Upper Pecos
Watershed Based Plan



Submitted to the New Mexico Environment Department

by:

The Upper Pecos Watershed Association

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Executive Summary

In 2016, the Upper Pecos Watershed Association (UPWA) received a grant from the U.S. Environmental Protection Agency (EPA) through the New Mexico Environment Department's (NMED's) Surface Water Quality Bureau (SWQB) to update this Watershed-Based Plan (WBP). The purpose of this update is to include new implementation projects and discussion of the effects of two major wildfires that occurred in the watershed in 2013. The previous version of this WBP was completed in 2012, prior to these fires. This version of the WBP also includes updates and revisions to other sections of the plan as discussed here in this Executive Summary.

The update process started with public scoping in the form of a workshop to solicit input for potential new implementation projects in the watershed. Poster-sized maps of the watershed showing all the Pecos River, Cow Creek and all of their main tributaries, with labels, were available at the workshop so that attendees could easily identify potential project locations. UPWA sent out an email to its contacts mailing list of over 400 people inviting them to attend a workshop in Pecos on April 15, 2017. The workshop was held at the UPWA office in Pecos and was attended by members of the UPWA Board of Directors, Devin Kennemore of Pathfinder Environmental, and Alan Klatt of SWQB. Two members of the Pecos community attended the workshop. Their suggestions were considered for inclusion in this updated WBP.

Section 1.4 of this WBP contains background information about UPWA and was updated to reflect UPWA's success with implementing on-the-ground projects in the watershed. To date, UPWA has received approximately $1.6M in grants for implementation, public outreach, and updating this plan. The following is a list of projects for which UPWA has either received funding to implemented directly or provided local support for implementation.

- Lower Cow Creek bank erosion restoration project
- Respect the Rio
- UPWA Community Foundation project
- Dalton Day Use Area River and Riparian Habitat Restoration
- New Mexico Department of Game and Fish campground improvements
- SFNF Dalton Canyon dispersed camping improvements
- UPWA "Hatchistery" Stream Restoration
- Tierra y Montes Soil and Water Conservation District projects
- Tererro Mine Tailing reclamation
- Pecos National Historic Park Glorieta Creek wetland project
- Truchas Chapter, Trout Unlimited habitat improvement projects
- Albuquerque District, US Army Corps of Engineers and Robert Mead Cow Creek restoration projects
- Upper Cow Creek Riparian Habitat and Channel Restoration Project
- Holy Ghost Canyon Creek and Drainage Post-fire Restoration Project
- Annual spring and Dia del Rio Cleanups
- NMDOT NM Highway 63 guardrail project
- Los Trigos Ranch river restoration projects

This updated WBP includes 11 maps. Ten of these maps are in the previous version of the WBP. Each of these maps was updated to include new information as currently available. The one new map shows the locations of the Tres Lagunas and Jaroso wildfires and the fire intensity in the drainages affected by those fires. This map was prepared to augment new discussion of these wildfires in Section 2.1 Fire History and Ecology. Chapter 2 was also updated with the latest climate data, as available.

Chapter 4 Causes and Sources of Impairments was updated with the most recent developments regarding the Glorieta Camps' wastewater treatment facility and their use of groundwater for irrigation. These new developments may have a long-term benefit to Glorieta Creek in terms of nutrient and flow impairment. Discussions involving the current impairment status of the various assessment units in the watershed reference the recently EPA-approved *2018-2020 State of New Mexico Clean Water Act 303(d)/305(b) Integrated Report*. Water quality monitoring in the upper Pecos watershed is scheduled for 2019. The results of this monitoring may result in significant changes to which assessment units are listed as impaired and the types of impairment. The results won't be available until the 2020-2022 report is completed.

Chapter 5 Management Measures was updated to include additional restoration techniques currently being employed in on-the-ground projects by UPWA's contractors. The tables in this chapter that list proposed projects by the type of impairment they would address were updated to include new projects developed for this new version of the WBP. Section 5.4 Existing Restoration Projects was updated to include descriptions of implementation projects completed or currently underway by UPWA since the last version of the WBP was completed.

Chapter 6 Pollution Load Reductions was updated by adding the new implementation projects to the appropriate tables (SSTEMP modeling and soil erosion calculations). The temperature modeling from the previous version of the WBP was retained because it SSTEMP could not be employed at the resolution of the scale of individual projects without obtaining a large amount of site-specific data, so the new projects were added to the modeling results according to the location of their corresponding sub-watershed. The soil erosion calculations were completed using scale data from the new list of implementation projects in Appendix A and parameters adapted for the projects that were included in the previous version of the WBP.

Chapter 7 Implementation Assistance and Schedule includes lists of UPWA's collaborators, technical assistants, and available sources of funding. These lists were updated to reflect their current status. This chapter also includes tables that were updated to present project priorities and a new general schedule for completion. The table that provides contact information for collaborators in Chapter 9 was updated with the most current available names, phone numbers, and email addresses.

The table of proposed implementation projects in Appendix A was updated to include all the newly proposed projects and exclude those projects that have been completed or are no longer necessary due to sufficiently improved water quality. The tables in Appendix B were updated to reflect current projected construction costs for the types of projects and management measures described in this plan.

Upper Pecos Watershed-Based Plan

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1. INTRODUCTION AND BACKGROUND INFORMATION

1.1 Watershed Location and Description

The Upper Pecos watershed (U.S. Geological Survey Hydrologic Unit Code 13060001, "Pecos Headwaters") is part of the larger Rio Grande Basin, located in north-central New Mexico about ten to twenty miles east of Santa Fe. The area covered by this Watershed-Based Plan extends from the headwaters of the Pecos River and its upper tributaries in the Sangre de Cristo Mountains to the point where Interstate Highway 25 crosses the Pecos, below its confluences with Cow Creek and El Rito. Our watershed includes the communities of Pecos, Tererro, Cowles, Glorieta, Upper and Lower Colonias, North and South San Ysidro, Rowe, and San Jose. The village of Pecos is the only incorporated municipality in the watershed.

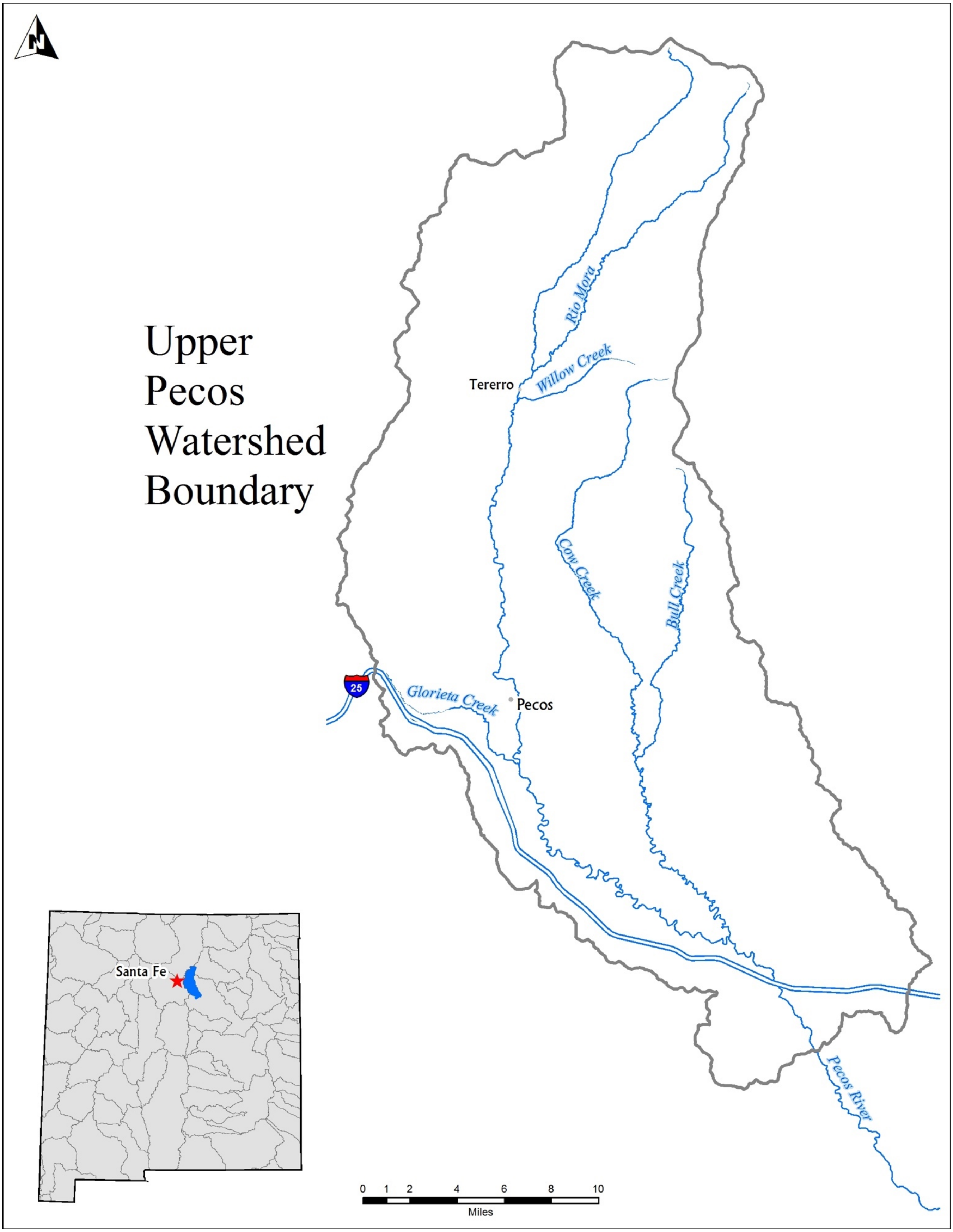
The Upper Pecos watershed covers approximately 360,000 acres, ranging in elevation from over 13,000 feet in the Truchas Peaks to about 6,100 feet as it crosses Interstate 25. The watershed includes private lands, land grants, Santa Fe National Forest lands, the Pecos National Historical Park, and the Village of Pecos, as well as small parcels of Bureau of Land Management and State land. Major tributaries of the Pecos River in this part of the watershed include Willow Creek, Holy Ghost Creek, Cow Creek, Bull Creek, Glorieta Creek, and the Rio Mora. Vegetation ecological zones range from alpine tundra and grassland at the highest elevations through spruce-fir, mixed conifer, and ponderosa forests, along with piñon-juniper, woodland savannah, grassland, and some sage at the lower elevations.

This Plan does not include the watershed of the Pecos River south of Interstate Highway 25. For purposes of assessing stream condition and planning for restoration, the Upper Pecos watershed can be subdivided into 12 sub-watersheds, as shown below. Although this is not a complete list of all of the named tributaries within the watershed, it does reflect the principal hydrologic units, or reaches of the Pecos River, its tributaries, and their associated watersheds, as mapped by the US Geological Survey in its Watershed Boundary Dataset.

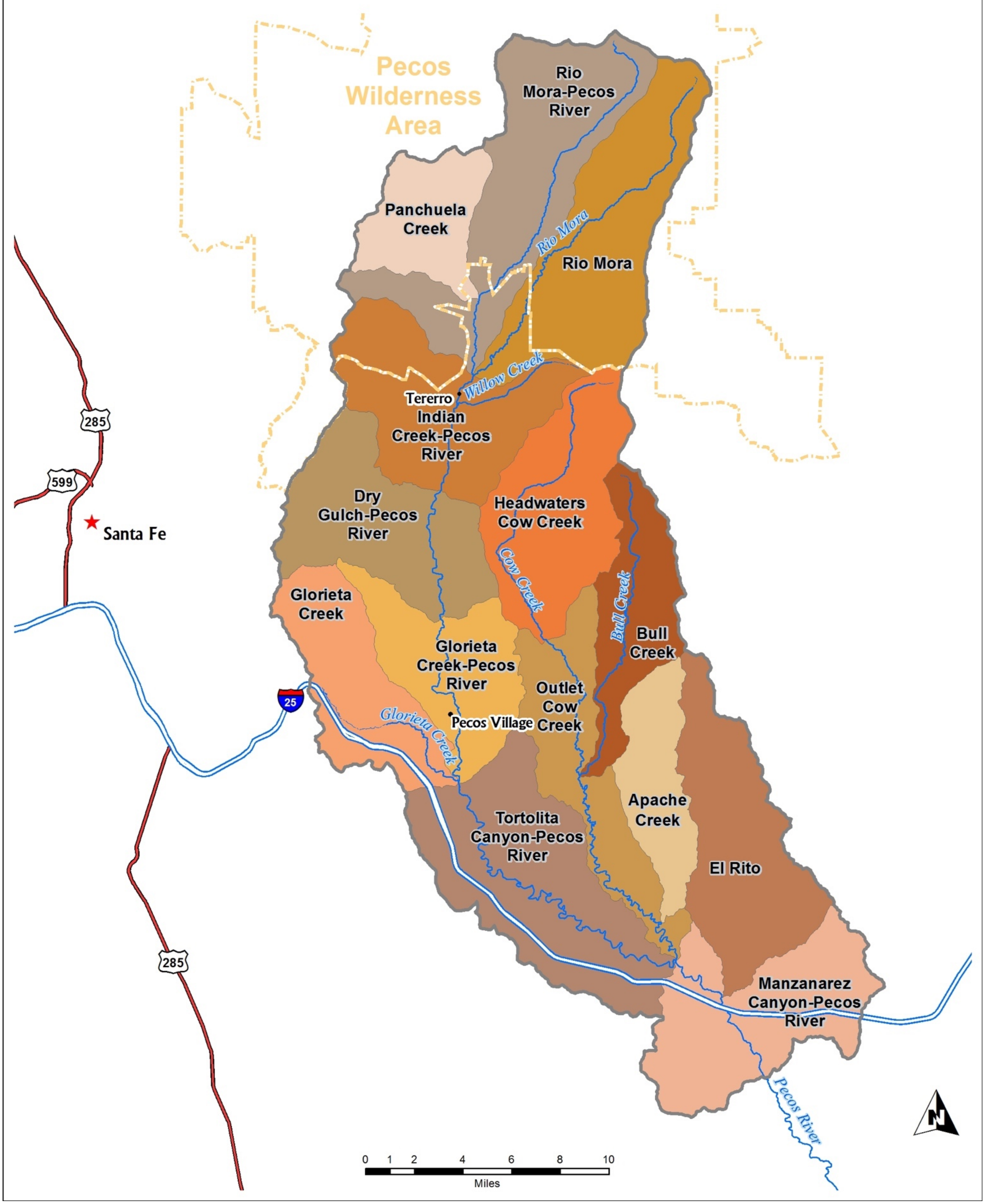
HUC 130600010101: Headwaters Cow Creek
HUC 130600010102: Bull Creek
HUC 130600010103: Apache Creek
HUC 130600010104: Outlet Cow Creek
HUC 130600010201: Rio Mora - Pecos River
HUC 130600010202: Panchuela Creek
HUC 130600010203: Rio Mora
HUC 130600010204: Indian Creek - Pecos River
HUC 130600010205: Dry Gulch - Pecos River
HUC 130600010206: Glorieta Creek
HUC 130600010207: Glorieta Creek - Pecos River
HUC 130600010208: Tortolita Canyon - Pecos River

Within the upper Pecos watershed there are reaches of six streams that fail to meet water quality standards - the **Pecos River, Cow Creek, Willow Creek, Macho Creek, Dalton Canyon Creek,** and **Glorieta Creek** - because of excessive water temperatures, turbidity, specific conductivity, or flow regime modification. In addition, New Mexico Water Quality Control Commission regulations provide for non-degradation of water quality in situations where standards are now being attained.

The location of the Upper Pecos watershed within New Mexico can be seen on the map on the following page. The locations of the sub-watershed hydrologic units within it are shown on page 3.


Upper
Pecos
Watershed
Boundary
Tererro
Rio Mora
Willow Creek
Cow Creek
Bull Creek
25
Glorieta Creek
Pecos
Pecos River
Santa Fe
0 1 2 4 6 8 10
Miles

Pecos Canyon HUC 12 Subwatersheds



1.2 Land Ownership and Demographic Information

The majority of land in the Upper Pecos Watershed is federally owned, with private in-holdings located primarily south of the village of Pecos, although there are also significant private lands along the Pecos River within the Pecos canyon, along Cow Creek, and in other tributary watersheds (Table 1). Even though most of the land in the watershed is public, the relatively large concentration of private land in the Pecos canyon is one reason that recreational use is so concentrated on public lands adjoining the river.

Land ownership in the Upper Pecos Watershed (approximate acreages)

Ownership	Acres (approximate)	Percentage of Land Area in Watershed
Private	96,366	26.8
Pecos National Historic Park	6,363	1.8
Santa Fe National Forest (non-wilderness National Forest land)	164,229	45.7
Pecos Wilderness (Santa Fe and Carson National Forests)	84,466	23.5
Department of Game and Fish	992	0.28
Bureau of Land Management	2,615	0.64
State of New Mexico (State Land Office)	4,624	1.3
Upper Pecos Watershed (total)	**359,655**	**100.0**

A map of land ownership within the watershed appears on the following page.

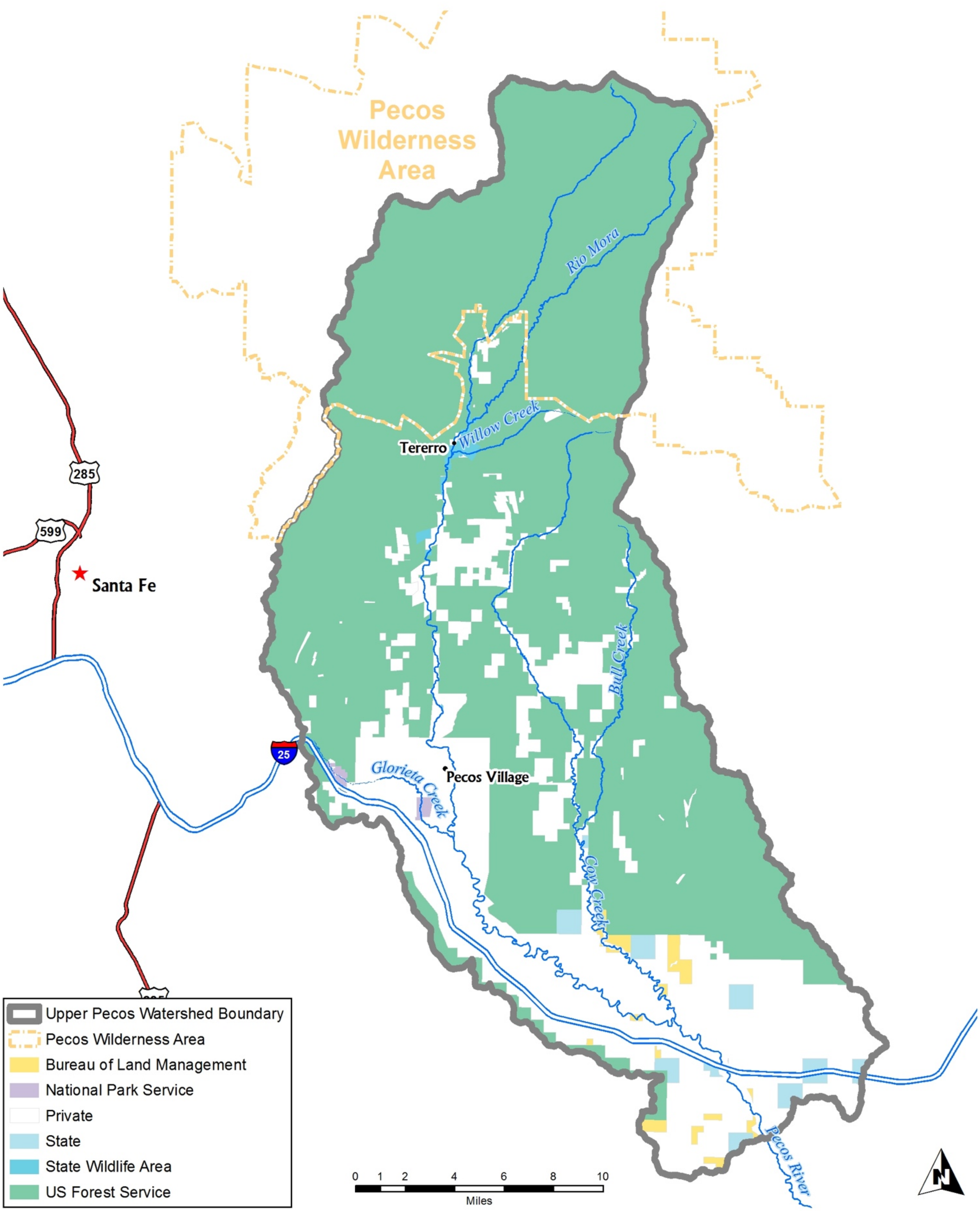
The Upper Pecos watershed is located almost entirely in San Miguel County, New Mexico (a small part of a tributary valley extends west into Santa Fe County). The one incorporated municipality is the village of Pecos, but the watershed also includes the unincorporated rural communities of Tererro, Glorieta, Upper and Lower Colonias, North and South San Isidro, Rowe, and San Juan, along with dispersed ranches, summer home and recreational cabin owners, and other rural residents as well.

The full-time population in the Pecos River valley is about 8,000 people. However, a recreational use assessment has observed that over 1,000 people at any given time may be camping within the Pecos Canyon on busy summer weekends, to say nothing of summer cabin owners or day-use visitors – confirming that recreational visitation to the Upper Pecos far exceeds the resident population.

1.3 Historical Overview

The upper Pecos Valley has presumably been occupied, at least occasionally, by humans for at least 12,000 years. It was first used seasonally by hunters and gatherers, with more permanent settlements increasing over time. The first permanent settlements in the area seem to have begun around 750 AD. Pecos Pueblo became the largest settlement for the previously dispersed farmers of the Pecos Valley around 1450 AD, although there was a pueblo near modern Rowe, as well. Pecos Pueblo thrived as a village and principal trading center on a major travel and trade route from Glorieta Pass to the Great Plains, well before the arrival of European settlers.

Surface Ownership



Spanish exploration of the area began in the 1500s, with settlement beginning very gradually at first. Pecos Pueblo was abandoned by the early 19th century. Spanish settlement began gradually in the 18th century, followed by Anglo-European and American settlements that increased considerably after American annexation in 1846, bringing increasing farming, ranching, logging, mining, and trapping activities. Because early settlement was concentrated along the cienegas (marshy springs) and meadows where irrigation systems could be constructed, most environmental effects were concentrated there as well. By 1831, an extensive system of irrigation ditches had been constructed along the Pecos River and its tributaries to serve the communities of Upper and Lower Colonias, North and South Ysidro, and El Macho, among others.

In 1878, the Atchison, Topeka, and Santa Fe Railroad completed its line across Raton Pass and entered New Mexico. In the late 1880s more extensive logging for railroad ties began, along with the construction of railroad lines into the canyon as far as what is now known as Tres Lagunas, extending later to the mine holdings of the Pecos Mining Group around Tererro. Prior to this time access into the area was limited and few people ventured beyond the mines at Willow Creek. In 1888, Joseph Blanger settled at the junction of the Pecos River and Jacks Creek, above Cowles near what is now the boundary of the Pecos Wilderness.

Prospector J.J. Case discovered copper, lead, and zinc ore near the confluence of Willow Creek with the Pecos River in 1881. Gold and silver ore were discovered by other prospectors later in the 19th and early 20th centuries, but large-scale mining did not begin until 1926 or 1927 when the American Metals Company opened the Tererro Mine. Ore was transported down-canyon on an aerial tramway to the "El Molino" site on Alamitos Creek near the Town of Pecos for milling and concentration. At the peak of operations in the 1930s, Tererro had a population of over 3,000 people, and the mine was New Mexico's largest single employer. Mining operations continued until 1939.

Public concerns were raised at least by the 1980s about potential water contamination from mine waste and mill tailings, and some site investigation took place by the mid-1980s. In 1991 there was a major fish kill in the Pecos River from metal contaminants washed into the river from mine waste by spring runoff, and by the end of 1992 an agreement had been reached between the State of New Mexico and Cyprus-AMAX mining company (successor to American Metals Company) for cleanup activities at the mining and milling sites, to avoid listing as a national EPA Superfund site. Site characterization and project planning began in 1993, and on-the-ground work followed from 1994 until 2003.

There are numerous references to logging for railroad ties (and associated road-building) in the Pecos Canyon in the early 1900s. Period photographs and a 1900 announcement of sale within the reserve for 700,000 board feet of lumber and/or 700 cords of firewood indicate that extensive logging was a routine practice into the first two decades of the twentieth century. These tie-cutting and other logging operations had significant effects in the watershed, including erosion and sediment movement down the river that led to problems with water management and farmland irrigation downstream. These same issues helped provide impetus for placing the forest and the headwaters of the Pecos River under federal protection. The area was proclaimed as the Pecos River Forest Reserve in 1892, later became the Pecos National Forest, and was combined with the Jemez National Forest in 1908 to become what is now the Santa Fe National Forest.

Many of the roads, bridges, and campgrounds that still exist along the mainstem of Pecos Canyon were built or improved during the 1930s by the Civilian Conservation Corps to support the mining operations and nascent recreation industry. The 1,967 acres owned by the New Mexico Department of Game and Fish were acquired from private landowners, much of it from successors to the owners of the former mine and mill sites, beginning in about 1950. This acquisition of public land greatly expanded access for fishing and camping, since most of the land along the Pecos River below Tererro was private, and public access opportunities were severely restricted.

1.4 The Upper Pecos Watershed Association

The Upper Pecos Watershed Association (UPWA) was originally formed in 2006 by residents in the Pecos watershed who were concerned about environment issues pertaining to the river. It is recognized as a 501(c)(3) nonprofit organization, and is overseen by a nine-member Board of Directors. UPWA's primary goals are to:

- Protect and improve the health of the watershed
- Address significant ecological, and environmental issues in the watershed
- Preserve traditional and cultural uses and benefit the local economy.

UPWA has received and successfully administered 11 significant grants (eight federal and three State, totaling over $1.6 million) for community outreach, watershed-based plan revision, and river restoration. UPWA has partnered with many organizations in the past, and actively continues to do so – with government agencies such as the USDA Forest Service, New Mexico Environment Department, New Mexico Department of Game and Fish, the New Mexico Department of Transportation, the Village of Pecos, and San Miguel County; and with non-governmental groups such as Trout Unlimited, local homeowners' associations, the Friends of Pecos National Monument, and the Pecos Community Foundation, for example.

The Pecos Canyon is a hot spot for tourism from Santa Fe, Albuquerque, and surrounding areas in the summer and fall for camping, hiking, hunting, and fishing. One of the ways UPWA is trying to help environmental concerns is to address the overuse and abuse of the campgrounds and recreation areas that are a probable source of the Clean Water Act listing of impaired streams as non-supporting for high-quality cold-water aquatic life. UPWA was a leading advocate for the formation of the Pecos Canyon State Park, and collaborated with San Miguel County, The Village of Pecos, US and State political representatives, the Pecos Business Association and other advocacy groups in favor of Park legislation. It was approved unanimously by the legislature, and signed into law in 2008. Since then, the properties were surveyed and determined to belong to the New Mexico Department of Game and Fish Commission. Negotiations for a Joint Powers Agreement were completed and all that now remains is for the State Legislature to provide funding to New Mexico State Parks so that they can take over management.

1.5 Water Quality Protection in New Mexico

The legal basis for most water quality protection in the Upper Pecos, as in the rest of New Mexico, is provided by the federal Water Pollution Control Act (the "Clean Water Act") and the New Mexico Water Quality Act. The Water Quality Control Commission has legal responsibility for upholding both laws, and for adopting water quality Standards. The New Mexico Environment Department is the agency with primary responsibility for implementation and enforcement of the regulations and standards adopted by the Commission.

Water quality protection in New Mexico is based on designating uses for which the quality of a given stream reach, lake, or other water body should be adequate. For the Upper Pecos these uses include domestic water supply, high-quality cold-water aquatic life (such as trout), and primary contact (such as swimming), among other uses. A water body in good condition will support all its designated uses; conversely, impaired water quality will prevent a water body from supporting one or more of its designated uses. The following stream reaches in our watershed are impaired, for the causes listed, and these are listed in the biennial *2018-2020 State of New Mexico Clean Water Act §303(d)/§305(b) Integrated Report*.

Impaired stream reach	Cause for impairment
Cow Creek (Bull Creek to headwaters)	Temperature
Cow Creek (Pecos River to Bull Creek)	Temperature

Dalton Canyon Creek (Pecos River to headwaters)	Specific conductance
Glorieta Creek (Pecos River to Glorieta Conference Center WWTP)	Nutrients & Specific conductance
Glorieta Creek (Glorieta Conference Center WWTP to headwaters)	Flow regime modification
Macho Canyon Creek (Pecos River to headwaters)	Specific conductance
Pecos River (Cañon de Manzanita to Alamitos Canyon)	Temperature
Willow Creek (Pecos River to headwaters)	Specific conductance

If a water body is listed as impaired, a Total Maximum Daily Load (TMDL) is developed to calculate the improvement needed to remove the impairment and allow the water body to fully support its designated uses.

In addition to restoration of stream and watershed conditions to repair conditions causing listed impairments, New Mexico Water Quality Control Commission regulations (20.6.4.8A, NMAC) include an "Anti-degradation policy" that requires that existing water quality shall be maintained at levels necessary to support designated uses.

Identifiable point sources of pollutants, such as wastewater treatment plants or industrial operations, are regulated by permits required under the federal National Pollutant Discharge Elimination System. There are three such permits within the Upper Pecos watershed. However, the vast majority of surface water quality impairments identified in New Mexico are due to nonpoint sources of water pollution that are not amenable to control by permitting. In our situation, some of these non-point pollution sources include recreational impacts to streambanks and watershed conditions, improper (and illegal) disposal of solid and liquid waste, grazing impacts, rangeland and arroyo conditions, inadequate streamside vegetation, and road runoff. In addition to these more manageable pollution sources, large-scale wildfires in the watershed would have drastic effects to water quality and hydrology (as seen after the Viveash fire in 2000, and Jaroso and Tres Lagunas fires in 2013), far exceeding other potential impairment causes for years after a large fire.

Non-point pollutants are addressed through a variety of incentive-based approaches that encourage better watershed and stream management practices, administered by several agencies. Most of these approaches involve grant funding, technical assistance, and outreach activities. The main goal of this Watershed-Based Plan is to identify the highest-priority nonpoint source water pollution problems in the Upper Pecos and to help address those problems as quickly and efficiently as possible, using whatever sources of assistance are available.

1.6 Plan Organization

This Plan is organized into nine more chapters, addressing our goals of watershed and water quality protection, as summarized below.

Chapter 2: **State of the Watershed**. Provides more detail about current conditions, historical influences on water quality, overall causes of water quality impairment, and information on specific sub-watersheds and stream reaches.

Chapter 3: **Vision for the Future**. Considers future scenarios for the upper Pecos watershed, and the vision for water quality and watershed health towards which UPWA and its stakeholders are working.

Chapter 4: **Causes and Sources of Pollution and Watershed Stress**. Discusses threats to water quality and the watershed, along with specific causes of water quality problems and stream impairments, sources of pollution, and data sources for this information.

Chapter 5: **Management Measures**. The actual projects, activities, and management practices needed to achieve water quality improvements and protect the watershed are described in this chapter, along with numerical estimates and model results of their expected effects.

Chapter 6: **Pollutant Load Reductions**. Describes the modeling and data analysis that quantifies the water quality improvements needed to remove impairments, and the anticipated results of management measures recommended.

Chapter 7: **Implementation Assistance and Schedule**. Discusses the level of financial and technical resources needed to implement the necessary management measures, and considers potential funding sources and project partners.

Chapter 8: **Criteria, Milestones, and Monitoring**. Suggests specific indicators to show progress towards reducing pollutant loads and meeting watershed goals, along with ways to measure those indicators and track them over time. This chapter also discusses ways to fill data gaps associated with pollutant sources.

Chapter 9: **Outreach and Community Involvement**. Ongoing and future efforts to educate and provide information to residents, visitors, local officials, and other partners – and involve them as much as possible in activities to protect and restore our watershed.

Chapter 10: **References and Other Resources**. Lists sources of information in the Plan, and ways to find more.

Watershed planning under the auspices of the Environmental Protection Agency centers around nine principal elements that focus on specific, achievable strategies for water quality restoration. The table below summarizes these nine key elements and where they are addressed in this Watershed-Based Plan.

Planning Element	Location in Plan
A. Causes and sources of pollutants	Chapter 4, beginning on page 52
B. Estimates of load reductions	Chapter 6, beginning on page 80
C. Management measures needed to reduce pollutants	Chapter 5, beginning on page 62
D. Technical and financial assistance needed	Chapter 7, beginning on page 87
E. Education and community outreach	Chapter 9, beginning on page 108
F. Implementation schedule	Chapter 7, beginning on page 94
G. Milestones for implementation	Chapter 8, beginning on page 104
H. Pollutant load reduction measurement criteria	Chapter 8, beginning on page 103
I. Monitoring strategies	Chapter 8, beginning on page 105

Impaired stream reaches and causes are identified on pages 53-56; contaminant sources are discussed on pages 56-61. Specific locations of impairments (and measures to remedy them) are discussed beginning on page 62. Impaired stream reaches are mapped on page 61, while sources (and projects to remedy them) are mapped on page 69.

2. STATE OF THE WATERSHED

Given the span of a human lifetime, we usually tend to see a landscape, like the upper Pecos watershed, as something more or less static and unchanging. Even long-time residents, who may indeed have seen real changes in parts of the landscape, can only witness what happens within their lifetimes. Historical records and anecdotal evidence can illustrate ecological changes in landscape, but seldom record such information intentionally or in any detail. Our landscape, however, is not a fixed and unchanging picture – it would be more accurate to think of it as a film – usually one in very slow motion - instead of a snapshot.

Over geologic time the changes in climate, vegetation, and even topography and elevation, have been dramatic. Since the last ice age, some 10,000 years ago, ecological and hydrological conditions have changed enormously. For instance, in the Pecos valley 10,000 years ago, tree line would have been at about the elevation of Cowles, and everything above that would have been tundra and alpine grassland. Nearly all the rest of the watershed would have been covered in spruce and high-altitude mixed conifer, with perhaps a few ponderosas on lower and south-facing slopes near what is now Interstate Highway 25. As the climate got warmer and dryer, the vegetation types we know today moved up and north into more or less their present ranges.

Human activities have also dramatically altered many aspects of our watershed, especially at lower elevations. It is difficult to completely separate the effects of an increasing human presence – European grazing animals, farming, logging, roads, recreation and other development, changing fire regimes, and so on – from factors like precipitation patterns and temperature that have been changing over time as well. However, there have been significant alterations over recorded history in some characteristics of the Upper Pecos – in particular, early accounts and even photographs indicate quite a bit more grass cover in the areas below the village of Pecos, with fewer trees and shrubs. The increasing grazing pressure that began with European settlement and surged dramatically with the arrival of the railroad in the late 19th century undoubtedly affected the Pecos area like most of the rest of New Mexico. It seems likely to have been a major contributor to the soil erosion, gullying, and flash flood runoff we see in the lower parts of our watershed. Other activities, like mining, logging, road construction, and recreational development have had greater effects in areas above the village of Pecos. This chapter will look at the landscape of the upper Pecos as it exists today, and consider some of the principal influences, human and natural, that have affected our watershed.

2.1 Fire History and Ecology

Naturally occurring wildfires have been a recurring element in the upper Pecos watershed for several millennia, if not far longer. While fire is a common and often necessary part of a properly functioning Rocky Mountain landscape, the severity, frequency, and extent of fires can have a dramatic impact on the water quality and watershed hydrology in a landscape. A large multi-drainage crown fire is undoubtedly the single biggest threat to the water quality within the Pecos, over the short term. This fact was made plain in the aftermath of the Viveash fire in 2000 and the Tres Lagunas fire in 2013, when much of Cow Creek, Holy Ghost Creek, and Pecos River were flooded with large amounts of sediment, ash and debris, killing aquatic life and causing dramatic local hydrologic modification in the form of head cuts, channel incision and channel avulsion. That kind of wide-scale surface run-off typically follows fires that burn with moderate to high severity because ground cover vegetation (grass, mostly) and soil organic matter that would typically absorb and infiltrate much of the precipitation is burned away leaving the soil exposed and sometimes hydrophobic.

Information is not available about fire frequencies in the upper Pecos specifically, although research in similar New Mexico forest types has shown that fire return intervals in high-elevation (greater than 9,000 or 10,000 feet) forests are often 150 to 300 years. When high-elevation forests do burn, they typically burn severely, racing through the forest canopy and eliminating the existing tree cover. However, these fires are essential for early-successional species like aspen that require large-scale disturbance to regenerate and thrive. This pattern is quite different from the more frequent fire cycle in lower-elevation ponderosa pine and dry mixed conifer that typically burn every 2 to 20 years with low to moderate intensity, leaving large trees intact, but consuming small diameter trees and ground fuels and promoting the growth of grasses and forbs. This understory layer of grass and forbs is vital for protecting soil, especially on steeper slopes and more erodible soils. Grass cover also causes much greater infiltration of precipitation and aquifer recharge*. Unfortunately, these low-intensity ground fires that help maintain good ground cover and proper watershed function are nearly absent in the Pecos watershed today.*

In the absence of frequent, low-intensity fire, combustible fuels such as dense, small-diameter trees accumulate with every growing season and easily form a fire ladder. This leads to situations where once a fire starts, it has all the more potential to quickly become a Viveash, Las Conchas, or Whitewater/Baldy-scale fire. Such very large, and highly destructive fires pose serious safety and property damage concerns in addition to causing very severe environmental damage to the watershed. Historically, in hopes of avoiding huge catastrophic fires, the decision has usually been to suppress any fire that starts. However, a policy of fire suppression cannot prevent an uncontrolled and potentially large fire forever. Both lightning strike and human ignited fires start every year. Even if there were no human presence in the area at all, lightning strikes are surprisingly common. Data from the National Climatic Data Center show 348 satellite-recorded lightning strikes, in the upper Pecos watershed, in the month of May of 1997 alone – as illustrated in the map on the following page.

