WATERSHED BASED PLAN FOR THE UPPER RIO GRANDE WATERSHED, COMANCHE CREEK SUBWATERSHED

Professional Services Contract # 17-667-2060-0005

Prepared by:

Submitted to:

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Table of Acronyms

Acronym	Full Name
AOI	Annual Operating Instructions
BMP	Best Management Practice
CCW	Comanche Creek Watershed
CCWG	Comanche Creek Working Group
CNF	Carson National Forest
CWA	Clean Water Act
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentive Program
FGDC	Federal Geospatial Data Committee
HQCAL	High-Quality Coldwater Aquatic Life
HUC	Hydrologic Unit Code
LLWW	Landscape position, Landform, Water flow path and Water body
NDVI	Normalized Difference Vegetation Index
NFF	National Forest Foundation
NMCHAT	New Mexico Critical Habitat Assessment Tool
NMDGF	New Mexico Department of Game and Fish
NMED	New Mexico Environment Department
NMHPD	New Mexico Historic Preservation Division
NRCS	Natural Resource Conservation Service
NWI	National Wetland Inventory
MUSYA	Multiple Use Sustained Yield Act
ONRW	Outstanding National Resource Waters
QAPP	Quality Assurance Project Plan
RERI	River Ecosystem Restoration Initiative
RGCT	Rio Grande Cutthroat Trout
RSP	River Stewardship Program
SSTEMP	Stream Segment Temperature Model
SWQB	Surface Water Quality Bureau
TMDL	Total Maximum Daily Load
TMU	Target Mapping Unit
TU	Trout Unlimited
US	United States
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VVGA	Valle Vidal Grazing Association
WAP	Wetland Action Plan
WBP	Watershed Based Plan
WQCC	Water Quality Control Commission

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ACKNOWLEDGEMENTS

Many individuals have worked to make the Comanche Creek Watershed a model for collaborative restoration in the southwestern United States. It is with gratitude that Quivira acknowledges the staff of the Carson National Forest and other members of the Comanche Creek Working Group. Without the commitment, collaboration, and support of the Questa Ranger District, the Comanche Creek Working Group would not have been successful in implementing projects and providing outreach to the stakeholder community for the past 18 years.

Many individuals at the Carson National Forest have made significant contributions over the years, including Jack Lewis, Greg Miller, Michael Gatlin, and George Long. Continued involvement and substantial support from the Valle Vidal Grazing Association, and from Mark Torres in particular, have been unparalleled. Many restoration contractors have contributed countless hours of unpaid work to make Comanche Creek projects and workshops happen year after year. Bill Zeedyk, Steve Carson, Craig Sponholtz, Jeffrey Adams, Neal Bertrando, Mark Reineke, Margie Tatro, Jan-Willem Jansens, and Aaron Kauffman have all contributed to both the art and the science of restoration in the Valle Vidal.

Staff from the New Mexico Environment Department have been critical to funding and completing substantial projects in the watershed without interruption since 2001. Abe Franklin, Maryann McGraw, Karen Menetrey, Alan Klatt, and Emile Sawyer have all contributed to projects in the watershed. Toner Mitchell of Trout Unlimited has stepped in to provide both higher level thinking and project management for being able to capture and capitalize on corporate funding sources. Philmont Scout Ranch, Conservation Department has been an invaluable partner, each year sending young, strong, and hilarious members of their conservation crew to volunteer at the annual Comanche Creek Volunteer Work Weekend.

Albuquerque Wildlife Federation and New Mexico Trout have made valuable contributions to restoration efforts in the watershed. Taos Soil and Water Conservation District was an early contributor to getting restoration projects off the ground. The New Mexico Department of Game and Fish (NMDGF) worked with Michael Gatlin to secure the NMDGF funding that will take restoration activities in the Comanche Creek Watershed to a whole new level. Finally, volunteers who have come to the Annual Comanche Creek Volunteer Work Weekends help all of the members of the Comanche Creek Working Group to remember just how lucky we are to be working with wonderful people in a truly beautiful landscape.

INTRODUCTION

The ultimate goals of this plan are to improve the condition of the Comanche Creek Watershed (CCW) (Fig. 1) to meet current water quality standards and to restore normal hydrologic function to Comanche Creek and its tributaries. The benefits of meeting these goals are numerous and include the primary objective of improving habitat for the Rio Grande cutthroat trout (RGCT). Secondary objectives include improving aquatic habitat for other native fish and aquatic species; improved habitat for wetland and riparian dependent species and improved habitat for upland terrestrial wildlife; providing the foundations for sustainable economic use; and creating enhanced recreational opportunities for people in local communities, as well as for visitors to the area.

Figure 1. Location of Comanche Creek Watershed within the Upper Rio Grande Watershed, Questa Ranger District, Carson National Forest, Taos County, New Mexico

The Comanche Creek Watershed is entirely within the Valle Vidal Management Unit of the Carson National Forest (CNF). It is under the management of a single federal agency (United States Department of Agriculture (USDA) Forest Service and is protected from future development. Both the primary and secondary objectives are consistent with current Forest Service management objectives for the Valle Vidal Management Unit. Most indicators of stream, riparian, and upland health are on upward trends, due to changes in management that occurred when the Forest Service gained ownership in 1982 and began restoration efforts.

QUIVIRA COALITION AND COMANCHE CREEK WORKING GROUP RESTORATION EFFORTS

Founded in 1997 by two conservationists and a rancher, the Quivira Coalition is a nonprofit organization based in Santa Fe, New Mexico. Quivira's mission is *to build resilience by fostering ecological, economic, and social health on western working landscapes through education, innovation, collaboration, and progressive public and private land stewardship*. Since 2001, the Quivira Coalition, in partnership with numerous organizations and state and federal agencies, has led a habitat restoration project on the CCW, along with the collaborative stakeholder group, the Comanche Creek Working Group (CCWG) (a watershed association). The CCWG is working to support and create positive change on the ground, working on stabilization and restoration activities continuously since 2001.

Different innovative restoration techniques are being tested in the watershed. Restoration and stabilization techniques (designed by Bill Zeedyk and many other restoration professionals) aim to store water in wetland soils in the face of a hotter and dryer Southwest (Zeedyk et al. 2014a and Zeedyk et al. 2014b).

The goals of the stakeholders in the working group include

- improving stream channel and associated wetland and riparian habitat conditions;
- improving water storage function of wetlands and associated riparian vegetation zones; and upland habitats;
- improve water quality;
- providing opportunities to educate the public about the importance of the watershed, its native trout populations and associated aquatic and wildlife assemblages; and
- serve as a demonstration forum showcasing the type of multiple use management practices that are effective in restoring and maintaining ecosystem function to support wildlife and livestock use of public lands.

The objectives of the Watershed Based Plan (WBP) proposed by Quivira and the CCWG partnership are to

- manage the watershed as an integrated whole;
- improve wetland, riparian, and upland habitat conditions;
- develop a plan and identify project proposals to reduce stream in Comanche Creek, Holman Creek, LaBelle Creek, and Gold Creek;
- improve soil water storage in headwater wetlands;
- improve habitat for the Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*);
- protect and restore water quality that supports the designated uses for surface water in Comanche Creek, which include domestic water supply, high quality coldwater aquatic life, irrigation, livestock watering, primary contact, and wildlife habitat;
- further solidify the Comanche Creek Working Group as the diverse stakeholder partnership for continued efforts in the watershed; and
- create a demonstration site showcasing multiple-use management practices that are effective in restoring and maintaining wetlands on public lands.

Quivira and the CCWG have successfully used practices and treatment options inspired by restoration experts to improve conditions in the watershed. References to the many publications that showcase these practices are cited in the Reference section.

CCW Site Description

Comanche Creek is located in northern New Mexico's Sangre de Cristo Mountains, in the Upper Rio Grande River Basin (United States Geological Survey (USGS) Hydrologic Unit Code (HUC) 13020101015) (Fig. 1). The entire watershed lies within the Valle Vidal Unit, Questa Ranger District, Carson National Forest, Taos County, New Mexico. The CCW contributes 27,430 acres (43 square miles) to the Costilla Watershed (Pittenger 2001). The average elevation of headwater tributaries to Comanche Creek is roughly 10,400 feet. All of the waters within the watershed are designated as Outstanding National Resource Waters (ONRWs) by the New Mexico Water Quality Control Commission (WQCC).

Currently, four creeks in the watershed are impaired by high water temperatures that do not support their designation as supporting high-quality cold water aquatic life (HQCAL) according to New Mexico Environment Department's (NMED) 2004 and 2011 Total Maximum Daily Load (TMDL) reports (Fig. 2).

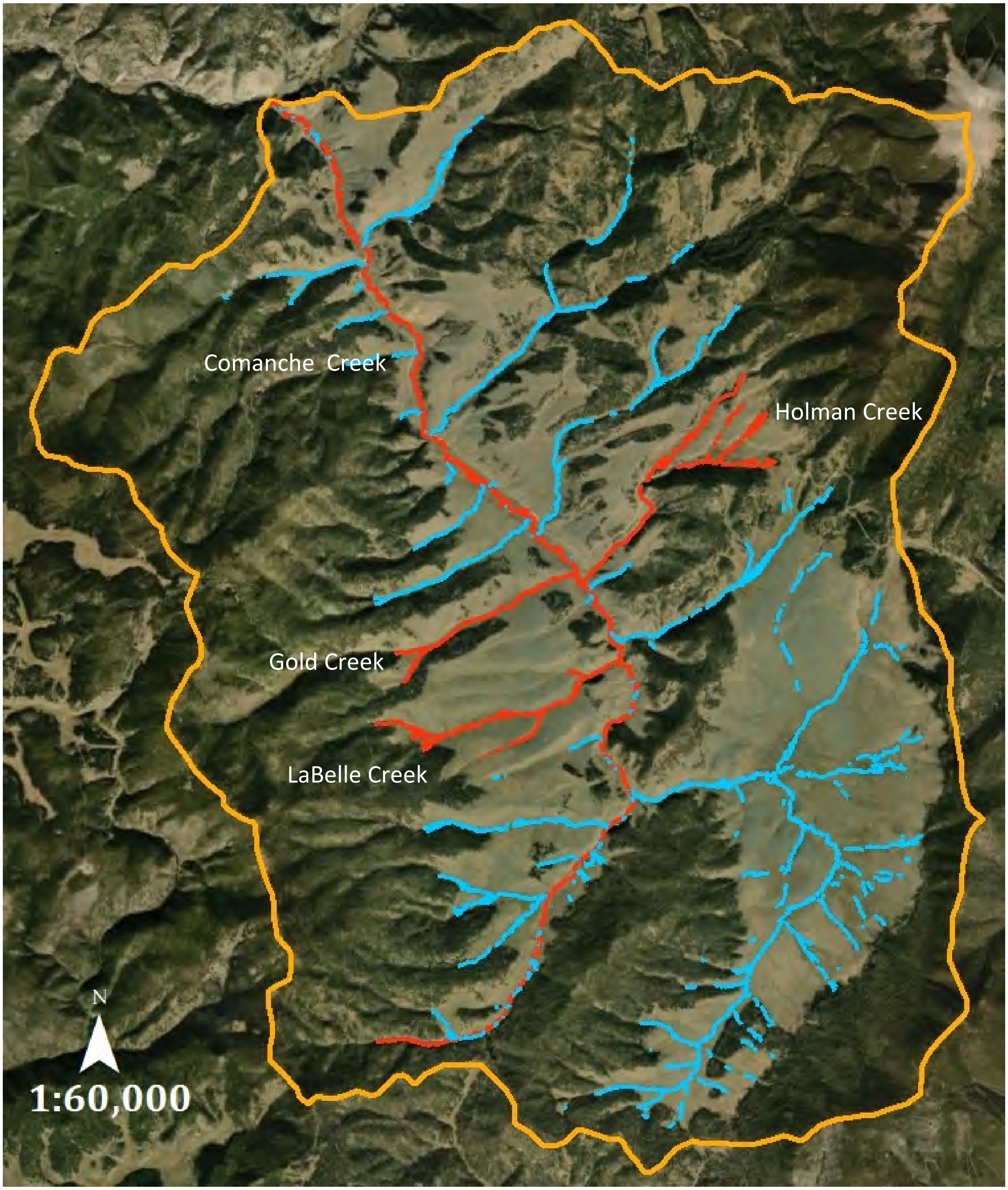

Figure 2. Impaired streams in the Comanche Creek Watershed in red

Geographical Context

Comanche Creek is an upper tributary to Costilla Creek, which delineates the boundary between the Culebra Range and the Taos Range of the Sangre de Cristo Mountains. The Sangre de Cristo Mountains are a north-trending chain of mountains that runs from northern New Mexico to southern Colorado and rises between the Rio Grande depression on the west and the Raton Basin on the east. The Culebra Range includes predominantly volcanic, conical peaks with narrow ridges of outwardly radiating dykes. Peaks of the Taos Range vary from 12,000 to more than 13,000 feet and include Wheeler Peak (elevation 13,173 feet), the highest point in New Mexico (Clark 1966).

Geology and Soils

Surficial deposits within the Comanche Creek Basin include valley alluvial deposits, mass-wasting, and middle Pleistocene- to Holocene-aged, glacially deposited terraces. Geology of Comanche Creek Basin is dominated by Lower and Middle Santa Fe Group (Tsf), Tertiary-aged, coarse grained, mixed clastic rock, unconsolidated, and plutonic rock of the Lower Proterozoic (Xg). Other rock units found in the CCW include Tuv, Tertiary-aged volcanic, and some volcaniclastic rock; Ti, Tertiary plutonic, and silicic to intermediate intrusive rock; Tvs, Tertiary sedimentary, and volcaniclastic rocks; Xvm, Lower Proterozoic mafic metamorphic rock; and Xs, Lower Proterozoic-aged metasedimentary rock (Clark 1966) (Fig. 3).

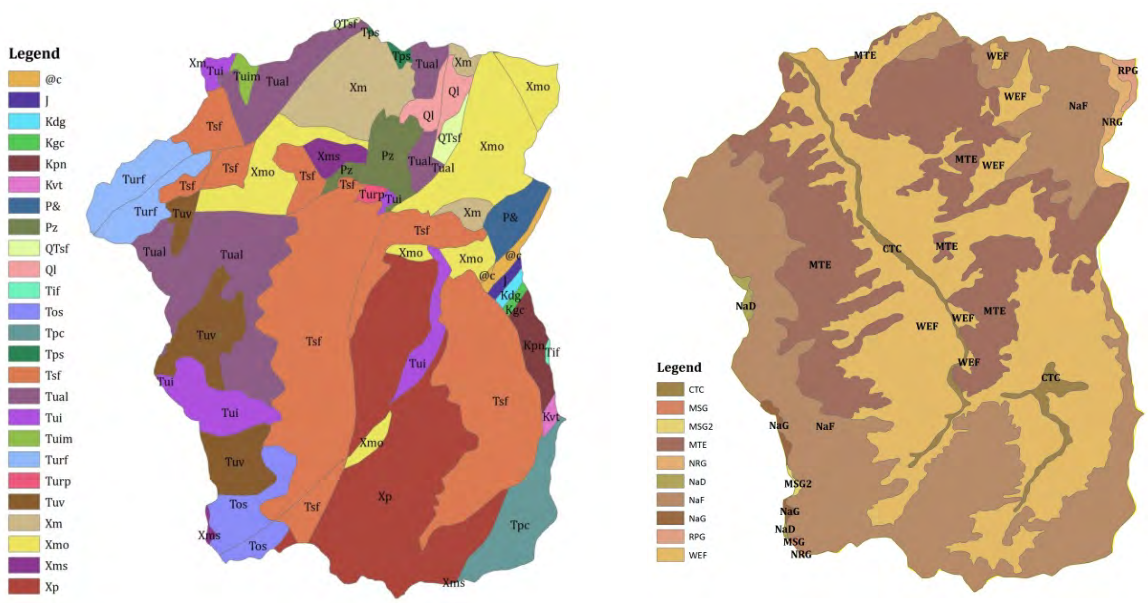

Figure 3. Geology of the Comanche Creek Watershed (left) and soil types in the watershed (right)

There are limited small-scale geologic maps available for this region of northern New Mexico and none available that include the entire CCW (Fridrich et al. 2012). Figure 3 shows the generalized geologic setting and soil types within the watershed. The image is an excerpt from a 1:500,000 scale New Mexico geologic map published by New Mexico Bureau of Geology and Mineral Resources (2003). For the legend key to the geologic map, see https://geoinfo.nmt.edu/publications/maps/geologic/state/home.cfml#download.

