Aquatic Resources Assessment of the Willow Creek Watershed

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U.S. Environmental Protection Agency, Region 8
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Acknowledgements

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List of Acronyms

CDMG	Colorado Division of Minerals and Geology
CDPHE	Colorado Department of Public Health and Environment
CGS	Colorado Geological Survey
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CWA	Clean Water Act
DEM	digital elevation model
EA	environmental assessment
EIS	environmental impact statement
EPT	Ephemeroptera, Plecoptera, and Tricoptera (macroinvertebrates)
FEMA	Federal Emergency Management Agency
GIS	geographic information system
HEC-RAS	Hydraulic Engineering Center River Analysis System
LOAEL	lowest observed adverse effects level
NOAEL	no observed adverse effects level
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NPS	non-point source
NRCS	Natural Resources Conservation Service [Department of Agriculture]
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RBP	Rapid Bioassessment Protocol
SRI/CSI	Stream Reach Inventory/Channel Stability Index
TMDL	total maximum daily load
TVS	table value standard
USDA	United States Department of Agriculture
USACOE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service [Department of Agriculture]
USFWS	United States Fish and Wildlife Service [Department of Interior]
USGS	United States Geological Survey [Department of Interior]
WCRC	Willow Creek Reclamation Committee
WQCC	Water Quality Control Commission [CDPHE]

1.0 INTRODUCTION

The Willow Creek Watershed is located in Mineral County, Colorado in the eastern part of the San Juan Mountains (Figures 1.1 and 1.2). Willow Creek and its tributaries, East Willow Creek and West Willow Creek, drain the Willow Creek Watershed, an area of 39.8 mi^2 (103.1 km^2). Willow Creek is a tributary of the Rio Grande. The City of Creede and part of the historic Creede Mining District are located within the watershed. Since 1999, the citizens of Creede and Mineral County, through the leadership of the Willow Creek Reclamation Committee (WCRC), have been engaged in environmental assessment and restoration efforts aimed at remediating environmental impacts from historic mining and in restoring healthy riparian conditions along Willow Creek. To support these efforts, the U.S. Environmental Protection Agency (USEPA) Region 8 Ecosystems Protection Program, in partnership with the WCRC, completed an aquatic resources assessment of the Willow Creek Watershed that summarizes the WCRC work and broadens its scope. This report provides a detailed summary of the aquatic resources assessment.

Figure 1.1 - Willow Creek Watershed in the State of Colorado

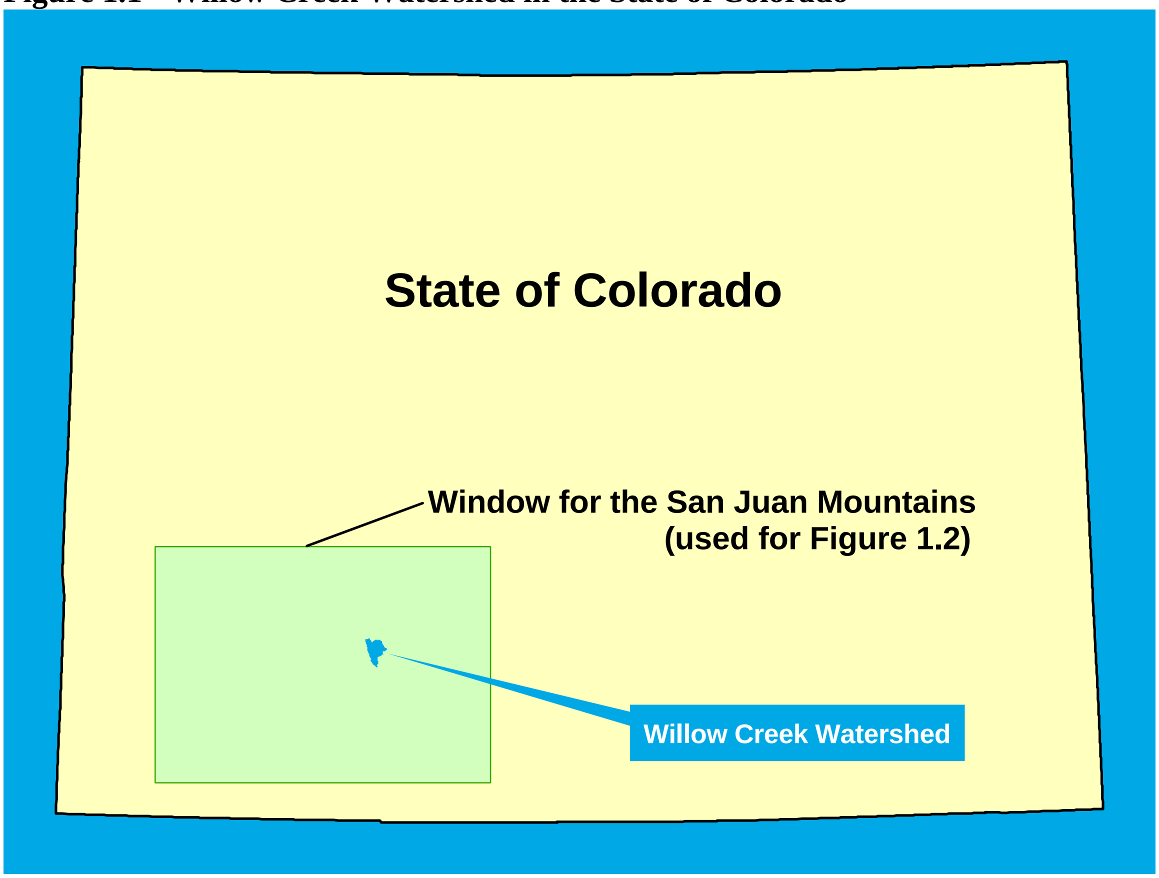
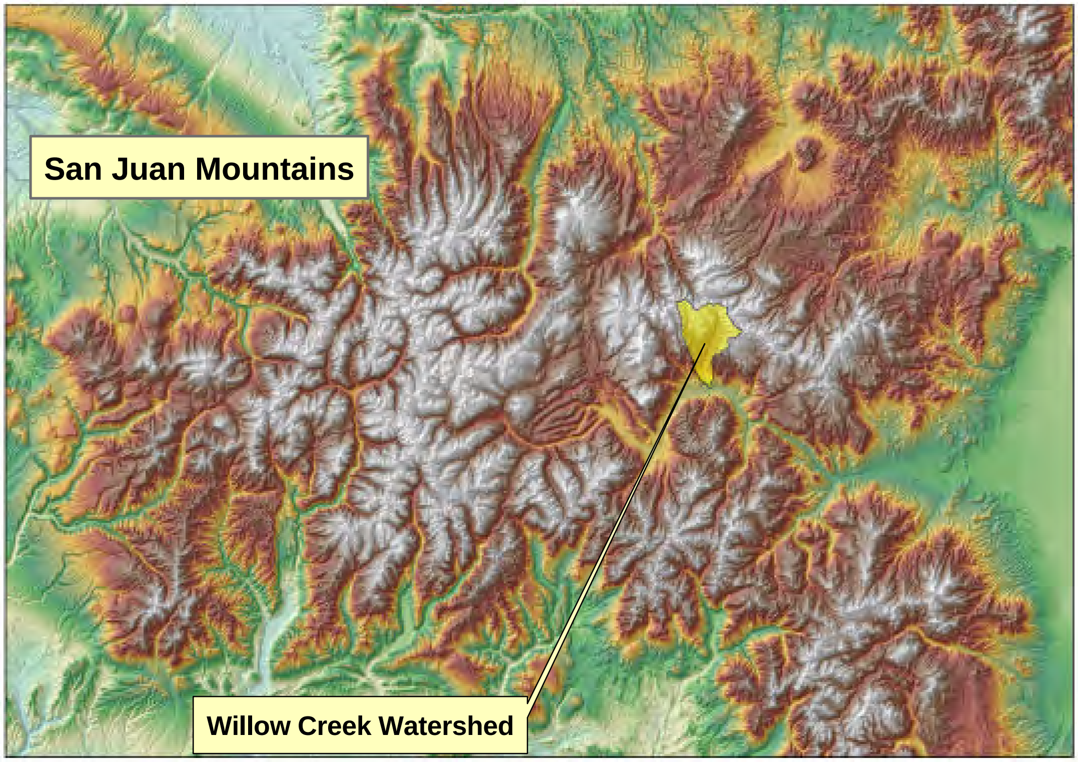


Figure 1.2 - Willow Creek Watershed in the San Juan Mountains of Colorado



1.1 Purpose, Scope, and Objectives

The purpose of this assessment is to analyze and interpret existing data in order to: 1) summarize the condition of aquatic resources within the Willow Creek Watershed and to describe the major stressors that affect the resources; 2) develop a set of recommendations for future studies and remedial actions; and 3) provide this information to the WCRC in an accessible and readable reference document.

This assessment emphasizes the ecological and the hydrological conditions of the watershed's surface water, ground water, wetlands, and riparian habitat, and identifies the potential stressors causing impairments to these resources. It organizes, synthesizes, and interprets data and information currently available from the WCRC and other sources, utilizing a watershed approach. The assessment is designed to support the WCRC's development and implementation of a Willow Creek Watershed Management Plan and revisions to the U.S. Forest Service's Rio Grande National Forest Plan for those parts of the Willow Creek Watershed that lie within the Rio Grande National Forest.

USEPA Region 8, in consultation with the WCRC, set forth the following objectives for the aquatic resource assessment:

(1) characterize the aquatic resources of the watershed as comprehensively as availability of time and people permit;
(2) identify local community and other stakeholder goals for the condition of the

watershed's aquatic resources;
(3) determine the current ecological condition of the aquatic resources of the watershed;
(4) identify the key stressors on the aquatic resources of the watershed and their magnitude; and
(5) characterize known and potential sources of contamination or impairment to the aquatic resources of the watershed.

These objectives have guided the assessment efforts described and discussed in this report.

1.2 Stakeholder Goals - Desired State of the Resources

In 1998, the USEPA and the Colorado Department of Public Health and Environment (CDPHE) were beginning to look at options for characterizing and remediating water quality impacts to Willow Creek and the Rio Grande from historic mining activities within the Creede Mining District. After some preliminary assessment work, the district was being considered for listing on the National Priorities List and subsequent assessment and remediation pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), often referred to as Superfund. The citizens of Creede and Mineral County were determined to avoid this listing primarily because they perceived that designating the mining district as a Superfund site would have negative impacts on the local economy and community.

As an alternative, the WCRC was established in 1999 to develop, guide, and implement a stakeholder-based watershed approach to remediating and restoring water quality and riparian conditions along Willow Creek. The WCRC set clear goals with regard to the community's vision for the Willow Creek Watershed. These are:

(1) *Protect the Rio Grande from future fish kills associated with nonpoint source releases during unusual hydrologic events*
(2) *Improve the visual and aesthetic aspects of the Willow Creek Watershed and its historical mining district*
(3) *Implement appropriate and cost-effective flood control and stabilization measures for nonpoint sources*
(4) *Protect and preserve historic structures*
(5) *Reclaim the Willow Creek Floodplain below Creede to improve the physical, chemical, biological, and aesthetic qualities of the creek as an integral part of the local community*
(6) *Continue to improve water quality and physical habitat in the Willow Creek Watershed as part of a long-term watershed management program*

These goals have guided the assessment and restoration efforts during the past six years. The WCRC, with financial and technical support from local citizens, the Rio Grande Water Conservation District, the U.S. Department of Agriculture (USDA), USEPA, CDPHE, and the Colorado Division of Minerals and Geology (CDMG), has made significant progress in assessing water quality impacts from historic mining activities and in remediating sources of contamination related to those activities.

1.3 Creede and the Willow Creek Reclamation Committee

Creede is a community of 377 people located in the lower portion of the Willow Creek Watershed (2000 U.S. Census) at an elevation of 8852 feet (2698 m). Towering rock formations rise to more than 11,000 feet (3353 m) just above the town. The region draws hunters, anglers, bicyclists, hikers, theater-goers, and other tourists.

The WCRC, formed in 1999, is comprised of representatives from a wide variety of public and private stakeholders, including local volunteers, the U.S. Forest Service (USFS), USEPA, CDPHE, the CDMG, the U.S. Fish and Wildlife Service (USFWS), the Colorado Geological Survey (CGS), and the Natural Resources Conservation Service (NRCS). The mission of the WCRC is "to address water quality and habitat issues in the Willow Creek Watershed in ways which are practical, cost-effective, and beneficial to the economic and environmental objectives of the community" (Appendix B, WCRC web site). Since 1999, the WCRC has been very active in pursuing its mission. The committee has championed numerous monitoring events, investigations, and reports, which have established the foundations for this assessment.

1.4 Methodology

The USEPA, USFS, and other agencies and organizations have developed numerous ecological assessment methodologies including *Ecosystem Analysis at the Watershed Scale* (USFS), *The Ecosystem Approach: Healthy Ecosystems and Sustainable Economies* (Interagency Ecosystem Management Task Force, 1995), *Biological Assessments and Criteria* (EPA web site), and *A Framework for Assessing and Reporting on Ecological Condition* (EPA, 2001). Among these methodologies are some common themes, including stakeholder involvement, issue and question identification, monitoring, condition statements, stressor identification, and recommendations. These themes have been incorporated in an EPA Region 8 ecological assessment methodology (Appendix A), and employed in the Willow Creek Watershed assessment effort.

The objectives stated in section 1.1 were achieved by compiling and interpreting existing data from many of the 25 technical reports and investigations completed by, or commissioned by, the WCRC (Appendix B; http://www.willowcreede.org). The interpretations were done with a watershed approach that focuses on hydrologically-defined drainage basins (watersheds), rather than on areas arbitrarily defined by political boundaries. The approach encompasses not only water resources (surface water, ground water, and springs), but all of the land the watershed drains. The watershed approach is action-oriented: it is driven by broad environmental objectives, and it involves key stakeholders. Additionally, this approach provides a coordinating framework for environmental management that focuses and integrates public- and private- sector efforts to address the highest-priority problems within the watershed.

The WCRC has employed the watershed approach in characterizing and remediating impacts from historic mining since its inception. The WCRC and its contractors have completed 25 technical reports to date. These reports characterize impacts to streams, ground water, fish, and macroinvertebrates from contamination sources associated with historic mining activities, and describe the results of restoration and revegetation efforts.

This aquatic resources assessment broadens reader knowledge base about the watershed by looking at the aquatic resources, stakeholders' desired state, and current condition throughout the watershed, not just within the Creede Mining District portion of the watershed. The assessment considers all known activities in the watershed that may impact aquatic resource condition, including, but not limited to, mining activities. It also assesses water uses and the known threats to water quality throughout the watershed.

The WCRC monitoring objectives targeted locations which would characterize the extent and severity of pollution and identify pollution sources. WCRC monitoring site selection included establishing sites upstream of the expected pollution 'zone', the watershed portion of the Creede Mining District, in order to confirm pollution extent. Sites were not established for much of the upper watershed since expectations were that the aquatic resources in the Upper Section were in good condition and the most upstream targeted sites would confirm that condition. Although there is limited monitoring data for the upper watershed, efforts were made to obtain additional insights through the use of geographic information system (GIS) data analysis, limited field survey, and communications with individuals with personal knowledge of the watershed.

This aquatic resource assessment addresses two areas of interest to the WCRC and other stakeholders. It investigates the ecological condition of the aquatic resources by addressing the biological, chemical, and physical habitat characteristics of the watershed. It also investigates the hydrological condition by considering watershed properties related to flooding, water uses, and legal water rights.

In order to better understand the desired state of the aquatic resources and their current ecological and hydrologic condition, EPA Region 8 staff developed 25 assessment questions with the assistance of the WCRC (Appendix C). This assessment is designed to answer these questions to the extent allowed by available information. Quantitative and qualitative analyses and interpretation of the data and information in the WCRC's 25 technical reports and other sources were utilized in conducting the assessment. GIS spatial analyses of multiple data layers from a variety of sources, including federal, state, and local organizations, allowed additional interpretation (Appendix D). The assessment also identifies numerous anthropogenic (human-caused) and naturally-occurring stressors, and includes conclusions and assessment-related recommendations.

The answers to the assessment questions confirm much of what is already known about the Willow Creek Watershed, yet the assessment enhances reader understanding by evaluating current conditions to the stakeholders' desired state for the resources. The analysis and interpretation of complex resource interactions and relationships provides additional information for decision-makers to better protect, manage, and restore the aquatic resources throughout the watershed.

1.5 Organization of the Assessment

The remainder of the assessment provides detailed descriptions of the natural and anthropogenic resources in the watershed followed by chapters that describe the desired state, characteristics, and current condition, of each of the aquatic resource components: streams, wetlands and riparian areas, and groundwater. Although these resource components are discussed in separate chapters, this assessment recognizes that they are fundamentally interconnected. The interactions and processes that occur in the Willow Creek Watershed are described in the conclusions chapter. Recommendations are found in the final chapter.

