Upper Pecos Watershed Restoration Action Strategy

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INTRODUCTION

Watershed Location and Description

The Upper Pecos Watershed (U.S. Geological Survey Hydrologic Unit Code 13060003) is part of the larger Rio Grande Basin (Figure 1). The Pecos River is a tributary of the Rio Grande flowing from its headwaters in northern New Mexico down through eastern New Mexico to its confluence with the Rio Grande in southwestern Texas. The area considered for this Watershed Restoration Action Strategy (WRAS) is the watershed of the Pecos River and its tributaries north of Interstate Highway 25. Major tributaries of the Pecos in this part of the watershed include Willow Creek, Cow Creek, Bull Creek, Glorieta Creek, and the Rio Mora.

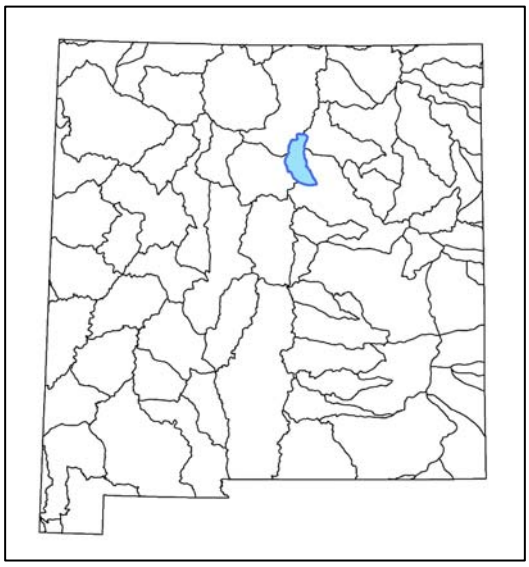


Figure 1. Location of Upper Pecos Watershed

The Upper Pecos watershed area covers approximately 350,000 acres, ranges in altitude from over 13,000 feet in the Truchas Peaks to about 6,700 feet as it crosses Interstate 25, and includes land grants, other private land, Santa Fe National Forest land, the Pecos National Historical Park, the Village of Pecos, and relatively small parcels of Bureau of Land Management and State land. This WRAS excludes the watershed of the Pecos River south of Interstate Highway 25, and the Gallinas and Tecolote watersheds. For assessing stream condition and considering restoration prospects, the Upper Pecos watershed can be subdivided into several sub-watersheds, as shown below in Table 1. These are not a complete list of named tributaries, but rather an indication of the stream reaches that have been the focus of water quality assessment and/or those most likely to need restoration activities to benefit water quality.

Table 1. Areas in HUC 13060003 included in Upper Pecos Watershed WRAS

Name	**Reach**
Pecos River	Willow Creek to headwaters
Pecos River	Alamitos Canon to Willow Creek
Pecos River	Cañon de Manzanita to Alamitos Canyon
Rio Mora	Confluence with Pecos River to headwaters
Willow Creek	Confluence with Pecos River to headwaters
Cow Creek	Pecos River to Confluence with Bull Creek
Bull Creek	Confluence with Cow Creek to headwaters
Cow Creek	Confluence with Bull Creek to headwaters
Glorieta Creek	Confluence with Pecos River to headwaters

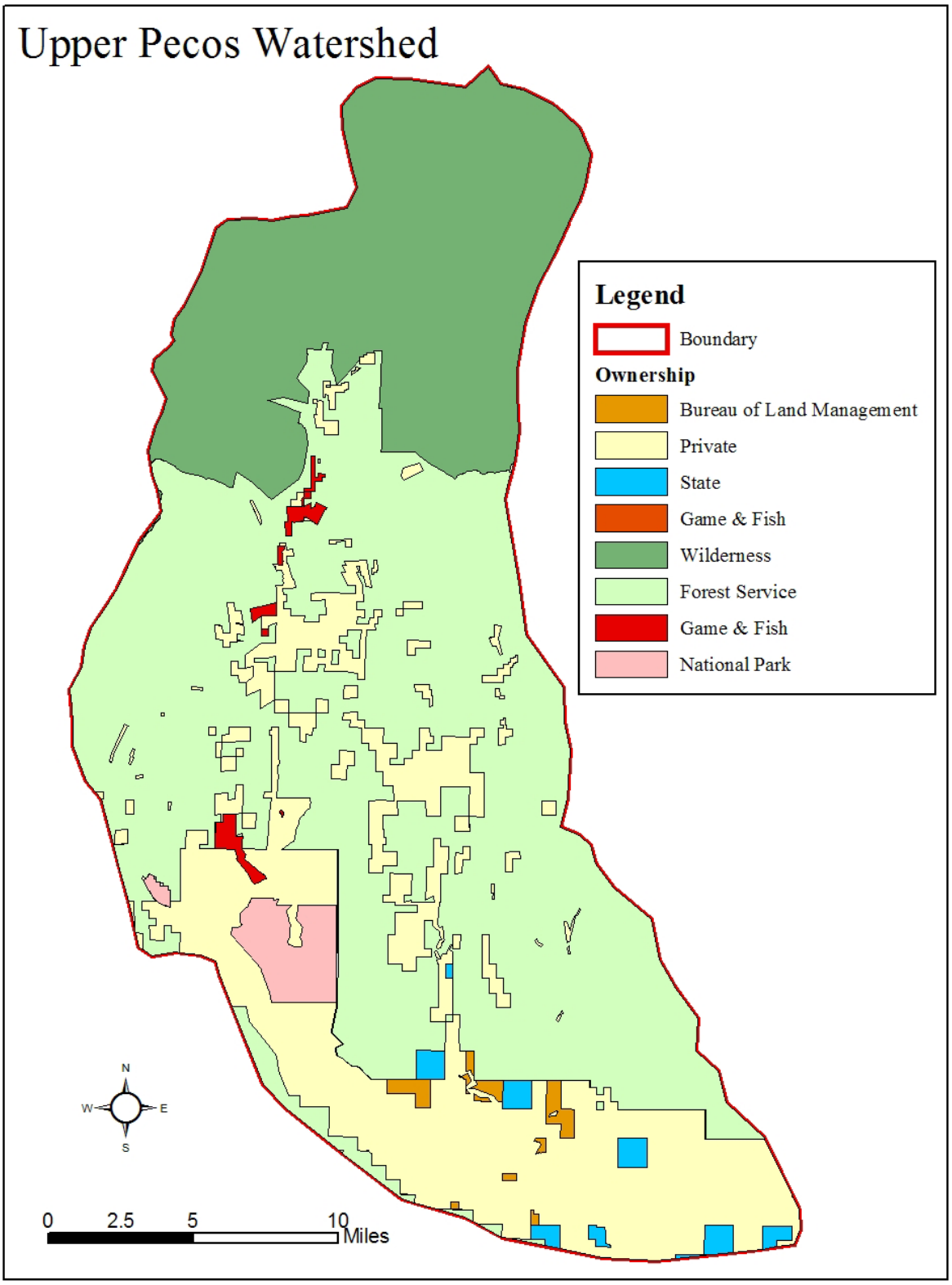


Figure 2. Land ownership in the Upper Pecos Watershed

Formation of the Upper Pecos Watershed Association

The Upper Pecos Watershed Association (UPWA) was formed in July of 2006 to engage stakeholders in finding ways to improve watershed conditions in the Upper Pecos watershed above Interstate 25. Both local residents and the New Mexico Environment Department have expressed a need to address non-point source water pollution in the watershed. By engaging a diverse group of stakeholders, multiple strategies can be developed to investigate and improve impaired stream reaches. The goals of the association are to work with stakeholders and the visiting public to improve the conditions in the Upper Pecos Watershed through education, hands-on restoration, and cooperation with public and private entities, for better management of the watershed as a whole. The UPWA has been incorporated in New Mexico, and has been recognized as a non-profit organization under the Internal Revenue Code. A list of members is included as an Appendix.