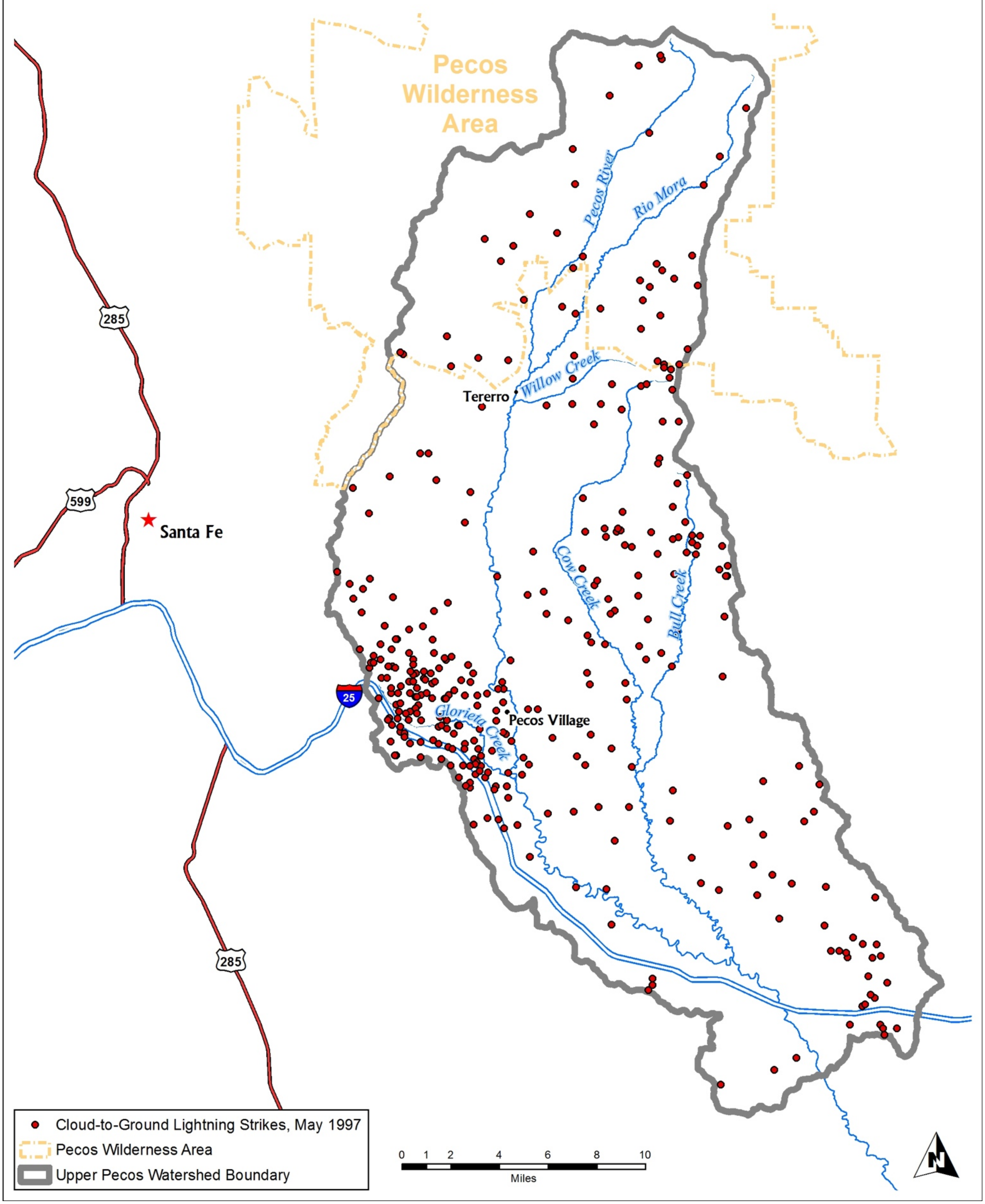
Lightning strikes seem to be relatively widely distributed throughout the watershed, but actual fires, from either lightning or human causes, are most concentrated in mid-elevation dry forests (ponderosa and dry mixed conifer) that have evolved with a regular cycle of burning every decade or two. The table below shows the total number of fire starts and acreage burned in the upper Pecos watershed by decade since 1970.

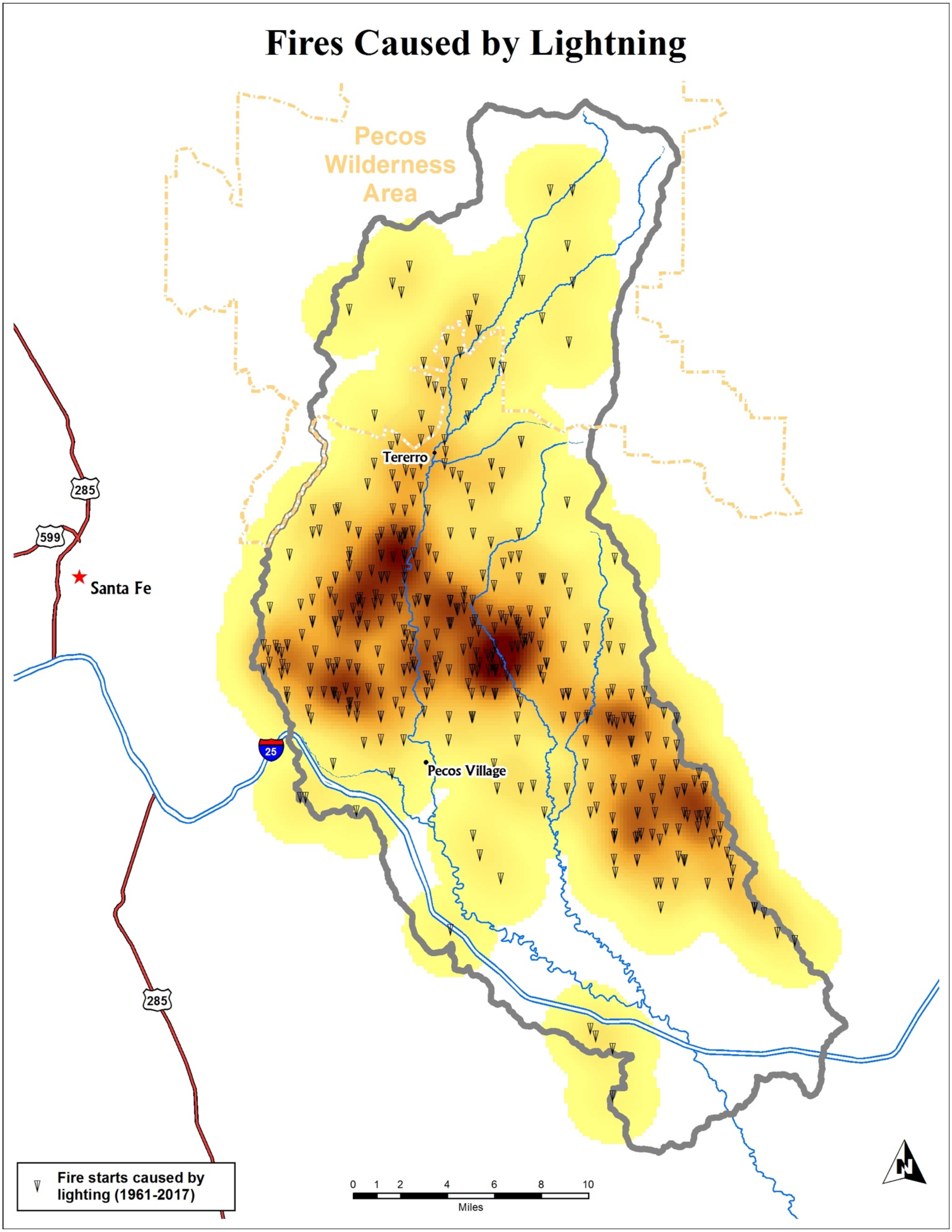
Upper Pecos fire starts from 1970

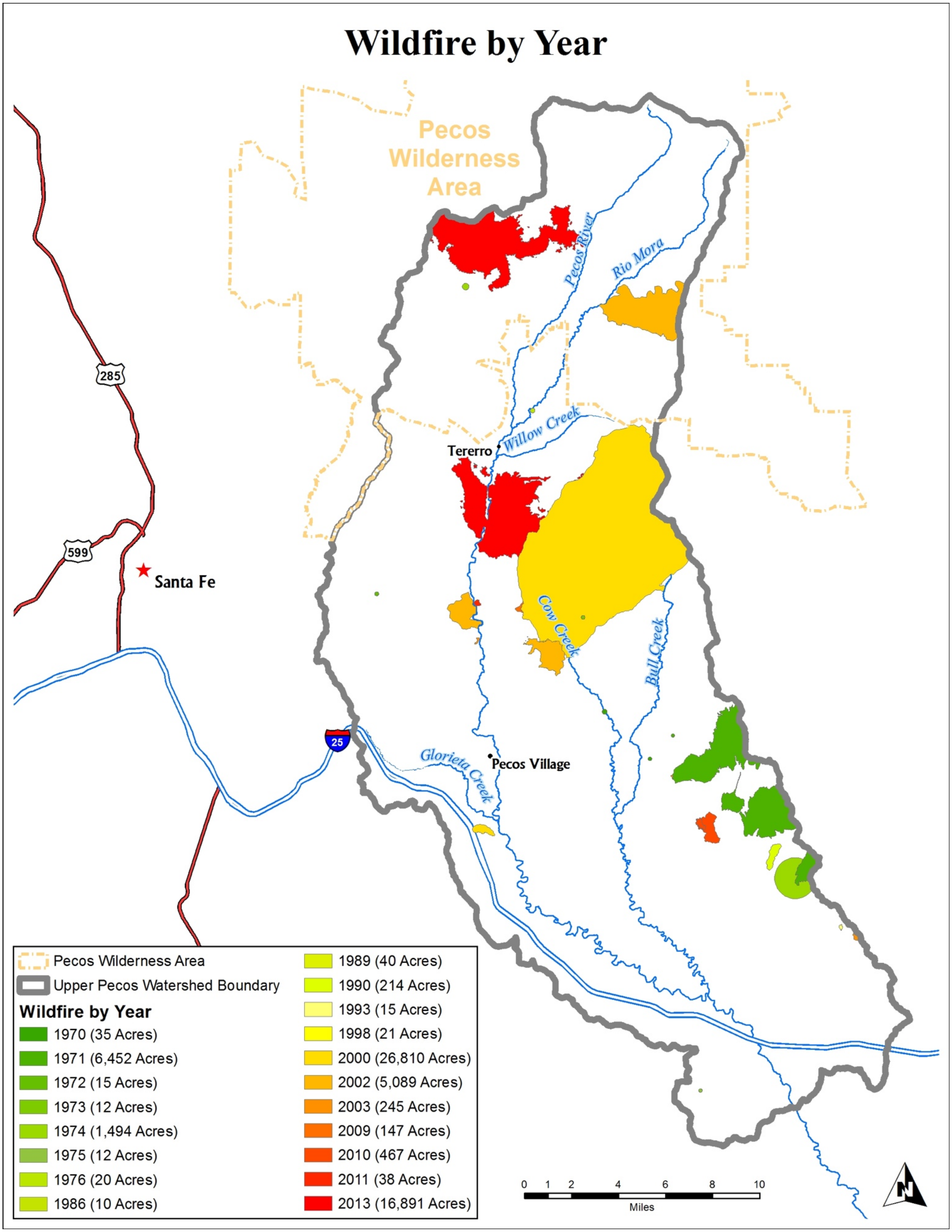
Decade	# fire starts	# fires >10 ac	Avg fire size (ac)	Total ac burned
1970s	160	10	92	14,674
1980s	102	2	1.3	130
1990s	82	1	1.1	91
2000s	144	9	254	36,563
2010-2017	87	3	153	13,276

The map on the following page shows the distribution of lightning ground strikes recorded by weather observation satellites during just one month – May of 1997. The next map, on page 13, shows lightning-caused fire starts (as distinct from the more numerous lightning strikes, most of which do not cause fires) in the Upper Pecos from 1961 through 2017 – concentrated in the ponderosa and lower-elevation mixed conifer forests. The third map, on page 14, shows the areas that have burned within the watershed since 1971.

Lightning Strikes




Fires Caused by Lightning
Pecos
Wilderness
Area
Tererro
285
599
Santa Fe
25
Pecos Village
285
Fire starts caused by
lighting (1961-2017)
0 1 2 4 6 8 10
Miles


Wildfire by Year
Pecos Wilderness Area
Pecos River
Rio Mora
Willow Creek
Tererro
Cow Creek
Bull Creek
Glorieta Creek
Pecos Village
Santa Fe
285
599
25
Pecos Wilderness Area
Upper Pecos Watershed Boundary
Wildfire by Year
1970 (35 Acres)
1971 (6,452 Acres)
1972 (15 Acres)
1973 (12 Acres)
1974 (1,494 Acres)
1975 (12 Acres)
1976 (20 Acres)
1986 (10 Acres)
1989 (40 Acres)
1990 (214 Acres)
1993 (15 Acres)
1998 (21 Acres)
2000 (26,810 Acres)
2002 (5,089 Acres)
2003 (245 Acres)
2009 (147 Acres)
2010 (467 Acres)
2011 (38 Acres)
2013 (16,891 Acres)
0 1 2 4 6 8 10
Miles
N

Fire suppression may seem an attractive option, given the increasing severity and larger area of typical wildfires after decades of fuel accumulation. However, continual fire suppression is counter-productive to the long-term health and sustainability of nearly every aspect of the watershed. Instead of small- to medium-size ground fires, we are now increasingly likely with each passing year to see large-scale, high-severity fires that affect multiple drainages simultaneously, creating wide-spread water quality issues instead of localized issues within one drainage or hillside.

In the absence of large-scale forest restoration along these lines, it is most assuredly a matter of when, rather than if, there will be a large-scale, stand-replacing fire in the Upper Pecos. If apparent recent trends towards warmer, drier, and more variable weather patterns continue, the probability and severity of fires in the Sangre de Cristo Mountains, as in many other places, will increase.

In 2013, two major wildfires occurred in the upper Pecos watershed, the Jaroso fire and the Tres Lagunas fire (Evans 2014). These fires, which were approximately equal in size, burned a combined 21,368 acres of forest at varying intensities. The map on page 17 shows the location and extent of these two fires. The Jaroso fire straddled the boundary of the upper Pecos watershed. The Tres Lagunas fire remained entirely within the watershed and reburned a portion of the area burned by the Viveash fire.

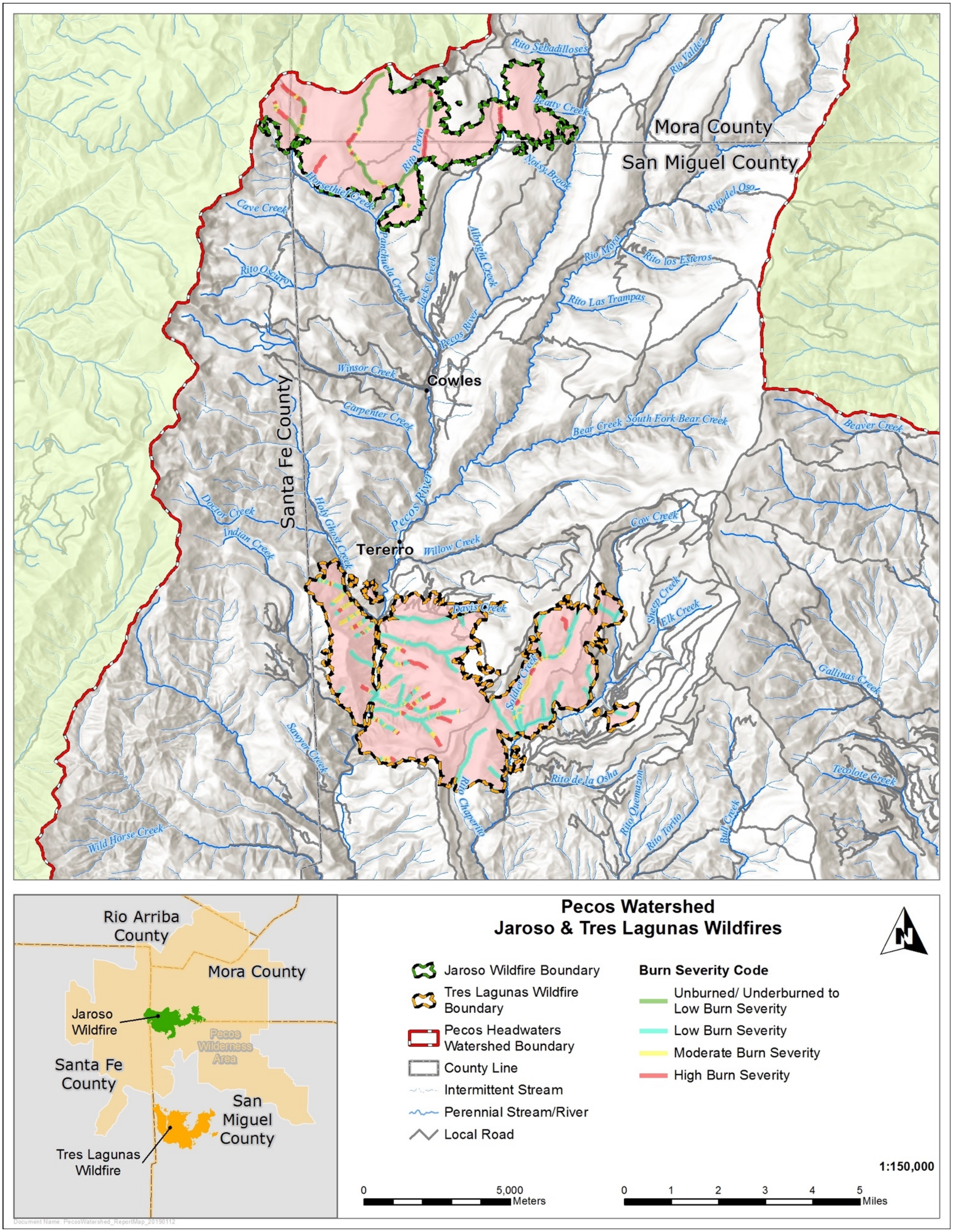
The Jaroso fire took place mostly within the Pecos Wilderness and was mostly allowed to burn because it did not threaten private property or loss of human life. Fire damage severity was high over most of the area it burned, although slightly over one third of the burn area experienced low severity damage. Approximately 10 percent experienced moderate damage.

The Tres Lagunas fire included significant areas of high severity, stand-replacing fire. Most of this high severity damage occurred in the Pecos River canyon. Most of the area within the Viveash burn scar experienced low intensity damage.

In a report prepared for the Tres Lagunas Fire, the US Forest Service Burned Area Emergency Response (BAER) Team predicted from 2.5 to 11 times normal erosion and runoff in the burned areas under an average 25-year rain storm event (USFS 2013). Heavy precipitation in the immediate post-fire period resulted in severe erosion and flooding in and below both burn areas. Soldier Creek in the Cow Creek basin was one of the hardest hit. Flood and fire damage to the creek and tributary drainages in Holy Ghost Canyon is shown in the photographs below.


The following photographs were taken in the aftermath of the Tres Lagunas Fire of an unnamed tributary drainage to the Pecos River located on the east side of the river approximately 0.86 mile south of Tererro.


The following two photographs were taken near Viveash Mesa in the aftermath of the Tres Lagunas Fire.

Pecos Watershed
Jaroso & Tres Lagunas Wildfires
Mora County
San Miguel County
Santa Fe County
Cowles
Tererro
Rito Sebadilloses
Rito Valdez
Beatty Creek
Noisy Brook
Rito del Oso
Horsethief Creek
Cave Creek
Panchuela Creek
Jacks Creek
Albright Creek
Rito Perro
Rio Mora
Rito los Esteros
Rito Oscuro
Rito Las Trampas
Pecos River
Winsor Creek
Carpenter Creek
Bear Creek
South Fork Bear Creek
Beaver Creek
Doctor Creek
Indian Creek
Holy Ghost Creek
Willow Creek
Cow Creek
Davis Creek
Sheep Creek
Elk Creek
Gallinas Creek
Soutier Creek
Sawyer Creek
Rito de la Osha
Tecolote Creek
Rito Chaperito
Rito Quemazon
Rito Torito
Bull Creek
Wild Horse Creek
Rio Arriba County
Mora County
Jaroso Wildfire
Pecos Wilderness Area
Santa Fe County
San Miguel County
Tres Lagunas Wildfire
Jaroso Wildfire Boundary
Tres Lagunas Wildfire Boundary
Pecos Headwaters Watershed Boundary
County Line
Intermittent Stream
Perennial Stream/River
Local Road
Burn Severity Code
Unburned/ Underburned to Low Burn Severity
Low Burn Severity
Moderate Burn Severity
High Burn Severity
N
1:150,000
0
5,000
Meters
0 1 2 3 4 5
Miles

Video of the post-fire flooding can be viewed on the UPWA Facebook page here: https://www.facebook.com/109064291171/videos/10202072564281427/?t=4

A news report on the flooding by KRQE News with video of the post-fire flooding can be viewed here: https://www.youtube.com/watch?v=5vOO3AKG5Q0

The following photograph was extracted from the video on the UPWA Facebook page.

The long-term observable effects of the post-fire flooding were bank erosion, loss of floodplains, entrenchment, and a broad, shallow channel with few or no deep pools. Recovery from these fires has been very slow and primarily manifested in the form of revegetation. In the immediate aftermath of the fire, steep slopes were aerial seeded with barley (*Hordeum vulgare*), little bluestem (*Schizachyrium scoparium*), muttongrass (*Poa fendleriana*), and slender wheatgrass (*Elymus trachycaulus*) in an effort to minimize the severity of anticipated erosion. Five years later, the dominant species in the herbaceous layer on the upper slopes of Holy Ghost Canyon continues to be slender wheatgrass. Native herbaceous species are not returning quickly.

2.2 Climate

Weather in the watershed is much different in the lower elevations below the Sangre de Cristo Mountains than in the upper elevations in the mountain headwaters. Pacific storms provide most of the winter moisture for the Upper Pecos watershed, with an annual average of 27 inches of snowfall in the village of Pecos. From July through September, moisture primarily from the Gulf of Mexico brings monsoon rains that occur as thunderstorms, and often cause short-term flash flooding in the Pecos and its tributaries. In the lower elevations of the watershed, average annual precipitation is about 16 inches, but it can be as high as 44 inches in the higher slopes of the mountain headwaters.

The only weather station currently in operation within the watershed is located at the ranger station in the village of Pecos. The following table summarizes the climatic information collected at the Pecos weather station for the period from 1916 to 2016.

Pecos Ranger Station Climate Summary

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temp. (F)	47.1	49.9	55.4	63.9	73.4	83.1	85.3	82.5	77.2	67.4	55.3	55.3	65.8
Average Min. Temp. (F)	15.1	19.2	23.5	30.0	38.2	47.0	52.9	51.6	44.2	33.7	23.1	16.5	32.9
Average Total Precip. (in.)	0.70	0.68	0.91	0.84	1.17	1.21	2.91	3.21	1.88	1.22	0.69	0.69	16.15
Average Total Snowfall (in.)	5.6	5.0	5.5	1.8	0.3	0.1	0.0	0.0	0.0	0.5	2.5	5.8	27.2
Average Snow Depth (in.)	1	0	0	0	0	0	0	0	0	0	0	1	0

2.3 Geology

The main core of the Sangre de Cristo Mountains is composed of Pre-Cambrian igneous and metamorphic rocks, resulting from or altered by past volcanic activity. These rocks are overlain by Paleozoic sandstones, shales, and limestones. Prominent sedimentary formations are composed of both marine and non-marine sediment of the Pennsylvanian Era. The steep canyons of the Pecos Valley have been carved through the layers of sedimentary rock, in some cases down to the Pre-Cambrian basement rock. Permian sandstones, conglomerates, and shales are also exposed towards the southern end of the watershed, south of the Village of Pecos. Perhaps the most important way that underlying geology influences the watershed is in the nature of the soils that derive from the different parent rocks, and in the erosion and runoff characteristics of these soils.

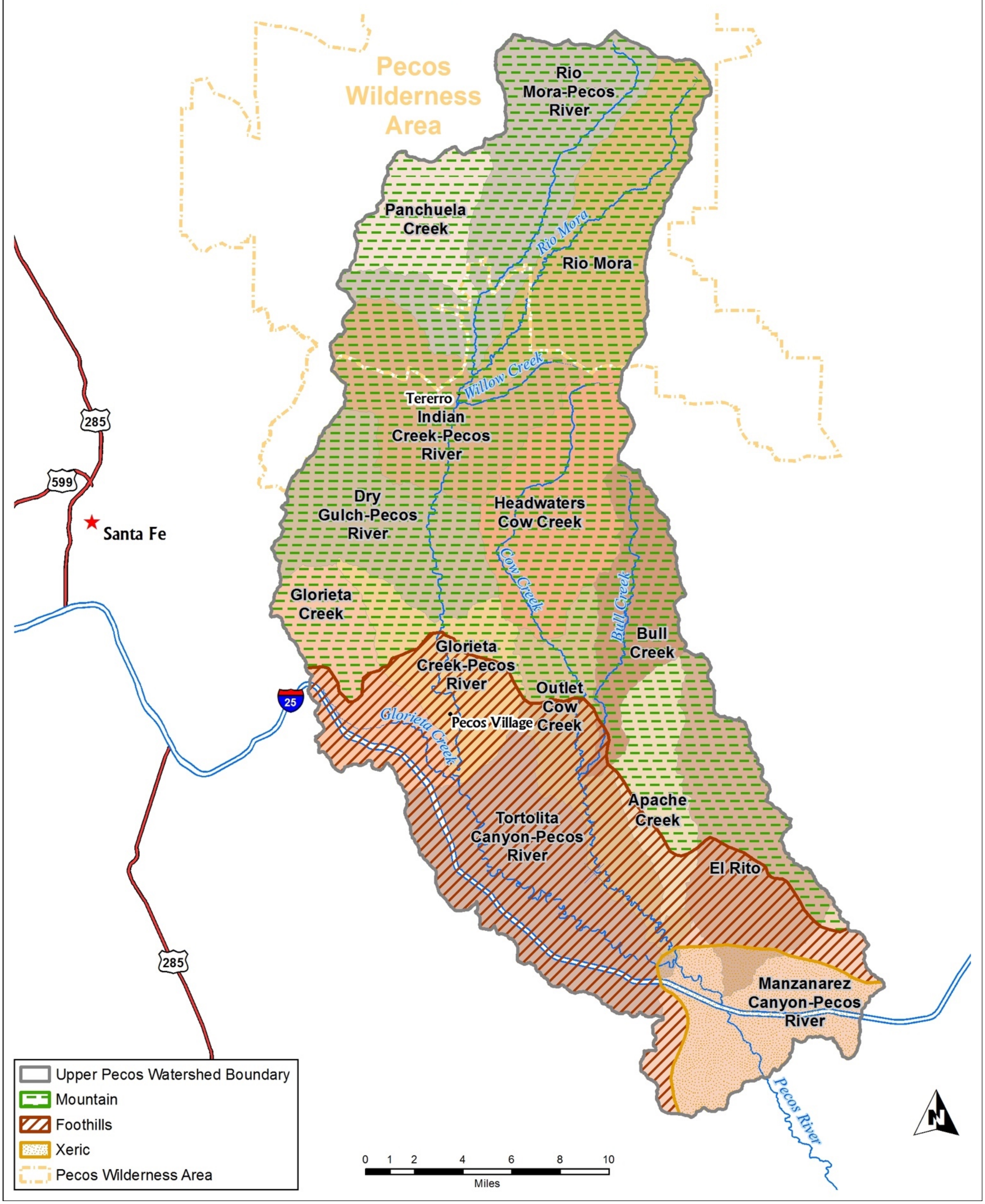
2.4 Soils, Sedimentation, and Erosion Classes

The soils in the region, except in high-elevation alpine areas, are typically sandy loam or loam with significant amounts of gravel, cobble, and boulders. Soils in the meadows and riparian areas of the forested uplands are finer textured than soils on adjacent slopes. From a water quality and watershed protection standpoint, the erodibility of a soil class is perhaps its most important characteristic, and many of the soils in this watershed are highly erodible.

A 2010 study by Tetra-Tech, Inc. (funded by the New Mexico Environment Department and EPA) analyzed data on both streambed and suspended sediment in a large sample of streams in New Mexico, eastern Arizona, and southern Colorado in relation to both disturbance patterns and geographical location. The focus of the study was to evaluate and suggest potential numerical sediment levels that would be valid indicators of disturbance or lack of it in New Mexico streams. These suggestions of sediment levels (percentages of different size classes of stream bottom sediment) are preliminary and have no regulatory status, but one significant finding of the study is that the percentages of sediment size classes present in relatively undisturbed streams is quite different in different geographical zones, based primarily on altitude and topography (with associated differences in vegetation types). In terms of expected background sediment transport levels in streams, the study found three relevant geographic or land-form types within New Mexico: mountain, foothill, and xeric zones.

Typical sediment class landforms in the upper Pecos Foothills (above), mountain (upper right), and xeric (lower right).

Landscape Overview



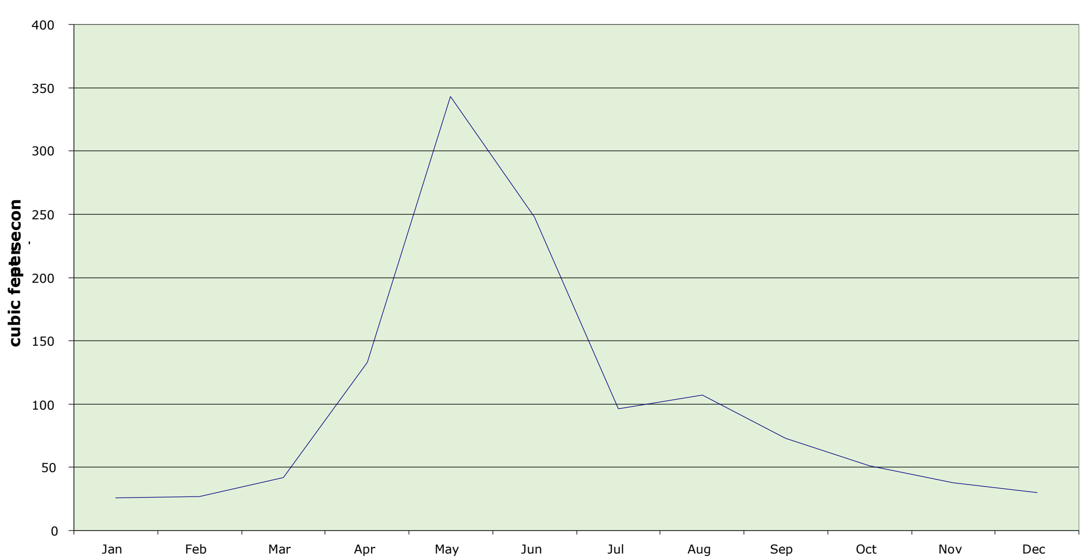
It is not surprising that the volume and composition of sediment appropriate or natural in streams would be different in a mountainous setting with very little fine sediment in undisturbed settings, as compared to a lower-altitude stream flowing through sandy valley fill. The Tetra-Tech report provides some numerical confirmation of this. It is relevant to watershed planning in the Upper Pecos primarily because all three sedimentation zones are found (and have been mapped) within the watershed, and the amounts of sediment that are acceptable or appropriate will be different in the different zones. It follows that the kinds of stream conditions and restoration practices that make sense in the mountain zone may be different than those in the foothill or xeric zones. For instance, a trampled bank contributing muddy runoff above Cowles is a much more “unnatural” situation, and affects the background water quality at that location more, than the same extent of disturbance near Interstate 25. Conversely, lower-altitude riparian ecosystems require a certain degree of geomorphological disturbance – erosion and sandbar deposition – to create conditions for new vegetation to sprout and become established.

2.5 Hydrology

The upper Pecos River and its tributaries flow through mountainous valleys that can be quite steep in their upper reaches. The highest elevation on the Pecos watershed is over 13,000 feet above sea level and is well above timberline. Streams in the upper Pecos watershed consist primarily of Rosgen classification types A and B in the mountainous headwaters (generally above the village of Pecos) and type C below the village. Rosgen types A and B stream channels are found along the higher-elevation stream reaches that tend to run straight and fast in narrow channels through steep, narrow valleys with little sediment and shallow streambank soil. Their course is largely controlled by the geology and shape of the surrounding valley, and they are not very sinuous. Streams in the lower lying areas are usually Rosgen type C channels, with slower flow rates, more valley floor sediment, and greater sinuosity. Stream reaches, especially those found in the middle and lower elevations, are typically (but not always) bordered by a 30 to 100-foot band of riparian vegetation that includes varying sizes of wetland areas.

The flow regimes for both stream types are dominated by springtime snowmelt runoff, followed by smaller, more localized, and more unpredictable secondary rises during the summer monsoons. The average flow rates for the Pecos River at the USGS gauging station near the Village of Pecos are shown in the graph below, while the major tributaries and sub watersheds of the upper Pecos are shown on the map on Page 2 above.

Pecos River near Pecos - Monthly Average Flows



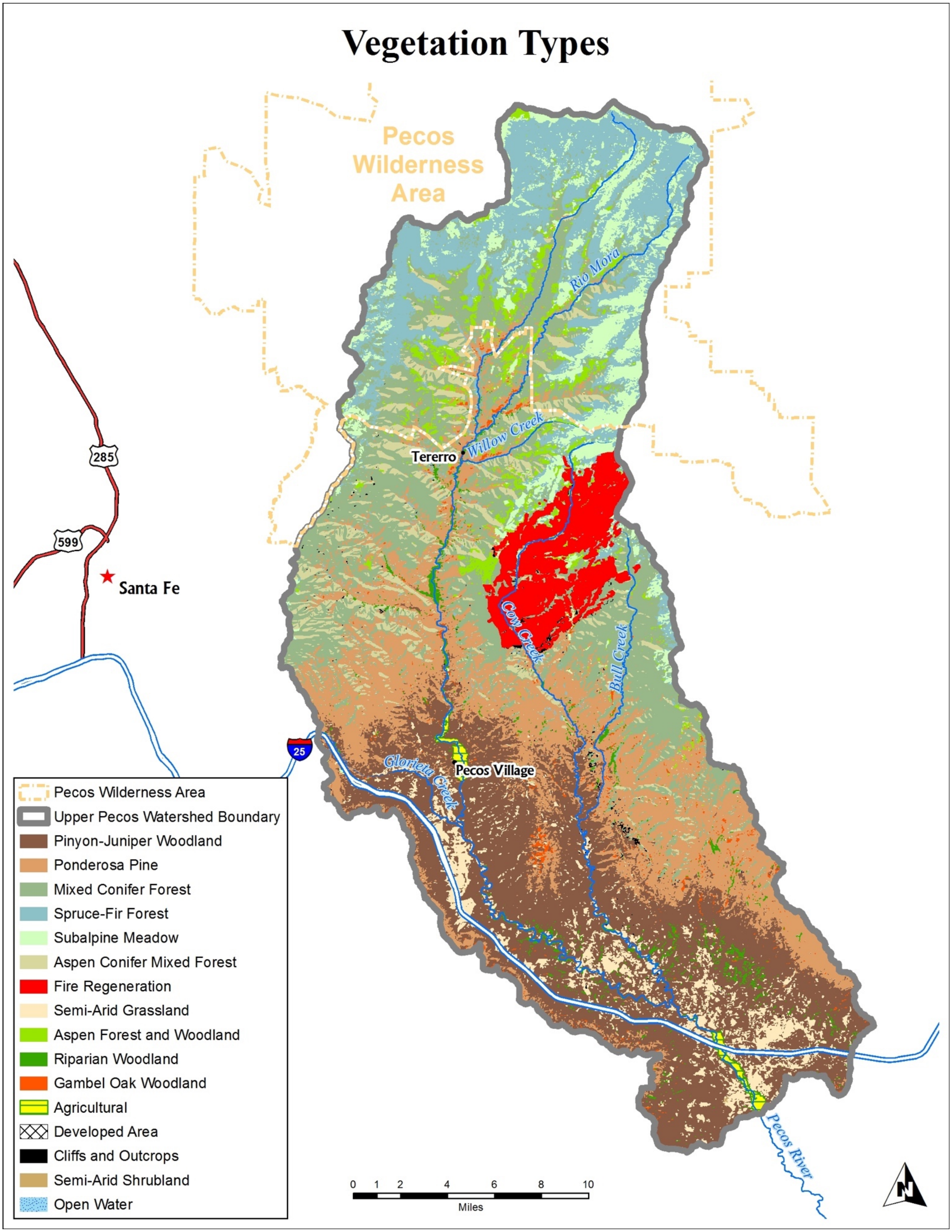
2.6 Vegetation

At the higher elevations of the watershed, from approximately 9,000 feet to tree line at 11,000 feet or more, Engelmann spruce is the dominant plant species, forming the primary forest canopy along with white and sub-alpine fir in about 11% of the watershed. Douglas fir and other mixed conifers are typically dominant between about 8,000 and 10,000 feet, covering about 19% of the watershed area; although a similar conifer mix with a significant fraction of aspen present covers another 5% of the watershed. Ponderosa pine dominates almost 20% of the area, at elevations between 7,000 and 9,500 feet, and is found mostly on south and west facing slopes at the higher elevations and north or east facing slopes at the lower elevations. At the lower elevations of the watershed, vegetation is dominated by piñon-juniper and oak woodlands, with some areas of grassland as well as savannahs with more scattered juniper and grass. High-altitude meadows (like Hamilton Mesa) and aspen groves are evident in much of the higher-altitude and more northerly parts of the watershed, but do not make up a large fraction of the total area. The table below shows the principal vegetation types present in the watershed, and the acreages and percentages of land dominated by each. The map on the next page illustrates the location of major vegetation types in the watershed.

