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Water resources assessment of the Cimarron River and evaluation of water quality characteristics at the Maxwell National Wildlife Refuge

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Water Resources Assessment of the Cimarron River

and

Evaluation of Water Quality Characteristics at the

Maxwell National Wildlife Refuge

Final Report

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Abstract

During the second week of June 2010, the UNM Masters of Water Resources students, staff, and collaborators studied the Cimarron River watershed from its head waters above Eagle Nest Lake to its confluence with the Canadian River near Taylor Springs, NM, and the Maxwell National Wildlife Refuge (NWR) near Maxwell, NM. The investigation included measuring flows and water quality characteristics at 34 surface water sites in the two study areas. The main objectives of the study were to conduct a river assessment of the Cimarron River and evaluate water quality characteristics and playa lake sediment chemistry at the Maxwell NWR. It is expected that this report will serve as a basis for future research on the hydrology, water quality, and to a lesser extent, the socioeconomic characteristics of the river and its watershed and the Maxwell NWR. The report is divided into two sections, the first second describes the work done on the Cimarron River watershed and the second section describes work done at the Maxwell NWR.

The Cimarron River watershed drains 1,032 square miles and is located on the eastern slopes of the Sangre de Cristo Mountains in northeastern New Mexico, originating in mountains with elevations over 12,000 feet above sea level. The Cimarron River then flows eastward onto the eastern plains of New Mexico, draining into the successively larger Canadian and Arkansas Rivers, which ultimately flows into the Mississippi River.

The principal source of water supply in the watershed is surface water, and most is used for agricultural activities consisting of irrigation and livestock watering. Drinking water is supplied almost entirely by ground water except for the communities of Cimarron, Miami and Springer. Raton, located outside of the watershed, also supplements its drinking water supply with surface water from the Cimarron watershed

Six reaches of the Cimarron River and one reach of Rayado Creek were subjected to intensive evaluation using EPA’s Environmental Monitoring Assessment Program (EMAP) protocol. Data was collected and analyzed concerning the hydrology, geomorphology, riparian vegetation, human impacts, benthic macroinvertebrates, and water quality. In addition, flow measurements and water quality samples were taken at 24 other locations within the basin.

This assessment found generally high quality conditions of the river and riparian environment throughout the Cimarron River. This conclusion was supported by the type and diversity of benthic macroinvertebrates, by channel geomorphic criteria, and by water quality measurements. Electrical conductivity, an indirect measure of salinity, was found to increase as the river flows onto the eastern plains; the source was not identified. The water in the river is hard and is dominated by calcium, magnesium and sulfate ions. It is recognized that this assessment was done near the peak of spring runoff; it is likely that low flow conditions later in the summer will present environmental stresses to the system. Low but measurable concentrations of nitrates were found throughout the watershed with the highest concentrations occurring in samples collected near a residential area and golf course in Cieneguilla Creek near the town of Angel Fire.

Recommendations are included for further studies to quantify stream flows and diversions in the watershed to gain a better understanding of water use. Information is also needed on the

seasonal concentrations of chemical constituents in the river and its tributaries to understand the impact of development, especially that associated with non-residential vacation homes and potential development of coal bed methane.

The water quality in lakes and irrigation ditches at the Maxwell NWR was of generally high quality and dominated by calcium, magnesium and sulfate salts. Salt crust collected on the surface of a dry playa lake contained high concentrations of calcium, magnesium, sodium, and sulfate ions. Slightly elevated selenium concentrations were detected in sediment samples collected from a playa lake at the refuge. However, selenium concentrations in lake water and irrigation ditch samples were less than 1 μg/L.

Preface

Water Resources 573, Field Problems, is one of three core class taught in the Water Resources Program at the University of New Mexico (http://www.unm.edu/~wrp). WR573 is taught each summer with the purpose of introducing students to methods used in water resources investigations. Included in the instruction are: the use of field equipment to measure hydrologic parameters, field and laboratory analysis of water samples to determine water quality characteristics, and methods of collecting and interpreting information on water resources management and policy in a particular watershed.

The class of 2010 studied the Cimarron River watershed in Colfax County in northern New Mexico. The class was taught by Dr. Bruce Thomson (Director, Water Resources Program) and Dr. Abdul-Mehdi Ali (Senior Research Scientist, Analytical Chemistry Laboratory Manager for the Department of Earth & Planetary Sciences). Questions regarding this report should be directed to Dr. Thomson (bthomson@unm.edu).

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This study could not have been conducted without the assistance of many people. Leann Wilkins and Aaron Mize of the Maxwell National Wildlife Refuge provided valuable information on the hydrology and characteristics of the refuge as well as assistance in contacting others in the community for help with the project. Most importantly, they allowed the class to stay at the refuge and use its facilities.

Several individuals with the State of NM provided information relevant to the issues and administration of the water resources in the region including Heidi Henderson (NM Environment Department, Surface Water Quality Bureau), Eric Frey (NM Game and Fish), Chris Cudia (NM Environment Department), and Tim Farmer and Buster Chavez (NM Office of the State Engineer).

Julia Safford allowed access to the Cimarron River on the CS Cattle Ranch and provided input on water issues. Doug Palmer and Greg Holmes allowed access to the Philmont Scout Ranch and Vermejo Park Ranch respectively. Alán Huerta of the Cimarroncita Ranch allowed access to the river near Ute Park, NM, and spent most of a day with the class during which he provide a wealth of information and insight regarding history, issues, and challenges facing the river and its managers.

Joanne Hilton, a consultant to the Cimarron Watershed Alliance, was especially helpful by sharing her knowledge of water issues on the Cimarron River as well as her previous work on the upper Canadian River watershed.

Introduction

The primary objective of this study was to assess the quality and quantity of surface waters within the Cimarron River watershed and the quality of surface water within the Maxwell National Wildlife Refuge. These study sites were chosen in part because of an expressed need by area stakeholders for additional data regarding regional water quality. Furthermore, because surface water supplies over 95 percent of the water used in Colfax County (DBS&A 2003; Longworth et al. 2008), it is important to develop a comprehensive picture of the surface water resources in the basin. It is intended that this study will provide baseline information for future studies of water resources in the region.

The Cimarron River originates in the Sangre de Cristo Mountains of north-central New Mexico and drains approximately 1032 square miles as it flows to the Canadian River. In the 60 miles between Eagle Nest Lake and its confluence with the Canadian River, the Cimarron River flows through a subalpine landscape at higher elevations and shortgrass prairie further downstream. Study sites along the Cimarron River were chosen to reflect this diversity. In addition to the Cimarron River itself, this study examined several of the Cimarron's major tributaries, including Cieneguilla, Moreno, Sixmile, Ponil, and Rayado creeks. Water samples were also collected at Monte Verde Lake in Angel Fire and Eagle Nest Lake, as well as the Canadian River near its headwaters.

The Maxwell National Wildlife Refuge is located northeast of the Cimarron River watershed near the town of Maxwell, New Mexico. It encompasses approximately 3,700 acres and provides short grass prairie, woodland, wetland, and agricultural habitat for a diversity of migratory and resident birds, including ducks, geese, swans, sandhill cranes, birds of prey, and songbirds (Hoban 2005). Several lakes that are managed by the Vermejo Conservancy District and used for irrigation comprise the main sources of surface water to the Refuge.

Field work at both study locations was conducted by students and faculty of the University of New Mexico's Water Resources and Civil Engineering graduate programs during the week of June 7, 2010. Water quality samples were collected from various points in the Refuge and the Cimarron watershed, and in-depth stream assessments using Environmental Monitoring and Assessment Program (EMAP) protocol were conducted at seven locations in the Cimarron watershed. Water quality and EMAP assessment data were processed and analyzed at UNM during the week of June 14, 2010.

This report is divided into two sections. Section 1 describes the work done on the Cimarron River watershed while Section 2 describes the work done on the Maxwell National Wildlife Refuge.

Section 1 – Introduction to the Cimarron Watershed

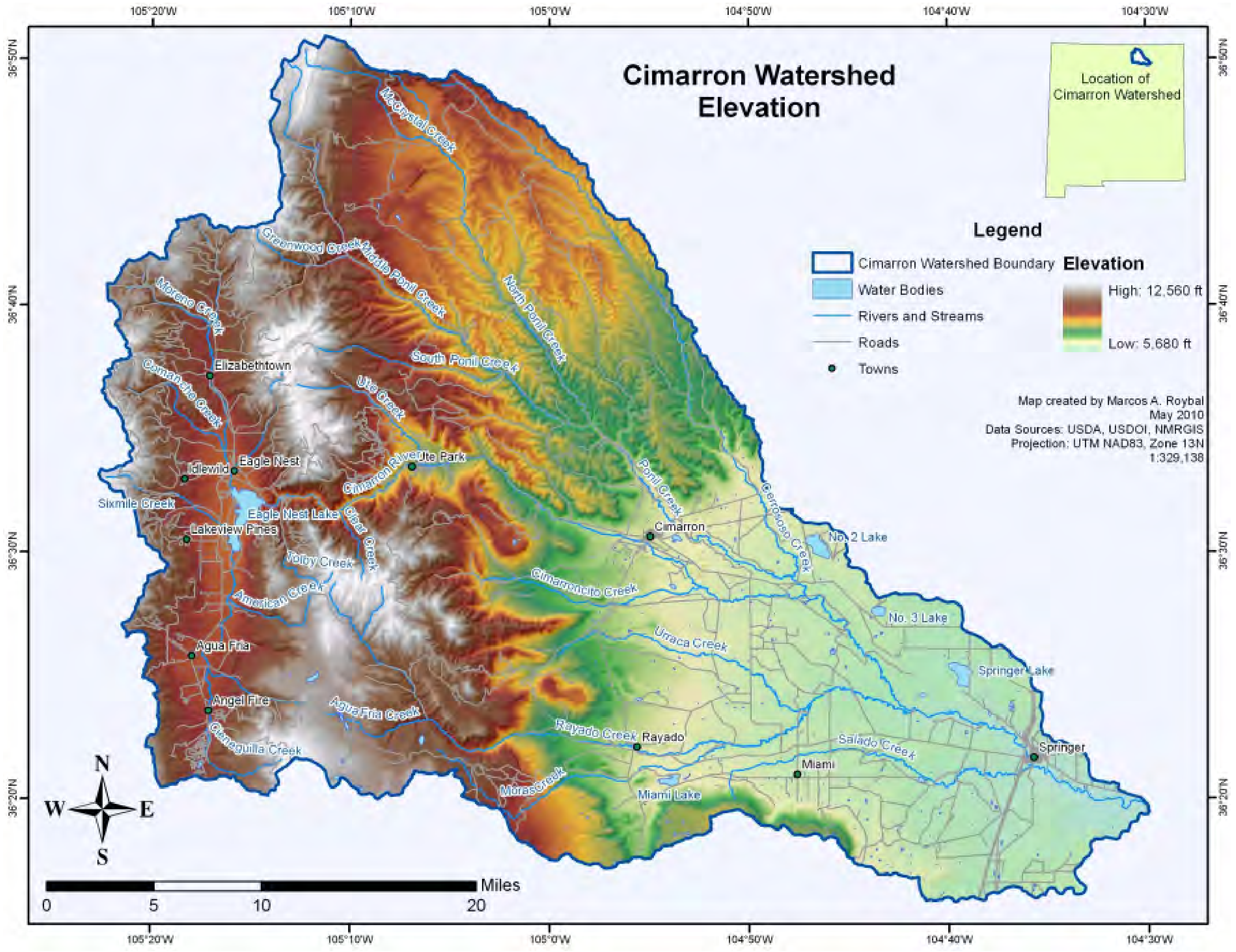
Physical Characteristics & Surface Hydrology of the Cimarron Watershed

The Cimarron River watershed is located in Colfax County in northeastern New Mexico. The watershed is approximately 1032 square miles in size and lies on the eastern slopes of the Sangre de Cristo Mountains. The Cimarron River is a part of the Arkansas/White/Red River Basin, which ultimately drains to the Mississippi River. Elevations in the watershed range from over 12,500 ft at its highest point to 5,680 ft at the Cimarron/Canadian River confluence (Figure 1).

The Cimarron River and its tributaries begin in the Sangre de Cristo Mountains, where three main tributaries (Cieneguilla, Sixmile, and Moreno creeks) converge at Eagle Nest Lake to form the Cimarron River. The Cimarron River then flows through Cimarron Canyon east through the towns of Cimarron and Springer. The major tributaries to the Canadian River below Eagle Nest Lake are the Vermejo River and Ponil and Rayado creeks. The Cimarron River then meets up with the Canadian River in the town of Springer (DBS&A 2003).

Of the numerous lakes and ponds in the Cimarron River watershed, Eagle Nest Lake is the largest with a surface area of 2200 acres and a total storage capacity of 79,120 acre-feet. The lake is located in the Moreno Valley and forms the headwaters of the Cimarron River (DBS&A 2003). The dam was constructed by area ranchers in 1918 for irrigation supply (eaglenestlake.org 2009), and is now operated by the state of New Mexico for irrigation, public water supply, and recreation (DBS&A 2003).

Surface water supplies over 95 percent of water used in Colfax County. However, surface water in the region is highly variable and dependent on precipitation. Surface water flows are also affected by irrigation demand and storage in numerous lakes and ponds, most notably Eagle Nest Lake (DBS&A 2003).



Cimarron Watershed Elevation

Map created by Marcos A. Roybal
May 2010
Data Sources: USDA, USDOI, NMRGIS
Projection: UTM NAD83, Zone 13N
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Figure 1. Elevations of the Cimarron Watershed.

Climate

The climate of the Cimarron watershed is characterized by high elevation alpine conditions in the Sangre de Cristo Mountains in the western portion of the basin and semiarid conditions in the high plains to the east. Temperatures in the watershed range from winter lows below 0°F in the mountains to summer highs of over 100°F on the plains (DBS&A 2003). Figure 2 displays average monthly temperatures for weather stations at Eagle Nest, Cimarron, Springer, and Maxwell.

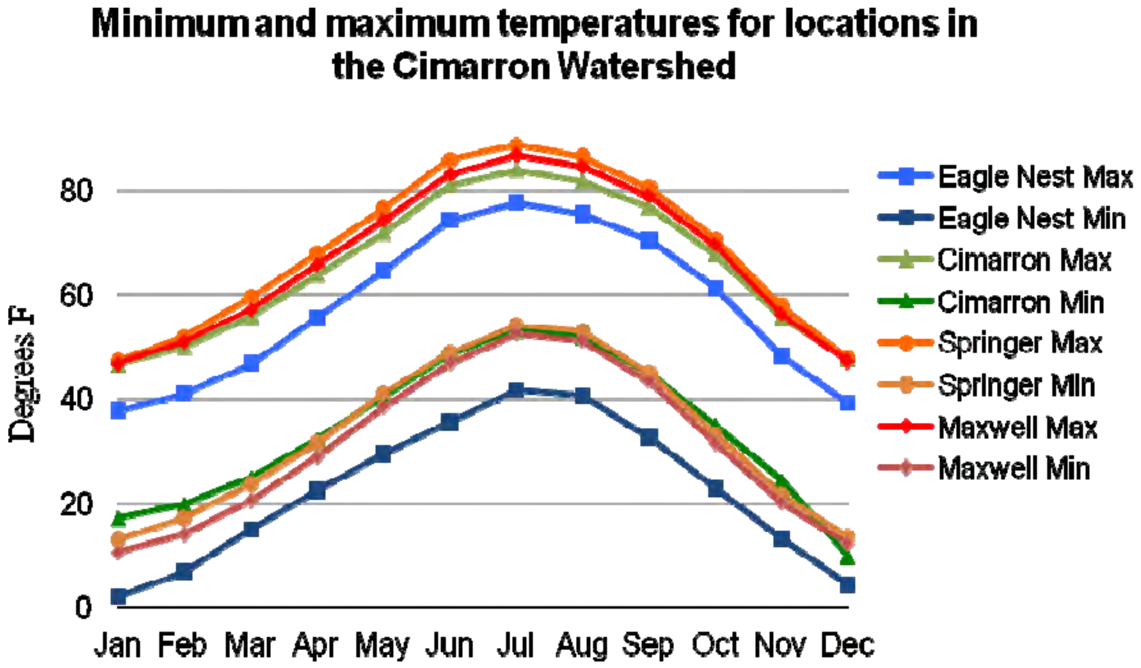


Figure 2. Average monthly temperatures for select locations in the Cimarron watershed (WRCC 2006)

Average precipitation in the watershed ranges from 17 to 31 inches annually and is generally positively correlated with elevation, with the exception of the Eagle Nest area (Figure 3). Most precipitation occurs during the summer months as a result of convective storms associated with monsoonal activity, but Arctic air masses from the plains and frontal systems from the Pacific supply winter moisture that falls primarily as snow (DBS&A 2003). As discussed below, most runoff in the Cimarron and nearby streams is the result of spring snow melt.

Maximum annual evaporation in the watershed ranges from 45 to 60 inches (Figure 4) The least evaporation occurs at higher elevations, and gradually increases with decreasing elevation to the east.

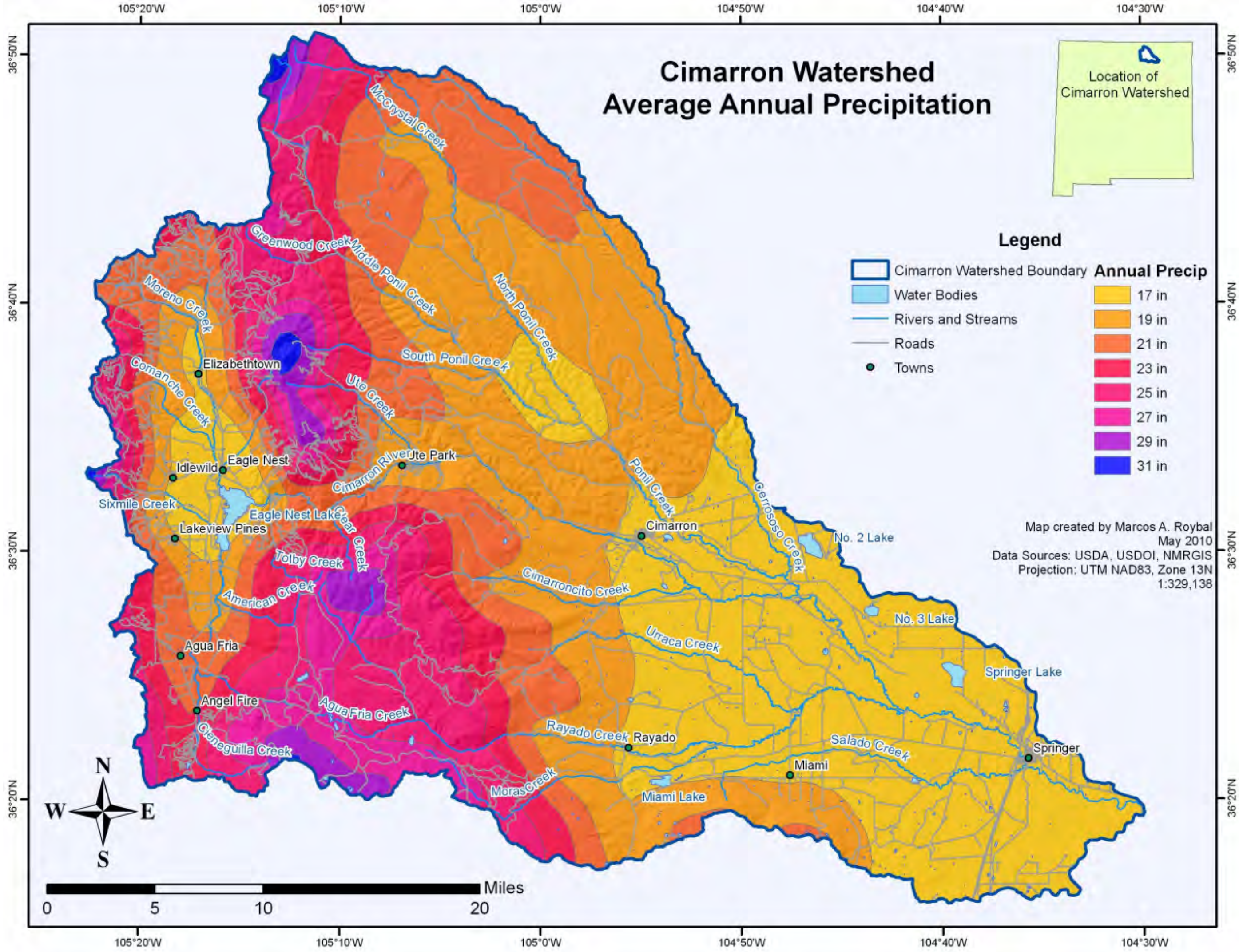


Figure 3. Distribution of average annual precipitation in the Cimarron Watershed.

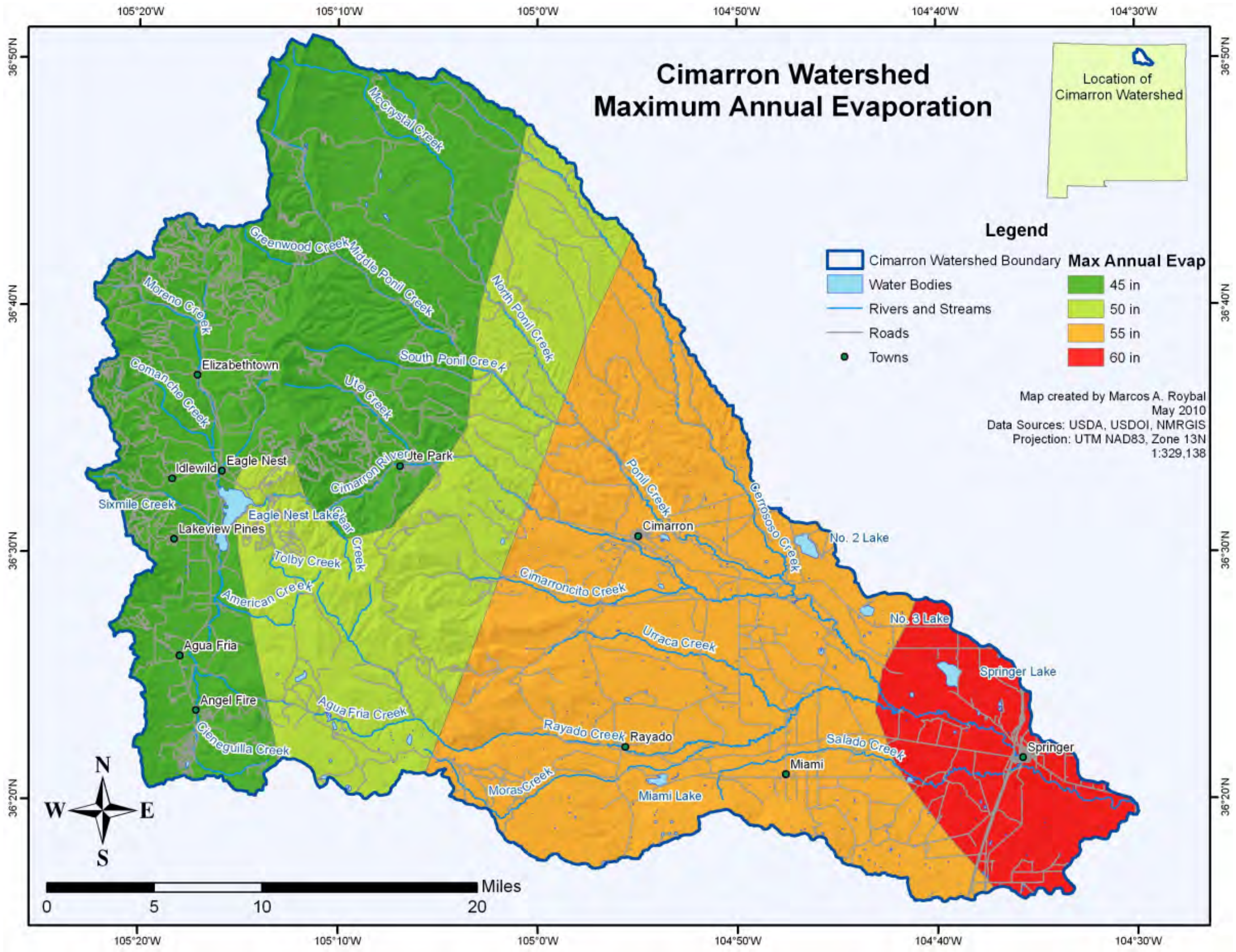


Figure 4. Distribution of maximum annual evaporation in the Cimarron Watershed.