WATERSHED ASSESSMENT

Historical Overview

The upper Pecos Valley has been occupied by humans for at least 12,000 years. It was first used seasonally by hunters and gatherers, with settlement gradually increasing in density and permanence. The first permanent settlements in the area seem to have begun about 750 AD, and Pecos Pueblo became the principal settlement for the previously dispersed farmers in the Pecos valley around 1450 AD. It thrived as a village and principal trading center on a major travel and trade route from Glorieta Pass to the Great Plains, until it was abandoned in the 1770s.

Spanish exploration of the area began in the 1600s and gradually more people began using resources and settling in the Pecos area. By 1776, Pecos Pueblo was abandoned, and permanent Spanish settlement began in 1794. Throughout the 1800s and into the 1900s Spanish and Anglo-European settlements increased in the area along with increasing farming, ranching, logging, mining, and trapping activities. By 1831, irrigation ditches were constructed along the Pecos River to serve the increasing farmland and larger settlements. In the late 1880s more extensive logging activities began, along with the construction of railroad lines. Mining started at the Terrero mine in 1882, and continued until 1939. Many of the roads, bridges, and campgrounds that still exist were built during the 1930s by the Civilian Conservation Corps. During this time, the entire watershed was used as summer range for cattle and sheep, and in 1866, the Goodnight-Loving trail crossed through the Pecos Valley. The area was proclaimed as the Pecos River Forest Reserve in 1892, later became the Pecos National Forest, and merged with the Jemez National Forest in 1908 to become what is now called the Santa Fe National Forest.

Mining

The Terrero mine operated between 1882 and 1939 where Willow Creek flows into the Pecos River. “Terrero” means mine dump in Spanish. Mining activity was relatively small-scale from 1882 until the American Metals Company took over the mine in 1925 and expanded both mining and milling dramatically. The mine produced approximately 2,200,000 tons of lead and zinc ore

between 1926 and 1939 (Robinson 1995). Ore was transported to the mill in El Molino (near the village of Pecos) for processing. Large amounts of mine tailings were disposed of in three sites, and some tailings were dumped into the Pecos River at the mine site.

In the 1950s, the State of New Mexico obtained the land where the mine and the mill had operated. Between the mine and the Village of Pecos mine tailings were used for construction projects. Road construction, federal and state campgrounds, the Lisboa Springs Fish Hatchery, and other projects utilized mine tailing material in construction. In addition, mine tailings were 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 in response to concerns raised by residents about water quality in the area as it related to the Terrero mining operations. In 1991, contaminants carried into the Pecos River were responsible for a large-scale fish kill 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 facilities construction.

A public meeting was called in Pecos in May 1991 to address problems associated with the contaminants leaching into the 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. The AOC specified a 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.

Acequias

There are at least six active acequias within our watershed, and acequias have a significant impact upon the riparian corridor and surrounding floodplain. Acequias can have positive effects 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 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.

Logging and Firewood Harvesting

Extensive logging in the area was initially undertaken in the late 1880s to support the infrastructure of Terrero mine, housing for its employees, and wood for the railroad. By 1939, the mine closed and logging activities slowed. Some logging occurred in the 1980s, with the Davis-Willow and Dalton Timber sales. Between 1989 and 2003, controlled burns were conducted in order to reduce fuels and improve habitat for wildlife. Poorly controlled firewood

harvesting is a concern voiced by some residents, not only because of the wood removed, but also because of the roads created to get to and remove the firewood.

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. This trend continued for many years even after the area was designated as a Forest Reserve.

Figure 3: Heavily grazed rangeland in 1930, near Pecos Ruins

Grazing became subject to permitting by the Forest Service once it assumed management responsibility over what is now National Forest land, but nevertheless by the 1960s the Santa Fe National Forest considered that it had more grazing permits than grazing capacity. Overgrazing is believed to have contributed to diminished grass-fire frequency and thus an increase in the density and extent of piñon-juniper and ponderosa pine stands (Dahm and Geils 1997, DeBuys 1985). Overuse of the area by domestic grazing animals was a topic addressed by the Forest Plan Environmental Impact Statement (EIS) in 1987. In 2003 there were 10 grazing allotments on the Santa Fe National Forest within the upper Pecos watershed, used by a total of 30 permittees (CEEM report, 2004).

Recreation

For decades, the upper Pecos valley has received a great deal of recreational use. This reach of the Pecos River is 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 six developed campgrounds, along with three picnic areas, and the New Mexico Department of Game and Fish is responsible for two campgrounds. Summertime demand generally far exceeds available capacity. One result is a great deal of unmanaged, dispersed camping, especially around Terrero and Cowles, as well as overuse of parts of the developed areas. 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, preventing regrowth) leads to increased streamside erosion and increased sediment washed into the river whenever there is rain or snowmelt. This degrades the water quality as well as the recreational experience.

Along the recreational segments of the rivers, off-road driving and user-created roads are another concern. There are over 350 miles of unpaved roads within the watershed, and at least 27 of these road miles are within 100 meters of a perennial stream, and likely to contribute significant sediment runoff to the stream. There is currently an initiative to establish a "designated roadways policy" on USFS lands. This would mean that all roads on Forest Service land in the watershed would be mapped and this map would be published nationally. This could encourage increased use of roads in the watershed, which could add to problems of recreational overuse in the river corridor and certainly raises concerns about increased upland erosion.

Geology

The main core of the Sangre de Cristo Mountains is composed of Pre-Cambrian igneous and metamorphic rocks, resulting form 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 sandstone, conglomerate, and shale are exposed towards the southern end of the watershed, south of the village of Pecos.

Soils

The soils in the region are typically sandy loam or loam with significant amounts of gravel, cobble, and boulders in the soil profiles. Soils in the meadows and riparian areas are finer textured than soil on adjacent slopes. Many of the soils in this watershed are highly erodible soils.. Figure 4 illustrates what can happen to some of the fine-grained, highly erodible soils found in the southern part of the watershed, downstream of the village of Pecos. Figure 5 on the next page shows the location of major soil types found in the watershed.