Upper Pecos watershed vegetation types

Vegetation Type	Total Acreage	Percentage
Pinyon-Juniper Savannah and Woodland	85,328	23.7%
Ponderosa Pine	70,925	19.7%
Mixed Conifer Forest	70,445	19.6%
Spruce-Fir Forest	40,440	11.2%
Subalpine Meadow and Grassland	21,355	5.9%
Aspen Conifer Mixed Forest	17,186	4.8%
Fire Regeneration (oak, aspen, and herbaceous vegetation)	17,089	4.8%
Semi-Arid Grassland	15,593	4.3%
Aspen Forest and Woodland	10,186	2.8%
Riparian Woodland	5,322	1.5%
Gambel’s Oak Woodland	2,895	0.8%
Agricultural	1,602	0.4%
Developed Area	1,289	0.4%

Due to a long-standing policy of fire suppression, tree stands in many places are dense, even aged, and often form a closed canopy. Historically, fire frequency would have been much higher in almost the entire watershed. In addition to intentional suppression of forest fires, grazing in the forested areas by cattle as well as elk and deer would have reduced the grass that would have been the fuel for frequent, low-intensity fires, making them less frequent and contributing to an eventual increase in tree density as seedlings were no longer killed by frequent but low-intensity fires. There is considerable scope for restoration forestry over the coming years throughout much of the watershed.


Vegetation Types
Pecos Wilderness Area
Rio Mora
Willow Creek
Tererro
285
599
Santa Fe
Cow Creek
Bull Creek
25
Pecos Village
Glorieta Creek
Pecos River
Pecos Wilderness Area
Upper Pecos Watershed Boundary
Pinyon-Juniper Woodland
Ponderosa Pine
Mixed Conifer Forest
Spruce-Fir Forest
Subalpine Meadow
Aspen Conifer Mixed Forest
Fire Regeneration
Semi-Arid Grassland
Aspen Forest and Woodland
Riparian Woodland
Gambel Oak Woodland
Agricultural
Developed Area
Cliffs and Outcrops
Semi-Arid Shrubland
Open Water
0 1 2 4 6 8 10
Miles
N

2.7 Endangered Species

There are two federally endangered species and one candidate species present within our watershed, including the Holy Ghost ipomopsis, that is endemic here and found nowhere else. A brief summary of information about these species follows below.

2.7.1. Holy Ghost Ipomopsis (endangered)

The Holy Ghost Ipomopsis is a short-lived perennial plant (very similar to star gilia) that grows to about 2 feet tall and produces showy pink flowers. It is known to exist only in Holy Ghost Canyon, where it is found in open areas within the ponderosa zone. The decline of this species and its restricted population may be a result of decreased fire frequency (hence fewer sunny openings) in forested areas. It now occurs mostly in road cuts and other areas opened up by human disturbance. Increasing the openings within existing ponderosa pine forests would likely increase the amount of open habitat available for the Holy Ghost Ipomopsis, although fire suppression has been the priority of the Forest Service in areas where the Holy Ghost Ipomopsis was historically found.

2.7.2. Mexican Spotted Owl (endangered)

The Mexican Spotted Owl is dependent on old-growth forest and healthy riparian areas. This species' decline is attributed to habitat degradation and habitat loss. It is unclear from published reports if or when Mexican Spotted Owls were found within the watershed, and how numerous they would have been, within the upper reaches of the watershed before logging and fire-suppression affected the composition and structure of these forests.

2.7.3. Rio Grande Cutthroat Trout (candidate species for listing as endangered)

The Rio Grande cutthroat trout (RGCT) is the only salmonid fish native to the Rio Grande (including the Pecos) watershed. For decades it has been outcompeted or hybridized with introduced trout (mostly rainbow or brown trout) throughout almost all of its former range. In 1992 through 1996, the New Mexico Department of Game and Fish reintroduced RGCT in Jacks Creek but with little success. Today, the upper reaches of the Pecos (above Pecos Falls) and the upper reaches of Macho, Dalton, and Jacks Creek still harbor small, pure populations of native Pecos strain RGCT. Upper Doctor Creek, also has a very small population of RGCT, which appears to be slightly hybridized based on mitochondrial DNA analysis (Eric Frey, pers. comm. August 15, 2011). Restoration of Pecos strain Rio Grande Cutthroat trout to the upper reaches of the Pecos and its tributaries (i.e. above Cowles) has become more urgent than ever with the damage done by the recent Jaroso fire.

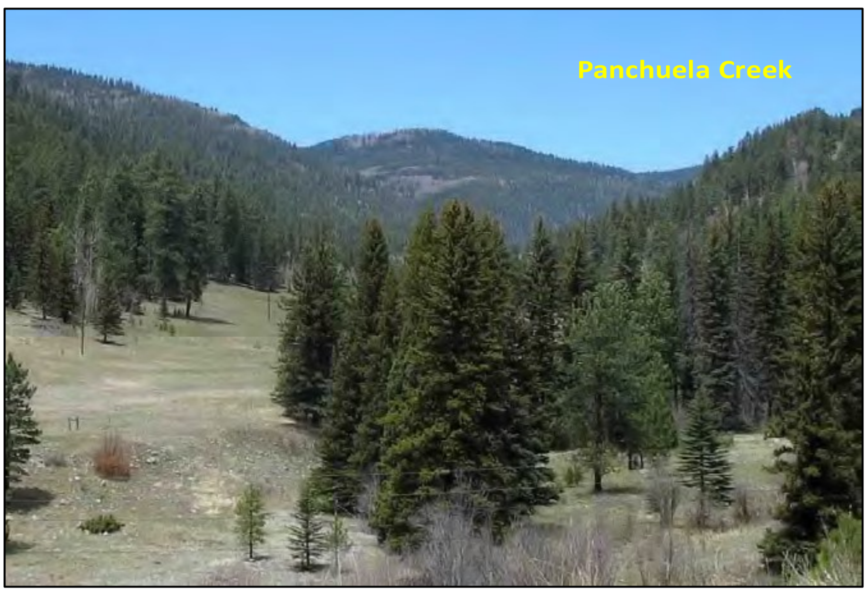
Like other salmonids, RGCT require cool water with adequate levels of dissolved oxygen, with low levels of stream bottom sediment and turbidity. They also require complete protection from non-native fish.

2.8 Sub-Watershed Information

An overview and key characteristics of the twelve sub-watersheds (defined by 12-digit hydrologic unit codes, or HUCs) of the upper Pecos are presented on the following pages. The locations of the sub-watersheds described below can be seen in the map on page 3.

2.8.1. Panchuela Creek

Area	14,386 ac.
Sedimentation category	100% Mountain
Principal perennial streams	Panchuela Creek; Horsethief Creek; Cave Creek
Stream length, perennial streams	21.9
Principal vegetation classes	Mixed conifer; spruce-fir
Impairment status	Fully supporting
Restoration needs	Bank protection in Panchuela Campground; possible reintroduction of Rio Grande cutthroat trout and encouragement of beaver in the wilderness.



The Panchuela Creek sub-watershed is entirely a high-altitude montane landscape, dominated by spruce-fir and mixed conifer forest, with some aspen stands. For all practical purposes it is located entirely within the Pecos Wilderness. Watershed conditions are good and the only restoration needs found were very limited streambank protection for a few places within the Panchuela campground and perhaps isolated trail maintenance issues.

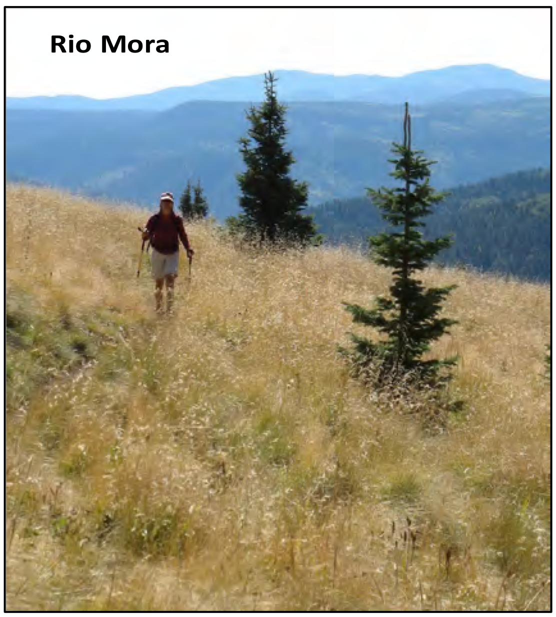
2.8.2. Rio Mora – Pecos River

Area	37,112 ac.
Sedimentation category	100% Mountain
Principal perennial streams	Pecos River; Jack's Creek; Winsor Creek; Carpenter Creek
Stream length, perennial streams	66.6
Principal vegetation classes	Mixed conifer; spruce-fir
Impairment status	Fully supporting
Restoration needs	Bank repair and protection at heavily-used access points; streambank revegetation around recreation sites; possible re-introduction of Rio Grande cutthroat trout and encouragement of beaver in the wilderness.

Like Panchuela Creek, the great majority of the Rio Mora-Pecos River sub-watershed is within the Pecos Wilderness, and is almost entirely covered in spruce-fir and mixed conifer forest, with scattered aspen and a few alpine meadows. Within the watershed proper, there are no identified restoration needs, with the possible exception of encouraging additional beaver presence in the wilderness, which would favor more perennial low flows in streams with beaver dams and enhance fish habitat. There are also opportunities to re-introduce populations of Rio Grande cutthroat trout. Stream bank restoration needs are concentrated in the area near Cowles and associated recreational areas, and near the Rio Mora confluence, and center around protecting banks from damage from intense foot traffic, and enhancing native riparian vegetation for bank protection and stream shading.

2.8.3. Rio Mora

Area	34,394 ac.
Sedimentation category	100% Mountain
Principal perennial streams	Rio Mora, Rio Valdez, Rito del Oso, Rito los Esteros, Rito las Trampas, Bear Creek
Stream length, perennial streams	44.9
Principal vegetation classes	Subalpine meadow, aspen; mixed conifer; spruce-fir
Impairment status	Fully supporting
Restoration needs	Bank repair and re-configuration of Mora campground; possible re-introduction of Rio Grande cutthroat trout and encouragement of beaver in the wilderness.



The Rio Mora sub-watershed is, like the other two high-altitude Pecos sub-watersheds, almost entirely within the Pecos Wilderness and is extensively forested with mixed conifer and spruce-fir vegetation types that include aspen stands of varying sizes. The Rio Mora, however, also includes some large sub-alpine meadows like those on Hamilton Mesa. The only identified restoration need is a re-design of the NM Game and Fish Department Mora campground, to repair streambanks damaged by many years of inappropriate vehicle access, heavy foot traffic, and high-water flooding of roads and camping areas. Similar opportunities for reintroduction of cutthroat trout and encouragement of beavers may exist within the Mora sub-watershed as well as the Rio Mora–Pecos.

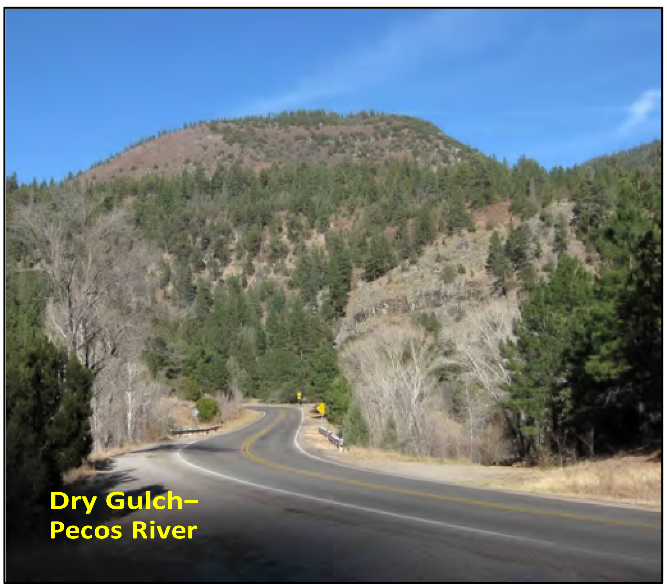
2.8.4. Indian Creek – Pecos River

Area	29,003 ac.
Sedimentation category	100% Mountain
Principal perennial streams	Pecos River, Willow Creek, Holy Ghost Creek, Doctor Creek, Indian Creek
Stream length, perennial streams	27.5
Principal vegetation classes	Mixed conifer; ponderosa; aspen
Impairment status	Fully supporting (except Willow Creek; Not supporting)
Restoration needs	Bank repair and protection at heavily-used access points; streambank revegetation around recreation sites; in-stream fish habitat improvement; conductivity investigation at Willow Creek.

The Indian Creek sub-watershed of the Pecos River, like those above it, is entirely mountainous and vegetation is still dominated by mixed conifer stands, although many south-facing hillsides support large stands of ponderosa, reflecting lower elevations. There are large stands of mixed aspen along with the mixed conifer, as well. The upper reaches of Holy Ghost Creek and its watershed are within the Pecos Wilderness, but the rest of the Indian Creek/Pecos River sub-watershed is not wilderness, and there are public fishing access sites along the Pecos River and Game and Fish campgrounds near Tererro, along with the Forest Service Holy Ghost campground. Restoration needs focus on the Pecos River and its banks and riparian areas, particularly near the popular public access sites.

2.8.5. Dry Gulch - Pecos River

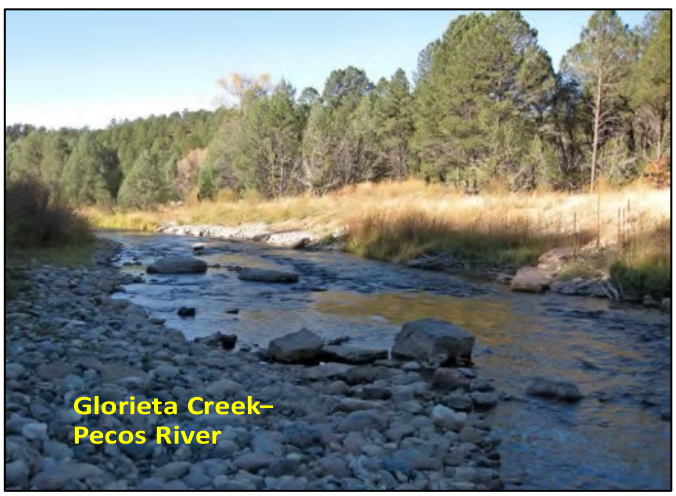
Area	27,254 ac.
Sedimentation category	100% Mountain
Principal perennial streams	Pecos River, Macho Creek, Dalton Canyon Creek, Wild Horse Creek
Stream length, perennial streams	23.9
Principal vegetation classes	Ponderosa; aspen, mixed conifer
Impairment status	Fully supporting (Pecos R.); Not supporting (Macho and Dalton Cr.)
Restoration needs	Bank repair and protection; runoff management from large areas of bare ground at recreational sites; streambank revegetation around recreation sites; conductivity investigation at Macho and Dalton Creeks.



Most of the area of this sub-watershed is actually the drainages for Macho and Dalton Canyons, although there is a great deal of recreational use of the Pecos River within this reach. There are popular public sites like the Forest Service Field Tract campground and the Windy Bridge, Dalton Day Use, and Dalton Fishing Access sites; dispersed camping in Dalton Canyon, and many private land holdings. The forest in this area becomes more dominated by ponderosa, although north facing slopes are still largely mixed conifer stands, with frequent aspen among the conifers. Restoration needs focus primarily on the fish habitat restoration in the Pecos River, and protecting stream banks from excessive recreational impacts.

2.8.6. Glorieta Creek – Pecos River

Area	20,252 ac.
Sedimentation category	42% Mountain; 58% Foothills
Principal perennial streams	Pecos River, Alamitos Creek
Stream length, perennial streams	9.1
Principal vegetation classes	Piñon-juniper, ponderosa
Impairment status	Fully supporting (Pecos R. above Alamitos Cr.); Not supporting (Pecos R. from Alamitos Cr. to Cañon de Manzanita)
Restoration needs	Water quality protection in this reach may be best served by collaborating with agencies on land use and waste disposal planning; some fish habitat and bank vegetation projects could still be done on private land, even though some have already been completed.



This sub-watershed includes the village of Pecos, Lisboa Springs fish hatchery, and the Monastery Lake recreation site. The UPWA "Hatchistery" project is also located here. Extensive in-stream habitat restoration has been completed on private land both above and below the Village of Pecos, and further needs may be present in this reach, but it has not been possible to determine for sure or to identify projects on private land. Some recreational improvements at Monastery Lake would be desirable. Other concerns in this sub-watershed include septage contamination of ground water, trash disposal, and some other land-use and development issues. Vegetation is mostly ponderosa pine in the northern part of the sub-watershed, grading into piñon-juniper in the southern areas. There are some appreciable lower-altitude grasslands east of the Pecos River below the Glorieta Creek confluence.

2.8.7. Tortolita Canyon - Pecos River

Area	38,367 ac.
Sedimentation category	99% Foothills; 1% Xeric
Principal perennial streams	Pecos River
Stream length, perennial streams	22.1
Principal vegetation classes	Grassland, piñon-juniper
Impairment status	Fully supporting
Restoration needs	Tree planting (for shade and seed) along Pecos River.

The Tortolita Canyon sub-watershed is the lowest, or furthest downstream complete sub-watershed within the Upper Pecos watershed. Land cover is dominated by piñon-juniper scrub, grading into savanna, with some patches of grass and occasional Gambel oak woodlands. The Pecos River flows within a shallow sandstone canyon for most of this reach, and there are no perennial tributaries, as the sub-watershed boundaries coincide with the Glorieta Creek confluence at the upstream end and the Cow Creek confluence at the southern end. While there is healthy riparian vegetation along the Pecos River for most of this reach, it is largely coyote willow and herbaceous plants; there are few full-size trees near the stream bank – where present, they are generally located at some distance (100 feet or more) from the actual riverbank.

2.8.8. Glorieta Creek

Area	21,416 ac.
Sedimentation category	45% Mountain; 55% Foothills
Principal perennial streams	Glorieta Creek
Stream length, perennial streams	15.3
Principal vegetation classes	Grassland, piñon-juniper
Impairment status	Not supporting (standards under review)
Restoration needs	Conductivity investigation at Glorieta Creek.

Vegetation in this sub-watershed is largely ponderosa in the upper reaches, with some mixed conifer on the northern slopes of the headwaters, and piñon-juniper in the lower half or so of the area. Glorieta Creek is listed as not attaining standards because of excessive conductivity below the Glorieta Conference Center wastewater treatment plant. The presence of the Conference Center, along with fairly dense (if rural) residential development that depends on septic tanks for liquid waste disposal, suggests a possible source for the dissolved material causing the conductivity; but additional investigation is needed to determine the actual source(s).

2.8.9. Headwaters Cow Creek

Area	27,622 ac.
Sedimentation category	100% Mountain
Principal perennial streams	Cow Creek, Soldier Creek, Elk Creek, Rito de la Osha, Rito Manzanares, Rito Torito
Stream length, perennial streams	36.4
Principal vegetation classes	Fire regeneration (includes grassland, Gambel oak, aspen, and conifer seedlings); mixed conifer
Impairment status	Not supporting
Restoration needs	Streamside vegetation; better runoff management; occasional stream narrowing; some natural stream channel restoration in areas of excessive erosion along roads etc.

The majority of the Headwaters Cow Creek sub-watershed was affected by the Viveash fire of 2000 and the Tres Lagunas fire of 2013, and vegetation is classified as "Fire regeneration", which includes primarily early-successional oak, aspen, conifer seedlings, and grasses. Areas not affected by the fire are mainly dominated by high-altitude mixed conifer forest, with some spruce-fir and subalpine meadow at the highest altitudes. Most of the sub-watershed is Forest Service land, but there are appreciable private inholdings totaling thousands of acres altogether. This entire reach of Cow Creek is listed as non-attaining because of excessive water temperatures, suggesting a need for additional streamside vegetation for shade, and some scope for correcting excessive stream width in places. There are also opportunities to keep runoff from roads and parking/camping areas from draining directly into Cow Creek and its tributaries, raising water temperature as well as bringing excessive sediment into the streams.

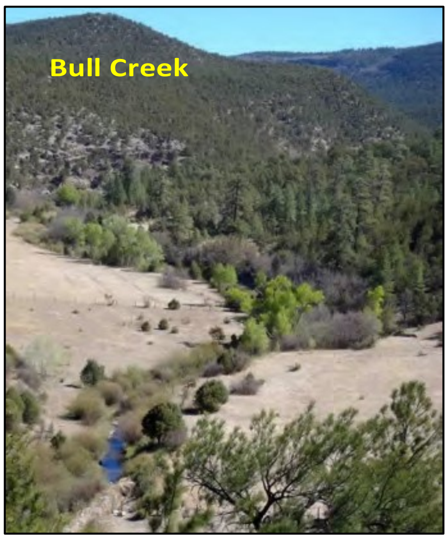
2.8.10. Outlet Cow Creek

Area	22,253 ac.
Sedimentation category	31% Mountain, 68% Foothills, 1% Xeric
Principal perennial streams	Cow Creek
Stream length, perennial streams	24.6
Principal vegetation classes	Gambel oak, piñon-juniper, ponderosa
Impairment status	Not supporting
Restoration needs	

Very little of this sub-watershed is accessible by road, and the majority is private land, making it very difficult to obtain direct information about watershed conditions. This reach of Cow Creek also fails to attain standards because of high temperatures, and examination of air photos suggests considerable opportunity for additional streamside vegetation, but actual riparian conditions could not be observed in the field for most of the reach. Site visits around the village of North San Ysidro identified a deeply incised channel and heavy sedimentation from agricultural runoff and riparian vegetation clearing by landowners. Stream restoration will be crucially dependent on collaboration with private landowners.

2.8.11. Bull Creek

Area	17,590 ac.
Sedimentation category	95% Mountain, 5% Foothills
Principal perennial streams	Bull Creek, Rito Ruidoso
Stream length, perennial streams	21.6
Principal vegetation classes	Ponderosa, mixed conifer
Impairment status	Fully supporting
Restoration needs	Streamside vegetation and grazing management



The upper reaches of Bull Creek are very similar to the un-burned parts of upper Cow Creek – pockets of spruce-fir and aspen among extensive mixed conifer. However, the Bull Creek sub-watershed extends through large areas of ponderosa and includes some piñon-juniper country by the time it reaches Cow Creek halfway along the reach of Cow Creek in the Outlet sub-watershed. Like the headwaters of Cow Creek, the majority of land in the sub-watershed is Forest Service, but there are some large private in-holdings, including land along the Creek. Although Bull Creek attains temperature and other water quality standards at present, there are reaches along at least one meadow where there is a need/opportunity for additional shade along the stream.

2.8.12. Apache Creek

Area	14,068 ac.
Sedimentation category	74% Mountain, 26% Foothills
Principal perennial streams	Apache Creek, Rito de la Vega
Stream length, perennial streams	May not be perennial
Principal vegetation classes	Piñon-juniper, ponderosa
Impairment status	Not assessed
Restoration needs	Streamside vegetation and grazing management; road erosion and runoff control

Apache Creek was not assessed for attainment of water quality standards, and may not be perennial in all years. Its upper reaches were flowing when visited for this study, and there are meadows where cattle grazing appears to have prevented any trees or shrubs at all from becoming established along the stream, and cattle are contributing to damaged streambanks. There are also some road segments in need of culvert replacements and other erosion control.

2.8.13. El Rito

Area	28,219 ac.
Sedimentation category	56% Mountain, 37% Foothills, 7% Xeric
Principal perennial streams	El Rito, Sebadilla Creek, Commissary Creek
Stream length, perennial streams	28.7
Principal vegetation classes	Grassland, piñon-juniper, ponderosa
Impairment status	Not assessed
Restoration needs	Streamside vegetation and grazing management; road erosion and runoff control.

Like Apache Creek, El Rito was not assessed for attainment of water quality standards, presumably because it also may not be truly perennial. The stream is only called El Rito for its lower few miles, after the confluence of Sebadilla Creek and Commissary Creek. The upper reaches of both were flowing when visited for this study. There are meadows on Sebadilla Creek where cattle grazing appears to have prevented any trees or shrubs at all from becoming established along the stream, and cattle are contributing to damaged streambanks and clear water quality degradation. The Forest Service has done substantial thinning in the ponderosa forest in this sub-watershed.

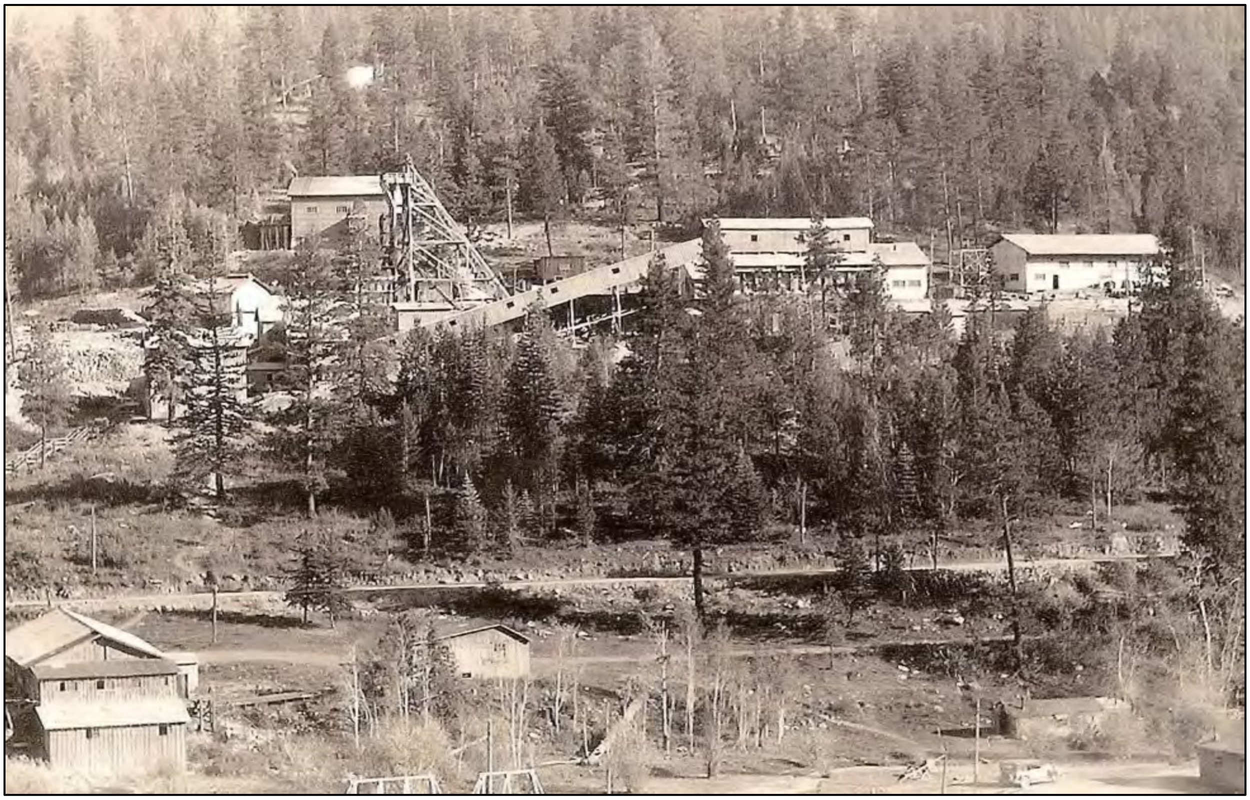
2.9 Human Activities and Influences

There has been a long history of human visitation and occupation in the Pecos valley, beginning in prehistory. However, the effects of human activities on the watershed and water quality increased dramatically in the 19th and 20th centuries, especially with larger-scale ranching and industrial activities like mining and road construction. Later in the 20th century, there have been significant restoration activities and improvements in water quality, as well. The more significant human effects on the watershed are discussed below.

2.9.1. Mining

The Tererro mine ("Tererro" means mine dump in Spanish) operated at the confluence of Willow Creek and the Pecos River between 1882 and 1939. Mining activities were relatively small-scale from 1882 until 1925, when the American Metals Company took over the mine and expanded both mining and milling operations dramatically (see photographs on next page). Between 1926 and 1939, the mine produced approximately 2,200,000 tons of lead and zinc ore (Robinson 1995). Ore was transported aerial tram-cars to the mill in El

Molino (near the village of Pecos) for processing. Large amounts of mine tailings were disposed of at three sites, and some tailings at the mine site were dumped into the Pecos River.



In the 1950s, the State of New Mexico obtained the land where the mine and the mill had operated. Mine tailings were used for construction projects between the mine and the Village of Pecos. Additional roads projects, federal and state campgrounds, the Lisboa Springs Fish Hatchery, also utilized mine tailings in their construction. Mine tailings were also used by residents for an unknown number of undocumented construction projects.

In 1985 and 1986, the New Mexico Environment Department (NMED) began investigating contamination issues and concerns about water quality in the area raised by residents as these related to the Tererro mining operations. In 1991, contaminants carried into the Pecos River were responsible for a large-scale fish kill in the Pecos River below the mine site and at the Lisboa Springs hatchery. The local economy then suffered from a drop in tourism from concerns over the safety of the area. Additionally, two campgrounds were closed due to high levels of contaminants from the mine tailings used in their construction.

A public meeting was called in Pecos in May 1991 to address problems associated with the contaminants leaching into the streams and rivers of the watershed. A priority of the concerned citizens of Pecos, the State of New Mexico, and the American Minerals Corporation (AMAX) was to work together to remediate the area themselves and avoid listing the area as a federal Superfund site by the Environmental Protection Agency (EPA). The Pecos Administrative Order of Consent (AOC) was signed by representatives of the New Mexico Environment Department, NM Game and Fish Department, NM Highway Department, and the AMAX mining company in December of 1992. The AOC specified a rigorous monitoring and remediation program for the site, which had the effect of preventing the listing of the site as a federal Superfund hazardous-waste cleanup project.

2.9.2. Acequias

There are at least six active acequias within the watershed. Acequias can have positive effects on riparian areas by enhancing the breadth of the floodplain, hydrating the riparian area, and supporting corridors of riparian habitat. They can also discharge into constructed wetlands and other riparian vegetation. However, acequias can also contribute to erosion problems (for instance, where downcutting occurs below head gates). Little is known about any possible role of acequias in contributing to, and/or suffering from, non-point source pollutants in the Upper Pecos watershed.

2.9.3. Logging and firewood harvesting

The Pecos River Forest Reserve was established in 1892, and later combined with the Jemez Forest Reserve to form the Santa Fe National Forest in 1915. Extensive logging in the area, however, began in the late 1880s to provide railroad ties for the Atchison, Topeka, and Santa Fe Railroad, and later to support the infrastructure of Tererro mine, housing for its employees, and saw timber for other uses. By 1939 the mine closed, and logging activities also slowed. Some logging occurred in the 1980s, with the Davis-Willow and Dalton Timber sales. Between

1989 and 2003, prescribed burns were conducted in order to reduce fuels and improve habitat for wildlife. Poorly controlled firewood harvesting has been a concern voiced by some residents, because of the roads created to get to and remove the firewood.

2.9.4. Livestock grazing

Beginning with Spanish settlement of the region, domestic livestock has used much of the watershed for summer if not permanent range. As livestock density increased, native grass cover in much of the region diminished. Not only did this expose more land surface to the erosive effects of wind and runoff, it likely contributed to breaking a cycle where frequent low-intensity grass fires maintained a more savannah-like landscape favoring grass cover and restraining the density of shrubs and trees. Once grass was grazed to the point it would no longer support periodic grass fires, piñon and juniper cover increased and grass cover decreased. Generally piñon-juniper tree cover does not form a closed canopy, but often its roots are dense enough to prevent grass cover between trees, leading to a regime of greatly increased runoff and erosion as compared to grassland or savannah. This trend continued for many years even after the area was designated as a Forest Reserve.

Livestock grazing became subject to permitting by the Forest Service once it assumed management responsibility over what is now National Forest land, and since the 1960s there has been a trend towards reduction in the grazing levels permitted in the Pecos Ranger District. The level of domestic grazing animal stocking in the area was a topic addressed by the Forest Plan Environmental Impact Statement (EIS) in 1987.

As of 2018, there are 8 grazing allotments on the Santa Fe National Forest within the upper Pecos watershed, five of which are actively grazed by cattle.

2.9.5. Recreation

The upper Pecos valley first began to receive recreational use beginning in the early 1920s, with the construction of summer residence cabins in Winsor and Holy Ghost Canyons and "dude" ranches along the main stem of the Pecos River at Tres Lagunas, Cowles, and Los Trigos. This reach of the Pecos River remains one of the most popular fishing locations in northern New Mexico, and in addition to fishing, the area is extensively used for camping, hiking, picnicking, hunting, and off-road vehicle use. Santa Fe National Forest provides seven developed campgrounds, along with one picnic area and extensive dispersed camping. The New Mexico Department of Game and Fish (NMDGF) is responsible for three largely unregulated "free" campgrounds plus two picnic or day-use areas. Because peak summertime demand far exceeds available capacity in developed campgrounds, there is a great deal of unmanaged, dispersed camping in Dalton Canyon and around Tererro and Cowles, as well as sometimes serious overuse of developed areas – especially the less-regulated NMDGF lands.

One of the principal effects of recreational overuse is damage to or complete trampling of native vegetation, especially along stream banks and in riparian areas or meadows. Removal of vegetation along with soil compaction and damage to seedlings, prevents vegetative re-growth and leads to increased streamside erosion and sediment transport into the river whenever there is rain or snowmelt. This degrades water quality as well as the recreational experience.

An EPA Section 319 Grant was awarded to the UPWA in 2008 to study the water quality degradation caused by recreational uses. The study, conducted by Nelson Consulting, Inc., concentrated on the section of the Pecos River from Dalton Creek upstream to Mora Creek and included designated recreational areas, user-created areas, and access points along NM 63 that are adjacent to the river. The study found that use of these areas exceeds the carrying capacity of these sites to support vegetative cover and prevent soil erosion. Many of the existing campsites located adjacent to the river are denuded and soil loss from these sites occurs during runoff conditions and storm events. The recreational sites also contribute significant amounts of sediments to the river – as does rill erosion along the area's roadsides. Proper functioning condition of the riparian areas has also been lost along portions of the river and its tributaries, resulting in bank destabilization and a reduction of riparian vegetation.

In 2008, the New Mexico Department of Game and Fish (NMDGF) funded a study by the US Forest Service TEAMS unit of the existing and future recreation use capacity in the Pecos River Canyon area. The study provided more quantitative data on the existing usage and potential capacities of the NMDGF recreation areas and also evaluated issues related to roadside parking, and emergency evacuation. Based on the results of this study, recreation demand for the majority of the NMDGF recreation areas appears to be predominantly fishing, and RV and tent camping uses by large family units who want to gather around shady locations near the river on summer weekends.

The TEAMS study found that existing facilities along the river were typically occupied to capacity, and to levels greater than their reasonable capacity at peak periods. This level of use, and the relative lack of infrastructure and organization at the facilities, has led to significant and sometimes serious degradation of vegetation cover and stream bank trampling, with associated excessive runoff, sediment, and trash flowing directly into the Pecos River and the Rio Mora. The TEAMS report in particular provides schematic designs for better arrangements of campsites and traffic flows at the NMDGF facilities, and makes the point that both the Jamie Koch and Links Tract areas are under-utilized even while the other sites are over-used – and a more comprehensive management strategy could spread the recreation usage more evenly among the available facilities, while better organization of campsites, toilets, trails, and river access could considerably reduce the soil and riparian damage done by recreational users. Specific recommendations from the reports include:

- Increase number of designated campgrounds, and move camping away from sensitive areas
- Designate parking facilities to improve safety and traffic flow
- Move high impact activities (ATV/OHV, group camping) away from sensitive areas; prevent vehicle access to streams and riparian areas except in designated campsites
- Implement “rest-rotation” for areas of high use
- Increase informational and regulatory signage to better educate and inform the public
- Develop an interpretive program for public education about resource values and issues
- Restore a demonstration site so people can see what the area can look like
- Charge fees to cover management costs and increase public recognition for value of experience
- Consider “displacement effects” as people potentially displaced from over-capacity areas move to more dispersed areas elsewhere

Throughout the watershed, but especially along the recreational segments of the rivers, official roads as well as off-road driving and user-created roads are a significant concern. There are over 350 miles of unpaved Forest Service and County roads within the watershed, and at least 32 of these road miles are within 100 feet of a perennial stream, and likely contribute significant runoff and sediment to the stream. In addition, there are unknown miles of ATV tracks and user-created roads, which are often eroding in places.

2.9.6. Point source discharges

There are three point-source discharges into the Pecos River with National Pollutant Discharge Elimination System (NPDES) permits under the Clean Water Act: the Life Way Glorieta Conference Center, the Lisboa Springs Fish Hatchery, and the Village of Pecos wastewater treatment plant. The Glorieta Conference Center (NPDES Permit NM 0028088) is allowed to discharge up to 45 milligrams per liter (mg/l) of total suspended solids into Glorieta Creek near the Interstate 25 Glorieta exit, averaged over 7 days. The Lisboa Springs Fish Hatchery (NPDES Permit NM 0030121) is permitted to discharge up to 15mg/l total suspended solids into the Pecos River about 2 miles above the Village of Pecos. The Pecos wastewater treatment plant (NPDES Permit NM 0029041) is permitted to discharge up to 135mg/l total suspended solids into the Pecos River just below the Village of Pecos.