Land Ownership

The majority of the Cimarron Watershed is privately owned and undeveloped. Private land consists of small parcels in and near the towns and villages as well as large tracts of land in the that are used for grazing and for the operation of the Philmont Scout Ranch. A portion of the Carson National Forest extends into the northern part of the watershed, and smaller parcels in the central and southern regions of the watershed are owned and operated by the Department of Game and Fish and the State of New Mexico (Figure 5).

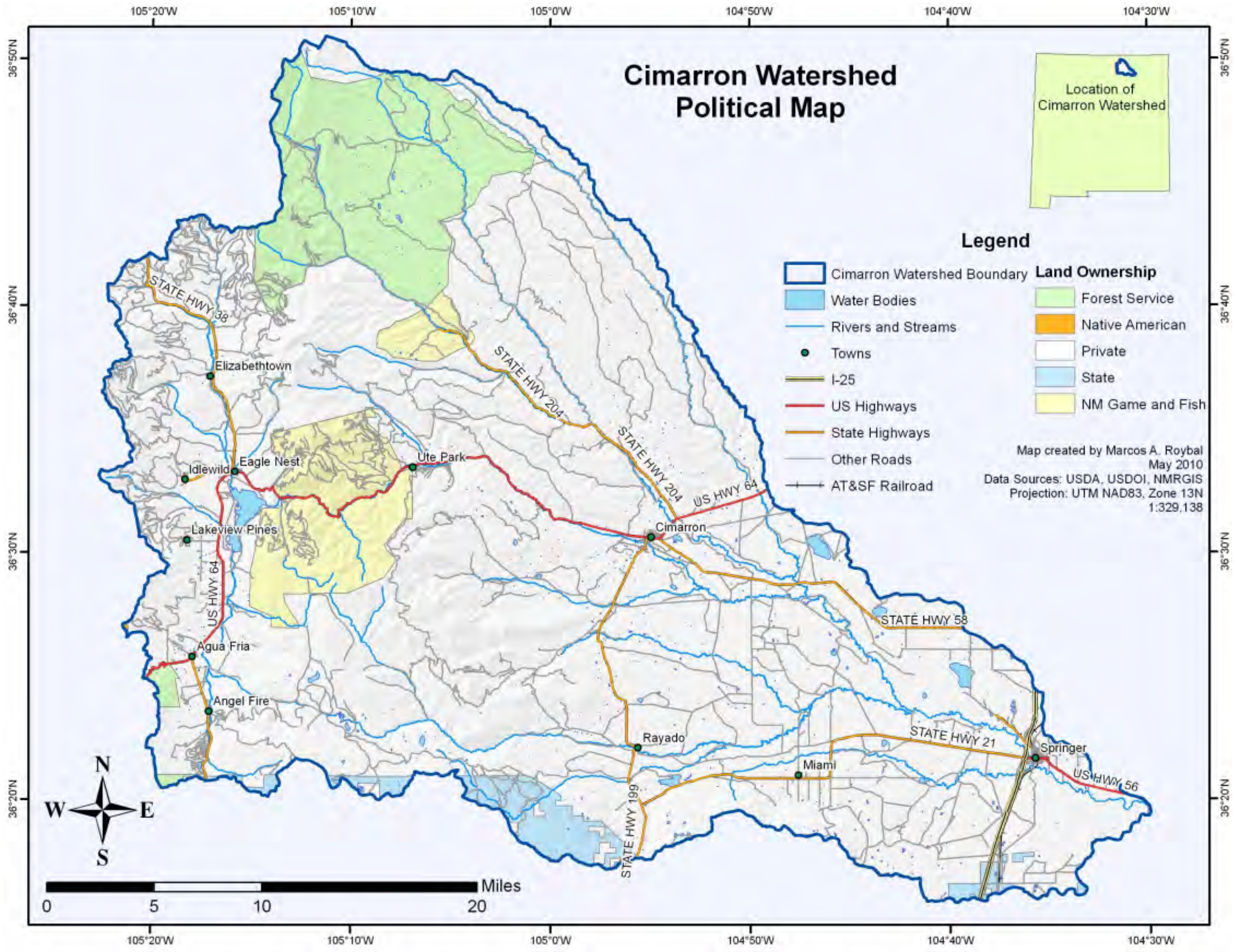
Vegetation

Vegetation distribution in the Cimarron River watershed (Figure 6) is largely determined by elevation. The western portion of the watershed is characterized by high mountain landscapes with subalpine and montane vegetation; this includes coniferous forests of Engelmann spruce (*Picea engelmannii*), ponderosa pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*) as well as deciduous aspen (*Populus tremuloides*) stands. The eastern portion of the watershed falls within the Great Plains Province and is distinguished by vast open areas of land dominated by grass and shrubs . Plains vegetation includes sagebrush (*Abutilon theophrasti*), annual and perennial grasses, and small trees such as piñon (*Pinus edulis*), juniper (*Juniperus monosperma*), and scrub oak (*Quercus berberidifolia*). Additionally, the watershed is bisected by numerous riparian corridors. Vegetation in riparian areas varies with elevation and land use, but is generally characterized by alder (*Alnus tenuifolia*), willow (*Salix* sp.), cottonwood (*Populus* sp.), and various herbaceous species (U.S. Forest Service 2009).

Geology and soils

Geology in the Cimarron watershed is diverse in age and type. The geology along the Cimarron River, Ponil Creek and Canadian River is primarily shale, limestone and sandstone formations dating from the Cretaceous to Quaternary periods. Additionally, a large portion of the Cimarron watershed consists of Pierre Shale and the Niobrara Formation in the southeastern part of the Cimarron watershed. The Niobrara Formation is limestone and shale including the Smoky Hill and Fort Hays Limestone Members (USGS n.d.). Finally, the western part of the watershed has lacustrine, playa, alluvial, colluviums, and landslide deposits (Geology and Soil Appendix NMRGIS n.d.).

A variety of soils are present in the Cimarron watershed. Soil types vary with slope, parent geology, and elevation (Geology and Soil Appendix). (NMRGIS n.d.)



Map created by Marcos A. Roybal
May 2010
Data Sources: USDA, USDOI, NMRGIS
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Figure 5. Land ownership in the Cimarron Watershed.

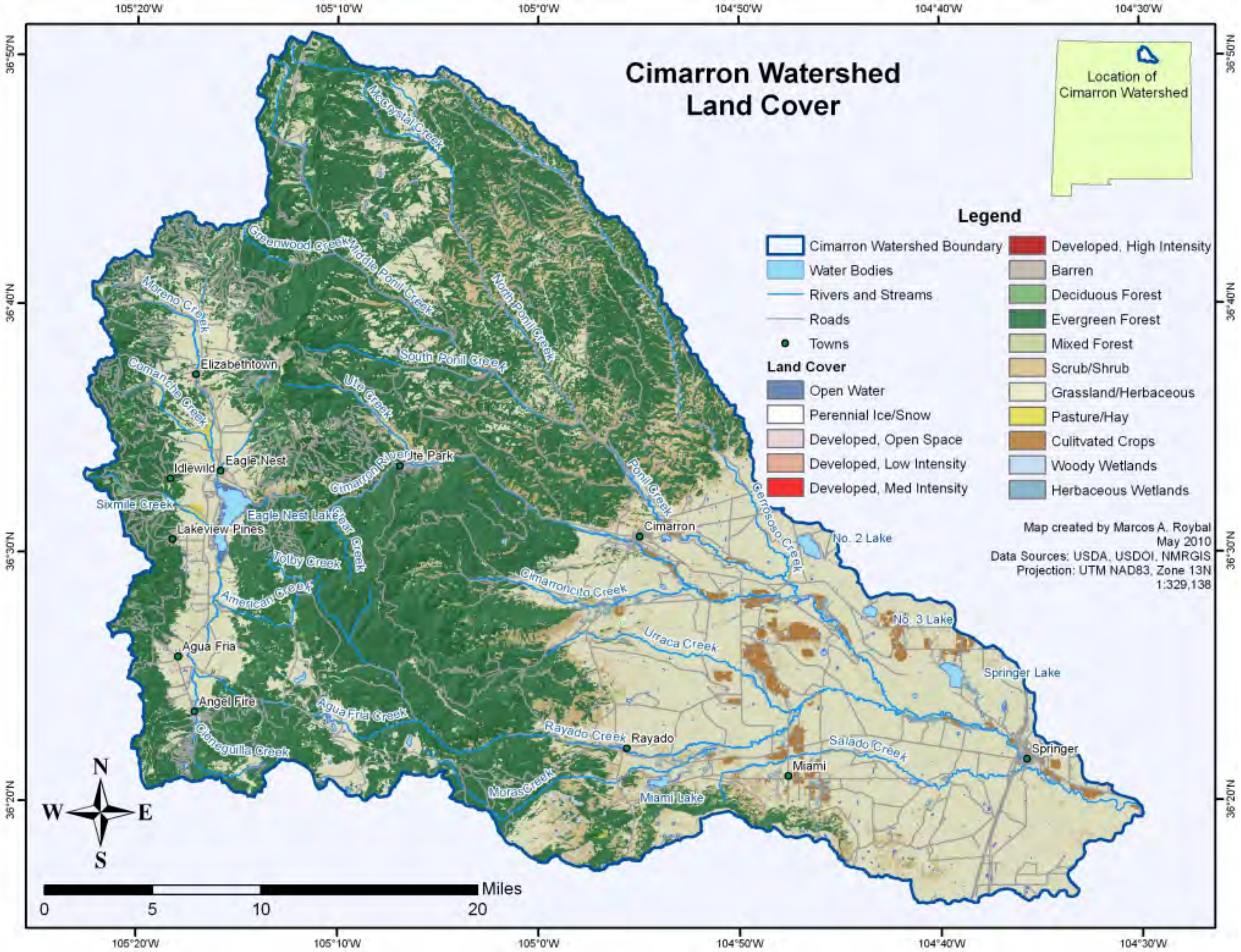


Figure 6. Land cover in the Cimarron Watershed.

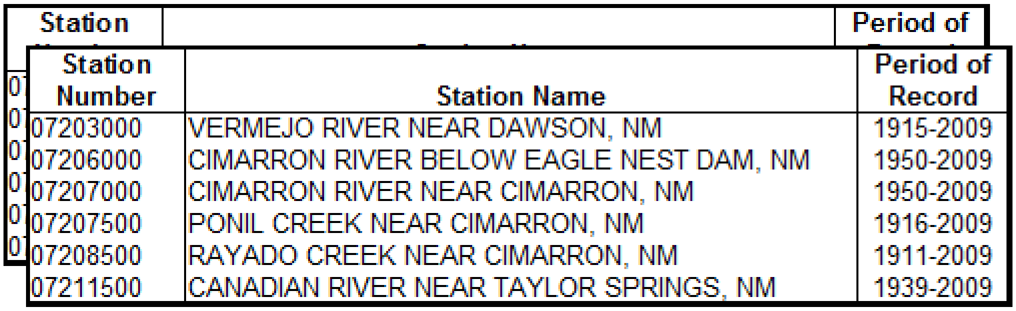
Hydrology

The Cimarron River basin, located in Colfax County, encompasses an area of 1023 square miles. Colfax County primarily relies on surface water as its source of supply with approximately 95% of water consumption being derived from surface water sources (DBS&A, 2003; Longworth et al. 2008). The largest water usage is for the irrigation of agriculture which accounted for around 80% of the water consumption between 1995 and 2000. The second largest water consumption is reservoir evaporation. This accounted for about 12% of the total between 1995 and 2000. Domestic supplies in the Cimarron River Basin are chiefly from ground water, except for the towns of Miami, Cimarron, and Springer, which utilize surface water sources. Additionally, the City of Raton, which is located outside of the watershed, supplements its drinking water supply with surface water from the Cimarron watershed.

Surface Water

Surface water in the Cimarron River basin consists of the Cimarron River and its tributaries. The principal tributaries are Ponil Creek and Rayado Creek. The Canadian River basin contains 39 ponds or reservoirs. Eagle Nest Lake is the largest with a total storage capacity of 79,120 acre-feet and it is located in the heart of the Cimarron River subbasin. The water quality section of this report includes a detailed description of Eagle Nest Lake. There are four USGS gages located within the Cimarron River subbasin. Two additional gages are included in this report due to their proximity to the Cimarron River subbasin. Table 1 provides a summary for these six USGS gages.

Table 1. Summary of USGS gaging stations in the Cimarron River basin and its vicinity.



Station Number	Station Name	Period of Record
07203000	VERMEJO RIVER NEAR DAWSON, NM	1915-2009
07206000	CIMARRON RIVER BELOW EAGLE NEST DAM, NM	1950-2009
07207000	CIMARRON RIVER NEAR CIMARRON, NM	1950-2009
07207500	PONIL CREEK NEAR CIMARRON, NM	1916-2009
07208500	RAYADO CREEK NEAR CIMARRON, NM	1911-2009
07211500	CANADIAN RIVER NEAR TAYLOR SPRINGS, NM	1939-2009

Figure 7 illustrates the average monthly streamflow for these six USGS gages. The peaks in May and August indicate that the Cimarron subbasin streamflow is largely influenced by snowmelt and monsoon activities. Figure 9 shows that the streamflow in the region from 2000-2003 was sustained at a low level, and Figure 9 further substantiates this observation because there is a measurable drop in precipitation in the region from 2000 though 2003. This produced the lower streamflows observed during that period. Another possible factor that may have contributed to reduced streamflows may be increased water diversions for agricultural use.

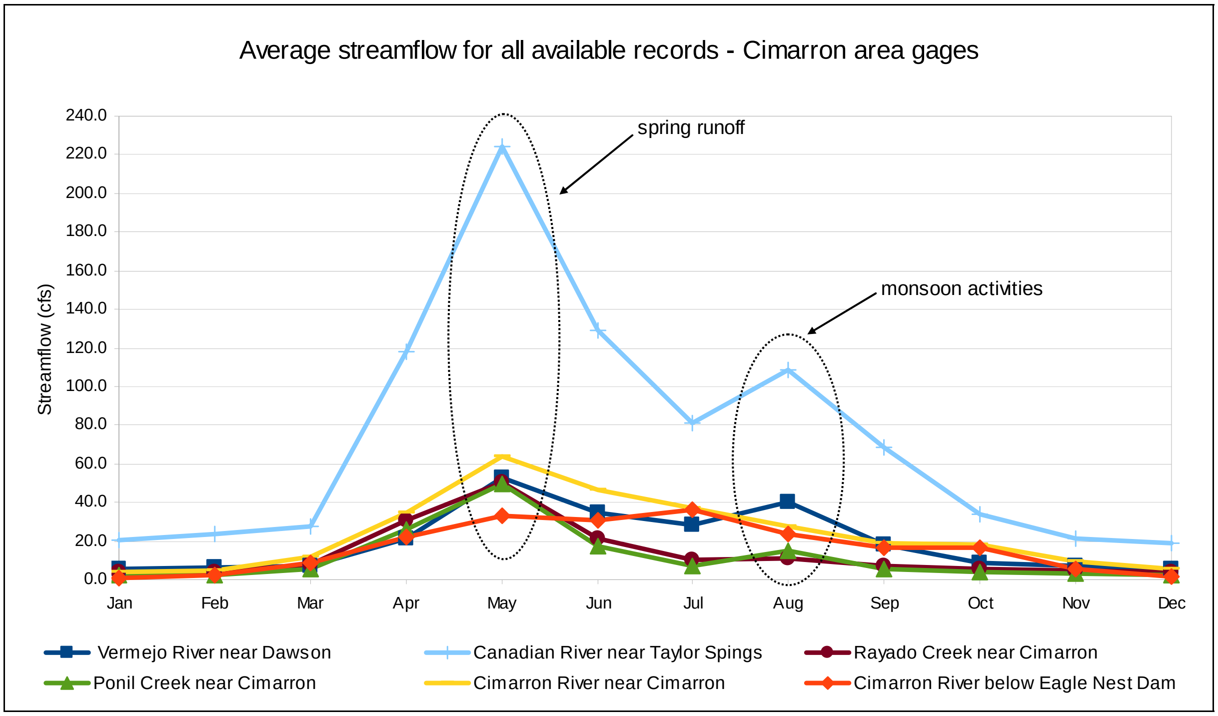


Figure 7. Average monthly streamflow for all available records (USGS, 2009)

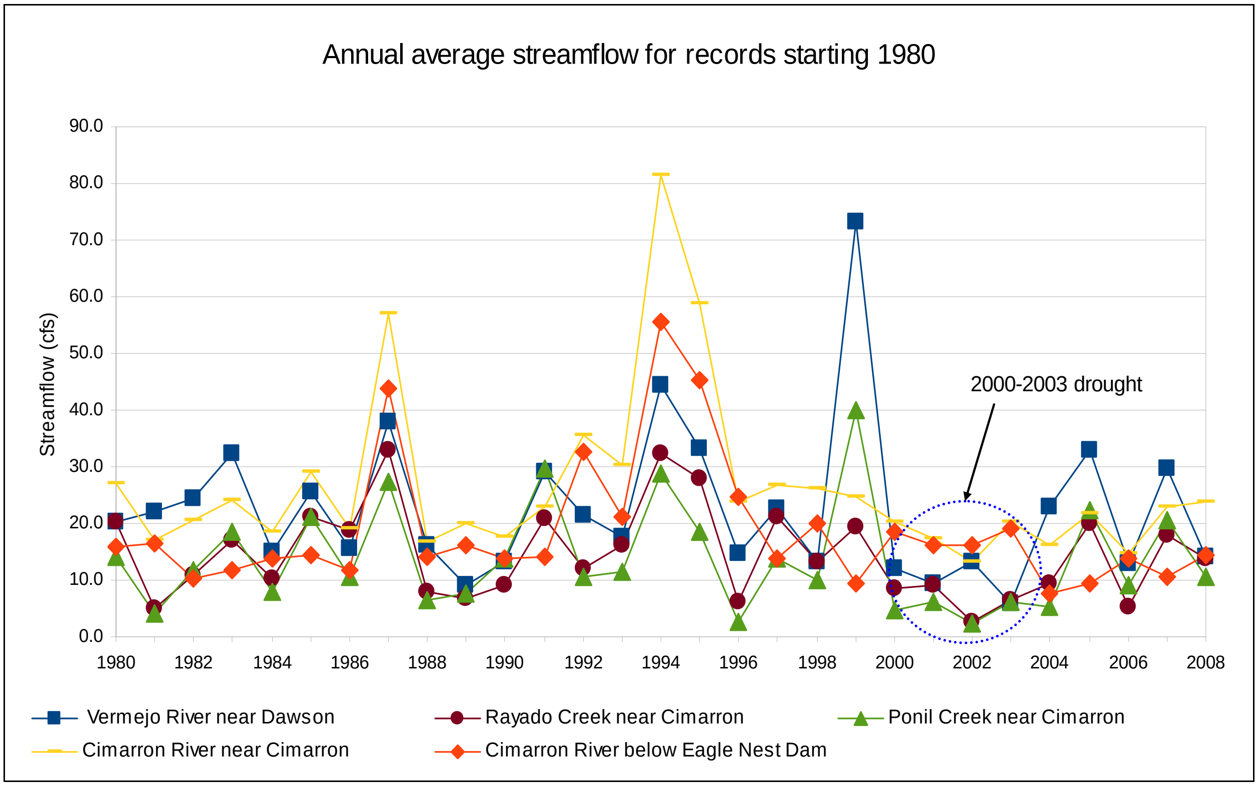


Figure 8. Average annual streamflow, starting 1980 (USGS, 2009)

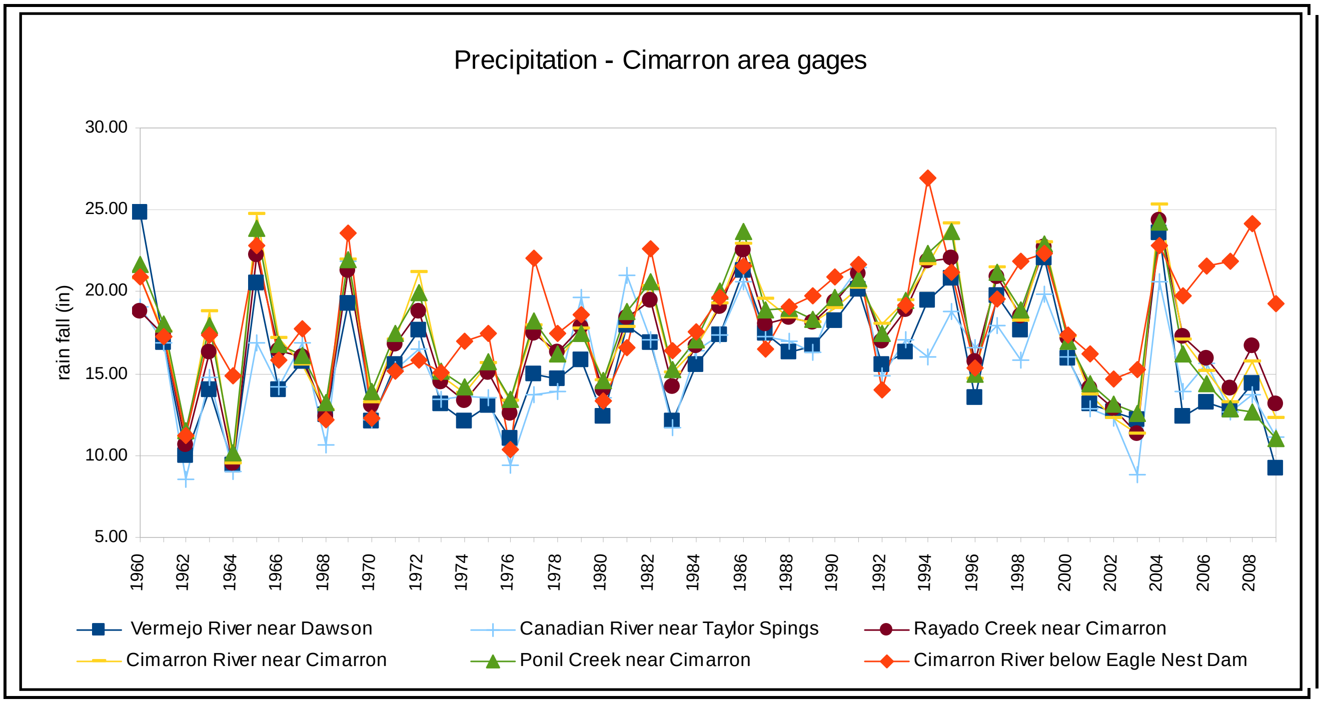


Figure 9. Precipitation, 1960-2009 (GIS at NACSE, 2009)

Ground Water

Though ground water pumping represents only about 5 percent of all water use in the county, its use in the region has consistently increased since 1975 (DBSA, 2003). Current literature contains limited information on groundwater throughout the watershed. Most of what is available is data from the Moreno Valley. Water-bearing zones in the Moreno Valley can be classified into four aquifers. The aquifers are: unconsolidated Tertiary valley fill, Tertiary dikes and sills, Mesozoic and Paleozoic sandstone and siltstone, and Precambrian crystalline rocks (Saye, 1990).