Soils in the CCW are dominantly Nambe cobbly loam, Wellsville-Ess association, and Marosa-Nambe association. Cryoborolls-Cryaquolls complex are alluvial deposits weathered from granite found along stream channels in the high-elevation mountain valley bottoms. For additional soil descriptions, a complete Custom Soil Resource Report for the CCW may be generated by the National Cooperative Soil Survey (USDA NRCS Web Soil Survey).

Hydrogeology and Surface Hydrology

The CCW hydrology is shallow, high elevation groundwater storage, feeding intermittent, ephemeral, and perennial channels (Figure 4). The hydrological cycle is driven by snowmelt runoff in the early spring, monsoon rains in July and August, and springs where groundwater emerges at the surface. The upper basins are home to extensive wetland meadows, fens, and springs. Faulting and porous rock layers (aquifers) that expel water in the form of springs in the valley walls or floor often dictate the location of slope wetlands. Riparian wetlands and slope wetlands are found within the tributary watersheds that make up the larger CCW. Wetlands classified in 2012 and 2013 according to the methods described below (Tiner 2011) are shown in Fig. 4.

In 2013, wetlands in the Canadian River Basin were delineated as part of a U.S. Environmental Protection Agency (EPA) grant to the NMED SWQB, Wetlands Program. In this effort, the wetlands within the CCW (in the Lower Rio Grande Basin) were also delineated. The *Mapping and Classification for Wetlands Protection, Northeastern New Mexico Highlands and Plains Project* relies on the subjective interpretation of wetland boundaries and wetland classification characteristics from a primary aerial image source supported by consultation with collateral spatial data.

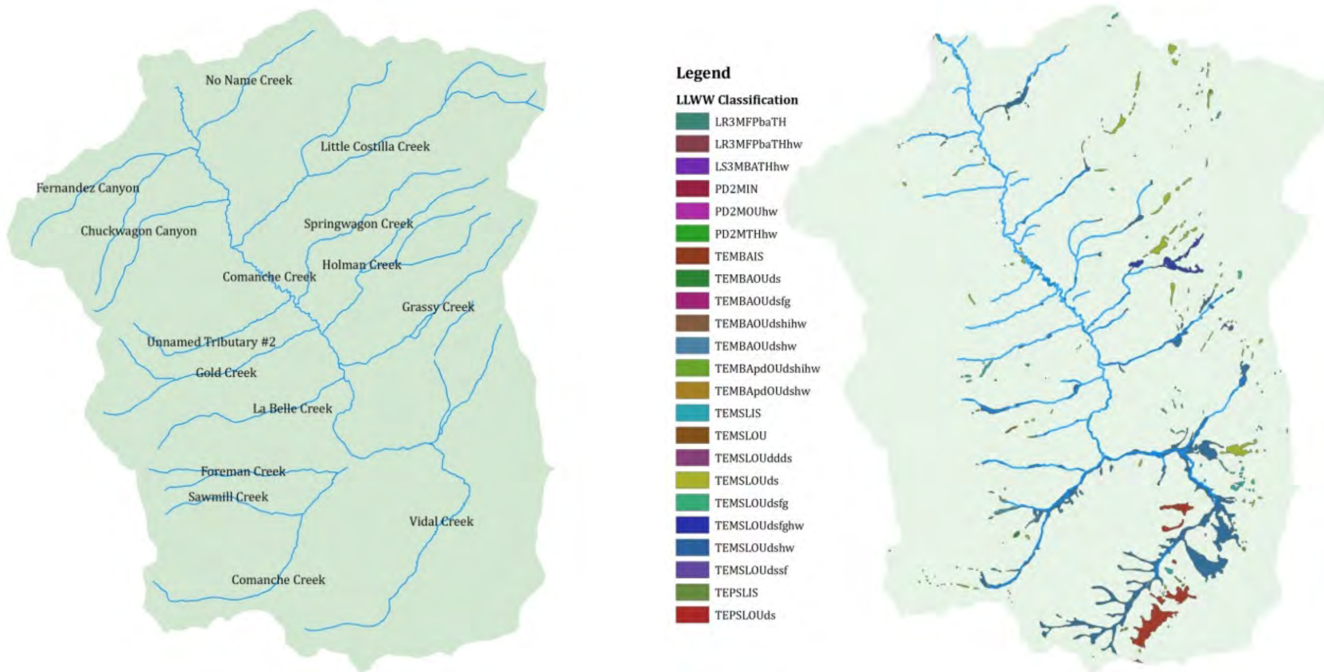

Figure 4. Creek names and NWI mapping data

The entire watershed was mapped for wetlands following the National Wetland Inventory (NWI) mapping conventions using the Cowardin System for classifying wetlands (Cowardin and Golet 1995) and the System for Mapping Riparian Areas in the Western United States (USFWS 2009); classification of wetlands using the LLWW functional assessment classification, which considers landscape position, landform, water flow path, and water body types (Tiner 2003); development of wetland classes and subclasses according to hydrogeomorphic characteristics (Brinson 1993); wetland photo interpretation from a variety of input image and collateral data sources; and field verification. All mapping was completed with at least 1:12,000 resolution—with a target mapping unit (TMU) of 0.5 acres or better—and complies with the National Wetlands Mapping Standard of the Federal Geospatial Data Committee (FGDC). The results of this wetland identification and classification effort help guide planning for wetland restoration efforts in the CCW.

ECOLOGICAL CONTEXT

The health and function of headwater slope wetlands in places such as the CCW are important to the function of the larger, surrounding watersheds. In this case, the larger watershed that includes the CCW flows into the Rio Grande via the Rio Costilla. Restoration in the headwater slope wetlands has the effect of improving water availability over time to the Rio Grande, the largest river system in New Mexico. The CCW is within the Southern Rockies Ecoregion 21, has broad, open valleys within high mountain peaks, and is further broken down into the regions labeled in Fig. 5. The vegetation community is dependent upon both the soils and the combined amount of surface and groundwater available at a particular site.

High, intermontane valleys of the CCW have sufficient water availability to support grasslands, wet meadows, and slope wetlands. Bunchgrasses are the dominant vegetation type, with few and scattered shrubs and subshrubs (Griffith et al. 2006). The majority of the creeks and wetlands are in the Grassland Park subecoregions (Fig. 5). Alder, willow, and narrowleaf cottonwood do exist in the lower reach of Comanche Creek and in limited locations in Gold Creek and Holman Creek. LaBelle Creek is largely devoid of any riparian trees or shrubs.

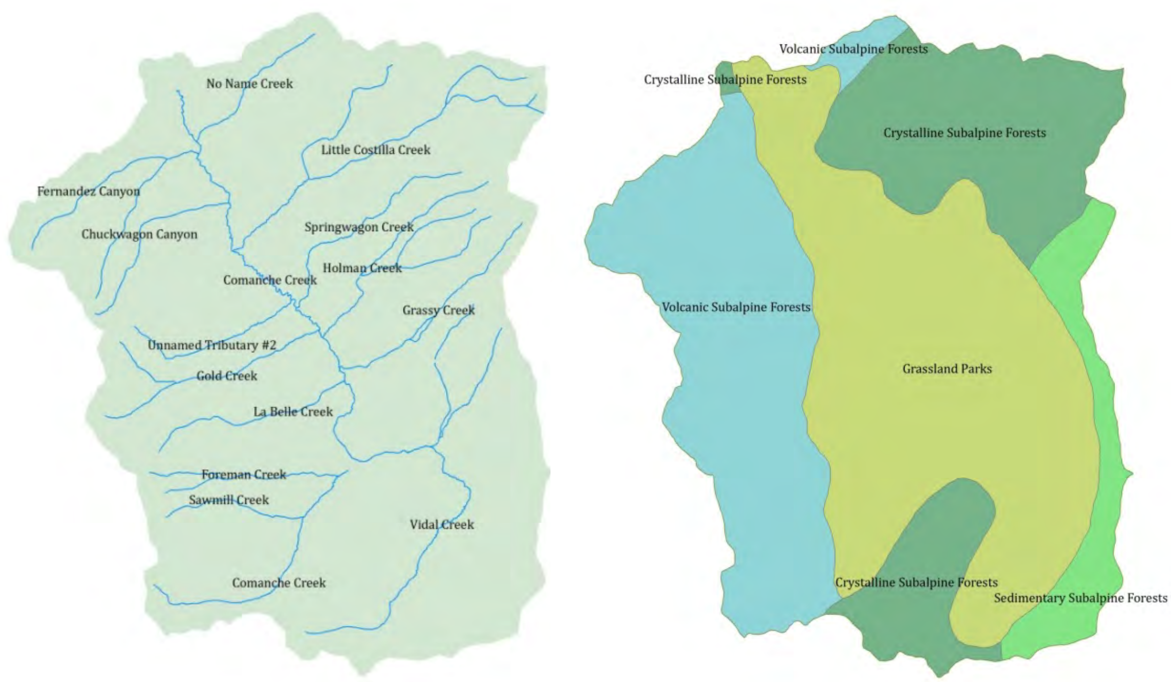

Figure 5. Subecoregions within the Southern Rockies Ecoregion 21 for the Comanche Creek Watershed (EPA 2011)

In slope wetlands that are not affected by degradation, vegetation is dominated by sedge species (*Carex* Spp.). In slope wetlands that have begun to degrade as the result of a change from dispersed flow to channelized flow, the vegetation will change to a mix of sedge with an increased component of species that can tolerate the dryer soil conditions (Fig. 6).

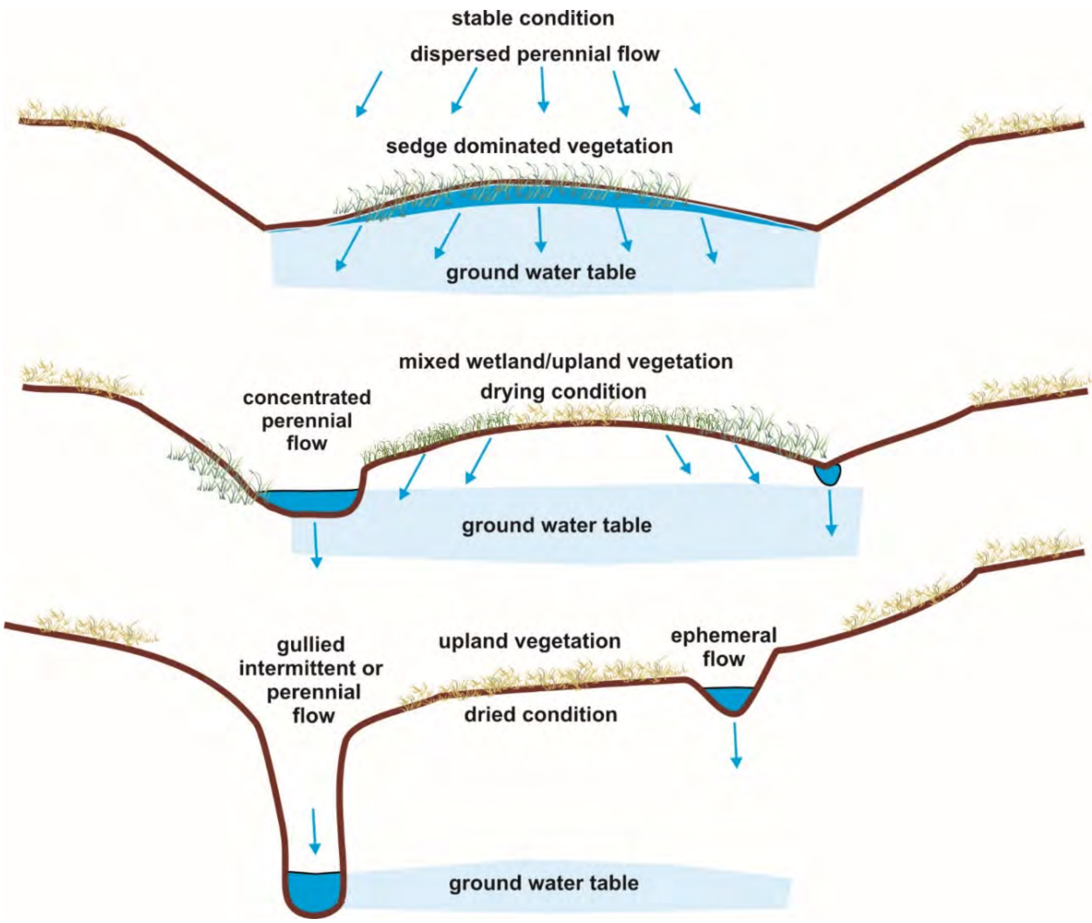

Figure 6. Wetlands in stable condition feature dispersed (sheetflow) over the channelized flow of a degraded wetland system (Zeedyk et al. 2014b).

Soil surface roughness (created in part by vegetation) favors sheetflow when the surface is of a relatively similar elevation. If the surface is very rough with large differences in surface elevation within a small area, the lowest places will intercept dispersed flow. Water will then flow to the lowest place on the landscape and begin to form a system in which surface roughness no longer facilitates dispersal but instead favors channelized flow. Channels are not a component of healthy slope wetland systems. Dispersed flow is integral to the formation and continuing function of slope wetland complexes. The presence of channels, and particularly incised channels, is a sign of degradation in these systems. It may be that prior to all the extractive land use in the watershed, Gold Creek, LaBelle Creek and Holman Creek were more extensively covered by slope wetlands than single creek channels.

Once a slope wetland complex has dried and is no longer continually saturated, or even seasonally saturated, the vegetation will transition to a combination of facultative and upland species. Once these species are dominant, the wetland and its associated ecosystem services are effectively gone. Depending on site conditions, it may or may not be possible to reverse this transition and reestablish a wetland or a wet meadow.

Wildlife Habitat

The CCW is home to a variety of large mammals, including mule deer, elk, black bear, and mountain lion. There are also many species of smaller animals, native Rio Grande cutthroat trout, and song birds. The New Mexico Crucial Habitat Assessment Tool (NMCHAT) is a web-based map tool, designed to aid early landscape-level planning, with spatial information on sensitive species and habitats across New Mexico (http://nmchat.org/). It is intended for conservation managers, industry, and the public to identify priority habitat. The website is a result of the collaboration between the NMDGF and Natural Heritage New Mexico. Table 1 contains Federally Listed species for Taos County, New Mexico, Forest Service Sensitive Species for the Questa District of the CNF, and Species of Concern for the State of New Mexico. Of the species in this table, only the RGCT occur in the CCW. Most of the restoration work in the watershed is undertaken to positively affect habitat for the RGCT.

Table 1. Federally Listed species for Taos County, New Mexico, Forest Service Sensitive Species, and State of New Mexico Wildlife Species of Concern (T = Threatened, E = Endangered, FSS = Forest Service Sensitive, and SC = Species of Concern)

Group	Species	Federal Status	Forest Service Sensitive	State of NM Status
Mammals	Canada lynx (*Lynx Canadensis)* Critical Habitat	T		
	Black-footed ferret (*Mustela nigripes*)	E		
	New Mexico meadow jumping mouse (*Zapus hudsonicus luteus)* Critical Habitat	E		
	Masked shrew (*Sorex cinereus cinereus*)		FSS	
	Water shrew (*Sorex navigator*)		FSS	
	Gunnison's prairie dog (*Cynomys gunnisoni*)		FSS	
	American marten (*Martes americana origenes*)		FSS	
Birds	Southwestern willow flycatcher (*Empidonax traillii extimus)* Critical Habitat	E		
	Western yellow-billed cuckoo (*Coccyzus americanus)* Critical Habitat	T		

Group	Species	Federal Status	Forest Service Sensitive	State of NM Status
	Mexican spotted owl (*Strix occidentalis lucida)* Critical Habitat	T		
	Bald eagle (*Haliaeetus leucocephalus*)		FSS	
	Northern goshawk (*Accipter gentiles*)		FSS	
	American peregrine falcon (*Falco peregrinus anatum*)		FSS	
	White-tailed Ptarmigan *(Lagopus leucurus)*		FSS	
	Boreal owl (*Aegolius funereus*)		FSS	
Fish	Rio Grande Cutthroat Trout (*Oncorhynchus clarki virginalis*)		FSS	SC
Plants	Robust larkspur (*Delphimium robustrum*)		FSS	
	Arizona willow (*Salix arizonica*)		FSS	

Figure 7 shows critical habitat for RGCT. Forest Service sensitive species for the CCW area of the CNF were obtained from the Regional Forester's list of sensitive plants and animals (USDA Forest Service 2013). Only those species with potential for habitat within the project area are listed in Table 1.