Figure 4: Gullies near San Ysidro

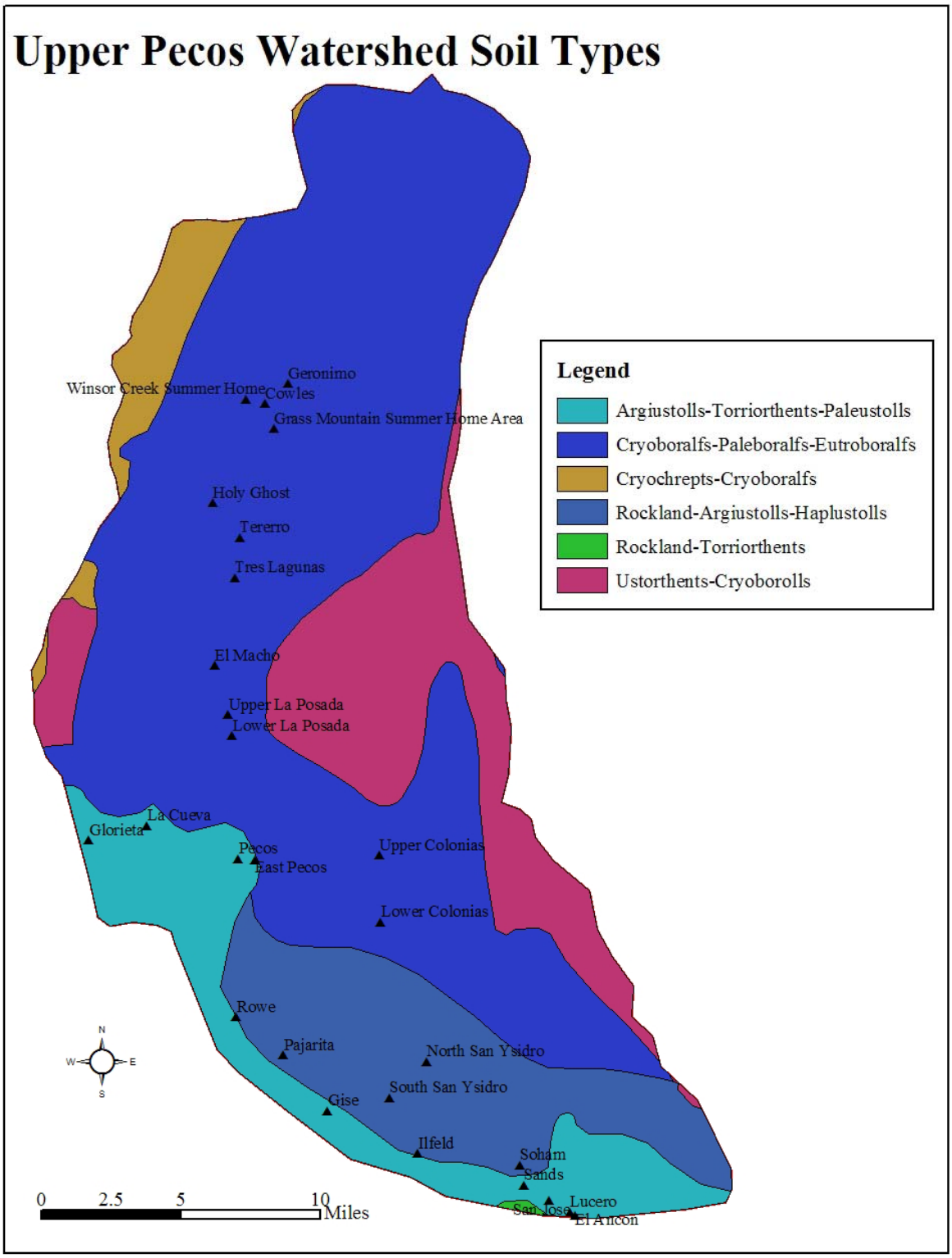


Figure 5: Major soil types

Climate

From November through March, Pacific storms provide much of the moisture for the Upper Pecos Watershed with an average of 23 inches of snowfall annually. Between July to September, monsoon rains occurring as thunderstorms often cause short term flooding in the Pecos and its tributaries. In the lower elevations, average annual precipitation is about14 inches, but can be as high as 44 inches in the upper elevations.

Table 2: Pecos Ranger Station climate summary

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	47.2	49.9	54.9	63.6	73.4	82.8	85.2	82.0	77.0	67.3	55.0	48.7	65.6
Average Min. Temperature (F)	14.9	19.1	23.2	30.1	38.2	47.1	52.6	51.3	44.2	33.6	23.0	16.4	32.8
Average Total Precipitation (in.)	0.74	0.66	0.88	0.83	1.07	1.28	2.88	3.38	1.73	1.18	0.75	0.68	16.05
Average Total Snowfall (in.)	5.6	4.1	4.4	1.6	0.0	0.2	0.0	0.0	0.0	0.3	2.5	4.8	23.5
Average Snow Depth (in.)	1	0	0	0	0	0	0	0	0	0	0	0	0

Vegetation

At the higher elevations in the watershed Engelmann spruce is the dominant plant species, forming the primary forest canopy in about 33% of the watershed, at elevations from approximately 9,000 to 12,000 feet. Douglas fir is typically dominant between 8,000 and 10,000 feet, covering about 19% of the watershed area. Ponderosa pine dominates over about 17% of the area, between about 7,000 and 9,500 feet, and predominating on south and west facing slopes at higher elevations and north or east facing slopes at lower elevations. At the lowest elevations in the watershed, vegetation is dominated by piñon-juniper and oak woodlands. High-altitude meadows 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. Figure 5 on the next page illustrates the location of major vegetation types in the watershed..

Due to 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 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 may be considerable scope for restoration forestry over the coming years throughout much of the watershed.