2.0 THE WILLOW CREEK WATERSHED

2.1 Introduction

In this chapter, natural and anthropogenic characteristics of the watershed are described from both a current and an historic perspective. The natural characteristics include geography, climate, geology, soils, ecology, and aquatic resources (streams, ground water, and wetlands/riparian areas) while the anthropogenic characteristics include history, demographics, and land stewardship. This assessment examines aquatic resources, geology, soils, vegetation, and climate, five physical components that can affect water quality and quantity, and studies the natural processes and functions that govern their interactions. The watershed is rich in diversity of landscape types, mining history, and scenic beauty.

2.2 Natural Resources and Natural History

Geography

The Willow Creek Watershed, located in the San Juan Mountains of southwest Colorado, is 39.8 mi^2 (103.1 km^2) and is shown in **Figure 2.1**. The primary community in the watershed is the City of Creede, which is the county seat for Mineral County. Creede's elevation is 8,852 ft (2,685m.) above mean sea level.

The watershed is roughly triangular, narrowing to the south to the point where Willow Creek enters the Rio Grande. The watershed is approximately 7 mi. (11.5km.) wide at its widest point. The highest point in the watershed is La Garita Peak, northeast of Creede, at an elevation of 13,894 ft. (4,235 m.). Much of the Upper Section exceeds 11,000 ft. (3,353 m.) in elevation. The lowest point is the confluence of Willow Creek with the Rio Grande at 8,602 ft. (2,622 m.). Thus, the vertical relief of the watershed is 5,292 ft. (1,613 m.). This relief is the basis for the significant variation in precipitation, temperature, and vegetation throughout the watershed.

The watershed has been divided into sections based on natural differences in landscape characteristics. Aggregations of sub-watersheds (Appendix D) served as the basis for creating the sections which have been named Upper, Middle, Creede, and Lower (Figure 2.2). The relatively pristine Upper Section of the watershed contrasts sharply with the Middle, Creede and Lower Sections, which have been profoundly impacted by historic mining. The Middle Section has steep terrain and stream gradient and narrow canyons and is the heart of the Creede Mining District. The Creede Section contains the City of Creede at the mouth of the Willow Creek Canyon. The Lower Section contains the relatively flat alluvial floodplain of Willow Creek before its confluence with the Rio Grande.

Figure 2.1 - Willow Creek Watershed

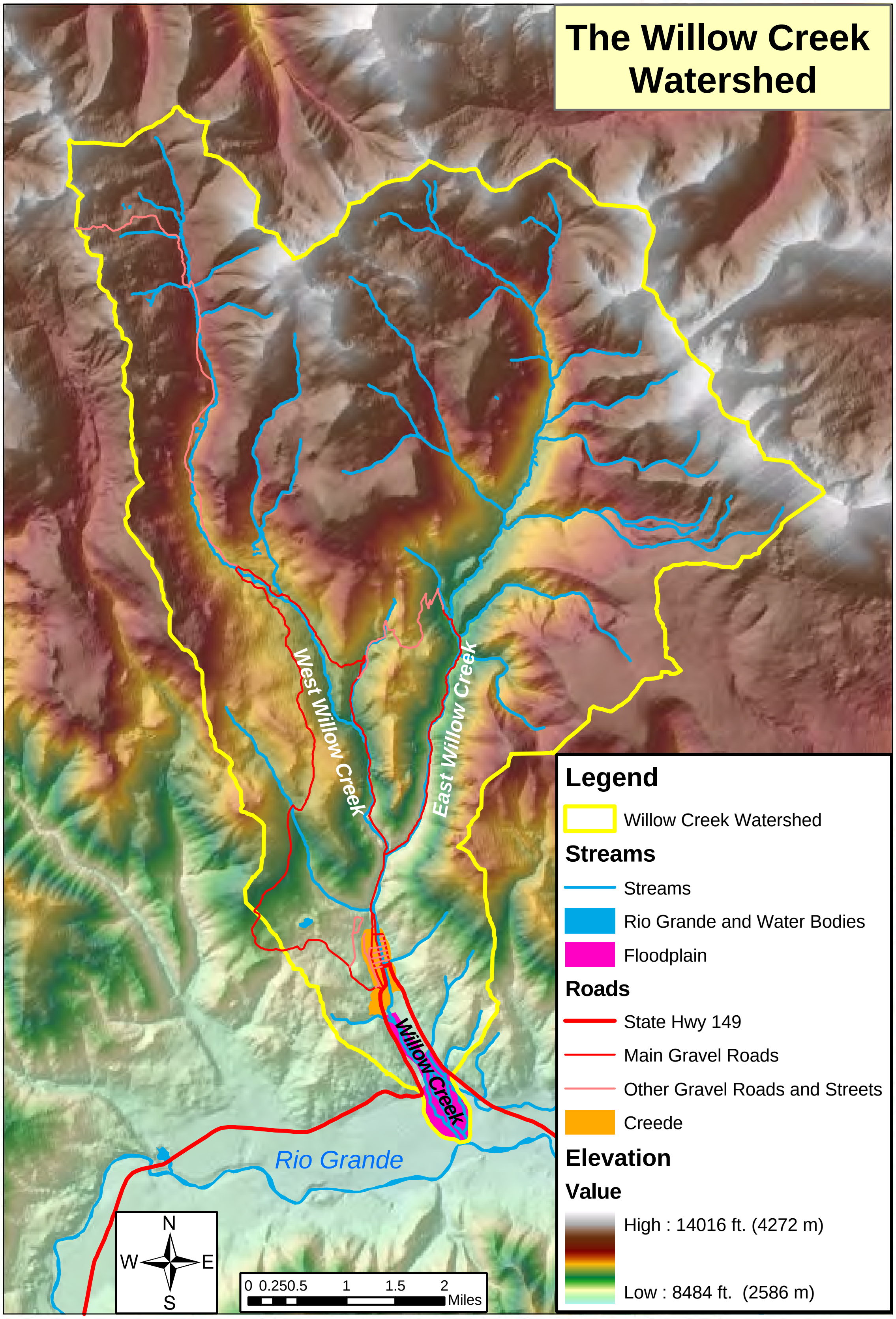
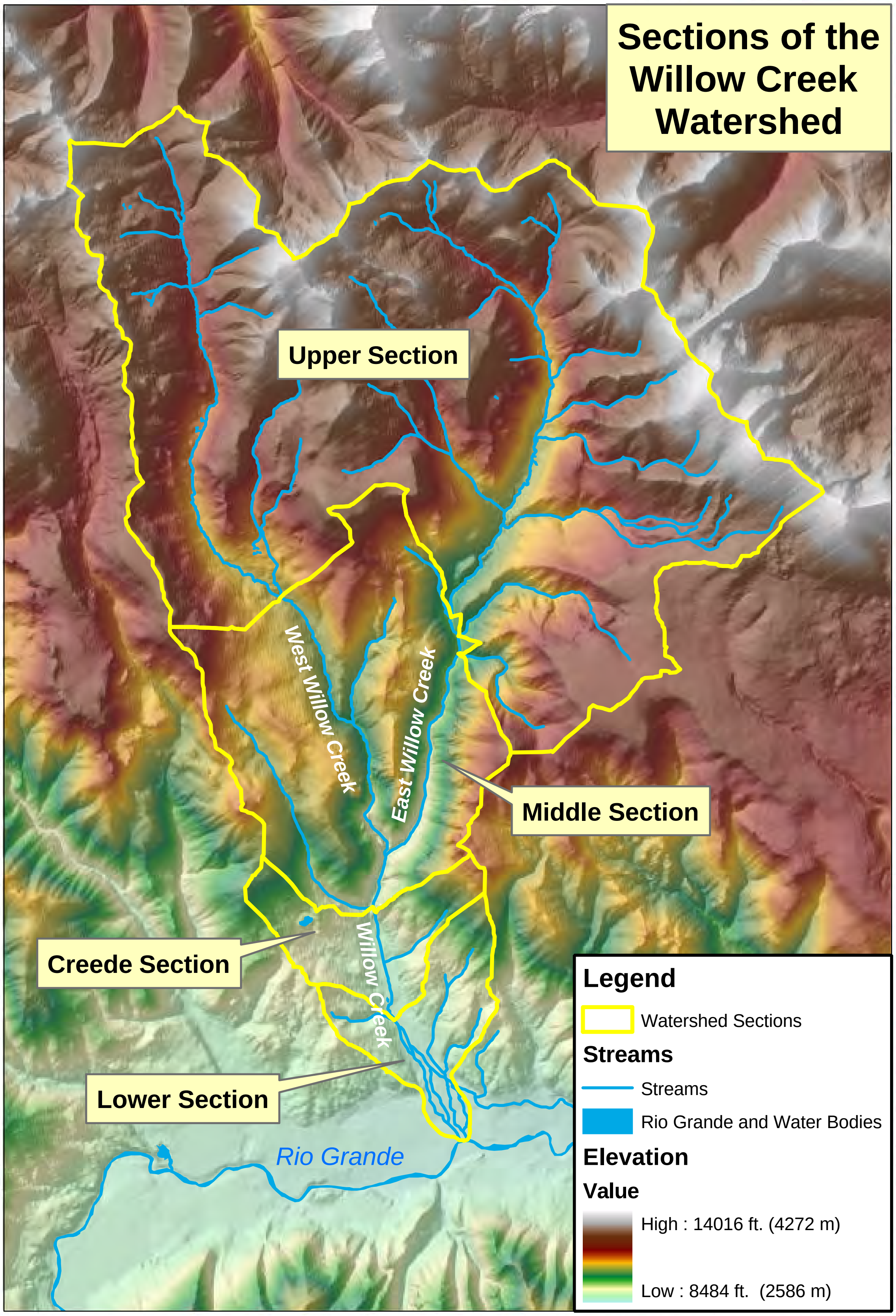


Figure 2.2 - Sections of the Willow Creek Watershed



Climate

The watershed's climate is partially understood by the analysis of average and extreme values of temperature and precipitation measured for the past 25 years at the Creede Weather Station. Climate heavily influences vegetative communities, stream-flow magnitude and timing, water temperature, ground water recharge, and many other key watershed characteristics. The climate varies considerably across the watershed sections due to the extreme elevation differences but the following data only apply to Creede (http://www.wrcc.dri.edu/summary/climsmco.html).

Data from the weather station shows that the watershed is arid to semi-arid. At the higher elevations, most of the moisture is from winter snowfall. The southerly exposure of the watershed and its steep slopes result in rapid snow melt and runoff. Climate data for the Creede Weather Station, the only weather station in the watershed, for the period of June 1978 through March 2004 is summarized as follows:

Average annual precipitation: 13.2 in. (335 mm.)

Month of highest precipitation: August (2.6 in. (65 mm.))

Month of lowest precipitation: December (0.5 in. (13 mm.))

Average annual snowfall: 47.9 in. (122 cm.)

Average annual temperature: 40.9º F (14.3º C)

Month of highest average temperature: July (60.8º F (16.0º C))

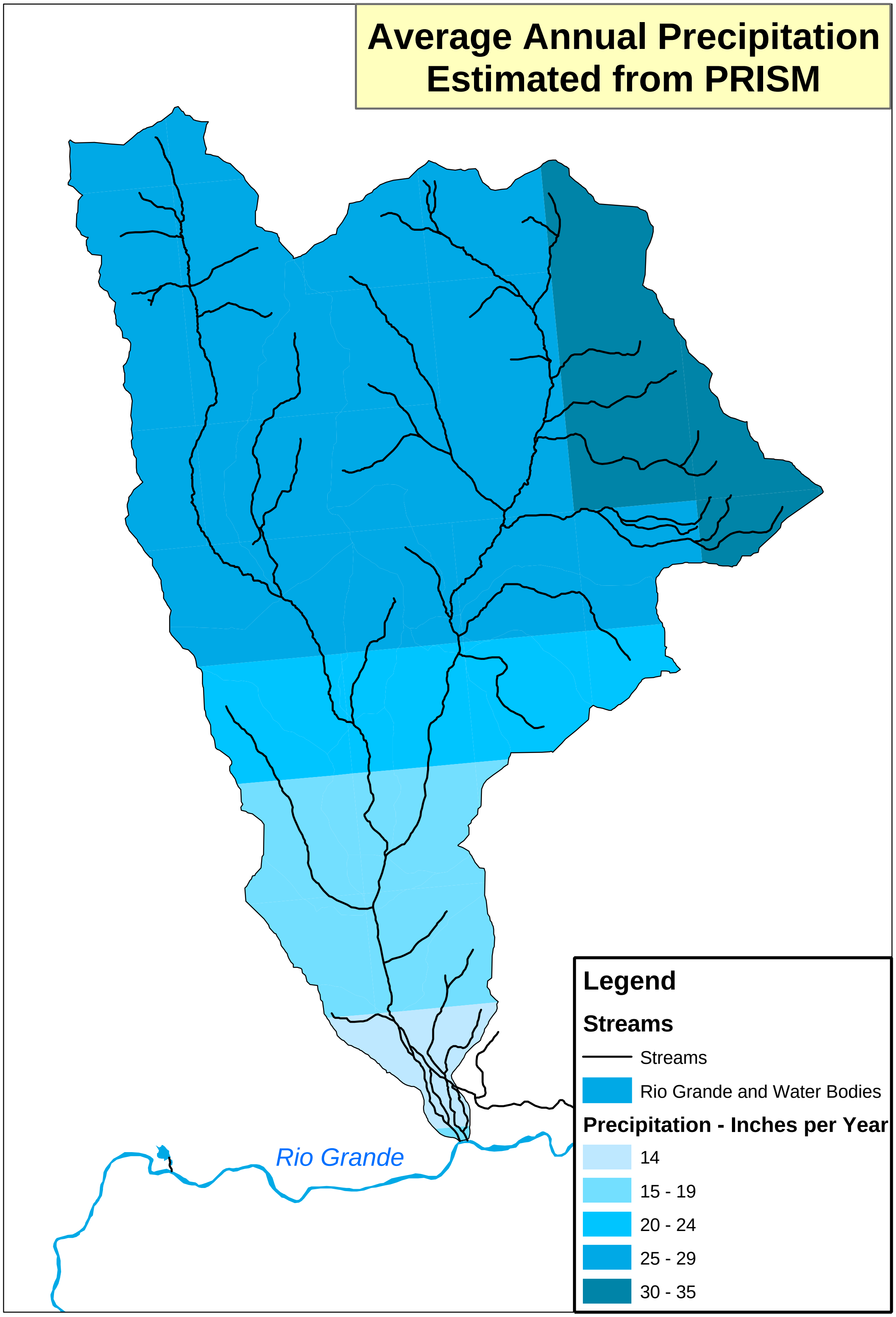
Month of lowest average temperature: January (21.9º F (-5.6º C))

(Source: http://www.wrcc.dri.edu/summary/climsmco.html)

On average, the area has 275 or more days of sunshine per year (Creede and Mineral County Chamber of Commerce web site). The record high was 97° F (36.1º C) in 1963 and the record low was -45° F (-42.8º C) in 1979 (The Weather Channel Interactive, Inc. web site).

Precipitation volumes vary with changes in elevation. In any given area, the largest volumes of snow or rain occur at the higher elevations. Since there is over a mile of relief within the Willow Creek Watershed and only one climate station, precipitation throughout the watershed was characterized with estimates from the Parameter-elevation Regressions on Independent Slope Model (PRISM) (Spatial Climate Analysis Service, Oregon State University, 1998). This national model estimates annual precipitation volume for 2 km by 2 km grid cells utilizing weather station inputs and interpolating between stations with adjustments for elevation. Since the Creede weather station is the closest weather station to all areas within the watershed, estimates throughout the watershed are primarily elevation adjustments to the precipitation volume measured at the Creede weather station. **Figure 2.3** shows the PRISM estimates of average annual precipitation for the watershed.