3. A VISION FOR THE UPPER PECOS

3.1 The Bigger Picture - A Watershed Context

In considering watershed health and water quality issues in the Upper Pecos it is easy to focus on the beauty of the river and the mountains and the many attractive features of the landscape that draw so many to the area as visitors or residents. However, some of the clear impairments to the current condition of our streams, especially at and/or due to the heavily-used and abused recreation sites, are inescapable. But larger processes, both natural and cultural, are at work, and it is important to be aware of them context in planning for the health of our watershed in the future.

3.1.1. Climate

There have been dramatic fluctuations in climatic patterns across the Southwest, and much of the rest of the world, even in recorded history – to say nothing of pre-historic events like ice ages and the melting of glaciers. Regardless of what effects human activities may or may not be having on climate, there is ample evidence both in current climate data and in paleo-climatic records such as tree ring chronologies and pollen deposits that conditions have been, and can be, much different from what we are used to. Not only can temperatures and average precipitation vary far outside what we consider normal, so can other variables like the timing (summer or winter), intensity, and duration of rain and snowfall. It is only sensible to plan for as much resilience as practical in our streams and watershed. Ways to provide for this kind of resilience include improving grassland and range conditions where we can, to minimize the volume of runoff from intense summer storms and enhance perennial stream flow; considering what would happen to fish populations in times of drought and providing deeper pools, shaded river reaches, and other features of fish habitat; and perhaps most importantly, minimizing the chances for a catastrophic wildfire that could affect a large fraction of the watershed at once.

3.1.2. Fire

As discussed in more detail on pages 10 - 15 above, fire has played a key role in shaping the ecological characteristics of the vegetation in the Upper Pecos, especially in the ponderosa and lower mixed conifer zones. There is ample evidence that in much of the mountainous Southwest a pattern of relatively frequent but small-scale fires prevailed in both grass-dominated and more wooded areas, resulting in a patchwork or mosaic of burned areas of different ages. For instance, fire-scar and tree-ring analyses have confirmed that pre-1900 fire intervals in the Jemez Mountains averaged from 5 to 25 years, depending on altitude and location. The same study documented a lightning strike every 82 acres in the Jemez mountains during 1986; other data recorded 348 lightning strikes within the Upper Pecos watershed boundaries in just the month of May, 1997. The picture that emerges is that fire has been a frequent and inevitable feature of life in the mountains of New Mexico, with ample opportunities for natural ignition, long before any human campers or arsonists. Fire behavior is complicated, to say the least, and highly dependent on local fuels and topographic conditions as well as climatic events; and there is historic evidence for some very large-scale fires in the Southwest long before human fire suppression activities. Nevertheless, it seems very probable that a mosaic of smaller wildfire scars, like that visible around parts of Dalton Canyon and in many other landscapes of the mountain Southwest, acts to restrain the likely size of a fire once ignited, whether by lightning or human causes.

There is little evidence of such a fire mosaic in large areas of the Upper Pecos, and apart from the Viveash fire in 2000, and the Jaroso and Tres Lagunas fires in 2013 (or, on a smaller scale, the Trampas fire of 2002), large-scale fires in the upper Pecos watershed have not generally been a part of recorded history. Policies of fire suppression have undoubtedly increased average tree density and reduced meadows and grass cover in the area, and the chances that a wildfire could engulf a large part of the Pecos, on the scale of the Viveash or even the Las Conchas or Whitewater Baldy fire, increase every year. The Tres Lagunas and Jaroso fires are prime examples of that increased chance of large fires and the vast majority of the Upper Pecos remains a tinderbox during the annual fire season.

Wildfires on the scale of the Viveash, Tres Lagunas, and Jaroso fires or larger, drastically alter the entire watershed for decades, impacting water quality through the entire Pecos River all the way to the Rio Grande. These large fires kill wildlife and fish, destroy property, and seriously diminish the economic base of the community, village, and entire local area.

There is no easy solution to this problem of growing fire risk. While small projects are important, meaningful efforts to significantly reduce the risk of such an event will take many years and require millions of dollars. Only a large-scale and sustained change in forest management could make a difference to this condition of increasing fuels and fire risk. The only long-term solution is to restore a more historically normal fire regime, where a wildfire, however caused, would not likely become huge. Forest restoration on a scale large enough to make much difference would almost certainly involve large-scale forest thinning, perhaps timber removal as well as mechanical mulching, and many prescribed fires over a number of years. It would be well beyond the scope of any forest management ever done in the Pecos, and would require political support at least from the Congressional level for a comprehensive restoration approach like that envisioned in the Collaborative Forest Landscape Restoration Program, or other Congressionally-appropriated funds.

3.1.3. Recreational use and overuse

Recreational uses are the most visible causes of negative impact to water quality and other environmental damage in the watershed. As user pressure continues to mount, so does the need for balancing water quality, the ecosystem, and the recreational environment with appropriate levels and types of uses. Most of the past damage from recreational use can be mitigated by undertaking a series of small to medium projects, and accomplished within 2-4 years. However, a minimum of 2-3 new developed campgrounds are needed on public or private land to compensate for movement of unregulated dispersed camping away from stream banks. Also, it is vital that an effective means of providing truly coordinated management of camping and other recreational uses be formulated and put in place. UPWA is ideally positioned to act as the facilitator for coordinating recreational management, but will require expanded funding to provide staffing needed to support this role. A Joint Use Visitor Center is an <u>urgent</u> requirement for UPW. This center, jointly supported by the various government agencies and entities, business and community groups, and advocacy groups would provide "one stop shopping" for recreational users coming to the area. It would also serve as the first point for Public Outreach and Education for visitors to the area providing specific guidance on what activities are permissible and where.

3.1.4. Land cover, erosion, and upland management

Upland erosion, in the sense of arroyo head-cuts and sediment washed from bare land surfaces into streams, is not a typical feature of most of the frequently-visited parts of the upper Pecos watershed. Nevertheless, it has been a very significant feature of the environmental history of the watershed, especially below the village of Pecos, as evidenced by the deep and extensive network of gullies and arroyos that still shapes the landscape. The land use history that has led to this situation is complex, and it is well beyond the scope of this Plan to unravel the relative contribution over time of factors like changing climate and precipitation patterns, grazing history, altered fire ecology, vegetation patterns, soil types, and runoff from roads, roofs, and other kinds of development. Nevertheless, in the watershed below the Village of Pecos or the Pecos

National Historic Park, summer thunderstorms can still produce dramatic flash flooding and contribute massive amounts of sediment to localized reaches of perennial streams in quantities that can do significant damage to fish habitat, to say nothing of further eroding rangeland and threatening structures like roads and bridges.

The key to managing this situation is maintaining or enhancing ground cover. In practice this means grass, and may mean reducing the density of piñon and juniper trees in some places, because the roots of both trees have the capacity to grow densely quite near the land surface as well as to extend to a depth of dozens of feet. In some cases the result can be that piñon and juniper trees are in direct competition with grasses and forbs for near-surface moisture, and prevent almost any ground cover between trees. This leads to massive overland stormwater flow, gullying, and severe erosion. In these cases the idea that "tree roots help hold the soil in place" is a very harmful misconception. Adequate grass cover not only restrains or essentially prevents soil erosion, it also encourages infiltration of precipitation (especially from summer thunderstorms) that dramatically reduces flash flooding and increases ground water recharge and perennial base flow into streams.

Most of the watershed where the maintenance or improvement of land cover is an issue is private land, except for some 40 sections (25,000 acres) of Santa Fe National Forest land surrounding Upper and Lower Colonias, north of North San Ysidro. Most of the private land in question is part of a small number of relatively large ranches, whose owners in many cases are not dependent on grazing income. There are a variety of US Department of Agriculture programs that can help with range or grassland improvements, but the key in this situation may well be convincing landowners that they can indeed make a big difference in the watershed.

3.1.5. Land use, waste management, and transportation planning

The most recent San Miguel County Land Use Plan for the area including the Upper Pecos is almost 30 years old and completely outdated. There is a serious deficit in the areas of zoning and other regulations needed in the face of increasing population and development. As property values continue to increase along the Pecos River, along with pressure for additional recreation facilities, the possibility of unregulated large-scale development is of grave concern. In addition to the threat of excessive or inappropriate development, there are existing problems with solid waste (garbage) disposal, liquid (human) waste disposal and treatment, and providing adequate safe drinking water supplies. At present planning, management, facilities, and enforcement are all inadequate to deal adequately with these issues, to say nothing of providing for future needs. San Miguel County realizes the increasing urgency of undertaking the necessary planning, management, and enforcement efforts, but lacks funding. Without funding needed to move forward with land use and related planning the risk of damaging and inappropriate development continues to accelerate. Development of a plan will have to have buy-in from the local community and the numerous private owners with widely varying interests. UPWA is an essential partner in the participation and coordination of these efforts, to mesh appropriate land use and waste issues with water and environmental issues and concerns.

The primary watershed access, NM Highway 63, is in poor condition, has numerous design and maintenance issues that impact water quality, and faces ever-increasing traffic. Unregulated parking along NM 63 is a safety hazard, and some parking areas are a source of direct pollution of the Pecos River. In addition, increasing use of off-highway vehicles degrades trails, causes more and more user-developed roads that cause erosion and increase runoff and sediment loads, destroy vegetation and harm wildlife. With the sole exception of the USFS Transportation Plan for the Santa Fe National Forest, there is no coordinated plan to address planning, construction, maintenance or improvements to public and private roads in the area.

As with land-use and other environmental planning needs, UPWA is uniquely positioned to help build community consensus and coordinate among affected agencies and stakeholders.

3.1.6. *Cultural and community context*

Our watershed is occupied by a diverse human community that includes families whose ancestors were among the residents of Pecos Pueblo or other local tribes or the earliest Spanish settlers in the area in the 17th century, some very well-known national celebrities, plus many thousands of summer recreational visitors – along with traditional cultural sites that still retain importance for the descendants of the now-abandoned Pecos Pueblo.

Unemployment in the area is high and there is no industry in the Pecos valley. The largest employers are the Pecos Valley public school system, the US Forest Service, and the Pecos Valley Medical Center. The Glorieta Baptist Convention Center, formerly an employer, has now ceased operation. One of the major sources of revenue in the Pecos canyon is from the influx of tourists in the summer and fall coming to visit our river and mountains. Vacationers come from all over the country to enjoy the Wild and Scenic Pecos River for fishing, camping, hunting, and hiking. The river is one of the most valued resources in the community and there are several events commemorating it. In 2009, Pecos celebrated its 10th annual Dia Del Rio, an event to clean, bless and celebrate the Pecos River and what it means to our community. The river is used in a plethora of ways including for recreation, irrigation, and drinking water. It is high community priority to keep the river clean so that our precious resource can continue being enjoyed and used responsibly.

3.2 Watershed Goals

Within this larger context of natural and human processes at work, there are seven goals the UPWA Board, Advisory Board, and Stakeholders have identified, discussed, and agreed on as vital to protect our watershed and the place it occupies in our community. We seek to protect our water quality where it is good – and restore it to the quality it should have where it falls short. These goals are:

1. Reduce the risk of, and likely damage from, wildfires.

The Viveash fire in 2000, and the Jaroso and Tres Lagunas fires of 2013, have been stark reminders of the effects a large-scale wildfire can have on our watershed. While there is no way to guarantee that similar fires will not happen elsewhere in the upper Pecos, and no simple way to reduce the likelihood or scale of future wildfires, moving towards restoring the natural fire ecology of the area so that any individual fire that starts will be much less likely to develop into a multi-thousand-acre conflagration is one of the most important long-term ways to protect our watershed.

The Upper Pecos watershed, like many in the West, is stuck in something of a negative feedback loop where every year the likelihood of a large, multi-drainage catastrophic wildfire increases, but that very threat discourages forest managers from allowing naturally occurring fires to burn unsuppressed, to say nothing of initiating prescribed burns. The potential solution is straightforward, but difficult in terms of scale, political acceptance, and expense. Using efforts like the USFS Collaborative Forest Landscape Restoration Program, substantial areas of the forest could be thinned and prescribed fires could be used to re-create conditions that would enhance watershed resilience in preparation for the fires that are undoubtedly coming in the future. These conditions are principally a mosaic or patchwork pattern of frequent but relatively small fires so that when a fire starts, it soon runs into the boundary of a prior fire where fuels are limited; average tree density is lower; and herbaceous ground cover is greater.

Large-scale forest restoration, facilitating more natural fire conditions, is already underway in adjacent watersheds: the Santa Fe River to the west and the Gallinas to the northeast. There is a precedent for treatment actions, and public acceptance for the work needed. At a minimum, treatments could be applied on ridges between drainages so that fires can be contained within individual drainages instead of affecting multiple watersheds simultaneously. Treatments should be prioritized to areas most prone to (and in need of) wildfire—

the mid-elevation dry ponderosa and mixed conifer forests where lightning starts are most likely to result in fire ignition.

One of UPWA's key goals is to collaborate with other agencies and community stakeholders, especially the Santa Fe National Forest, to encourage and facilitate forest thinning, prescribed burning, and other strategies for restoring watershed resilience in a context of natural fire ecology.

2. Encourage and promote appropriate recreation management.

Both residents and visitors to the watershed are drawn to the outstanding beauty and recreational opportunities in the upper Pecos. However, the largely unregulated use patterns that have developed in the area are not adequate to prevent significant future degradation of the very recreational experiences that support our economy and make life in the Pecos valley what it is. UPWA seeks to promote and support appropriate regulation of recreational uses to preserve and enhance the resources we all value, and to restore over-used areas to ecological health. Through its Pecos canyon Collaborative Planning Group, UPWA will also continue to work to coordinate management of recreational uses and planning for such uses.

3. Improve watershed ground cover conditions where feasible.

The deep and extensive gullies in the lower elevations of the watershed are reminders that, now or at some point in the past, the grass and other vegetation that once covered most of the soil in the area was disrupted over a considerable area. Some gullies have "healed", in the sense that they now support grass cover and are not actively eroding; but other parts of the lower-altitude watershed are still actively eroding, and thunderstorm runoff can still cause severe damage to roads, bridges, and even homes and other infrastructure. Increasing the percentage of the land surface covered by grasses and other herbaceous vegetation could reduce flood damage and increase aquifer recharge in many parts of the watershed.

4. Support improved land use, waste management, and transportation planning and management.

The Village of Pecos and San Miguel County are essentially the only local government entities in the watershed, and both face great challenges with very limited resources. Many aspects of resource use in the area have been adequate for a small and dispersed population, but show increasing strain in the face of increasing population and utilization. For instance, land use patterns can have dramatic effects on surface runoff and ground water contamination; there are already problems with improper disposal of both solid and liquid waste; and both roads and off-road vehicle use can cause serious watershed damage. UPWA is uniquely well positioned to serve as a catalyst and facilitator in local and regional planning efforts to mitigate and better manage these environmental and water quality effects.

5. Protect wildlife and improve habitat.

Fishing and hunting are cornerstones of our recreational economy as well as highly prized opportunities for residents – and neither will be possible without the aquatic and terrestrial wildlife habitat that fish and animals need. Wildlife habitat improvements go hand in hand with water quality improvements, whether protecting forests from excessive fire damage, revegetating denuded stream banks to provide additional shaded stream habitat, or preventing inappropriate erosion and sediment deposition. In addition, countless visitors are drawn to the Pecos valley by wild flowers, birds, and the opportunity to see countless non-game species (including an endangered plant species, the Holy Ghost Ipomopsis, and a Candidate species for Endangered status, the Rio Grande Cutthroat Trout). Historically, beavers and their dams help regulate runoff and provide fish and wildlife habitat, as well as expanding natural wetlands and increasing ground water recharge and storage. Preservation, proper management, and protection of habitat for species such as deer, elk, bears, mountain lions, bobcat, lynx, wild turkeys, and blue grouse not only protect the foundations of historic ecosystems, but are also extremely important to the area economy. Preserving all these kinds of habitat is an integral part of watershed protection and restoration in the upper Pecos.

6. Preserve traditions and local culture.

Many community members are involved in some way with local traditions and unique aspects of life in the Pecos valley: for example, acequias and their historic role in community life; firewood gathering; hunting and fishing; or maintaining family ranches. Watershed protection and restoration supports these traditional activities and contributes to their continued viability. Supporting and maintaining decades or even centuries of tradition in the upper Pecos will directly benefit water quality, ecology, and the environment – as well as the local economy and quality of life.

7. Support and enhance the local economy.

Without a healthy watershed, little will remain of the economy of Pecos and western San Miguel County. Appropriate commercial enterprises need to be encouraged and supported, including outfitters, guides, local agriculture, small-scale cattle grazing, and similar businesses. On the other hand, inappropriate commercial enterprises that would damage the very environment that supports the Pecos valley, and both its economy and quality of life, should be prevented.

3.3 Water Quality Implications

All the various physical and social situations discussed above interact to affect present and future water quality in several ways. Some of our watershed goals involve protecting the watershed, and our water quality, from the potential of severe future degradation - while others focus on restoring water quality that is now degraded. The goals that involve averting future damage – for instance, reducing the damage from wildfires, flash flooding, or inappropriate recreational development - will mostly be achieved by long-term collaboration with government agencies and elected officials, encouraging appropriate policies and funding, building public support, and serving as a community educational resource. Goals that involve repairing watershed damage and restoring water quality impaired by existing conditions will more often be achieved through specific on-the-ground management activities and projects. Both kinds of watershed protection are important and need to be pursued concurrently.

While there are some specific impairments that need to be addressed in the upper Pecos, there is also much that is properly functioning about our watershed, and should be protected. For instance, the USDA Forest Service Watershed Condition Class Assessment conducted for the Santa Fe National Forest found the upper Pecos watershed to be primarily functioning but at some risk, while two of the sub-watersheds in our upper headwaters, Panchuela Creek and the Rio Mora, are functioning properly. None of the upper Pecos watershed was identified as having impaired function in the Forest Service analysis. All this suggests that if the identified impairments can be restored to meet designated use standards – which is eminently achievable – the entire watershed could be a suitable candidate for inclusion in EPA's new Healthy Watershed Initiatives program.

The remainder of this Watershed Based Plan will focus more detailed attention on activities and projects to restore currently degraded water quality and watershed conditions. This is in no way intended to minimize the importance of working to reduce the probability of a massive wildfire, for instance, or other damage-prevention strategies. Indeed, specific activities to avert future watershed damage and water quality degradation are listed and discussed, but a greater level of detail seems appropriate for specific projects that can be located in a particular place with anticipated costs and clearly expected results. The next chapter, on **Causes and Sources of Pollution and Watershed Stress**, examines current water quality impairments in our watershed, and ways to remove those impairments and restore water quality.

4. CAUSES AND SOURCES OF WATERSHED STRESS

As discussed in previous chapters, there are ample reasons to be concerned about the potential for future watershed degradation in the upper Pecos, possibly on a massive scale. However, if these risks can be averted and existing impairments restored to proper functioning, there is a great deal about the upper Pecos watershed that is in very good condition and eminently worth protecting as a healthy watershed. This chapter will look at the causes of the water quality impairments that have been found and the sources of pollutants or watershed stress. It seems reasonable to begin with a discussion of the methods of analysis used to determine the existence and location of impaired stream reaches, as well as the management practices and locations of specific projects proposed for watershed restoration.

4.1 Methods of Analysis

4.1.1. NMED sampling

The foundation of this Watershed Based Plan is the sampling and analysis carried out by the Surface Water Quality Bureau of the New Mexico Environment Department on the mainstem of the Pecos River as well as its major tributaries. This sampling has been carried out intermittently for many years, most recently in 2010 as part of the NMED eight-year rotational sampling program for New Mexico's surface water. Chemical, physical, biological, habitat, and potentially toxicological data are collected from an extensive network of sampling sites during these rotational sampling events, which span several months. In addition to data collected specifically during these campaigns, other data may be used in determining whether a given stream reach can meet the water quality standards for its designated use. These additional types of data, which all have to meet NMED quality assurance and quality control (QA/QC) standards, include:

- Data from other recent studies or surveys by NMED staff or contractors
- USGS water quality data (after being reviewed for QA/QC requirements)
- Benthic macro-invertebrate, fish community, or fish tissue data collected by NMED or other organizations or individuals
- In-stream or effluent data collected during NMED effluent monitoring efforts
- NPDES storm water permit compliance monitoring data for receiving waters
- Citizen or volunteer monitoring data, with adequate QA/QC

Data are analyzed and maintained in databases by the NMED Surface Water Quality Bureau in Santa Fe.

4.1.2. Watershed-Based Plan field surveys

Many field surveys and other visits were made for this Watershed-Based Plan: by UPWA Board members, staff, and stakeholders; staff with ecological restoration consultant La Calandria Associates, Inc. of Santa Fe; local landowners; collaborating agency staff (Santa Fe National Forest, New Mexico Department of Game and Fish, and New Mexico State Parks Division, for instance); and other individuals with wildlife, ecological, hydrological, and forestry expertise. These systematic stream and riparian surveys and visits to specific sites took place on many occasions between November of 2009 and May of 2012. The focus of these surveys (conducted on foot, by bicycle, and motor vehicle) was to visually assess stream and watershed conditions and locate sources of pollutants or watershed impairments, rather than to collect more chemical, physical or other quantitatively-analyzed samples in addition to the NMED sampling already done. Survey results include GIS mapping and data, many pages of field notes, and nearly a thousand photographs of observed conditions, maintained by UPWA at their office in Pecos.

4.1.3. Aerial photography review

The majority of the upper Pecos watershed is not accessible by road, and much of it (especially in the Cow Creek, Bull Creek, Apache Creek, and El Rito sub-watersheds) is only visible from a road at a considerable distance, if at all. To evaluate areas not accessible otherwise, a comparison was made of 2008 and 2011 aerial photographs with one-meter resolution. For this revision of the plan, current imagery available online via Google Earth Pro was used extensively. A visual inspection was made of entire sub-watershed areas, unless better visibility was obtainable on the ground, but attention was concentrated on stream corridors, roads, any areas of apparent bare soil or other watershed stress, and stream reaches that seemed to lack streamside vegetation. These or other relevant features are mapped on the UPWA GIS system, and when appropriate they became part of restoration projects.

4.1.4. Local knowledge

The Board of Directors and membership of UPWA includes many people who have spent their whole lives, or large parts of them, in the upper Pecos and are intimately familiar with our watershed. In many cases they have seen significant changes over their own lifetimes and some have heard anecdotes of historic conditions or changes from previous generations. Their memories and collective expertise have been an invaluable source of information about watershed conditions and places where restoration work would be most valuable. In addition to countless informal conversations and several field visits to sites with Board and other community members, three annual stakeholder meetings open to the entire UPWA membership have included presentations and discussion about the goals of the WBP and requests for information or thoughts from community members about potential pollutant sources or other watershed problems, followed up by e-mail correspondence, telephone conversations, or site visits to obtain additional information.

For this current version of the Watershed-Based Plan, the UPWA held a public meeting in Pecos at its headquarters on April 15, 2017 from 10:00 AM to 1:00 PM. This meeting was advertised in advance by a mass-mailed postcard to the UPWA mailing list (over 400 recipients) and an email blast to the same list. The purpose of the meeting was to solicit input on potential projects from the public. The meeting was attended by two members of the public. No viable potential projects were identified during the meeting.

4.1.5. Modeling and load calculations

Anticipated water quality effects of restoration projects were calculated using two methods: the USGS Stream Segment Temperature (SSTEMP) model was used to evaluate measures to reduce water temperatures, and an estimate was made of soil volumes and mass eroding into streams from damaged banks and eroding overland flow adjacent to streams. Results of these models and calculations are presented in Chapter 6 on Pollutant Load Reductions, and in Appendix C.

4.2 Causes of Impairment

New Mexico's water quality standards are based on designated uses for streams or water bodies adopted by the New Mexico Water Quality Control Commission. Numerical or narrative standards are developed to provide adequate water quality for those uses. Periodic water quality monitoring by the Surface Water Quality Bureau (SWQB) of the New Mexico Environment Department establishes whether the applicable standards are being met, and if not, the relevant stream reach or water body is listed as "impaired" or not supporting one or more of its designated uses. For impaired water bodies, a "Total Maximum Daily Load" (TMDL) is calculated. TMDLs are a calculation of the maximum quantities of the pollutants causing impairment that a stream could assimilate without causing non-support for its designated uses. As a practical matter, not all impaired stream reaches have TMDLs, because the measurements and calculations required for developing TMDLs are a lengthy and ongoing process.

The status of streams in meeting water quality standards is evaluated by SWQB staff, following extensive sampling, approximately every 8 years. Streams in the upper Pecos were sampled in 2010, and several changes were made to the stream reaches listed as impaired. The *2018-2020 State of New Mexico Clean Water Act 303(d)/305(b) Integrated Report* lists the following stream reaches as impaired, for the reasons given:

Impaired stream reach	**Cause for impairment**
Cow Creek (Bull Creek to headwaters)	Temperature
Cow Creek (Pecos River to Bull Creek)	Temperature
Dalton Canyon Creek (Pecos River to headwaters)	Specific Conductivity
Glorieta Creek (Pecos River to Glorieta Conference Center WWTP)	Nutrients & Specific Conductivity
Glorieta Creek (Glorieta Conference Center WWTP to headwaters)	Flow Regime Modification
Macho Canyon Creek (Pecos River to headwaters)	Specific Conductivity
Pecos River (Cañon de Manzanita to Alamitos Canyon)	Temperature
Willow Creek (Pecos River to headwaters)	Specific Conductivity

The discussion that follows focuses on the causes of pollution that have led to the listed impairments, and the sources of these pollutants in our watershed. The site-specific, on-the-ground management actions that could address these pollutant sources are described in Chapter 6, **Management Measures.**

4.2.1. Temperature

(Cow Creek, Pecos River)

Decreased depth to width ratios, decreased streamside canopy vegetation cover, direct runoff from roads and impervious surfaces, and increased suspended sediments all contribute to higher water temperatures than those that would normally or naturally be found. These higher water temperatures have a direct negative impact on aquatic life in mountain streams and rivers like the Upper Pecos, most immediately by reducing the dissolved oxygen in the water available for fish. Water temperature exceeds acceptable levels in Cow Creek, and the Pecos River below the village of Pecos.

It should be noted that TMDL modeling, and SSTEMP modeling for this Watershed-Based Plan, were done for periods of low (mid-summer) flows, and maximum modeled temperatures (generally in early July). There are no appreciable irrigation withdrawals in any of the modeled stream reaches except for lower (outlet) Cow Creek, where there are acequia withdrawals at Lower Colonias. Modeled stream flows account for these withdrawals in the stream discharge inputs used.

4.2.2. Sediment and siltation (turbidity)

(Problem to be avoided throughout the watershed)

Sediment is a completely natural feature of a river system, at least once it leaves its alpine headwaters. In its mountainous upper headwaters, a river probably cascades down steep, rocky valleys that are almost entirely bedrock, with little soil or valley-bottom sediment. Before it has flowed very far down from its mountain origins, though, the river valley becomes broader and less steep, and bedrock is buried beneath increasing quantities of sediment - rock, gravel, sand, and silt - carried down by the river itself. Sediment filling the valley may be thousands of feet deep, as it is where the Rio Grande flows through Albuquerque; or perhaps only a few dozen feet deep, in the case of much of the upper Pecos. However deep the sediment, it fills with water, and the flowing stream also moves some of the sediment along with it. A river is not just the water we see flowing. It is an integral system of surface and sub-surface water, and the sediment it flows over and carries with it.

However, there is an appropriate level of sediment and sediment movement in any given stream reach, depending on the size of the material in the riverbed (boulders, cobbles, gravel, sand, silt, and so on) and the geology of the watershed. As discussed beginning on page 10, there are different regions of the upper Pecos watershed, characterized by different soil types and parent geology, where different levels of sediment movement in a stream and sediment composition of the streambed are natural. The further upstream in the watershed, in general, the less sediment should be present in the steam system. Aquatic life (like trout) adapted to a clear, cold mountain stream will generally be harmed or even killed by excessive sediment movement in a stream system or turbidity (suspended, very fine sediment) in the water.

Excessive sediment transport – erosion or deposition out of the range of long-term equilibrium - provides evidence of streambank erosion and/or upland sediments washed into and carried down a stream system. Causes of increased sedimentation and turbidity include soil erosion of stream banks and/or of upland areas within a watershed, high flow events, excess nutrients, and perhaps other pollutants.

4.2.3. Specific conductivity

(Dalton Canyon Creek, Glorieta Creek, Macho Creek, Willow Creek)

While turbidity (visible cloudiness) indicates fine particles *suspended* in water, specific conductivity is an indicator of the amount of *dissolved* material in water (pure distilled water is a poor electrical conductor). The presence of excessive conductivity in a water sample does not identify what is dissolved in the water, and additional testing will be necessary to find that out. The *2020 State of New Mexico Clean Water Act §303(d)/§305(b) Integrated Report* identifies Dalton Creek, Glorieta Creek, Macho Creek, and Willow Creek as being impaired by specific conductivity.

4.2.4. Nutrients and eutrophication

(Glorieta Creek)

Eutrophication is the response of an aquatic ecosystem to unusual or excessive levels of nutrients in water. The most common such response is excessive growth of algae, plankton, or other micro-flora, which in turn deplete oxygen from the water to the detriment of other plants, macroinvertebrates, fish, and other organisms. Phosphorus is typically a limiting nutrient for aquatic plant growth, and elevated levels of phosphorus from wastewater is often a cause of eutrophication. However, nitrogen from septic systems or fertilizers can also cause eutrophication in streams, though the causes in the Pecos are not known. When this Plan was revised in 2012, the only stream listed for this reason was Glorieta Creek below the Glorieta Conference Center wastewater treatment plant. As of this current revision in 2019, the *2018-2020 State of New Mexico Clean Water Act §303(d)/§305(b) Integrated Report* identifies Glorieta Creek below the Glorieta Conference Center wastewater treatment plant as being impaired by nutrients or eutrophication. Glorieta Camps currently has an agreement in place with the New Mexico Office of the State Engineer to update and upgrade its wastewater treatment facility over the next five years. This should have a positive effect on reducing nutrients in Glorieta Creek below the Glorieta Conference Center.

4.2.5. Flow modification

(Glorieta Creek)

Flow modification results from artificial, man-made barriers to natural stream flow. A prime example is a dam. Dams in the Upper Pecos generally occur in two forms, grade-control/diversion dams and pond dams. The former are fairly common at the upstream end of acequias/irrigation ditches. These structures only result in flow modification when they are drawing water off of the main channel for irrigation. In the Upper Pecos, this generally does not sufficiently reduce flows in the main channels downstream to result in an impairment. The latter modification only occurs in one place in the Upper Pecos, at the Glorieta Conference Center just below the headwaters of Glorieta Creek.

A member of the Glorieta Camps administration recently communicated that as part of their recent agreement with the State Engineer, they will be upgrading their wastewater treatment facility and using the effluent for irrigation. Currently they are pumping groundwater for irrigation. By using effluent for irrigation, they will be able (and required) to stop using their wells for this purpose. As a potential side effect of resting their wells, it is hoped that groundwater levels will rise and this could have the effect of restoring a base flow in Glorieta Creek. The wastewater treatment facility upgrades are expected to occur over the next five or so years, so the effects to Glorieta Creek will not be observable for some time.

4.2.6. Other issues

While temperature, turbidity, specific conductance, and flow modification are the specific impairments that have attracted regulatory attention, other issues mentioned in public input deserve further attention. Potential microbiological contamination is a widespread cause of concern. Discharge or leakage of human waste from recreational vehicle's holding tanks and from recreational area bathrooms is a substantial concern. Grazing animals in much of the watershed (even within the Pecos Wilderness in the upper reaches of the watershed) may, or may not, contribute significant microbial contamination as well as streambank degradation and temperature increases. No information is known about the potential presence of currently unregulated contaminants such as low levels of pharmaceuticals or endocrine disruptors that may persist in treated wastewater, even though there is no particular reason to think that these contaminants would be likely in our area.

Sampling should be done to determine the presence and extent of any problems. If problems are substantial, then perhaps corrective action should be planned. In addition to concern about physical or chemical water contamination per se, it seems important to remember that the overall goal behind setting water quality standards and controlling specific pollutants is to protect our health and to protect the ecological health and functionality of the river and the riparian ecosystems that it supports. It may be valuable occasionally to step back and assess the overall condition of the stream and its riparian corridor. Assessments should be conducted to determine if plants and trees are reproducing adequately, if appropriate wildlife can flourish, and whether invasive plants or animals are proliferating excessively.

4.3 Sources of Contaminants and Contributing Factors

The contaminants discussed above enter our streams as a result of the following situations or activities:

4.3.1. Recreational use and overuse

Overuse of recreational facilities and non-regulated recreational uses have, and are continuing to, significantly damage some stream banks and riparian areas along both the Pecos River and Cow Creek. Trampling, driving vehicles, and attendant soil compaction all kill or damage vegetation which leaves bare soil that erodes into the river, as well as raising water temperatures when shade is lost. There is also concern about discharge of human waste from recreational vehicle holding tanks and inadequate sanitation facilities. Problems along both the Pecos River and Cow Creek that are related to recreational use include:

- All-Terrain Vehicle (ATV) use in the riverbeds and adjacent riparian areas
- Camping in riparian zones, especially damaging on actual stream banks
- Gray and black water dumping by campers
- Improper waste disposal
- Lack of adequate toilets/outhouses in areas used for camping
- Inadequate maintenance of existing outhouses
- Lack of trash receptacles at campgrounds and picnic areas, and trash collection point(s) ∞ Lack of clean drinking water
- Lack of clear information on allowed facility uses and obtaining permits ∞ Law enforcement issues
- Lack of adequate regulation, especially on State lands, and insufficient law enforcement throughout the canyon

There are six Forest Service campgrounds and two picnic sites in area as well as the Bert Clancey, Tererro, Koch, and Mora areas that are managed by the New Mexico Department of Game and Fish. These facilities are generally inadequate to provide for the level of demand seen in much of the summer and early autumn. Designated facilities are prone to overuse, and users overflow into other areas not equipped or intended for camping or intensive use.

Water quality is degraded by excessive recreational use when damaged riverbanks are eroded by spring runoff or summer thunderstorms, when sediment is washed into the river from inappropriate vehicle tracks or other places where vegetation no longer protects the soil, and when trash, human waste, or other contaminants are washed into the river.

4.3.2. Damaged vegetation

There are many locations within the watershed where existing vegetation is significantly less than it would be under natural conditions. Stream reaches with impoverished riparian vegetation are a particular concern where water temperatures cause stream impairments, and increasing streamside vegetation and shade is a high priority. Degraded riparian vegetation may result from past or present grazing pressure (which prevents the regeneration of woody vegetation), vehicle damage, excessive foot traffic which tramples seedlings, shoots and small plants; or excessively "flashy" runoff, particularly from summer thunderstorms which can wash out young vegetation before it can become established and lead to down-cut stream channels that leave their former riparian areas desiccated. Some of these reasons for inadequate vegetation relate to the recreational pressures described above.

Grazing on public land in the watershed is largely regulated by the Forest Service, since there is very little other potential public grazing land (BLM and State lands make up a very small part of the total area). There is a significant acreage of private land that has been and could be grazed, but much of the private ranch land within the upper Pecos is within ranches whose owners are much less dependent on grazing income than previous owners, and therefore the stocking levels are probably much lower than in prior years. Grazing affects water quality primarily by influencing the amount of grass cover present to prevent soil erosion. The effects of damaged grass cover can be dramatic, but conversely, the effects of properly managed grazing to stimulate grass growth and protect the soil can be amazing.

4.3.3. *Stream channel geometry and dynamics*

Many reaches of the Pecos River, and some reaches of other streams, exhibit excessive width and inadequate depth relative to the stream channel geometry that would be expected of their geographic location and Rosgen stream type. The historic causes for this are not known with certainty, but seem likely to include damage to riparian vegetation from grazing or recreational impacts (leading to stream widening when riparian vegetation is no longer maintaining stream width); and/or changes in watershed land cover in response to logging, grazing, or other land use changes, leading to altered runoff patterns that in turn change channel dynamics and shape. The result of the shallower and wider stream, in any case, is to reduce the proportion of the stream shaded by what vegetation remains, and to increase the heat absorbed by water as it flows along the stream.

4.3.4. *Logging*

There is no commercial logging on any scale in the watershed going on at present, although there certainly has been in the past and it could happen in the future. The principal threat to water quality from logging is damage to the herbaceous soil cover – grass and forbs – that can be inflicted by building logging roads and skidding logs across the ground, especially on steeper terrain where any damage to protective vegetation can easily lead to serious gully erosion. Much of this damage can be avoided by adopting logging practices that protect, restore, and/or avoid damaging ground cover, and it should be noted that any meaningful attempt to reduce the threat of a large-scale forest fire within the watershed will involve some degree of timber management, whether or not logs are sold for use commercially. Logs can be harvested from a landscape without excessive damage to ground cover plants and soil erosion, although it may well require extra attention and some extra costs on the part of logging contractors, which will in turn affect the prices paid for timber products. However, without some fairly extensive thinning, mulching, and prescribed burning of many forest stands in the upper Pecos, a large-scale and potentially very damaging wildfire is all but inevitable.

4.3.5. *Fire damage*

Erosion from forested areas impacted by the Viveash, Dalton, Trampas, Jaroso, and Tres Lagunas fires contributed in the immediate aftermath of the fires to turbidity and sedimentation of the Pecos River and its tributaries. The report, *Special Water Quality Survey of the Pecos and Gallinas Rivers below the Viveash and Manuelitas Fires* (Hopkins 2001) has data tables which report water quality problems post Viveash Fire. The report can be downloaded in PDF format form the following web page: https://www.env.nm.gov/swqb/Wildfire/Viveash/index.html. Potential effects of large-scale wildfires on the watershed have been discussed at length already.