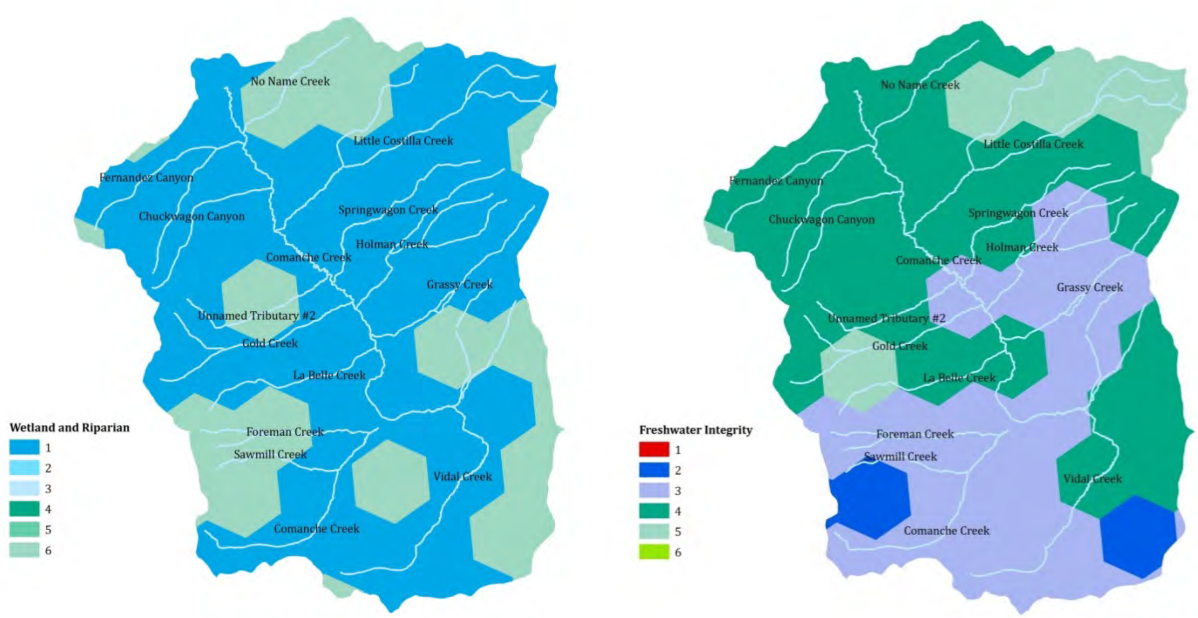

Figure 7. Critical riparian habitat in the CCW for the RGCT (1 is the most critical and 6 is the least critical habitat designation) (left). The freshwater integrity of the watershed is mostly at low risk for degradation (1 is at highest risk and 6 is at least risk of degradation) (right).

The CCW is protected from high risk of degradation to the habitat’s freshwater integrity (Fig. 7) because of the protective management of the United States Forest Service (USFS), CNF and the designation waters within the Valle Vidal as ONRWs.

SOCIAL CONTEXT

HISTORIC LAND USE

The CCW is one part of the larger Valle Vidal Unit in the Carson National Forest. The Valle Vidal Unit was donated to the USFS by Pennzoil in 1982 in exchange for a tax debt (Valle Vidal Deed 1982). The land area has been heavily used by human populations throughout recorded history. The land was occupied by the Jicarilla Apache and others before them (Montoya 2002). Colonization of the area by the Spaniards in the 1500s brought more settlers to the area. At one time, under the Maxwell Land Grant, granted by the Mexican government and then recognized by the United States (US) Government, the owner, Lucien Maxwell, employed more than 500 people who cultivated many acres and also ran large herds of sheep and cattle. Mining was also a common activity in the watershed after gold was discovered in the late 1800s in the Maxwell Land Grant (Fig. 8).

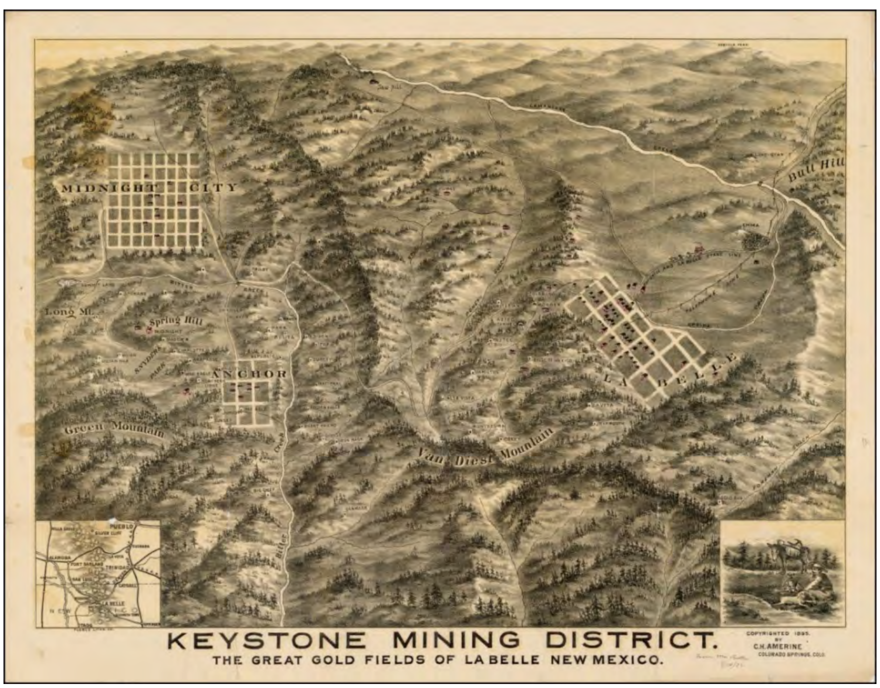

Figure 8. Historic map of the LaBelle and Gold Creek area of the CCW showing the nature of extractive industry in the watershed during the late 1800s (unrecorded birdseye-view style map of the Keyston Mining District, showing the gold fields of La Belle, New Mexico, lithographed by the Pueblo Lith Co. and published by C.H. Amerine of Colorado Springs, Colorado in 1895)

Some photos from this time showcase the intensity of activity that caused lasting degradation in the streams, wetlands, and uplands of the CCW (Fig. 9). Heavy grazing pressure (thousands of cattle and sheep) continued in the watershed up to the time Penzoil acquired the land in the 1960s. Trails from cattle and horses likely had significant negative impact, capturing early snowmelt in the spring, which contributed to channelization in the headwater wetlands.

Figure 9. La Belle, NM circa 1898 (photo courtesy Carson National Forest) (top left), mine and sluice on La Belle Creek, circa 1890s (photo courtesy Carson National Forest)(top right), placer mining in La Belle, New Mexico between 1890 and 1910 (Denver Public Library, Western History Collection, Aultman, Otis A., 1874-1943. CHS.A646) (bottom left), land impacted by livestock grazing in what is now Philmont Scout Ranch (photographers unknown) (bottom right).

Timber rights were in a third-party ownership and did not belong to Pennzoil to be transferred with the surface ownership. The rights belonged to a logging company with lumber mills in both Amalia and Cimarron. The CCW was logged using the "jammer logging" method, which uses a cable and winch system to drag or skid logs uphill to a collection and loading area (Stokes et al.

1989). Jammer cables have a limited reach of 100 to 300 feet; therefore requiring the construction of closely-spaced roads— in this instance, every 150 feet. Timber harvesting and the subsequent construction of many logging roads further impacted the watersheds of the Valle Vidal. Logging road construction resulted in changed water drainage patterns throughout the watershed. These road networks are clearly visible in aerial photos (Fig. 10). More than 700 miles of abandoned logging roads were drained and closed to traffic in the two years following acquisition of the Valle Vidal Unit by the USFS in 1982.

Figure 10. Aerial photograph from September 8, 1974 showing logging roads in headwaters of Comanche Creek (southernmost portion of the watershed)

The current condition of CCW creeks, wetlands, and wet meadows, and of its tributaries, is a product of past human land use within the watershed. This historical use has contributed to a significant amount of soil erosion, increase in sediment load in the streams, increases in stream water temperature, and overall degradation of riparian and wetland ecosystem services (Fig. 11).

Figure 11. Current conditions in Gold Creek in August 2018 showing downcut and incised channel with abandoned wetland floodplains

When the USFS gained ownership of the Valle Vidal, and within it the CCW, there was much to do to improve upon and reverse the impacts of the legacy land uses. In addition to closing logging roads, considerable restoration activities occurred after the USFS acquired the property, including the reduction of livestock numbers and a shift from season-long to rotational grazing in pasture systems. Grazing management, logging road closures, and improved road drainages all had a considerable positive impact in the watershed.

Present Land Use

Under management of the USFS, the Valle Vidal Unit is administered for multiple use and sustained yield after the Multiple Use-Sustained Yield Act of 1960 (MUSYA 1960), as modified by the National Forest Management Act. This law authorizes and directs the Secretary of Agriculture to develop and administer the renewable resources of timber, range, water, recreation, and wildlife on the national forests for multiple use and sustained yield of products and services (USFS Carson National Forest 1982).

The Valle Vidal Gazing Association (VVGA), under Forest Service authorization, uses the CCW and other pastures in the Valle Vidal Unit for summer grazing. Firewood harvesting permits are issued annually. A large elk herd managed by NMDGF brings many wildlife viewing and hunting enthusiasts into the watershed. The area is a popular hiking and camping location and is also a well-known destination for back country horseback groups. People also come to the CCW for catch-and-release fishing of Rio Grande cutthroat trout.

The health of headwaters tributaries to Comanche Creek is important to the function of the larger watershed. In this case, the larger watershed flows into the Rio Grande. Restoration in the headwaters has the effect of improving water base flow to the largest river system in New Mexico (Earman et al. 2004). The Rio Grande supports a high diversity of wildlife populations and provides drinking water to portions of the human populations in all or parts of Bernalillo, Catron, Cibola, Doña Ana, Grant, Hidalgo, Lincoln, Los Alamos, Luna, McKinley, Otero, Rio Arriba, Sandoval, Santa Fe, Sierra, Socorro, Taos, Torrance, and Valencia counties. It is not only the largest and but also the most populated river basin in New Mexico (Longworth et al. 2013).

Current understanding of the local effects of climate change include a significant increase in the severity and intensity of precipitation events, increased stream water temperatures, earlier snowpack runoff, and more severe and longer lasting droughts, all of which will increase stress on and put riverine, riparian, and wetland systems at risk (Garfin et al. 2013). Restoration activities in headwater systems ensure that the lower waterways can continue to support both human and wildlife populations in New Mexico in the face of climate change and extended droughts. If this ecosystem decline is not addressed in a proactive manner, there is the sobering probability that the associated ecological functions and services that humans depend on will suffer continued degradation as well.

The restoration of the creeks and wetlands within the CCW will implement proven, effective, cost-efficient, low-impact restoration techniques in order to help ensure that the current state of the CCW is maintained. The waters within the Valle Vidal Unit of the CNF are designated as ONRWs as stated by the Water Quality Control Commission (WQCC) (2000). This designation requires a higher standard of federal permitting in order to conduct restoration work in the creek channels.

Project Overview

Restoration projects in the CCW represent long-term investments by stakeholders of the Comanche Creek Working Group. Work has been completed on the Comanche Creek mainstem and in several of the upper tributaries to Comanche Creek, funded from many different sources. Road closures and placement of additional culverts have greatly reduced sediment in the streams of the watershed. Much of this work was completed by Zeedyk Ecological Consulting and Rangeland Hands, with funding by the USFS. Increasing the sinuosity of the creeks and stabilizing banks has also helped to improve water quality in the watershed. Trout Unlimited and Watershed Artisans, Inc. ha utilized funding from corporations (Coca Cola and Intel) seeking to implement wetland restoration projects for "water replenishment" values. These entities have contributed funding to restoration projects since 2015 (Coca Cola) and 2018 (Intel). Watershed Artisans, Inc., in coordination with Trout Unlimited (TU), completed a project to stabilized stream channel and slope wetlands in Gold Creek and the lower portion of Holman Creek in 2016. Additionally, the Watershed Artisans, Inc. team restored channel complexity and reconnected floodplain access and overbank flow to portions of riparian wetlands on Comanche Creek in 2017 and 2018.

The Quivira Coalition has a current project in Holman Creek funded by the NMED SWQB Wetlands Program. Other NMED SWQB projects have funded restoration activities in Foreman, Sawmill, Grassy, and Springwagon creeks. Restoration work completed in upper tributaries to Comanche Creek is part of a strategy to positively impact water quality before the water flows into the Comanche Creek mainstem.

NMDGF funded a project in 2019 in Holman Creek with Reineke Construction. Funding is also being requested under this program for restoration work in LaBelle Creek. NMDGF has funded many projects in the watershed to date.

Each project in the watershed is undertaken with the goal of stabilization and restoration of the degraded ecological function of creeks and wetlands in the watershed. Solving elevated temperature is a water quality problem that is difficult and is based on the complexity of factors contributing to the heat budget of stream systems (Kasahara and Wondzell 2003, Johnson 2004, Schuum 2005, Arrigoni et al. 2008, Buffington and Tonina 2009, Cranswick et al. 2014, Caissie and Luce 2017, and Surfleet and Louen 2018).

Many different best management practices are necessary to overcome temperature impairments in the largely grassland riparian ecosystem of the CCW. Shade canopy from riparian trees and shrubs will not be sufficient to reduce summer water temperatures, based on ecological limitations for woody riparian species in a Grassland Park Ecoregion. Where sedges dominate, additional stream-temperature-reducing BMPs will be needed.

Nine Elements of a Watershed Based Plan

The EPA has Nine Key Elements to address in the development of a Watershed Based Plan (WBP). The Nine Elements are:

1. Identify the causes and sources of temperature impairment
2. Estimate load reductions
3. Management measures to support load reductions
4. Technical and financial assistance needed
5. Education and outreach
6. Implementation schedule
7. Measurable milestones of implementation
8. Criteria for evaluating load reduction achievements
9. Monitoring program

Identify the Causes and Sources of Impairment

Causes of Impairment

Historic overuse on the land in the Comanche Creek Watershed resulted in degraded watershed function. Most sources of impairment in the watershed are non-point sources resulting from legacy use as well as current land use. These activities left the watershed degraded in many places, with incised creeks, shrinking wetlands, and a lowered groundwater table. Elevated water temperatures are believed to be caused by lack of riparian vegetation to shade the stream or changes in stream morphology due to historic management practices that resulted in widened, shallow streams or narrow, downcut channels, and a reduction in undercut banks.

Since 1982, 700 miles of roads have been closed in the Valle Vidal Unit of the Carson National Forest, and livestock numbers have been reduced to one-third of the animal units that grazed in the watershed prior to ownership conversion to the CNF. Grazing and browsing by cattle and elk have an important impact on riparian and wetland health as well as uplands. Managed grazing by the VVGA will help to reduce this as a primary source of watershed health impairment. Elk use is largely uncontrollable except for the use of exclosure fencing, which has limited value at the watershed scale.

In the past 34 years, the hydrological condition and channel stability of the Comanche Creek mainstem have improved. However, degraded riparian and wetland areas still require much stabilization and restoration to bring the system back to a condition where all designated uses are met, particularly the support of high quality, coldwater aquatic life. Intact and properly functioning wetlands in the upper tributaries should store water in wetland soils and slowly release it to downstream habitats, thus acting as a temperature buffer (Arrigoni et al. 2008) for streamflow entering the Comanche Creek mainstem.

