality Assessment (NAWQA) Program, which became fully implemented in 1991. The NAWQA Program builds upon an existing base of water quality studies of the USGS, and other federal, State and local agencies.

New Mexico Forestry Division

NPS categories to be addressed: Silviculture, Rangeland and Grazing/Wildlife Management, Road Construction

The New Mexico Forestry Division's forest resource management programs involve the application of both regulatory and voluntary silvicultural BMPs on State and private forest lands in New Mexico.

Voluntary Programs and Activities: Through the federally supported Cooperative Forestry Assistance Program, the New Mexico Forestry Division provides technical forest resource management assistance to landowners and recommends application of NPS pollution BMPs in all silvicultural activities. Types of technical assistance range from reforestation to harvesting of mature timber. This assistance is designed to meet a wide range of landowner management objectives. In conjunction with these programs, the New Mexico Forestry Division has technical responsibility for application of forestry practices in federally funded landowner cost share programs that include FIP and SIP. SIP provides for the widest range of practices, such as wetlands protection, disturbed site rehabilitation, and protection or re-establishment of riparian vegetation. Distribution of information and education to private forest landowners and other cooperators is a major effort of the New Mexico Forestry Division. Information is provided in the following manner:

Through three publications that prescribe, define, and illustrate BMPs for treatment of roads, skid trails, landings, etc., related to silviculture and other resource management operations. These publications are titled Water Quality Protection Guidelines for Forestry Operations in New Mexico (Forestry Division, 1994), Reducing Erosion from Unpaved Rural Roads in New Mexico

(Soil and Water Conservation Division, 1983), and New Mexico Forest Practices Guidelines (Forestry and Resources Conservation Division, 1990).

Training is provided to landowners and other interested individuals, individually or in group presentations. The New Mexico Forestry Division is the lead agency for the national Project Learning Tree Program, which is designed for educators of students from kindergarten through grade 12. It is a source of interdisciplinary instructional activities and provides workshops and in-service programs for teachers, foresters, park and nature center staff, and youth group leaders.

The New Mexico Forestry Division co-sponsors a Forestry Camp for interested youth. The camp's programs educate campers on complexity of forest ecosystems and importance of a healthy system for providing quality water and other benefits. Under the auspices of the Conservation Planting Revolving Fund, the New Mexico Forestry Division provides, at cost, seedling trees to landowners for conservation plantings that provide soil stabilization, reforestation, and afforestation. Seedlings planted for the above purposes help control erosion and improve water quality.

New Mexico Department of Transportation
NPS categories to be addressed: Road Construction

NMDOT is responsible for the planning, designing, construction and maintenance of New Mexico's federal and State roads and highways. Use of BMPs to control erosion from disturbed areas and road embankments, for chemical de-icers, for herbicides used for weed control, and for other sources of NPS pollution are required for all road construction and maintenance work performed or contracted by NMDOT. BMPs are routinely included in operational plans for construction and maintenance projects. Design and implementation of BMPs is overseen by the NMDOT's Engineering/Design Division. Additional controls are established under the National Pollutant Discharge Elimination System Stormwater Pollution Prevention Program (§402(p) of the CWA) for pollution prevention plans on all projects that incorporate a disturbance of five acres or more.

New Mexico State Land Office
NPS categories to be addressed: Agriculture, Rangeland and Wildlife/Grazing Management, Road Construction, Resource Extraction, Silviculture

The SLO administers approximately nine million surface acres and 13 million acres of mineral estate that are held in trust for the common schools, State universities, and other beneficiary institutions. The SLO is required to manage the trust's assets in a manner that maximizes income to beneficiaries. At the same time, assets (renewable and non-renewable) must be protected from waste and dissipation to ensure sustainability. The SLO is not legally authorized to expend trust funds for improvement of trust land. However, FSA funds may be expended on trust lands. The SLO uses a cooperative approach in dealing with conservation of natural resources in relation to grazing and agricultural practices on trust land. Lessees are encouraged to enter into EQIP contracts or develop ranch and farm plans with SWCDs, and NRCS. Communications frequently occur with the approximately 4,000 grazing lessees regarding evolving range conservation practices. The SLO has promulgated rules that stipulate BMPs designed to control sediment and other pollutants originating from construction and operation of roads. Similarly, the agency has rules establishing reclamation standards for oil and gas development on trust lands. Lessees of State lands are required to develop and implement management plans and reclamation plans as a condition of the lease. The SLO has the authority to cancel any lease that does not meet these conditions. SLO staff conducts on-site inspections to ensure that lease conditions are met.