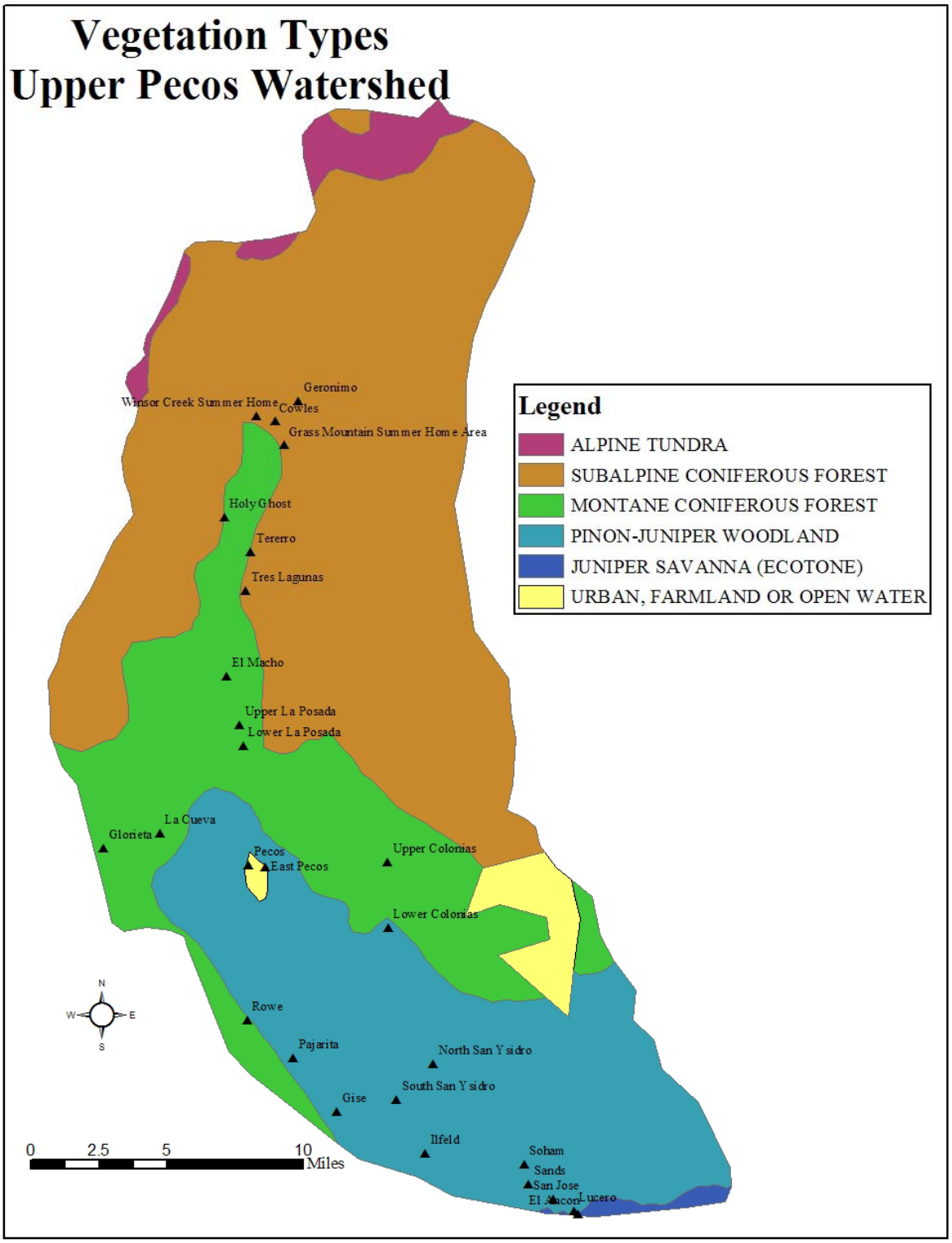
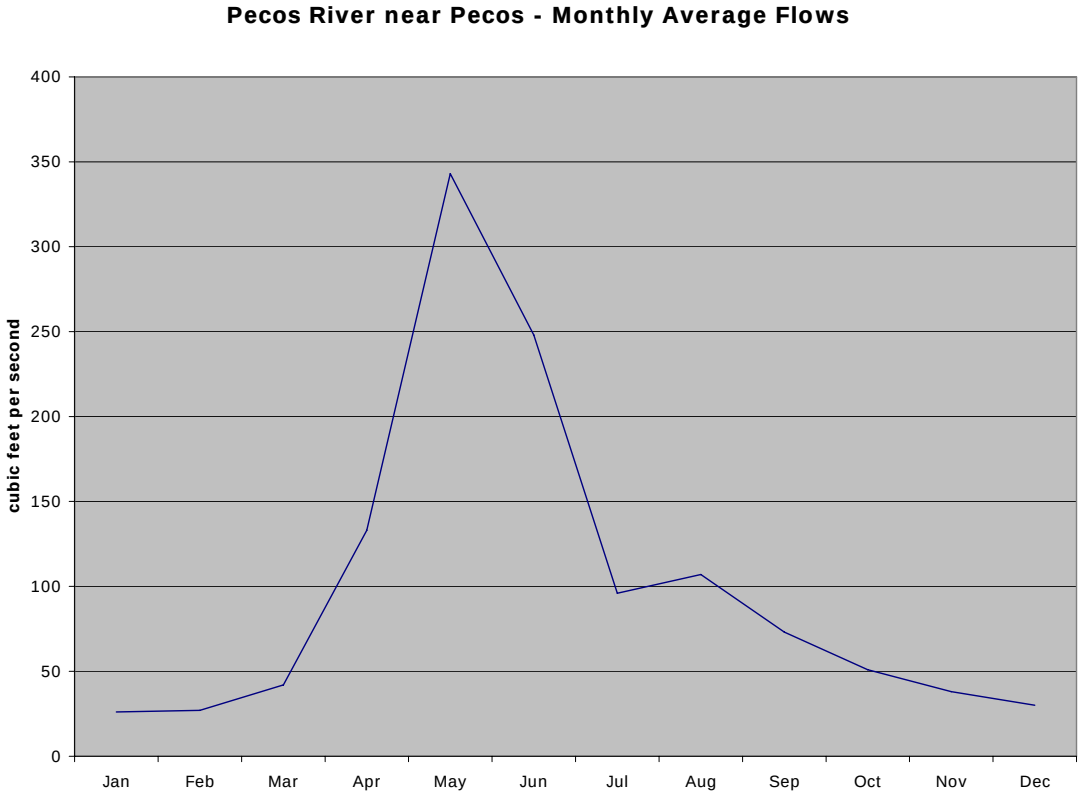


Figure 6. Vegetation types in the Upper Pecos Watershed

Hydrology

The upper Pecos River and 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 and is above timberline. Streams in the Upper Pecos Watershed are of two main Rosgen classifications: types B and C. Higher-altitude stream reaches are usually in fairly steep, narrow valleys, and run straight, fast, and narrow. Their course is largely controlled by the geology and shape of the surrounding valley, and they area not very sinuous – Rosgen type B stream channels. Streams in the lower lying areas are usually Rosgen C-type channels, with slower flow rates and greater sinuosity. Stream reaches, especially once they are not confined to narrow alpine valleys, are bordered by a 30 to 100 foot band of riparian vegetation that includes small, infrequent wetland areas. The flow regime for both stream types is dominated by springtime snowmelt runoff with a smaller secondary rise during the summer monsoons. The average flow rates for the Pecos River at the USGS gauging station near the village of Pecos are shown graphically in Figure 6 below, while the major tributaries of the upper Pecos watershed are shown in Figure 7 on the next page.



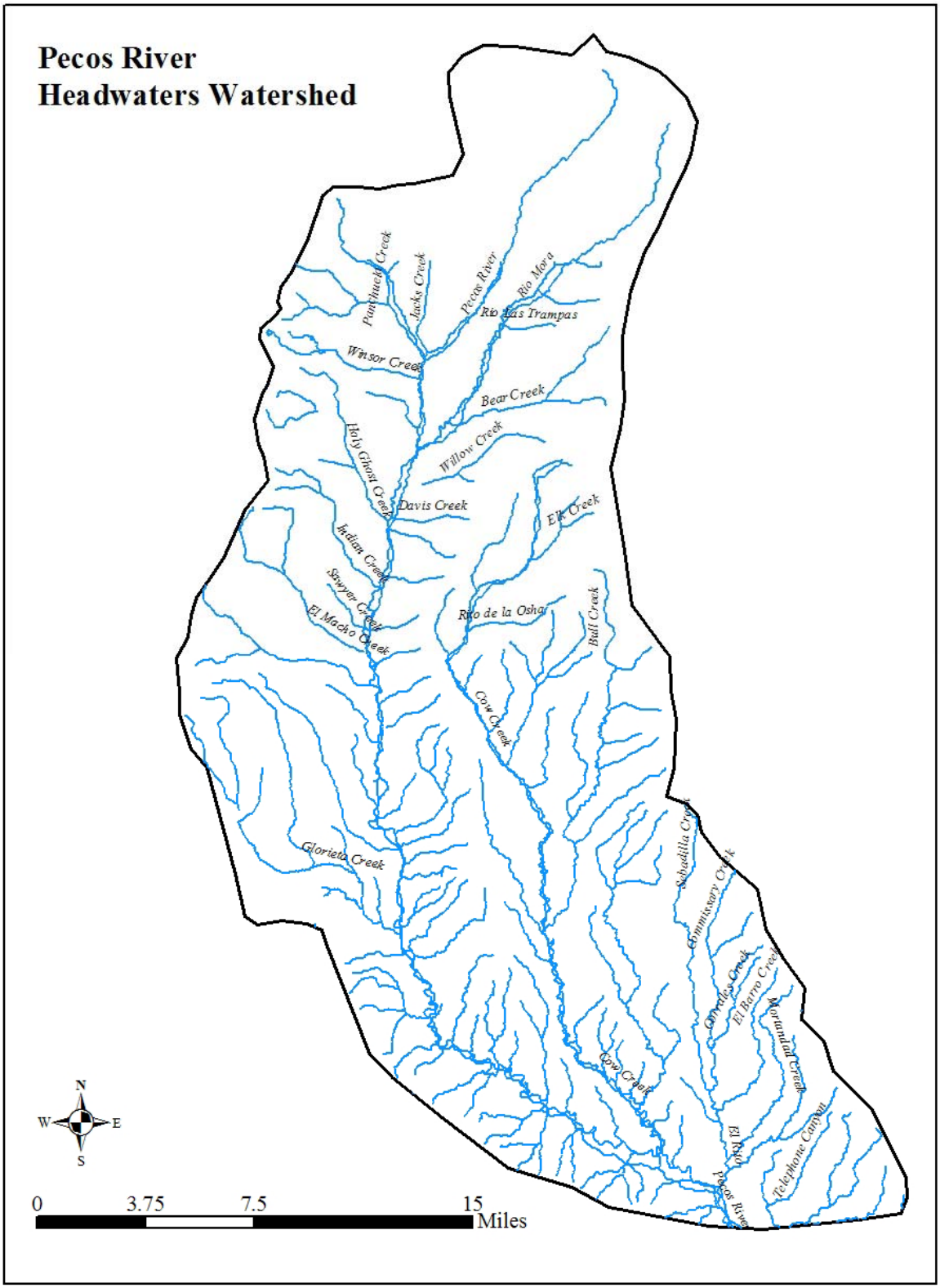


Figure 8: Major streams in the Upper Pecos Watershed.