Figure 2.3 - Annual Precipitation Estimated from PRISM



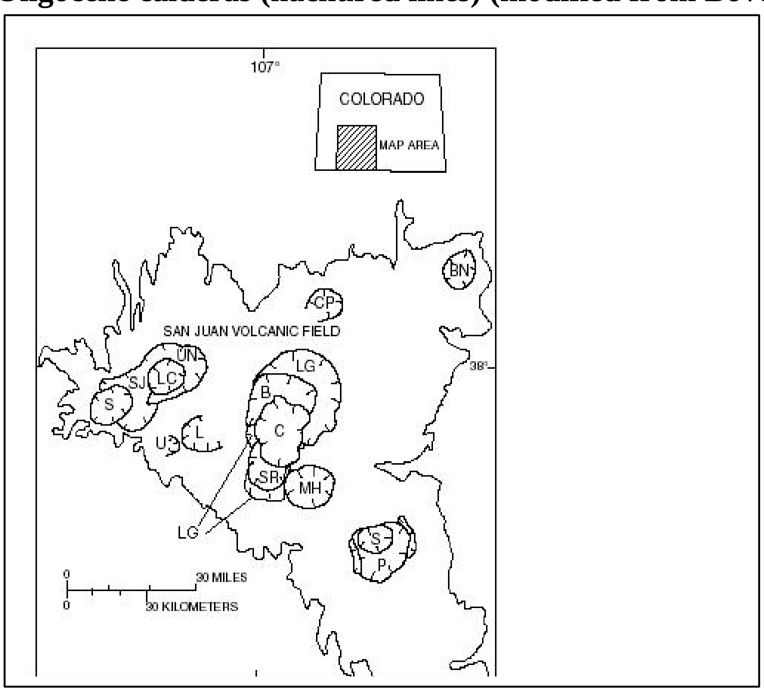
Geology

The Willow Creek Watershed is located within the San Juan Volcanic Field. Its bedrock geology is dominated by igneous rocks related to extensive tertiary volcanism which began about 28 million years ago and ended about 2 million years later. Caldera-forming eruptions were accompanied by extensive faulting during and after the collapse of the calderas (Steven and Ratte, 1973).

A caldera is formed during a massive, explosive volcanic eruption after which the volcano collapses inward, forming a large crater, generally with a resurgent dome in its center. These eruptions produce massive clouds of hot volcanic ash, which roll across the land, along with lava flows, volcanic breccias, and associated extrusive igneous rocks. Some of the ash flows are so hot that they weld back together into solid rock once the cloud of ash stops moving. Called ashflow tuffs, this type of rock is common in the watershed above Creede and is the dominant host rock for the mineral deposits in the mining areas along East and West Willow Creeks. These rocks can be very resistant to weathering and form cliffs along water courses (Steven and Ratte, 1973).

The Creede Mining District occurs within the Bachelor and Creede Calderas which developed within the older La Garita Caldera, which is roughly 25 mi. (40 km.) wide and 45 miles (75 km) long (Figure 2.4) (Ort, 1997). Tertiary rocks are covered in some areas by younger, Quaternary age deposits including landslides, till deposited by valley glaciers, alluvium, and alluvial fans (Figure 2.5 – Note: The detailed legend for this figure is in Appendix E). The ore veins along East Willow Creek and West Willow Creek are associated with very deep faults in, and perhaps beneath, the ashflow tuffs from the Bachelor Caldera (Neubert and Wood, 1999).

Figure 2.4 – Map of the San Juan Volcanic Field, Colorado, showing the location of Oligocene calderas (hachured lines) (modified from Bove, et. al., 1999)



Legend

Calderas of the western San Juan Mountains include the: Ute Creek (U), Lost Lake (L), Uncompahgre (U), San Juan (SJ), Silverton (S), and Lake City (LC) calderas.
Calderas from the central and eastern San Juan Mountains include: La Garita (LG), Bachelor (B), Creede (C), South River (SR), Mount Hope (MH), Cochetopa Park (CP), Silverton (S), Platoro (P), and Bonanza (B).

Figure 2.5 - Surficial Geology of the Willow Creek Watershed

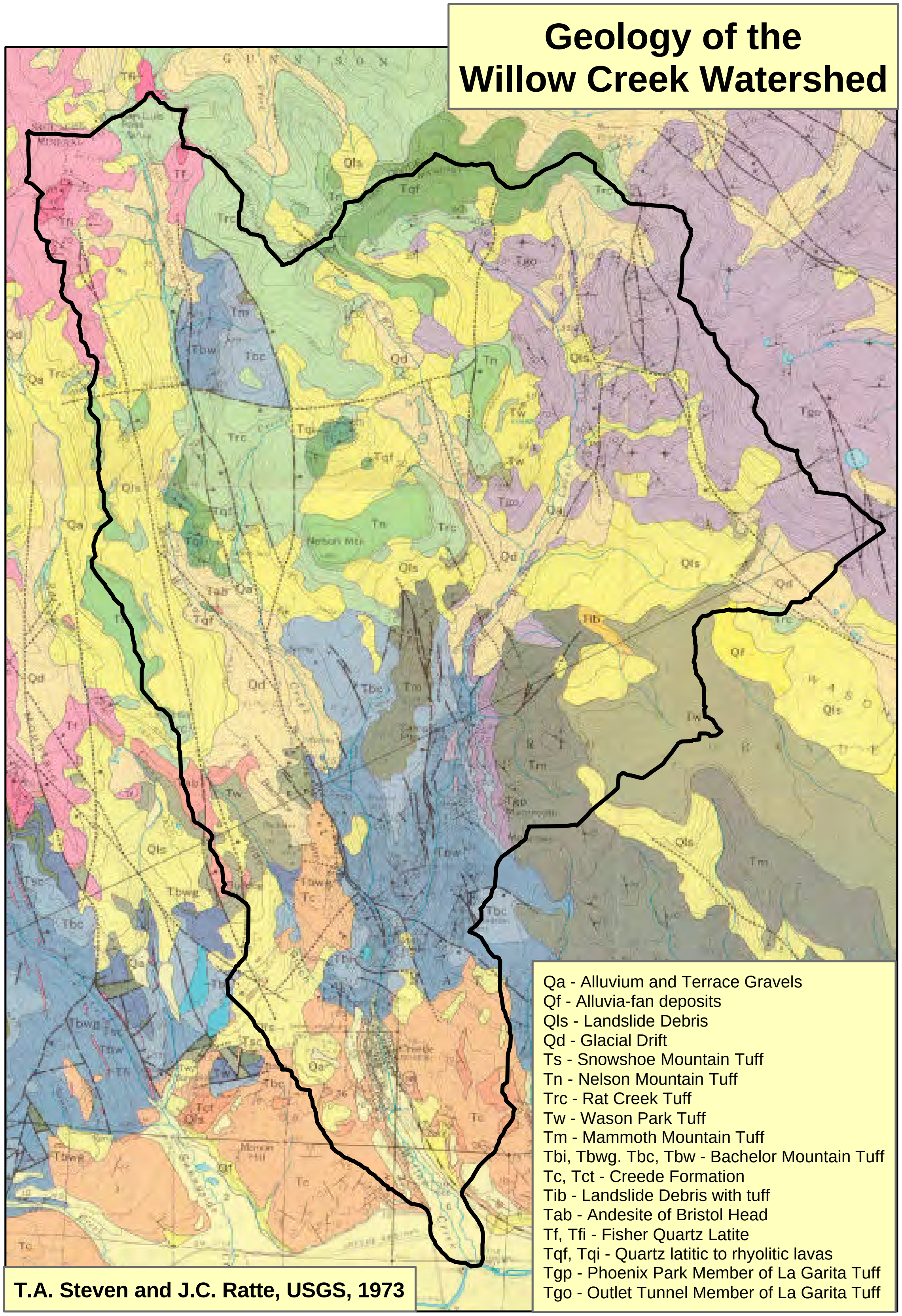
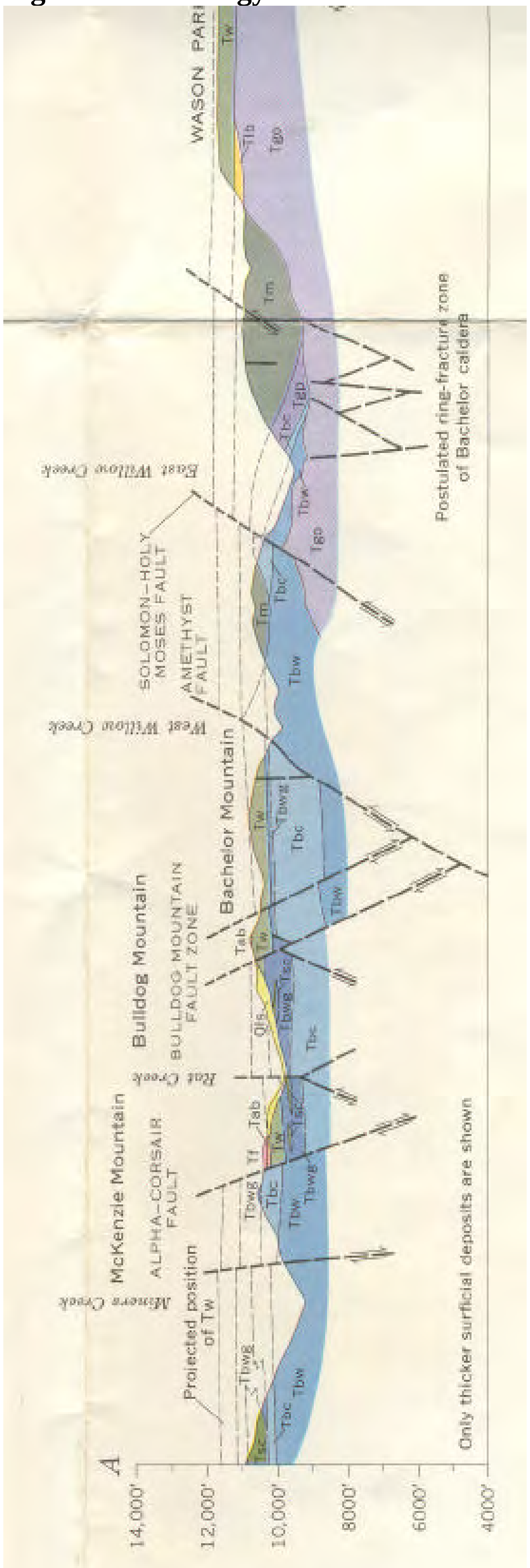


Figure 2.6 - Geology Cross-Section of the Willow Creek Watershed



(Steven and Ratte, 1973)

The area beneath Creede and southward to the confluence of Willow Creek and the Rio Grande is generally underlain by the Creede Formation, which is dominated by lake and river deposits of reworked ash, sand and gravel, and travertine deposits from numerous mineral hot springs that formed after the eruption of the Creede Caldera. These deposits filled in the area around the Creede Caldera's resurgent dome, now known as Snowshoe Mountain. Quaternary alluvium from Willow Creek and the Rio Grande cover much of the older rocks in the lower part of the watershed, especially along the waterways (Steven and Ratte, 1973).

The repeated eruptions and subsidence caused extensive faulting, both around the calderas and within existing rocks around them. Once volcanism was over, extensive mineralization along the faults created the great sulfide ore veins which attracted mining to the area in the late 1880s (Neubert and Wood, 1999).

Both Willow Creek and the Creede Mining District are located within the Creede Graben, a series of down-dropped fault blocks between the Solomon-Holy Moses Fault to the east and the Alpha-Corsair Fault Zone to the west, outside of the Willow Creek Drainage (Figure. 2.6 – Note: The legend for this figure is in Appendix E). The Solomon-Holy Moses Fault, which dips to the west, is exposed on the western side of East Willow Creek. A second major west-dipping fault, the Amethyst Fault, is located on the west side of West Willow Creek (Steven and Ratte, 1973). Both of these faults were extensively mined for their rich silver ores and other associated minerals, with the Amethyst Fault and associated hanging wall veins holding the richest ores. Both oxidized and primary ores are present on both veins. Minerals of the oxidized zones include both clear and amethystine quartz, barite, galena, sphalerite, pyrite, chalcopyrite, cerussite, anglesite, silver, gold, and cerargyrite. Where unoxidized, the primary sulfide minerals are galena, sphalerite, pyrite, and chalcopyrite, occurring with chlorite, talc, quartz, and sometimes fluorite or rhodochrosite (Neubert and Wood, 1999). Gold, zinc, lead, and copper were also products at these mines.

Soils

Soils provide the medium and nutrients for plant growth within the watershed. An unpublished soil survey that covers the watershed is available from the Rio Grande National Forest office (Soil Resource and Ecological Inventory of the Rio Grande National Forest – west Part, Colorado, U.S. Forest Service, 1996 Draft). The survey provides detailed information on the types of soils and the potential plant communities for each type of soil. The discussion of soils in this report is limited to describing soil characteristics and condition of two main types of soils, those of the uplands and those of riparian/wetland areas. Upland soils, as used in this report, are those that are not riparian or wetland soils.

The soil resources of the Willow Creek Watershed are described in terms of their relationships to the aquatic resources. Steepness of slope is the dominant soil characteristic of the upland soils in most of the watershed. Soils on steep slopes have a high hazard of erosion if the vegetative cover is removed. Also, shallow to bedrock are common in soils associated with areas of rock outcrop. Soils with bedrock at shallow depth have low water-holding capacity which, together with a shallow rooting zone, limits plant growth. The wetland/riparian soils have a water table at relatively shallow depth.

In order to simplify the soils information in this report, only those soil map units that cover more than five percent of the area in the watershed and the wetland/riparian soils are described. As a result, 11 of the 31 map units in the watershed covering just 77 percent of the surface area of the watershed are described.

Wetland and Riparian Soils

The wetland/riparian soil areas are depicted in **Figure 2.7** and described in **Appendix F**. The heavily disturbed floodplain below Creede is shown in **Figure 2.8**. One of the key characteristics of soils on the floodplain is surface salinity at a level that, together with droughtiness in the surface layers, decreases the chance of plant survival. Many places have an overburden of acid overwash material from mine waste from a few inches to several feet thick, increasing the depth to the water table and increasing droughtiness. Approximately 65 to 75 percent of the area is devoid of vegetation.

The other wetland/riparian soils in the watershed occur as small areas, predominately in the Upper Section. They are mostly well-vegetated with willow and sedge plant communities.

Upland Soils

The upland soil areas are depicted in **Figure 2.9** and described in **Appendix F**. Upland soils comprising less than five percent of the watershed and wetland/riparian soils are combined on this map in a unit named "Other Soils." A typical area of soils on steep slopes is shown in **Figure 2.10** and an alpine area is shown in **Figure 2.11**.

The upland soils in the Upper Section are in good condition (Les Dobson, USFS, personal communication, May 24, 2004). In addition to not being influenced by mining, this area has had limited human disturbance. This is also true of most of the upland soils in the Middle, Creede, and Lower Sections in areas not disturbed by mining. Many areas of upland soils in the Middle and Lower Sections have been impacted by mining activities (Figure 2.12) and, in some cases, to such an extent as to render them unfit for plant growth. The main potential effect of the upland soils on the aquatic resources of the watershed is the generation of sediment associated with the removal of vegetation. The preservation of forest and grassland cover will reduce soil erosion and sediment delivery to streams.