4.3.6. *Development and transportation*

Subdivision and development of land along the Pecos River for housing will continue to increase the likelihood of significant negative impacts on the watershed. Construction sites, septic systems, and additional roads, in addition to unregulated impacts such as illegal dumping of trash, can all impact water quality. Septic systems in areas with shallow ground water, like river valleys, have caused serious water pollution in northern New Mexico, and could quite possibly do so in the Pecos valley. The closer a septic leach field is to a stream, the shallower the water table, and the greater the density of septic systems, the greater the likelihood of water pollution.

Roads and other impervious surfaces like roofs and driveways can also greatly affect storm water runoff. Water that used to soak into the ground runs off much these surfaces more rapidly, increasing flash flooding, erosion and sediment transport. Many roads throughout the watershed have poor drainage and poor placement of (or need for more) road culverts, and this exacerbates erosion problems by improperly channeling and concentrating water flow. Some roads have been upgraded in regard to drainage and runoff, but it would be valuable to look for these problems throughout the watershed and prioritize remedial efforts.

New domestic wells can collectively have the effect of increasing infiltration of water from the river into depleted aquifers, reducing stream flow and increasing the concentration of any pollutants found in the water.

4.3.7. Waste disposal

There have long been anecdotal stories of liquid waste from recreational vehicles and even commercial septage haulers being disposed of illegally in streams or arroyos. Some dispersed camping areas suffer from inadequate toilet facilities, and even some developed campgrounds are in need of additional or updated facilities. In addition to recreational issues, there are concerns about nitrate or microbiological contamination from inadequate septic systems or even antiquated, now-illegal cesspools. Most settled areas within the watershed have high water tables, and are highly vulnerable to ground water contamination.

One significant issue for recreational use in the watershed is the lack of any legal way to dispose of RV waste, which is highly toxic to municipal wastewater systems because of the microbicides used in RV waste holding tank chemicals. The Pecos wastewater treatment plant cannot accept RV waste, or even septage, and no other nearby treatment facility can accept RV waste – a situation that adds encouragement for illegal disposal. Upgrading treatment facilities to accept RV waste or septage is a complex engineering problem and is not easy or inexpensive to accomplish. Nevertheless, it is an increasing priority for the Pecos area and our watershed, especially given increasing recreational pressure. A solution will require continuing collaboration with local government planners, legislators and other elected officials, and potential funding sources.

An additional ongoing concern is illegal dumping of household trash and other solid waste in arroyos and along rural roads. Both public education and additional enforcement are needed to reduce this source of contamination.

4.3.8. Mining

Concern has been voiced as to whether metal contamination from Tererro mine tailings may still be a problem, although the remediation project is periodically monitored. (See *Investigation of Trace Element Contamination from Tererro Mine Waste*. O' Brian, 1991). The UPWA may be a helpful forum for communication between the Pecos valley community and the New Mexico Environment Department about monitoring and other aspects of the Tererro mine cleanup.

4.3.9. Beaver as a keystone species

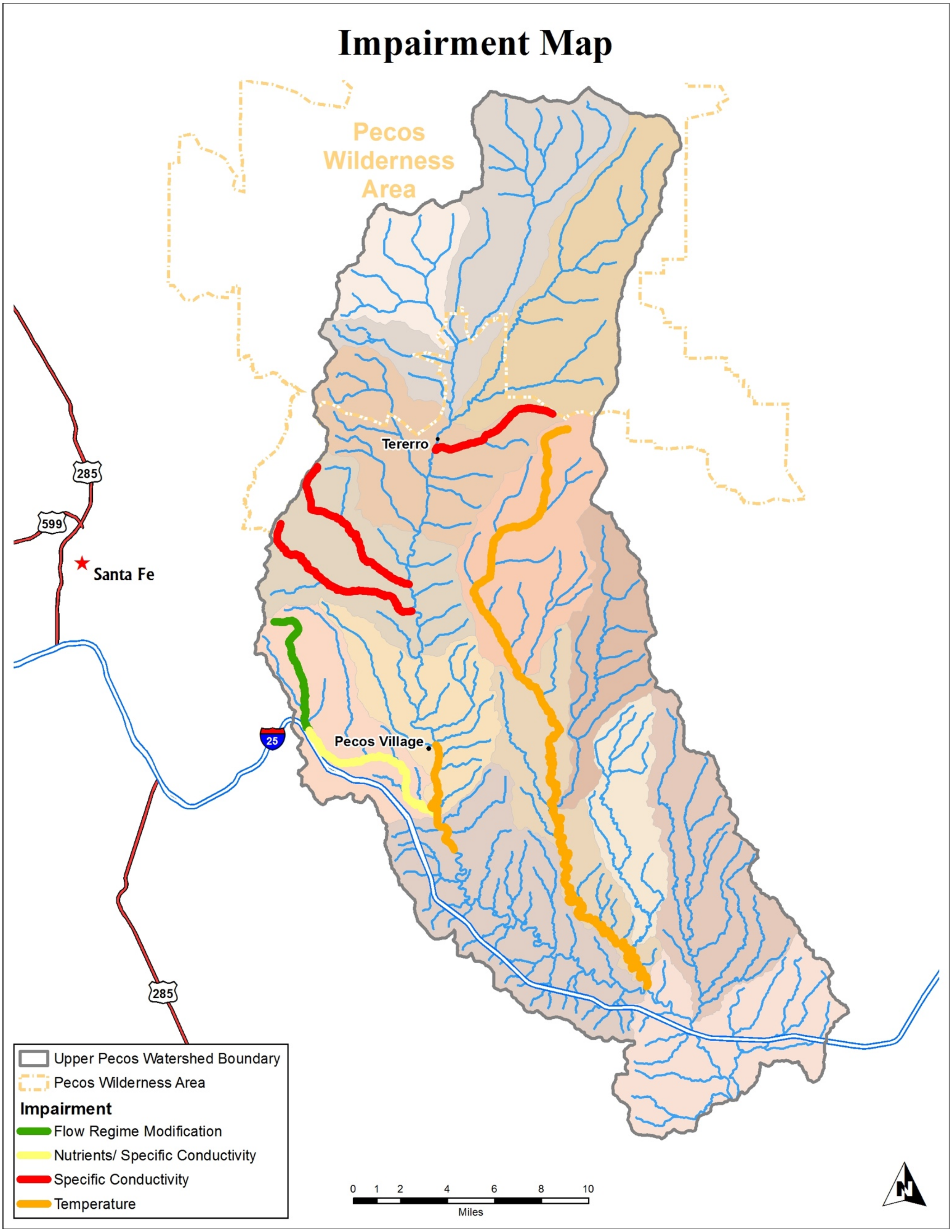
Beaver dams and riparian wet meadows go together. Among other benefits, beaver dams naturally induce stream meanders, dissipate high-energy flows, and create wetlands. Removal of beaver from watersheds in North America is thought to be one of the largest negative impacts to riparian areas. Not every landowner wants beaver on their property for a variety of reasons. For these landowners, the New Mexico Department of Game and Fish will trap and remove unwanted beaver. However, there are significantly fewer beavers and many fewer beaver dams on all Pecos tributaries than there once were, and where beaver presence will not conflict excessively with other land uses, their presence will help to stabilize our stream systems, moderate flood flows and increase mid-summer base flows, minimize sediment and turbidity in water, and maximize the resilience of the watershed.

4.3.10. Unknown sources

The source and exact nature of the conductance and nutrient levels measured in Glorieta, Dalton, Macho, and Willow Creeks is not known. Additional sampling needs to be done to determine these sources and to suggest restoration strategies to address them, if they are not natural background levels.

The sources of contaminants and stress that can be mapped to a particular location are shown on the following page. Source locations are shown based on those contributing primarily to temperature impairments; those that are clearly causing excessive sediment pollution (even if the affected stream reach is not currently listed as impaired for sediment); and sources that are contributing to both excessive temperatures and inappropriate sediment levels. The stream reaches impaired for excessive conductance, nutrients, and eutrophication are also shown – although the task before us in those streams is to determine the exact nature and source of the contamination. Once this data gap is filled, we can move on to addressing the source(s) to remove the water quality impairment.

The following chapter on **Management Measures** that begins after the contaminant source map discusses the particular projects and activities needed to accomplish watershed restoration. Chapter 6 on **Pollutant Load Reductions** explains the methodology used to estimate the quantitative levels of pollutants or stress causing water quality impairments, the level of improvements needed, and the anticipated effects of management measures to restore water quality.



Impairment Map
Pecos Wilderness Area
Tererro
Santa Fe
Pecos Village
285
599
25
Upper Pecos Watershed Boundary
Pecos Wilderness Area
Impairment
Flow Regime Modification
Nutrients/ Specific Conductivity
Specific Conductivity
Temperature
0 1 2 4 6 8 10
Miles
N

5. MANAGEMENT MEASURES

A variety of different projects, in numerous specific locations, are necessary to improve watershed conditions and remove the impairments to water quality in the upper Pecos. They are based on the restoration techniques discussed below, and combine those practices as needed in the particular situations to be addressed. These restoration projects are listed and summarized in the tables that follow in this chapter, organized by the major water quality impairment to be addressed and the stream affected. Estimates are included of project costs and water quality improvements expected, among other attributes. Details of cost calculations and model results for project effects are presented in more detail in Appendices B and C.

5.1 Restoration Techniques

5.1.1. Temperature control

In a healthy stream, essentially all water (except during periods of unusually intense rainfall) enters the stream as ground water – it percolates into the stream as baseflow from the stream bed and banks, and it enters the stream at something near the annual average air temperature – which may be 40 degrees Fahrenheit (F) or lower at higher altitudes, and is barely 50 degrees F even in the village of Pecos. Water in the stream warms up as it absorbs solar radiation in flowing downstream. The wider, shallower, and more slow-flowing the stream is, the faster it will warm up; and similarly, the less streambank shade it has, the warmer it will be.

The warmer the water, the less dissolved oxygen it contains. This is an ecological issue because trout, among other fish, cannot survive on the amount of oxygen in water that is too warm. Water warmer than about 68 degrees (f) is generally considered too warm for trout, although species adapted to conditions in the southwest (such as the Gila trout) seem able to survive in water somewhat warmer than this. There is some uncertainty that 68 degrees F (20 degrees Celsius) is an absolute cutoff point for trout survival, but there is no doubt that cooler water is better and water temperatures much above this reduce trout vigor and survival. Lack of oxygen in warm water is the basis for considering a stream impaired because of temperature: in a natural state it could support a trout fishery, but in actual conditions trout have difficulty surviving the high temperatures found during summertime, when river flows are low and temperatures at their highest. The unnaturally high temperatures are the cause of the impairment; and the source of the excessive temperature involves one or more of four factors:

1. Too little streamside vegetation to shade the water
2. Excessive stream width (and too little depth) relative to natural conditions
3. Surface runoff flowing directly into the stream from roads or similar surfaces, warmed by hot ground surfaces and entering the stream at significantly higher temperatures than natural base flow
4. Floodplain disconnect that results from channel incision and reduces cool water inflows in the hyporheic zone

Techniques to reduce water temperature address these factors, as described below.

Vegetation: There are many places along our temperature-impaired streams where there are few if any trees or shrubs on the streambanks. This may be a result of grazing pressure (present or past) that eventually kills all woody sprouts and prevents regeneration of trees and shrubs, excessive recreational use and trampling, down-cut river beds that cause former floodplains to dry out, or other reasons – but in most cases the solution is simply planting appropriate native species, once the cause(s) of the lack of vegetation have been addressed (i.e., recreational traffic may need to be re-routed, cattle fenced off, and so on). It is worth noting that improving the density and variety of riparian vegetation offers additional benefits besides just shade – such as improved aquatic and terrestrial wildlife habitat, reduction in stream bank erosion, and flood peak attenuation as water spreads out and slows down in the floodplain.

The principal re-vegetation techniques or practices applicable in our situation are:

- Planting rooted seedlings or saplings of native riparian trees and shrubs, appropriate for their altitude and other site characteristics (alder, Rock Mountain maple, high-altitude willow, box elder, or narrowleaf cottonwood, for instance, above the village of Pecos; coyote willow, Rio Grande cottonwood, or box elder at lower elevations).
- Planting native herbaceous riparian plants if they are missing from the community (sedges, spike rushes, rushes, and riparian grasses).
- Fencing cattle or other domestic grazing animals away from riparian areas, and providing them with hardened stream access points for drinking water (or other sources).
- Managing recreational traffic, foot and vehicle, to prevent or at least minimize vegetation damage.

Stream channel shape: The need for in-stream channel restoration and habitat improvement stems from the relatively broad and shallow channel geometry of much of the Pecos River in its publicly accessible reaches. The excessively broad and shallow character of some stream reaches may be caused by long-term damage to streamside vegetation from grazing, human traffic, or vehicles; former mining or other activities; past watershed conditions like excessively flashy runoff; upstream erosion in the past that led to increased sediment deposition at downstream locations; or reasons unknown. However, even though the quality of the water and most of the river-bottom substrate are both generally good, in terms of fish (especially trout) habitat, there are long reaches with relatively little contrast between pools and riffles, few deep pools or shady undercut banks, and little shade. While any angler will confirm that the Pecos supports trout, it could support considerably more. Perhaps more importantly, a more diverse aquatic habitat and increased streamside vegetation would provide greater resilience in the face of potential climate change, by reducing maximum water temperatures during summertime low flows and providing many more refugia for fish in the form of shady pools, in-stream holes, reversals, eddies, and bank-holes. Restoration that reduces water temperatures in the upper reaches of the Pecos River would help meet temperature TMDL goals in the non-attaining reach of the Pecos from Alamitos Creek to Manzanita, by lowering water temperatures at the beginning of the reach.

In the Cow Creek and other sub-watersheds, excessive stream width is not as widespread an issue as it is on the Pecos (although there are places where reducing width and increasing depth would be helpful). The most powerful tool for addressing the temperature-caused impairments on Cow Creek would be increasing shrubs and trees along its many un-shaded reaches. A number of specific project locations are identified along the publicly-accessible reaches of Cow Creek. There are undoubtedly many other opportunities along the lower reaches that flow through private land and are not accessible by road – air photo inspection suggests many locations that appear to have little if any streamside shrubs or trees.

Techniques to improve stream channel geometry, where needed, include (after design by an appropriate hydrologist, engineer, or aquatic ecologist):

- Direct manipulation of pool and riffle structure by careful in-stream excavation, rock placement, and deposition of excavated material adjacent to the banks to narrow the channel, create gravel bars, and induce meandering.
- Structures like vanes or barbs extending out from the stream bank to catch sediment, provide habitat for vegetation and fish, reduce near-bank hydraulic shear stress, and result in a narrower, more structurally varied, and deeper stream.

- Planting vegetation on islands or point bars to encourage meandering, channel narrowing, and other features of aquatic habitat diversity.
- Providing hardened access points for fishing and other recreation (for example, stone steps or ramps) and planting vegetation between access points, so that recreational traffic does not beat down entire reaches of riverbank; native vegetation can then re-establish in proper densities and reverse the tendency for over-wide and unshaded stream reaches.

Surface runoff control: The focus of drainage-related improvements to roads, parking areas, and similar hard surfaces is to prevent storm water from running directly off the road surface into nearby streams. As well as being generally warmer than stream water, road runoff almost always carries fine sediment and perhaps other pollutants from the road and erodes additional sediment as it runs over the land into the stream. Both excessive local sediment and elevated temperature cause problems for streams and fish. Excessive sediment harms fish by direct abrasion of eyes and gill surfaces, making it difficult for visual predators (like trout) to find prey, interfering with gravel streambeds needed for egg-laying, and contributing to excessive temperatures as turbid water absorbs more solar heat. Even in streams not listed for impairment because of sediment, sedimentation can still be a locally important pollutant - and it remains important to prevent excessive sediment from causing impairment in the future. Techniques to manage and prevent direct surface runoff therefore offer benefits for both temperature and sediment control.

The key to preventing direct runoff is simply to interrupt the flow of overland water before it reaches a stream, and allow it to soak into the ground. This can be done by:

- Re-grading large bare surfaces like parking areas so that they do not drain directly to a stream, but rather drain into a detention area where runoff can infiltrate.
- Creating swales (low banks to retain runoff on the upstream side of the bank), which should if possible be vegetated with native grass to protect them.
- Routing road drainage so that bar and roadside ditches empty into detention areas of some sort, and not directly into a stream.

5.1.2. Sediment control

The techniques just discussed for controlling surface runoff control sediment transport as well. There are a few more techniques that may be needed in certain locations for minimizing soil erosion and preventing mobilized sediment from entering streams in excessive quantities. Most of these involve roads and vehicle access, such as:

- Installing culverts that are properly designed and installed, or culvert-less rock crossings, where road drainage causes unsurfaced roads to erode
- Preventing vehicle access to streams and riparian areas
- Arranging picnic and camping areas so that vehicle access and parking areas drain into detention basins of some sort and are not too close to streams
- Creating sediment traps and erosion control structures, such as one-rock dams, log mats, Zuni bowls, and media lunas, in tributary drainages
- Protecting stream banks at recreational sites, with vegetation where excessive foot traffic will not damage it and with hard-scaping (stone, concrete, or gravel) in areas of high use and/or deep shade

Road-related erosion is generally greater in the lower (foothills and xeric) erosion zones, and seems particularly evident along some roads in the Alamitos Creek area. However, sediment from eroding ditches and road surfaces in the Alamitos watershed is probably mostly intercepted by the long, relatively level and hydraulically rough stream channel (lined with angular rock) created across the covered mill tailings from the former El Molino mining site. Reaches of Alamitos Creek above the remediation site may still be locally impacted by excessive sediment loading, however.

Both Rio de la Osha and Manzanares Creek are tributaries of Cow Creek, so minimizing road drainage into them will help reduce temperature impairment in Cow Creek. They are also small, but normally perennial streams, so excessive sediment transport, even if localized, can have a fairly dramatic impact on the affected stream reaches.

UPWA can also play an important role in collaboration with the New Mexico Department of Transportation and San Miguel County on land use planning in public education about the erosion and runoff effects of poorly-planned and excessively-steep roads and private driveways – some of which are clearly causing such problems already.

5.1.3. Conductance, nutrients, and eutrophication

The active restoration work needed in the upper Pecos focuses on impairments caused by excessive temperature or sediment. Other impaired stream reaches are affected by high levels of specific conductance (indicating excessive but unknown dissolved salts). The sources of these pollutants are not known, and the focus of our work at this point needs to be to identify more precisely the nature of these pollutants and their sources. The sampling and analysis techniques for this are described in Chapter 8 on Monitoring, and essentially involve more intensive sampling of pollutant levels to determine where they first appear (or if they are present everywhere), and some chemical analysis to determine the source of conductance present. With this information it should be possible to determine if the impairment is cause by human activities or is a natural background condition, and plan restoration work if needed.

5.2 Project Summaries

In the tables that follow, some project attributes are numerical values (such as cost), or verbal descriptions; others are presented with standardized values (high, medium, low) to permit sorting the project spreadsheet(s) on the basis of these values. A word of explanation about how these project attributes are derived may be helpful.

Cost: Estimated project costs are intended to be approximately correct at the time of the revision of this Plan (fall of 2018) and reasonably consistent, but are not by any stretch detailed, contract-ready bid prices. Cost estimates assume contracting with a commercial company to do the work; actual out-of-pocket costs could be less if a project can utilize volunteer labor, donated or locally-available material, or landowner participation, for instance. The actual amounts needed to complete any given project will of course change over time. Any project will need to be field checked and costs refined and updated before any real work can be done. Details of cost calculations are shown in Appendix B.

Duration: Project durations are also approximate and intended to allow meaningful comparisons rather than detailed construction scheduling. They do, however, give a reasonable basis for comparing the scope of different projects. The estimates in years, beginning with a minimum of “less than 1 year”, for projects that could reasonably be expected to go from initial selection through any necessary design and permitting to full completion in less than a year.

Preparation complexity: Some projects, for instance building stone steps or ramps at popular fishing access sites to prevent continual bank erosion into a stream, can be done without needing formal design or a Section 404 permit, NEPA clearance, or other advance permitting - although they would of course require permission from the landowner, public or private. Such a situation would have very low preparation complexity. At the other extreme, a change in landscape-scale forest management on the level of a CFLRP project would require years of outreach and lobbying, a multi-year NEPA process probably involving at least an Environmental Assessment, and many other procedural and political steps – extremely high preparation complexity. Three levels of complexity are shown in the tables: **low** complexity indicates that little or no formal permitting or professional engineering design would be required. **Medium** complexity indicates that a nationwide Section 404 permit, simple and uncontroversial NEPA documentation, or equivalent level of approval would be needed, along with more formal designs and specifications. **High** complexity indicates an individual 404 permit, lengthy and substantial NEPA process, some significant public involvement, design by a professional engineer or other specialized experts, extensive political background, long and complex grant proposal, and/or other lengthy and somewhat uncertain processes that have to take place before any actual project work can begin.

Public visibility: A **low**-visibility project would be one located on private land, or on little-visited and relatively inaccessible public land, and one with effects that might be valuable for the watershed but would not be apparent to casual visitors or residents not typically informed about watershed issues. **Medium-**visibility indicates work that some ordinary people would be aware of in visiting the watershed or going about daily life; while **high**-visibility projects would be those that significant numbers of people (like summer visitors to the Pecos Canyon) would be aware of in the course of normal activities.

Water quality effects: The anticipated effects of restoration projects are calculated using the Stream Segment Temperature model, or SSTEMP, for effects on water temperature; and site-specific calculations were used for erosion and sediment transport. The predicted pollutant load reductions or other project effects are summarized as **low, medium,** or **high.** These predictions were developed in 2012 and were not updated for this version of the Watershed-Based Plan.

Other project attributes are listed in the complete project spreadsheet (in Appendix A), and are hopefully self-explanatory. Summary tables of key project attributes are presented on the following pages, beginning with those intended to make a pro-active effort to prevent future watershed damage before it results in expensive, long-term impairment of water quality.

5.2.1. Projects and activities to prevent future watershed damage

Project name	Stream	Description	Duration	Prep complexity	Visibility
Visitor Center	multiple	Multi-agency visitor resource center	ongoing	high	high
CFRP thinning	multiple	Follow-on CFRP project(s) to implement roadside thinning	4 yr	high	high
NM Forestry	multiple	Assistance for hazardous fuel reduction	ongoing	low	low
NM Assoc of Counties	multiple	Assistance for non-federal WUI fuels reduction and CWPP development/updates	ongoing	low	low
CFLRP project	multiple	Build support for long-term CFLRP fire-ecology restoration project in upper Pecos	10 yr	high	high
Arroyo trash removal	multiple	Arroyo trash removal and dumping prevention (coordinated with other solid waste issues)	ongoing	low	med
RV waste disposal	multiple	Provide for disposal of RV waste (along with other liquid waste issues)	ongoing	high	med
Land use planning	multiple	Collaborate with San Miguel County in land use and waste management planning	ongoing	high	high
Jamie Koch campground	Pecos	Convert area to provide for camping: parking, sites, toilets, tables, etc; re-vegetation	<1 yr	med	high

Project name	Stream	Description	Duration	Prep complexity	Visibility
Links Tract campground improvements	Pecos	Expand and improve Links Tract area to provide for additional camping to alleviate crowding elsewhere	<1 yr	med	high
Monastery Lake improvements	Pecos	New toilets; improved picnic facilities, parking, and lake access; re-vegetation	<1 yr	med	high
Travel management	multiple	Work with Forest Service and other agencies to prevent inappropriate off-road truck and ATV use	ongoing	low	med
NM 63 Road Drainage	Pecos	Assess and address road drainage into Pecos River and Tributaries	<1 yr	med	med
Invasive Management Protocol for restoration activities	multiple	Retain wetland species after restoration disturbance event	ongoing	low	med
Wilderness Wetlands Enhancement Projects	multiple	Improve trail maintenance and install waterers for cattle and wildlife to protect wetland areas from trailing and gullying	2 yrs	med	low
Fish Structures	multiple	Assess and remove old log fish structures and replace with rock cross vanes or riffle structures based on location and stream type	ongoing	high	med
Recreation Improvements	multiple	Bathroom facilities at Cow Creek and create angler access points to reduce bank erosion. Trails down to banks need to be re-routed or drained	<1 yr	med	high
Riparian Conifer Treatment	multiple	Thinning project to reduce the encroachment of conifers in the riparian corridor	ongoing	low	low
Wetlands Action Plan Update	multiple	Current Wetlands Action Plan completed in 2009 needs updating to develop a better assessment of upper Pecos watershed wetlands	2 yrs	med	low

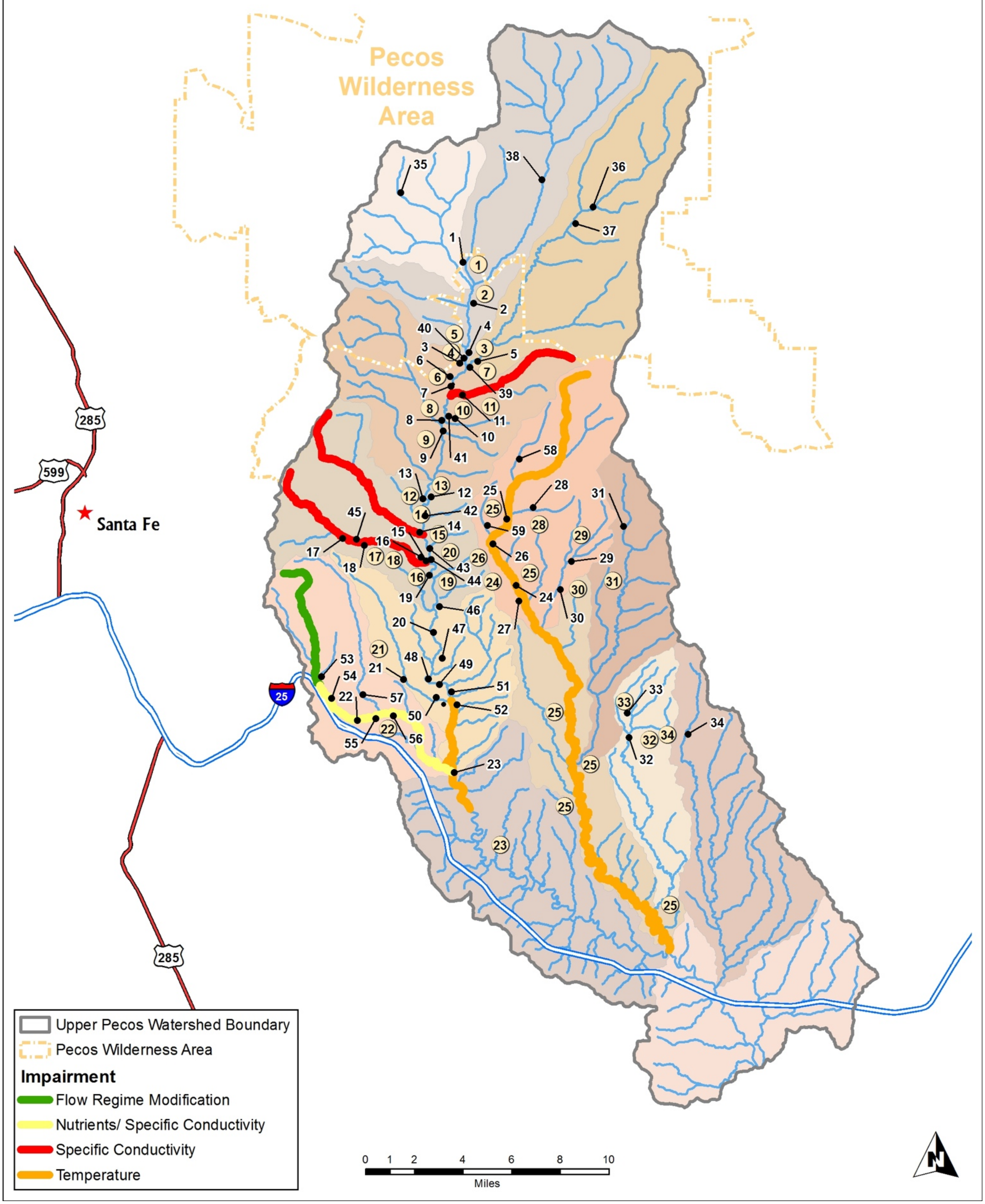
Water quality effects of these projects are impossible to summarize. They are not focused on immediate direct effects, but rather on averting future effects that could be disastrous. For instance, if a significant forest fire or large-scale inappropriate development can be prevented, massive water quality damage would also be averted. Similarly, it has also not been useful to try to calculate costs for these projects or activities in the same way that costs are included for other projects – largely because many of them are open-ended, ongoing campaigns of collaboration and persuasion to help build coalitions of stakeholders and agencies so that contributions and government appropriations can be combined and leveraged for large-scale efforts, the scale and cost of which are not yet known. As mentioned, all these projects primarily involve facilitation, collaboration, and partnership with stakeholders and agencies. For Collaborative Forest Restoration Program (CFRP) projects, such as follow-on roadside forest thinning to implement the project planning now underway, UPWA could be a direct project proponent and grant recipient. Collaborative Forest Landscape Restoration Program (CFLRP) projects are implemented internally by the Forest Service, but they do require external partnerships with organizations like UPWA, and a great deal of planning, organization, and political support before being funded. A new multi-agency Pecos Valley Visitor Center would necessarily involve multiple land-management agencies as well as other local interests.

The financial assistance provided by either the New Mexico State Forestry Division or the New Mexico Association of Counties for hazardous fuels reduction on non-federal land is normally targeted towards private landowners, and UPWA's role more likely to focus on encouraging landowners and helping to get them in touch with the right opportunities. As with fire damage reduction, collaborating with San Miguel County to help facilitate and encourage local planning for land use and solid waste management that protects the watershed is likely to yield water quality improvements on many different stream reaches over time, even though it is not possible to point to a specific load reduction or the elimination of a current impairment. There is an unacceptable level of illegal trash dumping in arroyos, and better citizen awareness and ultimately law enforcement will have a direct effect on the condition of those water bodies.

Disposal options for both domestic septage (pumped from septic tanks) and liquid waste from visiting recreational vehicles are severely limited in the area – in fact, there are no legal options for RV waste disposal within the watershed or nearby towns or cities at present. While UPWA itself is not likely to build or operate such a facility, it is uniquely positioned to help identify options and provide education about the importance of the issue.

The map on the next page shows the location of all projects that have a specific location, identified by the project number. Projects affecting the entire watershed (like fire damage reduction) or with an uncertain location (like a facility for managing RV waste) are not located on the map.

Project Location Map



The projects in the tables below focus on particular pollution sources in specific places, organized by pollution cause. Locations for these projects are mapped by project number in the figure above.

5.2.2. *Water temperature control projects*

No.	Project name	Stream	Description	Cost	Duration	Prep complexity	Visibility	WQ effect
23	Lower Pecos riparian trees	Pecos	Plant trees to shade river on National Monument and private land from Glorieta Cr downstream	$52,000	5-10 yr	low	low	med
25	Cow Creek stream shade	Cow Cr	Plant trees/shrubs (restrain grazing if needed); primarily on private land from approximately Rio de la Osha confluence downstream	$46,800	1-2 yr	low	low	high

These projects focus primarily on providing additional streamside vegetation for shade to reduce water temperatures. They would involve the kinds of activities discussed above (on pages 47-49) for mitigating conditions causing excessive temperature. They may incidentally offer additional bank protection from erosion, but there is no evidence that banks are eroding or contributing excessive sediment at present. Additional streamside vegetation would often, however, offer collateral wildlife habitat benefits for both terrestrial birds and animals and fish. The projects in the table below (the majority of proposed projects) will help reduce excessive water temperatures and will also help reduce excessive sediment runoff or bank erosion, whether or not a stream reach is currently considered impaired for sediment. There is considerable value in keeping sediment impairment from developing in the future, as well as reducing the immediate temperature impairment.

5.2.3. *Projects controlling sediment and temperature*

No	Project name	Stream	Description	Cost	Duration	Prep complexity	Visibility	WQ effect
1	Panchuela Campground	Panchuela	Minor bank repairs and revegetation	$7,621	<1 yr	low	med	low
2	Cowles area bank repair	Pecos	Bank repairs (harden or protect river access points with stone steps, cobble paving, or other ways to keep banks from being trampled by heavy use) and re-vegetation at access points around Cowles	$34,383	1-2 yr	med	high	low
3	UPWA Community Fnd. project	Pecos	Narrow and deepen Pecos River above Mora campground; revegetate banks	$68,069	<1 yr	low	med	med
4	Carpenter Creek to Rio Mora stream restoration	Pecos	Carpenter Cr to Rio Mora: reduce width, enhance fish habitat; protect/harden access points; replant along banks (includes 5Star project; continue/expand)	$125,000	1-2 yr	med	high	med

No	Project name	Stream	Description	Cost	Duration	Prep complexity	Visibility	WQ effect
5	Mora Campground re-development	Mora	Prevent excessive vehicle traffic/bank access; re-locate roads and camping areas; revegetate, grade to keep runoff out of stream	$250,000	1-2 yr	high	high	med
6	Rio Mora to Willow Cr stream restoration (public land)	Pecos	Reduce width, enhance fish habitat; protect/harden access points; replant along banks (NMDGF land; incl 0.9 river miles above and below private land)	$227,273	2-3 yr	high	high	med
7	Rio Mora to Willow Cr (private land)	Pecos	Similar treatment on private land; incl 0.7 mi between State parcels)	$48,295	2-3 yr	low	low	unk
8	Tererro Campground bank repair	Pecos	Tererro G&F site - harden access points and re-vegetation to keep runoff out of river	$22,105	<1 yr	low	high	low
9	Bert Clancy bank repair	Pecos	Bert Clancy site - minor re-grading to keep vehicles and runoff out of river; harden/protect river access; revegetate	$13,095	<1 yr	low	high	low
12	Former Windy Bridge left bank access	Pecos	Revegetate former user-created parking area	$28,838	<1 yr	low	med	low
13	Windy Bridge runoff control	Pecos	Windy Bridge site - create swales to keep runoff out of river; harden access points; revegetate	$16,460	<1 yr	med	high	med
19	Dalton Day Use bank and stream restoration	Pecos	Dalton Day Use area - reduce width at top and bottom of area, protect/harden access points to keep runoff out of river, replant along banks	$42,614	<1 yr	high	high	med
20	Hwy 63 Road drainage improvements	Pecos	Pull-off areas or other places where road runoff drains directly into river instead of soaking into ground	$19,225	<1 yr	low	low	low
24	Cow Creek 319 project	Cow Cr	319 project submitted for 2012: stabilize failing stream banks with bioengineering techniques; control grazing; plant native riparian vegetation; create wetlands	$313,704	1-2 yr	low	med	med
26	Cow Creek campgrounds	Cow Cr	Re-grade (swales, water bars?) FS campgrounds and re-vegetate	$48,300	1-2 yr	med	med	med
27	Cow Creek bioengineering	Cow Cr	Replace FS gabion project with appropriate bioengineering (Note: need to find out from FS what they're trying to do!)	Unknown	<1 yr	med	low	unknown
28	Rio de la Osha road repairs	Rio de la Osha	Culvert or crossing installation/repair and bar ditch re-routing	$57,330	<1 yr	high	low	med

No	Project name	Stream	Description	Cost	Duration	Prep complexity	Visibility	WQ effect
29	Manzanares Creek road repairs	Manzanares Cr	Culvert or crossing installation/repair and bar ditch re-routing	$44,772	<1 yr	high	low	med
30	Bar X Bar meadow restoration	Manzanares Cr	Plant trees/shrubs (restrain grazing if needed); private land on Rio Manzanares at Bar X Bar ranch	$22,468	1-2 yr	low	low	med
31	Bull Creek meadow restoration	Bull Cr	Plant trees/shrubs (restrain grazing if needed); private land on large meadow	$30,665	1-2 yr	med	low	low
32	Apache Creek meadow restoration	Apache Cr	Plant trees/shrubs and restrain grazing; private land on large meadow	$18,655	1-2 yr	med	low	low
33	Apache Creek road repairs	Apache Cr	Eroding road reaches (rolling dips, water bars, etc)	$9,828	<1 yr	med	low	med
34	Sebadilla Creek meadow restoration	Sebadilla Cr	Plant trees/shrubs and restrain grazing; private land on large meadow	$39,870	1-2 yr	med	low	med
35	Horsethief Meadows	Horsethief Creek	Treat post fire runoff, bank protection, wetland restoration, revegetation	$149,265	2 yrs	Medium	Low	Low
36	Upstream of Mora Flats	Mora	Incision upstream of beaver activity. Hand trail work. Restoration by hand of "diversion channel"	$32,736	1-2 yrs	Medium	Low	Medium
37	Mora Flats	Mora	Enhance shallow stream, reduce bank erosion, plantings on bank to reduce high water temperatures	$298,530	1-2 yrs	Medium	Medium	Medium
38	Wilderness Areas	Pecos, Mora	Trail work to reduce erosion and sedimentation into River	$327,360	2 yrs	Medium	Medium	Low
39	Mora River Campground	Mora	Restoration from mining activities, trail re-route or maintenance to reduce erosion, repair user damage (fishing trails) along bank.	$159,456	1-2 yrs	Medium	Low	Low
40	Pecos River above Mora Campground	Pecos	Enhance channel above the uppermost campground parking lot	$63,360	<1 yr	Medium	High	Medium
41	Tererro Dispersed Camping Revegetation & Road Drainage	Pecos	Revegetation of dispersed camping area and wetland restoration above and below road to capture sediment. Incl road work on Elk Mt Rd turn off to improve drainage	$92,506	<1 yr	Medium	High	Medium
42	Field Tract Campground Channel Restoration	Pecos	Abate channel incision with restoration structures and stabilize banks	$126,720	1-2 yrs	Medium	High	Medium
44	USFS Dalton Fishing Area Restoration	Pecos	Restore fishing habitat and pools impacted by sedimentation, stream restoration	$126,720	1-2 yrs	Medium	High	Medium

No	Project name	Stream	Description	Cost	Duration	Prep complexity	Visibility	WQ effect
45	Dalton Canyon Creek Restoration	Pecos	Enhance river features, esp. beaver ponds. Bank protection and Stream Restoration work. Address dispersed camping in the area.	$190,080	1-2 yrs	Medium	High	Medium
46	private land (FLW? #15)	Pecos	private land looks modified, not sure if it can be addressed	$253,440	<1 yr	Low	Low	Medium
48	River Restoration (Camino Rincon Area-private lands)	Pecos	Similar enhancement of river features in the channel to reduce erosion and address incised channel	$149,265	1-2 yrs	Low	Medium	Medium
51	River Restoration below St. Anthony's Church	Pecos	Enhance stream features, protect banks to reduce erosion and revegetate to improve habitat	$159,266	<1 yr	Low	Low	Medium
52	River Restoration at 550 bridge	Pecos	Bridge abutments cause braiding and over widening of stream, downstream reach suffers continuing bank erosion	$159,266	<1 yr	High	High	Medium
55	Glorieta Creek (near La Cueva Canyon private lands)	Glorieta Creek	Reduce sediments from gullies with bank protection and grade control	$126,720	<1 yr	Low	Low	Low
56	Glorieta Creek (private lands)	Glorieta Creek	Reduce sediments from gullies with bank protection and grade control	$506,880	1-2 yrs	Low	Low	Medium
59	Rito Chaparito Restoration	Cow Creek	Address post fire sediment runoff. Possible bank protection, revegetation and re-grading before sediments enter Cow Creek	$253,500	1-2 yrs	Medium	Low	Medium

These projects would also involve the temperature-control restoration techniques discussed on pages 59-61, but might also involve some of the sediment control techniques on pages 61-62. In most of the upper Pecos valley, thinly vegetated stream-banks are often associated with heavy visitor use in campgrounds and public fishing access sites. Simple trampling, and in some cases abuse by vehicles, has beaten down existing plants and shrubs and prevented successful regeneration of many species. Recovery begins with keeping all vehicles away from streams! After that, the solution to this problem is two-fold: access points that will receive heavy visitor foot traffic need to be hardened with rock or even concrete, because there is no vegetation that will take that kind of traffic. Either ramps or steps can be created, in many cases with locally available native stone, so that people can access the river without damaging riparian plants. Once adequate access points have been reinforced, reaches of streambank between access points can be re-vegetated with native plants, both herbaceous (rushes, sedges, forbs, and grass) and woody (willow, alder, maple, birch, and similar shrubs; along with narrowleaf cottonwood or box elder trees where needed). Vegetation for transplant needs to be appropriate for both shade and moisture conditions where it will be planted.