Point Source Discharges

There are two point source discharges into the Pecos River with National Pollutant Discharge Elimination System (NPDES) permits under the Clean Water Act: the Lisboa Springs Fish Hatchery and the Village of Pecos wastewater treatment plant. 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.

Land Ownership

The majority of land in the Upper Pecos Watershed is federally owned, with private holdings located primarily south of the village of Pecos, although a significant part of the limited land area within the Pecos river canyon is also private (Table 3).

Table 3. Land ownership in the Upper Pecos Watershed (approximate acreages)

Ownership	Acres	Percentage of Land Area in Watershed
Upper Pecos Watershed	350,000	
Private	50,820	14.5
Pecos National Historic Park	6,445	1.8
Santa Fe National Forest	200,000	57.2
Designated Wilderness	85,500	24.3
Department of Game and Fish	1,933	0.55
Bureau of Land Management	2,240	0.64
State of New Mexico	3,065	0.9

Endangered Species

Mexican Spotted Owl

The Mexican Spotted Owl is dependent on old-growth forest and healthy riparian areas. Decline in species numbers is attributed to habitat degradation and habitat loss. It is unclear from published reports if or when Mexican Spotted Owls were found, and how numerous they would have been, within the upper Pecos.

Rio Grande Cutthroat Trout

The Rio Grande cutthroat trout is the only salmonid fish native to the Rio Grande (including the Pecos) watershed, but has now been out-competed or hybridized with introduced trout (mostly rainbow or brown trout) throughout almost all of its former range. The upper reaches of the Pecos (above Pecos Falls) and the upper reaches of some tributaries still harbor small populations of native cutthroat trout. Cutthroat trout, like other salmonids, require cool water,

low levels of stream bottom sediment and turbidity, and they also need protection from excessive competition from non-native fish.

Holy Ghost Ipomopsis

The Holy Ghost Ipomopsis is a short-lived perennial plant that grows to about 2 feet tall and produces showy pink flowers. It is known to exist only in Holy Ghost canyon, is found in open areas within the Ponderosa zone, and has been declining in population. Its decline may be a result of decreased fire frequency (hence fewer openings) in forested areas. It now occurs mostly in road cuts and other areas opened up by human disturbance. Increasing the openness of 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 were the Holy Ghost Ipomopsis were historically found.

Figure 9: Holy Ghost Ipomopsis

WATER QUALITY PROBLEMS

At present, turbidity and temperature are the two major water quality problems in the watershed, although heavy metal contamination from former mining activities has been a concern. These water quality problems appear to stem largely from human use (and overuse) of parts of the watershed, such as recreational pressure, increasing development, and effects of grazing and logging in the past.

Turbidity

Turbidity is an optical property of water that causes light to be scattered or absorbed rather than transmitted. It generally results from suspended solid particles in the water. These particles are mostly soil particles (sand, silt, and clay); although they can also include plankton or other microscopic life forms. Turbidity tends to raise water temperature and lower dissolved oxygen levels, both of which are harmful to cold-water fish like trout. Turbid water also reduces photosynthesis in plants because of decreased light below the water surface. In addition to its directly harmful effects, turbidity also indicates sediment transport in a stream and provides evidence of streambank erosion and/or upland sediments washed into and carried down a stream system. Causes of increased turbidity include soil erosion of stream banks and/or of upland areas within a watershed, high flow events, excess nutrients, and perhaps other pollutants.

Temperature

Decreased depth to width ratios, decreased streamside canopy vegetation cover, and increased suspended sediments all contribute to higher than optimum water temperatures. These higher water temperatures have a direct negative impact on aquatic life in mountain streams and rivers

like the Upper Pecos. Temperatures exceed acceptable levels in some stream reaches in the watershed.

Metal Contamination

Metal contamination (particularly zinc and cadmium) in the past has contributed to major fish kills at the Lisboa Springs State Fish Hatchery. Remediation work to contain mine tailings from the old Terrero Mine site is designed to prevent these incidents, and monitoring is ongoing.

Other Issues

While turbidity, temperature, and metals are the specific contaminants that have attracted regulatory attention so far, there are other issues that have been mentioned in public input and may deserve attention. Sampling should be done to determine the presence and extent of any problems. If problems are substantial, then perhaps corrective action should be planned. Potential microbiological contamination is a widespread cause of concern. Discharge or leakage of human waste associated with recreational use 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. 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 here is no particular reason to think that these contaminants would be likely in our area.

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.

Sources of Contaminants and Contributing Factors

Recreational Use and Campgrounds

Overuse of recreational facilities and non-regulated recreational uses appear to be significantly damaging some streambanks 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 streambanks

- 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
- Lack of trash collection point(s)
- Trash left at campsites attracting wildlife contributing to pollution
- Lack of clean drinking water
- Increased pressure on areas not affected by Viveash Fire
- Lack of clear information on allowed facility uses and obtaining permits
- Law enforcement issues

There are six Forest Service campgrounds as well as the Bert Clancey, Terrero, Koch, and Mora areas managed by the New Mexico Department of Game and Fish, but all these facilities collectively are inadequate to provide for the level of demand seen in much of the summer and early autumn (Figure 9). 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.

Figure 10: Camping below the Rio Mora, July 2006

Figure 11: Terrero campground on July 22, 2006

Grazing and Logging

Grazing and logging in the watershed is regulated by the Forest Service. Both practices have the ability to contribute to erosion and subsequent sedimentation of waterways, and both activities have a direct impact on the frequency and severity of wildfires. Grazing affects water quality primarily by influencing the quality of grass cover protecting the soil and preventing soil erosion. The effects of damaged grass cover can be dramatic (see the gullies in Figure 4), but conversely, the effects of properly managed grazing to increase effective grass cover and protect the soil can be amazing. The principal threat to water quality from logging is also 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 logging practices that protect and/or restore ground cover.

Fire Damage

Erosion from forested areas impacted by the Viveash, Dalton, and Trampas fires contributed dramatically to turbidity and sedimentation in the Pecos and its tributaries in the immediate aftermath of the fires. The effects of these fires are still affecting the rivers. 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:
http://www.nmenv.state.nm.us/swqb/Viveash_Fire_Report_02-2001.html

Development and Urbanization

Subdivision and development of land along the Pecos River for housing increases 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 New Mexico have poor drainage and poor placement of road culverts which exacerbates erosion problems by improperly channeling and concentrating water flow. Some roads, especially in the upper reaches of the Pecos on Forest Service land, 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.

Mining

Concern has been voiced as to whether metal contamination from Terrero mine tailings may still be a problem, although the remediation project is periodically monitored. (See *Investigation of Trace Element Contamination from Terrero 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 Terrero mine cleanup.

Fish Stocking Programs

There is concern about Whirling Disease and other pollutants and infectious agents that could be introduced into the rivers through fish stocking programs. Additionally, log fish-habitat structures built between the 1930s and the 1950s have deteriorated and may no longer be contributing to fish habitat as they were originally intended.