Figure 2.7 - Wetland and Riparian Soils of the Willow Creek Watershed

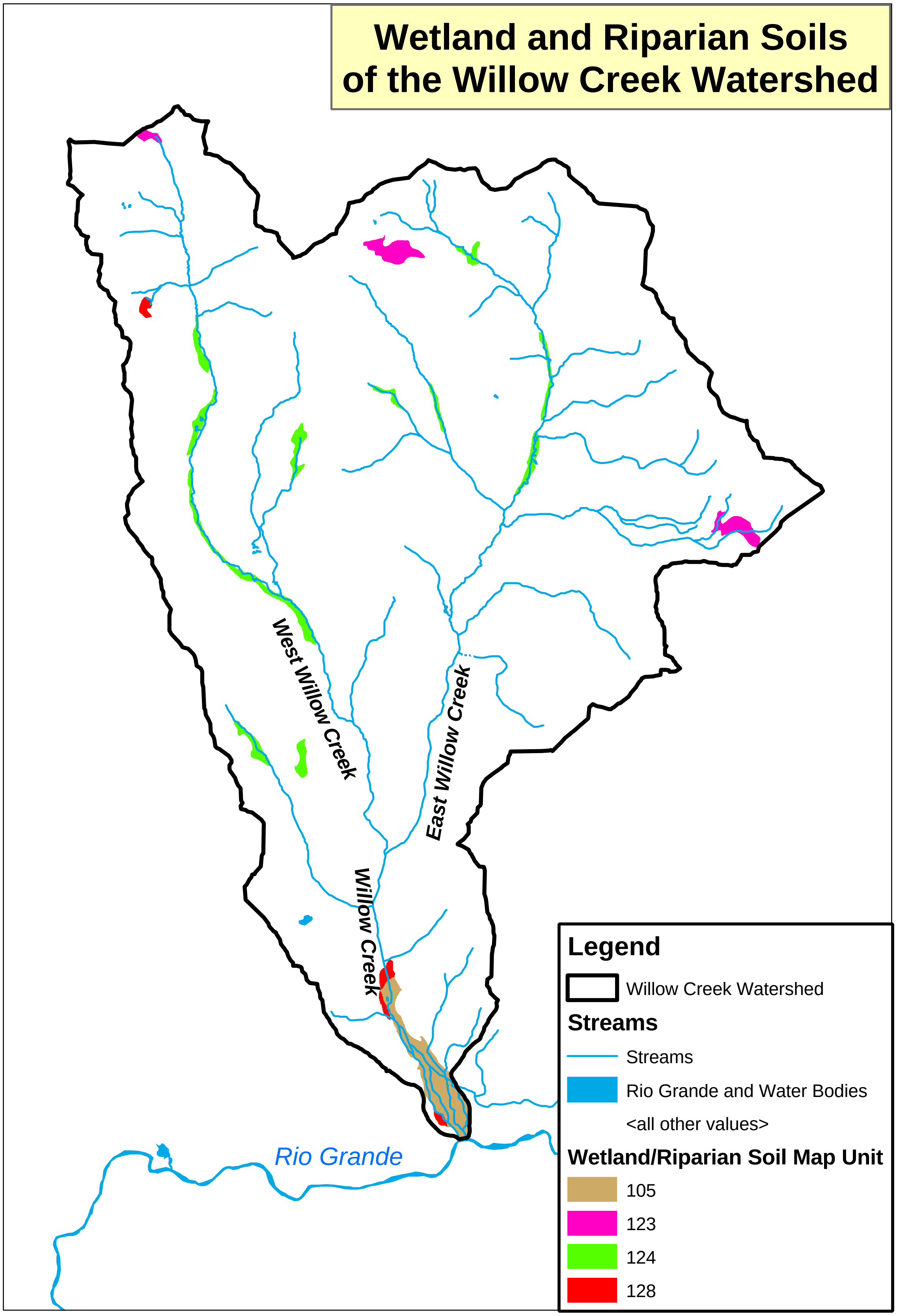


Figure 2.8 - Willow Creek Floodplain

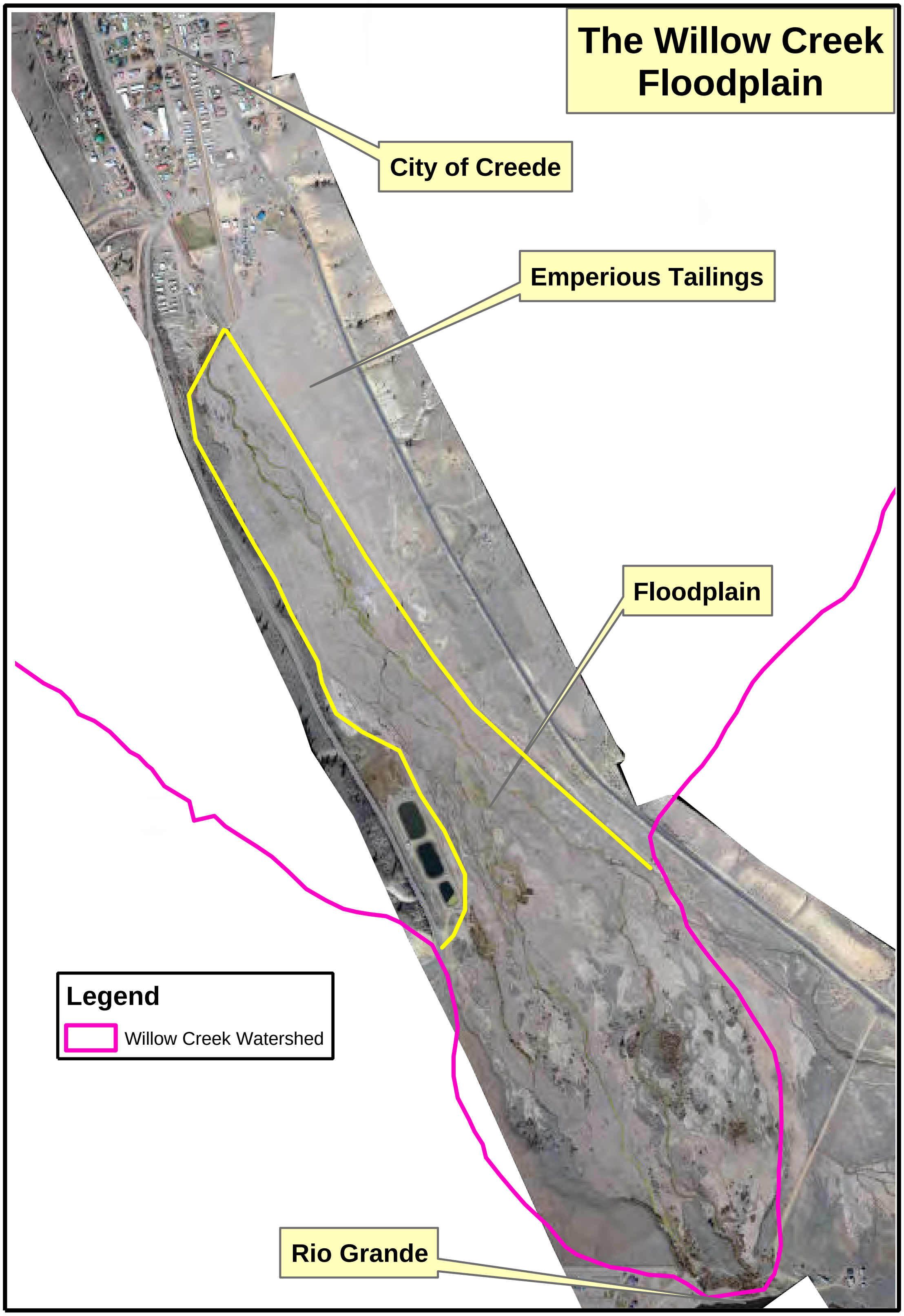


Figure 2.9 - Upland Soils of the Willow Creek Watershed

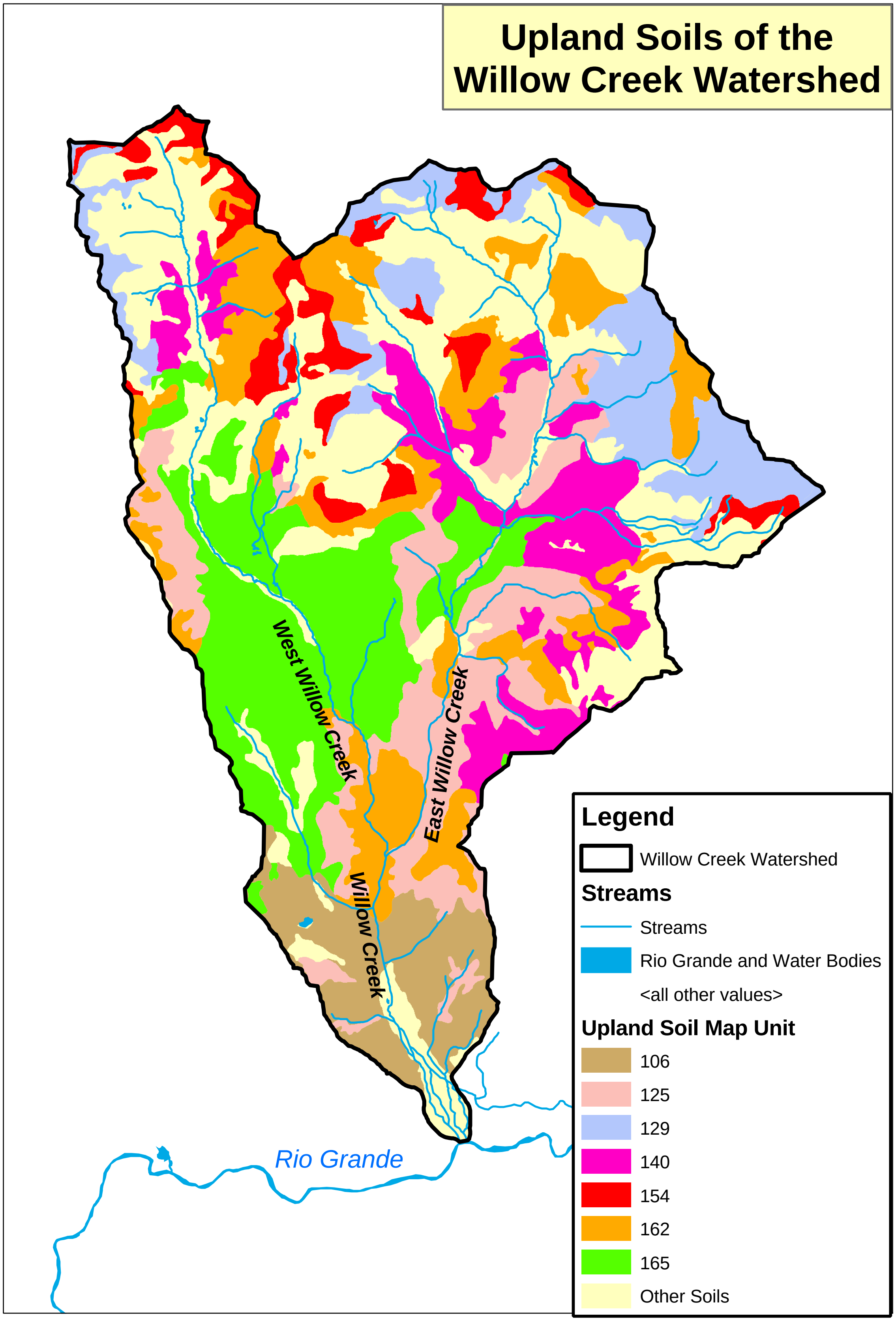


Figure 2.10 - Middle Section of the Watershed

Figure 2.11 - Alpine Area in the Upper Section

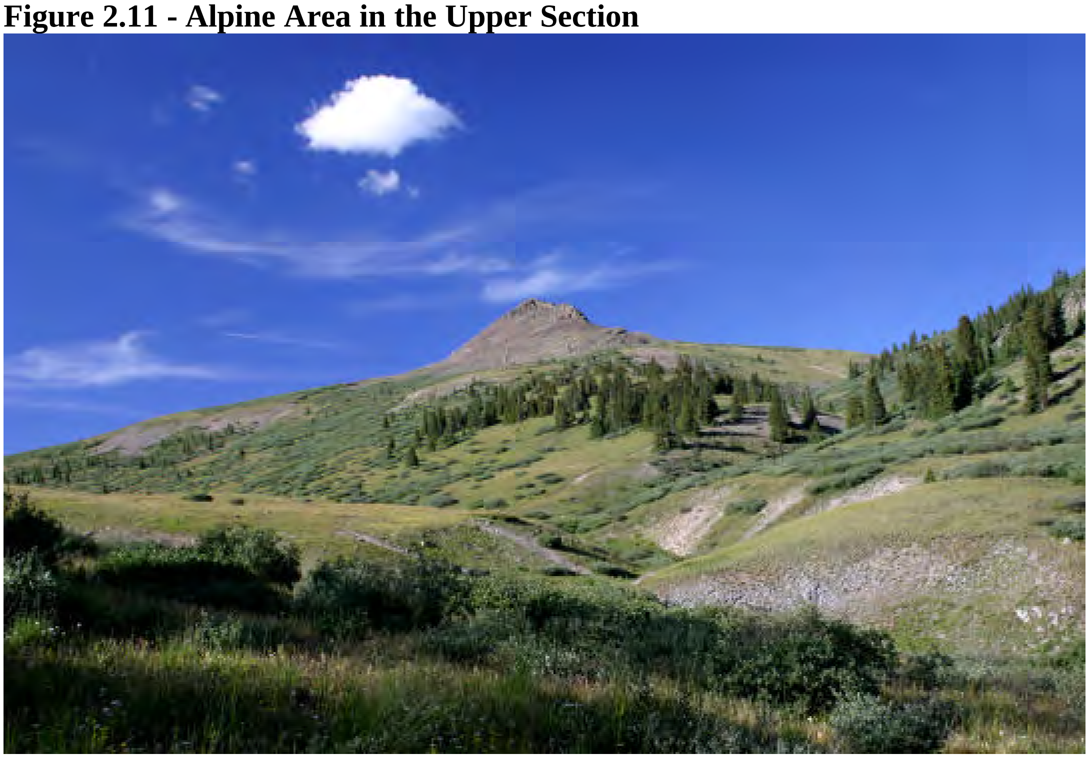
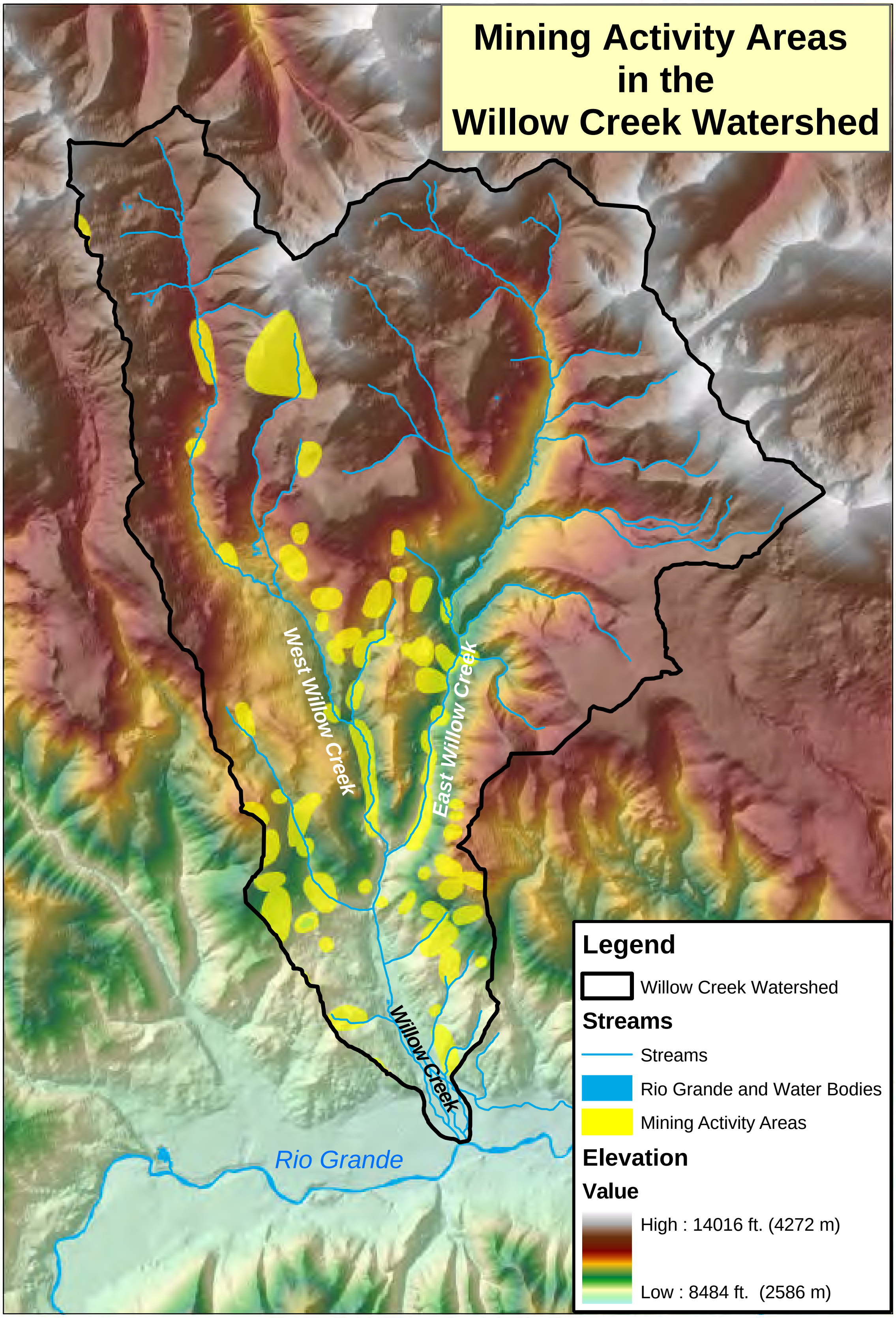


Figure 2.12 - Mining Activity Areas of the Watershed



Ecology

The flora and fauna of the watershed are characteristic of the South-Central Highlands Section of the Southern Rocky Mountain Steppe - Open Woodland - Coniferous Forest - Alpine Meadow Province, as defined by Robert Bailey (1998) of the USFS. This same area has been classified as part of the Southern Rockies Ecoregion (EPA, 2003).

Species diversity in the watershed is due to variation in habitat type (Figures 2.13 and 2.14). Each zone has fairly distinct fauna and characteristic plant species. A phenomenon called "vegetational zonation," which refers to vegetation changes in elevation, is an obvious feature of the watershed. Willow Creek crosses four major life zones in its descent from the high mountains to the Rio Grande Valley. The origins of Willow Creek are in the Alpine Zone. Tufted hairgrass-sedge and willow dominate this zone. Below the Alpine Zone, Willow Creek and its tributaries pass through the Engelman spruce, sub-alpine fir, and Thurber fescue grassland of the Sub-Alpine Zone. Lower in elevation are the aspen, Douglas fir, and bristlecone pine forests of the Montane Zone. Species of willow of the Sub-Alpine and Montane zones favor riparian areas along East Willow, West Willow, and Deerhorn Creeks. Arizona fescue grasslands occur in the Foothills Zone at the lower elevations of the watershed (USFS Vegetative Cover Survey, Appendix D).