Along the lower Pecos Canyon, below approximately the Glorieta Creek confluence, the riverbanks are generally well-vegetated, but the vegetation present near the river includes very few trees. Most larger trees occur at some distance from the river, certainly far enough from it that they provide little if any shade. The reasons for this are not known with certainty, but may include agricultural clearing for fields; grazing pressure at some point in the past that prevented seedling recruitment; flash flooding that removed larger woody species from the immediate riverbanks; river incision in response to changing watershed conditions (again, at some point in the past); or other factors. In any case, trees could be planted in appropriate places along the current riverbanks to provide shade and a seed source for propagating new trees.

There are stream reaches trampled by cattle and almost devoid of vegetation in places along Manzanares Creek, Apache Creek, Sebadillos Creek, and possibly Bull Creek. These are, as far as can be observed, not long stream reaches and restoration would not be difficult – but would require control of grazing cattle to keep them from destroying streambank vegetation.

The projects listed in the next table will primarily control excessive erosion and sediment transport into stream systems, and would utilize the sediment-control techniques on pages 61-62, although they may involve some re-vegetation as well. They may incidentally offer some reductions in water temperature, especially during thunderstorm events where stormwater warmed by contact with pavement or other sun-warmed impervious surfaces would enter streams at higher temperatures than normal ground water inflow, but their primary effect will be to reduce excessive sedimentation.

Even though none of the assessment units in the watershed arecurrently listed as impaired because of sediment, there are many instances where sediment could become a substantial problem if not addressed before it does. It is important to note the New Mexico Water Quality Control Commission regulation (20.6.4.8A, NMAC) that requires that existing water quality shall be maintained at levels necessary to support designated uses. With this in mind, it is not only common sense and good management to prevent excessive bank erosion or other sediment sources from degrading water quality in the future, there is also regulatory recognition for this goal.

5.2.4. *Sediment control projects*

No	Project name	Stream	Description	Cost	Duration	Prep complexity	Visibility	WQ effect
10	Tererro dispersed camping repairs	Pecos	Dispersed camping area between Tererro and mine site: close user-made road access that erodes to river; create swales and re-vegetate; organize dispersed camping better	$42,295	1-2 yr	med	med	med
15	USFS Dalton Fishing Access	Pecos	Dalton FS Fishing Access - keep runoff out of river; protect/harden access points; revegetate	$15,523	<1 yr	med	med	low
16	Rainy Day runoff control	Pecos	Rainy Day area - protect/harden river access points; some revegetation; manage camping	$14,045	<1 yr	med	med	low

No	Project name	Stream	Description	Cost	Duration	Prep complexity	Visibility	WQ effect
18	Dalton Canyon dispersed camping management	Pecos	Pullouts/dispersed camping in Dalton Canyon - keep vehicles away from river; harden access points as needed; grade or create swales to keep runoff out of river (coordinate with FS project)	$31,538	1-2 yr	med	med	med
21	Alamitos road erosion	Alamitos Cr	Repair worst of road erosion and runoff into streams	Unknown	1-2 yr	low	low	med
43	Restoration from Tres Lagunas Fire near Una Laguna Rd	Pecos	Enhance river features, esp. pools and their habitat which were impacted by post fire runoff	$63,360	<1 yr	Medium	Low	Medium
47	Monastery Area Road Drainage	Pecos	Create rolling dips to drain old roads to keep sediment out of river and arrest erosion. Erosion Control, revegetation, thinning of doghair Pinon trees.	$102,696	<1 yr	High	High	Medium
49	Town of Pecos Rd Drainage (near Water Tank Rd)	Pecos	Road repairs to address drainage (rolling dips, infiltration basins, etc.) Reduce sediment in culverts	$46,252	<1 yr	Low	High	Medium
50	Pecos Independent School District Lands	Pecos	Water Catchment from school building rooftops. Address runoff from parking lots with stormwater infiltration basins. Trail work and upland erosion control on 60 ac.	$73,894	<1 yr	Low	High	Medium
53	Glorieta Camps Area	Glorieta Creek	Address runoff from roofs and parking lots, road drainage and infiltration, create recreation access points	$463,320	2-3 yrs	Low	Medium	Medium
54	Glorieta Creek near Pigeon Ranch	Glorieta Creek	Reduce sediments from gullies with bank protection and grade control	$196,680	<1 yr	High	Low	Low
57	La Cueva Creek upstream of old quarry to main valley	Tributary to Glorieta Creek	Repair roads to address drainage with rolling dips, swales. Bank protection and grade control to arrest incision	$196,680	<1 yr	Medium	Low	Low

Willow, Macho, Dalton, and Glorieta Creeks do not meet water quality standards because of high specific conductivity, which is an indication of some kind of dissolved chemicals in the water. Sampling so far has not identified *what* is dissolved. All four are small streams that diminish to a trickle in the summer and autumn, so a relatively small source of contamination could cause a substantial effect. Contaminants in Glorieta Creek could be associated with the Glorieta Conference Center wastewater treatment plant; but this has not been established. Conductivity in Willow Creek could be associated with Tererro mine waste rock or other mining activities, but this has also not been established. Similarly, domestic septic tank effluent could perhaps account for raised conductivity Dalton or Macho Creeks by forming part of their base flow as it moves through ground water. In all these cases, additional sampling, including analysis for specific ions and perhaps other testing, will be needed to identify the sources of the conductivity, establish whether it is a natural background phenomenon or is human-caused, and suggest possible solutions to the problems.

5.2.5. Source identification projects

No	Project name	Stream	Description	Cost	Duration	Prep complexity	Visibility	WQ effect
11	Willow Cr conductivity	Willow Cr	Identify source and correct high conductivity issue	$2,738	Unknown	Medium	Low	Unknown
14	Macho Cr conductivity	Macho Cr	Identify source and correct high conductivity issue	$2,738	Unknown	Medium	Low	Unknown
17	Dalton Creek Conductivity	Dalton Cr	Identify source and correct high conductivity issue	$2,738	Unknown	Medium	Low	Unknown
22	Glorieta Creek conductivity and nutrients	Glorieta Creek	Identify source and correct high conductivity issue	$2,738	Unknown	Medium	Low	Unknown

5.3 Prioritizing projects

In a situation as complex as the Upper Pecos, there is no mathematical formula that can yield a simple, numerical ranking of project priorities. All of the characteristics listed above influence the priority of the project or activity. The timing and even possibility of any particular activity is dependent on funding, and several activities can potentially be going on at once. It is not really useful to try to numerically compare the value of moving, uncertainly, towards reducing the likelihood of the massive damage that would result from a large-scale wildfire, with the much smaller but much more immediate and certain effects of repairing damage from overuse of popular streamside recreation areas. Both are important, and we intend to do both together as funding permits.

Clearly the modeled or anticipated water quality improvements from a potential project are an important element in prioritizing it – but far from the only criterion. It seems better to do three smaller projects if funding is available, or a landowner is willing, instead of missing an opportunity until after a large project can be completed at some point in the future, even if the larger project would have a much greater effect. There may also be value in doing a smaller but highly visible project (especially if it can be combined with useful outreach) before doing a larger project located in a little-visited area. Similarly, it may be more valuable to address a situation that protects a stream from uncertain but serious future degradation than to address a known and certain, but not critical, area of existing damage. The project spreadsheet is intended more to match needs with opportunities – projects with funding sources or site access, for instance – than to develop a single, fixed numerical ranking system. The relative ranking of projects based on characteristics such as cost, planning complexity, and anticipated effects (generally rated as high, medium, or low) is included in the spreadsheet so that priorities can be compared within and between categories of project, to assist with a flexible and ongoing overall decision-making process.

5.4 Existing Restoration Projects

It may seem a daunting prospect to consider implementing all these 60-odd restoration projects within the watershed, and indeed it is an agenda that will occupy the community and the Watershed Association for many years to come. However, it can be done, with help from many sources. The next chapter discusses an implementation schedule, partners, funding sources, and other kinds of assistance needed. It is also encouraging to consider all the successful restoration work that has already been accomplished, as outlined below.

- **UPWA Lower Cow Creek bank erosion restoration project**

This project, funded in 2017 with CWA Section 319 funding, is currently restoring approximately 0.75 mile of Cow Creek on private property where grazing and agricultural pressure and other factors have led to collapsing banks and incision. Collapsing and eroding banks are being stabilized with induced-meander and bioengineering techniques; native riparian vegetation is being transplanted; and a more stable floodplain is being created. Two additional segments of approximately the same length would extend this project all the way through the village of North San Ysidro. These two additional segments would use CWA Section 319 funding over the next four years to be implemented.

- **Respect the Rio**

Forest Service seasonal staff, supported in part with 319 funds, place signage and contact recreational visitors in conversation to encourage good camping behavior and explain how to recreational impacts to streams and riparian areas. In addition, the Respect the Rio project has contributed to campground infrastructure improvements.

- **UPWA Community Foundation project**

This project, funded in spring of 2012, restored appropriate stream geometry and bank vegetation for approximately 250 yards of the Pecos River just above the Rio Mora confluence, with limited in-stream excavation, vanes, and riparian re-vegetation.

- **Dalton Day Use Area River and Riparian Habitat Restoration**

This project, funded in 2015, restored appropriate stream geometry and bank vegetation for approximately 1,300 feet of the Pecos River at the Dalton Day Use Area, just below the bridge and the Pink Rock swimming area, with in-stream excavation, scour pools, buried tree root-wads, and riparian re-vegetation. The planted riparian vegetation is currently becoming established and will eventually provide shade on the river and floodplain stability during floods.

- **New Mexico Department of Game and Fish campground improvements**

The Department has re-graded parking areas, provided gravel surfacing, and re-located camping sites at the Bert Clancy and Tererro campgrounds; and has completed stream channel restoration on the Pecos River on their properties in the Pecos canyon.

- **SFNF Dalton Canyon dispersed camping improvements**

The Santa Fe National Forest completed improvements in dispersed camping management in Dalton Canyon, an area now heavily over-used on busy weekends where camp sites and vehicle access are frequently far too close to Dalton Canyon Creek, causing riparian degradation and stream contamination. These improvements will be further enhanced by an additional CWA Section 319 grant, received by UPWA in 2018, that will restore the former channel in some locations and further limit vehicle access to the creek.

- **UPWA "Hatchistery" Stream Restoration**

UPWA received a grant under the New Mexico Riparian Ecosystem Restoration Initiative (RERI) to remove a gabion irrigation diversion structure near the Lisboa Springs fish hatchery, re-engineer the diversion that feeds Monastery Lake, divert the Pecos River back to its original channel, and restore a silted-up backwater to ecological functionality and proper connection with the river. Large boulder structures were installed for grade control, native vegetation was planted along banks, and new wetlands were created in the old channel.

- **Tierra y Montes Soil and Water Conservation District Projects**

Tierra y Montes Soil and Water Conservation District implemented 35 projects with private landholders between April 1998 and March of 2003 with EPA 319 funds. Each of these projects included at least one of the following components:

Streambank Stabilization (28)

Riparian Restoration (3)

Riparian Fencing (10)

Improve Wetlands (1)

Critical Area Plantings (8)

Disturbed Area Seeding (7)

Forest Land Erosion Control (2)

Erosion and Ash Control after Viveash Fire (1)

Noxious Weed Control (Salt Cedar) (1)

- **Tererro Mine Tailing Reclamation**

The Pecos Administrative Order of Consent (AOC) was signed by representatives of the New Mexico Environment Department, NM Game and Fish Department, NM State Highway Department, and the AMAX mining company. The AOC provided a remediation and monitoring program that is still ongoing.

- **Pecos National Historic Park Glorieta Creek wetland project**

The National Park Service implemented a small wetland rehabilitation project in the Glorieta Creek floodplain about a quarter-mile from its confluence with the Pecos River. The project was designed in 1997 and completed by 2000. Sand and gravel mining had taken place in the area and the former quarries were made into two ponds. Levees and dams were removed and the site was reshaped to create wet meadows and areas of higher ground, in addition to the ponds. In 2000, willows, cottonwoods, and local native herbaceous plants were planted.

- **Truchas Chapter, Trout Unlimited Habitat Improvement Projects**

The Truchas Chapter of Trout Unlimited has contributed to habitat improvement projects, Pecos River Clean-up, and native trout restoration programs. In the fall of 2011, UPWA collaborated with the chapter in writing an "Embrace a Stream" grant from Trout Unlimited National to restore and revegetate stream banks between Windy Bridge and Brush Ranch on the main stem of the Pecos. This grant was approved and work was completed in 2014.

- **Albuquerque District, US Army Corps of Engineers and Robert Mead**

Coordinated a restoration project on the portion of Cow Creek that runs through the Martin Ranch. Following the Viveash Fire of 2000, 32 habitat improvement projects were undertaken in order to restore the stream so that it could successfully be restocked with trout. Projects included construction of cover log structures, concave bend pools, rock vortex weirs, shelf pools, boulder arches, sediment ponds, and dredging of accumulated sediments and recontouring of eroded streambanks.

- **Upper Cow Creek Riparian Habitat and Channel Restoration Project**

UPWA received a CWA Section 319 grant to address surface runoff and temperature problems in upper Cow Creek on Santa Fe National Forest land adjacent to Forest Road 92 north of the Village of Pecos. The project re-contoured multiple public access points, blocked vehicle traffic from driving up into the access points, and constructed step-pools in the creek channel. It also hardened the creek bank in places where erosion was causing damage and transplanted several thousand coyote willows to improve bank and floodplain stability. This project was completed in the fall of 2017.

- **Holy Ghost Canyon Creek and Drainage Post-fire Restoration Project**

The lower half of Holy Ghost Canyon was severely damaged by the Tres Lagunas fire in 2013. Stand replacement fire burned almost all of the south side of the canyon for the first mile from the Pecos River. Post-fire flooding resulted in severe downcutting and incision of four of the main tributaries on the south side of the canyon in that first mile. UPWA obtained a River Stewardship grant to construct sediment traps and other structures in the damaged tributary drainages and restore damaged portions of the Holy Ghost Creek. Work began on this project in the fall of 2018 and will be completed in the spring of 2019.

Additional restoration and river improvement projects that have taken place in the Upper Pecos watershed include:

- **Annual spring and Dia del Rio Cleanups**, organized semi-annually by UPWA
- **NMDOT installation of guard rails on NM Highway 63**, supported by UPWA to prevent vehicle access to the river
- **Los Trigos Ranch** - Stream restoration projects by Bill Zeedyk and Bill Cowles

6. POLLUTANT LOAD REDUCTIONS

6.1 Methodology for Estimating Load Reductions

Three different methods were used to calculate the load reductions needed to achieve water quality standards and the results expected from management measures. Temperature-related load reductions and project effects were estimated using the Stream Segment Temperature (SSTEMP) model, while sediment-related project effects were calculated in some cases using the Revised Universal Soil Loss Equation (RUSLE 2), and in other cases, where RUSLE was not appropriate, effects were calculated using measured soil volumes and bulk density.

6.1.1. Temperature modeling

The SSTEMP model was developed by the USGS Biological Resource Division (Bartholow 2002). The model predicts mean, minimum, and maximum daily water temperatures throughout a stream reach by estimating the heat gained or lost from a parcel of water as it passes through a stream segment. Predicted temperature values are compared to actual thermograph readings measured in the field (in 2001 and 2003) in order to calibrate the model. The model quantifies the maximum loading capacity of the stream to meet water quality criteria for temperature. This model is a useful tool for estimating the effect of changing factors such as increased riparian shading, stream channel alteration, and reduced streamflow) on stream temperature.

The Pecos Headwaters TMDL (NMED, 2005) calculated the decrease in absorbed solar radiation that would be needed to achieve water quality standards for the impaired stream reaches in the upper Pecos using the SSTEMP model, and presented the load reductions in terms of joules per square meter per second, and (more usefully for project design) in terms of the increase in streamside shade that would be needed. The input parameters and model calibration were based on field data collected in 2001 and 2003.

Summary of load reductions (reduced temperature) needed, as calculated by the TMDL:

	Existing conditions				Desired conditions			
Stream reach	Observed max temp	Modeled max temp	Joules/ m^2/sec	% total shade	Modeled max temp	Joules/ m^2/sec	% total shade	**Increase in shade needed**
Bull Creek (Cow Creek to headwaters)	26.6	20.3	173.5	40%	19.2	137.93	52%	12%
Cow Creek (Pecos River to Bull Creek)	29.0	22.0	121.7	40%	19.5	73.0	65%	25%
Cow Creek (Bull Creek to headwaters)	26.3	20.1	156.0	30%	19.2	138.4	38%	8%
Pecos River (Cañon de Manzanita to Alamitos Canyon)	26.6	25.1	153.9	40%	19.7	53.1	79%	39%

In 2010, data were once again collected for each of the impaired reaches within the Pecos River watershed. These new data allowed for an independent test of SSTEMP's ability to accurately predict maximum water temperature for a single date. It is worth emphasizing that while SSTEMP is capable of estimating a maximum water temperature on any given day, that temperature may not perfectly match data collected in the field on the same day. Watershed conditions can be highly variable even within a few days during the summer. For instance, thunderstorms (especially at higher altitudes) may deliver large volumes of cold rain or hail that may temporarily but significantly lower local stream temperature. The following table presents the SSTEMP-predicted maximum water temperatures and actual maximum water temperatures recorded by NMED staff during the 2010 field season for the same date.

Stream reach	Date							
	July 1		July 15		August 1		August 15	
	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed
Bull Creek (Cow Creek to headwaters)	19.8	18.1	19.9	19.7	20	15.8	20.5	17.4
Cow Creek (Pecos River to Bull Creek)	21.4	20.2	21.5	22.8	21.7	17.8	21.8	20.9
Cow Creek (Bull Creek to headwaters)	18.8	19.7	19.0	17.1	19.2	17.5	19.5	19.5
Pecos River (Cañon de Manzanita to Alamitos Canyon)	24.9	21.1	25	27.0	25.3	18.7	25.6	23.2

While the model was not 100% accurate predicting the maximum high temperatures, it was typically within 2 or 3 degrees of the observed high temperature and seems reliable for the purposes of discussing load reductions needed to achieve water quality standards. Model results correlate much better with longer-term average stream temperatures than instantaneous values. SSTEMP modeling is most directly affected by shade along the river corridor, but is less affected by changes in river morphology including pool creation or decreasing width to depth ratios. Despite their effects not being reflected in SSTEMP modeling, however, those activities are still useful for other reasons including improved habitat for aquatic life, and creating cool-water refugia for fish and other species during the hot summer months.

It is not difficult to imagine increasing the shade along Cow Creek and Bull Creek by 8 to 25 percent: neither stream is very wide, so almost any mature native riparian shrub or tree will shade much of the width of the steam for much of the day. It may be a lengthier process to provide 40 percent more shade for the lower reach of the Pecos than it has now, because the larger river will need larger trees – cottonwoods and box elders – to achieve the increase in shade, along with smaller trees and shrubs like willows or alder. Other alterations to stream morphology can help reduce temperatures as well, particularly reducing the width of over-widened streams and providing more (hopefully shady) pools. Stream shading (and depth increases) further upstream will also help achieve standards within the impaired reach by lowering water temperatures flowing into the impaired reach – even if those temperatures are within standards in the upstream reaches.

To predict the effects of proposed management measures, the SSTEMP model was run using parameters published in the 2003 TMDL report as a baseline. Each impaired reach was then analyzed for the effect of increased shade on stream reaches targeted for management measures. Shade-enhancing management measures are proposed for those areas observed either in the field or on aerial photographs to be deficient in normally-present riparian vegetation in the form of shrubs (willow and alder) or trees (cottonwood, and box elder typically). These management areas were mapped, and their length along with the total length of the treatment area was calculated. The length of these management areas (where shade is to be increased) and the length of reaches that will remain unaffected by restoration projects are reflected in SSTEMP modeling in a weighted average of streamside shade for the whole reach.

As an example of using a weighted average of riparian shade: assume a one mile impaired reach with two management sections of .25 miles and .3 miles for a total of .55 miles or 55% percent of the total analyzed reach. Assuming a 40% shade on the non-management section and 70% on the management section, the overall shade value for the entire reach would be 56.5 percent (70% shade x .55 miles + 40% shade x .45 miles). Using the weighted average for shade a single

SSTEMP run was made for the entire reach keeping all other variables consistent with the 2003 TMDL input parameters. This approach was especially useful for small tributaries that have inflow volumes of zero at the headwaters and an outflow measurement at the mouth, but no data between that can help gauge the volume of water coming from tributaries.

It has not been possible to model temperature effects of individual projects, because data on channel geometry, temperatures, and flow rates was not available for individual localized stream reaches. Available data and the dynamics of the SSTEMP model indicate that modeling a longer stream reach (particularly ones that can be compared with TMDL modeling) with and without the effects of restoration projects will yield more reliable predictions than attempting to model multiple smaller reaches using output data from an upstream reach as input data for the next reach below, in the absence of accurate data for the necessary parameters. We believe SSTEMP can provide tolerably accurate estimates of the effects of suites of restoration projects on complex stream reaches (like the Pecos River), even though it has not been possible to accurately estimate the effects of some individual, smaller projects.

6.1.2. Sediment and erosion calculations

Even though only Willow Creek is currently listed as impaired because of excessive sediment, estimates have been made of the effects of various projects in other parts of the watershed in reducing sediment transport into streams. This has been done for two primary reasons: First, even though a stream may not be formally listed as impaired, excessive sediment, even if localized in only some places, can be a significant problem for fish and aquatic habitat – an undesirable situation. Second, from a regulatory perspective, New Mexico water quality standards provide for non-degradation of waters currently supporting their designated uses, and there are situations where uncontrolled erosion and inappropriate or poorly managed surface runoff could easily threaten the high-quality cold-water fishery uses of the upper Pecos – a situation clearly to be avoided.

Sediment transport into streams from appreciable nearby areas of bare or erodible soils, where stormwater runoff funnels into concentration points and carries eroded sediment into a stream, as well as erosion of vulnerable or damaged streambanks themselves, has been calculated using soil bulk density values from Juma (1999) and estimates of erosion rates based on observation of various sites along the Pecos and its tributaries over the time UPWA staff and stakeholders have been active. This methodology, while it could be argued to be more “rough and ready” than modeling such as the Revised Universal Soil Loss Equation (RUSLE), actually seems to be more reliable in riparian conditions. RUSLE is set up to model situations with some appreciable expanse of homogeneous conditions (typically agricultural fields or construction sites), are these not really found in the riparian areas that are the focus of this Plan. The conditions where soil loss and sediment transport into streams is a concern in the upper Pecos are smaller areas characterized by irregular shape and topography, or else are areas of eroding stream banks that RUSLE cannot model at all.

6.2 Model and Calculation Results

6.2.1. Temperature

Results are reported in terms of overall change at the end of a particular reach. Typically this is either the mouth of the creek where it joins a larger water body, or, as in the case of Cow Creek, at a designated end-point that corresponds to an impaired reach as delineated by NMED.

Temperature model results (SSTEMP)

Stream reach	Projects involved	Model results		
		Effect of mgmt measures	After mgmt measures: modeled max temp	Current conditions: max temp in TMDL model
Pecos River above Alamitos Creek	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 19, 20, 35-42, 44, 46	0.2° C cooler	18.8	19.0
Pecos River below Alamitos Creek	23, 48, 51, 52, 55, 56	4.1° C cooler	21.0	25.1
Cow Creek headwaters	24, 25, 26, 27, 28, 29, 30, 58, 59	2.2° C cooler	17.9	20.1
Cow Creek outlet	25, 60	1.7° C cooler	20.3	22.0
Bull Creek	31	0.6° C cooler	19.7	20.3
Apache Creek	32, 33	0.1° C cooler	19.7	Not modeled
Sebadilla Creek	34	0.5° C cooler	19.4	Not modeled

It should be noted that SSTEMP is highly generalized, but does depend on accurate data inputs. While the initial SSTEMP modeling for the TMDL report was based on solid field based measurements, most streams were measured in only one or two locations. Data for those measurement points are accurate and precise, but they may not be representative of other stream reaches elsewhere. Shade can be highly patchy across the landscape, and stream geometry can also vary, especially as streams flow out of mountainous headwaters into more alluvial valleys. However, the model results do offer reasons to be optimistic about the potential benefits of restoration projects.

Temperature modeling has been done by stream reach, for the reaches listed, rather than project-by-project, because we do not have accurate data for stream geometry, temperature, and discharge for each potential project area. Attempts to model short reaches using data inputs for other parts of the stream in question did not seem to produce consistent or credible results.

For most smaller streams (Cow Creek and Bull Creek) SSTEMP demonstrates that for every 10% shade increase an associated 1 degree C water temperature drop can be expected. This is especially useful information for those stream segments or tributaries that are not currently impaired because any management that includes increasing the riverside shade in these reaches will be transferred, at least in part, to impaired reaches downstream, helping them achieve water quality standards.

6.2.2. Sediment

Estimated reductions in sediment transport into streams that would be averted by sediment-related projects, and the methodology used to arrive at the estimates, are shown in the table below, based on a soil density of 2,400 pounds per cubic yard, or 88.9 pounds per cubic foot.

		Annual streambank erosion (ft.)			Annual soil surface erosion to stream (ft.)				
Project No.	Project name	length	width	depth	area (sq ft)	depth eroded	volume of eroding soil (cu ft/yr)	volume of eroding soil (cu yds/yr)	mass of eroding soil (tons/yr)
1	Panchuela Campground	330	0.2	0.1			6.6	0.24	0.3
2	Cowles area bank repair	940	0.25	0.1			23.5	0.87	1.0
3	UPWA Community Foundation project	750	0.01	0.01			0.075	0.003	0.003
4	Carpenter Creek to Rio Mora stream restoration	4400	0.1	0.1			44	1.63	2.0
5	Mora Campground redevelopment				55,000	0.01	550	20.37	24.4
6	Rio Mora to Willow Cr stream restoration (public land)	8300	0.1	0.1			83	3.07	3.7
7	Rio Mora to Willow Cr (private land)	1700	0.1	0.1			17	0.63	0.8
8	Tererro Campground bank repair	1100	0.1	0.1			11	0.41	0.5
9	Bert Clancy bank repair	300	0.1	0.1			3	0.11	0.1
10	Tererro dispersed camping repairs				22,000	0.05	1100	40.74	48.9
12	Former Windy Bridge left bank access				15,000	0.01	150	5.56	6.7
13	Windy Bridge runoff control	200	0.1	0.1	52,000	0.01	522	19.33	23.2
15	USFS Dalton Fishing Access	120	0.1	0.1	7,400	0.01	75.2	2.79	3.3
16	Rainy Day runoff control	150	0.1	0.1	5,000	0.01	51.5	1.91	2.3
18	Dalton Canyon dispersed camping management	1200	0.1	0.1	10,000	0.02	212	7.85	9.4

Project No.	Project name	Annual streambank erosion (ft.)			Annual soil surface erosion to stream (ft.)		volume of eroding soil (cu ft/yr)	volume of eroding soil (cu yds/yr)	mass of eroding soil (tons/yr)
		length	width	depth	area (sq ft)	depth eroded			
19	Dalton Day Use bank and stream restoration	1500	0.1	0.1			15	0.56	0.7
20	Hwy 63 Road drainage improvements				10,000	0.05	500	18.52	22.2
21	Alamitos road erosion				34,000	0.05	1700	62.96	75.6
24	Cow Creek 319 project	8900	0.1	0.1			89	3.30	4.0
26	Cow Creek campgrounds				106,000	0.01	1060	39.26	47.1
28	Rio de la Osha road repairs				31,500	0.01	315	11.67	14.0
29	Manzanares Creek road repairs				24,500	0.01	245	9.07	10.9
30	Bar X Bar meadow restoration	4700	0.1	0.1			47	1.74	2.1
31	Bull Creek meadow restoration	3200	0.1	0.1			32	1.19	1.4
32	Apache Creek meadow restoration	2800	0.1	0.1			28	1.04	1.2
33	Apache Creek road repairs				6,000	0.01	60	2.22	2.7
34	Sebadilla Creek riparian restoration	10000	0.1	0.1			100	3.70	4.4
35	Horsethief Meadows	2,640	0.1	0.1			26	0.98	1.2
36	Upstream of Mora Flats	2,640	0.1	0.1			26	0.98	1.2
37	Mora Flats	5,280	0.1	0.1			53	1.96	2.3
38	Wilderness Areas				264,000	0.01	2640	97.78	120
39	Mora River Campground				26,400	0.01	264	9.78	12
40	Pecos River above Mora Campground	1,320	0.1	0.1			13	0.49	0.6
41	Tererro Dispersed Camping Revegetation & Road Drainage				26,400	0.01	264	9.78	12
42	Field Tract Campground Channel Restoration	2,640	0.1	0.1			26	0.98	1.2

Project No.	Project name	Annual streambank erosion (ft.)			Annual soil surface erosion to stream (ft.)		volume of eroding soil (cu ft/yr)	volume of eroding soil (cu yds/yr)	mass of eroding soil (tons/yr)
		length	width	depth	area (sq ft)	depth eroded			
43	Restoration from Tres Lagunas Fire near Una Laguna Rd	1,320	0.1	0.1			13	0.49	0.6
44	USFS Dalton Fishing Area Restoration	2,640	0.1	0.1			26	0.98	1.2
46	private land (FLW #15)				26,400	0.01	264	9.78	12
47	Monastery Area Road Drainage				13,200	0.01	132	4.89	5.9
48	River Restoration (Camino Rincon Area-private lands)	2,640	0.1	0.1			26	0.98	1.2
49	Town of Pecos Road Drainage (near Water Tank Rd)				13,200	0.01	132	4.89	5.9
50	Pecos Independent School District Lands				13,200	0.01	132	4.89	5.9
51	River Restoration below St. Anthony's Church	2,640	0.1	0.1			26	0.98	1.2
52	River Restoration at 550 Bridge	2,640	0.1	0.1			26	0.98	1.2
53	Glorieta Camps Area				79,200	0.01	792	29.3	35
54	Glorieta Creek near Pigeon Ranch	2,640	0.1	0.1			26	0.98	1.2
55	Glorieta Creek (near La Cueva Canyon private land)	2,640	0.1	0.1			26	0.98	1.2
56	Glorieta Creek (private lands)	10,560	0.1	0.1			106	3.91	4.7
57	La Cueva Creek upstream of old quarry to main valley	2,640	0.1	0.1			26	0.98	1.2
58	Soldier Cr Post fire Restoration	10,560	0.1	0.1			106	3.91	4.7
59	Rito Chaparito Restoration				13,200	0.01	132	4.89	5.9
60	Lower Cow Creek (North San Ysidro) Restoration	100,032	0.1	0.1			1000	37.1	44

7. IMPLEMENTATION ASSISTANCE AND SCHEDULE

It can be daunting to confront all the different watershed restoration and protection needs in the upper Pecos. Some of the long-range needs for protecting the watershed against fire damage, inappropriate or excessive development, and other complex planning projects will necessarily be ongoing responsibilities for many years to come. However, it is also very encouraging to look back at the progress that has already been made in many areas. Examples include: the Pecos Canyon State Park that will enable better recreation management (still awaiting funding from the State); the Respect the Rio program in collaboration with the Forest Service has made contact with thousands of visitors to spread the word about river-friendly camping; the Community Wildfire Protection Plan was completed by San Miguel County with assistance from UPWA; and UPWA has been the primary proponent of two major (and successful) river restoration projects on the Pecos River mainstem. These success stories illustrate the two major strategies that have worked in the past and seem likely to continue to work in the future for accomplishing our watershed restoration and protection goals:

1) serving as a catalyst for action by collaborating with and creating support for other agencies, organizations, and stakeholders to act for the benefit of our watershed; and

2) undertaking restoration work ourselves, where UPWA is the primary project proponent.

7.1 A catalyst for action

The Upper Pecos Watershed Association has achieved a great deal of success so far by serving as an advocate for the watershed and organizing members of the public, local organizations, government agencies, and other stakeholders around activities for the benefit of our streams and watershed. Some examples of these successes have been mentioned above, and they are far from the only ones.

However, UPWA needs financial support as well as community goodwill and participation to continue to fulfill this role. UPWA needs to focus its efforts in the areas where it can do the most good, especially as they relate to our primary mission. The two top priority areas for long range watershed protection are **Fire Risk Reduction**, and **Recreational Use Issues.** For fire risk and damage reduction**,** UPWA will continue efforts using opportunities like the Collaborative Forest Restoration Program (CFRP) and new initiatives with the New Mexico State Forestry Division for work on private land, plus strong advocacy for a larger scale approach to restoring forest health and natural fire regimes. Recreational issues include mitigation of existing damage, planning to prevent future damage, and improved facilities for recreation use.

There will never be adequate appropriated funds to accomplish the efforts needed. However, other western states, notably Colorado, do provide some appropriated funding to support their Watershed Associations' overhead costs, and supporting a similar program in New Mexico should be a priority. A variety of funding sources must be considered and identified to fund "on the ground work" plus organizational overheads and expenses, including federal and State grants and loans, private grants and donations, small levies from state, county and local taxes if possible, utilities, recreational license fees and even profit-producing activities.

7.2 Where the shovel meets the ground – implementing restoration projects

Needs for over $2 million in restoration projects have been specifically identified in the chapter on **Management Measures**. This is indeed a large and perhaps intimidating number. However, our goals for watershed restoration are much more achievable than it might seem at first glance.

The first ray of hope to be kept in mind is that UPWA itself does not have to be responsible for all this work. Just as we have a crucial role to play in advocating for the watershed in long-term planning, we also have a very important – and so far quite successful – role to play in creating support for actions on the part of government agencies, non-profit organizations, and others to achieve watershed restoration on the ground. As an example, UPWA was highly instrumental in achieving legislative support for a Pecos Canyon State Park under the administration of the State Parks Division, which will be an important contribution to long-term improvements in recreation management and riparian conditions in recreation sites. Further examples include UPWA's role in supporting the Respect the Rio program funded by the Forest Service; working with the Forest Service towards reduced fire risk along Highway 63; implementing a trash pick-up program at the Dalton Day Use Area during the summer; funding and installing a seasonal port-a-potty at the Dalton Day Use Area; encouraging better management of dispersed camping in Dalton Canyon; encouraging stream and riparian restoration in Game and Fish Department properties along the Pecos River; and encouraging needed restoration work and infrastructure repairs at Windy Bridge, the Rainy Day area, or other Dalton Canyon facilities. Many additional opportunities exist: for instance, supporting re-development of the Mora campground and provision for additional camping capacity (perhaps at the Links Tract, for instance); or convincing private landowners of the benefits of grass cover improvements and helping them to secure available funding.