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 land owner wants beaver on their property for a variety of reasons. For these landowners, Animal Protection of New Mexico has a program to live trap unwanted beaver and move them to properties where landowners are more amenable to having beaver dams.

WATER QUALITY GOALS

Impaired Streams

Surface water quality regulation begins with designation by the New Mexico Water Quality Control Commission of uses that each stream reach should be able to support. Sampling is then done, on a rotating basis, by the New Mexico Environment Department to determine if these uses can in fact be made of the stream reach in question. Periodically a list is published of stream reaches that are impaired, or do not support their designated uses, along with assessments of the likely pollutants causing the impairments and the sources of those pollutants. The list is published as the *2004-2006 New Mexico Integrated 303d-305b List*, and the impaired stream reaches in our watershed are listed in Table 4 below, along with pollutants and likely sources.

The next step in the regulatory process is determining "Total Maximum Daily Loads", or TMDLs, for impaired stream reaches. TMDLs are a calculation of the maximum quantities of pollutants that a stream could assimilate without causing non-support for its designated uses. As a practical matter, not all impaired stream reaches may have TMDLs, because the measurement and calculation required for developing TMDLs is a lengthy and ongoing process. The last column in Table 4 indicates whether TMDLs exist for the stream reaches listed as impaired.
The purpose of a WRAS is to suggest ways to achieve the TMDLs – management practices, remedial strategies, or other activities that can reduce the amount of pollution (including excessive temperature) entering a stream. Table 8, on page 21, suggests practical ways to move in the direction of achieving TMDLs for the upper Pecos watershed.

Table 4. Impaired stream reaches for the Upper Pecos Watershed

Stream reach	Non-supported use	Causes	Sources of pollutants	TMDL Exceeded
Bull Creek, Cow Creek to headwaters	High quality cold water fishery	Temperature	Loss of riparian habitat Rangeland grazing Runoff following forest fire	Yes
Cow Creek, Bull Creek to headwaters	High quality cold water fishery	Temperature Turbidity	Road runoff Loss of riparian habitat Rangeland grazing Streambank destabilization Runoff following forest fire	Yes
Cow Creek, Pecos River to Bull Creek	High quality cold water fishery	Temperature Turbidity	Road runoff Loss of riparian habitat Rangeland grazing Streambank destabilization Runoff following forest fire	Yes
Glorieta Creek	High quality cold water fishery	Temperature Turbidity Ammonia Nitrate Dissolved O_2	Municipal point source discharge	No

		Conductance		
Pecos River (Alamitos Canyon to Willow Creek)	High quality cold water fishery	Turbidity	Aquaculture Road runoff Recreational use Mining reclamation Natural sources	Yes
Pecos River (Cañon de Manzanita to Alamitos Canyon)	High quality cold water fishery	Temperature Turbidity	Flow alterations from diversions Loss of riparian habitat Rangeland grazing Natural sources	Yes
Willow Creek, Pecos River to headwaters	Domestic water supply High quality cold water fishery Irrigation	Aquatic and sediment toxicity Sediment Conductance Cadmium Zinc	Habitat modification Road runoff Mine tailings Streambank destabilization Unknown sources	No

Turbidity

Where TMDLs have been developed, a numerical target has been established for the pollutant(s) causing the stream impairment. Stream reaches without formal TMDLs may still benefit from restoration work or improved management, but quantified goals have not been set. Table 5 presents calculations derived from the TMDL document for turbidity for our watershed: the pollutant load now affecting the stream reach, the maximum acceptable quantity of pollutant per day for the stream reach, and the reduction needed to achieve the TMDL, expressed a pounds per day, cubic yards per day, and cubic yards per year.

Table 5: Calculation of load reductions for turbidity

Stream reach	**Existing pollutant load (lbs/day)**	**Acceptable pollutant load (lbs/day)**	**Reduction needed (lbs/day)**	**Reduction needed (cu yds/day)**	**Reduction needed (cu yds/yr)**
Cow Creek (Pecos River to Bull Creek)	13,629	311	13,318	5.5	2027
Cow Creek (Bull Creek to headwaters)	14,232	795	13,437	5.6	2045
Pecos River (Alamitos Canyon to Willow Creek)	28,762	22,360	6,402	2.7	974
Pecos River (Cañon de Manzanita to Alamitos Canyon)	46,666	21,488	25,178	10.5	3832

A glance at Table 5 shows that the estimated quantity of eroded soil and bank material to be kept out of the Cow Creek system is nearly 27,000 pounds per day; and over 31,000 pounds per day needs to be kept out of the Pecos River, most of it below Alamitos Creek (below the village of

Pecos, but above the Cow Creek confluence). Soil, as a ball-park estimate, weighs more than a ton per cubic yard (sandy loam, one of our common soil types, weighs approximately 1,400 kilograms per cubic meter (Juma, 1999), which converts to 2,400 pounds per cubic yard). At 2,400 pounds per cubic yard, the fifth column in the table shows how many cubic yards per day of sediment needs to be kept from eroding into the river; and the last column on the right shows how many cubic yards per year must be kept in place to meet the TMDL goals.

It is difficult to predict the erosion that will be prevented by any particular bank restoration or other remedial action, but it may help to visualize the need: at present a large dump truck (27,000 lbs, thirteen and a half tons) worth of erosion every day enters the Cow Creek watershed and a bit more than that in the Pecos main stem. The reality of stream sediment transport is that the vast majority of erosion happens and is carried downstream during high flows, either during spring runoff or summer thunderstorms. It is during these times that streambank or other sediment needs to be kept in place. Perhaps it would be more accurate to visualize about 400 dump trucks worth of sediment to keep out of Cow Creek and about 500 out of the Pecos every spring and summer. It might be surprising how much sediment actually is removed from all the miles of streambank and enters the river each year in the Pecos watershed. Restoring native vegetation on river banks contributes to shading the stream and moving in the direction of achieving our temperature goals, as will be discussed shortly, in addition to reducing bank erosion and stream turbidity.

An important goal of monitoring in the Pecos watershed should be to better understand relative contributions to stream turbidity from different sources: erosion of the stream bank or bed itself; as compared with erosion from upland areas, carried down arroyos a considerable distance from the stream; or other sources. At present few data are available to shed any light on this question. Table 6 should be thought of as a planning tool to help evaluate the likely effects of streambank restoration in various stream reaches, with numbers to be entered and modified in the light of local knowledge and future observation, rather than as an accurate prediction at present. Nevertheless, it can help us visualize the order of magnitude of sediment than could be kept out of the river as a result of streambank restoration.

Table 6: Estimating stream bank erosion

Stream reach	**stream length**		**dimensions of eroding bank (ft)**			**annual**		**daily**
	total	eroding (%)	length	width	depth	volume of eroding soil (cu ft/yr)	volume of eroding soil (cu yds/yr)	mass of eroding soil (lbs/day)
Cow Creek (Pecos River to Bull Creek)	15.6	20	16,474	1	0.5	8,237	305	2,007
Cow Creek (Bull Creek to headwaters)	22.3	20	23,549	1	0.5	11,774	436	2,869
Pecos River (Alamitos Canyon to Willow Creek)	16.2	10	8,554	1.5	0.5	6,415	238	1,563

Pecos River (Cañon de Manzanita to Alamitos Canyon)	5.7	50	15,048	3	0.5	22,572	836	5,500

No doubt part of the turbidity problems in Cow Creek result from the fires in that part of the watershed, even though the initial huge pulse of ash and eroded sediment has moved through the system already. A study published in 1987 comparing soil erosion rates in the Colorado Front Range before and after forest fires found erosion rates during the first year after a fire increased three orders of magnitude (1000 times greater than before the fire), but declined rapidly in the months following. They were still about one order of magnitude (ten times greater) four years after the fire than they had been just before it (Morris and Moses, 1987). This scenario, if correct in our situation, would suggest that some of the turbidity issues in Cow Creek may gradually resolve themselves over time as the watershed continues to move closer to a pre-fire runoff equilibrium. Intentional restoration, however, may be able to accelerate the process considerably.