There are more than 200 species of amphibians, reptiles, birds, and mammals known to occur in Mineral County, and about 35 additional species that are likely to occur in the county (Natural Diversity Information Source website), potentially including the watershed. Large mammals such as elk, mule deer, and moose are fairly common to abundant. The Colorado Division of Wildlife introduced moose to Mineral County in the early 1990s and their population is now well established since (Colorado Department of Natural Resources, News About Colorado's Natural Resources, 2004).

Beaver are an important species for maintenance of healthy wetlands and riparian areas. The beaver is "a definitive example of both a keystone species and an ecosystem engineer." (Baker and Hill, 2003). The species is known to exist in the watershed (observation and confirmed by Les Dobson, USFS, personal communication, May 24, 2004) (Figure 2.15) and suitable beaver habitat is estimated with a model for the watershed (Figure 2.16). The habitat model determines stream areas where stream gradient is less than six percent slope and willow or aspen vegetation are present. Most of the suitable habitat is identified in the Upper Section of the watershed. Beaver provide substantial benefits to watersheds, such as water quality improvement, improved hydrologic function, and wildlife and habitat diversity (Collen and Gibson, 2001; Colorado Game, Fish and Parks Department, 1964). If beaver populations are too high and the food source is diminished, beaver may abandon an area, resulting in a loss of benefits, damaging potential physical habitat in the streams (Neff, 1957). However, beaver within the narrow canyons of the Middle Section may have negative consequences, including flooding of roads and/or mine waste piles adjacent to streams and woody debris obstruction of culverts and pipes resulting from beaver dam blowout.

Figure 2.13 - Primary Vegetation Types of the Willow Creek Watershed

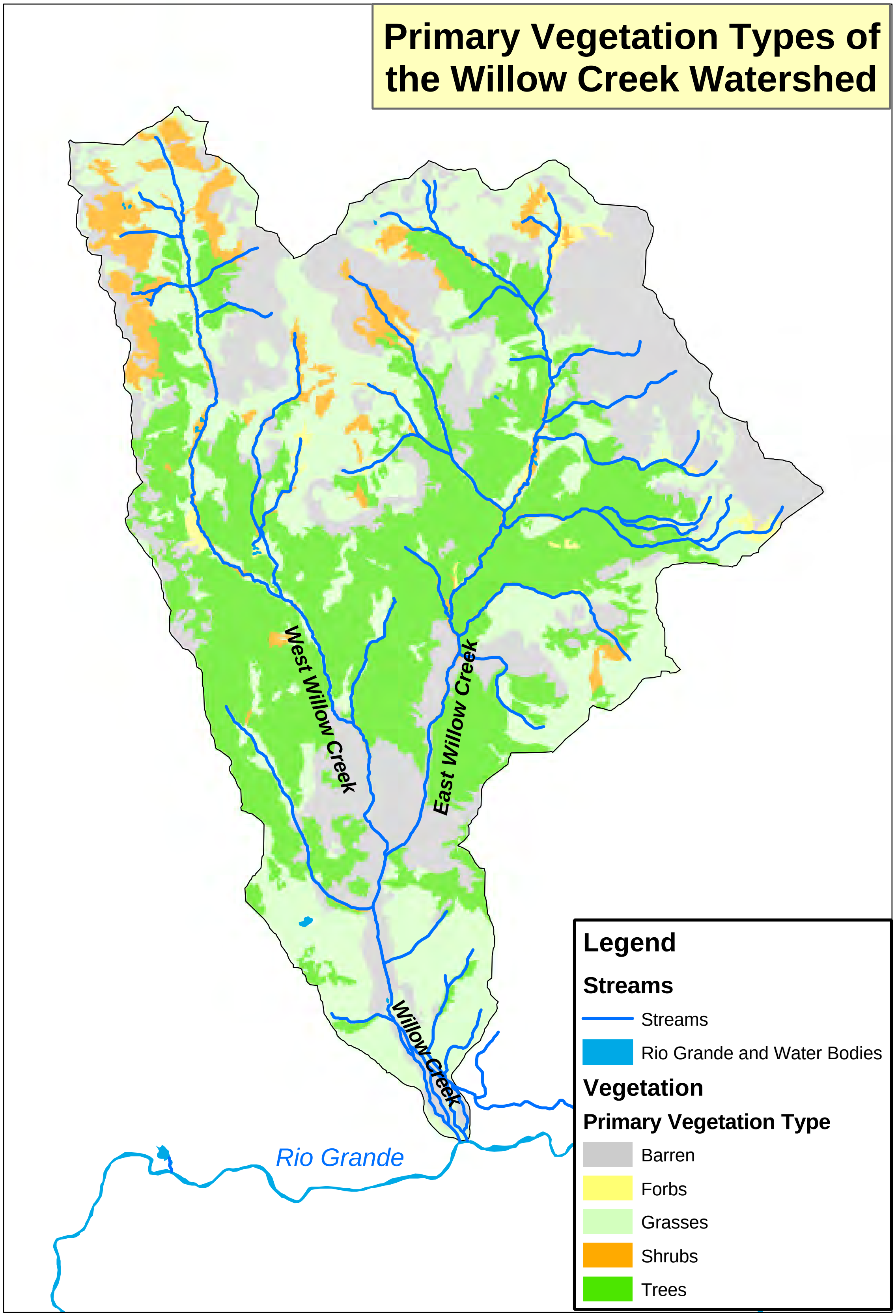


Figure 2.14 - Percentage of Primary Vegetation Types

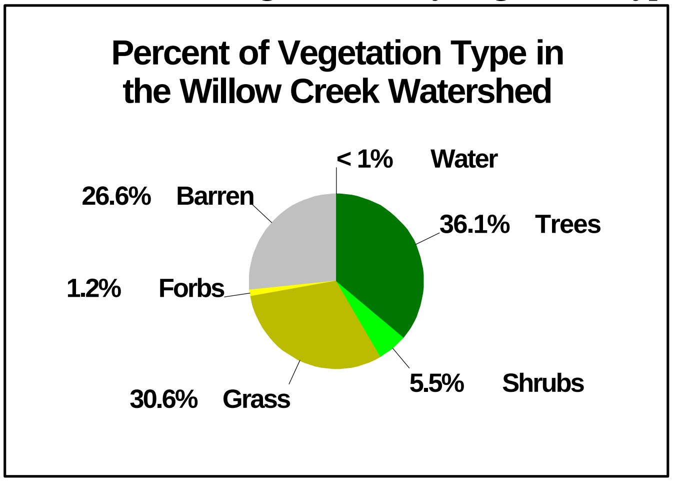
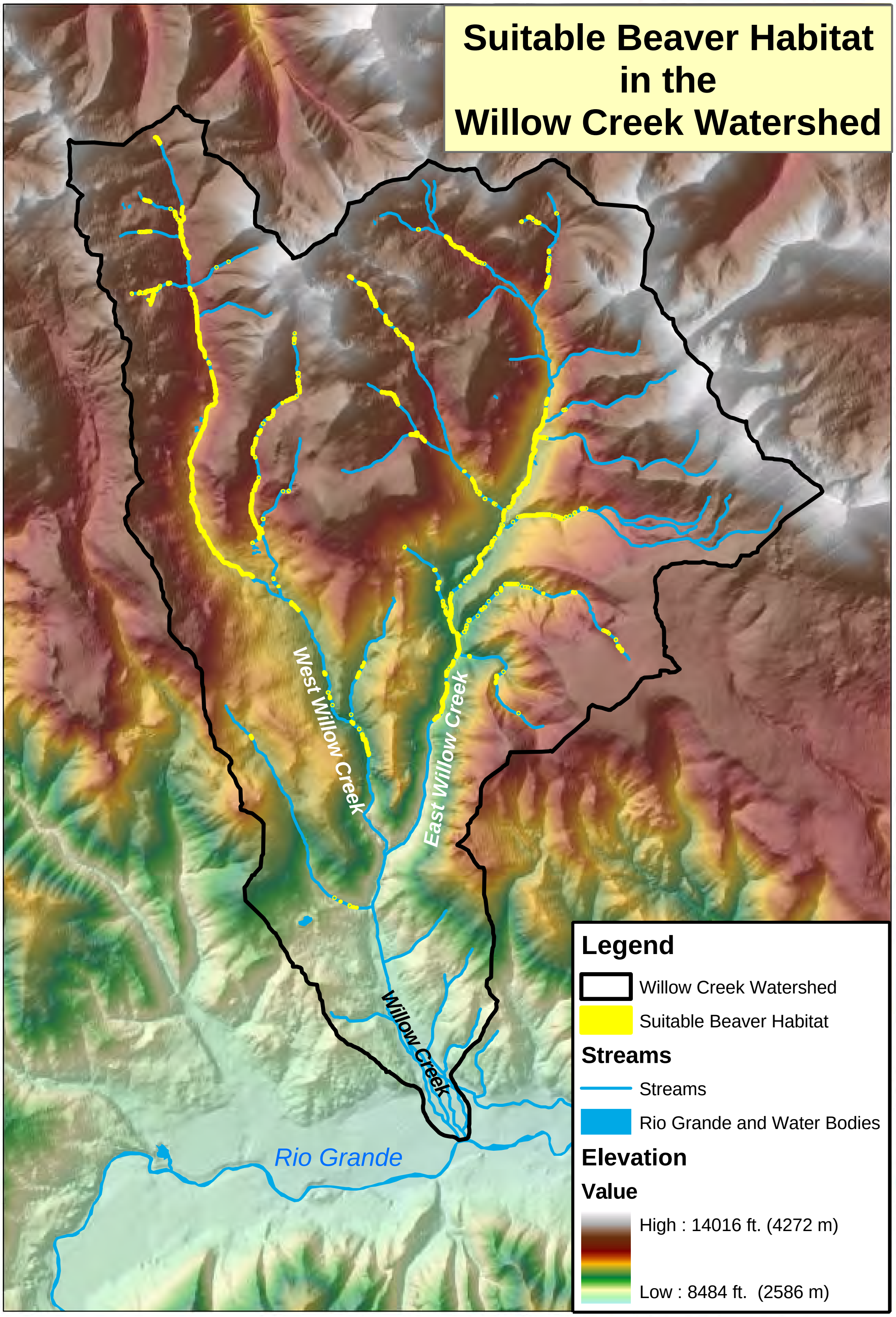


Figure 2.15 - Beaver Dam in the Upper Section of the Watershed

Figure 2.16 - Suitable Beaver Habitat



Aquatic Resources

The aquatic resources of the watershed will be characterized in subsequent chapters and are only addressed briefly in this section. The dominant aquatic resource types in the watershed are perennial and non-perennial streams. Beavers have created some ponds; there are some small wetlands, particularly in the Upper Section, and there is a large floodplain in the Lower Section. Chapter 3 will discuss stream resources, Chapter 4 will discuss wetlands and riparian resources, and Chapter 5 will discuss ground water resources.

Summary

Willow Creek Watershed has a vertical relief of about one mile (1.6 km) and is characterized by steep slopes, distinct vegetative communities, and climate based on elevation. The watershed is also characterized by the geology that gave rise to mining, and is characterized by aquatic resources that are mainly in the form of streams, but include ecologically-important wetlands and riparian areas.

2.3 People and Anthropogenic History

History

Most of the following history came from the History of Colorado, Volume 1, by J.A. Baker and L.R. Hafan (Baker and Hafan, 1927). Other information was obtained from a variety of web-based sources.

Most historians think that the Ute Indians occupied the entire area of western Colorado beginning around 1200 A.D. The area of the Willow Creek Watershed is believed to be part of the Ute's ancient hunting grounds. Twelve family groups, or bands, were spread out across the region, living at low elevations during winter and higher elevations in summer. The Ute frequently visited the hot springs at the present day Wagon Wheel Gap and the Wheeler Geologic Area. The Ute probably used what is presently known as the Creede Pack Trail to reach the San Luis Pass at the northern border of the watershed, as a route between the Rio Grande and the Gunnison River drainages.

The Spanish were the first Europeans to refer to the Ute and Ute Territory in 1625, and between 1765 and 1775, they conducted the first known expeditions into this vast wilderness. In 1776, the year in which the Declaration of Independence was signed, two Spanish Friars, Silvestre Velez de Excanante and Francisco Antanasio Dominguez, were exploring a route from Santa Fe, New Mexico (in the Spanish domain), to the Pacific coast through Ute territory. After this expedition were the famous expeditions into Colorado territory of Captain Zebulon Montgomery Pike, who explored Pike's Peak in 1806, and that of Major Steven H. Long, who explored Longs Peak in 1820.

Spain recognized Mexico's independence in 1821, bringing political and economic change to the region. Independence from Spain meant that the frontiersman could engage in trapping, hunting, and trading with no risk of confiscation of their belongings or of imprisonment. This opened the West to untold numbers of frontiersmen, who fanned out across the land, mainly in search of beaver. Beaver fur at the time was literally a form of currency; the quest for beaver fur was an economic driver and many fur traders became rich during this time.

Development continued, and by 1856, populations of wild game were significantly depleted throughout the Colorado Territory. During this turbulent period of the mid-nineteenth century, the Ute population dwindled from disease, conflict, and starvation. The remaining Ute ceded their lands to the U.S. government and were relocated to reservations. Likewise, Mexico lost the Mexican-American War, ceding their expansive southwestern territories to the United States.

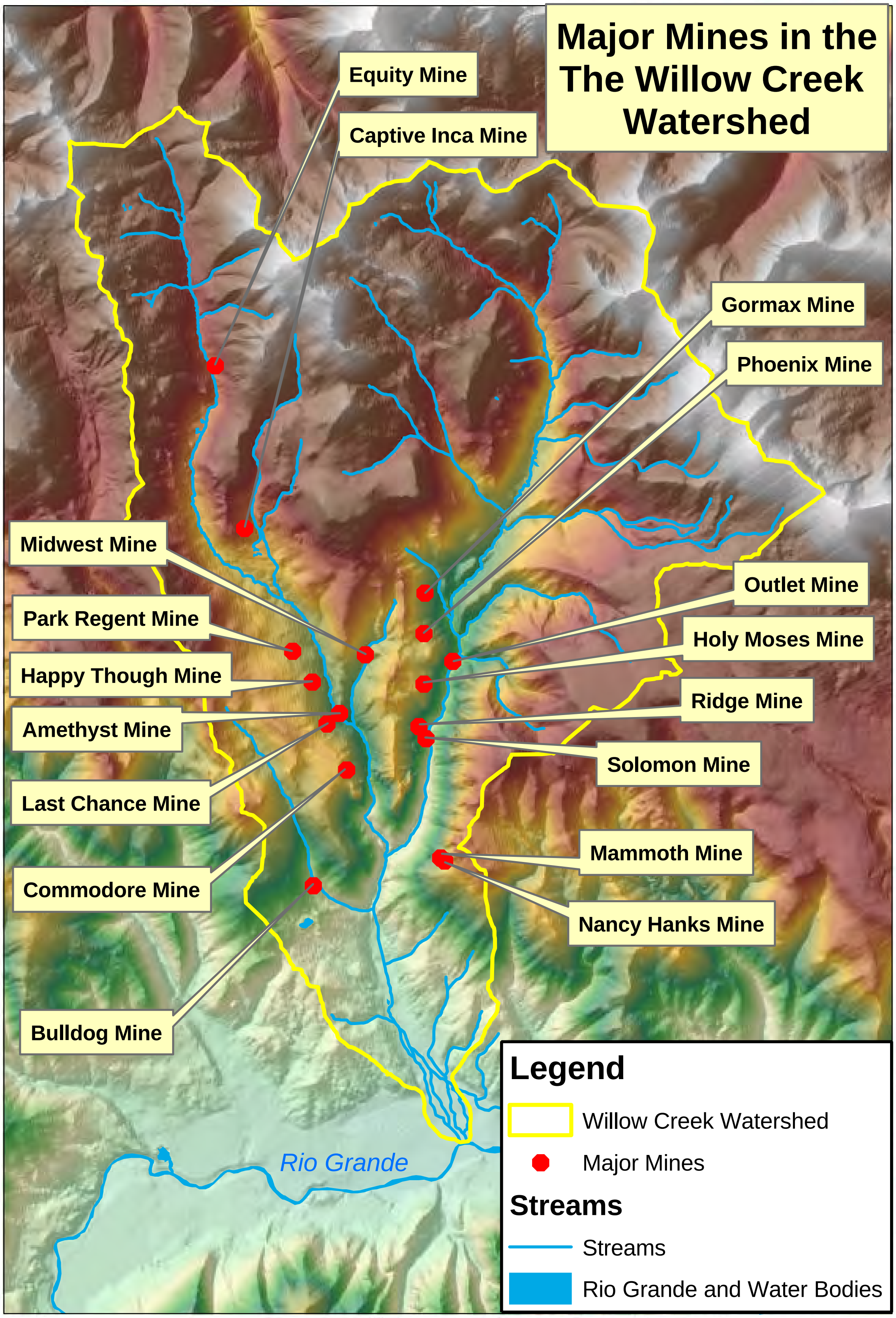
By 1870, with increasing commerce and westward expansion through the Louisiana Territory, tourists began to experience the wilderness of the Rio Grande Valley. In 1883, the Denver Rio Grande Railroad Depot opened at Wagon Wheel Gap. In 1887, Mr. Ryder constructed the first cabin in the area along Willow Creek, which subsequently grew into the town of Willow. Meanwhile, others were earnestly prospecting for minerals in the surrounding mountains. Following the discovery of the Solomon-Holy Moses Vein along East Willow Creek on October 22, 1890, residents of the expanding town changed its name from Willow to Creede, in honor of Nicholas C. Creede (real name William Harvey) who discovered the vein.