Major water withdrawals by users within the Cimarron watershed are represented in Table 2 and withdrawals in Colfax County are summarized in Table 3. Though ground water represents a small fraction of the total withdrawals in the basin and in the county, it is the sole source of water supply for all private domestic users and for all of the communities in the county except Cimarron, Miami, Springer, and Raton.
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Table 2. Water withdrawal by user in the Cimarron River watershed (Longworth et al. 2008)

Water User	Population	GW Withdrawal (AF/Yr)	SW Withdrawal (AF/Yr)
Angel Fire MHE	45	2.62	0
Angel Fire Services Corp	2200	552	0
Cimarron Water System	920	0	162.36
Eagle Nest Water & Sanitation Dist.	292	50.84	0
Miami WUA	150	0	20.73
Springer Water System	2000	0	200.61
Total	**5607**	**605.46**	**383.7**

Table 3. Total water withdrawals by category in Colfax County, NM (Longworth et al. 2008).

Category	Surface Water Withdrawals (AF/Yr)	Groundwater Withdrawals (AF/Yr)	Total Withdrawals (AF/Yr)
Commercial (self-supplied)	76	22	98
Domestic (self-supplied)	0	102	102
Industrial (self-supplied)	0	0	0
Irrigated Agriculture	52,505	1,921	54,426
Livestock (self-supplied)	282	308	590
Mining (self-supplied)	308	0	308
Power (self-supplied)	13	0	13
Public Water Supply	1,993	645	2,638
Reservoir Evaporation	6,827	0	6,827
County Total	**62,004**	**2,998**	**65,002**

Water Quality Issues

Water Quality Issues

Water quality criteria for streams, lakes and rivers in NM are established by the NM Water Quality Control Commission and contained in 20.6.4 NMAC. These uses form the basis for development of surface water quality criteria known as stream standards. Designated uses for Eagle Nest Lake include sourcing Domestic, Industrial, Municipal, Irrigation, and Livestock water from the lake, as well as High Quality Coldwater Aquatic Life, Wildlife Habitat, and Secondary Contact. The lake is fully supporting these all of these uses except for Domestic Water Supply and High Quality Coldwater Aquatic Life. Designated uses for Cieneguilla, Moreno, Ponil, Rayado, and Sixmile Creeks, and the Cimarron River above the town of Cimarron include domestic water supply, irrigation, high quality coldwater aquatic life, livestock watering, wildlife habitat, municipal and industrial water supply and secondary contact (NMAC 20.6.4.309). Below the town of Cimarron the designated uses are irrigation, warmwater aquatic life, livestock watering, wildlife habitat and secondary contact (NMAC 20.6.4.306).

Based on the 2010-2012 Integrated Report on the Assessed Surface Waters (NMED SWQB, April 13, 2010), there are seven impaired stream reaches in the Cimarron Watershed. This report was submitted by the New Mexico Water Quality Control Commission (WQCC) as part of EPA requirements that states report the quality of their surface waters and prepare Total Maximum Daily Load (TMDL) analyses for any impaired reaches. Here, the impaired reaches are Cieneguilla Creek, the Cimarron River from the Canadian River to Cimarron, Eagle Nest Lake, Moreno Creek, Ponil Creek, Rayado Creek, and Sixmile Creek. These reaches all fall in category 5/5A, which states a reach is impaired for 1 or more designated uses, and therefore, TMDL's have been scheduled for these reaches. The reaches were assessed based on a range of uses including Domestic Water Supply, Warmwater Aquatic Life, High Quality Coldwater Aquatic Life, Irrigation, Industrial Water Supply, Livestock, Municipal Water Use, Secondary Contact, and Wildlife Habitat.

The causes and sources of impairment are listed in Table 4. Sources of impairment in the watershed include rangeland grazing, loss of riparian habitat, subsurface mining, municipal point source discharge, animal feeding operations, livestock, and natural sources. The causes of impairment ranging from E. coli to nutrient/eutrophication to sedimentation make sense in the context of present and historical land uses in the region. These uses include livestock grazing, agriculture, tourism, and mining. The arsenic found in Eagle Nest Lake has been attributed to historic gold mines in the area (Huerta, personal communication, June 9, 2010).

Table 4. List of Impaired Surface Water Reaches in the Cimarron River watershed (2010 – 2012 State of New Mexico Clean Water Act 303(d)/305(b) Integrated Report, NMED SWQB, April 2010).

303(d)/305(b) List of Impaired Surface Water Reaches

Reach Name	Causes of Impairment	TMDL Schedule	Sources of Impairment
Cieneguilla Creek	E. Coli Nutrient Eutrophication Sedimentation/Siltation Temperature Turbidity	2010 2010 1999 2010 1999	Loss of Riparian Habitat Municipal Point Source Discharges (Eagle Nest) Recreational Pollution Sources (Eagle Nest Reservoir) Rangeland Grazing
Cimarron River	Nutrient/Eutrophication	2010	Flow Alterations from Water Diversions Impervious Surface/Parking Lot Runoff On-Site Septic Treatment Rangeland Grazing
Eagle Nest Lake	Arsenic Oxygen, Dissolved	2017 2017	Natural Sources On-Site Septic Treatment Rangeland Grazing Subsurface Mining
Moreno Creek	Nutrient/Eutrophication Temperature, water	2010 2010	On-Site Septic Treatment Rangeland Grazing Wastes from Pets
Ponil Creek	E. coli	2010	Avian Sources On-Site Septic Treatment Source Unknown Wastes from Pets
Rayado Creek	Nutrient/Eutrophication Sedimentation/Siltation	2010 2010	Dam Habitat Modification Highway/Road/Brdige Runoff Loss of Riparian Habitat Rangeland Grazing
Sixmile Creek	E. coli Nutrient/Eutrophication Temperature, water Turbidity	2010 2010 2010 1999	Animal Feeding Operations Habitat Modification Livestock Natural Sources Rangeland Grazing On-Site Septic Treatment

Point Sources of Pollution

There are three discharge permits in the Cimarron River basin that have been issued under the National Pollutant Discharge Elimination System were retrieved from the Surface Water Quality Bureau database (Table 5). The permits from the Angel Fire Wastewater Treatment Plant, the Village of Cimarron WWTP, and the town of Springer WWTP were surveyed to determine effluent flow and the receiving reach.

Non-point Sources of Pollution

Non-point sources of pollution into the watershed area include seepage from on-site wastewater treatment, surface runoff from roads and bridges, and recreation on Eagle Nest Lake.

Table 5. NPDES wastewater discharge permits in the Cimarron watershed.

NPDES Discharge Permits			
Permit No.	WWTP Municipality	Flow (MGD)	Receiving Reach
NM0030503	Angel Fire	0.5	Cieneguilla Creek
NM0031038	Cimarron	0.0083	French Lake/Cimarron River
NM0030295	Springer	0.3	Cimarron River

Watershed Restoration Projects

There are two nonprofit groups that have been active participants in Cimarron River watershed restoration activities. These are the Cimarron Watershed Alliance and the Quivira Coalition. There are various other groups who have played marginal or supporting roles. The Cimarron Watershed Alliance (CWA) was formed in 2004 in response to the findings of a watershed study done by the New Mexico Environment Department, which indicated potential water quality problems within some of the streams and rivers within the watershed, including high levels of aluminum, Total Suspended Solids (TSS), and fecal Coliform bacteria. The CWA's main goals are improving water quality and availability within the watershed and the restoration and maintenance of the watershed and its natural resources; the group consists of volunteers from Colfax County, New Mexico, including business owners, public officials, land owners, and the general public.

The CWA is guided by the Cimarron River Watershed Restoration Action Strategy (WRAS). Some of the actions identified in the WRAS include replanting riparian areas, improving wastewater management, and reducing biomass which fuels forest fires (Cimarron River Watershed Restoration Action Strategy/Watershed Implementation Plan, July 21, 2003). CWA funding comes primarily through grants from the Federal Clean Water Act Section 319 from the State of New Mexico Environment Department and donations from its members and from members of the community within the watershed.

The CWA (http://cimarronwatershed.org) is a volunteer-based 501(c)3 corporation that seeks to restore, maintain, and preserve the areas surface and groundwater quality. CWA projects are driven by the broad base of constituents represented. General areas of focus include riparian restoration, education, water quality monitoring, erosion control, forest restoration, and wastewater management monitoring. There are several restoration projects that the CWA has coordinated. The Sixmile/Cieneguillla Creak Stream Project targets the restoration of native riparian plant communities in order to control stream bank erosion thereby improving the turbidity in Cieneguilla and Sixmile creeks (Huerta, A.C., CWA 2007 Annual Report, 15).

Another project involves collecting samples from Cieneguilla and Moreno creek to provide data on the relationship between turbidity and fecal coli-form. Genome analysis has been conducted to determine the type of animal is contributing to the E. coli found in the creeks (ibid). This study was done to determine the source of the coliform bacteria. The study found that the majority of E. coli in Moreno and Cieneguilla Creeks were from native wildlife, including elk, deer, coyote, bear, rabbit, and avian sources (Table 6).

Table 6. Summary of sources of E. Coli in Moreno and Cieneguilla Creek (ibid, 20)

	Sources of E. Coli in the Moreno and Cieneguilla Creek (%)	
	Wildlife (avian, racoon, elk/deer, bear, rabbit)	Anthrophogenic (cattle, horse, dog, sewage)
Moreno	50.90%	39.10%
Cieneguilla	55.20%	28%

The CS Ranch Corral Road Relocation Project seeks to move the CS Ranch livestock and handling facility and associated holding areas away from the riparian zone of Cieneguilla Creek. The effort is to move these facilities to the Angel Fire area (ibid, 21).

The other major watershed group working in the region is the Quivira Coalition. The mission of this Santa Fe-based organization is “to build resilience by fostering ecological, economic and social health on western landscapes through education, collaboration, and progressive public and private land stewardship. Projects have occurred throughout much of New Mexico. They are currently undertaking a restoration project on Ponil Creek, which includes decreasing the creek temperature through restoration of riparian forests, stream bank stabilization and erosion control treatments, with a goal of having Ponil Creek removed from the 303(d) list of impaired waterways by 2011. While the Quivira Coalition heads the project, it is being implemented by the CWA in collaboration with Philmont Scout Ranch, three cattle ranches in the basin, the Village of Cimarron, New Mexico State Forestry Department, and New Mexico Department of Game and Fish (Quivira Coalition n.d.).

Irrigation Districts

Many areas of northern New Mexico use the acequia system to allocate water among users in the region. However, there are only a few acequias in the basin. Instead, irrigation districts manage and deliver water to users in the area. The major irrigation districts in the basin include: Antelope valley irrigation district, Vermejo Conservancy District, and the Springer Ditch Company.

Demographics and Economics

The 2000 Census listed the population for Colfax County as approximately 14,200 people. The population fluctuates seasonally largely due to the influx of tourists but the mining industry also contributes to this trend. Mines in the area experience times of high economic activity but as prices for the resource fall the mines will cease or drastically slow operations. This also contributes to the flux in local population.

Colfax County has been very proactive in planning for future development. Two scenarios have been evaluated; one that projects future population growth (to 2040) and the other projects no change in the growth rate (to 2040). The growth scenario, projects a more optimistic future with a slight population increase for the Cimarron River Watershed to year 2040. With respect to Water Resources planning, the Comprehensive Plan for Colfax County suggests that both scenarios be considered as they are both equally likely. (CBD&PI, 2004)

Economic activity in the Cimarron River watershed centers on natural resources and land use, including ranching and agriculture, along with tourism including, hunting, fishing and other outdoor recreational activities. Historically, mining and associated industries have been a significant source of regional economic stability, providing a number of high-paying jobs. However, intensive mining activities have reduced the amount of economically recoverable coal in the region by about the 1950s, the York Canyon Mine near Raton, the last productive coal mine in the county, closed in 2003.

Most of the workforce in Colfax County is employed by state, local, or federal government (26% of County's workforce). The next largest employer is the accommodations and food service industry (17% of county's workforce), followed by the retail (13% of workforce). In 1999 the average annual income for an individual in Colfax County was less than the average annual income for the State of New Mexico ($28,283), which was lower than the average annual income for the Country ($36,316). The rate of unemployment in the county went from 5% in 2002 to 7.3% in 2003, primarily due to the closing of the York Canyon Mine. (CBD&PI, 2004)

The majority of land in the watershed is privately owned. The tracts are generally large and primarily used for cattle grazing and beef production and provide little regional employment. Local, state and federal government jobs provide employment for one quarter of the population in Colfax County.

Water Law and Policy

Eagle Nest Lake and the surrounding land was originally owned by the C.S. Ranch, which applied for a permit in 1907 to build the dam. The dam, completed in 1918, was intended as a means of creating a reservoir to store Cimarron River water for power plants, mining, and irrigation. In 2002 The State of New Mexico purchased the reservoir from the C.S. Ranch, creating Eagle Nest State Park. While the State Park is a popular spot for a variety of recreational activities, the water in the lake still belongs to owners who obtained water rights years before (Eagle Nest Chamber of Commerce 2007).

Administration of water rights to Eagle Nest Lake is governed under Permit 71(DBS&A 2003) (obtained by the C.S. Cattle Ranch when the dam was constructed). Under Permit 71 there are three different types of contracts: first tier, which have a priority date of 1907; second tier, which have various priority dates (depending on when the contracts were signed); and storage contracts, which allow for rights holders to store certain quantities of water in the reservoir for specific amounts of time (DBS&A, 2003; see Table 7 and Table 8).

The people in/of the Cimarron River Watershed primarily use surface water for all of their needs. All of the surface water in the watershed has been fully appropriated (meaning there is no water that has not been previously claimed) and adjudicated (meaning that all of the water rights in the watershed have clearly established dates and specific amounts attached, which are recognized by the courts). The adjudication, finalized in 1932, determined that there was a total of 40,000 acre-feet of water rights for the Cimarron and its tributaries including the Rayado Creek, Cimarroncito Creek, Ponil Creek, various tributaries, and Eagles Nest Lake. The size of the allocation under this decree is 1.0 acre-foot per acre for irrigated pasture and 1.5 acre-feet per acre of irrigated land. (DBS&A, 2003).

In addition to the adjudicated water rights in the Cimarron River Watershed there are Federal and State Water Laws that must be taken into consideration with respect to waters of the Cimarron River. There are currently no endangered species in the area, thus the Federal Endangered Species Act does not currently affect water resources in the area, but must be kept in mind as the status of any of the different species of wildlife in the area could change over time. (DBS&A, 2003)

Please refer to the section on Water Quality for a more in-depth description of which reaches within the Cimarron River Watershed are on the 303(d)/305(b) list, and for what contaminants, in the section of this report on water quality.

Due to the importance of the quality of water various Federal and State government agencies have been created to monitor the quality of water resources in the United States. The Federal Clean Water Act (CWA), New Mexico Surface Water Quality Standards (passed under the CWA), and the Safe Drinking Water Act are the primary laws that regulate what is discharged into the water as well as the quality of the water. There are certain standards for a variety of contaminants that the State of New Mexico must meet, the water must be periodically tested and reports must be given to the United States Environmental Protection Agency (EPA). Waters that do not meet the State's standards are placed on the EPA's 303(d)list or 305(b) report, and flagged for poor water quality. After a water body has been deemed out of compliance, the state and local government must take action to clean up the water body as well as putting safe-guards in place to protect the users of that water.

Table 7. Permit 71 Water Contract Users (DBS&A, 2003)

Water Rights (Ac-ft)/yr	Agriculture	Municipal/Domestic	Coal
Tier 1	5,827	4,162	50
Tier 2	5	1,120	0

Table 8. Water storage contract holders for Eagle Nest Lake (DBS&A, 2003)

Contract Holder	Storage Amount (Ac-ft)/yr
City of Raton	15,000
Town of Springer	1,000
Village of Angel Fire	750
Robert S. Gordon, MD	6
Agua Fria Enterprises, Inc.	1,500
PICS Investment Company	45
Valley Mix, Ltd.	9
Agua Fria Enterprises, Inc.	3,750
Village of Eagle Nest	30

Natural Gas Development

Extensive development of coal bed methane (CBM) reserves is occurring in the Canadian River watershed. However, no evidence of CBM development in the Camarron watershed was noticed, nor was there any indication of this type of activity presented by land owners or residents of the basin. Although CBM development elsewhere is reported to produce wastewater that can contaminate receiving water, observation of CBM activities within the Vermejo Park Ranch did not show any evidence of wastewater production or impact to local streams.

Agriculture

Irrigated agriculture is the largest water use in Colfax County, the vast majority of which is supplied by surface water. In 2000, 48,400 acre-feet of surface water were withdrawn for irrigated agriculture. Of this, approximately 20,000 acre-feet were used consumptively (DBS&A 2003). Field observations indicated that much of the agriculture in the Cimarron River watershed consisted of irrigation for livestock pasturage.

Vegetation

Vegetation in the watershed ranges from grasslands to deciduous forest to coniferous forest, with a mix of obligate and facultative flora. The majority of deciduous trees were cottonwood, willow, alder, Russian olive and salt cedar. Conifers included bristlecone pine, limber pine, ponderosa pine, and junipers. Throughout the watershed there was a varied selection of shrubs, forbes and grasses, including apache plume, four wing saltbrush, horsetail rush, foxtail and cattail, scouring rush, silver sage, spike bentgrass, clover, various asters, iris, New Mexico sunflower, thistle, mint, wild roses, muhly grass, nodding onion, golden eye, Indian tea, globe mallow, and various penstemon. Depending on site characteristics, there were various degrees of bank stability, canopy cover and ground cover. Some bank characteristics were determined by human influences.

Study Methodology

The methodology used in this study was adapted from the Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) (EPA, 2003) as modified by the NMED SWQB (SWQB, 2007a). The EMAP protocol was abbreviated somewhat for this study due to time and, in some cases, limitations associated with availability of equipment and analytical support. Deviations from EMAP procedures are noted below. By using standard protocols, results of this study contribute to the limited data available about the Cimarron River system.

Seven primary sites on the Cimarron River were selected for EMAP evaluation. The seven sites represent the upper reach of the Cimarron River as near to Eagle Nest Lake as practicable and ending on the C.S. Ranch just below the confluence of the Cimarron River and Rayado Creek. Other locations within the watershed and nearby areas were chosen for flow and, in some cases, water quality characterization. These included other sites on the Cimarron River, its tributaries, two irrigation ditches and two sites on the Canadian River.

Characterization of water quality and sediment chemistry at the Maxwell Wildlife Refuge is described in Part II of this study.

Site Selection

Access to the groups EMAP sites was critical to our study. Land access was granted by the following land owners: Cimarroncita Ranch, Philmont Scout Ranch, and CS Ranch. In addition, sites with public access were used for flow measurement and sample collection.

The first EMAP site was located at the Tolby Day-Use area in Cimarron State Park just below Eagle Nest Lake on US Hwy 64. Selection of this site was based upon close proximity to Eagle Nest Dam and easy access to the Cimarron River.

The second and third sites were on the Cimarroncita Ranch in Ute Park, NM. Two complete EMAP evaluations were completed by the teams along with quality analysis of a tributary on the property. The ranch houses the Cimarron Conservation Camp (CCC) which uses the natural assets of the ranch as a living laboratory for conservation education dedicated to the promotion, development and dissemination of ecological education for and by teachers, and students of all academic levels (Huerta, 2010). For more information about the Cimarroncita Ranch and the CCC refer to Appendix II. The site was selected because of efforts by the landowner to promote the overall ecological health for the river and its surroundings. Also, recent research done by Sandia National Laboratories (Jepsen et al, 2009) provided baseline data for which comparison can be evaluated.

The fourth and fifth EMAP assessments were on the Philmont Scout Ranch. One was conducted on Rayado Creek approximately 2.5 miles west of Hwy 21 and the other was conducted on the Cimarron River at Turkey Creek Turnaround. The Rayado site was selected because of close proximity to the headwaters and the limited amount of human impact upon the creek. The Cimarron site was selected because of close upstream proximity to the Village of Cimarron.

The sixth and seventh final locations were on the CS Ranch southwest of the Village of Cimarron on Hwy 58. One evaluation was conducted on the Cimarron River where Miami Lane crosses the watercourse. The other was conducted on the Cimarron River just below its confluence with Rayado Creek. The Miami Lane site was selected because of its downstream location from the Village of Cimarron. The other site was selected because of the confluence of Rayado Creek with the Cimarron River.
Sampling sites are displayed in Figure 10 and Table 9 shows specific sampling procedures conducted at each site.

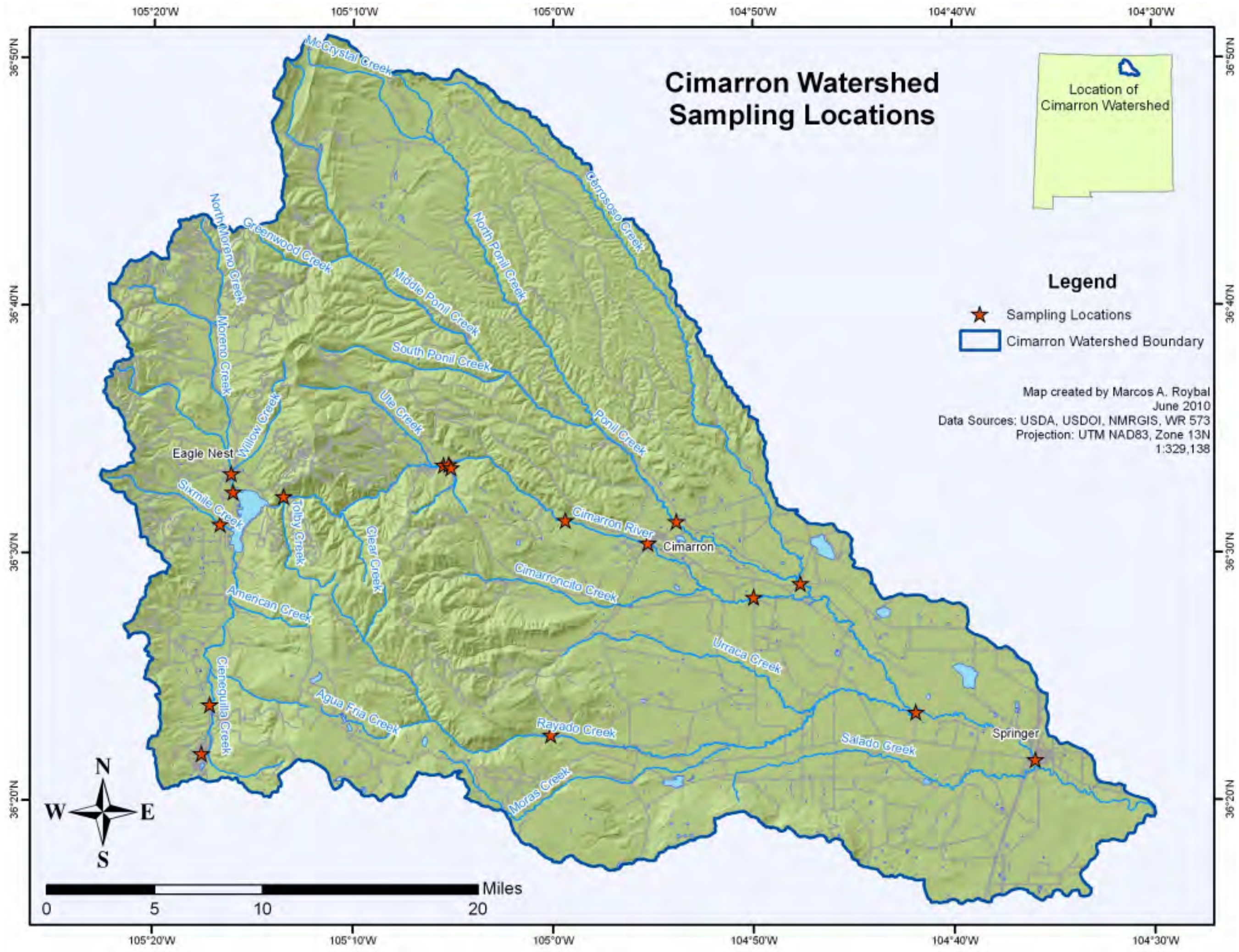

Figure 10. Location of sampling sites in the Cimarron River Watershed.