Soil erosion from upland areas, carried into the rivers down arroyos in thunderstorms, should not be overlooked as a way to reduce turbidity and save some of those tons of sediment – especially since the way to do this is to increase grass cover, which brings other attendant benefits. A study in Bandelier National Monument, published in 2003 (Hastings et al.) found that soil erosion rates had increased substantially in the Monument over time as piñon-juniper woodland (with little grass or other plant cover between trees) had replaced grassland or Ponderosa–grass savanna. In the study, some areas of piñon-juniper were thinned and grass re-established on formerly bare soil. Soil loss rates were measured in the piñon-juniper woodland before treatment and after establishment of better grass cover. Before treatment they varied between 2070 and 2990 kilograms per hectare per year (1844 to 2663 pounds per acre); after treatment they varied from 30 to 70 kilograms per hectare (27 to 62 pounds per acre). The reductions in soil loss from improved vegetation cover were on the order of 1800 to 2600 pounds per acre per year. To avoid eroding our desired 27,000 pounds per day in Cow Creek, we need to save 9,862,000 pounds per year. In order to achieve the same reductions in soil loss as in the Bandelier study, we could enhance the grass cover on 3800 to 5500 acres within the watershed. We could achieve our erosion reduction on about the same number of acres for the Pecos River below Alamitos Canyon by similarly enhancing grass cover.

The Alamitos to Willow Creek reach may not offer quite as much potential for avoiding upland erosion, even though the terrain is much steeper, because herbaceous ground cover is better in many places due to higher precipitation and soil moisture levels. The total amount of sediment that needs to be kept out of the river is smaller in this reach, and repairing damaged stream banks and preventing erosion from roads, trackways, and vehicle-damaged meadows may be able to achieve much of the desired reduction of 6,400 pounds per day, or about 1000 cubic yards per year.

Temperature

The other "pollutant" causing problems in our watershed is excessive temperature. Trout, in particular, cannot survive in water that is too warm, and four stream reaches are too warm, in places, in the summertime. The TMDL is presented in this case in terms of - don't panic – joules

per square meter per second. This is just a way of expressing the energy of sunshine, as it falls on a square meter of stream every second. The TMDL calculations also used a computer model to relate joules per square meter per second of solar energy falling on the stream to the predicted temperature of the water and to an estimate of how much shade over the stream is needed to keep the maximum temperature below 20º C (68º F). This is much easier to visualize. Table 7 summarizes these calculations, in simplified form.

Table 7: Temperature TMDL calculation results

Stream reach	**Existing conditions**		**Desired conditions**		**Increase in shade**
	Joules/m^2/sec	% total shade	Joules/m^2/sec	% total shade	
Bull Creek (Cow Creek to headwaters)	173.5	40	137.93	52	12%
Cow Creek (Pecos River to Bull Creek)	121.7	40	73.0	65	25%
Cow Creek (Bull Creek to headwaters)	156.0	30	138.4	38	8%
Pecos River (Cañon de Manzanita to Alamitos Canyon)	153.9	40	53.1	79	39%

It is not difficult to imagine increasing the shade along Cow Creek and Bull Creek by 8 to 25 percent: neither stream is terribly wide, so almost any 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 – 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.

RECOMMENDED ACTIONS AND IMPLEMENTATION SCHEDULE

The TMDL calculations presented in Tables 5, 6, and 7 provide numerical goals that will help substantially in achieving the desired uses in the Pecos River and Cow Creek. Outreach and education activities for both stakeholders and the recreating public should be a component of all suggested activities to improve water quality in the Upper Pecos Watershed. But what real-life, on-the-ground actions can we take to get there? Table 8 below makes some suggestions. It is, of course, only a starting point. Sampling and monitoring, as described below beginning on page 25, can help prioritize from among the potential projects. The timing and scope of restoration projects will be influenced by the availability of funding opportunities and volunteer effort. Once specific projects are selected, project details like budgets, timelines, and the people and organizations responsible for different kinds of work will have to be determined.

Table 8: Recommended actions

Location	Problem	Proposed Action
Bull Creek – Cow Creek to Headwaters	Temperature	• Revegetate stream banks for shading and erosion control. • Evaluate stream for possible alterations to reduce width, encourage meanders, pools, etc. if warranted.
Cow Creek – Bull Creek to Headwaters	Turbidity Temperature	• Improve grazing management and provide upland restoration to restore and improve grass cover. • Construct upland erosion control measures (head cut repair, check dams, etc); on private and government (mostly Forest Service) land. • Repair roads to reduce erosion (improved culverts, crossings, ditches, and road alignments). • Revegetate stream banks for shading and erosion control. Evaluate stream for possible alterations to reduce width, encourage meanders, pools, etc. if warranted
Cow Creek (Pecos River to Bull Creek)	Turbidity Temperature	• Improve grazing management and provide upland restoration to restore and improve grass cover. • Construct upland erosion control measures (head cut repair, check dams, etc); on private and government (mostly Forest Service) land. • Repair roads to reduce erosion (improved culverts, crossings, ditches, and road alignments). • Revegetate stream banks for shading and erosion control. • Evaluate stream for possible alterations to reduce width, encourage meanders, pools, etc. if warranted.
Pecos River (Alamitos Canyon to Willow Creek)	Turbidity	• Improve grazing management and provide upland restoration to restore and improve grass cover. • Construct upland erosion control measures (head cut repair, check dams, etc) on private and government (mostly Forest Service) land. • Repair roads to reduce erosion (improved culverts, crossings, ditches, and road alignments). • Revegetate stream banks for shading and erosion control. • Manage recreational use and off-road vehicle use better to prevent land and stream damage. • Repair damaged campgrounds. • Limit dispersed recreational use to locations and levels that don't degrade the watershed. • Provide additional facilities. (parking, toilets, trash removal) where needed to prevent damage. • Close/repair user-created roads and trackways where inappropriate.
Pecos River (Canon de Manzanita to Alamitos Canyon)	Turbidity Temperature	• Improve grazing management and provide upland restoration to restore and improve grass cover. • Construct upland erosion control measures (head cut repair, check dams, etc); on private and government (mostly Forest Service) land. • Repair roads to reduce erosion (improved culverts, crossings, ditches, and road alignments). • Revegetate stream banks for shading and erosion control. • Evaluate stream for possible alterations to reduce width, encourage meanders, pools, etc. if warranted.

WATERSHED AND RIVER RESTORATION PROJECTS

Terrero 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

The National Park Service implemented a small rehabilitation project in the Glorieta Creek floodplain about one fourth of a 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

The Truchas Chapter of Trout Unlimited has contributed to habitat improvement projects, Pecos River Clean-up, and native trout restoration programs.

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)

Figure 12: Stream bank restoration project in cooperation with Tierra y Montes Soil and Water Conservation District

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.