Mining History

Past mining activities, resulting in hydrologic modifications and past and on-going metals loading from mine drainage and mine waste piles, are the most significant influences on the current state of the aquatic resources in the Willow Creek Watershed. The most important mines in the watershed are shown in **Figure 2.17**. The history of mining in the Creede district is well documented in a three-volume series by Eric Roy Twitty of Mountain States Historical Society (Appendix B, WCRC #15, 16, and 17). Below is a brief discussion summarized from Twitty's thorough writings.

The history of mining in the Creede Mining District (Figure 2.18) can be traced back indirectly to 1865 when a party of prospectors, led by Charles Baker, explored the upper Animas River drainage in search of placer gold. While Baker's exploration did not locate economically-viable quantities of gold or silver, it did open the door for subsequent prospecting parties to explore the San Juan Mountains for hard-rock gold and silver. The success of these efforts led to the mining camps such as Ouray, Silverton, Telluride, Lake City, and Rico. Mining in these districts developed slowly until 1873, when the U.S. Government and the Ute Indians signed the Brunot Treaty. The terms of the treaty required the U.S. Government to pay the Ute Tribe $25,000 for four million acres of mineral-rich land while the Ute Tribe retained the right to hunt on the ceded land. After the treaty was signed, access into the San Juan Mountains increased

Figure 2.17 - Primary Mine Sites in the Willow Creek Watershed



significantly by the construction of wagon roads and rail lines. The Denver & Rio Grande Railroad constructed a line to South Fork, just 20 miles south of present-day Creede. This greatly increased prospecting activities along the upper Rio Grande and its tributaries.

Figure 2.18 - Historic Mining in the Willow Creek Watershed

In 1876 a group of prospectors, including J. C. McKenzie and H. M. Bennett, explored the Willow Creek Watershed. They discovered silver ore west of the present-day City of Creede and staked the Alpha Claim. In 1878, McKenzie discovered another ore body and staked the Bachelor Claim. McKenzie failed to find investors to mine these claims and, in 1885, sold the Alpha Claim to Richard and J. N. H Irwin. McKenzie retained the title to the Bachelor, but soon gave up attempts to mine and process its ore. Thirteen years would pass before the next significant discovery occurred in the Willow Creek Watershed. In May of 1889, a party of prospectors, including Nicholas C. Creede, E. R. Taylor and G. L. Smith, located the Holy Moses Vein on Campbell Mountain, which was extremely rich in silver. The discovery began nearly100 years of mining in the Creede district.

The discovery of the Holy Moses Vein greatly increased prospecting in the King Solomon District, as the area was known in 1890. In 1890, Richard Irwin discovered more silver ore near the Old Alpha Claim. In 1891, a party of miners prospected along West Willow Creek. They encountered samples of floating metals and followed the lead upstream along West Willow Creek. An examination of the samples revealed the high-grade nature of the ore and led to the establishment of the Last Chance Claim. With a developing understanding of the orientation of the ore body, Creede staked the Amethyst claim a short distance north of the Last Chance Claim. The Last Chance and Amethyst Mines, located along the Amethyst Vein, would become the richest, most profitable mines in the Creede Mining District.

From 1890 through the 1980s, mining activity, economic vibrancy, and population in the watershed fluctuated interdependently. Many factors influenced the boom-bust cyclical nature of mining in the watershed. These included prospector discoveries of high-grade silver ore veins at different mine claims, the Brunot Treaty of 1873, development of a rail line from South Fork to North Creede, the Bland-Allison Act of 1878, the Pittman Act of 1922, the Silver Purchase Act of 1934, technological advances in mine ore processing, and multiple mine claim ownership. By the 1980s, all mining had ended in the Creede District. After 100 years of silver production (Figure 2.19), the District is now undergoing environmental cleanup and its residents continue to treasure its mining past.

Figure 2.19 - Current Picture of Mining Legacy

Figure 2.20 shows the major producing veins of the Creede Mining District. **Figure 2.21** shows the percentage of precious metal value taken from mines associated with the different veins. Mines along the Amethyst Vein were by far the richest, accounting for $53.2 million, or 93.5 percent of the total value in the district. The Amethyst Vein, along with the Solomon-Holy Moses and Equity Veins, are in the Willow Creek Watershed. The Monon Hill and Alpha-Cosair Veins are west of the watershed.

Figure 2.20 - Major Veins shown with Major Mines

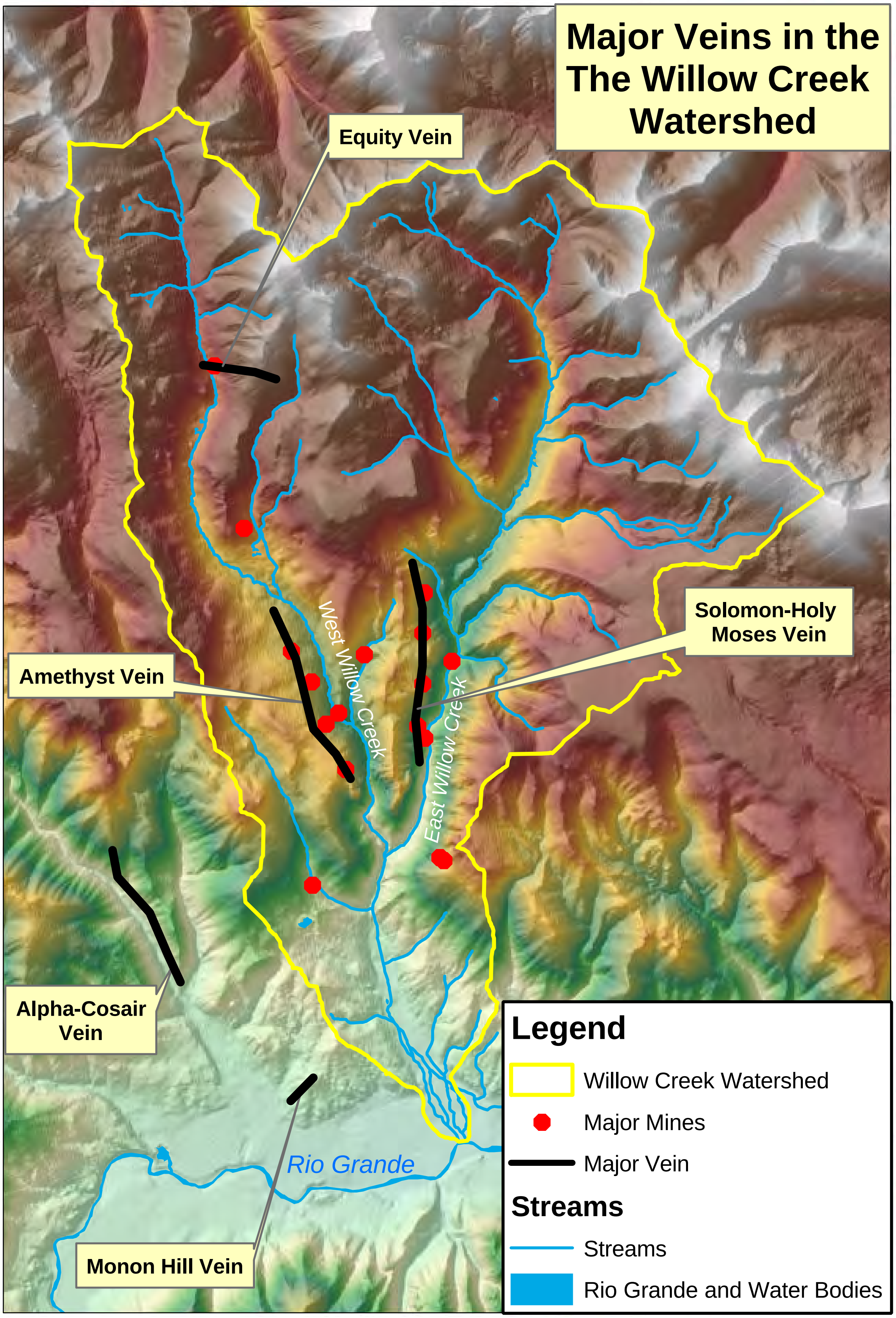
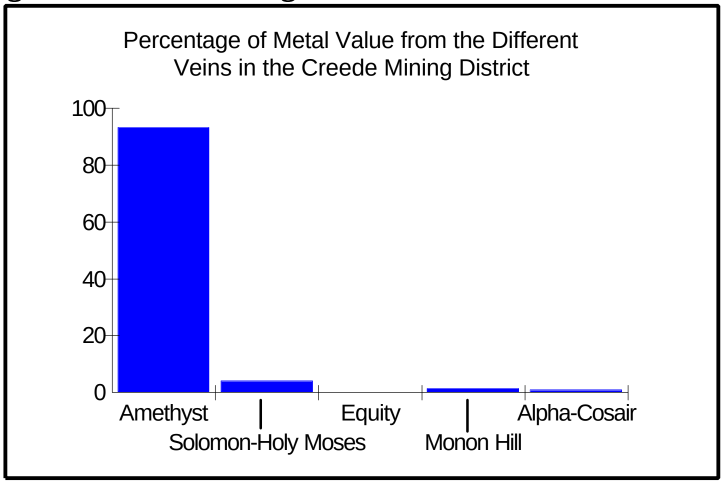


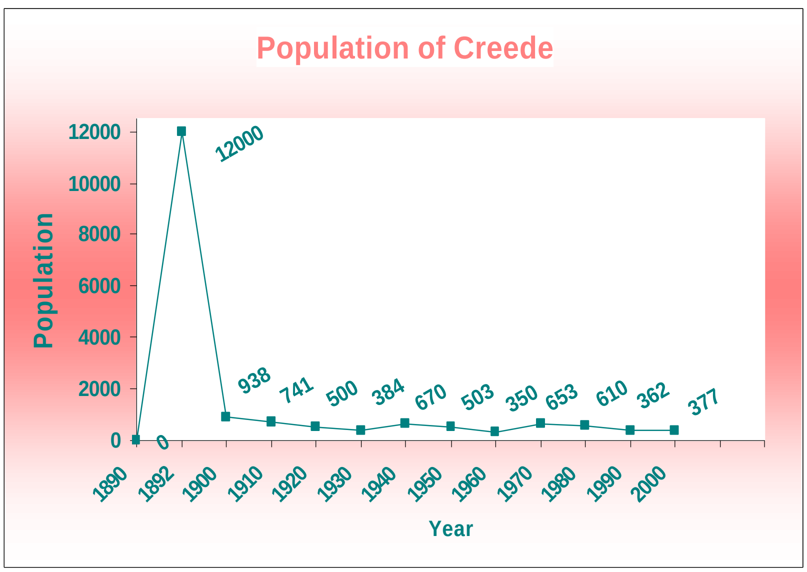
Figure 2.21 - Percentage of Precious Metal Value for Different Veins



Demographics and Land Stewardship

Census data are not available on a watershed basis; however, the majority of the population in the watershed lives in Creede. **Figure 2.22** provides historical population information for Creede.

Figure 2.22 - Creede Population over Time



Source: http://dola.colorado.gov

According to the 2000 Census, Creede had a population of 377, or 45 percent of Mineral County's 838 residents (U.S. Census, 2000). Current land ownership, the topography of the watershed, and the availability of infrastructure such as electricity, water, and sewer limit growth in the watershed.

In 1999, the median household income was $30,893 in Creede and $34,844 in Mineral County, compared to $47,203 statewide. A little less than two-thirds of the population over 16 years of age was in the work force, primarily in management and professional, service, sales and office and construction and extraction positions. In Creede, 12.2 percent of families and 13.4 percent of individuals were considered to be at or below the level of poverty, compared to statewide poverty levels of 6.2 percent of families and 9.3 percent of individuals (Colorado Demography Office, U.S Census, 2000).

More than 85 percent of the watershed is the Rio Grande National Forest (public land) managed by the USFS (U.S. Forest Service Public Land, Appendix D) (Figure 2.23). The national forest percentage in the Upper Section is even higher.

The USFS first developed the Rio Grande National Forest Plan in January 1985. The Draft Revised Forest Plan was released in December 1995, concluding a process of public comment that began in 1992. Following a second period of public comment, the Revised Rio Grande National Forest Land and Resource Management Plan was issued in November 1996.

The Rio Grande Forest Plan is far-reaching in scope: “The Forest Plan provides guidance for all resource management activities on the Rio Grande National Forest. It establishes management Standards and Guidelines; it describes resource management practices, levels of resource production, people-carrying capacities, and the availability and suitability of lands for resource management” (Final Revised Rio Grande National Forest Plan, Preface, 1996).

The Forest Plan identifies “Management Area Prescriptions,” which are resource uses and kinds of management activities that can occur within an area. The activities allowed for each Management Area Prescription are shown in **Table 2.1**, the areas are shown in **Figure 2.24**, and the relation of Management Area Prescriptions to the watershed sections is presented below.

Upper Section

Almost all of the East Willow Creek Watershed in the Upper Section is in Management Area Prescription Category 3 in which “ecological values are in balance with human occupancy, and consideration is given to both.” The largest area is in Management Area Prescription 3.3, *Backcountry*. Most of the remainder is in Management Area Prescription 3.1, *Special Interest Areas*, *Emphasis on Use or Interpretation*.