7.2.1. Assistance and collaboration

Since one of the keys to UPWA's success so far has been our collaboration with other watershed stakeholders, this will remain one of the principal kinds of support and assistance we will need: a good working relationship with other organizations and individuals with a role to play. Some of the principal stakeholders in a position to help with watershed protection and restoration, with whom we should maintain or develop our relationships, include:

- Santa Fe National Forest, Pecos/Las Vegas Ranger District
- New Mexico Department of Game and Fish
- State Parks Division, Department of Energy, Minerals, and Natural Resources
- New Mexico Environment Department
- New Mexico Department of Transportation
- San Miguel County
- Village of Pecos
- Pecos valley acequias
- Pecos National Historic Park
- Private landowners in the Pecos valley
- Pecos Benedictine Monastery
- Trout Unlimited
- New Mexico Volunteers for the Outdoors
- Albuquerque Wildlife Federation
- Tierra y Montes District (Soil and Water Conservation – NRCS)
- United States Fish and Wildlife Service
- Pecos Independent School District
- Santa Fe Conservation Trust
- New Mexico Land Conservancy

- Wild Earth Guardians
- Audubon New Mexico
- The Nature Conservancy
- Animal Protection of New Mexico
- National Park Service – Rivers, Trails, and Conservation Assistance Program
- New Mexico Forest and Watershed Restoration Institute, at Highlands University

Another key need for assistance faced by UPWA is for certain kinds of additional technical expertise. Our main current needs focus on GIS system management and expansion; project design, management, and funding; water quality sampling equipment and expertise; and forestry and ecological restoration consulting. Some sources for these kinds of expertise include:

- New Mexico Environment Department, Surface Water Quality Bureau
- New Mexico Forest and Watershed Restoration Institute, N.M. Highlands University
- Private consulting expertise, including consultants already involved with UPWA such as Pathfinder Environmental and other local firms or individuals
- Local non-profit groups, including Watershed Watch, Wild Earth Guardians, Audubon
- New Mexico, the Nature Conservancy, and various universities

The final and perhaps crucial assistance need we have is of course for funding. UPWA has been successful in securing grant funding so far from the New Mexico Environment Department (both Clean Water Act Section 319 funds and New Mexico River Stewardship funds); the New Mexico Community Foundation; the Collaborative Forest Restoration Program; Trout Unlimited, and other sources. It is also true that the general prospects for grant funding are becoming more difficult, but there are many resources still available.

One potentially important resource is the *Directory of Watershed Resources*, available online from Boise State University at https://www.env.nm.gov/wp-content/uploads/2018/04/FundingSourcesforWatershedProtection.pdf. This database includes information about federal, state, and private foundation funders for environmental work, as well as online tools to help with project prioritization and other organizational needs. A partial list of locally available potential funding sources, many of which we have approached in some way already in the past, includes:

- Clean Water Act section 319 grants
- The New Mexico River Stewardship Program, as funding becomes available
- EPA Healthy Watersheds Initiative
- US Forest Service CFRP program
- USDA Rural Community Assistance funds
- US Fish and Wildlife Service "Partners for Fish and Wildlife" and "Landowner Incentive Program"
- NRCS/SWCD assistance
- New Mexico Water Trust Board
- New Mexico Association of Counties
- NM State Forestry Division, fire protection and noxious weed programs

- Special legislative appropriations
- Foundation and nonprofit organization support
- Private landowner contributions

An important component of managing the fund-raising challenge is to organize contributions to leverage available funding as much as possible by arranging advantageous cost-matching – for instance, private funds or in-kind services could leverage foundation support requiring a cost match, which could (in an ideal scenario) in turn leverage a federal grant with a non-federal match requirement. Such a scenario could potentially multiply the value of a private contribution several times over.

The other key reality about seeking restoration funding is that it is a never-ending, iterative, ongoing process of matching needs with available funding sources. Funding may be available for a particular activity this year, but next year the possibilities may be different. We will need to be perennially on the lookout for opportunities, matching potential projects and activities with available funding, and leveraging funds as much as possible.

7.2.2. Priorities

It is a complex task to sort out priorities among the competing restoration and protection needs in the upper Pecos. As discussed in Chapter 6 on **Management Measures**, there is no simple numerical formula that can make a worthwhile ranking among competing projects and needs. A number of long-term planning and watershed protection initiatives will need to be advanced when and how they can be in collaboration with other entities, while more immediate restoration priorities are addressed in approximate order of importance – without missing an opportunity to accomplish something useful when possible, even if it might not be at the top of the list at the moment.

With this in mind, some key principles will still be helpful in deciding which projects to pursue first.

- UPWA should concentrate its own restoration work on needs no other agency or entity is likely to take on.
- In principle, there is value in tackling the projects likely to yield the greatest water quality improvements first, but…
- There is also value in pursuing projects with high public visibility earlier rather than later, to raise awareness and public support for watershed goals and water quality protection.
- It is also valuable to take advantage of opportunities that arise (for instance, willing landowners or opportunities to dovetail with agencies or other entities' work) even if they would not otherwise be top priorities

Reviewing the list of 20 watershed protection activities and 59 potential restoration projects in the watershed with these principles in mind, they can be organized into 4 basic priority categories: ongoing planning and political support efforts for watershed protection that need to be advanced however possible as opportunities arise; and groups of on-the-ground projects that can be considered high, medium, and lower priority projects. Within these priority groups, there is really no good way to rank projects in numerical order. Instead, it is more realistic to pursue any projects that grant funding or other implementation opportunities may be available for; concentrating our own efforts on pursuing the high-priority projects first, but not neglecting opportunities for lower-priority projects as they may appear.

High-priority implementation projects

No.	Project name	Description
4	Carpenter Creek to Rio Mora stream restoration	Carpenter Cr to Rio Mora: reduce width, enhance fish habitat; protect/harden access points; replant along banks (includes 5-Star project; continue/expand)
5	Mora Campground redevelopment	Mora Campground - prevent excessive vehicle traffic/bank access; relocate roads and camping areas; re-vegetate, grade to keep runoff out of stream, etc.
25	Cow Creek stream shade	Plant trees/shrubs (restrain grazing if needed); primarily on private land from approximately Rio de la Osha confluence downstream
42	Field Tract Campground Channel Restoration	Abate channel incision with restoration structures and stabilize banks
45	Dalton Canyon Creek Restoration	Enhance river features, esp. beaver ponds. Bank protection and Stream Restoration work. Address dispersed camping in the area. (Currently funded.)
49	Town of Pecos Road Drainage (near Water Tank Road)	Road repairs to address drainage (rolling dips, infiltration basins, etc.) Reduce sediment in culverts
A	Visitor Center	Multi-agency visitor resource center
B	CFRP thinning	Follow-on CFRPj projects to implement roadside thinning
C	NM forestry	Assistance for hazardous fuel reduction
D	NM Association of Counties	Assistance for non-federal WUI fuels reduction and CWPP development/updates
E	CFLRP project	Build support for long-term CFLRP fire-ecology restoration project in upper Pecos
G	RV waste disposal	Provide for disposal of RV waste (along with other liquid waste issues)

Medium-priority implementation projects

No.	Project name	Description
2	Cowles area bank repair	Bank repairs (harden or protect river access points with stone steps, cobble paving, or otherwise keep banks from being trampled by heavy use) and re-vegetation at access points around Cowles
8	Tererro CG bank repair	Tererro G&F site - harden access points and re-vegetation to keep runoff out of river
10	Tererro dispersed camping repairs	Dispersed camping area between Tererro and mine site: close user-made road access that erodes to river; create swales and re-vegetate; organize dispersed camping better
11	Willow Cr conductivity	Identify source and correct high conductivity issue
12	Former Windy Br left bank access	Revegetate former user-created parking area
13	Windy Bridge runoff control	Windy Bridge site - create swales to keep runoff out of river; harden access points; revegetate
14	Macho Cr conductivity	Identify source and correct high conductivity issue
17	Dalton Cr conductivity	Identify source and correct high conductivity issue
18	Dalton Canyon dispersed camping	Pullouts/dispersed camping in Dalton Canyon - keep vehicles away from river; harden access points as needed; grade or create swales to keep runoff out of river (coordinate with FS project) (Currently funded with #45.)
21	Alamitos road erosion	Repair worst of road erosion and runoff into streams

No.	Project name	Description
22	Glorieta Cr conductivity and nutrients	Identify source and correct high conductivity issue
27	Cow Cr bio-engineering	Replace FS gabion project with appropriate bioengineering (Note: need to find out from FS what they're trying to do!)
28	Rio de la Osha road repairs	Culvert or crossing installation/repair and bar ditch re-routing
29	Manzanares Cr road repairs	Culvert or crossing installation/repair and bar ditch re-routing
30	Bar X Bar meadow restoration	Plant trees/shrubs (restrain grazing if needed); private land on Rio Manzanares at Bar X Bar ranch
31	Bull Cr meadow restoration	Plant trees/shrubs (restrain grazing if needed); private land on large meadow
33	Apache Creek Road Repairs	Eroding road reaches (rolling dips, water bars, etc)
34	Sebadilla Cr meadow restoration	Plant trees/shrubs and restrain grazing; private land on large meadow
36	Upstream of Mara Flats	Incision upstream of beaver activity. Hand trail work. Restoration by hand of "diversion channel"
37	Mora Flats	Enhance shallow stream, reduce bank erosion, plantings on bank to reduce high water temperatures
39	Mora River Campground	Restoration from mining activities, trail re-route or maintenance to reduce erosion, repair user damage (fishing trails) along bank.
40	Pecos River above Mora Campground	Enhance channel above the uppermost campground parking lot
41	Tererro Dispersed Camping Revegetation & Road Drainage	Revegetation of dispersed camping area and wetland restoration above and below road to capture sediment. Incl road work on Elk Mt Rd turn off to improve drainage
43	Restoration from Tres Lagunas Fire near Una Laguna Rd	Enhance river features, esp. pools and their habitat which was impacted by post fire runoff
44	USFS Dalton Fishing Area Restoration	Restore fishing habitat and pools impacted by sedimentation, stream restoration
48	River Restoration (Camino Rincon Area- private lands)	Similar enhancement of river features in the channel to reduce erosion and address incised channel
50	Pecos Independent School District Lands	Water catchment from school building rooftops. Address runoff from parking lots with stormwater infiltration basins. Trail work and upland erosion control on 60 ac.
51	River Restoration below St Anthony's Church	Enhance stream features, protect banks to reduce erosion and revegetate to improve habitat
52	River Restoration at 550 bridge	Bridge abutments cause braiding and over widening of stream, downstream reach suffers continuing bank erosion
57	La Cueva Creek upstream of old quarry to main valley	Repair roads to address drainage with rolling dips, swales. Bank protection and grade control to arrest incision
F	Arroyo trash removal	Arroyo trash removal and dumping prevention (coordinated with other solid waste issues)
H	Land use planning	Collaborate with San Miguel County in land use and waste management planning
M	Invasive species management protocol	Retain wetland species after restoration disturbance event
N	Wilderness wetlands enhancement projects	Improve trail maintenance and install waterers for cattle and wildlife to protect wetland areas from trailing and gullying

No.	Project name	Description
P	Recreation improvements	Bathroom facilities at Cow Creek and create angler access points to reduce bank erosion. Trails down to banks need to be re-routed or drained
R	Wetlands Action Plan	Current Wetlands Action Plan completed in 2009 needs updating to develop a better assessment of upper Pecos watershed wetlands

Lower-priority implementation projects

No.	Project name	Description
1	Panchuela CG	Minor bank repairs and re-vegetation
15	FS Dalton Fishing Access	Dalton FS Fishing Access - keep runoff out of river; protect/harden access points; revegetate
20	Hwy 63 Road drainage improvements	Pull-off areas or other places where road runoff drains directly into river instead of soaking into ground
23	Lower Pecos riparian trees	Plant trees to shade river on National Monument and private land from ~Glorieta Cr downstream
32	Apache Cr meadow restoration	Plant trees/shrubs and restrain grazing; private land on large meadow
35	Horsethief Meadows	Treat post fire runoff, bank protection, wetland restoration, revegetation
38	Wilderness Areas	Trail work to reduce erosion and sedimentation into River
46	private land (FLW #15)	Private land looks modified, not sure if it can be addressed
53	Glorieta Camps Area	Address runoff from roofs and parking lots, road drainage and infiltration, create recreation access points
54	Glorieta Creek near Pigeon Ranch	Reduce sediments from gullies with bank protection and grade control
55	Glorieta Creek (near La Cueva Canyon private lands)	Reduce sediments from gullies with bank protection and grade control
56	Glorieta Creek (private lands)	Reduce sediments from gullies with bank protection and grade control
58	Soldier Cr Post fire Restoration	Identify source and address pollutant most likely reduce sedimentation from Viveash and Tres Lagunas Fires, Stream Restoration and revegetation
59	Rito Chaparito Restoration	Address post fire sediment runoff. Possible bank protection, revegetation and re-grading before sediments enter Cow Creek
I	Travel Management	Work with Forest Service, National Park Service, NM State Park and other agencies to prevent inappropriate off-road truck and ATV use
J	Links Tract campground improvements	Expand and improve Links Tract area to provide for additional camping to alleviate crowding elsewhere
K	Jamie Koch campground conversion	Convert area to provide for camping: parking, sites, toilets, tables, etc; re-vegetation
L	Monastery Lake improvements	New toilets; improved picnic facilities, parking, and lake access; revegetation
O	Fish Structures	Assess and remove old log fish structures and replace with rock cross vanes or riffle structures based on location and stream type
Q	Riparian Conifer Treatment	Thinning project to reduce the encroachment of conifers in the riparian corridor

Ongoing watershed-protection activities

Project/Activity	Description
Pecos Valley Visitor Center	Multi-agency visitor resource center
CFRP thinning	Follow-on CFRP project(s) to implement roadside thinning
NM State Forestry	Assistance for hazardous fuel reduction
NM Association of Counties WUI assistance	Assistance for non-federal WUI fuels reduction and CWPP development/updates
CFLRP project	Build support for long-term CFLRP fire-ecology restoration project in upper Pecos
Arroyo trash removal	Arroyo trash removal and dumping prevention (coordinated with other solid waste issues)
RV waste disposal	Provide for disposal of RV waste (along with other liquid waste issues)
Land use planning	Collaborate with San Miguel County in land use and waste management planning

7.3 Schedule

Some of the projects listed in the tables above are already underway: for instance, the UPWA Community Foundation restoration work on the Pecos River, additional Dalton Canyon recreational improvements, and the upper and lower Cow Creek restoration projects. Developing a schedule for implementing all the work needed and listed above for the upper Pecos watershed is a difficult process at best, because so much of any realistic scheduling depends on the availability of funding in the future, which is uncertain. The schedule below is based on the assumption that funding will become available, from a variety of public and private sources that is not entirely predictable, on an adequate basis to permit work to proceed without major interruptions. In other words, we are making the perhaps optimistic assumption that some combination of EPA Section 319 funding, work by agencies like the Forest Service and the New Mexico Department of Game and Fish, private foundation support, other grant funding, and work or contributions by private landowners or individuals will be adequate to enable work to continue without lengthy delays caused solely by lack of funding.

The schedule below is therefore something of a best-case scenario for reaching our watershed restoration goals, and lack of necessary funding will of course extend the schedule. It illustrates an achievable timetable for watershed restoration given the personnel and contract expertise available to UPWA and our partners, if a realistic level of funding is available. It should also be noted that the order of implementing projects is somewhat arbitrary. We have assumed that it will be possible to more or less concentrate on high-priority projects first, with some lower priority projects undertaken along with them, but it is impossible to know exactly which projects will be implemented in exactly what order, so some substitution and re-ordering of projects is inevitable. The schedule presented is a realistic template for restoration, but not an immutable blueprint.

No.	Project Name	2019	2020	2021	2022	2023	2024	2025	2026	2027	out years
High-priority projects											
4	Carpenter Creek to Rio Mora stream restoration										

No.	Project Name	2019	2020	2021	2022	2023	2024	2025	2026	2027	out years
5	Mora Campground redevelopment										
25	Cow Creek stream shade										
42	Field Tract Campground Channel Restoration										
45	Dalton Canyon Creek Restoration										
49	Town of Pecos Road Drainage (near Water Tank Road)										
A	Visitor Center										
B	CFRP thinning										
C	NM forestry										
D	NM Association of Counties										
E	CFLRP project										
G	RV waste disposal										
Medium-priority projects											
2	Cowles area bank repair										
8	Tererro CG bank repair										
10	Tererro dispersed camping repairs										
11	Willow Cr conductivity										
14	Macho Cr conductivity										
17	Dalton Cr conductivity										
18	Dalton Canyon dispersed camping										
21	Alamitos road erosion										
22	Glorieta Cr conductivity and nutrients										
27	Cow Cr bio-engineering										

No.	Project Name	2019	2020	2021	2022	2023	2024	2025	2026	2027	out years
28	Rio de la Osha road repairs										
29	Manzanares Cr road repairs										
30	Bar X Bar meadow restoration										
31	Bull Cr meadow restoration										
33	Apache Creek Road Repairs										
34	Sebadilla Cr meadow restoration										
36	Upstream of Mora Flats										
37	Mora Flats										
39	Mora River Campground										
40	Pecos River above Mora Campground										
41	Tererro Dispersed Camping Revegetation & Road Drainage										
43	Restoration from Tres Lagunas Fire near Una Laguna Rd										
44	USFS Dalton Fishing Area Restoration										
48	River Restoration (Camino Rincon Area- private lands)										
50	Pecos Independent School District Lands										
51	River Restoration below St Anthony's Church										
52	River Restoration at 550 bridge										
57	La Cueva Creek upstream of old quarry to main valley										
F	Arroyo trash removal										
H	Land use planning										

No.	Project Name	2019	2020	2021	2022	2023	2024	2025	2026	2027	out years
M	Invasive species management protocol										
N	Wilderness wetlands enhancement projects										
P	Recreation improvements										
R	Wetlands Action Plan										
Lower-priority projects											
1	Panchuela CG										
15	FS Dalton Fishing Access										
20	Hwy 63 Road drainage improvements										
23	Lower Pecos riparian trees										
32	Apache Cr meadow restoration										
35	Horsethief Meadows										
38	Wilderness Areas										
46	private land (FLW #15)										
53	Glorieta Camps Area										
54	Glorieta Creek near Pigeon Ranch										
55	Glorieta Creek (near La Cueva Canyon private lands)										
56	Glorieta Creek (private lands)										
58	Soldier Cr Post fire Restoration										
59	Rito Chaparito Restoration										
J	Links Tract campground improvements										
K	Jamie Koch campground conversion										
L	Monastery Lake improvements										

No.	Project Name	2019	2020	2021	2022	2023	2024	2025	2026	2027	out years
O	Fish Structures										
Q	Riparian Conifer Treatment										

Criteria for evaluating how well these projects, and our cumulative progress towards watershed restoration, are working are discussed in the next chapter - along with some milestones along the way and methods for monitoring these restoration criteria.

7.4 Implementation Successes

Since the completion and approval of the first WBP, UPWA has successfully implemented, and collaborated with partners who have successfully implemented, nine projects. These projects are listed here in the table below. UPWA is currently under contract to implement two more project with funding by EPA 319 grants, one in Holy Ghost Canyon and one in Dalton Canyon. Construction of the project in Holy Ghost Canyon began in the fall of 2018 and will be completed in the spring of 2019. The Dalton Canyon project is expected to start construction in the fall of 2019 or spring of 2020.

Completed Watershed Protection and Restoration Projects List						
Project No.	Project Name	Stream	Sub-watershed	Description	Scale	Cost
3	UPWA Community Foundation project	Pecos	Rio Mora-Pecos	Narrow and deepen Pecos River above Mora campground; re-vegetate banks	250 yds	$68,069
6	Rio Mora to Willow Creek stream restoration (public land)	Pecos	Indian Creek - Pecos	Rio Mora to Willow Creek: reduce width, enhance fish habitat: protect/harden access point; replant along banks (NMDCF land; include 0.9 river miles above and below private land)	1.6 miles	$227,273
9	Bert Clancey bank repair	Pecos	Indian Creek - Pecos	Bert Clancey site - minor re-grading to keep vehicles and runoff out of river; harden/protect river access; revegetate	100 yards	$13,095
12	Former Windy Bridge left bank access	Pecos	Dry Gulch-Pecos	Revegetate former user-created parking area	.35 acre	$37,800
13	Windy Bridge runoff control	Pecos	Dry Gulch-Pecos	Windy Bridge site - create swales to keep runoff out of river; harden access points; revegetate	1.2 acre	$32,285
16	Rainy Day runoff control	Pecos	Dry Gulch-Pecos	Rainy Day area - protect/harden river access points; some revegetation; manage camping	.1 acre	$18,977
19	Dalton Day Use bank and stream restoration	Pecos	Dry Gulch-Pecos	Dalton Day Use Area - reduce width at top and bottom of area, protec/harden access points to keep runoff out of river, replant along banks	.25 mile	$216,366
26	Cow Creek campgrounds	Cow Creek	Cow Creek Headwaters	Re-grade (swales, water bars?) FS campgrounds and revegetate.	.5 mile	$48,300

	NM Highway 63 guardrail	Pecos	Pecos - Headwaters	Install guard rail between Windy Bridge and Brush Ranch	0.66 mile	

The NM Highway 63 guardrail project was one of UPWA's first collaborative successes. It was undertaken by the New Mexico Department of Transportation (NMDOT) with input early-on from UPWA. This project, in addition to increasing safety along the highway, dramatically reduced off-road vehicle traffic up to the bank of the Pecos River. The photograph below shows an area between the highway and the river just upstream of Windy Bridge where the guardrail is allowing vegetation to recover after years of damage from vehicular traffic.

In the spring of 2016, UPWA used a River Stewardship Grant from the NMED to implement a restoration project at the Dalton Day Use Area in Pecos Canyon. Flooding after the Tres Lagunas fire had scoured the bank of the river through this reach and left the channel over-wide and shallow. The restoration project resulted in the excavation of a series of deep scour-pools protected by large boulders over a 1,300 foot reach of the river. The excavated riverbed material was deposited in the channel along the bank on river left to create gravel bars that narrow the channel and provide an opportunity for the natural revegetation of the bank. The project also removed an old rock gabion wall that was preventing the natural flow of floodwaters into the adjacent floodplain. Tree root-wads were buried in the floodplain to dissipate flow energy during future floods and along the bank on river right to redirect flow back to the middle of the channel. The following three photographs are of the Dalton Day Use Area project after construction.



The Cow Creek Campgrounds project, called the Upper Cow Creek Habitat Restoration Project, was approved by the Santa Fe National Forest and implemented in fall of 2017. This project was conceived as a response to both the Viveash and Tres Lagunas fires. It was also designed to reduce off-road vehicular traffic at seven identified public access points along the creek. These access points were graded to slow down precipitation runoff, spread it out, and direct it away from the creek, so that more of it soaks into the ground and less sediment flows into the creek. Large boulders were placed along the side of the road to prevent vehicles from driving up into the access points and in some cases right up to the creek. Space was reserved by the side of the road for vehicles to pull off so that the public can still use these access points. In the creek, step pools were excavated to provide refugia for fish and reduce solar heating in the summer. The following six photographs are from the Upper Cow Creek project area after construction.

The most recently implemented project is on lower Cow Creek and is located just upstream from the village of North San Ysidro. Cow Creek in this location is deeply incised, over-wide in some areas, and subject to substantial sediment loading from adjacent lands where heavy grazing and tilling for agriculture take place. Bank erosion in one location was threatening to undermine the local irrigation ditch and in another it was encroaching on the road where it had been redirected under a bridge. Scour pools, pools, and bank protection measures were installed along with willow transplants to address these issues with the goal of reducing sediment and water temperature. The following four photographs are of the lower Cow Creek project area after construction in November 2018.

8. ACHIEVEMENT CRITERIA, MILESTONES, AND MONITORING

8.1 Restoration Goals

The primary goal of the work proposed in this Watershed-Based Plan is to restore the Pecos River and its tributaries to an unimpaired condition so that they achieve all their designated uses. In most cases this involves reducing the maximum water temperatures experienced during mid-summer conditions of low flows and maximum solar heat gain. The criteria to be used to determine success in this goal, and milestones towards its achievement, are described below.

The immediate goal of activities in the Plan for Willow and Macho Creeks, is to determine the sources and composition of contamination well enough to formulate restoration strategies. The ultimate goal for these streams also is to remove the source(s) of pollution causing impairment, but neither the cause(s) of elevated conductance, nor the sources, are well enough understood at present to allow a remedial strategy to be developed. Accordingly, the first goal of Plan activities is to gather additional information about pollution causes and sources, and the second goal is to design and implement activities to remove these sources and restore water quality.

An additional important goal is to keep sediment from runoff or eroding stream banks from becoming a source of impairment (as it has been in the past). This goal will be an important aspect of complying with New Mexico's anti-degradation water quality standard, which states that: *"Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected in all surface waters of the state."* Some restoration projects on streams in addition to Willow Creek are focused on reducing sediment levels or preventing predictable sediment loading from becoming a problem in these streams.

8.2 Achievement Criteria

8.2.1. *Temperature*

The key criterion for achievement of our temperature reduction goals is very straightforward: lower water temperature. This can be measured both at restoration sites and within the stream reaches listed as impaired.

The most important technique for reducing water temperature is to increase streamside shading (although in some cases deepening a stream and reducing its width will be important, too). Because of this, measuring and monitoring streamside shade (or canopy closure) is a useful proxy variable that can be measured quickly at multiple sites and tracked as an interim measure of likely stream temperature reductions.

The Pecos Headwaters TMDL calculates the following needed temperature reductions and increases in riparian shade, for impaired stream reaches:

Stream reach	Temperature reduction	Shade increase
Cow Creek (Bull Creek to headwaters)	2.5 degrees C	25%
Cow Creek (Pecos River to Bull Creek)	0.9 degrees C	8%
Pecos River (Alamitos Creek to Cañon de Manzanita)	5.8 degrees C	39%

8.2.2. *Conductance and nutrients*

The numerical achievement criterion for pollutants in Willow and Macho Creeks would be the standard of 300 µS/cm or less for the Pecos River Basin at 20.6.4.217 NMAC. However, because the natural background levels of specific conductance or nutrients in these streams is not known, it is possible that the conductance (and dissolved solids causing the conductance) result from natural background conditions, and part of the goal of additional sampling will be to determine whether observed levels seem to be anthropogenic or natural. The initial project phase of sampling is intended to determine the extent, sources, and composition of the dissolved salts or other constituents in these streams. Along with sampling to determine these parameters, it will be possible to determine whether elevated contaminant levels appear in the streams at a particular point on their course, suggesting a source location; or alternatively if water chemistry seems similar throughout the length of the stream, suggesting either a natural background level of the "contaminant" in question, or potentially an anthropogenic source that affects the entire stream.

8.2.3. Sediment and siltation

Numerical achievement criteria are also impossible to specify for sediment and siltation, because the New Mexico water quality standard is narrative rather than numerical, specifying: "*Surface waters of the state shall be free of water contaminants including fine sediment particles (less than two millimeters in diameter), precipitates or organic or inorganic solids from other than natural causes that have settled to form layers on or fill the interstices of the natural or dominant substrate in quantities that damage or impair the normal growth, function or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom."*

8.2.4. NMED sampling and assessment

The ultimate criterion for achievement of water quality goals is the periodic collection of water quality data by NMED SWQB and comparison of that analyzed data with water quality standards. This kind of data collection took place in the upper Pecos in 2010, and will be collected again in 2019 and 2020. If the projects and activities in this Plan have been substantially implemented in advance of this sampling campaign and streams in the upper Pecos are found to have met water quality standards, the Plan will have achieved its water quality goals. Assessment of standards attainment is anticipated in 2022.

If this Plan has been substantially implemented by 2025 and water quality improvements are less than expected, then the Plan will be revised using guidance, information about management measures, and program approaches available then (which may not yet have been developed). If water quality within the watershed is found to meet standards, the Plan will be revised to focus on protecting water quality.

If a lower TMDL is developed for any relevant pollutant, the management measures identified in the Plan will continue to be implemented until such time as they can be revised in the light of the new TMDL(s). In addition, many other developments could occur which would warrant revision of the Plan.

8.3 Milestones

Restoration projects that involve planting native riparian vegetation will inevitably involve a time lag, for vegetation to grow and spread, between initial project completion and full achievement of project goals in terms of reducing water temperature or sediment transport.

Accordingly, for the majority of the projects proposed, there will be a progression from initial project initiation, through project completion, growth and development of vegetation and streamside canopy, to achievement of intended reductions in water temperatures as vegetation matures and shade deepens. This progression may span as much as a decade or more, where full-stature trees like cottonwoods or box elders are an important shade component. So, for most projects, the first milestone would be starting a project (or number of projects started); the next logical milestone would be finishing a project (or total number finished); and then perhaps a measure of vegetation density or development (such as canopy or ground cover, or canopy height). The final milestone, and criterion for successful achievement, would be water temperature confirmed to be within standards by appropriate measurement.

For the four streams that require additional sampling and analysis, logical milestones would be beginning and completion of stream sampling; followed by designing projects (if needed) to control pollution sources; and finally initiating and completing the restoration projects. Success can be confirmed by water quality sampling once restoration is complete.

Restoration implementation milestones and achievement criteria can be summarized in the table below.

Indicator	Milestone or Criterion
Stream/riparian projects undertaken	Project schedule in Watershed-Based Plan
Stream/riparian projects completed	Project schedule in Watershed-Based Plan
Vegetation development in completed projects	Appropriate increases in vegetation density, height, vigor, and/or canopy closure as compared to pre-treatment conditions and project-specific desired conditions
Source determination sampling projects undertaken/completed	Project schedule in Watershed-Based Plan
Control projects/strategies designed for sources of now-unknown contaminants	Project schedule in Watershed-Based Plan
Pollutant levels in streams with now-unknown contaminants	Contaminant levels within standards in follow-up monitoring, or determination that conditions are natural (***achievement criterion***)
Water temperatures in temperature-impaired streams	Measured to be within standards (***achievement criterion***)

8.4 Monitoring

Fortunately, the kinds of monitoring needed to measure progress towards, or success with, our restoration goals are fairly simple and straightforward. There are really three key monitoring methodologies needed: data logging water temperature sensors, canopy cover measurements, and water quality sampling for conductance, principal dissolved ions, and nutrients.

8.4.1. Temperature

Temperature monitoring can be done using small temperature sensors that record temperatures on a pre-determined schedule and provide a data log of temperatures over time that can be downloaded to a computer periodically. These datalogging sensors (such as the HOBO® Water Temperature Pro V2 Data Logger, for example) are relatively inexpensive ($135 each) and readily available. They could be deployed in multiple locations, for instance above and below restoration projects and at temperature sampling locations used in NMED sampling and/or TMDL calculations, for extended periods of time. The biggest challenge in using them may well be discouraging people from absconding with them, and this could be helped by making shade and shelter structures for them out of (rusted) steel pipe with perforated holes to allow unimpeded water flow and a closed top for shade and visual hiding for the temperature sensor. The pipe container could then be partially disguised in the stream with rock and/or vegetation.

8.4.2. *Canopy and shade*

The most straightforward and inexpensive way to measure canopy cover and shade will be using spherical densitometers, available from many forestry and ecological suppliers for about $100 each. Multiple users can be trained to be reasonably consistent in using the densitometers, and their use is fairly quick and simple in the field. Typically, densitometer readings are made at frequent intervals (every 20 to 50 feet, depending on the length of stream shading to be measured) along the center of a stream like the Pecos River or Cow Creek that are shallow enough to be waded safely. If reaches of stream are too deep to be waded, they could be sampled from a boat or by averaging readings from both banks. Readings need to be taken at consistent times of day, relatively near mid-day, to permit valid comparisons over time; and are generally averaged over the entire stream reach being monitored. Measurements should be taken before any additional vegetation is planted or other restoration work begun, and then they can be repeated as new vegetation develops. Densitometer measurements can be supplemented by photographs from consistent photo-points (at consistent times of day) and by vegetation height measurements made using stadia rods (such as those used with optical surveyors' levels) or clinometers

8.4.3. *Water chemistry*

Water chemistry sampling for the three streams with unresolved conductance and contaminant source issues will begin with more intensive conductivity measurements along the entire length of the perennial reaches of the streams, to determine if there is an identifiable point where conductance levels increase above an upstream background level, suggesting the location of some kind of source. This level of water chemistry can be performed using hand-held portable conductivity or multiple-parameter sampling devices that are widely available beginning at around $400.

If the source is not apparent, the next phase of sampling would be to identify major dissolved ions to suggest the nature of the substance(s) dissolved in the water that cause high conductance levels, again in hopes of suggesting a likely source (potential sources that come to mind include effluent from domestic septic systems, concentrations of grazing animals, old mining or prospecting activities, or perhaps other kinds of waste disposal). Field equipment adequate for this kind of analysis (such as Hach® colorimetric kits) cost approximately $2,000.

The same inorganic water chemistry sampling kit can also be used to identify the kinds and levels of nutrients present in Glorieta Creek. In this case as well, initial sampling would compare nutrient levels above and below the Glorieta Conference Center wastewater treatment plant, to establish if nutrients present in the creek are indeed coming from the wastewater facility. If so, discussions would be appropriate between UPWA, the Conference Center, and NMED about the terms of the Center's NPDES point-source discharge permit. If the Center does not appear to be the source of the nutrients, more intensive sampling along the length of the perennial reach of Glorieta Creek, as described above for the other three creeks, would be the next step to identify the geographic source of the nutrients, and hopefully the chemical source as well.

8.4.4. *Sediment*

Visual inspection of Willow Creek and its surroundings seems likely to be all that would be necessary to identify the source of excessive sediments and suggest remedial action. The source(s) of excessive conductance would be located and identified as discussed above.

8.5 Quality Assurance

If EPA funding is received for monitoring activities, and Quality Assurance Project Plan will be prepared to ensure that all data collected is of known and adequate quality. The QAPP will describe the necessary quality assurance (QA), quality control (QC), and any other necessary technical activities that will be implemented, and seek to ensure that the results of the work performed will be adequate for informed and confident decision-making. The QAPP will describe the acquisition of information from direct measurement activities or existing data; and will include discussion of project management, data acquisition (sampling), quality assessment, and data review and reporting. It is anticipated that preparing a QAPP will require between $2,500 and $3,500 of consulting expertise.

9. OUTREACH AND COMMUNITY INVOLVEMENT

9.1 UPWA Community Events

The Upper Pecos Watershed Association has a long track record of community outreach, and is ideally positioned to serve as a community coordinator and clearinghouse for the many environmental issues that need be addressed in the Upper Pecos. UPWA is the only existing organization involving all the public and private stakeholders in the area, and we have a respected and successful track record of implementing restoration projects as well as encouraging participation in environmental planning by agencies, non-government community groups, and individuals. UPWA has successfully spearheaded public participation in EPA-funded watershed planning and Forest Service FIREWISE outreach, and we intend to continue building on previous success to maximize public participation and encourage watershed-scale vision and solutions to our problems.

We will continue our volunteer participation opportunities, including river cleanup days and opportunities to participate in monitoring and restoration projects, which have resulted in thousands of contact hours with our neighbors and stakeholders so far. Public meetings will continue, along with opportunities for public participation at Board of Directors and other UPWA meetings. We have engaged local facilitators in the past very successfully for public meetings, and anticipate continuing to do so. Our brochure is available the Pecos/Las Vegas Ranger District office and at many local businesses, and we intend to continue distributing it and to update it periodically.

UPWA organized and conducted public outreach meetings as part of the NEPA compliance process for fire risk reduction planning in the upper Pecos in 2012, and continues to coordinate NEPA public involvement and comment on behalf of the Pecos/Las Vegas Ranger District of the Santa Fe National Forest.

UPWA has organized and hosted Pecos Canyon Collaboration meetings among the various agencies with activities and interests in the upper Pecos approximately every two months beginning in 2009. Principal regular participants include:

- Santa Fe National Forest, Pecos-Las Vegas Ranger District
- New Mexico Department of Game and Fish
- New Mexico State Parks Division
- New Mexico Department of Transportation
- New Mexico Environment Department
- Pecos National Historic Park
- US Army Corps of Engineers
- San Miguel County
- Village of Pecos
- Pecos Benedictine Monastery
- Trout Unlimited
- Staff of elected officials (US Senators Heinrich and Udall, and Representative Lujan)

9.2 Collaboration and Partnerships

Many local organizations (including some of those mentioned above), as well as individuals, have partnered with us in the past in activities beyond regular meetings, and are committed to continuing collaboration. We are confident most will continue as active participants in watershed protection and restoration. Personal conversation with UPWA members, staff, and/or Board members has been the most effective way of encouraging involvement in our small community in the past, and we will enthusiastically continue these efforts. The table below lists major organizations, businesses, and agencies that are already active collaborators.

Partner entity	Representation	Contact person
San Miguel County	County government	Vidal Martinez 505.425.9333 x115
Trout Unlimited, Truchas Chapter	Anglers and outdoors-people	Art Vollmer 505.428.0707
El Valle Water Alliance	Mutual Domestic Water Users Assoc. (local cooperative water utilities)	Veronica Castro 575.421.3892
Holy Ghost Homeowners' Assn.	Homeowners in Holy Ghost Canyon	Don Norton 316.683.1104
Village of Pecos	Municipal government	Ted Benavidez 505.757.6591
Tierra y Montes Soil and Water Conservation District	Landowners; conservation practitioners	Frances Martinez 505.425.9088
USDA Forest Service, Pecos/Las Vegas Ranger District	Federal land managers for large fraction of watershed and recreation areas	Steve Romero 505.757.6121
NM Environment Department, Surface Water Quality Bureau	Funding agency for Watershed-Based Plan; water quality regulators	John Moeny 575.956.1545
NM Department of Game and Fish	Managing agency for many recreation sites in Pecos Canyon	Tristanna Bickford 505.476.8027
Friends of the Pecos National Historic Park	Community group supporting local National Historic Park	Bill Zunkel 505.310.0920

A number of local businesses are represented *de facto* because their owners are members or Directors of UPWA, including a gasoline station/convenience store, a ranch, and an insurance agency. Additional partners and collaborators include local businesses, focusing on recreation related businesses like cabin rentals, outfitters, and outdoor suppliers. We will also contact the remaining homeowners' association in the area and the agricultural irrigation associations (*acequias*, in New Mexico) to invite and encourage their participation. We do not anticipate any particular difficulties in persuading these entities to join in support of watershed restoration, and representation will then be essentially complete across all major community groups.