- **Dia del Rio Cleanup** – Organized by the Upper Pecos Watershed Association, October 14, 2006

- **Los Trigos Ranch** - Stream restoration projects by Bill Zeedyk and Bill Cowles

- **Forked Lightning Ranch**

- **Nature Conservancy Projects**

MONITORING AND EVALUATION

Existing Data

The principal sources of existing data about water quality and related parameters for the upper Pecos watershed are:

- Final Approved Total Maximum Daily Load (TMDL) for the Pecos Headwaters Watershed, New Mexico Environment Department, Surface Water Quality Bureau, June 2005.
- New Mexico Unified Watershed Assessment, 1998
- Landscape Scale Assessment, Pecos Headwaters Watershed, CEEM X, June 2004
- NMED Terrero remediation project reports and in-house data
- US Forest Service PFC sampling data
- Clean Water Act Integrated 303(d).305(b) List
- Various other studies are included in the watershed association's library files

Data Gaps

Data has been collected over some years regarding the water quality parameters discussed above – turbidity, temperature (as it affects fish), and some chemical contaminants. However, some significant questions remain unanswered. One of the principal things that is not well understood is from where turbidity in the Pecos River comes. It would help in planning restoration to have a better idea how much turbidity comes from erosion of the stream bank and bottom, how much from upland erosion (and when that erosion occurs), how much from road surfaces and embankments, and whether there are other sources too. It would also be advantageous to know if there are other problems for which we have not sampled so far, such as microbial contamination.

There are four principal situations where existing data about water quality in the upper Pecos watershed is inadequate. These are:

1. Establishing background levels of parameters (for instance, how much turbidity, or what level of microbiological presence, arises from purely natural causes and how much comes from human alteration of the watershed). Sampling within the Pecos Wilderness, or as a stream leaves the wilderness and enters land more impacted by human activities, may help to determine background values.

2. Sampling to determine more accurately the sources and timing of pollutants entering streams. For instance, more information is needed on whether turbidity comes from bank or bed erosion within stream channels, upland erosion and sediment carried into the stream, or other sources. We also need to have a better idea how much contamination enters the river with spring snowmelt runoff, how much with summer thunderstorms, and how much comes in other ways. One way to establish this would be to measure changes in stream quality above and below particular areas or activities (for example, sampling above and below a heavily used campground or an arroyo that may contribute substantial sediment when flowing), to determine more accurately what the effects these situations or activities may have.

3. Monitoring the effects of actions to improve water quality (such as measuring shade levels and temperature before and after revegetating a reach of streambank, or measuring turbidity before and after a bank revegetation or grass cover enhancement project). More systematic recording of restoration projects on private lands is also necessary.

4. Evaluating potential problems for which sampling has not yet been done (for example, there is no data about possible pharmaceutical residuals in effluent from the Pecos wastewater plant, or the extent of invasive trees like Russian olive or salt cedar in this area).

To help answer questions about any of these situations, and to help prioritize restoration efforts, many kinds of parameters could be sampled for. Some of the parameters most likely to be of interest include:

- Turbidity
- Temperature
- Changes to stream channel geomorphology
- Stream bottom characteristics
- Aquatic macroinvertebrates
- Flow rates and stream depth
- Shading
- Streamside vegetation characteristics
- Upland vegetation characteristics
- Soil erosion rates

- Recreational use levels
- Microbiological presence and activity
- Chemical constituents in water or soil
- Presence/abundance of sensitive species
- Presence/abundance of indicator species
- Location and extent of invasive vegetation (exotic trees, noxious weeds)
- Location of more serious soil erosion sites
- Weather and climatic data

Other parameters may well come to the attention of UPWA members as time goes on and greater familiarity with the watershed develops. This list should certainly be thought of as a starting point rather than an exhaustive or final catalog. We should also bear in mind that these monitoring parameters are parameters are of interest because of what they tell us about the health of the river, in terms of human uses and stream ecology, and we may occasionally need to step back and "look at the big picture" in terms of overall stream and riparian health.

Data collection

Data collection, in most cases, is not rocket science – it is a much more accessible kind of science, and it can be usefully done by almost anyone with a bit of training and access to expertise to answer questions. Pecos High School classes have already collected useful data, and many more opportunities exist for both elementary and secondary students to play a very helpful role in understanding (as well as restoring) our watershed. As an example, the Bosque Ecosystem Monitoring Project (BEMP) operates a very successful and respected network of student sampling sites along the Rio Grande from approximately Socorro to San Juan Pueblo, with all data collected by students ranging from fourth graders to high school classes. Volunteer samplers from the UPWA or other community members can also collect nearly any of the data that would be necessary or interesting in restoring or protecting our streams. Local colleges and universities (Santa Fe Community College, Highlands University, the University of New Mexico, or the College of Santa Fe, for example) may also be able to help, as a way of making useful experiences available to students. Certain kinds of information can best be collected or analyzed by scientific professionals (such as highly sensitive chemical sampling, or managing data to produce a GIS map of invasive trees in riparian areas based on many peoples' input).

PUBLIC OUTREACH AND EDUCATION

Many organizations, both public and private, and individuals have been identified as stakeholders in the Upper Pecos River Watershed. Tax records can be used to identify and approach individual landowners. In order to address the different needs and interests of a diverse group of stakeholders, many different approaches will be taken to contact, inform, and solicit participation from these stakeholders.

Public meetings will be held in the Village of Pecos. After formation of the "WRAS Steering Group" to function under the guidance of a Project Coordinator, meetings will be held on a

quasi-monthly basis. Development of a website to inform stakeholders and educate the public, mailing lists and media contacts will be developed.

There is a possibility of coordinating with several organizations for educational opportunities. General topics for watershed education include:

- Importance of Healthy Riparian Areas
- Water Quality Issues
- Soil Erosion Issues
- Low Impact Recreational Use
- Creation of a demonstration area for stream restoration techniques
- Creation of a demonstration area for upland soil erosion restoration techniques
- Coordinate a tour of existing Pecos watershed projects for interested parties

A need for more targeted education has been identified for the following issues:

- Water rights and building permit issues on irrigated lands and in the river floodplain
- Educational materials on the effects of illegal dumping into streams of the watershed
- Proper grazing management on riparian areas
- Small "How-to" project demonstrations to remediate excessive stream bank erosion
- ATV use in riparian zones
- Beaver habitat management and beavers as a keystone species
- Soil quality and soil erosion on uplands
- How septic tanks affect water quality

POTENTIAL PARTNERS AND FUNDING SOURCES

Potential funding sources

Clean Water Act section 319 grants
US Forest Service CFRP program
US Fish and Wildlife Service "Partners for Fish and Wildlife", "Landowner Incentive Program", and similar grant programs
NRCS/SWCD assistance
New Mexico Water Trust Board
New Mexico Association of Counties
N. M. State Forestry Division, fire protection programs
Special legislative appropriations
Foundation and nonprofit organization support
Private landowner contributions

Potential partner organizations

Village of Pecos
Tierra y Montes District (Soil and Water Conservation – NRCS)

United States Fish and Wildlife Service
Pecos National Historic Park
Santa Fe National Forest (Pecos Ranger District)
New Mexico Environment Department
N. M. Department of and Game and Fish
N. M. Energy, Minerals, and Natural Resources Department (especially Parks and Recreation Division and State Forestry Division)
La Gente del Rio Pecos – volunteer support
Truchas Chapter, Trout Unlimited – matching funds
Watershed Watch
University of Oklahoma Department of Environmental Engineering
Wilson and Co., consulting engineers (Albuquerque)
La Calandria Associates
Rocky Mountain Youth Corps
Pecos High School
Santa Fe Conservation Trust
Forest Guardians
Acequias
Audubon New Mexico
Animal Protection of New Mexico
National Park Service – Rivers, Trails, and Conservation Assistance Program
New Mexico Forest and Watershed Restoration Institute, N.M. Highlands University

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