In the 2011 NMED TMDL Report, many sections of Comanche Creek were successfully delisted for sediment exceedances in response to restoration efforts in the watershed. In 2013, Comanche Creek was featured as a Section 319 Nonpoint Source Program Success Story (EPA 2013). However, portions of La Belle, Holman, and Gold creeks are still listed for TMDL temperature exceedance (Figure 2, Table 2). Probable current sources for impairment include rangeland grazing, impact on riparian habitat by cattle and elk in the absence of predators, and loss of riparian habitat due to eroded and destabilized watershed conditions.

Over time these conditions have reduced wetland habitat and negatively impacted upland drainages by the creation of numerous headcuts and gully formations affecting stream water quality, and decreased water flow in streams throughout the uppermost reaches of the CCW. These degraded channels cause water to flow through the system more quickly than if the riparian and wetlands ecosystems were performing to the pre-degradation capacity in their performance of ecosystem services (Schumm 2005).

Currently, members of the CCWG are collaborating to improve rangeland grazing practices in the CCW. Trout Unlimited is spearheading a project to work with grazers to improve upland conditions, which will ultimately improve trout habitat. The VVGA is actively collaborating on this project.

Table 2 lists probable sources of impairment for each stream reach that does not meet water quality criteria, based on the 2004 TMDL for Comanche Creek and the 2011 TMDL for Holman, Gold, and LaBelle creeks. Sources can be either pollutants or stressors. Forest roads and low water crossings are likely no longer an important source of impairment.

Table 2. Comanche Creek watershed tributaries listed in the 2004 and 2011 CWA 303(d)/305(b) Integrated List & Report

Impaired Creek	Assessment Unit ID	Impairment (TMDL)	Probable Sources
Comanche Creek	NM-2120.A_827	Temperature not supporting High Quality Coldwater Aquatic Life	Channelization, hydro-modification, drought-related impacts, forest roads, low water crossing, rangeland grazing, and wildlife other than waterfowl
Gold Creek	NM-2120.A_835	Temperature not supporting High Quality Coldwater Aquatic Life	Channelization, drought-related impacts, forest roads and low water crossing, rangeland grazing, wildlife other than waterfowl, and unknown sources
Holman Creek	NM-2120.A_837	Temperature not supporting High Quality Coldwater Aquatic Life	Channelization, drought-related impacts, forest roads and low water crossing, rangeland grazing, and wildlife other than waterfowl
LaBelle Creek	NM-2120.A_839	Temperature not supporting High Quality Coldwater Aquatic Life	Channelization, drought-related impacts, forest roads and low water crossing, rangeland grazing, and wildlife other than waterfowl

The effects of climate change in the southwestern US are thought to be significant, although climate change is not listed as a probable source in Table 2. Garfin and others (2013) predict that droughts in parts of the Southwest will become hotter, more severe, and more frequent under future climate change scenarios. Climate stressors are another component of the preservation or restoration success for addressing water quality concerns in the watershed. Restored watersheds are more likely to have greater resiliency than nonfunctioning watersheds and will be more likely to maintain greater function under climate change scenarios. Increases in the severity and intensity of precipitation events and earlier seasonal snowpack runoff will impact the stability of the wetland and streams and RGCT habitat quality (Williams et al 2009).

However, there is hope and a continued reason to restore and protect streams in the watershed. Recent literature suggests that although climate change effects are largely deleterious to headwater systems, they may not be as dire as once feared (Morelli et al 2016) (Fig. 12).

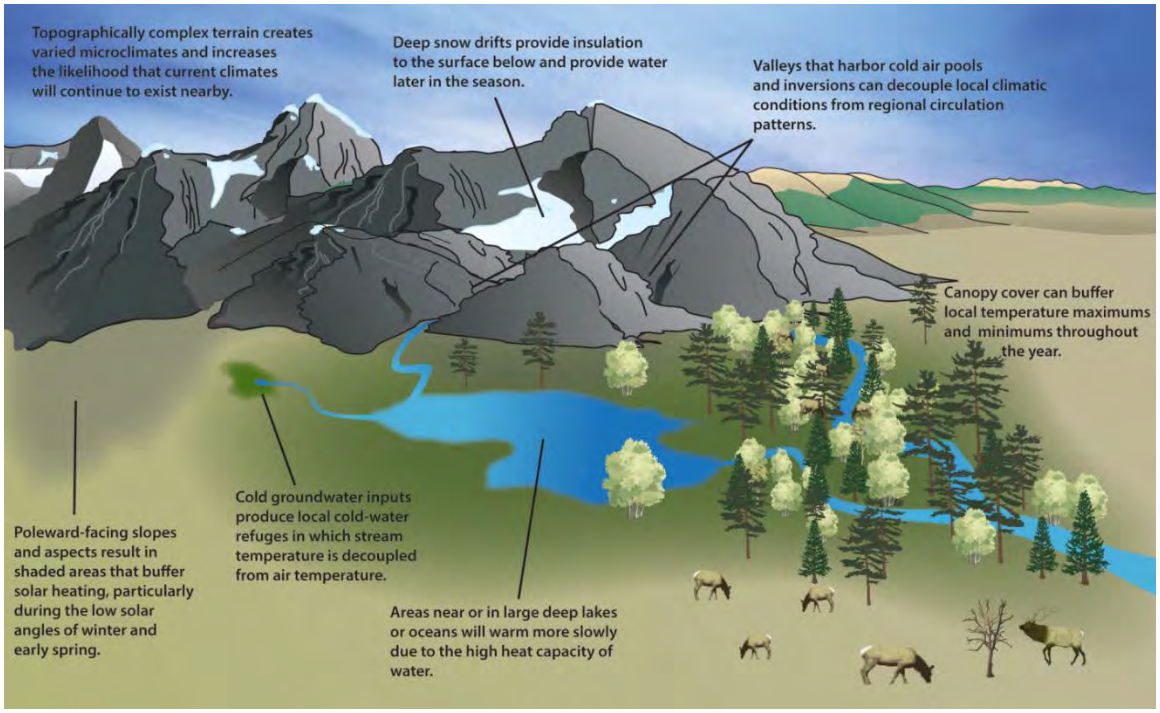

Figure 12. The Comanche Creek Watershed has many of the aspects of montane systems, which may dampen the most severe results of climate change (graphic from Morelli et al. 2016)

Field reconnaissance has been conducted for each impaired stream reach addressed in this WBP. Additionally, the CCWG stakeholders have discussed each creek in the watershed during the drafting of the 2014 Comanche Creek Wetland Action Plan (WAP) and have also reviewed the plan drafted by Watershed Artisans, Inc. for project prioritization of NMDGF. Impairment sources identified outside of the TMDL document by Quivira staff or the CCWG members are noted below:

- The degraded state sets into motion a positive feedback loop in which the degraded state itself becomes a stressor.
- Livestock grazing during periods of drought (even if lasting only one year) results in continuous overuse of riparian bottom vegetation and increase destabilization of stream banks due to hoof shear. This sets the stage for accelerated channel degradation and increased erosion.
- Loss of predators (such as wolves) causes changes in behavioral patterns and populations of prey species (such as deer, elk, and cattle), and resulting in increased and prolonged herbivory of vegetation in wetland systems

SOURCES OF IMPAIRMENT

Legacy issues have resulted in degradation of ecosystem function (channelization, erosion, loss of wetlands etc.) in the watershed. The current conditions reflect this degraded state and loss of function. The basic geomorphology of the watershed has changed due to erosion and loss of sediment in the riparian and wetland systems. The degraded state sets into motion a positive feedback loop in which the degraded state itself becomes a stressor.

Current conditions include the exacerbating effects of climate change on a high elevation watershed already facing challenges to its ecological resiliency. Earlier snowmelt, coupled with the increased duration and severities of drought, is an abiotic stressor that acts upon an already vulnerable system.

Air temperature is a predictor of water temperature (Bartholow 2002, Brown 1969, Johnson 2004). The trend under climate change may already be apparent in the higher air temperatures for Taos County (Fig. 13).

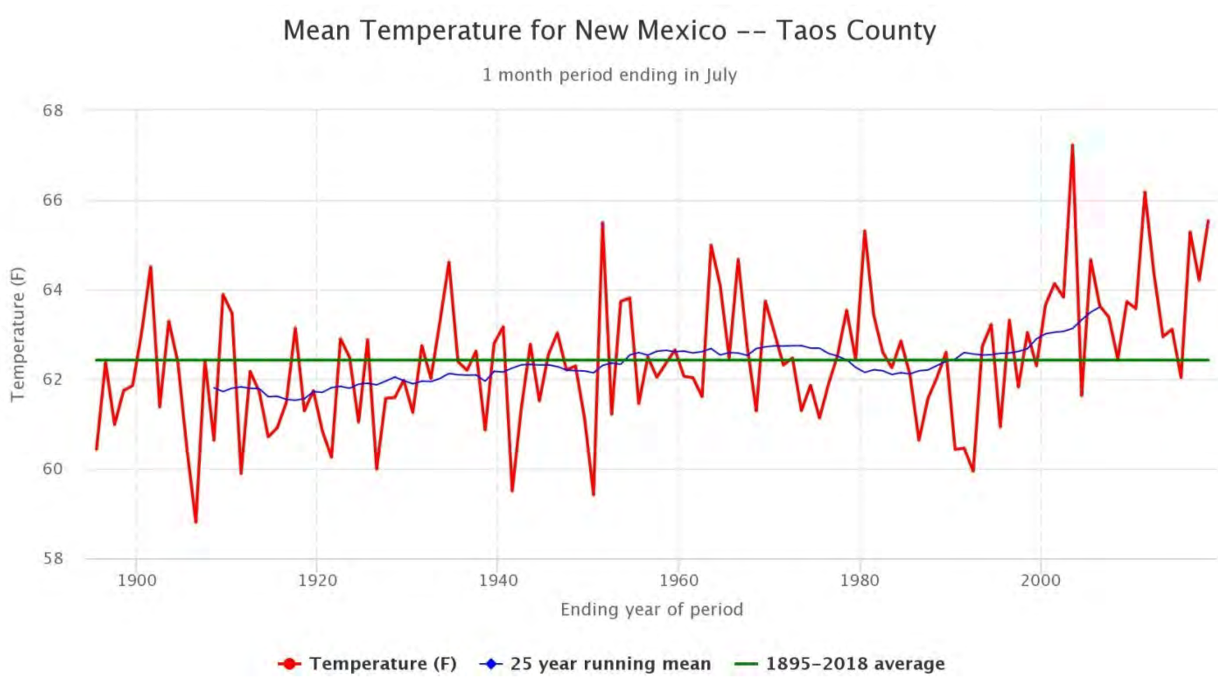

Figure 13. July temperatures have increased in Taos County compared to the 125 year running mean. https://cefa.dri.edu/Westmap/

DATA GAPS

There is no stream gauge providing information on stream flow out of the CCW to the Rio Costilla. The gauging station on the Rio Costilla (USGS 082540000) is below Costilla Dam, and stream flow is therefore regulated by water releases from the Costilla Reservoir. These data are not reliable indicators of natural hydrograph data for creeks draining the watershed.

Critical conditions for water quality often occur during low-flow conditions (for temperature) or conversely under high-flow conditions that contribute higher sediment loads and bacterial contaminants to the creeks (Nilsson and Renöfält 2008). Though likely cost prohibitive, data collected annually would likely better inform the water quality conditions in the watershed. Datasets for streamflow are based on data sources that are not locally collected, and are temporally sparse. Yet, these data are the best approximation of conditions to use in modelling predicted changes due to management actions.

Based on summer 2018 data collection, there was 0% stream canopy cover throughout LaBelle Creek. In Gold Creek, canopy cover was only recorded in two locations (the highest recoded canopy cover was 41%). Shade due to graminoid species is not captured using a densitometer at one foot above water level. Holman Creek canopy was not recorded due to the complexity of the system (four tributaries of Holman Creek). Canopy cover along Comanche Creek was only significant (maximum of 88% cover at one location) in elk exclosures near the confluence with Costilla Creek (data tables in Appendix A). Due to drought conditions the water surface in all creeks was low and flow was minimal.

Data collected only once a decade, although the best available under current funding and staffing levels, are wholly inadequate for more than very broad characterizations of potential treatments for water temperature reduction. Because watershed-scale data are limited both spatially and temporally, inadequate amounts of data are available for informing pattern and process in the CCW. Data needs include the number and quality of coldwater habitat refugia. Most stabilization and restoration treatments in the CCW are placed to stabilize erosional features (headcuts, incised channels, etc.) and reconnect hydrologic flow patterns that have been degraded over time. Most of these stabilization structures (Zuni bowls and log step falls) should increase hyporheic flow. Many processes govern the hyporheic exchange in a stream system (Fig. 14).

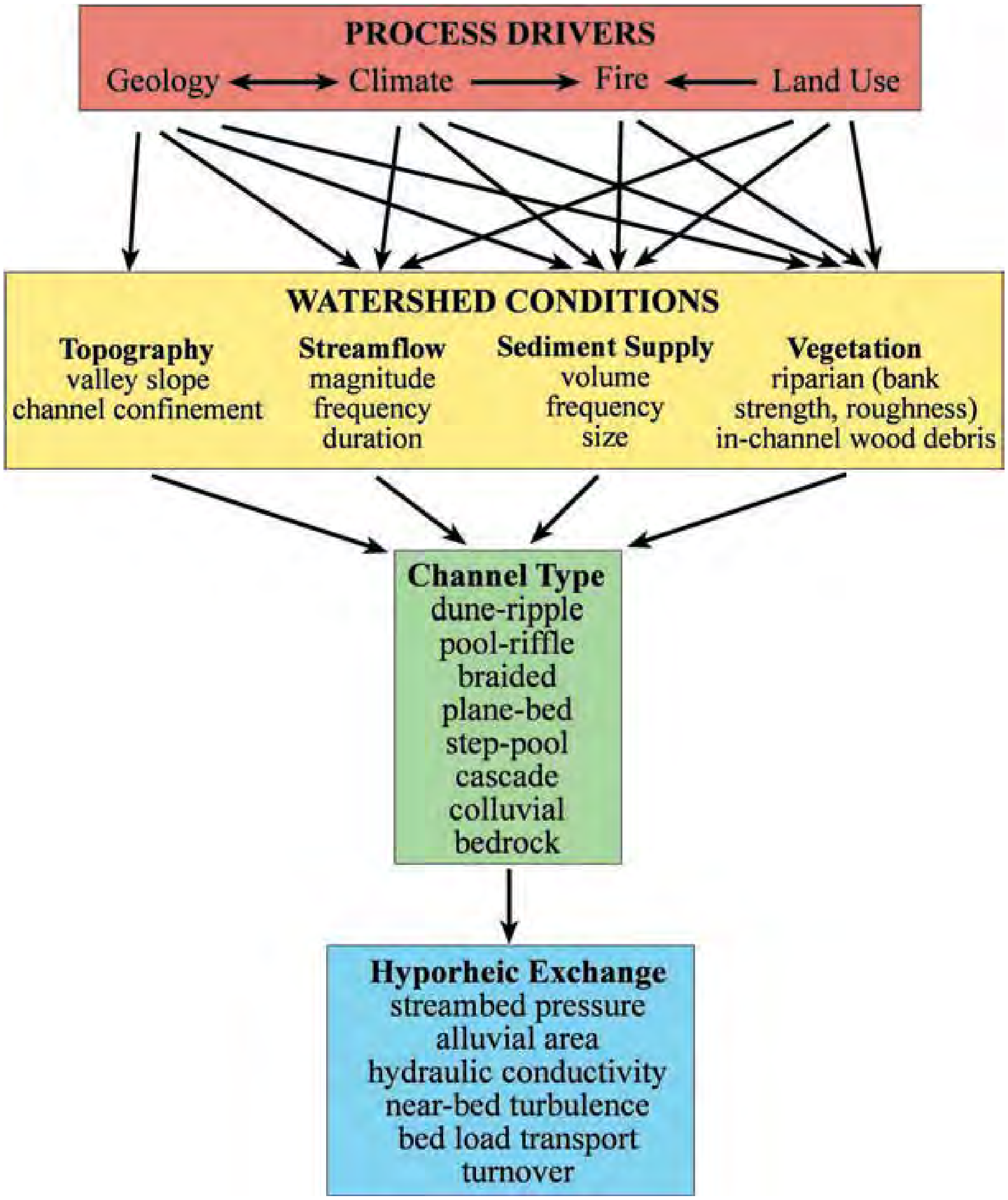

Figure 14. Hydrologic complexity of effects of process drivers on hyporheic exchange (graphic from Buffington and Tonina 2009)

Because hyporheic exchange processes are so complex, the introduction of restoration structures to the heat budget of a stream system only increases the complexity in understanding the heat budget of the stream (or wetland). Researchers have studied both field structures and conducted modelling to explore changes in hyporheic flow due to in-stream structures (Hester and Doyle 2008, Crispell 2009, Ward and Gooseff 2011, and Gordon et al 2013). There is little data agreement regarding quantification of how increasing hyporheic flow buffers stream water temperature. There are so many processes involved for any particular system (Cranswick et al 2014, Buffington and Tonina 2009, Johnson 2004, Schmadel and

Wondzell 2017) that it is difficult to model how increased hyporheic exchange buffers stream water temperature. One example of a site-specific variable is one of the original research studies conducted by Lapham (1989), which demonstrated that stream temperature fluctuations infiltrate deeper beneath the streambed where there are coarse-grained sediments as opposed to fine-grained sediments. Within the CCW, as in most headwater systems, each tributary has different conditions that determine channel type and subsequent hyporheic exchange. However, restoration structures that increase hydraulic pressure in the creek channels should increase hyporheic flow, though to different degrees based on soils and bedrock.