Table 9. Sampling locations and site procedures.

Site No.	Location	Site Name	Waterbody	Procedures	Dist. from Confluence at Taylor Springs (mi)
1	Maxwell Wildlife Refuge	Lake 13	Lake 13	Quality	out of watershed
2	Maxwell Wildlife Refuge	Lake 13 Inlet	Lake 13 Inlet	Quality	out of watershed
3	Maxwell Wildlife Refuge	Lake 12	Lake 12	Quality	out of watershed
4	Cimarroncita (Upstream)	Cimarron Boys Ranch N of Island	Cimarron River	Quality	55.2
5	Six Mile Creek	Six Mile Creek	Six Mile Creek	Quality, Profile, Flow	70.2
6	West Tributary to Cieneguilla	Cieneguilla (W. Tributary)	Tibutary to Cieneguilla Creek	Quality	82
7	Cieneguilla Downstream of Angel Fire	Cieneguilla Downstream of Angel Fire Village	Cieneguilla Creek	Quality	80.2
8	Cimarroncita (Upstream)	Cimarroncita Boys Ranch Corral	Cimarron River	EMAP	55.2
9	Eagle Nest Lake near Visitor Center	Eagle Nest Lake	Eagle Nest Lake	Quality	68.8
10	San Mateo and Country Club	San Mateo & Country Club Cieneguilla	Cieneguilla Creek	Quality, Profile, Flow	81.9
11	Moreno Creek	Moreno Creek @ Eagle Nest Lake	Moreno Creek	Quality, Profile, Flow	69.6
12	Tolby Day Use Area	Tolby Day Use Area	Cimarron River	EMAP	65.8
13	Moraine Way	Morain Way (Downstream of Culvert)	Tributary to Cieneguilla Creek	Quality,	82.9
14	Confluence at Moraine Way	Morain Way (Confluence)	Cieneguilla Creek below confluence with Tributary	Quality, Profile	82.9
15	Mountain View Blvd	Mountain View Culvert 2	Cieneguilla Creek	Quality	82
16	Lake View Park Rd	Lake View Park Rd.	Tributary to Cieneguilla	Quality	83.2
17	Monte Verde Lake	Monte Verde	Monte Verde Lake	Quality	83.5
18	Ponil Creek	Ponil Creek @ Bridge	Ponil Creek	Quality	29.1
19	Cimarroncita (Upstream)	Cimarroncita (1st upstream site of Island)	Cimarron River	Quality, Profile, Flow, Pebble Count, Benthics	55.2
20	Village of Cimarron Bridge	Village of Cimarron Bridge	Cimarron River	Quality, Profile, Flow	42.2
21	Snapper Creek	Un-named Ditch	Unnamed Creek	Quality	out of watershed
22	Cimarroncita (Downstream)	Cimarron River @ Cimarroncita	Cimarron River	EMAP	55
23	Cimarroncita (Behind Dance Hall)	Cimarron Tributary @ Cimarroncita	Cimarron Tributary	Quality	55
24	Springer Ditch (Near Vermejo)	Irrigation Ditch	Springer Irrigation Ditch	Quality	out of watershed
25	CS Ranch @ Confluence	Cimarron River Downstream Confluence @ CS Ranch	Cimarron River/Rayado Creek Confluence	EMAP	17.7
26	Ponil Creek @ Hwy 58	Ponil Creek @ CS Ranch	Ponil Creek	Quality	20.5
27	Miami Lane	CS Ranch @ Miami Lane	Cimarron River	EMAP	33.8
28	Philmont	Cimarron River Boy Scouts Ranch Site-1	Cimarron River	EMAP	47
29	CS Ranch @ Confluence	Rayado @ Confluence	Rayado Creek	Quality	17.7
30	CS Ranch @ Confluence	Cimarron @ Confluence	Cimarron River	Quality	17.7
31	Rayado at Philmont	Rayado Creek	Rayado Creek	EMAP	42.7
32	Vermejo N. Gate	Vermejo N. Gate (T Turner Ranch)	Canadian River	Quality, Profile, Flow	out of watershed
33	Dos Rios Ranch	Dos Rios Canadian River-Downstream of Confluence	Canadian River (Below Cimarron and Canadian Confluence)	Quality, Profile, Flow	out of watershed
34	Springer Bridge	Cimarron River @ Springer	Cimarron River	Quality, Profile, Flow	8.7
35	Maxwell Wildlife Refuge	Playa Lake	Playa Lake	Soil	out of watershed

Each site in the study was considered a “wadeable stream” using the EPA criteria: “the stream can be sampled with wadeable stream protocols, continuous water flow and greater than 50% of the sample reach is wadeable” (EPA, 2003). GPS coordinates and weather conditions, were recorded at each site to provide site description and document site conditions, and photographs were taken to document site characteristics. Measurements and site descriptions were recorded either on NMED SWQB data sheets or in field notebooks. Specific sites were chosen per EMAP protocol to be as much like a canal as possible using the following criteria (EMAP, 2003):

- segment of the river up/downstream is generally straight
- depths mostly greater than 15 centimeters and velocities mostly less than 0.15 meters per second
- flow is generally uniform with no obstructions, eddies, backwater or excessive turbulence
- a cross-section of the river bottom is U-shaped with a uniform streambed free of large debris (according the EMAP protocol, large rocks and debris may be removed *before* measurements, however, minor site adjustment up/down stream obviated the need to do this).

EMAP protocol for a full evaluation of a reach recommends selecting a baseline river transect and five upstream and downstream transect locations for a total of 11 transect evaluations. However, in this study only five transects were evaluated at each of the seven EMAP sites consisting of a central location, two transect stations upstream and two downstream. The stations were 100 feet apart so that a total of 400 feet of stream was evaluated at each site. An exception was made at Rayado Creek on the Philmont Ranch (location 31) where the stations were only 50 feet apart due to the rugged terrain and relatively small channel width.

The group was divided into two teams of 8 with each professor acting as a team leader. At each of the EMAP sites, the UNM teams divided into smaller teams to perform site evaluation tasks. These tasks were rotated at each primary site to ensure that each team member performed each task at least once. The primary team consisted of 16 UNM graduate students led by two UNM professors.

Hydrology

River discharge in all cases was measured using the EMAP velocity-area procedure. This involves measuring the cross-section of a stream and the flow of the stream to obtain the amount of discharge in the stream at any point in time. However, because the flow is not uniform across a channel, multiple measurements of depth and flow must be taken to provide a better estimate of total discharge. To accomplish this, a measuring tape was staked across each transect near the water surface perpendicular to the stream flow. The channel was divided into 10 to 20 equal segments with no interval less than 10 centimeters. Beginning at the left bank when facing downstream, the depth and flow at each interval was recorded. Depth was measured using a surveyor’s rod and velocity was measured using a Marsh-McBirney Flo-Mate Model 2000 electromagnetic flow meter suspended at 60% of stream depth. Data were entered into a spreadsheet which was used to calculate flows and plot channel profiles at each transect.

Geomorphology

Geomorphologic characteristics at each of the seven EMAP sites were recorded as described below.

- The thalweg depth (the deepest point in the stream's cross section) was measured every ten feet for entire reach of stream assessed (400 ft at all sites except Rayado Creek at the Philmont Ranch which was 200 ft in length) centered on the baseline transect using a surveyor's rod (Figure 11).
- At each transect, bank-full height and bank-full width (i.e., river height and width at a nominal two-year maximum flow) were identified and measured, as was the wetted-width (i.e., current width of river). Bank angle was recorded to the nearest degree, with undercut banks recorded as having a negative bank angle.
- River bottom composition was characterized by selecting locations at each bank and at 25%, 50% and 75% across each transect. The surveyor's rod was placed at each location and the underlying substrate was estimated by determining the size of the particle(s) directly beneath the rod and the fractional embeddedness of the particle using EMAP criteria.
-

Figure 11. Measurement of thalweg depth at EMAP site number 2, Cimarroncita Ranch

Benthic Macroinvertebrates

Aquatic invertebrates live in the bottom parts of our waters. Commonly referred to as benthic macroinvertebrates, they are good indicators of watershed health because they:

- live in the water for all or most of their life

- stay in areas suitable for their survival
- are easy to collect
- differ in their tolerance to amount and types of pollution
- are easy to identify in a laboratory
- often live for more than one year
- have limited mobility
- are integrators of environmental condition

Generally, the more taxa present in a stream the “healthier” the stream. Certain taxa are not tolerant of pollution. In the absence of excessive organic material, the waters have oxygen available for the benthic organism’s uptake. This use of certain taxa, as an "indicator" of water quality, has been occurring for many years. For example, stoneflies are often considered to be clean water benthos due to their intolerance of pollutants. Worms and midges may be present in pollutant free water, but indicator taxa such as may flies and stoneflies will not be present in waters of compromised quality. (USEPA, 2010).

At the baseline transect for each primary site a two-foot wide net was stretched across a representative riffle section of the river and firmly seated to the bottom. Immediately upstream of the net, a team member(s) kicked about the river bottom and disturbed/lifted rocks on the bottom to dislodge organisms clinging to the substrate. The net was quickly and cleanly lifted into the upstream flow and the contents deposited onto two collection trays. The net was rinsed with water from a bucket to dislodge organisms onto the trays. Organisms were then identified using the Taxonomic Key to Benthic Macroinvertebrates from the Hoosier Riverwatch website, sponsored by the Indiana Department of Resources Division of Fish and Wildlife. Organisms were then totaled by type and sorted as one of four Pollution Tolerant (PT) Index Groups as identified by Hoosier Riverwatch to create a Pollution Tolerance Index Rating (PTIR) (INGOV, 2010).

Water Chemistry

At the central transect for each EMAP site and at selected other sites, the pH, temperature, electro-conductivity (EC), and dissolved oxygen (DO) were measured, and water samples were collected for determination of alkalinity, metals and non-metal constituents as described below.

An Oakton pH/Con multi-probe meter was used to measure pH, temperature, and EC of river water samples. The probe was calibrated with a buffer solution of pH 7 every morning. A Yellow Springs Instruments (YSI) DO meter was used to measure DO in the river. The DO meter was calibrated at each site to correct for site elevation prior to measuring DO. Elevation at each site was determined using handheld GPS receivers.

Prior to any disturbance at a site a one liter sample of river water was collected in a clean plastic bottle which had been acid-washed and rinsed with 18MΏ (de-ionized) water. The sample bottles were rinsed with river water prior to collecting a sample. The bottles were completely filled to achieve zero headspace. Each evening the water samples collected that day were prepared for analysis for preservation. Two 125 ml portions of each sample were filtered through Whatman Qualitative Paper filter to remove suspended material and placed in plastic bottles.

Approximately 10 drops of HNO_3 were placed in one of the bottles to lower the pH to less than 2. Both bottles were then placed on ice for preservation. The acidified and filtered water was analyzed for the concentration of metals while the filtered water was analyzed for anions.

A third aliquot of each filtered sample collected during the day was used to measure alkalinity by acid titration using dilute, standardized sulfuric acid (0.02 N H_2SO_4). Two indicators, phenol phthalein and bromocrysol methylred (BC-MR), were used to test for carbonate and bicarbonate alkalinity respectively.

After completing the field work, all of the water samples were analyzed for metal and non-metal constituents in the Environmental Analysis Laboratory of the Department of Earth and Planetary Sciences at UNM. Metal concentrations were measured using an Optima 5300 Dual View (DV) inductively coupled plasma optical emission spectrophotometer (ICP OES). Anion concentrations were measured using a Dionex Ion Chromatograph (IC). All samples were analyzed using procedures listed in Standard Methods (APHA et al., 2005). Analysis of total nitrogen was performed by a persulfate digestion procedure which oxidizes organic nitrogen compounds and ammonia to nitrate. Nitrate was then determined by a chomotropic acid colorimetric procedure. Total Kjeldahl Nitrogen (TKN, which is the sum of ammonia and organic nitrogen compounds) was determined by subtracting nitrate concentrations measured by IC from the Total N concentration. The reporting limit was estimated at 0.2 mg/L measured as N.

Riparian Vegetation and Human Influence

Riparian vegetation and human influence throughout the Cimarron Watershed is highly variable. It is difficult to show vegetation and human influences at every site sampled because of the large number of sample sites and variations in stream size, precipitation, elevation and stream use throughout the sample areas. This section looks at regional vegetation and human influence characteristics of seven areas throughout the watershed. The seven areas were chosen based on number and proximity of sample sites. The watershed is divided up into areas near Eagle Nest, Angel Fire, Ute Park, Cimarron, Rayado, State Highway 58 and Springer. Common human influences also vary in the seven areas. Included in this section are the two lakes that we studied within the watershed were Monte Verde Lake and Eagle Nest Lake, and both had similar physical characteristics.

Measurements of the riparian vegetation density per EMAP procedures were not performed. However, visual inspection of the vegetation at each primary site was performed and recorded using the EMAP criteria for canopy, understory, and ground cover plants. Evidence of human influence on the river, beaver activity, presence of filamentous algae and other indications of river health were also recorded on the appropriate NMED SWQB assessment forms. Photographs were taken looking upstream and downstream at each site.

Human Influence

The degree of human influence at the sites varied. Some sites were virtually untouched by human influences, and some were heavily altered, especially in the form of grazing, dams, irrigated fields, culverts or campsites. Human influence in this report is considered alterations or intrusions on the waterbody itself, the riparian area, or areas immediately adjacent to the riparian area. Upstream influences are also taken into consideration on some test sites, mostly to explain water quality, stream bank or vegetative discrepancies that could be explained by grazing, roads, culverts or other upstream changes to the natural system.

Flow measurement and sample sites near Eagle Nest Lake included Six Mile Creek, Tolby Day Use Area, Monte Verde Lake and Moreno Creek. These exhibited a range of human influences, mostly in the form of alterations for tourism, camping, roads and fishing. There was not much grazing or irrigated lands in the area, and the riparian vegetation was largely intact despite the human influences on the area. The vegetation in this area was mostly mixed deciduous and coniferous forest, with multiple levels of understory, including shrubs wildflowers, forbes and grasses.

Flow measurement and sample sites near the town of Angel Fire, include sites along Cieneguilla Creek and it's tributaries. This area also included Monte Verde Lake. This area is more heavily impacted by human influences, with residential development, a golf course, roads and culverts cutting through the area. This area near Angle Fire is mostly coniferous forest, and grass lowlands.

Flow measurement and sample sites near Ute Park include Cimarroncita Ranch on the Cimarron River and its tributaries. There was mixed deciduous and coniferous forest, with open grasslands, wildflowers and some understory including native shrubs. Besides essential roads and a few homesites, this test area was mostly free of major human influences. This is in part due to Cimarroncita Ranch being privately owned.

Figure 12. EMAP site at Cimarroncita Ranch.

Near the village of Cimarron, flow measurement and water quality samples were collected at Ponil Creek, the City of Cimarron Bridge, Ponil Creek at the bridge and an unnamed creek. Both the Cimarron River running through the City of Cimarron and Ponil Creek at the bridge were heavily influenced by humans with bridges, fences, and grazing at the river. The unnamed creek was very influenced by grazing, with little vegetation along the banks, eroded banks, and heavy turbidity. Vegetation was mostly deciduous trees in the area, with grassland and a few shrubs.

Rayado Creek on the Philmont Boy Scout Ranch was very different from the confluence of Rayado Creek and the Cimarron River on the ranch, due in part to its location in the mountains. The creek at this EMAP site had the steepest gradient of any of the sites visited. Vegetation consisted of a coniferous forest with some deciduous trees, lush understory and many wildflowers. There were few grasslands, and the banks and riparian area had minimal impact from humans.

Figure 13. Photo of the Rayado Creek EMAP site on the Philmont Boy Scouts Ranch had little human influence and lush riparian growth.

The area near State Highway 58, includes test sites of Ponil Creek and the Cimarron River on the CS Ranch, on the county road identified as Miami Lane. This area was mostly deciduous forest and some grasslands away from the riparian area. The Miami Lane EMAP site had high banks covered in grasses, shrubs and deciduous forest. This test site was relatively untouched by humans, but the water was turbid and may have been affected by grazing upstream.

Near the town of Springer, there were three flow measurement and sampling sites, including the confluence of the Rayado Creek and Cimarron River on the Philmont Boy Scouts Ranch, the

Canadian River below the Cimarron and Canadian confluence, and the Cimarron River at Springer. The confluence of Rayado Creek and Cimarron River was influenced by grazing, which led to turbid waters, bank instability and little riparian vegetation. Extensive beaver activity was noted in some reaches of the lower Cimarron River and its tributaries.

Figure 14. Photo of the Miami Lane EMAP site on the Cimarron River.

Results

Hydrology

There were a total of 34 flow measurement and/or sampling stations visited with 30 of them being located within the Cimarron River subbasin. Table 7, summarizes the water quality and geomorphology data as well as any flow measurements that were taken. Sample sites that were located on the Cimarron River are highlighted in green, and any site where EMAP assessments were completed includes an asterisk. Field instruments were used to measure dissolved oxygen (DO), electrical conductivity (EC), pH, air and water temperature, elevation, latitude and longitude, flow velocity, depth, and width. However, due to a limited amount of equipment, all parameters could not be measured at each location.

Table 9 identifies the location of each site visited during this study, the procedures performed and the approximate distance upstream from the confluence of the Canadian and Cimarron Rivers at Taylor Springs, NM. The field measurements taken at each site are summarized in Table 10 which includes both hydraulic and geomorphic data as well as field measurements of water quality parameters. There were six EMAP assessments completed on the stretch of the river between Eagle Nest dam and its confluence with the Canadian, and one assessment done on Rayado Creek on the Philmont Scout Ranch covering a total stream distance of approximately 50 miles. In addition, flow and water quality samples were obtained from a location near the headwaters of the Cimarron River, down to its confluence with the Canadian River, west of Springer, New Mexico.

Table 10. Summary of field measurements at each sampling site.

Site No.	Site Name	Waterbody	pH	DO (mg/L)	EC (µS/cm)	TDS (mg/L)	Temp (°C) $_{water}$	Elev (ft)	Flow (cfs)	Rapid Assessment (0-200)	Avg. Depth (ft)	Width (ft)
1	Lake 13	Lake 13	8.59	12.3	630	320	23.3					
2	Lake 13 Inlet	Lake 13 outlet							2.76		1.10	3.83
5	Six Mile Creek	6 Mile Creek	8.20		210		19.4		3.92		0.46	3.75
6	Cieneguilla (W. Tributary)	Cieneguilla (W. Tributary)	8.47		431		19.9					
7	Cieneguilla Downstream of Angel Fire	Cieneguilla Creek	8.30	10.2	349		18.3					
8	Cimarroncita Boys Ranch Corral	Cimarron River	8.10		193	96	15.4		42.39		0.68	36.00
9	Eagle Nest Lake	Eagle Nest Lake	7.68		285	145	19.6					
10	San Mateo & Country Club	Cieneguilla Creek	8.30		225		15.4		0.82		0.24	2.83
11	Moreno Creek @ Eagle Nest Lake	Moreno Creek	8.23	10.6	329		22.0		5.77		1.03	3.83
12	Tolby Day Use Area	Cimarron River	8.82		252		17.1		15.89	$156_{(pool)}$, $174_{(riffle)}$	0.33	34.00
13	Morain Way (Downstream of Culvert)	Tributary to Cieneguilla	8.25			200	16.0					
14	Morain Way (Confluence)	Cieneguilla below confl. With tributary	7.63			100	14.4					
16	Lake View Park Rd.	Tributary to Cieneguilla	7.50			150	23.5					
17	Monte Verde	Monte Verde Lake	7.56			150	20.0					
18	Ponil Creek @ Bridge	Ponil Creek	8.29	7.0	123		23.7		16.13		1.18	15.50
20	Village of Cimarron Bridge	Cimarron River			221	112	21.0		28.36		0.77	30.00
21	Snapper Creek	Unnamed Creek	8.13	6.5	520		21.7					
22	Cimarron River @ Cimarroncita	Cimarron River			189	97	16.3		49.62		0.78	28.00
23	Cimarron Tributary @ Cimarroncita	Cimarron Tributary	8.23	6.8	321		23.7	7,200				
25		Cimarron River/Rayado Crk Confluence	8.20		500	250	26.4		11.24	$114_{(pool)}$	0.92	24.00
26	Ponil Creek @ Hwy 58	Ponil Creek	7.44	4.9	1,565		24.7					
27	Miami Lane @ CS Ranch -* EMAP site	Cimarron River	8.45		357		26.9		20.36	$138_{(pool)}$, $158_{(riffle)}$	0.71	18.00
28	Philmont- *EMAP site	Cimarron River	7.30		219	112	15.5		40.87	$190_{(riffle)}$	0.82	24.00
31	Rayado at Philmont - *EMAP site	Rayado Creek	8.29	9.2	115		15.4	7,058	21.97	$165_{(riffle)}$	0.81	18.00
32	Vermejo N. Gate	Canadian River	8.03	6.5	685		20.0					
33	Dos Rios Ranch	Canadian River	8.90		2,140	1080	25.6		3.45		0.43	40.00
34	Springer Bridge	Cimarron River	8.10		1,430	720	21.9		7.75		0.67	24.00

The EMAP protocol includes a Rapid Assessment evaluation which evaluates ten characteristics of the stream including the substrate, sediment deposition, channel alteration and sinuosity, bank stability, and vegetation (USEPA, 2003).

The Tolby Day Use Area EMAP area is located immediately downstream from Eagle Nest Dam, at an elevation of nearly 8000 ft and is located in a montane forest. The river bottom substrate consisted of sand, fine and course gravels, and a relatively large portion of cobble throughout the site. Substrate embededdness at the Tolby site generally ranged from 5% to 20%, though at one location, the rocks were embedded by up to 70% .On average the left bank angle was approximately 25 degrees from horizontal while the right bank angle was approximately 50 degrees from horizontal. However there were other reaches of the river where the banks were undercut and there was a negative bank angle. The negative bank angle provides valuable habitat for fish.

The Cimarroncita sample area is located near the headwaters approximately three miles above the community of Chacon at an elevation of around 7,200 ft and is also located in a mixed conifer forest. Two EMAP assessments were completed at this location, one where the river enters the ranch, and another further downstream. The river bottom substrate was a mixture of sand, fine and course gravels, and cobble. The bank angles were highly variable with a range from 10 degrees below horizontal to being undercut by six inches. An island about six feet wide currently exists at parts of both locations. The ranch owner commented on the recently improved health of the stream along with a strong fish population, and attributed these to some small measures that were taken. For instance grazing of cattle is no longer allowed along the banks (Huerta, 2010).