Figure 2.23 - U.S. Forest Service Public Lands in the Willow Creek Watershed

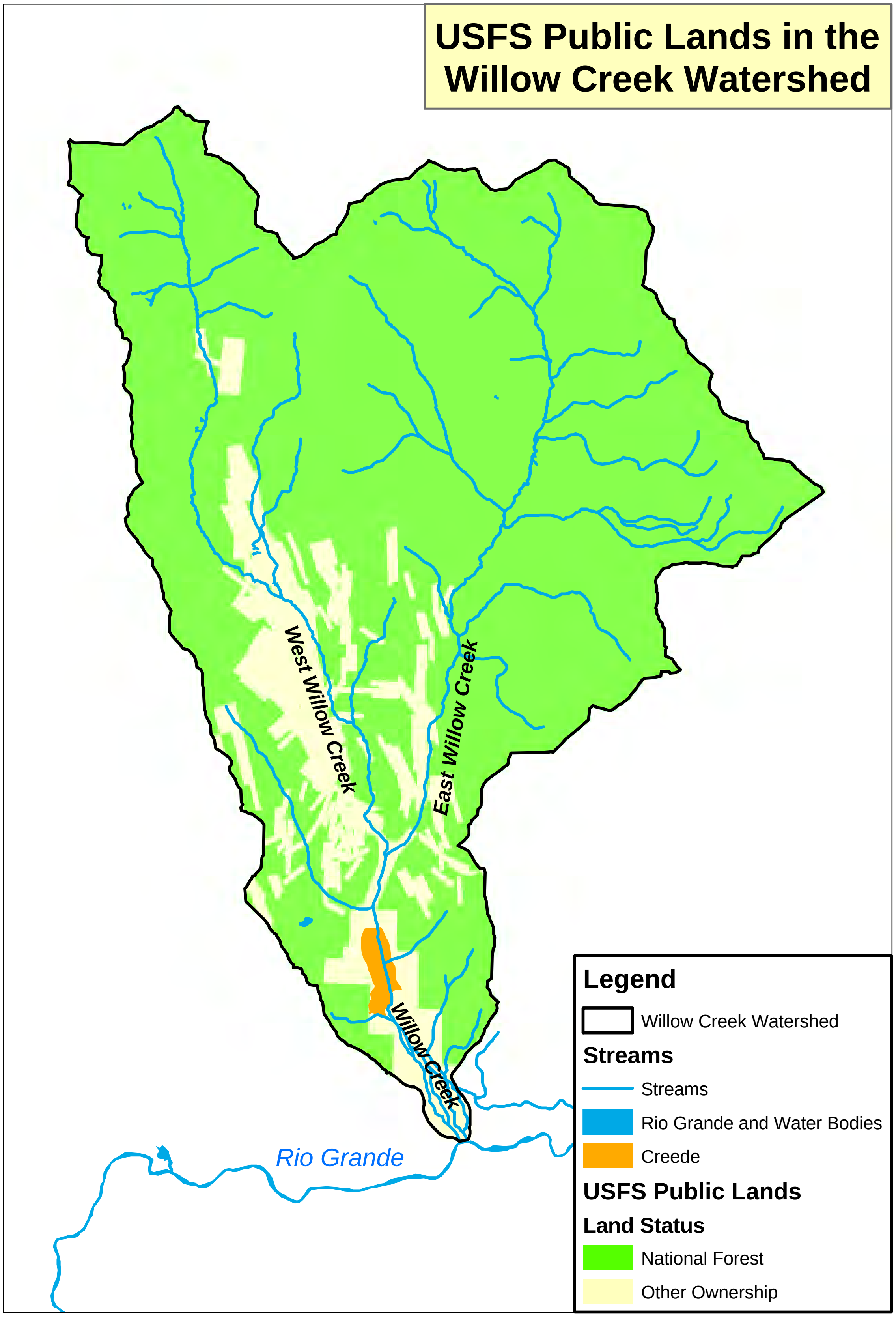
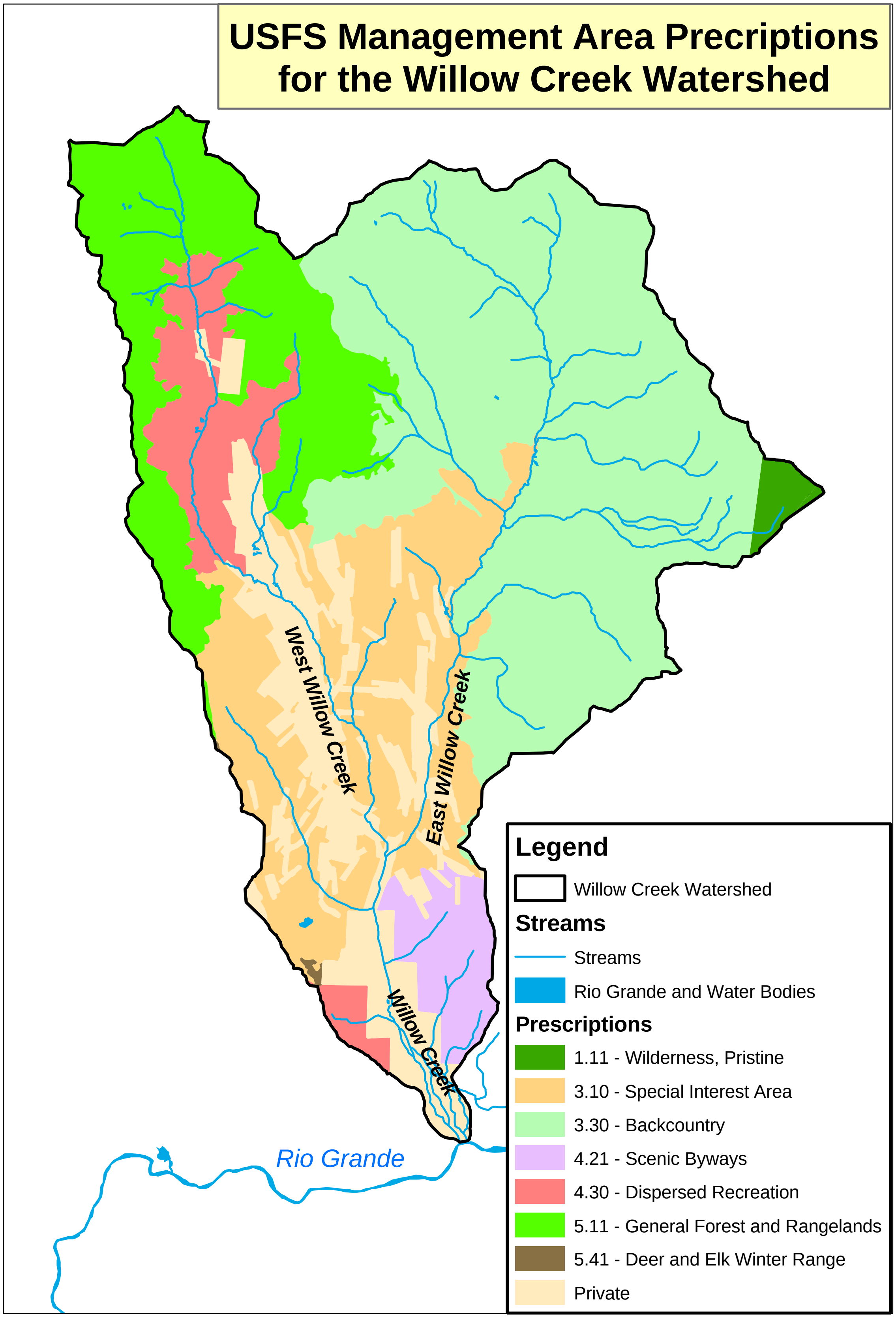


Figure 2.24 US Forest Service Management Prescription Areas



West Willow Creek Watershed in the Upper Section is mainly in Management Area Prescription Categories 4, in which “ecological values are managed to be compatible with recreation use, but are maintained well within the levels necessary to maintain overall ecological systems” and Category 5, in which “Forest areas are managed for a mix of forest products, forage, and wildlife habitat, while protecting scenery and offering recreation opportunities.” The largest area is in Management Area Prescription 5.11, *General Forest and Intermingled Rangelands*. Most of the remainder of the Upper Section is in Management Area Prescription 4.3, *Dispersed and Developed Recreation*.

Table 2.1 - U.S. Forest Service Management Area Prescriptions

Management Area Prescription Number	Management Area Prescription Name	Activities Allowed				
		Timber Harvest	**Motorized Recreation**	**Grazing**	**Locatable Minerals**	**Oil & Gas Leasing ***
3.1	Special Interest Areas -- Emphasis on Use or Interpretation	No	Yes	Yes	Limited	NSO
3.3	Backcountry	No	Limited	Yes	Yes	NSO/Closed
4.21	Scenic Byways or Railroads	Yes	Yes	Yes	Yes	CSU
4.3	Dispersed Recreation	Yes	Yes	Yes	Yes	CSU
5.11	General Forest and Intermingled Rangelands	Yes	Yes	Yes	Yes	STD

* These lands are available and authorized for oil and gas leasing with STD (Standard), NSO (No Surface Occupancy, or CSU (Controlled Surface Use) Stipulations.

Middle Section

Most of the Middle Section is in Management Area Prescription 3.1, *Special Interest Areas, Emphasis on Use or Interpretation* with significant private holdings.

Creede and Lower Sections

The City of Creede and the areas along Willow Creek are private holdings. The steeper portions are in Management Area Prescriptions 3.1, *Special Interest Areas,* *Emphasis on Use or Interpretation*; 4.21, *Scenic Byways and Scenic Railroads*; and 4.3, *Dispersed and Developed Recreation*.

Summary

Today, the City of Creede and growing tourism based on historic mining are the dominant anthropogenic forces in the Middle, Creede, and Lower Sections of the watershed. The Upper Section remains relatively natural with little anthropogenic influence.

3.0 STREAMS

3.1 Introduction

This chapter discusses the desired state, characteristics, and current condition of the stream resources of the Willow Creek Watershed. The current condition is evaluated with respect to the desired condition, as defined by stakeholders, and is classified into condition classes. In addition, stream condition stressors are identified for the entire watershed and ranked for stream reaches with *poor* or *very poor* conditions.

3.2 Desired State of the Resource

In order to evaluate the current condition of the streams of the Willow Creek Watershed, values, or goals, for the desired condition need to be established. These values and goals are determined through an examination of stakeholders' needs and goals for the streams. Three stakeholder groups were identified for the purpose of determining the desired condition of streams in the Willow Creek Watershed: the WCRC, the USFS, and the CDPHE.

Willow Creek Reclamation Committee's Goals for Stream Condition

The WCRC is comprised of interested community stakeholders and local decision-makers as well as State and Federal agency representatives. It is the primary representative group of local stakeholders dealing with aquatic resources of the Willow Creek Watershed. The WCRC has clearly-stated goals for restoring water quality in Willow Creek. One of these goals is healthy ecological stream condition that supports aquatic life. Another WCRC goal is flood control to protect the City of Creede.

State of Colorado's Desired Condition for Streams

The CDPHE is responsible for implementing of the Federal Clean Water Act. The objective of the Clean Water Act is to protect the chemical, physical, and biological integrity of the Nation's waters.

Implementation of the Clean Water Act requires that goals (values or expectations) be established for specific water bodies. The water body-specific goals are expressed as water quality standards. A water quality standard consists of three elements: (1) the designated beneficial use or uses of a water body or segment of a water body; (2) the water quality criteria necessary to protect the use or uses of that particular water body; and (3) an anti-degradation policy. Typical uses of water bodies include public water supply, propagation of fish and wildlife, recreation, and agriculture. Water quality criteria are expressed in either numeric form or narrative form. Examples of numeric criteria are chemical concentration in milligrams per liter, or a condition, such as pH. Narrative criteria are expressed in concise statements such as, "water is free from toxic pollutants in toxic amounts."

Criterion is established to protect designated uses of water bodies, such as support for aquatic life. This includes biocriteria, nutrient criteria, sediment criteria, and water quality criteria to target specifics needs of aquatic life support. There are two kinds of water quality criteria to deal with chemical exposures in efforts to protect aquatic life: (1) ***acute*** criteria cover short-term exposures and (2) ***chronic*** criteria cover long-term or permanent exposures. The anti-degradation policy is designed to conserve, maintain, and protect existing uses and the water quality necessary to protect these uses (EPA, 1994).

To ensure that quality of the State's surface waters is maintained or improved, the CDPHE's Water Quality Control Commission has promulgated regulations designating beneficial uses and stream classifications for particular water bodies. **Table 3.1** presents the State's designated uses and associated classifications for the streams of the Willow Creek Watershed and the segment of the Rio Grande directly influenced by Willow Creek.

Table 3.1 - State of Colorado Stream Designations and Classifications
(CDPHE Water Quality Control Commission – Regulation 36)

Stream Segment Description	Designation	Classification
Segment 4: Mainstem of the Rio Grande, from a point immediately above the confluence with Willow Creek to the Rio Grande/Alamosa County line.		Ag Life Cold 1 Recreation 1a Water Supply Agriculture
Segment 5: All tributaries to the Rio Grande, including all wetlands, lakes, and reservoirs, from immediately above the confluence with Willow Creek to State Highway 112 bridge in Del Norte, except for specific listings in segments 6 through 10.		Ag Life Cold 1 Recreation 1a Water Supply Agriculture
Segment 6: Mainstem of West Willow Creek from immediately above Deerhorn Creek to the Park Regent Mine dump.		Ag Life Cold 1 Recreation 1a
Segment 7: Mainstem of West Willow Creek from the Park Regent Mine dump to the confluence with East Willow Creek; mainstem of East Willow Creek from the confluence with Whited Creek to the confluence with West Willow Creek, mainstem of Willow Creek, including all tributaries from the confluence of East and West Willow Creeks to the confluence with the Rio Grande.	Use Protected	Recreation 1a Agriculture

Much of the watershed's Middle, Creede, and Lower Sections exceed Colorado State criteria for aluminum, cadmium, copper, lead, and/or zinc. The CDPHE Water Quality Control Commission granted a temporary modification to numeric standards until

December 31, 2007, because the stream segments did not meet standards due to "human-induced conditions deemed correctable within a twenty (20) year period, etc." The WCRC decided to choose a temporary modification as preferable to downgrading the classifications or adopting site-specific narrative standards (Regulation #31: The Basic Methodologies for Surface Water, CDPHE – WQCC).

The WCRC has decided to improve the water quality in order to meet the existing classifications of recreation class 1a, and agriculture. Recreation class 1a means that; (1) "surface waters are suitable or intended to become suitable for recreation activities in or on the water when ingestion of small quantities of water is likely to occur, and (2) waters are capable of sustaining cold-water aquatic life." Agricultural classification addresses water suitable or intended to become suitable for irrigation of crops and drinking water for livestock.

U.S. Forest Service's Expectations for Stream Condition

The USFS sets expectations for the quality of aquatic resources within its Forest boundaries. USFS management prescriptions, introduced in Chapter 2, and the desired condition for waters within the Rio Grande National Forest, including portions of the Willow Creek Watershed, are in the Rio Grande National Forest Plan, which is found on the internet (http://www.fs.fed.us/r2/riogrande/planning/planning.htm). The following excerpt from the Revised Rio Grande National Forest Land and Resource Management Plan explains the overall goals for water and aquatic resources in the watershed (USFS, 1996):

> *Healthy watersheds operate in a dynamic equilibrium between extreme natural events. Surface-disturbing activities are managed so that floods, droughts, sediment loads, bank erosion, rills, gullies, and landslides are not markedly increased.*
>
> *Water quality is maintained or improved, with all stream segments having a near-reference stream appearance. Water is suitable for municipal water supplies after normal treatment, including those using shallow alluvial aquifers. Chemical, physical, and biological attributes are improved and maintained in a healthy condition, ensuring future use. Stream health is maintained through natural processes without artificial controls.*
>
> *Streams have the expected range of habitat features, (for example, healthy riparian vegetation, stable banks, over-wintering pools and healthy aquatic organisms). Riparian areas and floodplains are healthy, fully functioning ecosystems. Vegetation is diverse and is generally in a later-seral condition, to provide site stability. Fish thrive in Forest lakes and streams due to adequate habitat and water quality. Natural fish habitat is preferred and promoted over human-made habitat* (USFS, 1996).

Summary

The WCRC, the State of Colorado, and the USFS goals for the condition of streams in the Willow Creek Watershed are similar. They either state or imply a goal of healthy ecological condition that supports aquatic life. This desired state, or condition, expressed by these three primary stakeholder entities is used to evaluate the current condition of streams throughout the watershed. In the condition evaluation, it is important to consider the least-disturbed condition as a reference for what is achievable in a similar setting. Thus, stakeholder goals are placed in the perspective of what may be possible to achieve for streams in the Willow Creek Watershed.

3.3 Stream Characterization

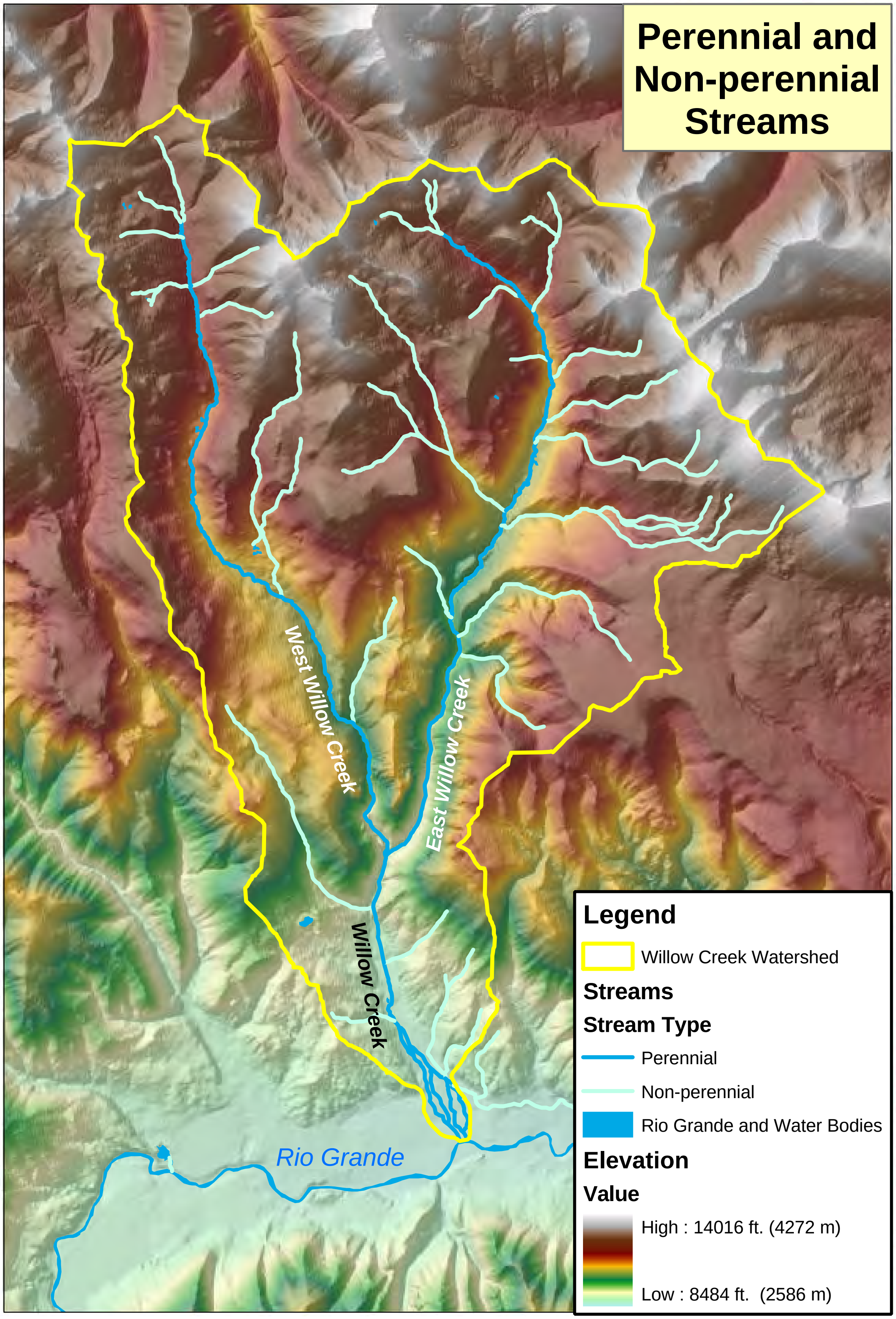
Hydrography

The streams of the Willow Creek Watershed were mapped at the 1:24,000 scale by the U.S. Geological Survey (USGS) as part of the national 7.5-minute topographic map series. The watershed is covered by portions of San Luis Peak, Creede, and Half Moon Pass quadrangles from the 7.5-minute series. Although, there are other mapping versions of the Willow Creek streams from the USFS and other sources, the USGS 1:24,000 scale version was selected for use in the assessment. The USGS stream mapping was converted into GIS. The delineation, depicted in **Figure 3.1**, was used in determination of stream length and location, and for GIS analyses.