In a study by Surfleet and Louen (2018), in which weirs were used to create a step pool effect, the average daily total of weir-induced hyporheic heat advection always resulted in a cooling effect on surface water. Increased weir heights resulted in increased cooling effect. The hydraulic data collected confirmed that the weir-created backwater produced a curved hyporheic flow cell. This response was expected based on previous research by Freeze and Cherry (1979), and Hester and Doyle (2008). This hyporheic temperature modification was caused by advection of heat from the stream surface through the weir-induced hyporheic flow cell. On average, hyporheic water cooled as it flowed through the hyporheic flow cell. This resulted in a water-cooling effect on the surface water when the hyporheic water discharged downstream of the weir. These flow cells can be enhanced with carefully placed in-stream structures in the CCW.

The Surfleet and Louen (2018) study confirms patterns from many previously published studies, in which surface water temperatures have been shown to be reduced downstream across the weir just as other research shows a similar drop across step pools (Moore et al. 2005) and riffles (White et al. 1987; Hendricks and White 1991; Evans and Pettes 1997).

Mapping the locations of coldwater refugia habitat for RGCT in Comanche Creek should be a priority. Once these locations are identified, they will form the baseline for determining the need for more coldwater refugia habitat to benefit RGCT and other coldwater aquatic life if water temperatures cannot be restored to fully support high quality coldwater aquatic life as a result of climate change (Williams et al 2009). Peer reviewed scientific papers report that a range of temperatures in coldwater refugia created by thermal stratification results in a cooler water temperature at the bottom of pools, compared to the surface water temperatures of the same pools (Table 3).

Table 3. Degrees of difference between surface water and pool refugia temperatures

Source	Difference in degrees (C) of cooler pool bottom water compared to surface water temperature
Tate et al 2006	7.6
Matthews et al 1994	4.5
Nielsen et al 1994	3.5-9
Matthews and Berg 1997	6.9-10.4
Ebersole 2001	3-8

ESTIMATE LOAD REDUCTIONS

Achieving TMDL goals (the objective of the watershed-based planning process) will be challenging. Table 4 shows calculations for load reductions.

Table 4. Calculations of load reductions for temperature

Stream	Target Load (j/m2/sec)	Measured Load (j/m2/sec)	Reduction Goal (j/m2/sec)	% Reduction
Comanche Creek	115.1	254.4	139.3	55
Holman Creek	124.04	166.99	42.95	26
Gold Creek	144.71	243.62	98.91	41
LaBelle Creek	139.59	180.95	41.36	23

Table 5 shows the increase in amount of riparian canopy shade in each creek, based on the necessary reductions determined by Stream Segment Temperature Model (SSTEMP) parameters (Bartholow 2002).

Table 5. Results of SSTEMP modelling data for impaired creeks

Parameters from 2006 Valle Vidal TMDL	Comanche Creek	Gold Creek	Holman Creek	LaBelle Creek
Segment Inflow (cfs)	0.019	0	0	0
Inflow Temp (F)	59.7	32	32	32
Segment Outflow(cfs)	1.151	0.14	0.15	0.07
Accretion Temp (F)	46.683	43.783	43.783	43.783
Latitude(degrees)	36.8	36.77	36.8	36.76
Segment Length (mi)	10.3	2.87	2.86	2.57
Upstream elevation (ft)	9222	10400	11000	10200
Downstream Elevation(ft)	8963	9200	9250	9240
Width's A Tem (s/ft2)	6.681	0.641	6.78	0.641
B Term	0.16	0.528	0.102	0.528
Manning's n	0.031	0.25	0.022	0.25
Air Temperature	60.695	55.76	55.76	55.76
Relative Humidity	58.007	53.5	68.07	64.61
Wind Speed	5.226	3.708	4.292	4
Ground Temperature	52	43.783	43.783	43.783
Thermal Gradient	1.65	1.65	1.65	1.65
Possible Sun	76	76	76	76
Solar Radiation	550.1	503.09	415.48	410.64
Existing Shade (%)	4.5	0	17	9
Increased Shade (%) to Reach Temperature Goal	51	34	25	23
Increased to Shade (%) to reach Target Load	54	41	35	40
Target Load	115.1	144.71	124.04	139.59

SOURCE IDENTIFICATION

Legacy impacts resulting in lack of streamside shading, over-wide creeks, downcut channels, and reduction in the ability of wetland soils to buffer water temperature all contribute to sources of impairment. Current impacts include climate-related stressors, such as reduced snowpack and increased severity and duration of drought conditions. When combined with grazing and browsing pressure from cattle and elk, these can significantly impact wetlands and creeks. Table 6 details some of these stressors.

Table 6. Probable sources of temperature impairments

Impaired Creek	Primary Probable Sources	Secondary Probable Sources
Comanche Creek	Legacy practices that resulted in channel down cutting and loss of water storage capacity in slope, riparian, and floodplain wetland soils in the CCW, contributing to degradation of ecological function in tributaries to Comanche Creek. Changes in precipitation patterns resulting from the effects of climate change (increasing the frequency of low-flow conditions and the associated water quality problems)	Removal of herbaceous riparian vegetation in Upper Comanche Creek Removal of willow and alder shade cover by cattle and elk in Lower Comanche Creek Overstocked forest in higher elevations may reduce available effective precipitation (Huff et al 2000 and Roche et al 2018)
Holman Creek	Legacy practices that resulted in channel down cutting and loss of water storage capacity in slope and riparian wetland soils, contributing to degradation of ecological function. Climate change (see above)	Bisection of the slope wetlands and fens by Forest Service Road 1950 Removal of herbaceous riparian vegetation Reduction of willow and alder shade cover by cattle and elk Hoof shear impact on fens
Gold Creek	Legacy practices that resulted in channel down cutting and loss of water storage capacity in slope and riparian wetland soils, contributing to degradation of ecological function. Climate change (see above)	Removal of herbaceous riparian vegetation by elk and cattle Removal of willow and alder canopy cover by cattle and elk in some areas Hoof shear impact on fens
LaBelle Creek	Legacy practices that resulted in channel down cutting and loss of water storage capacity in slope and riparian wetland soils, contributing to degradation of ecological function. Climate change (see above)	Removal of herbaceous riparian vegetation Hoof shear impact on fens

MANAGEMENT MEASURES TO SUPPORT LOAD REDUCTIONS

The following management measures are being undertaken to reduce impairments on creeks in the CCW.

EXISTING AND PLANNED MANAGEMENT MEASURES

Proactive land management in the CCW has been ongoing since the Forest Service obtained the property in 1982. Wetland and riparian stabilization and restoration activities have gained traction in the watershed through CCWG efforts to fund projects. Table 7 shows existing and planned projects in the CCW.

Table 7. Management measures necessary to achieve load reduction goals

Impaired Creek	Cause of Impairment	Grant Projects Completed	Planned Projects
Comanche Creek	Legacy practices that resulted in channel down cutting and loss of water storage capacity in riparian and floodplain wetland soils along Comanche Creek Degradation of ecological function in tributaries to Comanche Creek Changes in precipitation patterns resulting from the effects of climate change (exacerbating low-flow water quality conditions) Removal of herbaceous riparian vegetation in Upper Comanche Creek Removal of willow and alder shade cover by	2001 CWA 319 2004 CWA 319 2004 NM Trout 2006 NRCS grant 2006 5 Star Supplemental 2007 Skylark Foundation 2007 RERI 2008 Patagonia 2010 CWA 319 2011 RERI 2014 RSP 2015-2018 Watershed Artisans projects funded by Coca Cola and Intel	Seek 319 grant money to repair and modify riparian exclosures on Lower Comanche Creek Seek 319 grant money to increase monitoring activities including flow measurements and piezometers for measuring the effect of restoration measures for increased soil water storage in wetlands Work with the CNF, VVGA, and NMDGF to discuss proactive planning for ungulate management during drought conditions in order to prevent significant damage to wetlands on the Valle Vidal

Impaired Creek	Cause of Impairment	Grant Projects Completed	Planned Projects
	cattle and elk in Lower Comanche Creek Overstocked forest in higher elevations reducing available effective precipitation	through the National Forest Foundation and TU 2016 Patagonia	
Holman Creek	Legacy practices that resulted in channel down cutting and loss of water storage capacity in slope wetland soils Changes in precipitation patterns resulting from the effects of climate change (exacerbating low-flow water quality conditions) Bisection of the slope wetlands and fens by Forest Service Road 1950 Removal of herbaceous riparian vegetation Hoof shear impact on fens Removal of willow and alder shade cover by cattle and elk	2015 Watershed Artisans and Trout Unlimited Project funded by Coca Cola and Intel through the National Forest Foundation 2018 Quivira Coalition Innovative Wetland Restoration grant from NMED for testing Keyline Design Principles	Seek 319 funds to implement proposed actions from this WBP to complete more work in the upper tributaries, including completion of more Bebb willow exclosures
Gold Creek	Legacy practices that resulted in channel down cutting and loss of water storage capacity in slope wetland soils Changes in precipitation patterns resulting from	2010 Quivira Coalition Multi-Basin 319 grant, 2015 Watershed Artisans and Trout Unlimited Project funded by Coca Cola and Intel through the National Forest	Seek 319 funds to implement proposed actions from this WBP including riparian exclosure fencing in uppermost Gold Creek to protect alder populations until they

Impaired Creek	Cause of Impairment	Grant Projects Completed	Planned Projects
	the effects of climate change (exacerbating low-flow water quality conditions) Removal of herbaceous riparian vegetation by elk and cattle Removal of willow and alder shade cover by cattle and elk in some areas Hoof shear impact on fens	Foundation	grow above browse height
LaBelle Creek	Legacy practices that resulted in channel down cutting and loss of water storage capacity in slope wetland soils Changes in precipitation patterns resulting from the effects of climate change (low-flow conditions) Removal of herbaceous riparian vegetation Hoof shear impact on fens	None	Request NMDGF grant funds to implement these same treatments based on the plan recommendations provided by Watershed Artisans, Inc. Build riparian exclosures around newly created open water sources

LAND MANAGEMENT MEASURES

Stream Bank Modification/Channel Reconstruction

Hyporheic flow in mountain streams is often highly influenced by step pool and riffle pool sequences (Cranswick et al 2014, Kashara and Wondzell 2003). Most in-channel treatments are designed to increase hyporheic flow based on modification of hydrologic pressure and water infiltration (Fig. 15). Increased hyporheic flow should buffer summer stream temperatures, although available data are highly specific to site conditions.

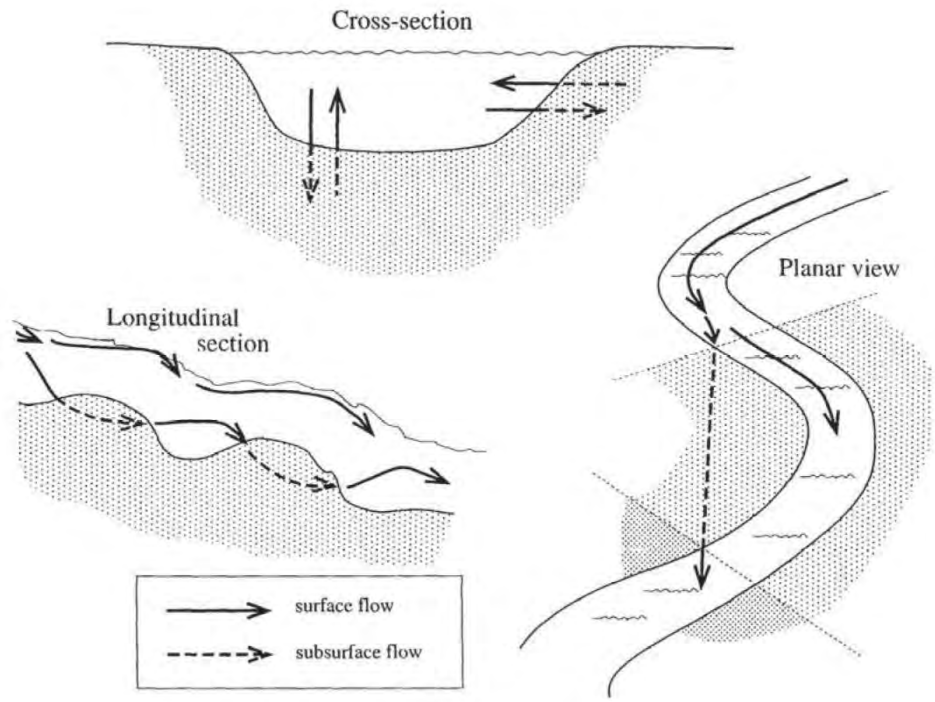

Figure 15. Stream hyporheic zone and water flow pathways for the hyporheic zone (graphic from Findley 1995)

Slope Wetland Stabilization and Restoration

Continued work to reconnect wetland soils with water sources will occur watershed-wide. Techniques to complete this work follow existing restoration techniques used in the CCW and other headwater systems in northern New Mexico (Sponholtz and Anderson 2013, Zeedyk et al 2014a, Zeedyk, et al 2014b, Zeedyk 2015, Zeedyk and Vrooman 2017, and Walton, et al 2019).

Riparian Fencing

Existing alder and willow populations will be identified for locations of riparian exclosure fencing. If allowed to grow, these riparian trees and shrubs will shade the channel through the exclosure as well as contributing to bank stabilization and lowering water temperature. Riparian exclosures on the lower Comanche Creek mainstem have shown variable success. Exclosures that allowed willows to establish were constructed with high, woven-wire fencing on one bank of the creek. Exclosures that have had variable success were constructed to span the channel. These structures have had limited success due to animals being able to enter and exit the exclosures through the creek channel. The channel openings were purposeful to prevent death of elk calves, which occurred prior to this more open design.

Maintenance of exclosures has been completed every few years by Quivira volunteers and Rocky Mountain Youth Corps, however continued maintenance is uncertain. Existing exclosures with substantial willows should be modified to prevent animal encroachment. Non-performing structures without willows should be assessed and potentially removed and the fencing materials used to shore up other exclosures. Some exclosures without willow have been shown (through Forest Service monitoring activities) to have had a positive effect on channel width and depth due to increased sedge presence with reduced grazing pressure.
The Holman Creek watershed contains many wetland areas where Bebb willow (*Salix bebbiana*) exist but are browsed each year to the point where they remain at one foot in height regardless of maturity. Exclosures have been constructed in Holman Creek to allow these wetland willows to escape repeated browse.