There were two EMAP sites at the CS Ranch. One was located near the eastern boundary of the ranch at Miami Lane, and the second was downstream at the confluence with Rayado Creek. Both sites were at an elevation of approximately 6,200 ft. and were located in a high plains region. The banks were significantly steeper, generally up to 75 or 80 degrees from horizontal on either side, and in some cases, even negative from horizontal, indicative of an undercut bank. The river bottom substrate consisted of primarily of silts and sands, with small deposits of fine and course gravels. Embededdness of gravel and cobbles in the river channel at the CS Ranch site generally ranged from 5% to 20%.

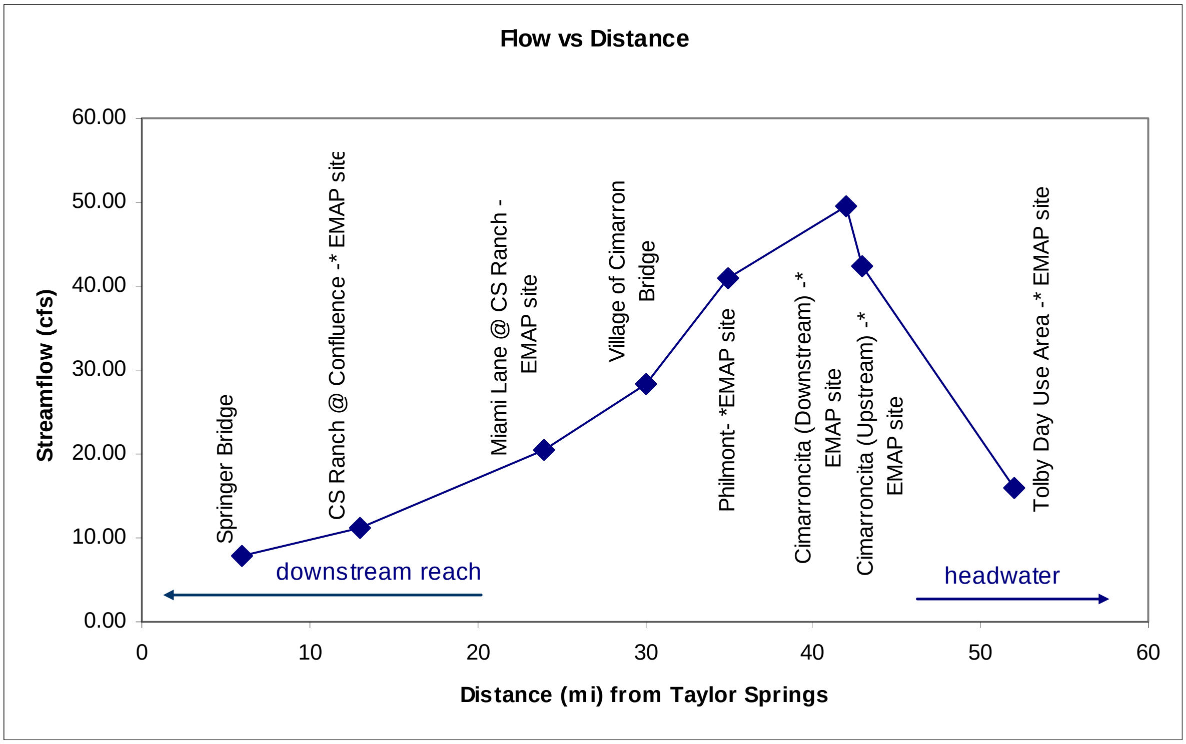

Figure 15. Flow data for the Cimarron River below Eagle Nest Dam.

The variation in Cimarron River flow for the EMAP sites and the river near its confluence with the Canadian River is shown in Figure 15. Beginning just downstream of Eagle Nest Dam, the measured flow in the Cimarron River was 16 cfs. Approximately ten miles downstream at the Cimarroncita sites near Ute Park, the flowrate was found to be between 42 and 50 cfs. EMAP assessments were completed at the upstream and downstream boundaries of the Cimarron River at Cimarroncita, and these provided flowrates that vary by 15%. The large increase in flow from the outflow of Eagle Nest Lake and Cimarroncito is believed to be due to the inflow of Ute Creek located upstream from the Cimarroncito site, along with a few smaller tributaries. No flow measurements were made on these tributaries.

Flow downstream from the Cimarroncita Ranch decreased due principally to diversions for agricultural use. The farthest downstream site was located at Highway 21 bridge in Springer, where a flowrate of 7.75 cfs was recorded. This represents a decrease in flow of around 85% from the flows at the Cimarroncita Ranch. According to the Colfax County Regional Water Plan, an average of approximately 33,500 acre-feet of water are withdrawn from the Cimarron River each year for irrigation though withdrawals vary considerably from year to year (DBS&A, 2003).

It was reported by a Conservation Officer with NM Game and Fish (Frey, 2010) that the lowest flow levels in the Cimarron River occur in the fall as the river leaves the CS Ranch. Flows of one to five cfs are believed to occur regularly in this reach. The very low flows are believed to be due to diversion to an irrigation ditch downstream from the CS Ranch by the Springer Ditch Company. This water is used to fill their lake each fall, thereby using all of their water rights. It is suspected that flows in the Cimarron River below this diversion consist mainly of exfiltration from shallow groundwater formations through seep springs along the river channel. The dramatic increase in electrical conductivity in the lowest reaches of the river suggest that some of this seepage might be irrigation water that has infiltrated through shallow soils and migrated horizontally to the river.

Flow Measurements & Channel Characteristics

EMAP procedures require measurements of flow and geomorphic characteristics of multiple transects at each site. Duplicate measurements of flow permit estimation of the accuracy of the measurements. The stream flow and width measurements are shown in Table 11. Measurements of flow and channel width at three EMAP sites on the Cimarron River.. The relative standard deviations of the flow measurements (standard deviation divided by average flow) range from .09 to 0.21. At the Tolby Day Use Area site, the relatively large standard deviation to average stream flow ratio is probably caused by its highly irregular channel width, an island at one transect, the presence of large woody debris (downed logs) in the channel, and because it was the first EMAP site visited by the team. Its bed materials consist of boulders and gravels, making velocity highly variable from one spot to another. On the other hand, the Cimarroncita Ranch site has a smaller relative standard deviation of stream flow. This particular reach has relatively uniform width which facilitated accurate flow measurements.

Table 11. Measurements of flow and channel width at three EMAP sites on the Cimarron River.

Location	**Flow (cfs)**	**Width (ft)**	**Distance from Confluence (mi)**
Upper EMAP Site - Tolby Day Use Area			
Transect 1	17.7	20	65.8
Transect 2	14.2	40	65.8
Transect 3	20.0	34	65.8
Transect 4	16.3	26	65.8
Transect 5	11.2	24	65.8
Average	**15.9**	**28.8**	
Std. Dev.	**3.4**	**8.1**	
Rel. Std. Dev.	**0.21**	**0.28**	
Middle EMAP Site - Cimarroncita (downstream)			
Transect 1	38.9	26	55
Transect 2	38.6	24	55
Transect 3	45.1	24	55
Average	**40.9**	**24.7**	
Std. Dev.	**3.7**	**1.2**	
Rel. Std. Dev.	**0.09**	**0.05**	
Lower EMAP Site - Miami Lane			
Transect 1	18.5	14	33.8
Transect 2	17.1	16	33.8
Transect 3	24.3	18	33.8
Transect 4	21.6	11	33.8
Transect 5	23.4	11	33.8
Average	**21.0**	**14.0**	
Std. Dev.	**3.1**	**3.1**	
Rel. Std. Dev.	**0.15**	**0.22**	`
Rayado Creek at Philmont EMAP Site			
Transect 1	20.3	18	
Transect 2	19.6	8	
Transect 3	26.2	10	
Transect 4	24.6	15	
Transect 5	23.5	12	
Average	**22.8**	**12.6**	
Std. Dev.	**2.8**	**4.0**	
Rel. Std. Dev.	**0.12**	**0.32**	

Thalweg profiles were measured at each EMAP site. Figure 16 through Figure 18 illustrate the thalweg depth profiles for three EMAP sites on the Cimarron River. The thalweg depth profile at the Tolby Day Use Area shows a mixture of deep pools and shallow riffles. The profile at the Cimarroncita Ranch Downstream site is a bit more uniform, though it does show the clear presence of riffle and glide areas. Note that the average depth is greater than at either of the other two sites which is consistent with the occurrence of the highest flow as shown in Figure 15. These two sites have coarse bed materials such as gravel and boulder, promoting quick transition of different channel features such as riffles and pools. In contrast, the EMAP site on the

Cimarron River at Miami Lane at CS Ranch shows the least variation in depth and has the most homogenous bed materials, mainly silt and clay. With these fine sediments, transition of different channel features would be sparser. Overall, all three sites have a good variation of thalweg depth that provide potential habitat for different aquatic organisms.

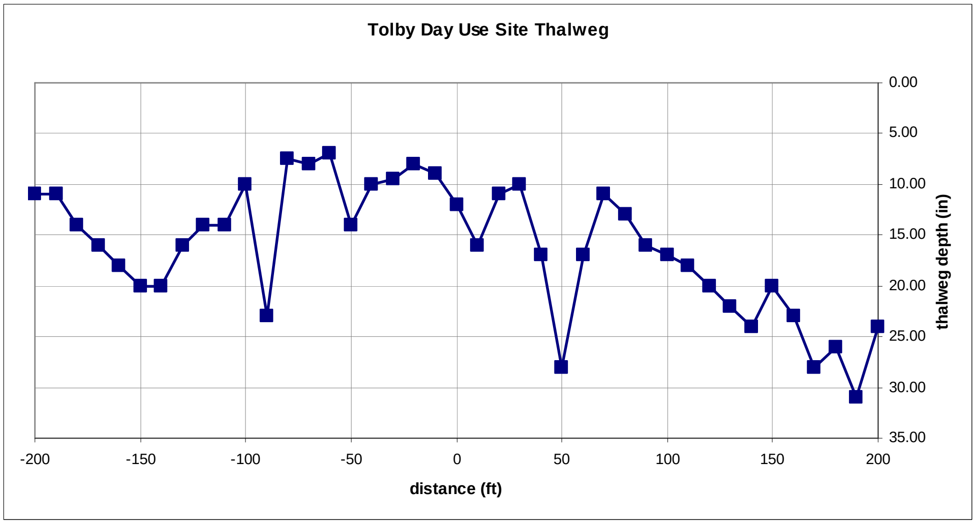

Figure 16. Thalweg depth profile at the Tolbay Day Use EMAP site on the Cimarron River.

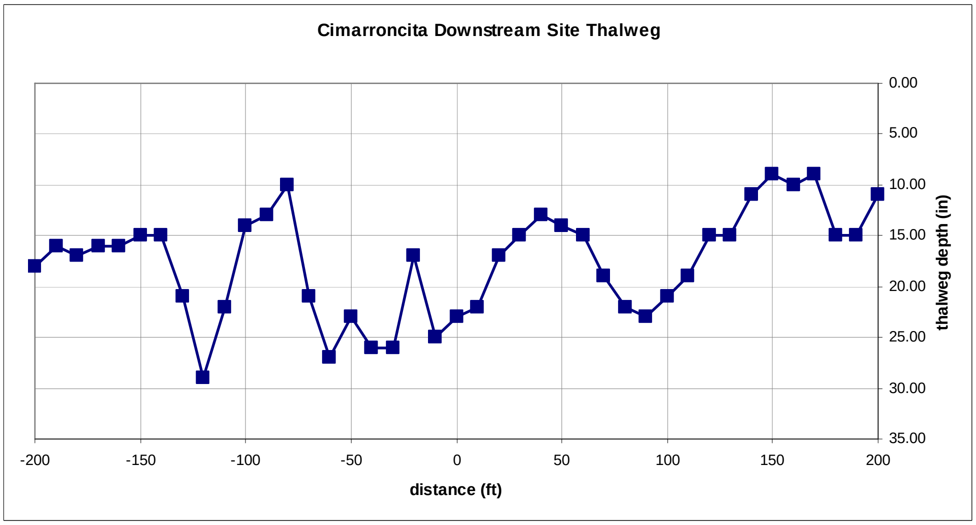

Figure 17. Thalweg depth profile at the Cimarroncita Downstream EMAP site on the Cimarron River.

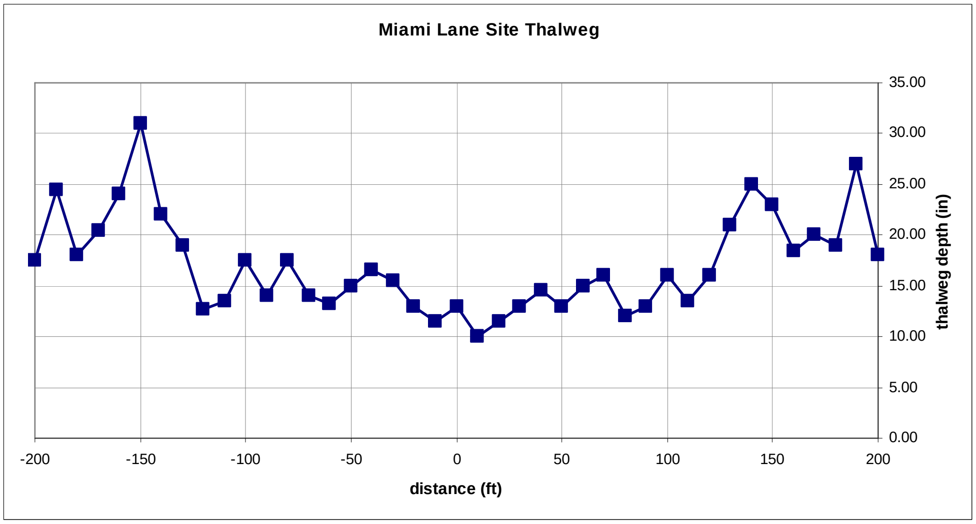

Figure 18. Thalweg depth profile at the Miami Lane EMAP site on the Cimarron River located on the CS Ranch.

General Water Quality Characteristics

31 water samples were collected for analysis of their inorganic water quality characteristics. Two playa lake soil samples from the Maxwell National Wildlife Refuge were also collected and subjected to a deionized water leach to determine leachable constituents. All of the results are contained in Appendix I. Those results relevant to the ecological health of the stream reaches studied are presented in this section.

Elevated water temperatures have been identified by the NMED as evidence of impairment of some of the streams in the basin. As the stream flows out of the Southern Sangre de Cristo Mountains it ends up in the plains region of C.S. Cattle Ranch. Temperature measurements in the Cimarron River are shown in Figure 19. The maximum water temperature recorded was 26.9°C at CS Ranch while the lowest recording was 15.4°C at Cimarroncita Ranch.

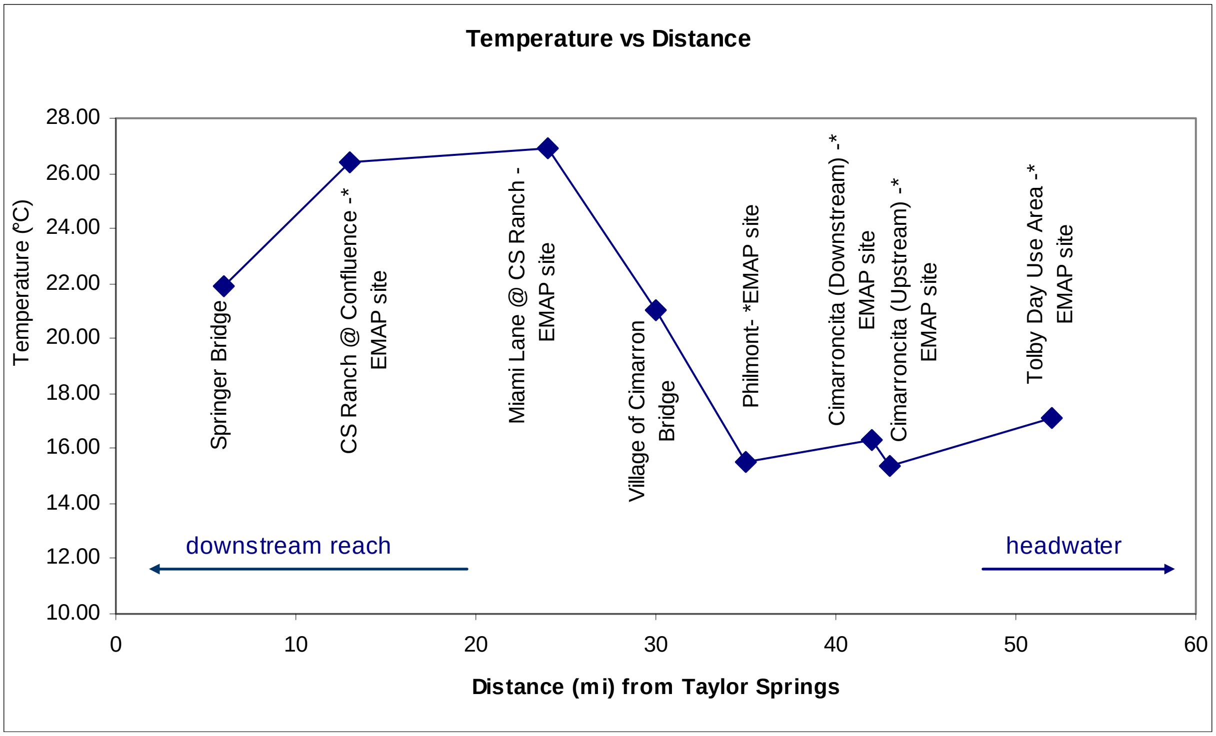

Figure 19. Water temperature for sites on the Cimarron River

In general, the temperature increases as the river flows out of the mountains and onto the high plains. A combination of decreased velocity due to lower gradients and reduced riparian cover contributes to this temperature increase. These temperature measurements meet the criteria in the stream standards for this reach of river (20.6.4.306 NMAC). However, the study was conducted during spring. The water temperature will likely be higher and flows lower during summer months. Given the variability of precipitation before monsoon rain, and high temperatures during the summer months, the streamflow of Cimarron River will likely decrease even further.

Figure 20 shows the variation in electrical conductivity (EC) with distance for the Cimarron River. Recall that EC is proportional to the concentration of dissolved ions in the solution and so is an indication of salinity. The data show a steady increase in EC as the river flows eastward towards the confluence with the Canadian River. Some of this increase is almost certainly due to evaporation. However, the salinity increases by nearly a factor of three in the last 18-mile stretch from 500 to 1430 µS/cm. If evaporation was the sole cause it would require loss of two-thirds of the river water to evaporation (evaporation and transpiration losses from the Rio Grande over the ~150 mile stretch from Cochiti Reservoir to San Acacia is estimated at 19% of the river flow, Middle Rio Grande Water Assembly, 1999). Possible causes of the increase in EC are the influence of agricultural return flows present as seepage flows along the river channel, seasonal runoff from playa lakes with elevated salinity, and dissolution of salts that have accumulated as crusts on the soil surface in the hyporheic zone by seasonal high fluxes associated with spring runoff.

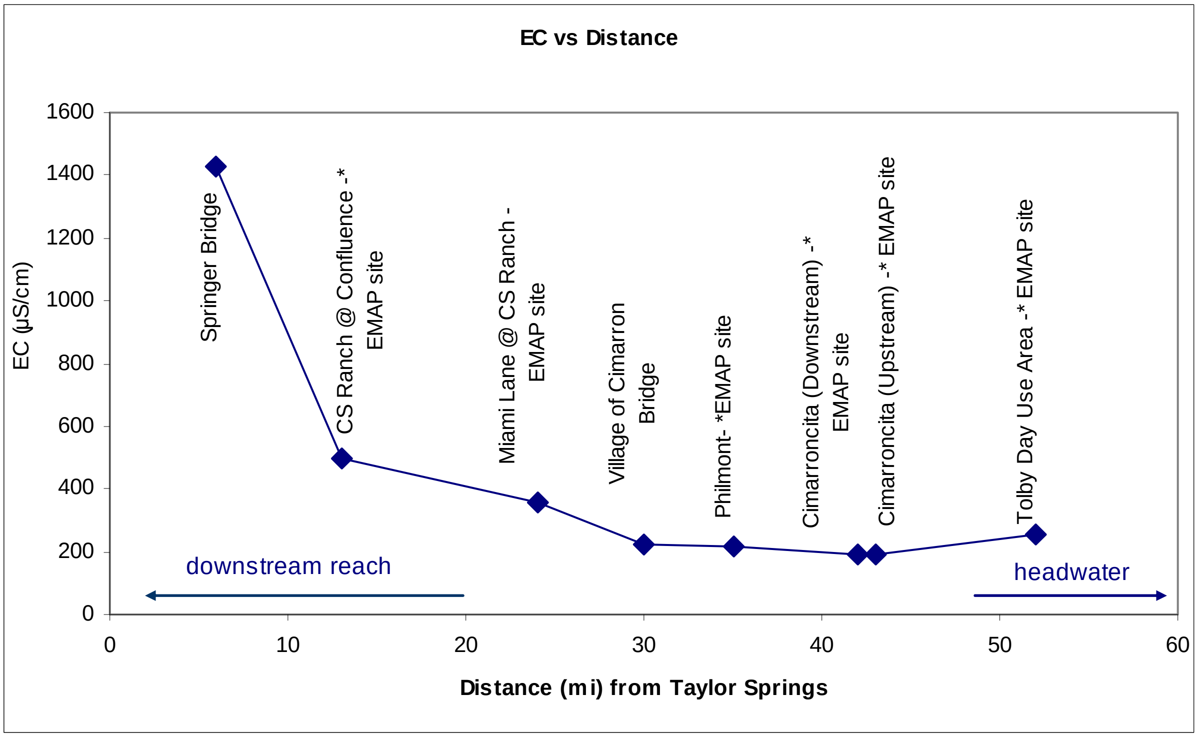

Figure 20. Electrical Conductivity for sites on the Cimarron River

The general characteristics of natural waters are frequently reported in terms of their salinity (in the case of this study it is indicated by electrical conductivity), pH, and major ion concentrations. The major ions consist of cations (sodium – Na^+, potassium – K^+, calcium – Ca^{2+}, and magnesium – Mg^{2+}) and anions (chloride – Cl^-, sulfate – SO_4^{2-}, nitrate NO_3^-, and bicarbonate/carbonate – HCO_3^-/CO_3^{2-}). Bicarbonate and carbonate are measured and reported as alkalinity in units of mg $CaCO_3$/L.

A summary of the major ion chemistry for all samples collected in this project is presented in Table 12. A pH of between 7.0 and 8.5 in freshwater streams and lakes is normal. The pH values for all samples collected in this study consistent with waters that have not been impacted by introduction of acidic or basic solutions. Total alkalinity is the measure of a solution's acid neutralizing capacity (ie: its buffering capacity). In natural waters it is also the sum of the HCO_3^- and CO_3^{2-} concentrations. Alkalinity values in the range of 20-200 mg $CaCO_3$/L are normal and indicate a well buffered water. The presence of extensive amounts of limestone in the basin is likely the cause of alkalinity increases as the river flows east towards its confluence with the Canadian River.

Table 12. Summary of major ion chemistry for all samples collected.