New Mexico Water Resources Research Institute (WRRI)

The New Mexico Water Resources Research Institute (WRRI) administers funds from State, federal, and other sources to support a statewide program that promotes research, training, information dissemination, and other activities to meet the needs of the state and nation. Basic and applied research is conducted by scientists of state academic institutions, with research priorities established by the state Program Development and Review Board. Water quality, including nonpoint source impacts, is one of the key research priorities of the WRRI. State appropriations support a substantial part of the program. Federal appropriations are provided through the Water Resources Research Act (42 USC 109 et seq.), which authorizes a program of water-related research and training through establishment of water research institutes at land grant colleges in each state, and authorizes awarding of grant funds for research projects. The program addresses water resource management problems, such as abundance and quality of our water supplies, sources of water contaminants and methods of remediation, and training of research scientists, engineers, and technicians. Other important topics, such as water conservation, planning, and management, and atmosphere-surface-ground water relationships are represented in the program. WRRI reports annually to SWQB and the NPS Task Force/UWA* Work Group on research related to NPS activities.

Office of the State Engineer (OSE); Interstate Stream Commission (ISC)
NPS categories to be addressed: Agriculture, Hydromodification, Silviculture, and Land Disposal

The OSE and ISC are responsible for the administration, investigation, planning, development, conservation, and protection of New Mexico's water resources. Office of the State Engineer (OSE) In addition to water-rights and water adjudication responsibilities, the OSE maintains a Water Conservation Program that provides information on water conservation to the general public, technical assistance to water users on water conservation, and develops the water conservation policies implemented in the administration of water rights.

Soil and Water Conservation Districts

NPS categories to be addressed: Agriculture. SWCDs in New Mexico are political subdivision of the State and are responsible under State law for directing soil and water conservation programs. Each of the 47 SWCDs in New Mexico are operated by a board of five locally-elected District Supervisors who are familiar with local soil and water conservation problems. SWCDs can provide assistance at the local level to establish watershed management associations, develop watershed action plans, provide technical expertise on water quality and NPS pollution issues, promote the use of the CW-SRF, assist local governments with NPS pollution management and prevention, and provide water stewardship education to private landowners.

FUNDING RESOURCES

A spreadsheet of funding resources will be added to the *WIPS* (as Appendix B), and posted at its website sometime in the future. The spreadsheet will include contact and descriptive information along with each source's typical funding cycle.

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APPENDIX A
COMMENT SHEET for Gila River *WIPS* users

Your comments or responses to any of these questions are appreciated!

Please email or call David Menzie, NMED SWQB Silver City:
(575) 956-1548 / David.Menzie@state.nm.us, or

Matthew Schultz, NMED SWQB Silver City:
(575) 956-1550 / Matthew.Schultz@state.nm.us

- Which subwatersheds do you or the group(s) or agency you represent have an active interest in? That is (circle those applicable),

a) you are interested in developing a proposal and obtaining funding for improvement efforts

b) own land in the subwatershed and may be interested in talking with agency or group representatives about watershed improvement support

c) represent an agency seeking support or leveraging capacity for planned work in the subwatershed

d) you have implemented and/or completed a project not included in the current *WIPS*

- Do you have suggestions for other best management practices in any of the subwatersheds currently listed as water-quality impaired?

Subwatershed:

Suggestions:

- Have you identified other stream reaches or subwatersheds that you believe may be impaired or potentially impaired by current conditions? Please be specific.

Subwatershed:

Stream reach (describe by length and geographic location, if possible):

Condition(s) causing impairment:

Your thoughts on potential improvement strategies?:

- Are there data that you or the group(s) or agency you represent are lacking in your efforts to target your improvement efforts, draft funding proposals, leverage funds, obtain agency or other assistance, or develop substantive monitoring plans? Please identify them here:

Subwatershed, if applicable:

Data lacking:

If available, data would facilitate:

- Do you have suggestions on additional literature or websites that may be of interest to others? (Monitoring strategies, other groups' relevant work, scientific reviews, suggested management practices...)

- How often would you prefer to see the *WIPS* updated and made available to you or the group(s) or agency you represent?

- What other assistance in implementing improvement practices would you or the group(s) or agency you represent find helpful?

- Was there information in the *WIPS* with which you disagreed? If so, what was it? Please be specific, by page number if possible.

- Was there information you hoped to find in the *WIPS* that was missing? If so, what was it?

- If you or the group(s) or agency you represent have concerns about the "mechanics" of 319(h) funding and EPA-supported watershed improvement strategies, what are they?

- Was there information in the *WIPS* that you found particularly helpful? Why?