Public meetings are generally held in the Village of Pecos. Our website continues to inform stakeholders and educate the public, and mailing lists and media contacts will be continue to be maintained and updated.

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PHOTO CREDITS

All photos are by La Calandria Associates, Inc. except for the following:

Front cover: Dalton Day Use Area and upper Cow Creek following restoration construction, courtesy of Pathfinder Environmental, LLC. Lower Cow Creek following restoration construction, courtesy David Lemke of the Upper Pecos Watershed Association.

Pages 15-16: Post-Tres Lagunas fire flood damage, courtesy Pathfinder Environmental, LLC.

Page 16: Middle two photographs and bottom two photographs of unnamed drainage and forest on Viveash Mesa post-Tres Lagunas fire, courtesy of Jarrett Sasser of High Desert Angler in Santa Fe, NM.

Page 23: Rio Grande Cutthroat Trout caught in the Pecos River, courtesy of www.nativetroutflyfishing.com.

Pages 37: Tererro mine operations and housing, ca. 1930. Photographs courtesy of the Museum of New Mexico, Palace of the Governors Archives.

Page 38: Logging on Indian Creek in 1936- Photograph by R. C. Salto, courtesy of the USDA Forest Service, Southwest Region, Santa Fe National Forest Historical Photographs.

Page 39: Heavily grazed rangeland, ca. 1930, looking south from the Pecos Ruins. Photograph from the Herbert W. Yeo Papers, courtesy of New Mexico State University, Las Cruces.

Page 40, 41: Photos of campgrounds on July 4 weekend, courtesy of the Upper Pecos Watershed Association

Page 44: Flash flood aftermath, courtesy of Neal Schaeffer.

Pages 98-100: Post-construction photos of the guard rail project on NM 63, Dalton Day Use Area, and upper Cow Creek, courtesy of Pathfinder Environmental, LLC.

Page 101: Post-construction photos of the lower Cow Creek project, courtesy of David Lemke of the Upper Pecos Watershed Association.

Upper Pecos Watershed-Based Plan

Appendices

Appendix A: Restoration project master spreadsheet

Appendix B: Restoration project cost estimates

Appendix C: Temperature and sediment control modeling and calculations

Project List for Watershed Protection and Restoration

Project No.	Project Name	Pollutant cause addressed	Source focus	Priority	Stream	Sub-watershed	Description	Current status	Scale	Cost	Duration	Prep - complex	Visibility	Water quality effects
1	Panchuela Campground	sediment + temperature	Recreation	Low	Panchuela	Panchuela	Minor bank repairs and re-vegetation	no work has been done	150 yd	$ 9,904	< 1 year	Low	Medium	Low
2	Cowles area bank repair	sediment + temperature	Recreation	Medium	Pecos	Rio Mora-Pecos	Bank repairs (harden or protect river access points with stone steps, cobble paving, or other ways to keep banks from being trampled by heavy use) and re-vegetation at access points around Cowles	no work has been done	300 yd	$ 41,751	1-2 years	Medium	High	Low
4	Carpenter Creek to Rio Mora stream restoration	sediment + temperature	Recreation	High	Pecos	Rio Mora-Pecos	Carpenter Creek to Rio Mora: reduce width, enhance fish habitiat; protect/harden access points;replant along banks (includes 5-Star project; continue/expand)	no work has been done	0.83 miles	$ 216,700	1-2 years	Medium	High	Medium
5	Mora Campground redevelopment	sediment + temperature	Recreation	High	Mora	Mora	Mora campground - prevent excessive vehicle traffic/bank access; relocate roads and camping areas; revegetate, grade to keep runoff out of stream, etc	Some campsite improvements, but work remains to be done	4.5 acres	$ 250,000	1-2 years	High	High	Medium
7	Rio Mora to Willow Creek stream restoration (private land)	sediment + temperature	Recreation	unknown	Pecos	Indian Creek - Pecos	Similar treatment on private land; include 0.3 miles between state parcels)	no work has been done	.31 miles	$ 83,725	2-3 years	Low	Low	unknown
8	Terrero Campground bank repair	sediment + temperature	Recreation	Medium	Pecos	Indian Creek - Pecos	Terrero G&F site - harden access points and revegetation to keep runoff out of river	no work has been done	400 yards	$ 26,950	< 1 year	Low	High	Low
10	Terrero dispersed camping repairs	sediment	Recreation	Medium	Pecos	Indian Creek - Pecos	Dispersed camping area between Terrero and mine site: close user-made road access that erodes to river; create swales and revegetate; organize dispersed camping better	Camping beside stream eliminated, camping sites delineated, stream banks still need work	.5 acres	$ 53,900	1-2 years	Medium	Medium	Medium
11	Willow Creek conductivity	conductivity	Unknown	Medium	Pecos	Indian Creek - Pecos	Identify source and correct high conductivity issue	no work has been done	2 miles	$ 2,738	unknown	Medium	Low	unknown
14	Macho Creek conductivity	conductivity	Unknown	Medium	Macho Creek	Dry Gulch-Pecos	Identify source and correct high conductivity issue	no work has been done	1.4 miles	$ 2,738	unknown	Medium	Low	unknown
15	USFS Dalton Fishing Access	sediment	Recreation	Low	Pecos	Dry Gulch-Pecos	Dalton FS Fishing Access - keep runoff our of river protect/harden access points; revegetate	no work has been done	.2 acres	$ 21,102	< 1 year	Medium	Medium	Low
17	Dalton Creek conductivity	conductivity	Unknown	Medium	Dalton Creek	Dry Gulch-Pecos	Identify source and correct high conductivity issue	no work has been done	5 miles	$ 2,738	unknown	Medium	Low	unknown
20	Hwy 63 road drainage improvements	sediment + temperature	Transportation	Low	Pecos	Multiple	Assess and address road drainage into Pecos River and Tributaries	no work has been done	0.25 mi	$ 73,895	< 1 year	Low	Medium	Low
21	Alamitos road erosion	sediment	Transportation	Medium	Alamitos Creek	Glorieta - Pecos	Repair worst of road erosion and runoff into streams	no work has been done	2 miles	unknown	1-2 years	Low	Low	Medium
22	Glorieta Creek conductivity and nutrients	conductivity	Unknown	Medium	Glorieta Creek	Glorieta Creek	Identify source and correct high conductivity issue	no longer listed for conductivity	8 miles	$ 2,738	unknown	Medium	Low	unknown
23	Lower Pecos riparian trees	temperture	Damaged vegetation	Low	Pecos	Tortolita-Pecos	Plant trees to shade river on National Monuent and private land from Glorieta Creek downstream.	no work has been done	15 miles	$ 76,800	5-10 years	Low	Low	Medium
25	Cow Creek stream shade	temperture	Damaged vegetation	High	Cow Creek	Cow Creek Headwaters	Plant trees/shrubs (retain grazing if needed); primarily on private land from approximately Rio de Osha confluence downstream.	some work has been done post landowner workshop. More needed	13.5 miles	$ 69,120	1-2 years	Low	Low	High

Project No.	Project Name	Pollutant cause addressed	Source focus	Priority	Stream	Sub-watershed	Description	Current status	Scale	Cost	Duration	Prep - complex	Visibility	Water quality effects
27	Cow Creek bio-engineering	sediment + temperature	Channel dynamics	Medium	Cow Creek	Cow Creek Headwaters	Replace FS gabion project with appropriate bioengineering (Note: need to find out from FS what they're trying to do)	no longer a problem	unknown	unknown	< 1 year	Medium	Low	unknown
28	Rio de la Osha road repairs	sediment + temperature	Transportation	Medium	Rio de la Osha	Cow Creek Headwaters	Culvert or crossing installation/repair and bar ditch re-routing	no work has been done	2 miles	$ 85,995	< 1 year	High	Low	Medium
29	Manzanares Creek road repairs	sediment + temperature	Transportation	Medium	Manzanares Creek	Cow Creek Headwaters	Culvert or crossing installation/repair and bar ditch re-routing	no work has been done	1.6 miles	$ 67,158	< 1 year	High	Low	Medium
30	Bar X Bar meadow restoration	sediment + temperature	Damaged vegetation	Medium	Manzanares Creek	Cow Creek Headwaters	Plant trees/shrubs (retain grazing if needed); primarily on private land on Rio Manzanares at Bar X Bar Ranch.	no work has been done	1500 yards	$ 43,285	1-2 years	Low	Low	Medium
31	Bull Creek meadow restoration	sediment + temperature	Damaged vegetation	Medium	Bull Creek	Bull Creek	Plant trees/shrubs (restrain grazing if needed); private land on large meadow	no work has been done	1100 yards	$ 37,190	1-2 years	Medium	Low	Low
32	Apache Creek meadow restoration	sediment + temperature	Damaged vegetation	Low	Apache Creek	Apache Creek	Plant trees/shrubs (restrain grazing if needed); private land on large meadow	no work has been done	900 yd	$ 22,710	1-2 years	Medium	Low	Low
33	Apache Creek road repairs	sediment + temperature	Transportation	Medium	Apache Creek	Apache Creek	Eroding road reaches (rolling dips, water bars, etc)	no work has been done	.35 miles	$ 14,742	< 1 year	Medium	Low	Medium
34	Sebadilla Creek riparian restoration	sediment + temperature	Damaged vegetation	Medium	Sebadilla Creek	El Rito	Plant trees/shrubs (restrain grazing if needed); private land on large meadow.	no work has been done	3300 yards	$ 49,380	1-2 years	Medium	Low	Medium
35	Horsethief Meadows	sediment + temp	Damaged vegetation	Low	Horsethief Creek	Panchuela Creek	Treat post fire runoff, bank protection, wetland restoration, revegetation	New 2018	0.5 mi	$ 149,265	2 years	Medium	Low	Low
36	Upstream of Mora Flats	sediment + temp	Damaged vegetation	Medium	Mora	Rio Mora	Incision upstream of beaver activity. Hand trail work. Restoration by hand of "diversion channel"	New 2018	0.5 mi	$ 32,736	1-2 years	Medium	Low	Medium
37	Mora Flats	sediment + temp	Damaged vegetation	Medium	Mora	Rio Mora	Enhance shallow stream, reduce bank erosion, plantings on bank to reduce high water temperatures	New 2018	1 mi	$ 298,530	1-2 years	Medium	Medium	Medium
38	Wilderness Areas	sediment+ temp	Damaged vegetation	Low	Pecos, Mora	Pecos River, Rio Mora, Panchuela Creek, Indian Creek	Trail work to reduce erosion and sedimentation into River	New 2018	5 mi	$ 327,360	2 years	Medium	Medium	Low
39	Mora River Campground	sediment+ temp	Recreation	Medium	Mora	Rio Mora - Pecos River	Restoration from mining activities, trail re-route or maintenance to reduce erosion, repair user damage (fishing trails) along bank.	New 2018	0.5 mi	$ 159,456	1-2 years	Medium	Low	Low
40	Pecos River above Mora Campground	sediment+ temp	Recreation	Medium	Pecos	Rio Mora - Pecos River	Enhance channel above the uppermost campground parking lot	New 2018	0.25 mi	$ 63,360	< 1 year	Medium	High	Medium
41	Tererro Dispersed Camping Revegetation & Road Drainage	sediment + temp	Recreation	Medium	Pecos	Indian Creek - Pecos River	Revegetation of dispersed camping area and wetland restoration above and below road to capture sediment. Incl road work on Elk Mt Rd turn off to improve drainage	New 2018	0.5 mi	$ 92,506	< 1 year	Medium	High	Medium
42	Field Tract Campground Channel Restoration	sediment + temperature	Recreation	High	Pecos	Dry Gulch - Pecos River	Abate channel incision with restoration structures and stabilize banks	New 2018	0.5 mi	$ 126,720	1-2 years	Medium	High	Medium
43	Restoration from Tres Lagunas Fire near Una Laguna Rd	sediment	Damaged vegetation	Medium	Pecos	Dry Gulch - Pecos River	Enhance river features, esp. pools and their habitat which was impacted by post fire runoff	New 2018	.25 mi	$ 63,360	< 1 year	Medium	Low	Medium
44	USFS Dalton Fishing Area Restoration	sediment + temperature	Recreation	Medium	Pecos	Dry Gulch - Pecos River	Restore fishing habitat and pools impacted by sedimentation, stream restoration	New 2018	0.5	$ 126,720	1-2 years	Medium	High	Medium
46	private land (FLW #15)	sediment + temperature	Damaged vegetation	Low	Pecos		Private land looks modified, not sure if it can be addressed	New 2018	1 mi	$ 253,440	< 1 year	Low	Low	Medium
47	Monastery Area Road Drainage	sediment	Transportation	High	Pecos	Glorieta Creek - Pecos River	Create rolling dips to drain old roads to keep sediment out of river and arrest erosion. Erosion Control, revegetation, thinning of doghair Pinon trees.	New 2018	0.5 mi	$ 102,696	< 1 year	High	High	Medium

Project No.	Project Name	Pollutant cause addressed	Source focus	Priority	Stream	Sub-watershed	Description	Current status	Scale	Cost	Duration	Prep - complex	Visibility	Water quality effects
48	River Restoration (Camino Rincon Area-private lands)	sediment + temperature	Damaged vegetation	Medium	Pecos	Glorieta Creek - Pecos River	Similar enhancement of river features in the channel to reduce erosion and address incised channel	New 2018	0.5 mi	$ 149,265	1-2 years	Low	Medium	Medium
49	Town of Pecos Road Drainage (near Water Tank Rd)	sediment	Transportation	High	Pecos	Glorieta Creek - Pecos River	Road repairs to address drainage (rolling dips, infiltration basins, etc.) Reduce sediment in culverts	New 2018	0.25 mi	$ 46,252	< 1 year	Low	High	Medium
50	Pecos Independent School District Lands	sediment	Transportation	Medium	Pecos	Glorieta Creek - Pecos River	Water catchment from school building rooftops. Address runoff from parking lots with stormwater infiltration basins. Trail work and upland erosion control on 60 ac.	New 2018	0.25 mi	$ 73,894	< 1 year	Low	High	Medium
51	River Restoration below St Anthony's Church	sediment temperature	Damaged vegetation	Medium	Pecos	Glorieta Creek - Pecos River	Enhance stream features, protect banks to reduce erosion and revegetate to improve habitat	New 2018	0.5 mi	$ 159,266	< 1 year	Low	Low	Medium
52	River Restoration at 550 bridge	sediment, temperature	Transportation	Medium	Pecos	Glorieta Creek - Pecos River	Bridge abutments cause braiding and over widening of stream, downstream reach suffers continuing bank erosion	New 2018	0.5 mi	$ 159,266	< 1 year	High	High	Medium
53	Glorieta Camps Area	sediment	Transportation	Low	Glorieta Cr	Glorieta Creek	Address runoff from roofs and parking lots, road drainage and infiltration, create recreation access points	New 2018	1.5 mi	$ 463,320	2-3 years	Low	Medium	Medium
54	Glorieta Creek near Pigeon Ranch	sediment	Damaged vegetation	Low	Glorieta Cr	Glorieta Creek	Reduce sediments from gullies with bank protection and grade control	New 2018	0.5 mi	$ 196,680	< 1 year	High	Low	Low
55	Glorieta Creek (near La Cueva Canyon private lands)	sediment, temperature	Damaged vegetation	Low	Glorieta Cr	Glorieta Creek	Similar treatments on private land	New 2018	0.5 mi	$ 126,720	< 1 year	Low	Low	Low
56	Glorieta Creek (private lands)	sediment, temperature	Damaged vegetation	Low	Glorieta Cr	Glorieta Creek	Similar treatments on private land	New 2018	2 mi	$ 506,880	1-2 years	Low	Low	Medium
57	La Cueva Creek upstream of old quarry to main valley	sediment	Transportation	Medium	trib to Glorieta Cr	Glorieta Creek	Repair roads to address drainage with rolling dips, swales. Bank protection and grade control to arrest incision	New 2018	0.5 mi	$ 196,680	< 1 year	Medium	Low	Low
58	Soldier Cr Post fire Restoration	sediment, nutrients, temperature	Fire	Low	trib to Cow Cr	Bull Creek	Identify source and address pollutant most likely reduce sedimentation from Viveash and Tres Lagunas Fires, Stream Restoration and revegetation	New 2018	2 mi	$ 506,880	1-2 years	Medium	Low	High
59	Rito Chaparito Restoration	sediment, temperature	Fire	Low	Cow Cr	Headwaters Cow Creek	Address post fire sediment runoff. Possible bank protection, revegetation and re-grading before sediments enter Cow Creek	New 2018	1 mi	$ 253,500	1-2 years	Medium	Low	Medium
60	Lower Cow Creek (North San Ysidro) Restoration	temperature	Fire, Damaged vegetation	High	Cow Creek	Cow Creek - Pecos River to Bull Creek	Address bank erosion/incision, channel width, riparian vegetation destruction. Hold Landowner workshops.	Phase 1 of 3 completed and monitoring in progress	1.9 mi	$ 596,000	6 years	Low	High	High
A	Visitor Center	Future damage prevention	Recreation	High	Multiple	Multiple	Multi-agency visitor resource center	no progress	N/A	unknown	ongoing	High	High	N/A
B	CFRP thinning	Future damage prevention	Fire	High	Multiple	Multiple	Follow-on CFRPj projects to implement roadside thinning	Applying for planning grant in 2019	830 acres	$360,000 max grant;20% match	4 years	High	High	N/A
C	NM forestry	Future damage prevention	Fire	High	Multiple	Multiple	Assistance for hazardous fuel reduction	no progress	variable	$300,000 max grant;50% match	ongoing	Low	Low	N/A

Project No.	Project Name	Pollutant cause addressed	Source focus	Priority	Stream	Sub-watershed	Description	Current status	Scale	Cost	Duration	Prep - complex	Visibility	Water quality effects
D	NM Association of Counties	Future damage prevention	Fire	High	Multiple	Multiple	Assistance for non-federal WUI fuels reduction and CWPP development/updates	no progress	variable	$50,000 fuel reduction; $15,000 outreach; 10% match	ongoing	Low	Low	N/A
E	CFLRP project	Future damage prevention	Fire	High	Multiple	Multiple	Build support for long-term CFLRP fire-ecology restoration project in upper Pecos	no progress	variable	up to $40m	10 yr	High	High	N/A
F	Arroyo trash removal	Future damage prevention	Waste disposal	Medium	Multiple	Multiple	Arroyo trash removal and dumping prevention (coordinated with other solid waste issues)	no progress	variable	$400 per pickup load removed	ongoing	Low	Medium	N/A
G	RV waste disposal	Future damage prevention	Waste disposal	High	Multiple	Multiple	Provide for disposal of RV waste (along with other liquid waste issues)	no progress	N/A	unknown	ongoing	High	Medium	N/A
H	Land use planning	Future damage prevention	Multiple	Medium	Multiple	Multiple	Collaborate with San Miguel County in land use and waste management planning	supposedly in process	N/A	unknown	ongoing	Low	High	N/A
I	Travel Management	Future damage prevention	Transportation	Low	Multiple	Multiple	Work with Forest Service, National Park Service, NM State Park and other agencies to prevent inappropriate off-road truck and ATV use	USFS and SFNF Travel Management Plan complete and implemented	N/A	unknown	ongoing	Low	Medium	N/A
J	Links Tract campground redevelopment	Future damage prevention	Recreation	Low	Pecos	Indian Creek - Pecos	Expand and improve Links Tract area to provide for additional camping to alleviate crowding elsewhere	no progress	2 acres	$ 83,000	< 1 year	Medium	High	N/A
K	Jamie Koch campground conversion	Future damage prevention	Recreation	Low	Pecos	Indian Creek - Pecos	Convert area to provide camping, parking, sites, toilets, tables, etc; re-vegetation.	no action pending creation of Pecos Canyon State Park	12 acres	$ 430,000	< 1 year	Medium	High	N/A
L	Monastery Lake improvements	Future damage prevention	Recreation	Low	Monastery Lake	Dry Gulch-Pecos	New toilest; improved picnic facilities; parking and lake access; re-vegetation	some progress by NM DG & F	8.5 acres	$ 210,000	< 1 year	Medium	High	N/A
M	Invasive Management Protocol for restoration activities	Future damage prevention	Damaged vegetation	Medium	Multiple	Multiple	Retain wetland species after restoration disturbance event	New 2018	N/A	unknown	1-2 years	Low	Low	N/A
N	Wilderness Wetlands Enhancement Projects	Future damage prevention	Damaged vegetation	Medium	Multiple	Multiple	Improve trail maintenance and install waterers for cattle and wildlife to protect wetland areas from trailing and gullying	New 2018	N/A	unknown	1-2 years	Medium	Medium	N/A
O	Fish Structures	Future damage prevention	Recreation	Low	Multiple	Multiple	Assess and remove old log fish structures and replace with rock cross vanes or riffle structures based on location and stream type	New 2018	N/A	unknown	ongoing	High	High	N/A
P	Recreation Improvements	future damage prevention	Recreation	Medium	Multiple	Multiple	Bathroom facilities at Cow Creek and create angler access points to reduce bank erosion. Trails down to banks need to be re-routed or drained	New 2018	0.1 mi	unknown	ongoing	Medium	Medium	N/A
Q	Riparian Conifer Treatment	future damage prevention	Fire	Low	Multiple	Multiple	Thinning project to reduce the encroachment of conifers in the riparian corridor	New 2018	N/A	unknown	ongoing	Low	Medium	N/A
R	Wetlands Action Plan Update	future damage prevention	Damaged vegetation	Medium	Multiple	Multiple	Current Wetlands Action Plan completed in 2009 needs updating to develop a better assessment of upper Pecos watershed wetlands	New 2018	N/A	$ 25,000	1-2 years	High	Low	N/A

APPENDIX B

WATERSHED RESTORATION PROJECT COST ESTIMATES

Following are details of cost estimates for the stream and watershed restoration projects summarized in Chapter 5 of the Watershed-Based Plan. To estimate project costs, generalized cost estimates were made for the various activities that will be involved in the restoration projects, based on a project scale likely to be typical for the activity involved. From this estimate, typical unit costs (per linear foot of stream bank, square foot of revegetation with native plants, and so on) were calculated.

Costs were then estimated for each specific project by multiplying the unit cost for each activity needed for the project by the number of units involved in the particular project, and adding the resulting cost estimates for all the necessary activities.

Project activity cost calculations are shown in the tables below; followed by costs for individual projects beginning on page 6. Note that the "activity cost" estimate for sampling the four streams where pollutant sources remain unknown is also the "project cost", since the activity estimate is for sampling and assessing all four streams.

Streamside access point protection				
Input costs - 2018				
Description	**unit**	**unit cost**		
Stone (delivered to Cowles)	cu. yd.	$70.00		
Excavation (backhoe + Operator)	hour	$140.00		
Labor	hour	$37.00		
Geotextile	sq. ft	$0.30		
Example project for cost calculations				
20-foot streambank access point protection; 20ft. x 10ft. sloping stone ramp 1 ft. deep				
Description	**unit**	**unit cost**	**no. units**	**total cost**
Stone: 20x10x1 = 200 cu. ft. = 7.5 yd	cu. yd.	$70.00	7.5	$525.00
Mechanical excavation work (Machine + Operator)	hour	$140.00	3	$240.00
Hand labor: final slope shaping; stone and fabric placement	hour	$37.00	16	$592.00
Geotextile: 20x10 = 200 sq ft.	sq. ft.	$0.30	200	$60.00
TOTAL COST				**$1,417.00**
Project size unit for cost estimates:	linear foot of streambank			
No. units in example project	20			
Example unit cost	**$70.85**			
Minimum size for valid cost estimation:	10 l.f.			

Revegetation with native plants				
Input costs 2018				
Description	**unit**	**unit cost**		
Trees (Willow whips or Cottonwood Poles)	ea	$7.00		
Herbaceous plants (planting plug or transplanting wetland plants)	ea	$1.00		
Grass and forb seed	lb	$25.00		
Delivery of plant material	lump sum	$150.00		
labor	hour	$37.00		
Example project for cost calculations				
100-ft streambank revegetation; 5 ft x 100 ft = 500 sq ft re-planted with willow and cottonwood poles, wetland transplants, grass seed				
Description	**unit**	**unit cost**	**no. units**	**total cost**
Trees: Spaced every 5 feet; 40 total	ea	$7.50	10	$75.00
Herbaceous transplants: clumps, 100 per 100 sq ft x 5	ea	$1.00	500	$500.00
Seed - 0.5 lb per 100 sq ft x 5	ea	$25.00	2.5	$62.50
Delivery of plant material	lump sum	$200.00	1	$200.00
Planting labor	hour	$37.00	35	$1,295.00
TOTAL COST				**$2,132.50**
Project size unit for cost estimates:	sq ft of revegetated area			
No. units in example project	500			
Example unit cost	**$4.27**			
Minimum size for valid cost estimation:	1000 sq ft			

Revegetation - trees only					
Input costs - 2018					
Description	**unit**	**unit cost**			
Trees (NMRD conservation seedling 40" cu container)	20	$60.00			
Transportation and Handling	lump sum	$150.00			
labor	hour	$37.00			
Example project for cost calculations					
1000-foot re-planting project; 1 cottonwood or box elder per 20 feet, 50 trees total					
Description	**unit**	**unit cost**	**no. units**	**total cost**	
Trees: 1000 ft/ 20 ft per tree	20 trees	$60.00	2.5	$150.00	
Delivery of material	lump sum	$150.00	1	$150.00	
Labor (includes allowance for remote access)	hour	$37.00	18	$666.00	
TOTAL COST				**$966.00**	
Project size unit for cost estimates:	linear foot of streambank				
No. units in example project	1000				
Example unit cost	**$0.96**				
Minimum size for valid cost estimate:	1000 l. f.				

Road Re-grading and Re-vegetation - only 2012 project list				
Input costs 2018				
Description	**unit**	**unit cost**		
Equipment time (backhoe or mini-excavator and operator)	hour	$140.00		
Herbaceous plants (planting plug)	ea	$1.00		
Grass and forb seed	lb	$25.00		
Delivery of material	lump sum	$150.00		
labor	hour	$37.00		
Example project for cost calculations				
Creation of two rolling dips and an infiltration basin along a 100 ft stretch of road to slow and treat runoff before entering river				
Description	**unit**	**unit cost**	**no. units**	**total cost**
Machine excavation	hour	$140.00	2.5	$350.00
Hand earthwork	hour	$37.00	4	$148.00
Herbaceous transplants: 100 per 100 sq ft x 10	ea	$1.00	1000	$1,000.00
Seed - 2 lb per 100 sq ft x 10	lb	$25.00	2.5	$62.50
Delivery of material	lump sum	$150.00	1	$150.00
Planting labor	hour	$37.00	22	$814.00
TOTAL COST				**$2,524.50**
Project size unit for cost estimates:	Sq ft of treated area			
No. units in example project	1000			
Example unit cost	**$2.52**			
Minimum size for valid cost est:	500 sq ft			

Road Repairs and Upgrading - 2012 project list only				
Input costs - 2018				
Description	**unit**	**unit cost**		
Equipment	hour	$140.00		
Equipment, large excavator	hour	$200.00		
Engineering design or supervision	hour	$125.00		
Culvert (12"x20 ft typical)	ea.	$350.00		
Labor	hour	$37.00		
Example project for cost calculations				
1000-ft section of road repair: 1 culvert installed; 2 bar ditch repairs to prevent direct stream runoff				
Description	**unit**	**unit cost**	**no. units**	**total**
Equipment	hour	$140.00	32	$4,480.00
Equipment, large excavator	hour	$200.00	5	$1,000.00
Engineering design or supervision	hour	$125.00	10	$1,250.00
Culvert (12"x20 ft typical)	ea.	$350.00	1	$350.00
Labor	hour	$37.00	30	$1,110.00
TOTAL COSTS				**$8,190.00**
Project size unit for cost estimates:	linear foot of streambank			
No. units in example project	1000			
Example unit cost	**$8.19**			
Minimum size for valid cost estimation:	1000 LF			

In-stream habitat improvements				
Note: costs for in-stream geomorphological re-alignment and aquatic habitat improvements were averaged among successful projects recently implemented on private land near Pecos.				
Example project for cost calculations				
0.1-mi section of stream repair: vanes/stone bank protection; enhancement of pools/riffles; narrowing of over-wide stream sections. NOTE: costs include 404/401 permitting but not NEPA compliance				
TOTAL COST				**$15,000.00**
Project size unit for cost estimates:	linear foot of stream channel repair			
No. units in example project	528			
Example unit cost	**$28.41**			
Minimum size for valid cost estimation:	500 linear feet			

Fencing				
Input costs - 2018				
Description	**unit**	**unit cost**		
6-foot T-post	ea	$6.00		
Barbed wire ($52/1300 ft x 4 strands)	ft	$0.16		
Delilvery of material	lump sum	$100.00		
Labor	hour	$37.00		
Example project for cost calculations				
1000-ft section of fence: 1 post per 15 ft; 4 strands of barbed wire				
Description	**unit**	**unit cost**	**no. units**	**total**
T-posts	ea	$12.00	70	$840.00
Barbed wire	ft	$0.30	1000	$300.00
Delivery of material	lump sum	$100.00	1	$100.00
Labor	hour	$37.00	20	$740.00
TOTAL COST				**$1,980.00**
Project size unit for cost estimates:	linear foot of fence			
No. units in example project	1000			
Example unit cost	**$1.98**			
Minimum size for valid cost estimation:	200 l.f.			

Contaminant source sampling: 4 streams				
Updated 2018				
Description	**unit**	**unit cost**		
Sampling equipment (used for all projects)				
Field water chemistry kit (Hach or similar)	ea	$2,250.00		
Multi-parameter water sampling meter	ea	$120.00		
Labor	hour	$70.00		
Fixed costs needed prior to sampling; valid for all sampling to be done				
Description	**unit**	**unit cost**	**no. units**	**total cost**
Sampling equipment	ea	$2,270.00	1	$2,270.00
QAPP preparation	hour	$70.00	40	$2,800.00
TOTAL FIXED COSTS				**$5,070.00**
Field sampling costs				
Description	**unit**	**unit cost**	**no. units**	**total cost**
Stream sampling hour	hr	70	60	$4,200.00
Report preparation	hr	70	24	$1,680.00
TOTAL FIELD COSTS				**$5,880.00**
Project size unit for cost estimates:	single project			
No. units in example project	1			
Project cost	**$10,950.00**			
Minimum size for valid cost estimation:	entire project			

Stream Restoration				
Note: Design and construction costs for in-stream geomorphological re-alignment and aquatic habitat improvements averaged among successful projects recently implemented in the Pecos area. Costs based on 2018.				
Example project for cost calculations				
0.5-mi section of stream assessment and repair: vanes/stone bank protection; enhancement of pools/riffles; narrowing of over-wide stream sections. NOTE: costs include 404/401 permitting but not NEPA compliance				
TOTAL COST				**$126,720.00**
Project size unit for cost estimates:	linear foot of stream channel repair			
No. units in example proj	2640 LF			
Example unit cost	**$48.00**			
Minimum size for valid cost estimation:	1000 LF			

Road Drainage and Re-vegetation				
Input costs 2018				
Description	**unit**	**unit cost**		
Equipment time (backhoe or mini-excavator and operator)	hour	$140.00		
Herbaceous plants (planting plug)	ea	$1.00		
Grass and forb seed	lb	$25.00		
Delivery of material	lump sum	$150.00		
labor	hour	$37.00		
Example project for cost calculations				
Creation of two rolling dips and an infiltration basin along a 100 ft stretch of road to slow and treat runoff before entering river				
Description	**unit**	**unit cost**	**no. units**	**total cost**
Machine excavation	hour	$140.00	6	$840.00
Hand earthwork	hour	$37.00	4	$148.00
Herbaceous transplants: 100 per 100 sq ft x 10	ea	$1.00	1000	$1,000.00
Seed - 2 lb per 100 sq ft x 10	lb	$25.00	2.5	$62.50
Delivery of material	lump sum	$150.00	1	$150.00
Planting labor	hour	$37.00	12	$444.00
TOTAL COST				**$2,644.50**
Project size unit for cost estimates:	Sq ft of treated area			
No. units in example project	100			
Example unit cost	**$26.50**			
Minimum size for valid cost est:	1000 sq ft			

Hand Built Restoration Structures and Trail Work				
Input costs 2018				
Description	**unit**	**unit cost**		
Supervision	hour	$55.00		
Tools	lump sum	$100.00		
Travel and per diem	hour	$12.50		
Labor	hour	$37.00		
Example project for cost calculations				
1,000 feet of restoration or trail work by hand includes supervision and labor to make trail improvements and channel structures such as one rock dams, post vanes. Note: this does not include restoration design				
Description	**unit**	**unit cost**	**no. units**	**total cost**
Supervision	ea	$55.00	40	$2,200.00
Tool fee	lump sum	$100.00	1	$100.00
Travel and per diem	hour	$7.50	260	$1,950.00
Labor	hour	$37.00	220	$8,140.00
TOTAL COST				**$12,390.00**
Project size unit for cost estimates:	Linear foot of trail work or restoration by hand			
No. units in example project	1000			
Example unit cost	**$12.40**			
Minimum size for valid cost estimation:	1000 LF			

The unit costs estimated in the tables above were combined as appropriate to determine a cost estimate for each separate restoration project. Project cost estimates for the projects are shown in the following tables, grouped by pollutant cause in the same format used in Chapter 5.

APPENDIX C

SSTEMP MODELING FOR RESTORATION PROJECT TEMPERATURE EFFECTS

To evaluate the effects of restoration scenarios on streams in the upper Pecos watershed, seven stream reaches were modeled using the SSTEMP water temperature modeling program developed by the US Geological Survey. For the stream reaches currently listed as “nonattaining” by NMED (Lower Pecos, Upper and Lower Cow Creek, and Bull Creek) existing hydrologic, meteorologic, and stream geometry data published in the 2003 TMDL report were used for this modeling effort. The TMDL report gives detail explanations for and data used for each model parameter.

For three other stream reaches (the Pecos River above Alamitos Creek, Apache Creek, and Sebadilla Creek) that had not been previously modeled with SSTEMP, a surrogate set of data was used to approximate model parameters. For Apache Creek and Sebadilla Creek, the surrogate data set was Bull Creek. For the upper Pecos, the hydrologic and stream geometry data from Lower Pecos (Alamitos Canyon to Manzanares Canyon) were used, while the meteorologic data were derived from Upper Cow Creek. Beginning and end elevations for each stream reach were derived from USGS topographic quadrangle maps. For every stream reach, a weighted shade average was computed to demonstrate the increase in shade resulting from improving riverside vegetation on specific areas within a stream, calculated based on the length of restoration projects (where shade is to be increased) and the length of reaches that will remain unaffected by restoration projects, as percentages of the whole reach.

As an example of using a weighted average of riparian shade: assume a one mile impaired reach with two management sections of .25 miles and .3 miles for a total of .55 miles or 55% percent of the total analyzed reach. Assuming a 40% shade on the non-management section and 70% on the management section, the overall shade value for the entire reach would be 56.5 percent (70% shade x .55 miles + 40% shade x .45 miles). Using the weighted average for shade a single SSTEMP run was made for the entire reach keeping all other variables consistent with the 2003 TMDL input parameters. This approach was especially useful for small tributaries that have inflow volumes of zero at the headwaters and an outflow measurement at the mouth, but no data between that can help gauge the volume of water coming from tributaries.

It was not possible to model temperature effects of individual projects, because data on channel geometry, temperatures, and flow rates was not available for individual localized stream reaches. Available data and the dynamics of the SSTEMP model indicate that modeling a longer stream reach (particularly ones that can be compared with TMDL modeling) with and without the effects of restoration projects will yield more reliable predictions than attempting to model multiple smaller reaches using output data from an upstream reach as input data for the next reach below, in the absence of accurate data for the necessary parameters. We believe SSTEMP can provide tolerably accurate estimates of the effects of suites of restoration projects on complex stream reaches (like the Pecos River), even though it has not been possible to accurately estimate the effects of some individual, smaller projects.

Model input parameters and predicted temperature outputs, after restoration, are shown in the table on the next page.

Reach	Inflow CFS	Inflow ˚C	Acc Temp ˚C	Lat.	Length (km)	Begin elev (ft)	End elev (ft)	A Term s/ft^2	B term	Man-ning's N	Air Temp ˚C	RH	Wind (mph)	Grnd Temp ˚C	% Shade	Outflow ˚C
Apache Creek*	0	0		35.62	24.1	9200	6160	4.37	0.338	.052	16.77	35.5	6.2	8.8	41.7	19.72
Bull Creek	0	0	8.8	35.62	24.6	10000	6900	4.37	0.338	0.052	16.77	35.5	6.2	8.8	41.3	19.69
Cow Creek (Lower)	1.119	16.8	8.879	35.48	25.1	6900	6300	7.0	.227	0.055	22.25	39.9	4.75	8.8	53.24	20.28
Cow Creek (Upper)	0	0	8.807	35.53	35.9	11000	6900	4.37	.338	.052	13.52	65.3	5.3	8.8	40.4	17.9
Pecos River (Upper)	0	0	8.879	35.62	77.0	11660	6889	52.2	.045	.052	13.52	65.3	4.75	8.8	41.2	18.8
Pecos River (Lower) (Impaired Reach)	4.34	20.5	8.88	35.52	9.173	6889	6700	52.2	0.045	.052	21.5	50.35	5.28	8.8	57	21.05
Sebadilla Creek*	0	0	8.8	35.62	45.0	9000	6100	4.37	0.338	0.052	16.77	35.5	6.2	8.8	43.3	19.4

*Stream reaches modeled with data from nearby Bull Creek. See discussion above.