Sample No.	Sample Name	EC (uS/cm)	pH	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Cl (mg/L)	NO_3 (mg/L as N)	SO_4 (mg/L)	Alkalinity (mg $CaCO_3$/L)	TKN (mg/L as N)
1	Lake 13	630	8.59	45.5	5.2	34.0	22.2	15.5	0.6	207.2	156	0.0
2	Lake 13 Inlet			37.6	3.8	30.1	15.4	9.9	0.6	130.3	137	3.1
3	Lake 12			28.5	6.3	49.3	19.7	11.5	0.5	179.1	171	0.9
4	Cimarron Boys Ranch N. of Island			6.5	2.3	20.0	4.0	6.2	0.5	18.1	87	0.0
5	Six Mile Creek	210	8.2	5.7	2.4	31.4	3.2	2.9	1.2	10.8	130	4.0
6	Cieneguilla (W. Tributary)	431	8.47	18.7	2.8	53.7	8.6	17.4	0.7	18.8	188	0.0
7	Cieneguilla Creek Dwnstream of Angle Fire Vil	349	8.3	10.5	2.9	40.3	7.6	1.5	0.1	1.4	169	10.28
8	Cimarroncita Boy Ranch Corral	193	8.1	6.5	2.4	20.4	4.0	5.7	0.4	17.2	78	ND
9	Eagle Nest Lake	285	8.3	13.5	3.7	30.9	6.9	9.7	0.6	19.7	130	ND
10	San Mateo & Country Club Cieneguilla	225	8.23	6.1	2.8	24.7	5.9	5.6	1.5	11.9	112	0.0
11	Moreno Creek Inflow Eagle Nest Lake	329	8.82	11.8	2.6	37.4	7.2	8.7	1.1	17.5	156	ND
12	Tolby Day Use Area	252	8.25	11.6	3.3	26.4	5.8	6.9	0.9	16.4	106	ND
13	Morain Way (Dwnstream of Culvert)		7.63	11.6	2.4	51.9	9.9	0.0	0.0	0.0	187	0.00
14	Morain Way (Confluence)			4.7	2.7	26.4	5.4	4.6	0.6	8.2	110	ND
15	Mountain View Culvert 2		7.5	5.4	2.6	25.8	5.4	4.7	0.6	9.6	114	ND
16	Lake View Park		7.56	12.1	2.6	43.3	8.7	19.3	2.2	25.2	152	ND
17	Monte Verde		8.29	7.8	2.6	35.5	7.0	15.5	0.5	28.5	120	0
18	Ponile Creek @ Bridge	123		12.0	2.4	28.0	7.7	4.2	0.7	70.4	88	0
19	Cimarroncita (1st upstream site of Island)			7.1	2.4	20.1	3.9	6.0	0.7	19.3	76	ND
20	City of Cimarron Bridge	221	8.13	8.1	2.5	22.8	4.8	6.1	0.5	26.0	84	0
21	Un-named Ditch	520		110.5	3.2	40.0	22.3	32.0	0.6	214.8	300	ND
22	Cimarron River @ Cimarroncita	189	8.23	6.5	2.4	20.7	4.1	5.9	0.6	19.3	76	0
23	Cimarron Tributary @ Cimarroncita	321		9.1	2.2	34.7	7.4	2.9	0.1	30.5	130	0.49
24	Irrigation Ditch [Springer Irrigation Ditch]		8.2	12.0	3.0	24.9	5.1	2.6	0.1	34.2	95	ND
25	Cimarron River Dwnstream Confluence @ CS	500	7.44	19.5	2.9	45.0	17.1	6.3	0.1	135.2	141	ND
26	Ponile Creek @ CS Ranch	1,565	8.45	43.2	3.8	61.7	32.4	8.8	0.6	316.2	173	ND
27	CS Ranch @ Miami Lane	357	7.3	15.3	4.0	34.9	10.3	7.5	0.7	90.4	111	ND
28	Cimarron River Boy Scouts Ranch-Site 1	219		7.4	2.4	22.7	4.5	5.8	0.5	20.0	82	ND
29	Rayado @ Confluence			16.6	2.9	41.7	14.6	7.3	0.7	134.2	133	4.603
30	Cimarron @ Confluence		8.29	72.7	3.3	121.6	58.0	16.3	0.7	857.7	146	0
31	Rayado Creek	115	8.9	3.9	2.5	8.6	3.1	2.8	0.5	8.6	45	ND
32	Vermejo N. Gate (T Turner Ranch) [Canadian	685	8.1	100.7	3.1	21.5	10.4	29.3	0.5	29.3	321	ND
33	Dos Rios Canadian River-Dwnstream of Conflu	2,140		169.0	5.1	140.3	83.7	65.1	0.7	1286.4	202	ND
34	Cimarron River @ Springer	1,430		74.8	3.3	118.2	61.3	20.9	0.1	770.6	171	ND

The major ion characteristics of natural waters is frequently summarized graphically through the use of trilinear diagrams (also known as Piper diagrams) (Hem, 1985). These diagrams are prepared by plotting the fraction of major ion concentration when expressed as meq/L. This permits visual comparison of the ratios of these ions for a large number of water samples (Figure 21). A couple of notable observations can be made. The first is that major cations are fairly tightly grouped in all water samples at roughly 80% Ca and Mg ions, and 20% Na and K ions. This is consistent with the previous observation that all of the waters sampled were relatively hard. The second point is that, in contrast to the cation data, there is a wide variation in the distribution of anions. All of the samples had Cl concentrations that were less than 20% of the total anion concentration when expressed as meq/L; the waters were dominated by bicarbonate-carbonate ions and sulfate ions. But the sulfate fraction ranged from near zero near the headwaters of Cieneguilla Creek to greater than 80% of the total anions on the Canadian River near Taylor Springs. The high sulfate concentrations at the Maxwell National Wildlife Refuge are consistent with the observed white Ca-SO_4 deposits collected at the Playa Lake.

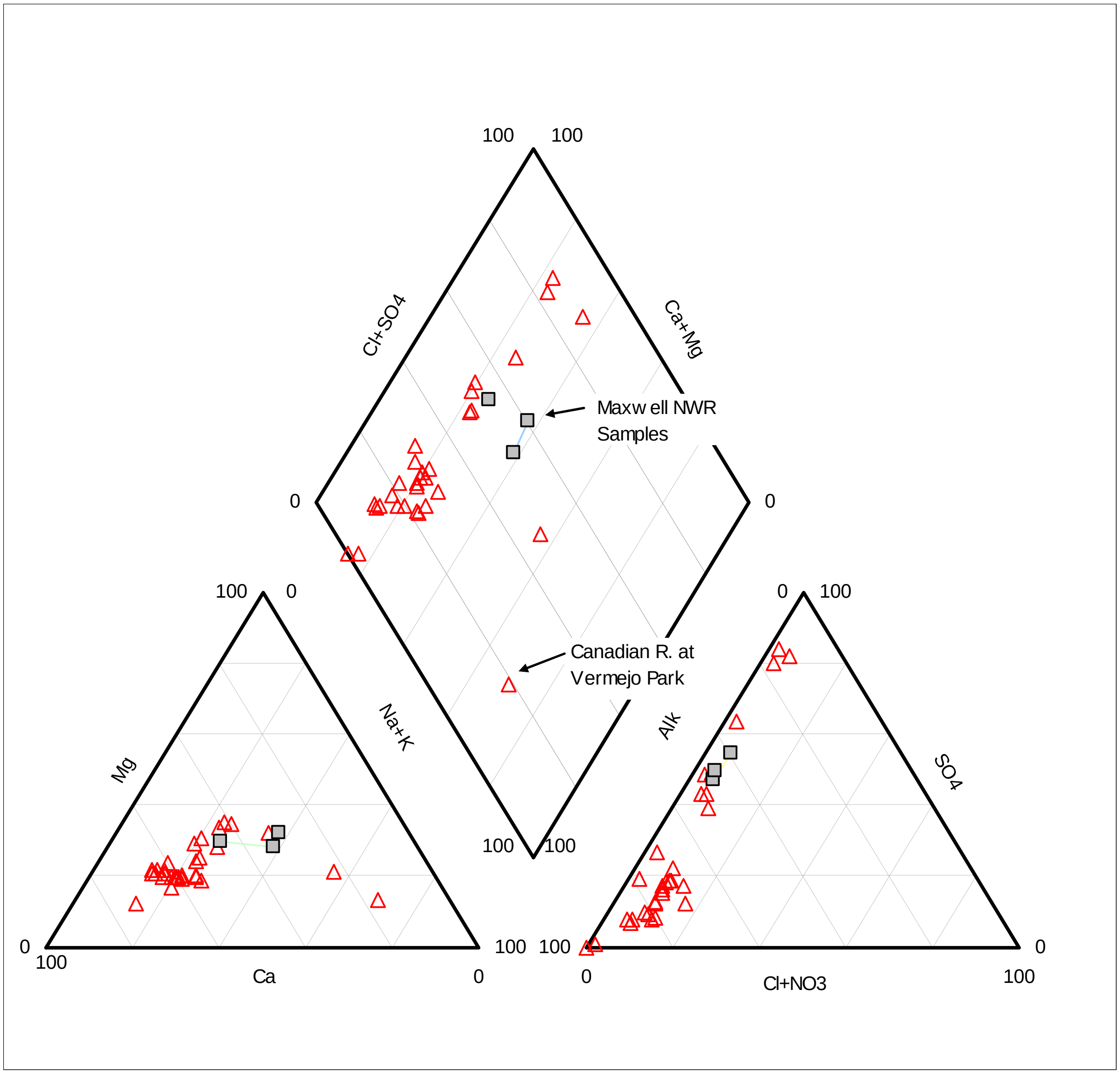

Figure 21. Trilinear diagram representation of the major ion composition of all of the water samples collected during this investigation. Samples collected at the Maxwell National Wildlife Refuge are presented as gray boxes.

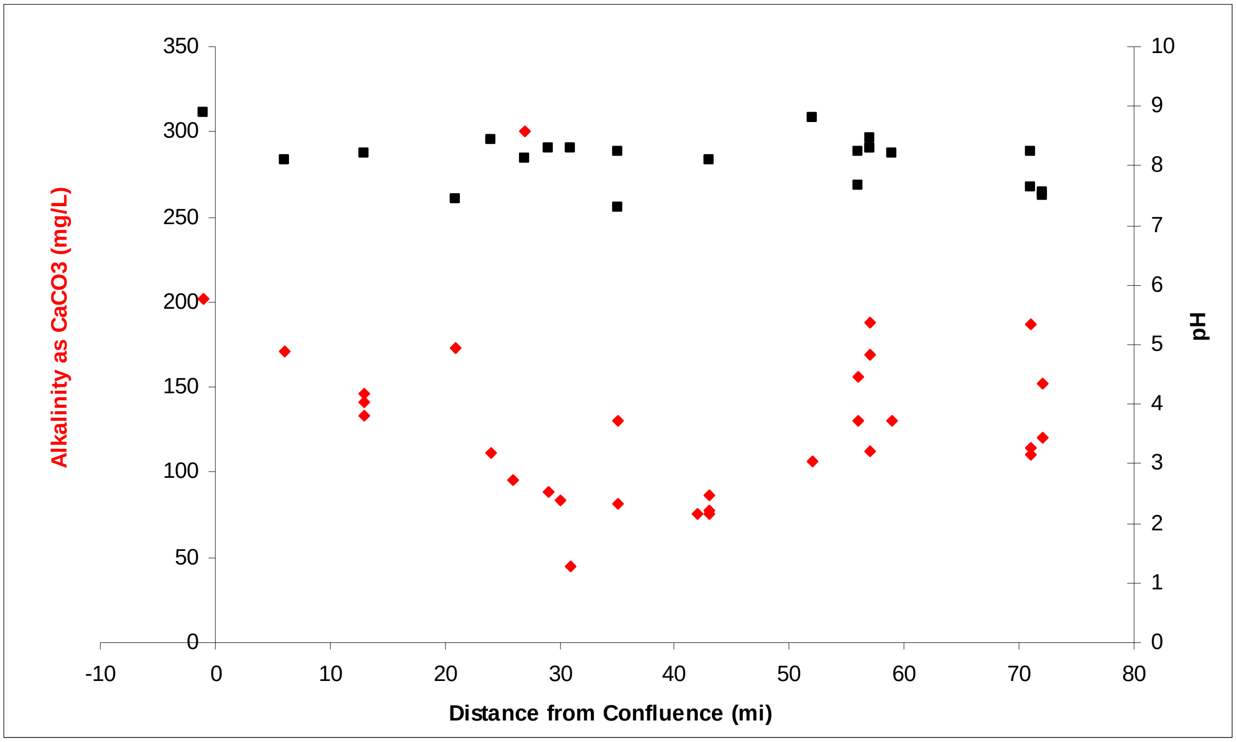

Figure 22. Variation of pH and alkalinity at sample sites along the Cimarron Watershed. Distances are approximate mileage from the confluence of the Canadian and Cimarron Rivers near Taylor Springs, NM.

Though the fraction of Ca remains fairly constant in all samples, it is interesting to consider the increasing concentration of this constituent as the Cimarron River flows east. As with alkalinity, this is likely due to dissolution of limestone materials in the basin. A plot of Ca concentrations versus distance is provided Figure 23. Though there are no stream standards for Ca, by the time the river reaches Springer the hardness due to Ca alone is roughly 300 mg $CaCO_3$/L and the total hardness (including Mg ions) is greater than 500 mg $CaCO_3$/L; this water is very hard!

The geology near Taylor Springs is dominated by the Pierre Shale and Niobrara Formation. The Niobrara Formation includes Smoky Hill and Fort Hays Limestone deposits. The calcium concentration decreases with increased distance from Taylor Springs because the geology changes from shale and limestone to sandstone, fluvial, alluvial, colluvium, and landslide deposits.

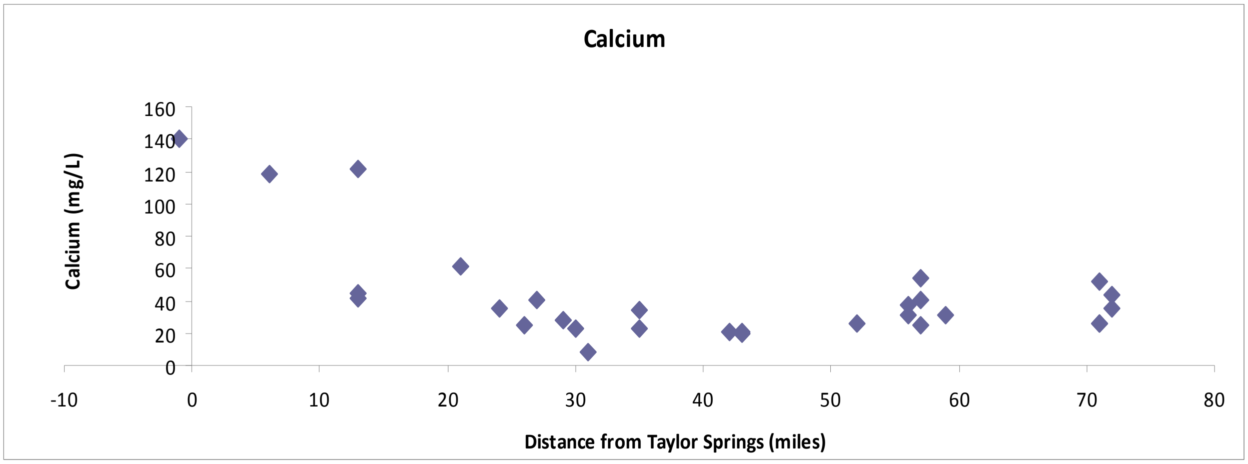

Figure 23. Calcium concentrations in the Cimarron Watershed plotted versus distance from its confluence with the Canadian River near Taylor Springs, NM

Nitrogen Compounds

In natural waters the three principal forms of nitrogen are nitrate (NO_3^-), ammonia/ammonium (NH_3/NH_4^+) and organic nitrogen (organic compounds which contain nitrogen such as urea and amino acids). The reduced forms of nitrogen, ammonia/ammonium and organic nitrogen are frequently reported as Total Kjeldahl Nitrogen (TKN) in reference to the analytical method which is used to measure them. Sources of nitrogen in watersheds include discharge from wastewater treatment plants, discharges from on-site wastewater treatment and disposal systems (i.e. septic tank-absorption field systems), fertilizers, and animal wastes. Under aerobic conditions reduced nitrogenous compounds will become oxidized to nitrate.

Elevated concentrations of nitrogen compounds will stimulate growth of aquatic plants, especially algae, resulting in a process known as eutrophication. Plant growth can be observed more in low water flow sites where plants can more easily get established (Campbell & Wildberger 2001). Nitrate is the only nitrogen compound regulated for drinking water; its maximum contaminant level (MCL) is 10 mg/L measured as N. A plot of the nitrate and TKN concentrations along the Cimarron River is presented in Figure 24. The nitrate concentrations are greatest in water samples taken near the Angel Fire Country Club. The highest concentration of TKN was found in a sample taken immediately downstream from the town of Angel Fire. Possible sources include fertilizer from the golf course and high density of residences served by on-site wastewater disposal systems. It is worth noting that of 25 samples analyzed for nitrate in the Cimarron watershed, only 5 were less than 0.5 mg/L. Confirmation of elevated nitrate levels was suggested by the presence of noticeable algal growth on cobbles and boulders at most sampling locations.

A TKN concentration of 4.6 mg/L was measured in a water sample taken from Rayado Creek at its confluence with the Cimarron River. The cause of this high nitrogen concentration is not known. Re-sampling of this location is needed to provided confirmation of the elevated value.

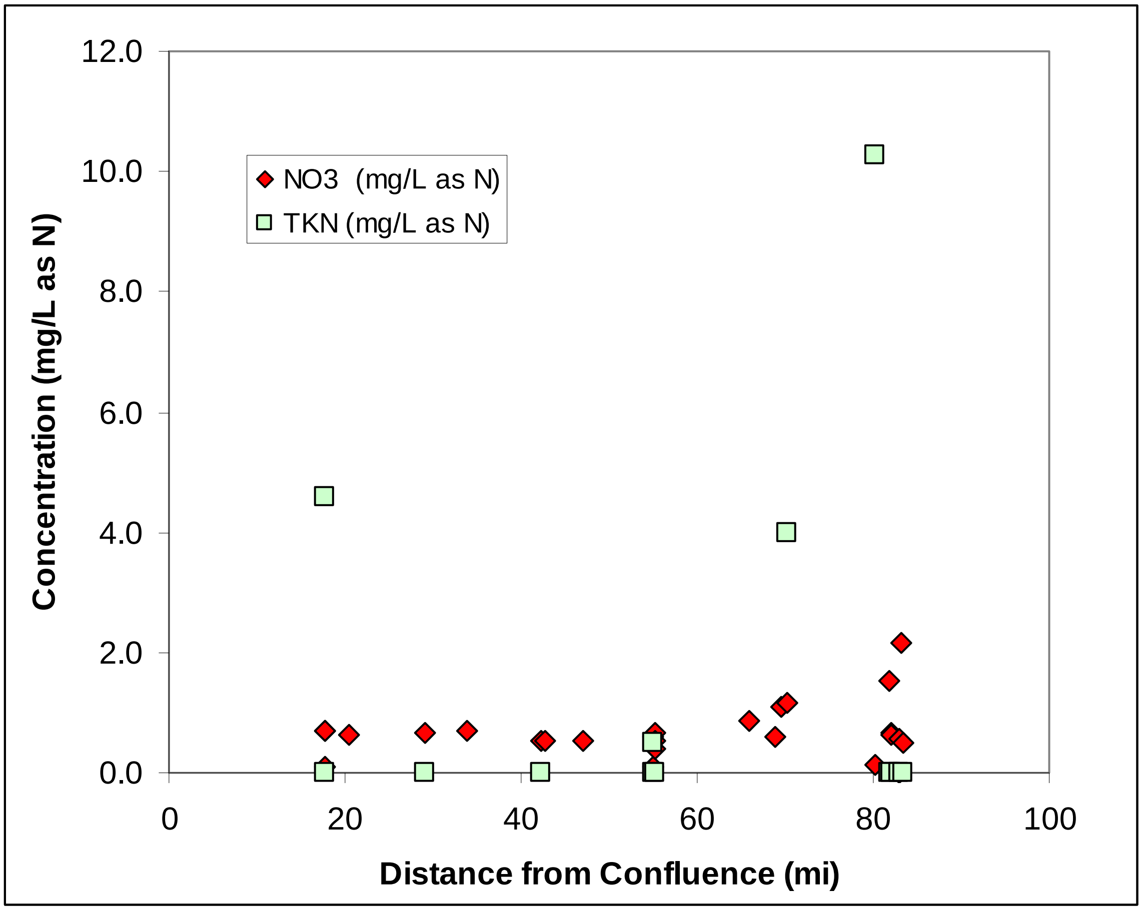

Figure 24. Variation of nitrate (NO_3) and Total Kjeldahl Nitrogen (TKN) concentrations along the Cimarron River upstream from its confluence with the Canadian River near Taylor Springs, NM.

The results of trace metals analyses are presented in Appendix I. Note the reporting limits in the second row of the column. No detectable concentrations were found of beryllium (Be), cobalt (Co), copper (Cu), nickel (Ni), lead (Pb), and selenium (Se). Barium (Ba) was detected at .207 mg/L which is slightly above the reporting level (0.2 mg/L) in a single sample on Cieneguilla Creek. None of the results for these metals is contained in the Appendix.

Because it has previously been identified as a possible problem constituent, arsenic (As) was analyzed by hydride generation atomic absorption spectroscopy (HG-AAS) which has very low detection limits. The maximum concentration found in the Cimarron River watershed was about 2 ug/L which is well below the drinking water MCL of 5 ug/L. Most samples had As concentrations well below 1 ug/L. This study did not identify any problems due to elevated As concentrations. Five samples were analyzed for selenium (Se) by graphite furnace atomic absorption spectroscopy (GF-AAS); lake water samples and the playa lake sediment samples at the Maxwell NWR. This was done because Se is a potential contaminant of concern at the refuge and GF-AAS has a detection limit of 1 µg/L compared to the 750 µg/L detection limit of ICP-OES.

Several samples had aluminum present above the reporting level of 0.4 mg/L. This is believed to be due to colloidal clay particles that were not removed by filtration using qualitative filter paper.

Measurable iron (Fe), manganese (Mn), strontium (Sr), and zinc (Zn) concentrations were found in about of the samples collected but at concentrations less than 1 mg/L. These are low concentrations and not believed to be of environmental significance. Silicon (Si) was present at concentrations ranging from less than 1 mg/L to 10.1 mg/L and is also not believed to be of environmental significance.

Benthic Macroinvertebrates

Benthic macroinvertebrates inhabit channels, clinging to the substrate or the bottom of water courses. Certain classes of these organisms have proven more intolerant of pollution or other stressors (e.g., heat, direct sunlight, stream disturbance, less oxygen) than others. Several methods of measuring stream health by using a combination of the diversity of organisms within the stream and the relative abundance of the stress tolerant vs. the stress intolerant organisms have been formulated (USEPA, 2003). This study used a Pollution Tolerance Index (PTI) rating adopted from the Hoosier Riverwatch organization (INGov, 2010).

The system separates the organisms by taxa into four groups of varying pollution tolerance or PTI Groups where PTI Group 1 contains taxa which are pollution intolerant, PTI Group 2 organisms which are moderately intolerant, PTI Group 3 organisms are fairly tolerant, and PTI Group 4 organisms are very tolerant. The PTI Groups are then weighted and totaled to provide a Pollution Tolerance Index Rating (PTIR). An excellent rating is defined as any score 23 and above, good is 17-22, fair is 11-16, and poor is 10 or less. According to this system the reaches sampled of the Cimarron River and Rayado Creek four were rated fair, two being rated excellent and one rated poor. The results of the benthic macroinvertebrate analyses at each of the EMAP sites is presented in Table 13.