Prior efforts to establish willows have had very limited success. Soil type may be a constraint. The timing of plantings is also an important factor. Planting willows during the dormant season is difficult at this high elevation. Soil is still frozen in early spring and snowmelt runoff increases creek water levels and flow velocity in areas where willows would be planted. Often the willows dormancy in the fall sometimes occurs after snow has fallen and the ground is frozen. Past planting efforts have been completed in August, when volunteers are in the watershed. These plantings occurred during low creek flow periods, with willow stems that had not entered dormancy. Survival rates with this technique have been extremely low. In the zone on lower Comanche Creek that has a viable willow population, a planting technique that might be considered is using a machine to plant an established clump of willow during the growing season. The majority of impaired streams (Gold, LaBelle, Holman, and upper Comanche) are in a grassland riparian ecosystem, where willows may not be ecologically viable or even advisable.

Management for Climate Change and Grazing Pressure

The CCWG has discussed how to manage grazing by cattle and elk during drought events. In 2018, the watershed experienced extreme drought. Wetlands were adversely impacted during the spring and summer until monsoon rains started in July. The grazing management conversation is difficult, but it is one that has to be undertaken to plan for a future with new climate extremes.

Potential grazing management practices include the following:

- Adopt a clearly articulated drought management plan.
- Formalize consideration of climate change impacts to determine stocking rates of both cattle and elk (though elk population is difficult to assess and manage) (CNF, NMDGF, VVGA).
- Consider flexibility in the Annual Operating Instructions (AOI) seasonally in response to changing conditions, as is currently practiced.
- Revisit pasture rotations and include drought, climate change, and restoration efforts as factors for decision making.
- Consider installing upland water sources.
- Make additional funds available for hiring a second rider in drought years.
- Consider long-term changes in pasture fencing as a way to better protect riparian zones.

Priority Projects

Many restoration and stabilization practices have been completed in Comanche Creek, Gold Creek, and Holman Creek. Future monitoring efforts may be able to determine if these efforts are successful in addressing water quality concerns. New exclosures on Gold Creek and expanding and repairing existing elk and cattle exclosures on the Comanche mainstem are priorities to address water temperature.

Holman Creek has also had many restoration and stabilization structures installed, and will continue to have restoration activities in the subwatershed in 2019 and 2020. In Appendix B, monitoring photographs show before and after restoration treatments in the east tributary of Holman Creek. Additional exclosures might be warranted if current stream and wetland restoration efforts are unsuccessful in lowering water temperature.

LaBelle Creek will not support a willow or alder population. A map and photograph from 1895 and 1898 respectively (Figs. 8 and 9) show that the stream channel is not populated by willows. Additionally, no old beaver dams have been recorded in the Comanche Creek Watershed other than between Little Costilla Creek and the confluence of Comanche and Costilla Creeks. It may be that zones of soil conditions that support willow stands are limited in extent outside of this location. Evidence of the lack of beaver historically in the grassland park zones may not take into account the dramatic changes from legacy uses which may have contributed to the lack of willows in the watershed.

Table 8 shows the priority order of planned BMPs to address water temperature goals and functional lift in riparian and wetland ecosystem services.

Table 8. Prioritized best management practices by creek

Stream	Impairment	Primary BMP	Secondary BMP	Planned Projects
Comanche Creek	Temperature	Reconnection of hyporheic flow from channel to wetland soils (completed by Watershed Artisans, Inc.) Riparian exclosures repaired and expanded Headwater slope wetland stabilization and restoration	Channel stabilization in the uppermost part of the Comanche Creek mainstem Grazing BMPs	Apply for grant funding in 2020 to repeat drone flight to assess Coca Cola/Intel and Watershed Artisans and Trout Unlimited project Reconfigure and repair riparian exclosures on mainstem (apply for 319 implementation funds)
Holman Creek	Temperature	Reconnection of hyporheic flow from channel to wetland soils using plug and pond/spread techniques	Channel stabilization Riparian exclosures Grazing BMPs	Request NMDGF grant funds
Gold Creek	Temperature	Reconnection of hyporheic flow from channel to wetland soils using plug and pond/spread techniques	Channel stabilization Riparian exclosures Grazing BMPs	Apply for 319 implementation funds
LaBelle Creek	Temperature	Reconnection of hyporheic flow from channel to wetland soils using plug and pond/spread techniques	Channel stabilization Grazing BMPs	Request NMDGF grant funds Apply for 319 implementation funds

Management Measure Priorities and Associated Load Reductions

Comanche Creek, Holman Creek, Gold Creek and LaBelle Creek:

Continue watershed-wide restoration activities that

- stabilize creek channels with Natural Channel Design and Zeedyk structures;
- reduce over-wide reaches (decrease width-to-depth ratios) with induced meandering techniques;
- raise the grade of incised channels with in-channel rock structures;
- spread flow to recharge wetland soils by encouraging sheetflow in headwater wetlands and reconnecting old oxbows in the Comanche Creek mainstem; and
- increase channel complexity to provide hyporheic recharge and coldwater refugia for aquatic species by installing log and rock structures that increase hydraulic head at multiple locations within a stream channel.

Comanche Creek, Holman Creek, and upper Gold Creek:

- Address temperature as a function of riparian tree and shrub shade by building riparian exclosures where tree and shrubs already exist but are heavily browsed.

Measures of success will be tracking using canopy measurements (spherical densitometer) and measuring channel cross sections for reduction in channel incision, or conversely, by the narrowing of over-wide stream channels, wetland greenline monitoring as a proxy for increased soil water storage in wetland soils, and continued stream temperature monitoring by NMED.
It is difficult to quantify the associated load reductions from stabilization and restoration treatments based on the paucity of quantitative data detailing how restoration structures in smaller streams affect water temperature. Data collected on similar projects show that there are effects of temperature reduction due to increased hyporheic flow immediately adjacent to restoration structures. This facilitates increased infiltration and reconnection of stream corridors to associated wetlands (White et al. 1987, Evans and Pettes 1997, Hester and Doyle 2008, Surfleet and Louen 2013). Evans and Pettes (1997) recorded lower water temperature at the tail of riffles due to in part to the cooling effects on increases in hyporheic flow. However, all of the studies point out that the complexity of interactions between climate, geology, bed substrate, soils, and hydrologic flow regimes make it impossible to quantify the effects from one ecosystem’s restoration experiment and relate them to a different stream system (Kasahara and Wondzell 2013).

A study of the effect of beaver dams and beaver dam analogs in central Oregon showed that "increased dam and pond creation contributes to moderation of diurnal temperature cycles during periods of low surface flow by increasing water storage, and encouraging surface water—groundwater exchange"(Weber et al 2017). They also noted that "buffering of surface water temperatures by beaver impoundments was influencing downstream un-impounded reaches, thereby greatly increasing the availability of thermally suitable salmonid habitat." Weber et al report that summer maximum stream temperatures decreased between 0.56°C and 2.56°C between an upstream control site with no beaver and sites below active beaver dams. Their results identified two different means by which stream temperature may be affected by beaver dams: a moderation of summer temperature extremes at the reach scale, and increased channel scale temperature heterogeneity.

Many of the plug and pond treatments and stabilization treatments used in the CCW are similar in function to beaver dams, although usually smaller in scale. However, some beaver dam analogs have been installed in the watershed. Many in-stream structures and treatments such as induced meandering, plug and pond and headcut stabilization treatments that create a step pool-like sequence will increase hyporheic flow (Hester and Doye 2008, Gordon et al 2013, Crispell and Endreny 2009, and Surfleet and Louen 2018)(Fig. 16). The increased hyporheic flow from a single structure can reduce stream bottom temperature minimally at the structure location, but may buffer water temperature at a reach scale if enough structures are in place. Quantifying structure type temperature effects between different tributaries is not possible under current funding levels.

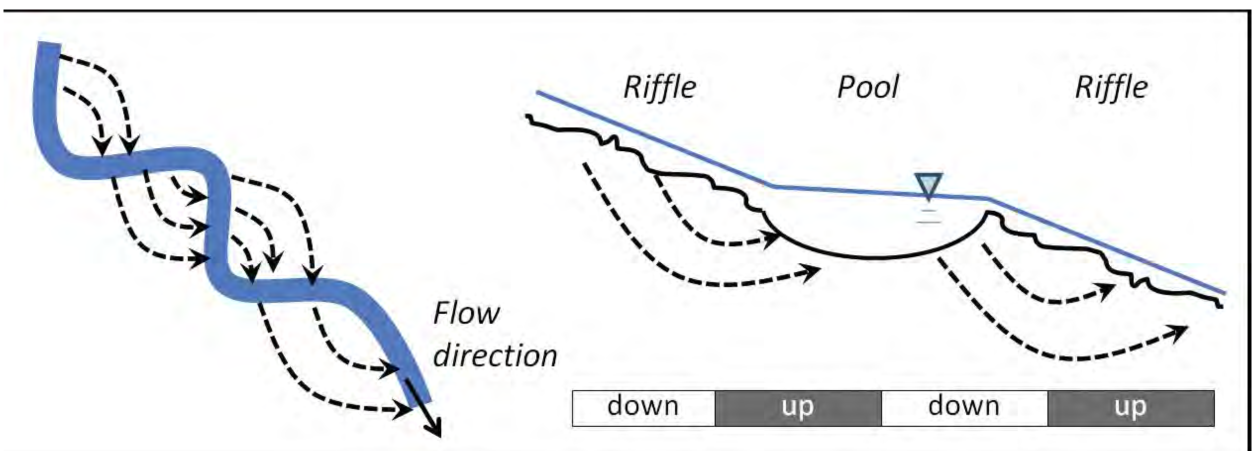

Figure 16. Increasing stream sinuosity and the number of stream pools and riffles increases hyporheic flow in the riparian system and thereby helps buffer water temperature (graphic from Torgersen et al 2012).

Increasing riparian shade where possible in this predominantly grassland riparian ecosystem and increasing hyporheic flow through stabilization and restoration efforts may not be enough to lower temperature impairment during the summer months. For this reason, mapping of existing coldwater refugia habitat is necessary to manage for HQCAL in the future.

TECHNICAL AND FINANCIAL ASSISTANCE NEEDED

FUNDING SOURCES

The Quivira Coalition and the CCWG will continue to seek grant funds for ongoing assessment and restoration work in the CCW. Quivira has obtained grant funding from the NMED SWQB Wetlands Program to work in the Carson National Forest through November 2019. Coca Cola funded work starting in 2015 through a donation to the National Forest Foundation (in collaboration with TU) which continued to 2018. Intel also donated funds in 2018.

Quivira and other members of the CCWG would like to conduct annual Comanche Creek volunteer work weekends continue past 2019 and will seek other grant funds to continue this tradition. Table 9 is a summary of potential funding sources for continued restoration project funds in the Comanche Creek Watershed and Table 10 shows estimated financial assistance needed for restoration projects.

Table 9. Potential funding sources

<table>
<tr><th>Source</th><th>Agency</th><th>Grant</th></tr>
<tr><td rowspan="12">Federal</td><td rowspan="3">U.S. Environmental Protection Agency</td><td>Clean Water Act Section 319 Watershed Restoration Grants</td></tr>
<tr><td>5 Star Restoration Challenge Grant Program</td></tr>
<tr><td>Environmental Education Grants</td></tr>
<tr><td rowspan="2">U.S. Department of Agriculture, Natural Resource Conservation Service</td><td>Environmental Quality Incentive Program (EQIP) (private lands cost matching)</td></tr>
<tr><td>Wetland Reserve Program</td></tr>
<tr><td rowspan="3">U.S. Fish and Wildlife Service</td><td>North American Wetland Conservation Act</td></tr>
<tr><td>Western Native Trout Initiative</td></tr>
<tr><td>Fish Passage</td></tr>
<tr><td rowspan="2">U.S. Forest Service</td><td>Collaborative Forest Restoration Program</td></tr>
<tr><td>Collaborative Forest Landscape Restoration Program</td></tr>
<tr><td>U.S. Bureau of Reclamation</td><td>WaterSMART</td></tr>
<tr><td>State</td><td>State of New Mexico</td><td>River Stewardship Program (RSP), formerly River Ecosystem Restoration Initiative</td></tr>
</table>

		(RERI)
	New Mexico Finance Authority	Water Trust Board loans
	New Mexico Department of Game and Fish	NMDGF grant funds
	New Mexico Community Foundation	NM River Conservation & Restoration Fund
	New Mexico State Forestry	New Mexico Forestry Division Watershed Restoration Project
County	Taos Soil and Water Conservation District	
Source	**Agency**	**Grant**
Private	Patagonia 1% for the Planet Grant and World Trout Initiative	
	Western Native Trout Initiative	
	Orvis Conservation Grant Program	
	National Fish and Wildlife Foundation	
	Trout Unlimited	
	Mule Deer Foundation	
	Rocky Mountain Elk Foundation	
	National Wild Turkey Federation	
	Wildlife Conservation Society	
	The Nature Conservancy	Rio Grande Water Fund
	Mitigation Funds	
	Private Donors	
	Volunteer Labor	

Table 10. Estimated financial assistance required

Project Type	Cost/ Unit	Units	Total Estimated Cost
Lower Comanche Creek Riparian Exclosures	$500	Riparian Exclosures	$20,000
Upper Comanche Creek Wetland Restoration	$2,000	Acre	$134,000
Gold Creek	$4000	Riparian Exclosures	$16,000
Holman Creek	$1400	Acre	$148,700
LaBelle Creek	$2000	Acre	$118,000
LaBelle Creek	$4000	Riparian Exclosures	$12,000

Personnel time needed to write grants to obtain funding necessary to implement restoration work, permitting, monitoring, and education and outreach are all necessary components of wetland and riparian restoration projects.

Technical assistance needed

In the face of climate change, a prudent approach to preserving habitat for high quality coldwater aquatic species would be to map out existing coldwater refugia in RGCT habitat. Once surveyed, NMDGF and the CNF fish biologist could determine if more coldwater refugia habitat are needed for the RGCT population in order for the creek to support habitat for HQCAL even during times of drought and increased temperatures.

Education and Outreach

The goal of the public involvement process is to ensure a multifaceted, proactive, and responsive interaction among the CCWG, the public, and resource agencies. Current stakeholder efforts for ecological stabilization and return of ecological functioning in the CCW are built upon the efforts of a number of organizations and individuals.

Outreach

The target audiences for outreach are people in surrounding communities, recreationists, and interested parties throughout the region who could easily be considered stakeholders with vested interests in the continued health and viability of the CCW. Outreach efforts will focus on informing individuals and groups about stream and watershed restoration in general, with activities in the Comanche Creek Watershed as an example. Most of this audience is not expected to become directly involved in restoration activities on Comanche Creek, but they can learn about the ecological processes involved with restoration through these materials. However, these outreach tools can also serve as a gateway for those who would like to become directly involved with projects on Comanche Creek or in other watersheds. People have come from as far away as Texas and California to attend the volunteer weekends. As projects move more toward restoration with heavy equipment, new stakeholders have become more active in the CCWG.

Quivira in conjunction with NMED SWQB Wetlands Program has been able to complete two publications that showcase restoration and stabilization activities in the watershed (https://www.env.nm.gov/surface-water-quality/wetlands-technical-guides.

Finally, Quivira maintains a website dedicated to projects related to Comanche Creek (www.comanchecreek.org). The transfer of technology guarantees that lessons learned in the CCW (concepts, technology, and methods that worked and those that did not) are transferred to other agencies, including nongovernmental watershed and stream restoration groups. Efforts will also be included to see that technology, including knowledge, is passed along through time, so that restoration in the CCW can be maintained and continued past the foreseeable future.

Involvement

If grant funding can be obtained for the CCWG stakeholder meetings and annual volunteer work weekends, these activities will continue into the future. With advent of the corporate funding and the NMDGF grant funding in the watershed, the basic nature of restoration activities is scaling up and the dynamics of stakeholder group participation will change. An effort to significantly scale up watershed restoration efforts using local restoration contractors through NMDGF grant funds is currently driving future projects.