Table 13. Pollution Tolerance Index Rating (PTIR) based on results of benthic macroinvertebrate counts at each EMAP site.

Site	Pollution Tolerance Index Rating (PTIR)
Excellent	
Cimarroncita Upstream (Cimarron River)	29
Cimarroncita Downstream Site (Cimarron River)	23
Fair	
Rayado Creek at Philmont	16
Cimarron River at Miami Lane	15
Cimarron River at Philmont	13
Tolby Day Use Area (Cimarron River)	15
Poor	
CS Ranch Confluence	13

Figure 25 shows the total number of taxa per PTI Group and for each of the EMAP study sites. The variation of the overall Pollution Tolerance Index Rating (PTIR) with location along the river is plotted in Figure 26

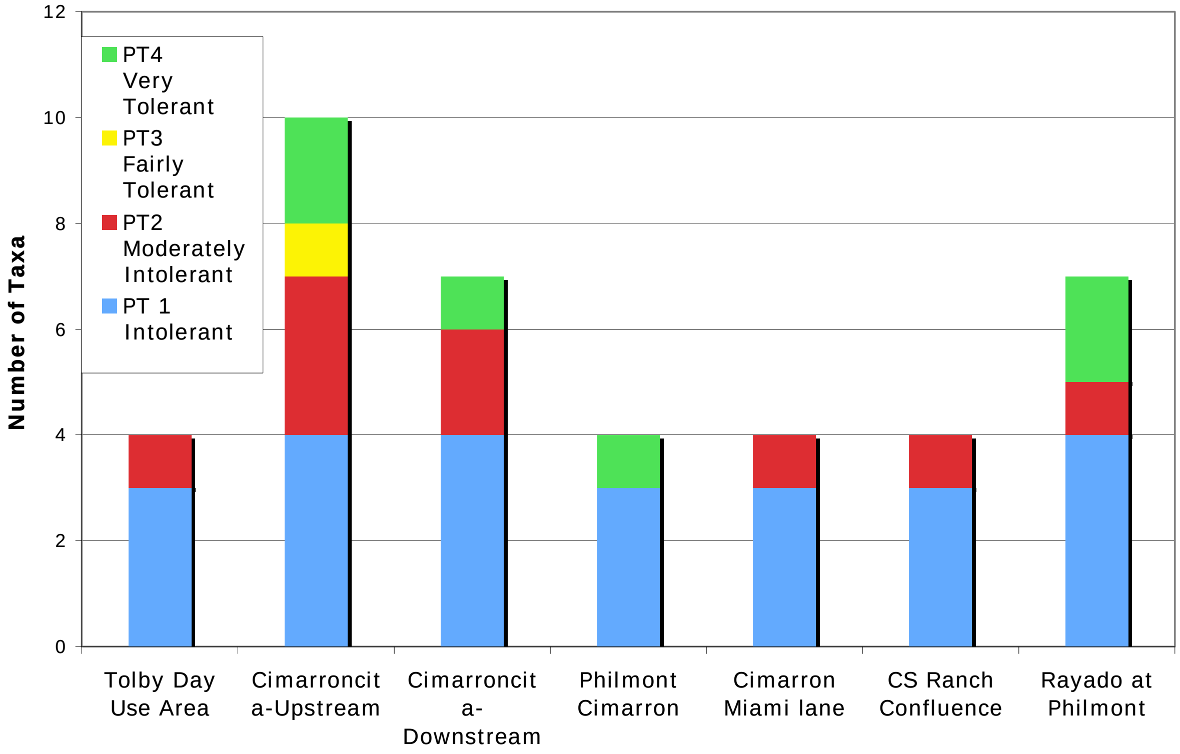

Figure 25. Number of taxa for benthic macroinvertebrate populations at each of the EMAP sites.

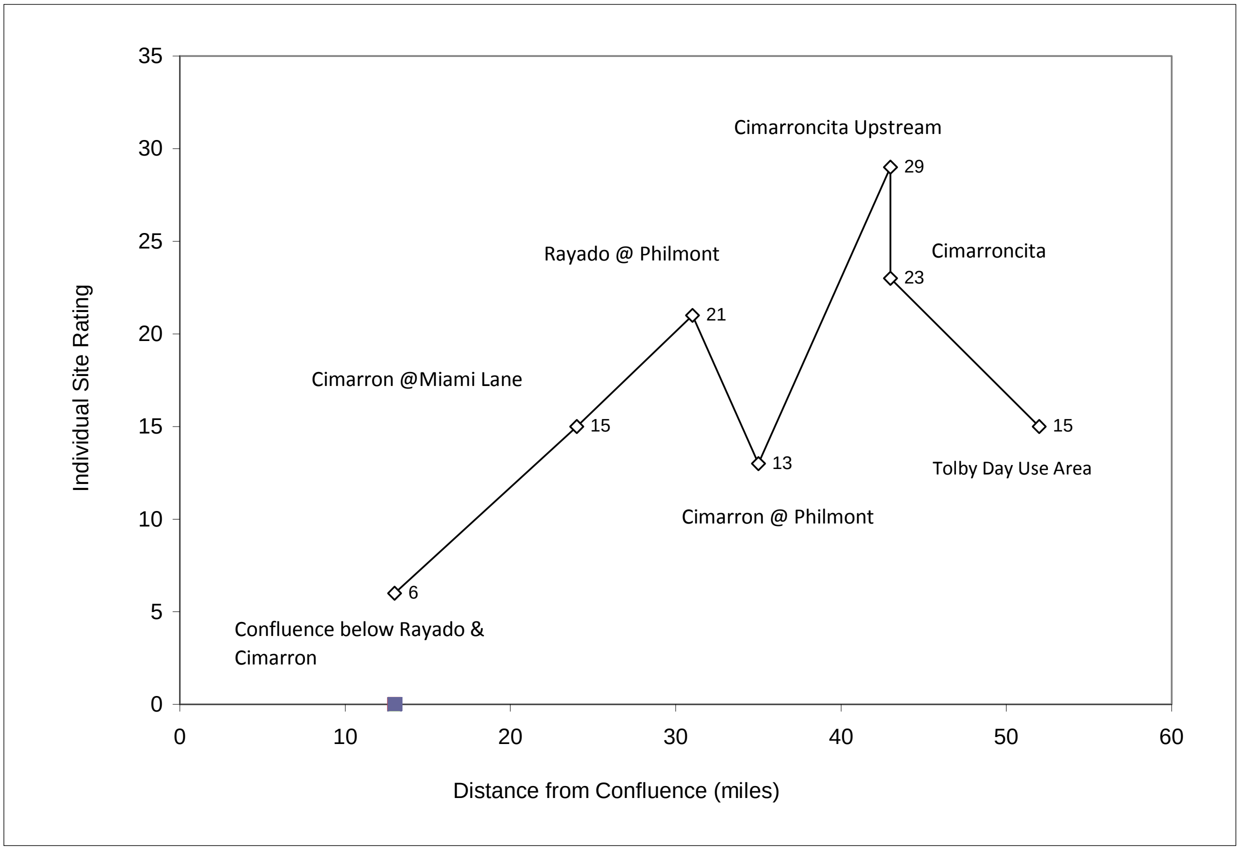

Figure 26. Variation in overall Pollution Tolerance Index Rating for EMAP sites on the Cimarron River.

Both sites at the Cimarroncita Ranch were rated as excellent. The surrounding environment has been restored using passive restoration techniques (A. Huerta, 2010). Cattle that grazed the area in the past have been removed and active grazing no longer takes place on the ranch. Removal of the vector was all that was done and the area was then allowed to recover without much more human influence. The other four areas that are rated as fair are under varying human influence factors. Some are under the direct influence of agricultural diversions and grazing animals while others are directly used by humans for recreational purposes. The flow, sediment amounts, and streambed morphology at each site also varied and this is another factor that affected the number of taxa found. The site at the confluence of the Cimarron River and Rayado Creek had a poor PTI Rating. The confluence was very sediment heavy and the water had high turbidity. They reach is likely influenced by low flows (< 5 cfs) late in the summer. The temperature in this reach was high (26.4° C) which likely influences benthic macroinvertebrates.

Interpretation of the benthic data should be made with the recognition that the stream morphology, chemistry, hydrology and ecological characteristics change dramatically as it leaves the mountains and flows eastward across the high plains. Thus, although the overall PTIR score decreases, it is not inconsistent with that which would be expected for a meandering stream with a low gradient flowing through pastureland with little riparian vegetation.

Data Gaps & Information Needs

In the course of this study, it became clear that there are a number of gaps in data that was collected. These gaps principally stem from time limitations associated with the compressed project schedule. The study was collected during the week of June 7 through the 11. During this time, the majority of flow in the river is from snow melt and most streams and rivers sampled were flowing at or near bank full conditions. Later in the summer flows will be substantially less which in turn will affect the chemical concentrations in the surface waters. A further advantage of studying the watershed later in the summer is that aquatic organisms, including the benthic macroinvertebrates, would be more fully developed, easier to identify, and possibly would be influenced by the stresses associated with low flow conditions.

A more accurate assessment of the quality of the stream and water resources in the basin would be obtained by repeating this study during low flow conditions in early fall or at the end of summer. Seasonal variation would help develop information on the seasonality of hydrologic, water quality, and biological conditions in the basin. These patterns would be expected to correlate to climate and human activity. Fuller recommendations regarding monitoring and protection of the watershed could be made based on a year-round seasonal study of the watershed.

The study would have been improved by the ability to obtain flow and water quality data at all of the tributaries and diversions along the river. Important locations that were not visited include Ute Creek at its confluence with the Cimarron River, and irrigation diversion structures. Data collected at all of these points would permit development of a water balance within the basin which could identify water use for irrigation, infiltration to underlying ground water formations, and evaporative losses. This study did include sample and flow measurements at the highest points in the watershed above Eagle Nest Lake, moving west to east through the course of the watershed gathering data at points roughly equivalent in distance along the course of the Cimarron River. This data suggests impacts of residential development on the quality of the tributary streams above the lake.

The EMAP protocol (USEPA, 2003) includes analyses of several properties that were not conducted in this study including: periphyton, sediment community metabolism & toxicity, aquatic vertebrates, and fish tissue contaminants. While it is desirable to analyze all of these characteristics, it appears unlikely to the study team that results obtained from these analyses would change the findings obtained in this study.

Irrigated agriculture constitutes the greatest water use in Colfax County, the majority of which is conveyed through irrigation ditch systems, however irrigation flows were not assessed in this study with the exception of a water sample taken from the Springer Ditch. Because the Cimarron River is fully adjudicated, estimates of irrigation diversions are prepared by the Office of the State Engineer based on consumptive use estimates and study data (DBS&A, 2003). In order to create an accurate water balance for the watershed, the volume of these diversions should be measured. At the very least, measurements of flow from the main channels from the Springer Ditch Company, Antelope Valley Irrigation District and Vermejo Conservancy District would provide baseline data for a regional water balance. In addition, because there is no gage on the lower Cimarron River, flow data from a location above the Cimarron-Rayado confluence would be useful in developing a more complete picture of the water resources and its use within the Cimarron watershed.

The almost total reliance on surface water by users in the Cimarron watershed makes the implications of climate change on water resources an area worthy of further study. Changes in snowmelt pulses and increased rates of evaporation as a function of increases in seasonal temperature could have a significant impact on appropriators in a region that is fully adjudicated and is economically dependent upon surface water supply.

Lastly, while field measurements are necessary for this type of study, data accuracy can be impacted by equipment malfunction or limitations, human error, and environmental changes such as local fires, rain events, and other human activity. While not intentionally subjective, flow measurements in the field are influenced by site selection, weather, and human interpretation.

Conclusions

Hydrology

Hydrology in the Cimarron River basin is most heavily influenced by three factors: spring runoff, monsoonal rain events, and irrigation diversions. Plotting the average monthly streamflow reveals that spring runoff and monsoon activities generate the two highest peaks. On the other hand, the streamflow measurements show that water flow is lowered by irrigation diversions from headwater near Eagle Nest Lake to furthest downstream reach studied at Springer Bridge. This impact can be significant, especially during summer months when temperature is high and precipitation is minimal.

Streamflow measurements collected during this study are similar to the USGS data. Historic seasonal and annual flows are plotted in Figure 7 and Figure 8 respectively. The historic average monthly flow at Cimarron (yellow line) is higher than the flow at Eagle Nest Dam (orange line). The actual streamflow measurements show similar difference between the Village of Cimarron and Tolby Day Use sites. However, the actual flow measured was lower than the USGS monthly June average. Actual flow measured at Tolby Day use was 16 cfs while the average monthly streamflow for June was 25 cfs below Eagle Nest Dam. On the other hand, actual flow measured at Cimarron Bridge was about 28 cfs while the average monthly streamflow for June was 31 cfs at Cimarron.

The lack of flow data on the lower reaches of the Cimarron River near Springer, NM limits the long term evaluation of the water resources in the lower basin. Location of a gage on this reach of the river would be of significant value in understanding water use in the basin and also in tracking the long term changes in the availability and variability of this use as a result of anthropogenic and climate changes.

Water Quality

The results of this study showed that the Cimarron River and its tributaries are of high quality and appear to support the criteria established for the designated uses in the NM Stream Standards. A dramatic increase in salinity as measured by electrical conductivity in the lower reaches of the Cimmarron River was noted, however, its cause was not determined in this study. Very high Ca and Mg concentrations in the lower reaches of the river cause the water to be remarkably hard, however, this appears to be due to the presence of extensive limestone formations in the basin and is not believed to have an impact the ecological health of the river.

The overall quality of the Cimarron River and its tributaries appears to be excellent as evidenced by both water quality data and analysis of benthic macroinvertebrate populations. The benthic macroinvertebrates identified in the study were those that are associated with high quality waters. The concentrations of all chemical constituents measured in this study are also consistent with excellent water quality. The only constituents that were identified at slightly elevated concentrations were nitrogen species, both nitrates and TKN (ammonia/ammonium and organic nitrogen species). With the exception of a few samples taken near the Angel Fire Country Club golf course and residential subdivision, these concentrations were less than 1 mg/L measured as N and do not present an immediate threat to the quality of the stream. Nevertheless, the slightly elevated nitrogen concentrations suggest there is an anthropogenic impact on the quality of the river that should be monitored in future studies.

The concentration of all other chemical constituents in the water samples do not suggest any impacts due to development or range management. Elevated Al concentrations in a few samples is believed to be due to the presence of colloidal suspensions of clay sized particles that were not completely filtered from the samples prior to analysis.

Part II – Maxwell National Wildlife Refuge

History and Background

The 3700 acre Maxwell National Wildlife Refuge (NWR) in northeastern New Mexico was purchased by the US Fish and Wildlife Service (USFWS) in 1966 under the Migratory Bird Conservation Act to alleviate crop depredation problems and provide habitat for migratory waterfowl. Migrating bird concentrations were damaging crops in the region, which prompted the U.S. Fish and Wildlife Service to purchase scattered tracts of land and grow 350 acres of grain crops of wheat, corn, barely and alfalfa to support fall and spring migrating populations of geese, swans, ducks and cranes.

There are 700 acres of wetland lake habitats, with lakes 12, 13 and 14 constituting the principal areas **Error! Reference source not found.**. These lakes pre-date establishment of the refuge. Most were simply constructed at the site of existing playa lakes. These lakes hold water all year and are function as reservoirs to provide storage for water delivery to farmers and ranchers in the area. The flow of water is managed by the Vermejo Conservancy District and the District owns the water rights within the refuge. The refuge purchases water from the District and report that this is the single biggest expense associated with operating the refuge (Wilkins, 2010).

The refuge ecosystem is classified as short-grass prairie which consists primarily of buffalo grass, blue grama, western wheatgrass, alkali sacaton, and red three-awn.

Figure 27. Photograph of Lake 12 at the Maxwell National Wildlife Refuge.

According to the U.S. Fish and Wildlife Service, many non-game bird species considered unusual in New Mexico pass through or reside at the refuge. There are more than 350 species of birds that use the refuge, which provides breeding, feeding and shelter throughout the year. The Service says there are approximately 70 species, including the Swainson's Hawk, Eared Grebe, and three species of kingbird (Cassin's, Western, and Eastern) breed and raise young within the refuge (USFWS, 2010).

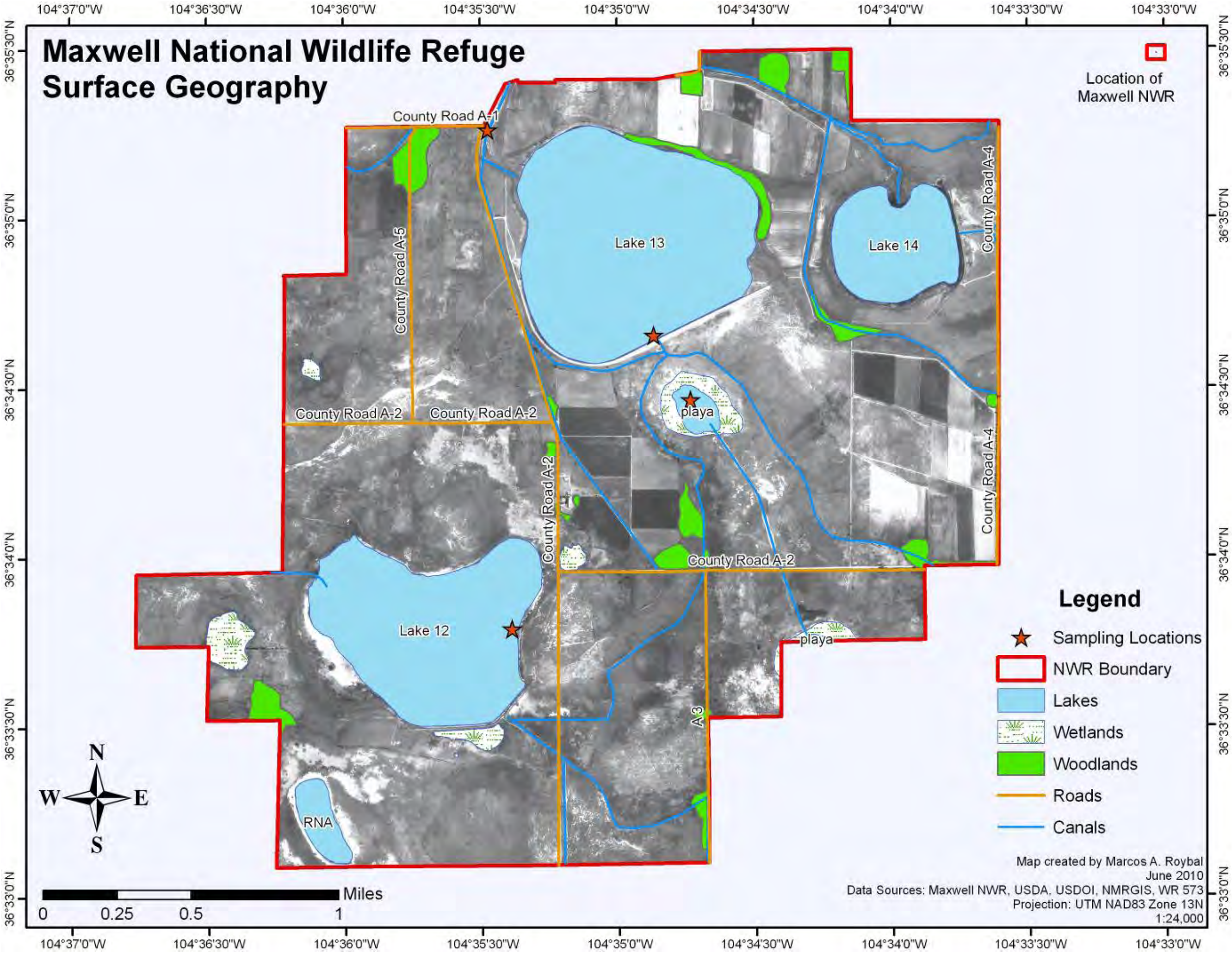

Figure 28. Sampling locations at the Maxwell National Wildlife Refuge.

Riparian vegetation along the lakes, canals, and drainages of the refuge largely consists of monotypic cattail (*Typha latifolia*), forming dense colonies in standing water in places. In addition, where water levels are shallow or fluctuate, rushes and sedges including American bulrush (*Scirpus pungens*), three-square sedge (*Schoenoplectus americanus*), Baltic rush (*Juncus balticus*), common spikerush (*Eleocharis spp.*) and Mexican dock (*Rumex salicifolius var. mexicanus*) are common. Weeds are more common in highly disturbed sites such as along canals, where vegetation may be mixed with weedy species such as broadleaf milkweed (*Asclepias latifolia*) and western whorled milkweed (*Asclepias subverticillata*). Riparian vegetation is lacking adjacent to the riprap-lined dam of Lake 13.

Water supply for the Maxwell NWR is primarily obtained from irrigation ditches operated by the Vermejo Conservancy District. The district also operates Lakes 12 and 13 and the irrigation ditch system that passes through the refuge. The principal source of water for the Vermejo Conservancy District is the Vermejo River which is diverted by the Vermejo Diversion Dam and delivered by the Vermejo Canal.

Study Methods

The study methodology used at the Maxwell Wildlife Refuge study included collections of soil and water and water samples. Water samples were collected from Lakes 12 and 13, and the irrigation ditch that feeds Lake 13. Two soil samples were taken from the playa lake; one at the surface and one 30 cm (12 in) below the surface.

Field measurements of the water samples were taken of electrical conductivity (EC), pH, dissolved oxygen (DO) and temperature. The study also included flow measurements from Lake 13 discharge to a small tributary. An Oakton pH/Con multi-probe meter was used to measure pH, electrical conductivity and temperature. The probe was calibrated against a pH 7 buffer before use. A Yellow Springs International (YSI) meter was used to measure DO. The DO meter was calibrated in the field before use.

Prior to any disturbance of a site a one liter water sample was collected in a clean plastic bottle which had been acid-washed and rinsed with 18MΏ (de-ionized) water. The sample bottles were rinsed with river water prior to collecting a sample. The bottles were filled with zero headspace. The water samples collected were prepared for analysis preservation. Two 50 ml portions of each sample was filtered through Whatman Qualitative Paper filter to remove suspended material and placed in plastic bottles. Approximately 5 drops of HNO3 was placed in one 50 mL aliquot to lower the pH to less than 2 for sample preservation. Both bottles were then placed on ice for preservation. The acidified and filtered water was analyzed by an ICP-OES for the concentration of metals. Non-filtered water samples were preserved with ice and filtered in the lab for analysis of anions by using ion chromatography, and total nitrogen by persulfate digestion and subsequent colorimetric determination of nitrate following color development by addition of chromotropic acid.

A 50 mL aliquot of each filtered sample collected during the day was used to measure alkalinity by acid titration using dilute, standardized sulfuric acid (0.02 N H_2SO_4). Two indicators, phenol 30 phthalein and bromocrysol methylred (BC-MR), were used to test for carbonate and bicarbonate alkalinity respectively.

After completing the field work, all of the water samples were analyzed for metal and non-metal constituents in the Environmental Analysis Laboratory of the Department of Earth and Planetary Sciences at UNM. Metal concentrations were measured using an Optima 5300 Dual View (DV) inductively coupled plasma optical emission spectrophotometer (ICP-OES). Anion concentrations were measured using a Dionex Ion Chromatograph (IC). All samples were analyzed using procedures listed in Standard Methods (APHA et al., 2005).

Soil samples were taken using a reagent grade shovel. Shovel and collection bottles were cleaned prior to collection. Soil samples were placed in 1 L polyethylene screw-top bottles and refrigerated until analyzed at UNM.