The CCWG has received substantial support from the Carson National Forest, the Valle Vidal Grazing Association, and Trout Unlimited. It is anticipated that restoration contractors and the NMDGF will play a large role in future stakeholder meetings and outreach.

Strategy

To a great extent, the progress currently being made on Comanche Creek is the result of outreach and collaborative efforts by involved stakeholders and those groups currently active within the working group. Continued engagement by the diverse stakeholders of the CCWG is essential to reaching water quality goals in the watershed. Engagement at the current level will require grant funds to continue. All stakeholders are committed to continuing the strategic work of the CCWG. Table 11 shows the proposed implementation schedule.

IMPLEMENTATION SCHEDULE

Table 11. Five-year implementation schedule and interim measurable milestones

Stream	Impairment	BMP	Schedule	Milestone	Date
Comanche Creek	Temperature	Riparian exclosure repair and expansion on lower Comanche Creek mainstem	Summers (dependent on funding)	Riparian exclosures completed In-stream structures constructed	October 2022
Holman Creek	Temperature	Stabilization of degraded slope wetlands Reconnection of hyporheic flow from channel to wetland soils using plug and pond/spread techniques	Summers (dependent on funding)	Riparian exclosures completed In-stream structures completed Wetland restoration structures	October 2023
Gold Creek	Temperature	Riparian exclosures	Summers (dependent on funding)	Exclosures completed	October 2024
LaBelle Creek	Temperature	Channel stabilization and aggradation Slope wetland stabilization and restoration Grazing BMPs	Summers (dependent on funding)	In-stream structures completed Wetland restoration structures	October 2025

All of these planned restoration techniques will be implemented as project funds become available. The CCWG has weighted the need for restoration with the costs, logistics of treatment, probability of success, and estimated ability to fund stabilization and restoration and prioritized wetland restoration by tributary watershed (Quivira Coalition 2015) and the efforts prioritized by Watershed Artisans, Inc. (2018). Photographs and brief descriptions of site conditions and pertinent monitoring data from each tributary wetland system are contained in Appendix A.

Measureable Milestones of Implementation

Restoration milestones in the next five years are shown in Table 12.

Table 12. Milestones of implementation

Stream	Milestone	Date
Comanche Creek	Exclosures completed	October 2022
Holman Creek	In-stream and wetland restoration structures completed	October 2023
Gold Creek	Exclosures completed	October 2024
LaBelle Creek	In-stream and wetland restoration structures completed	October 2025

Quantitative Measureable Milestones

Reduction in water temperatures on impaired streams, measurable increase in riparian canopy in exclosures, stabilization, and restoration treatments will increase wetland health and extent helping to buffer temperatures and steady baseflow in the system.

Qualitative Measureable Milestones

Continued collaboration of the CCWG through the many planned projects will be an important aspect of the restoration of the CCW.

Criteria for Evaluating Load Reduction Achievements

Monitoring data will be used to determine if water temperature goals are being reached. It may take several growing seasons before riparian canopy in exclosures reaches a height adequate to shade streams. Restoration structures should have an overall effect of lifting ecosystem function. These efforts will also take many seasons to effect positive change in the system. The number and locations of restoration structures will be recorded. Stream temperature data from NMED will be analyzed to determine whether the structures have a positive effect in the reduction of high water temperatures in the summer months.

MONITORING PROGRAM

WATERSHED WIDE

NMED annually deploys and manages data from 10 temperature probe data loggers in the Comanche Creek Watershed (Table 13).

Table 13. Locations for NMED temperature probes

Waterbody	ID_CODE	Site Name	Latitude NAD 83	Longitude NAD 83
Comanche Creek	CC-CONF	Comanche Creek above Costilla Creek	36.831710	-105.318310
Comanche Creek	CC-DWN8	Comanche Creek at USFS #8 0.8 km upstream of confluence	36.827750	-105.312917
Comanche Creek	CC-BLCO	Comanche Creek below Little Costilla Creek	36.795860	-105.298030
Comanche Creek	CC-ALCO	Comanche Creek above Little Costilla Creek	36.795700	-105.297050
Comanche Creek	CC-UURG	Comanche Creek below upper exclosure	36.786750	-105.282950
Comanche Creek	CC-UPPR	Comanche Creek above Holman Creek	36.779500	-105.276417
Comanche Creek	CC-VIDA	Comanche Creek below Vidal Creek	36.758301	-105.270889
Comanche Creek	CC-CABN	Comanche Creek above confluence with Vidal Creek near abandoned Clayton Cabin up Forest Rd 1905	36.756060	-105.269590
Holman Creek	CC-HOLD	Holman Creek downstream subwatershed	36.791250	-105.267950
Holman Creek	CC-HOLU	Holman Creek upstream subwatershed	36.795480	-105.255420

In 2017, with grant funding from Patagonia, Quivira contracted with the Quiet Creek, LLC to provide a Normalized Difference Vegetation Index (NDVI) map of the entire mainstem of Comanche Creek (Appendix C). NDVI quantifies vegetation by measuring the difference between near-infrared and red light. A lower relative NDVI results when water limits vegetation growth.

The drone flight was conducted in August 2017, before the majority of in-channel work was completed on the mainstem of Comanche Creek by Watershed Artisans, Inc. using funds from Coca Cola and Intel. This imagery may provide a baseline for comparing vegetation health and productivity before and after restoration activities, as a proxy for increased soil moisture in riparian and slope wetlands as a result of restoration activities. Quivira or another member of the CCWG will seek another Patagonia grant in 2022 to repeat the drone flights to gather NDVI data on the entire length of Comanche Creek in order to determine the effects of the Watershed Artisans, Inc. restoration treatments.

Proactive monitoring is needed to determine numbers and locations of coldwater refugia in creeks within the CCW. With this knowledge, the CNF, NMED, and the NMDGF could create a plan to increase the quantity of these habitats if necessary. Flow data for creeks in the CCW, collected in conjunction with mapping coldwater refugia, would also help inform land managers how to manage for high quality coldwater aquatic life by determining the quantity of habitat refugia that still exist under low-flow conditions. It would also reveal the frequency of occurrence of low-flow conditions that negatively affect HQCAL.

Project Specific Monitoring

All restoration projects in the CCW include collection of monitoring data that conform to grant requirements and USACE monitoring requirements. At a minimum, repeat photography is employed for every project.

For any future CWA 319 funding to address temperature exceedance in Comanche, Holman, Gold, and La Belle creeks, the following data will be recorded before and after restoration treatments for the duration of the grant:

- Greenline vegetation monitoring,
- Width and depth measurements,
- Percent canopy, and
- Repeat photography.

All data collection conforms to the procedures described in the Watershed Based Plan Quality Assurance Project Plan (QAPP) approved July 12, 2018 for future CWA 319 projects. As other projects are funded in the watershed, specific project designs and monitoring plans for restoration projects will be developed by grant recipients.

Reporting of Monitoring Results

Specific monitoring data per project reflect the requirements of the project funding source. Monitoring results are always shared with the CNF Questa Ranger District and are available to the CCWG upon request.

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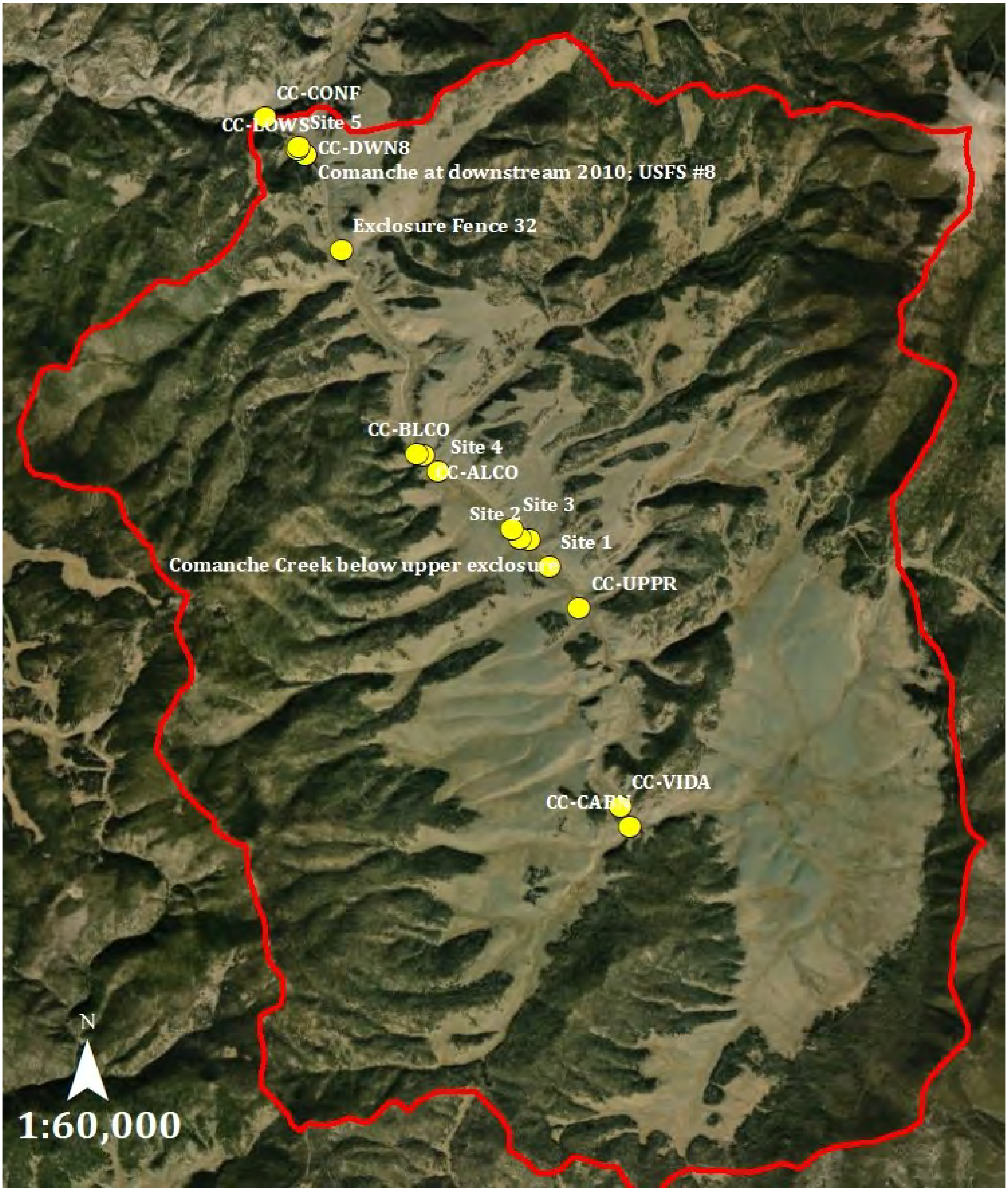
Appendices

APPENDIX A – CREEK ASSESSMENT NOTES AND FIELD DATA

COMANCHE CREEK



2018 sampling locations for streamflow and canopy cover

Appendix A – Creek Assessment Notes and Field Data

Comanche Creek - Table of Flow Measurements

Date: August 3-4, 2018											Initials: ATK, AQ, VW, and EW	
Transect	Length (ft)	Channel Width (ft)	Avg. Width (ft)	Depth (in)		Avg. Depth (ft)	Time (sec)	Avg. Time (sec)	Velocity = Time/ Length	Runoff coefficient	Discharge (cu ft/sec) W x D x V
CC Cabin	10	1'-4"	1.61	2	2.5	0.18	12.98	13.04	1.30	0.8	0.30
		2'-2"		0.25	2.75		12.44				
		1'-4"		2.5	2.75		13.71				
CC Vida	10	5'-4"	4.53	1.25	3.25	0.20	14.64	11.67	1.17	0.8	0.87
		3'-6"		2.75	3		10.56				
		4'-9"		3	1.5		9.82				
CC UPPR	10	4'-2"	4.25	2.5	4.75	0.28	34.88	31.82	3.18	0.8	3.08
		5'-4"		3.5	4.5		26.5				
		3'-3"		4	1.25		34.08				
Site 1	10	3'-9"	3.69	5	3.25	0.33	26.21	25.95	2.60	0.9	2.82
		3'-10"		3.75	3.75		25.99				
		3'-6"		4.75	3		25.65				
CC BUEX	10	4'-11"	3.92	3	6.75	0.37	13.95	15.61	1.56	0.9	2.03
		3'-8"		4	2.75		18.29				
		3'-2"		6.5	3.5		14.59				
Site 2	10	4'-0"	3.56	0.75	2.75	0.18	7.54	7.58	0.76	0.8	0.39
		3'-2"		1.5	3.5		7.48				
		3'-6"		2.5	2		7.73				
Site 3	10	5'-1"	4.19	0.5	2.25	0.22	15.81	17.24	1.72	0.8	1.29
		3'-10"		1.75	5.25		16.75				
		3'-8"		2.5	3.75		19.16				
Site 4	10	3'-2"	2.89	2	3	0.21	7.41	7.32	0.73	0.8	0.36
		2'-8"		1.5	4		6.74				
		2'-10"		1.75	3		7.8				
CC ALCO	10	7'-3"	6.36	3	5.5	0.32	37.34	36.35	3.64	0.9	6.72
		6'-0"		3.25	3.5		36.19				
		5'-10"		6.5	1.5		35.53				
CC BLCO	10	5'-10"	6.31	9	11	0.67	15.5	16.85	1.69	0.9	6.44
		6'-3"		10	6		15.83				
		6'-10"		7.5	5		19.22				
CC EX32	10	3'-10"	4.47	7	5	0.38	7.15	7.43	0.74	0.8	1.01
		4'-3"		6	2		7.45				
		5'-4"		5.5	2		7.68				
CC 2010	10	5'-9"	5.56	5	4.5	0.58	26.96	24.91	2.49	0.8	6.46
		5'-5"		5	12.5		24.74				
		5'-6"		8.5	6.5		23.04				
CC LOWS	10	7'-10"	7.31	4.5	4	0.33	9.48	9.67	0.97	0.8	1.88
		7'-8"		2	5.75		10.28				
		6'-5"		4.25	3.5		9.24				

Appendix A – Creek Assessment Notes and Field Data

Transect	Length (ft)	Channel Width (ft)	Avg. Width (ft)	Depth (in)		Avg. Depth (ft)	Time (sec)	Avg. Time (sec)	Velocity = Time/ Length	Runoff coefficient	Discharge (cu ft/sec) W x D x V
0.8 km above confluence w/ Costilla	10	4'-6"	4.81	4	5	0.40	6.1	8.78	0.88	0.8	1.36
		5'-3"		6	4.25		8.73				
		4'-8"		3.25	6.5		11.52				
CC above confluence	10	7'-11"	7.83	12.5	9.5	0.94	38.73	33.91	3.39	0.9	22.41
		7'-4"		12.5	11.5		31.58				
		8'-3"		13.5	8		31.41				
Site 5	10	6'-10"	6.81	8.75	4.5	0.57	11.97	14.29	1.43	0.8	4.40
		5'-10"		12	6		18.33				
		7'-9"		2.5	7		12.56				
CC INEX BLCO	10	5'-8"	6.42	2.75	2	0.23	10.91	10.39	1.04	0.8	1.20
		7'-4"		1	3		10.15				
		6'-3"		2	5.5		10.1				
CC INEX2	10	3'-2"	3.28	6	6.5	0.42	8.07	8.25	0.82	0.8	0.92
		3'-3"		8	3		10.83				
		3'-5"		3.5	3.5		5.84				
CC INEX 3	10	7'-7"	6.69	2	3.5	0.34	22.25	23.44	2.34	0.8	4.31
		6'-10"		1.5	6		22.24				
		5'-8"		4.25	7.5		25.82				
CC INEX36	10	5'-3"	6.39	6	6.5	0.52	18.91	20.83	2.08	0.8	5.58
		6'-8"		2.5	9		20.06				
		7'-3"		9	4.75		23.51				

Comanche Creek - Table of Canopy Percentages

Transect	Left Bank	Center-Upstream	Center-Right	Center-Downstream	Center-Left	Right Bank
CC Cabin	11.76	5.88	23.53	11.76	5.88	29.41
CC Vida	0.00	0.00	0.00	0.00	0.00	0.00
CC UPPR	11.76	0.00	0.00	0.00	0.00	0.00
Site 1	5.88	0.00	0.00	0.00	11.76	5.88
CC BUEX	17.65	0.00	0.00	0.00	0.00	0.00
Site 2	41.18	0.00	5.88	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00
CC ALCO	5.88	0.00	0.00	0.00	0.00	0.00
CC BLCO	88.24	17.65	47.06	17.65	35.29	64.71
CC EX32	0.00	0.00	0.00	0.00	0.00	11.76
CC 2010	0.00	0.00	0.00	0.00	0.00	0.00
CC LOWS	5.88	0.00	0.00	0.00	0.00	23.53
CC CONF	17.65	0.00	0.00	0.00	0.00	5.88
CC 0.8km Up from Confluence w/Costilla	0.00	0.00	0.00	0.00	0.00	0.00
CC Site 5	11.76	0.00	11.76	0.00	0.00	0.00
CC INEX BLCO	0.00	0.00	0.00	0.00	5.88	17.65
CC INEX2	23.53	11.76	82.35	29.41	17.65	64.71
CC INEX3	0.00	0.00	0.00	0.00	0.00	0.00
CC INEX36	11.76	0.00	11.76	0.00	23.53	0.00

Appendix A – Creek Assessment Notes and Field Data

Holman Creek

Holman Creek has been the site of active restoration efforts in the past few years. Watershed Artisans, Inc. completed Coke Wetland Replenishment Program funded projects in 2015, Quivira completed NMED SWQB Wetlands Program projects in 2018 and 2019 and Reineke Construction, LLC completed New Mexico Department of Game and Fish funded projects in 2019.