Water Quality Characteristics

Elevated concentrations of selenium in water, sediment, plants, and animals in the wildlife refuge have been detected in USFWS studies (USGS, 1997). Several possible sources of selenium and other contaminants in the watershed upstream from the irrigation project include bedrock, soils, agricultural return flows, coal mining, and atmospheric deposition (USGS, 1997). Field measurements of water samples collected at the reservoir are summarized in Table 14.

Table 14. Summary of field water quality measurements at the Maxwell National Wildlife Refuge.

	Dis. Oxygen (mg/L)	**Temp. (° C)**	**pH**	**Elect. Cond. (µS/cm)**
Lake 12	7.9	22.5	8.3	639
Lake 13	12.3/14.7	23.8	8.59	630
Lake 13 Inlet	7.5	22.6	8.60	500

Concern was expressed by the refuge managers that selenium might exist at toxic levels below Lake 13 based on a report by Seiler (1997) and Seiler et al. (1999). No detectable concentrations of Se or other toxic metals (Ba, Be, Co, Cu, Ni, Pb, or Se) were found in either the water samples taken at the refuge. These analyses were performed by graphite furnace atomic absorption spectroscopy (GF-AAS) which has a detection limit of 1 µg/L. Seiler et al. (1999) reference studies which suggest that Se concentrations as low as 5 ug/L may have some impact on freshwater aquatic life. The NM stream standard for Se in domestic water supply and irrigation is 50 ug/L, and the standard for aquatic life is 20 ug/L for acute effects and 5 ug/L for chronic effects for total recoverable Se.

The selenium concentrations of the two playa lake sediment samples was 159 µg/kg (ppb) and 151 µg/kg for samples taken at the surface of the lake bottom and 30 cm depth respectively. These results indicate that selenium is present, though not at especially high concentrations.

The major ion chemistry for water samples collected at the Maxwell NWR are presented in Table 12 and the complete analyses are presented in Appendix I. The water has high concentrations of Ca and Mg resulting in a total hardness of greater than 150 mg $CaCO_3$/L, as well as high alkalinity which is likely due to the prevalence of limestone deposits in the Canadian River watershed. A plot of the major ion chemistry of the water samples collected at the refuge is presented in Figure 21.

No detectable concentrations were found of nitrite (NO_2^-), barium (Ba), chromium (Cr), manganese (Mn), cobalt (Co), nickel (Ni), copper (Cu), silicon (Si), or sodium (Na). Aluminum was measured in a Lake 12 sample at 0.44 mg/L; just barely above the reporting value of 0.4

mg/L. The likely source is colloidal Al associated with clay sized particles that were not completely removed by sample filtration.

Nitrate concentrations of 0.6 mg/L as N were found in Lake 13 and the ditch that feeds it, and 0.5 mg/L in Lake 12. A TKN concentration of 3.1 mg/L as N was found in Lake 13. These concentrations are sufficiently high that algal growth may be a concern during summer months. The source of nitrogen was not determined, but the concentrations are similar to those found at some sampling sites on the Cimarron River and its tributaries.

Riparian vegetation is lacking by the dam, which is lined with riprap. Elsewhere, fluctuating lake levels limit riparian vegetation to willows and similar species. However, there are cottonwood trees and cattails, among others along the Lake 13 shoreline. Below the dam, dominant species include buffalo grass, blue grama, western wheatgrass, alkali sacaton, and red three-awn. Over 350 acres are planted with wheat, corn, alfalfa, and barley. Two hundred acres are woodlots and other lands recovering from previous farming and grazing uses. Exotic vegetation control is one focus of the refuge. These species include Russian knapweed, hoary cress, Russian olive, saltcedar, Siberian elm, and Canada, bull and musk thistles (Hoban, 2009).

Two soil samples were collected in the Playa Lake, one of the white crust at the surface of the lake and a second at a depth of 30 cm (12 in). The samples were dried at 105 C then ashed at 550 C to estimate the fraction of solids that is organic (LOI or Loss on Ignition). The surface sample had 9.1% volatile solids (LOI) and the sample collected at 30 cm depth had 5.5% volatile solids. The samples were extracted with deionized water which was then subjected to analyses of metals and non-metals. The results are presented in Table 15. They show that the white crust present on the surface of the lake sediments is a sulfate crust containing calcium, magnesium, and sodium sulfates. The sulfate concentration at 30 cm depth is two orders of magnitude less, which is consistent with the observation that the mineral deposits were not visually present at depth.

Table 15. Summary of constituents identified in soil samples collected from the playa lake bed at the Maxwell NWR.

	Concentration (ppm)	
Constituent	**Surface Sample**	**Sample at 30 cm Depth**
Al^{3+}	12.6	ND
Ca^{2+}	7,820	897
Mg^{2+}	8,630	2,020
Na^{2+}	--	5,860
Se	0.159	0.151
Br^-	30.9	16.5
Cl^-	5,270	1,660
NO_2^-	22.0	20.0
NO_3^-	1.3	65.1
SO_4^{2-}	3,898,000	30,857

Information Gaps and Future Data Needs

Water samples were taken at five locations, including the three lakes and ditch that feeds Lake 13. While believed to be representative of the refuge, samples at other lakes and ditches would provide a more comprehensive analysis. Samples could be taken from deeper within each lake. Macro- and micro-invertebrate studies could be performed.

The extent of Lake 13 sedimentation could be more thoroughly investigated. Rehabilitation of Lake 12 would likely increase lake turbidity. The impact of potential climate change on water resources needs further investigation. A National Weather Service weather station in the refuge or in the nearby town of Maxwell would enhance data collection, which could be integrated into a watershed water budget.

A further limitation of this study was that it only documents conditions during the second week of June, 2010. This time period reflects conditions near the peak of spring runoff when the effects of dilution would be most apparent. It is clear that the water quality characteristics of the refuge lakes and the ditches that supply them vary seasonally. A more comprehensive study would include assessment of the water quality throughout the course of the year, particularly during late summer and fall, periods of reduced flow when the benefits to water quality of dilution are minimized. An assessment in late summer would be especially informative because the impacts of agriculture and other non-point sources of contaminants to the lakes would be expected to be most significant.

Conclusions

The water quality in Lakes 12 and 13 and in the feed ditch is of high quality. Slightly elevated nitrogen levels were found in Lake 13. The chemistry of the water is dominated by sulfate salts and analyses of salt deposits of the surface of a playa lake at the refuge found them to consist of calcium, magnesium, and sodium salts.

Although concern has been expressed about elevated selenium concentrations in refuge lakes and sediments, the results of this study suggest that, although present, selenium concentrations are low enough that they do not present a threat to waterfowl. Additional analyses of the lake water samples is needed to determine if selenium is present at environmentally relevant concentrations later in the summer when it may have become concentrated by evaporation and agricultural return flows.

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Appendix I – Analytical Data

Analyses of field parameters, major ions and Total Kjeldahl Nitrogen (TKN)

Sample No.	Sample Name	EC (uS/cm)	pH	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Cl (mg/L)	NO_3 (mg/L as N)	SO_4 (mg/L)	Alkalinity (mg $CaCO_3$/L)	TKN (mg/L as N)
1	Lake 13	630	8.59	45.5	5.2	34.0	22.2	15.5	0.6	207.2	156	0.0
2	Lake 13 Inlet			37.6	3.8	30.1	15.4	9.9	0.6	130.3	137	3.1
3	Lake 12			28.5	6.3	49.3	19.7	11.5	0.5	179.1	171	0.9
4	Cimarron Boys Ranch N. of Island			6.5	2.3	20.0	4.0	6.2	0.5	18.1	87	0.0
5	Six Mile Creek	210	8.2	5.7	2.4	31.4	3.2	2.9	1.2	10.8	130	4.0
6	Cieneguilla (W. Tributary)	431	8.47	18.7	2.8	53.7	8.6	17.4	0.7	18.8	188	0.0
7	Cieneguilla Creek Dwnstream of Angle Fire Vil	349	8.3	10.5	2.9	40.3	7.6	1.5	0.1	1.4	169	10.28
8	Cimarroncita Boy Ranch Corral	193	8.1	6.5	2.4	20.4	4.0	5.7	0.4	17.2	78	ND
9	Eagle Nest Lake	285	8.3	13.5	3.7	30.9	6.9	9.7	0.6	19.7	130	ND
10	San Mateo & Country Club Cieneguilla	225	8.23	6.1	2.8	24.7	5.9	5.6	1.5	11.9	112	0.0
11	Moreno Creek Inflow Eagle Nest Lake	329	8.82	11.8	2.6	37.4	7.2	8.7	1.1	17.5	156	ND
12	Tolby Day Use Area	252	8.25	11.6	3.3	26.4	5.8	6.9	0.9	16.4	106	ND
13	Morain Way (Dwnstream of Culvert)		7.63	11.6	2.4	51.9	9.9	0.0	0.0	0.0	187	0.00
14	Morain Way (Confluence)			4.7	2.7	26.4	5.4	4.6	0.6	8.2	110	ND
15	Mountain View Culvert 2		7.5	5.4	2.6	25.8	5.4	4.7	0.6	9.6	114	ND
16	Lake View Park		7.56	12.1	2.6	43.3	8.7	19.3	2.2	25.2	152	ND
17	Monte Verde		8.29	7.8	2.6	35.5	7.0	15.5	0.5	28.5	120	0
18	Ponile Creek @ Bridge	123		12.0	2.4	28.0	7.7	4.2	0.7	70.4	88	0
19	Cimarroncita (1st upstream site of Island)			7.1	2.4	20.1	3.9	6.0	0.7	19.3	76	ND
20	City of Cimarron Bridge	221	8.13	8.1	2.5	22.8	4.8	6.1	0.5	26.0	84	0
21	Un-named Ditch	520		110.5	3.2	40.0	22.3	32.0	0.6	214.8	300	ND
22	Cimarron River @ Cimarroncita	189	8.23	6.5	2.4	20.7	4.1	5.9	0.6	19.3	76	0
23	Cimarron Tributary @ Cimarroncita	321		9.1	2.2	34.7	7.4	2.9	0.1	30.5	130	0.49
24	Irrigation Ditch [Springer Irrigation Ditch]		8.2	12.0	3.0	24.9	5.1	2.6	0.1	34.2	95	ND
25	Cimarron River Dwnstream Confluence @ CS	500	7.44	19.5	2.9	45.0	17.1	6.3	0.1	135.2	141	ND
26	Ponile Creek @ CS Ranch	1,565	8.45	43.2	3.8	61.7	32.4	8.8	0.6	316.2	173	ND
27	CS Ranch @ Miami Lane	357	7.3	15.3	4.0	34.9	10.3	7.5	0.7	90.4	111	ND
28	Cimarron River Boy Scouts Ranch-Site 1	219		7.4	2.4	22.7	4.5	5.8	0.5	20.0	82	ND
29	Rayado @ Confluence			16.6	2.9	41.7	14.6	7.3	0.7	134.2	133	4.603
30	Cimarron @ Confluence		8.29	72.7	3.3	121.6	58.0	16.3	0.7	857.7	146	0
31	Rayado Creek	115	8.9	3.9	2.5	8.6	3.1	2.8	0.5	8.6	45	ND
32	Vermejo N. Gate (T Turner Ranch) [Canadian	685	8.1	100.7	3.1	21.5	10.4	29.3	0.5	29.3	321	ND
33	Dos Rios Canadian River-Dwnstream of Conflu	2,140		169.0	5.1	140.3	83.7	65.1	0.7	1286.4	202	ND
34	Cimarron River @ Springer	1,430		74.8	3.3	118.2	61.3	20.9	0.1	770.6	171	ND

Nitrite and phosphate were not detected in any of the water samples collected.

Analyses of metals

Sample No.	**Sample Name**	**As (ug/L)**	**Al (mg/L)**	**Ca (mg/L)**	**Fe (mg/L)**	**K (mg/L)**	**Mg (mg/L)**	**Mn (mg/L)**
	Reporting Limits (ug/L)	**0.5**	**0.4**	**0.15**	**0.2**	**0.1**	**0.05**	**0.10**
1	Lake 13	0.43	ND	34.0	0.35	5.2	22.2	0.14
2	Lake 13 Inlet	0.66	ND	30.1	ND	3.8	15.4	0.14
3	Lake 12	1.88	0.44	49.3	0.25	6.3	19.7	0.23
4	Cimarron Boys Ranch N. of Island	0.82	ND	20.0	ND	2.3	4.0	0.17
5	Six Mile Creek	0.59	ND	31.4	ND	2.4	3.2	0.15
6	Cieneguilla (W. Tributary)	ND	ND	53.7	ND	2.8	8.6	0.14
7	Cieneguilla Creek Dwnstream of Angle Fire Village	0.65	ND	40.3	0.32	2.9	7.6	0.26
8	Cimarroncita Boy Ranch Corral	0.73	ND	20.4	ND	2.4	4.0	0.16
			ND	20.2	ND	2.4	4.0	0.16
9	Eagle Nest Lake	1.49	ND	30.9	ND	3.7	6.9	0.15
10	San Mateo & Country Club Cieneguilla	0.21	ND	24.7	0.21	2.8	5.9	0.14
11	Moreno Creek Inflow Eagle Nest Lake	0.96	ND	37.4	0.29	2.6	7.2	0.22
12	Tolby Day Use Area	1.58	ND	26.4	0.20	3.3	5.8	0.17
13	Morain Way (Dwnstream of Culvert)	2.00	ND	51.9	0.25	2.4	9.9	0.21
14	Morain Way (Confluence)	0.35	ND	26.4	ND	2.7	5.4	0.15
15	Mountain View Culvert 2	0.36	ND	25.8	0.26	2.6	5.4	0.17
16	Lake View Park	0.00	ND	43.3	0.29	2.6	8.7	0.41
17	Monte Verde	0.01	ND	35.5	ND	2.6	7.0	0.14
18	Ponile Creek @ Bridge	1.31	0.43	28.0	0.25	2.4	7.7	0.14
19	Cimarroncita (1st upstream site of Island)	1.20	ND	20.1	ND	2.4	3.9	0.16
20	City of Cimarron Bridge	0.51	ND	22.8	ND	2.5	4.8	0.15
21	Un-named Ditch	1.20	0.77	40.0	0.46	3.2	22.3	0.18
22	Cimarron River @ Cimarroncita	0.46	ND	20.7	1.58	2.4	4.1	0.16
23	Cimarron Tributary @ Cimarroncita	0.17	ND	34.7	ND	2.2	7.4	0.13
24	Irrigation Ditch [Springer Irrigation Ditch]	0.26	0.57	24.9	0.43	3.0	5.1	0.16
25	Cimarron River Dwnstream Confluence @ CS Ranch	0.34	ND	45.0	ND	2.9	17.1	0.14
26	Ponile Creek @ CS Ranch	1.28	0.44	61.7	0.28	3.8	32.4	0.90
27	CS Ranch @ Miami Lane	1.07	0.45	34.9	0.21	4.0	10.3	0.14
28	Cimarron River Boy Scouts Ranch-Site 1	1.01	ND	22.7	ND	2.4	4.5	0.14
29	Rayado @ Confluence	0.44	0.45	41.7	0.22	2.9	14.6	0.15
30	Cimarron @ Confluence	0.52	ND	121.6	0.43	3.3	58.0	0.16
			ND	81.6	0.32	3.1	36.3	0.15
31	Rayado Creek	0.27	ND	8.6	ND	2.5	3.1	0.13
32	Vermejo N. Gate (T Turner Ranch) [Canadian River]	0.60	0.53	21.5	ND	3.1	10.4	0.13
33	Dos Rios Canadian River-Dwnstream of Confluence)	ND	ND	140.3	ND	5.1	83.7	0.15
34	Cimarron River @ Springer	2.28	ND	118.2	ND	3.3	61.3	0.14
35	Playa Lake (Sub-surface)	2.35	0.46	32.6	0.22	5.3	73.4	0.13
36	Play Lake (Surface)		ND	270.7	ND	13.3	298.8	0.16

Sample No.	**Sample Name**	**Na (mg/L)**	**Ni (mg/L)**	**Pb (mg/L)**	**Se (mg/L)**	**Si (mg/L)**	**Sr (mg/L)**	**Zn (mg/L)**
	Reporting Limits (ug/L)	**0.7**	**0.20**	**0.40**	**0.75**	**0.20**	**0.10**	**0.10**
1	Lake 13	45.5	ND	ND	< 1 ug/L	2.01	0.51	0.26
2	Lake 13 Inlet	37.6	ND	ND	< 1 ug/L	1.76	0.48	0.24
3	Lake 12	28.5	ND	ND	< 1 ug/L	3.58	0.63	0.29
4	Cimarron Boys Ranch N. of Island	6.5	ND	ND	ND	4.01	0.17	0.22
5	Six Mile Creek	5.7	ND	ND	ND	3.30	0.13	0.28
6	Cieneguilla (W. Tributary)	18.7	ND	ND	ND	3.04	0.24	0.31
7	Cieneguilla Creek Dwnstream of Angle Fire Village	10.5	ND	ND	ND	8.21	0.21	0.29
8	Cimarroncita Boy Ranch Corral	6.5	ND	ND	ND	4.04	0.17	0.22
		6.5	ND	ND	ND	4.03	0.17	0.22
9	Eagle Nest Lake	13.5	ND	ND	ND	2.76	0.21	0.26
10	San Mateo & Country Club Cieneguilla	6.1	ND	ND	ND	10.11	0.15	0.23
11	Moreno Creek Inflow Eagle Nest Lake	11.8	ND	ND	ND	6.54	0.31	0.26
12	Tolby Day Use Area	11.6	ND	ND	ND	2.90	0.18	0.25
13	Morain Way (Dwnstream of Culvert)	11.6	ND	ND	ND	5.22	0.23	0.30
14	Morain Way (Confluence)	4.7	ND	ND	ND	9.97	0.12	0.24
15	Mountain View Culvert 2	5.4	ND	ND	ND	9.72	0.12	0.24
16	Lake View Park	12.1	ND	ND	ND	5.20	0.21	0.28
17	Monte Verde	7.8	ND	ND	ND	4.58	0.18	0.26
18	Ponile Creek @ Bridge	12.0	ND	ND	ND	4.38	0.32	0.24
19	Cimarroncita (1st upstream site of Island)	7.1	ND	ND	ND	4.05	0.16	0.22
20	City of Cimarron Bridge	8.1	ND	ND	ND	4.00	0.19	0.22
21	Un-named Ditch	110.5	ND	ND	ND	4.36	0.93	0.27
22	Cimarron River @ Cimarroncita	6.5	ND	ND	ND	4.14	0.17	0.23
23	Cimarron Tributary @ Cimarroncita	9.1	ND	ND	ND	6.53	0.41	0.26
24	Irrigation Ditch [Springer Irrigation Ditch]	12.0	ND	ND	ND	5.04	0.25	0.23
25	Cimarron River Dwnstream Confluence @ CS Ranch	19.5	ND	ND	ND	4.81	0.45	0.27
26	Ponile Creek @ CS Ranch	43.2	ND	ND	ND	4.08	0.78	0.30
27	CS Ranch @ Miami Lane	15.3	ND	ND	ND	4.84	0.31	0.26
28	Cimarron River Boy Scouts Ranch-Site 1	7.4	ND	ND	ND	4.03	0.18	0.22
29	Rayado @ Confluence	16.6	ND	ND	ND	4.99	0.40	0.29
30	Cimarron @ Confluence	72.7	ND	ND	ND	1.70	1.41	0.36
		44.7	ND	ND	ND	3.34	0.90	0.33
31	Rayado Creek	3.9	ND	ND	ND	7.59	ND	0.16
32	Vermejo N. Gate (T Turner Ranch) [Canadian River]	100.7	ND	ND	ND	4.31	0.46	0.22
33	Dos Rios Canadian River-Dwnstream of Confluence)	169.0	ND	ND	ND	2.88	2.21	0.36
34	Cimarron River @ Springer	74.8	ND	ND	ND	3.98	1.41	0.34
35	Playa Lake (Sub-surface)	213.3	ND	ND	151 ppb	1.57	0.39	0.25
36	Play Lake (Surface)		ND	ND	159 ppb	1.27	5.27	0.38

Note: Analyses for beryllium (Be), cobalt (Co), copper (Cu), nickel (Ni), and lead (Pb), were below reporting levels and are not listed. Barium (Ba) was detected at .207 mg/L in a single sample on Cieneguilla Creek and is also not listed.

Appendix II – Summary of Interview with Alán Huerta, Cimarroncita Ranch

6/9/2010 with Alán Huerta, Facility & Natural Resources Manager/Owner, Cimarron Conservation Camp (CCC); Cimarroncita Ranch, Ute Park New Mexico; P.O. Box 68, Ute Park, NM 87749 (575) 376-2376

Interviewees: Patricia Dominguez and Victoria R. Martinez

Mr. Huerta said that the water body that runs through his property is the Cimarron River but he feels that it is really become a large irrigation ditch. His purpose for the CCC is conservation, including passive restoration and recreation. It was originally established many years ago as a young ladies summer camp. The CCC currently provides fishing, horseback riding, hiking, and guided hunts. In the Cimarron River, there are Brown and Rainbow trout fish. With a good fishing guide, guests can catch and release up to 30 fish in one day. The water flow in the water way is typically between 10-60 cfs. Mr. Huerta has found that the optimal flow for a high quality fish environment is between 10-30 cfs.

Mr. Huerta has been trying to acquire donated water rights to keep the flow at an optimal level during drought or when diversions are high and is making efforts to spread information about conserving water by requesting irrigators irrigate at night to prevent evapotransporation. Mr. Huerta mentioned a Highland University website tool called ‘Land Sat’ in which irrigation activity can be viewed. It could potentially be used as a tool to determine who, if anyone, is abusing water rights.

It was discussed that Mr. Tim Farmer of the OSE has responsibility for administration of water on the Cimarron River. It was mentioned Mr. Huerta operates under Permit 51.

Mr. Huerta mentioned that an August 2009 water release from the deepest water level (tier 1) resulted in a large algal bloom, which resulted in low fish reproduction. The fish’s eggs needed to be able to latch onto the rocks, but the algal population blanketed much of the rock surfaces. Since the determination of the cause of the unfortunate water quality incident, Mr. Huerta is a strong proponent of water releases from tier 2 or 3 (middle to upper water striations). It was discussed that the lower tier 1 is rarely used, has higher organic matter and belongs (?) to original water right owners. The tier 2 water is typically used by Municipal and Industrial Water users, like Eagle Nest, Springer, Angel Fire and Raton) and Tier 3 is the top layer at Eagle Nest Lake, used for recreation.

Other information included; there has been beaver activity within the water stretch, cow grazing ceased in 1999 because of the overgrazing that had occurred. Passive restoration was allowed after that point. There are currently Parcharon Horses that graze in the area and they are invasive, but are currently on site for guests. Historically, Spaniards introduced sheep, but managed movement of the herds and would perform natural burning to rejuvenate the land. During the time of eastern migrants during gold rush time, a lot of land was devastated due to many trees being cut down (logging started around 1870) and the introduction of cows and overgrazing.

There was a 2001 Ponil Complex fire that burned about 262,000 acres and in 2002/2003 time frames, there was the Horse Shoe Fire. They did not seem to affect the water quality of the

Cimarron River, but did affect the middle and northerly Ponil River sites, with a lot of ash flow. There was an increase of temperature in the river, which cause the TMDL river.

There has been recent work on the river with support from a section 319 watershed restoration grant. One example give was of a low water crossing that caused deep cuts and it was repaired by giving the river greater meandering characteristics, planting of vegetation and put in several stream structures such as boulders and pools to dissipate water flow strength.