Holman Creek has multiple reports documenting progress in this four-tributary creek. Water temperature measurements recorded in the next few years should determine whether these efforts have had a cooling effect on stream water. More restoration work could be completed in the large Holman Creek watershed to further the goal of increasing water quality by reducing water temperature.

Appendix A – Creek Assessment Notes and Field Data

LaBelle Creek

LaBelle Creek has a long history of human impact. These impacts have resulted in a creek with many problems. Creek incision and drying of wetlands and fens is the main problem in La Belle Creek. Canopy cover measurements were zero in every recorded location along LaBelle Creek in 2018. However; based on old maps, the absence of old/abandoned beaver dams, and no current presence of alder or willow species, it appears that LaBelle Creek was always a grassland park system with little riparian shade.






Appendix A – Creek Assessment Notes and Field Data

Gold Creek

Though Gold has been partially treated with Coke Wetland Replenishment funds and CWA 319 funds through a project with the Quivira Coalition, there are still many opportunities to install in-stream features to raise and stabilize the channel grade, rewet portions of floodplain and provide stream shading in the upper watershed.

August 2018. Wetland stabilization work was complete in Gold Creek by Watershed Artisans using Coke Wetland Replenishment Funds.

High in the watershed, there are locations where riparian exclosures might allow alder to shade the narrow channel and associated wetlands. Much of the lower Gold Creek subwatershed is broad open, wetland meadows with little opportunity for shade treatments. Some portions of the stream reach are deeply entrenched and provide little opportunity for restoration successes.

APPENDIX A – CREEK ASSESSMENT NOTES AND FIELD DATA

GOLD CREEK - TABLE OF CANOPY PERCENTAGES

Sample Location	Left Bank	Center-Upstream	Center-Right	Center-Downstream	Center-Left	Right Bank
1	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	5.88	0.00	5.88
6	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00
8	29.41	5.88	0.00	0.00	41.18	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00

Appendix B - East Holman Creek – 2019 Photo Monitoring

September 2018

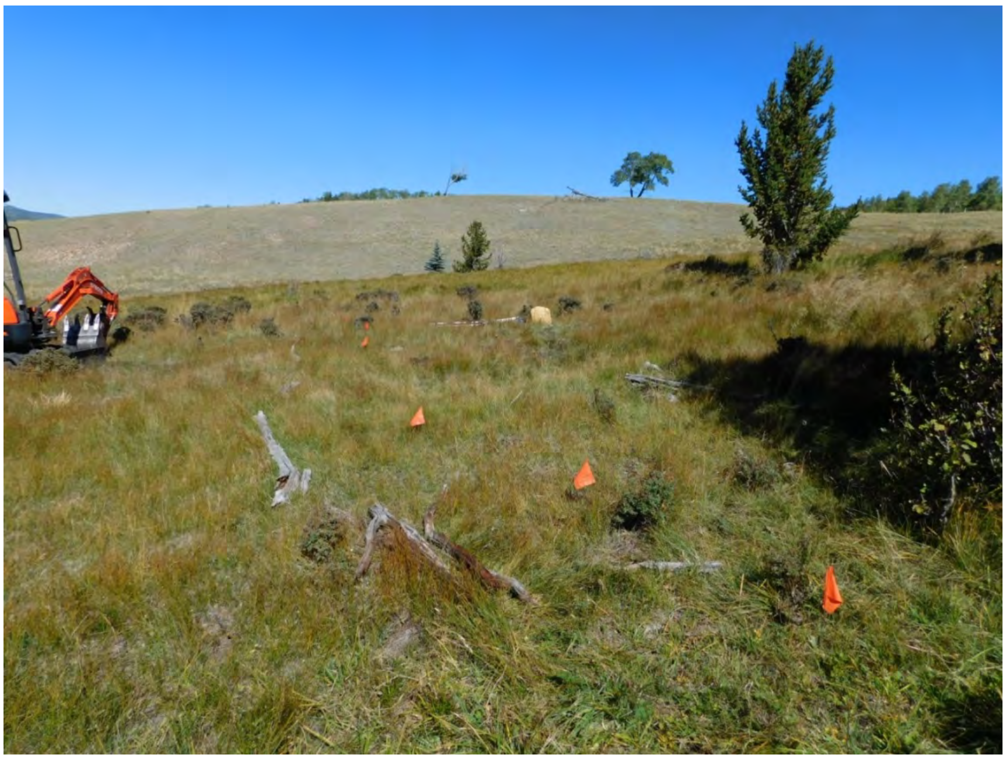
September 2018

August 2019. Restoration treatment addressed an incised secondary channel through valley wetlands. High banks were collapsed and the new channel profile was armored with angular cobble.

September 2018

September 2018

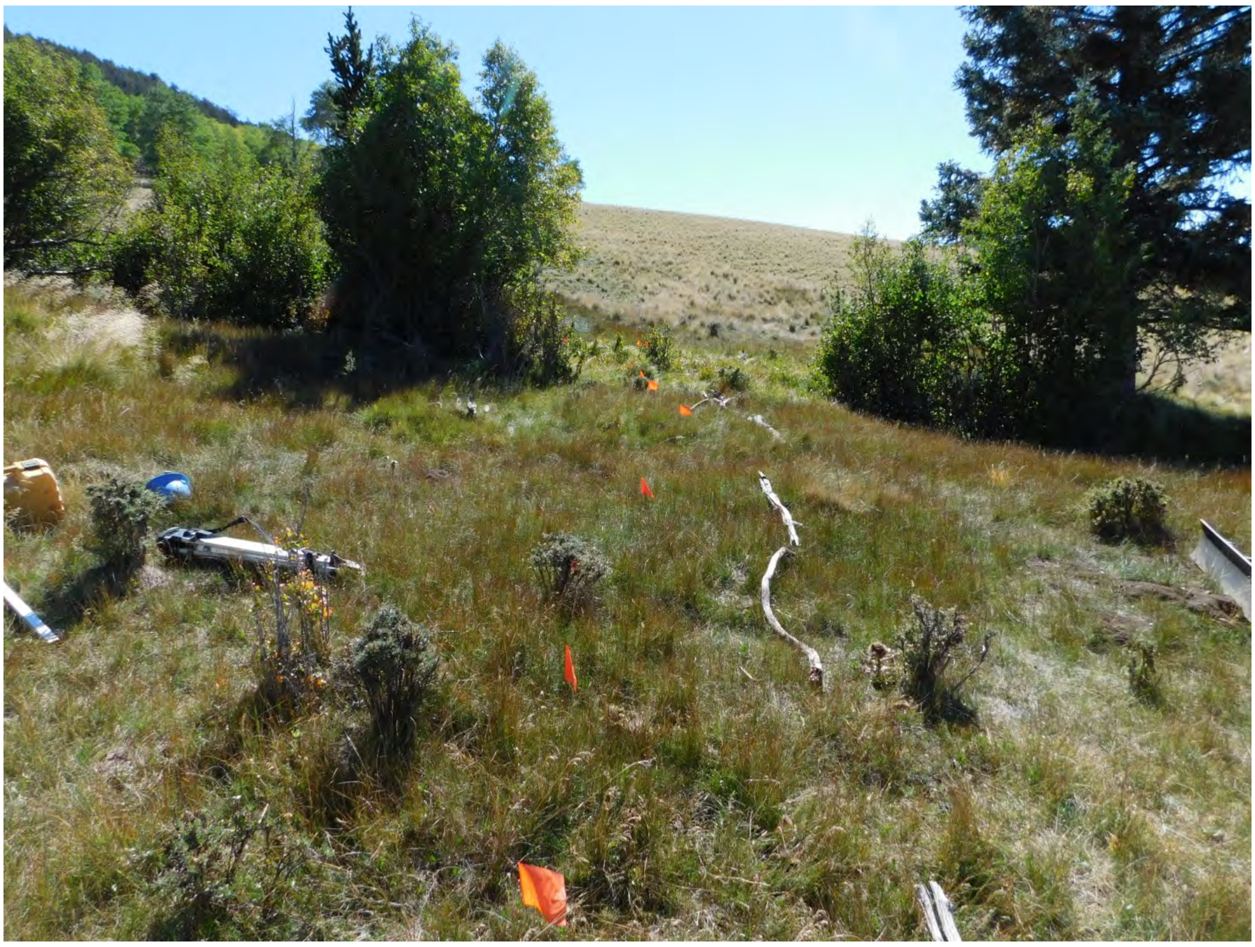
August 2019. Restoration treatment included an in-channel log flow splitter in the main channel to lift the channel and to spread water to a log and rock berm that directs surface water to valley right.


September 2018. View is from valley left to valley right


September 2018


August 2019. Log and rock berm designed to move water toward the center of the valley

APPENDIX B - EAST HOLMAN CREEK – 2019 PHOTO MONITORING



September 2018. View is from valley right to valley left.

August 2019

Appendix B - East Holman Creek – 2019 Photo Monitoring

September 2018

August 2019. A rock media luna was constructed to further spread from the flow splitter and lead out berm upvalley.

September 2018

September 2018.

August 2019. A log mat flow splitter with rock armor was installed to move water to rewet a dried swale downslope at valley right.


June 2018


August 2019

APPENDIX B - EAST HOLMAN CREEK – 2019 PHOTO MONITORING


September 2018


August 2019. One rock dams

APPENDIX B - EAST HOLMAN CREEK – 2019 PHOTO MONITORING

August 2019. Sod swale with rock-armoured stable return

APPENDIX B - EAST HOLMAN CREEK – 2019 PHOTO MONITORING


August 2014


August 2019, Zuni Bowls and rock rundown to stabilize head-cutting and gully formation (2019 NMDGF Funding)

September 2018. View from valley right to valley left

August 2019. Bebb willow exclosure, view from valley left to valley right

Appendix B - East Holman Creek – 2019 Photo Monitoring

August 2018

August 2019. Restoration treatment addressed an incised secondary channel through valley wetlands. High banks were collapsed and the new channel profile was armored with angular cobble (2019 NMDGF Funding).

Appendix B - East Holman Creek – 2019 Photo Monitoring

August 2014

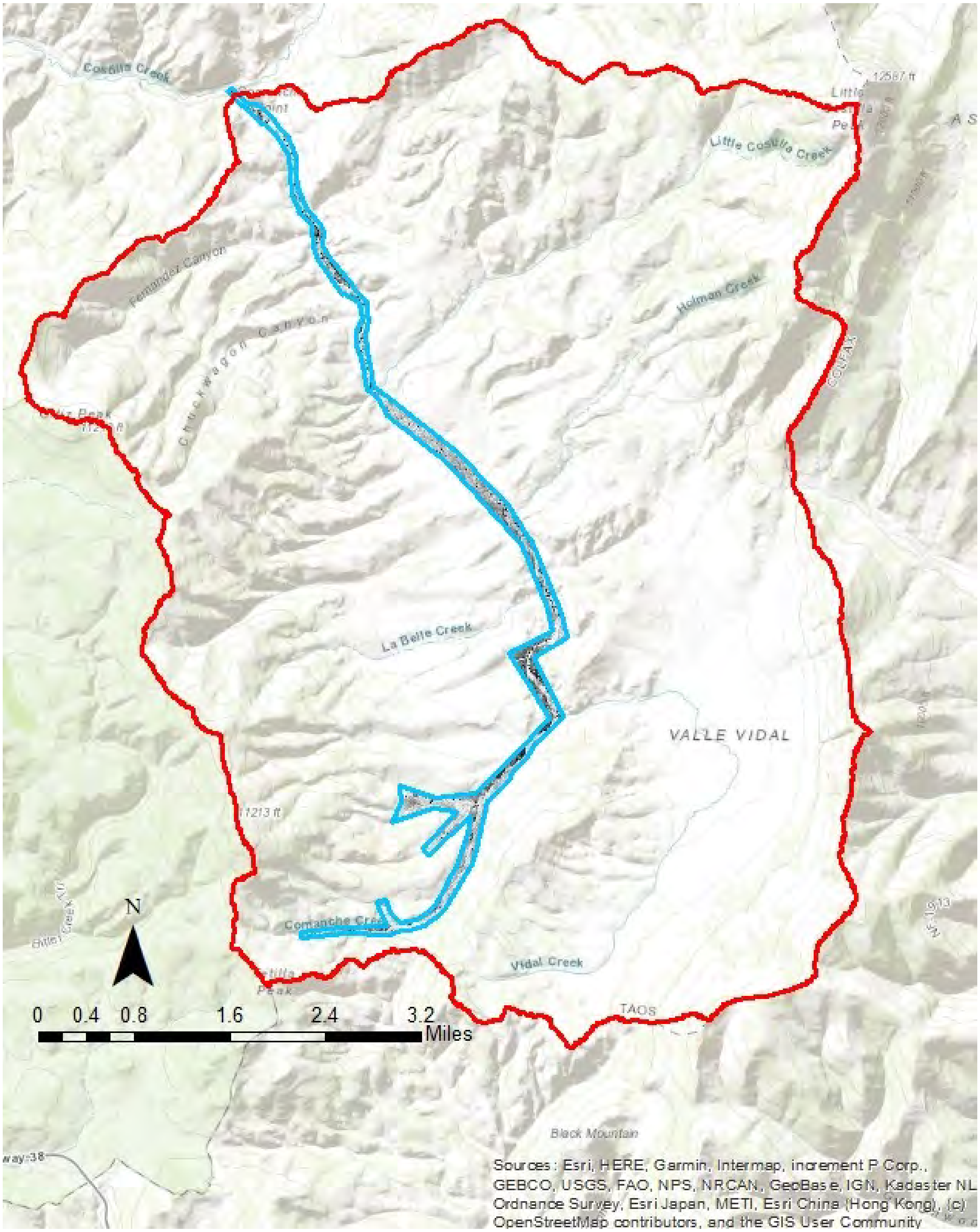
August 2019. Zuni bowl and large rock rundown constructed by Quivira volunteers and Reieneke Construction in 2019

APPENDIX B - EAST HOLMAN CREEK – 2019 PHOTO MONITORING

August 2014

August 2019, Zuni Bowl and rock rundown to stabilize head-cutting and gully formation from Forest Service Road 1950 culvert (2019 NMDGF Funding)

Appendix C – Normalized Difference Vegetation Index (NDVI) Imagery of Comanche Creek Mainstem



High resolution, drone-captured imagery and NDVI layer indicate where subsurface flows exist in the Comanche Creek Floodplains.

APPENDIX C – NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) IMAGERY OF COMANCHE CREEK MAINSTEM

Appendix C – Normalized Difference Vegetation Index (NDVI) Imagery of Comanche Creek Mainstem