One shortcoming of the USGS stream delineation was that it did not differentiate between perennial and non-perennial streams. The WCRC monitoring efforts and other observations reveal that many of the tributaries to East Willow Creek, West Willow Creek, and Willow Creek are non-perennial. **Figure 3.1** shows the best estimate of the breakdown between the perennial and non-perennial stream resource types. Non-perennial streams include ephemeral and intermittent stream classes, which don’t have continuous surface flow or don’t flow on a regular basis. While many of the non-perennial classified streams are known with certainty, other streams classified as non-perennial still require confirmation. The streams classified as perennial are simply the mainstems of West Willow Creek, East Willow Creek, and Willow Creek.

The stream resource in the Willow Creek Watershed is estimated to have a total length of 67.7 miles, or 108.9 kilometers (km). Of the total stream length, 34.7 percent, or 23.5 miles (37.8 km), are estimated to be perennial. The remaining 65.3 percent, or 44.2 miles (71.1 km), are estimated to be non-perennial. In the floodplain where braided channels occur, only a single channel was used for stream length calculations.

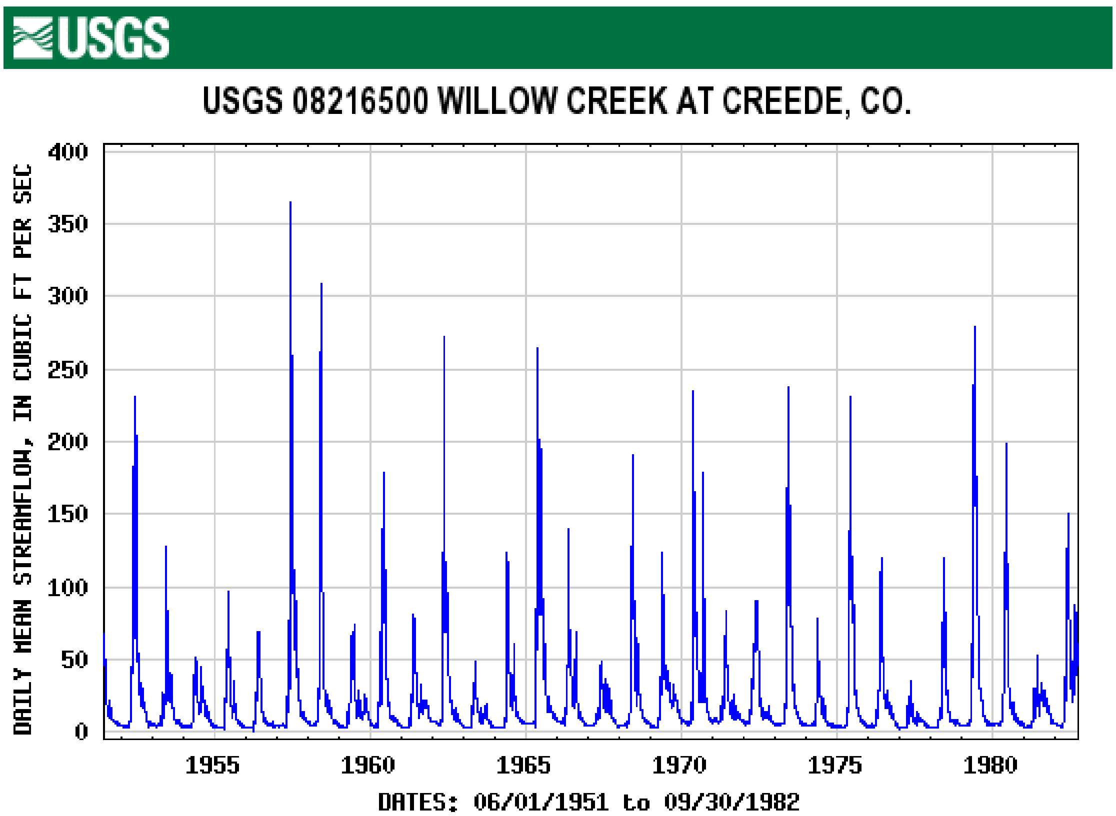
Figure 3.1 - Perennial and Non-Perennial Streams of the Willow Creek Watershed



Hydrology

The stream flow within the watershed is estimated from both USGS stream gauge measurements and flow measurements taken during stream sampling events. A USGS stream gauge is located on Willow Creek, just upstream of the City of Creede. The gauge was active from June, 1951 through September, 1982. **Figure 3.2** shows the hydrograph of daily mean stream discharge for Willow Creek at the USGS Willow Creek gauge for that time period of more than thirty years (USGS, 2004). **Table 3.2** shows the average monthly stream flows at the gauge for the same time period (USGS, 2004). Both the hydrograph and the table show the variation of flow throughout the year. Willow Creek and its perennial tributaries, East and West Willow Creeks, have relatively low-flow volumes, as shown from flows measured on specific high and low-flow dates in **Table 3.3** (Appendix B, WCRC #1).

Figure 3.2 - Hydrograph of Daily Mean Flow at the USGS Willow Creek Gauge (1951 – 1982)



Characteristic of western semi-arid climates, the Willow Creek Watershed experiences a late spring, high-flow runoff from snow melt. In addition, high intensity rain storm events generate short-term, episodic, high-flows. Late summer, fall, and winter flows are low, with groundwater as the primary source for the stream flow.

Table 3.2 - Monthly Mean Stream Flow at the USGS Stream Gage (1951 – 1982)

Month	Mean Flow (cfs)
January	4.33
February	4.07
March	4.75
April	15.00
May	66.50
June	76.60
July	29.40
August	20.80
September	15.20
October	10.10
November	7.20
December	5.22

In the Upper Section, West and East Willow Creeks flow gradually down a relatively mild gradient. As the streams enter into the Middle Section, the narrowing stream channel and steeper gradient yield greater stream power, which is a function of amount of vertical drop for a specific distance.

The highly-permeable soils, flattening-gradient, and wider bank-full channel widths in the Willow Creek Floodplain contribute to a loss of stream flow. Furthermore, some of the water leaves the stream channel to flow through the adjacent stream banks and streambeds in what is called the hyphoreic zone. Chapter 5 further discusses the interface of surface and ground water. **Table 3.3** shows a drop in stream flow from the upper site (Site W-A) on Willow Creek to the combination of the two separate Willow Creek channel sites (Sites W-I and W-J) just above the confluence with the Rio Grande. However, there is a diversion ditch at the upper end of the Willow Creek floodplain that may account for some of the flow loss. No other information about the diversion is available in this report.

Table 3.3 - Stream Flows from Selected Monitoring Dates

Stream	High-flow (cfs)	Low-flow (cfs)
West Willow Creek	27.3 (5/16/00)	13.9 (9/18/99)
East Willow Creek	28.2 (5/16/00)	22.0 (9/18/99)
Willow Creek (Site W-A - just below the confluence with East and West Willow Creeks)	62.5 (5/16/00)	29.6 (9/18/99)
Willow Creek (Sites W-I & W-J Combined – the two channels before the Rio Grande)	43.9 (5/16/00)	26.0 (9/21/99)

3.4 Current Condition

Condition is evaluated with respect to two sets of endpoint values determined from stakeholders' goals for the desired state of the stream resource. These condition endpoints are 1) ecological condition for aquatic life, and 2) hydrologic condition for flood control.

As mentioned in Chapter 2, this assessment partitions the watershed into four major sections: the Upper, Middle, Creede, and Lower Sections (Figure 2.2). These sections are aggregations of sub-watersheds that were delineated for analyses in this assessment (Appendix D). The sections provide an effective framework for referring to stream condition because the condition classifications align well with the sections.

Ecological Condition

In this ecological condition section, each of the ecological components (biological, chemical, and physical habitat) is presented separately, and then in a composite ecological condition classification, which considers all of the components. The ecological condition of the watershed's streams is determined by monitoring and assessing biological, chemical, and physical characteristics of streams. These characteristics are compared to the desired condition and the expectations described by characteristics of the least-disturbed areas. Anthropogenic activities and other influences, such as past and present land uses, water policies and uses, and pollutant discharges to streams in the watershed can also be used in the evaluation of condition.

This assessment emphasizes the biological, chemical, and physical habitat characteristics of the streams derived from monitoring information. Monitoring data, collected or sponsored by the WCRC, were used for chemical (Appendix B, WCRC #1), biological, and physical habitat assessment (Appendix B, WCRC #2). However, given the lack of monitoring coverage for the entire watershed, GIS layers and analysis (Appendix D), and observational information, are employed to supplement the monitoring data in order to achieve watershed-wide condition classifications in this assessment.

Composite ecological condition classes are presented for both perennial and non-perennial stream types. While biological and physical habitat conditions are estimated only for perennial streams, the ecological and chemical conditions were determined for all of the perennial streams and 21 percent of the non-perennial streams. A total of 18.5 perennial stream miles (31.3 km), representing 83 percent of all perennial streams, were assessed with monitoring data. Only 8.7 non-perennial stream miles (14.8 km) were assessed with monitoring data. This represents only 20.9 percent of non-perennial streams. Ecological and chemical conditions were not estimated for non-perennial streams that did not have monitoring data.

Biological Condition

The biological condition of perennial streams in the Willow Creek Watershed was determined from evaluation of aquatic macroinvertebrate and fish samples and from GIS analysis. GIS analysis was employed when monitoring data did not exist in the Upper Section. In September 1999, May 2000, and May 2001, the USFWS conducted biological sampling in the watershed (Appendix B, WCRC #2). **Figure 3.3** shows the sites sampled in the USFWS study. The sites are a subset of the stream chemistry monitoring sites and are the same sites used for physical habitat monitoring. Although no sample inventory of beaver has occurred in the watershed, the importance of beaver, and observations of their presence, is discussed as a part of this biological condition section.

Quality of Biological Data

WCRC developed a sampling and analysis plan for biological data (Appendix B, WCRC #7). The plan details the collection methods and laboratory analyses performed with the biological data used in this assessment. Based on that document, quality biological data were assumed for this assessment.

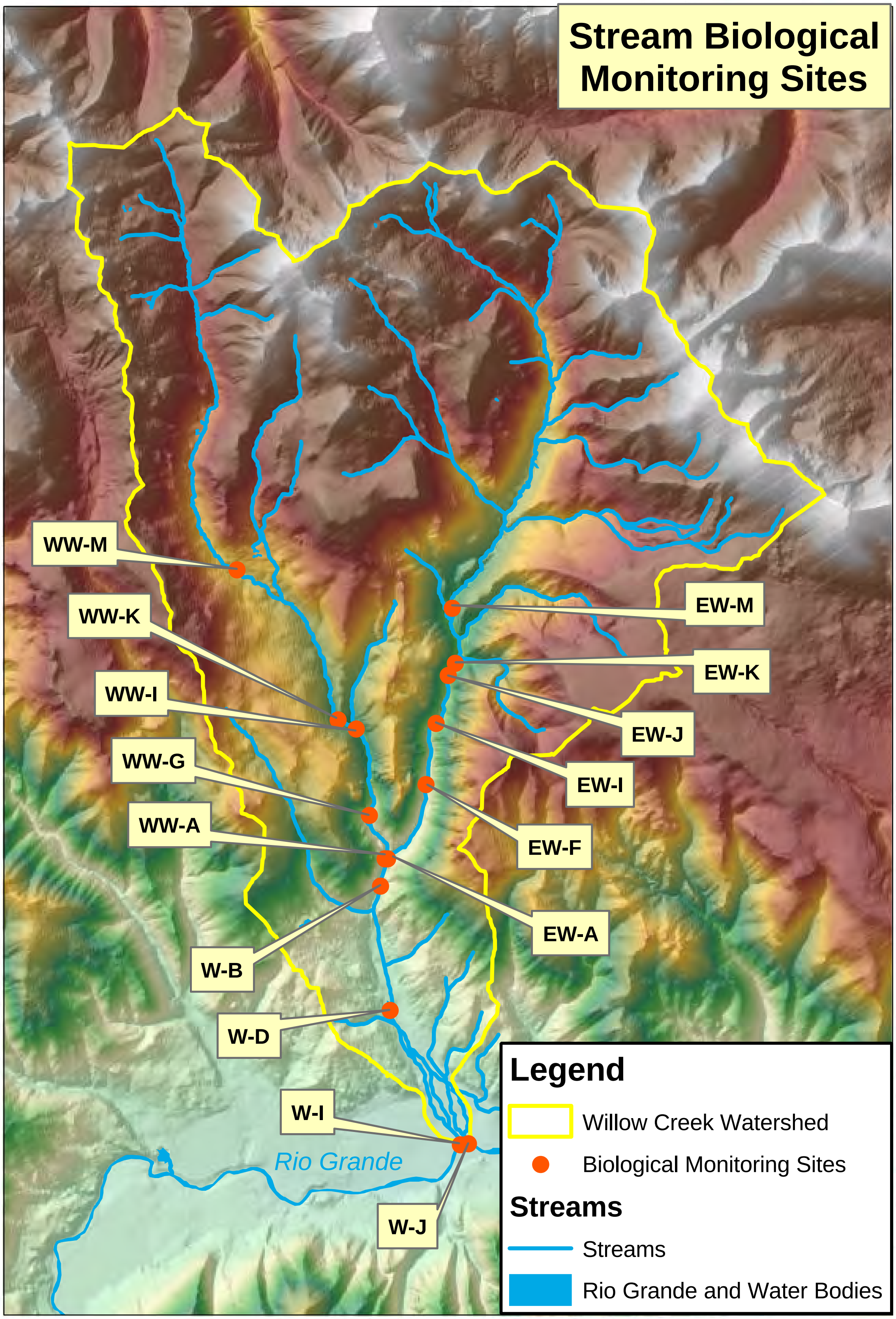
Macroinvertebrates

Aquatic macroinvertebrates are extremely important organisms in mountain streams, in part because they are a primary food source for many species of fish, including trout. The term 'aquatic macroinvertebrate' refers to a taxonomically artificial group consisting of diverse, non-related organisms such as insects, arachnids, mollusks, crustaceans, annelids, helminthes, etc. They are also important because their relative abundance can be used as an indicator of stream quality. Generally, large numbers of different sensitive species indicate high-quality water and habitat. Features that make aquatic macroinvertebrates especially well suited for determining stream quality include 1) optimal life cycle time scales, 2) sedentary nature, 3) range of tolerance, across species to environmental conditions, and 4) central position in the food chain.

The primary macroinvertebrates of mountain streams are mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*), caddis flies (*Tricoptera*), aquatic beetles (*Coleoptera*), and true flies (*Diptera*). Of these organisms, some tolerate high metal concentrations, whereas others do not tolerate metals, so macroinvertebrate analyses offer information on water quality. *Ephemeroptera*, *Plecoptera*, and *Tricoptera* (EPT) are the three most commonly used taxa in stream macroinvertebrate analysis in terms of good water indicators. Many *Ephemeroptera* and *Plecoptera* are metals-intolerant, so the lack of their presence, or low abundance, is useful as an indicator of poor chemical conditions.

In September 1999, May 2000, and May 2001, aquatic macroinvertebrates were sampled in East Willow, West Willow, and Willow Creeks at selected sites (Figure 3.3). The sampling was part of the USFWS biological sampling in the watershed (Appendix B, WCRC #2). One of the monitoring objectives was to determine the total number of macroinvertebrates organisms and to ascertain the level of taxonomic diversity at each

Figure 3.3 - Stream Biological Monitoring Sites in the Willow Creek Watershed



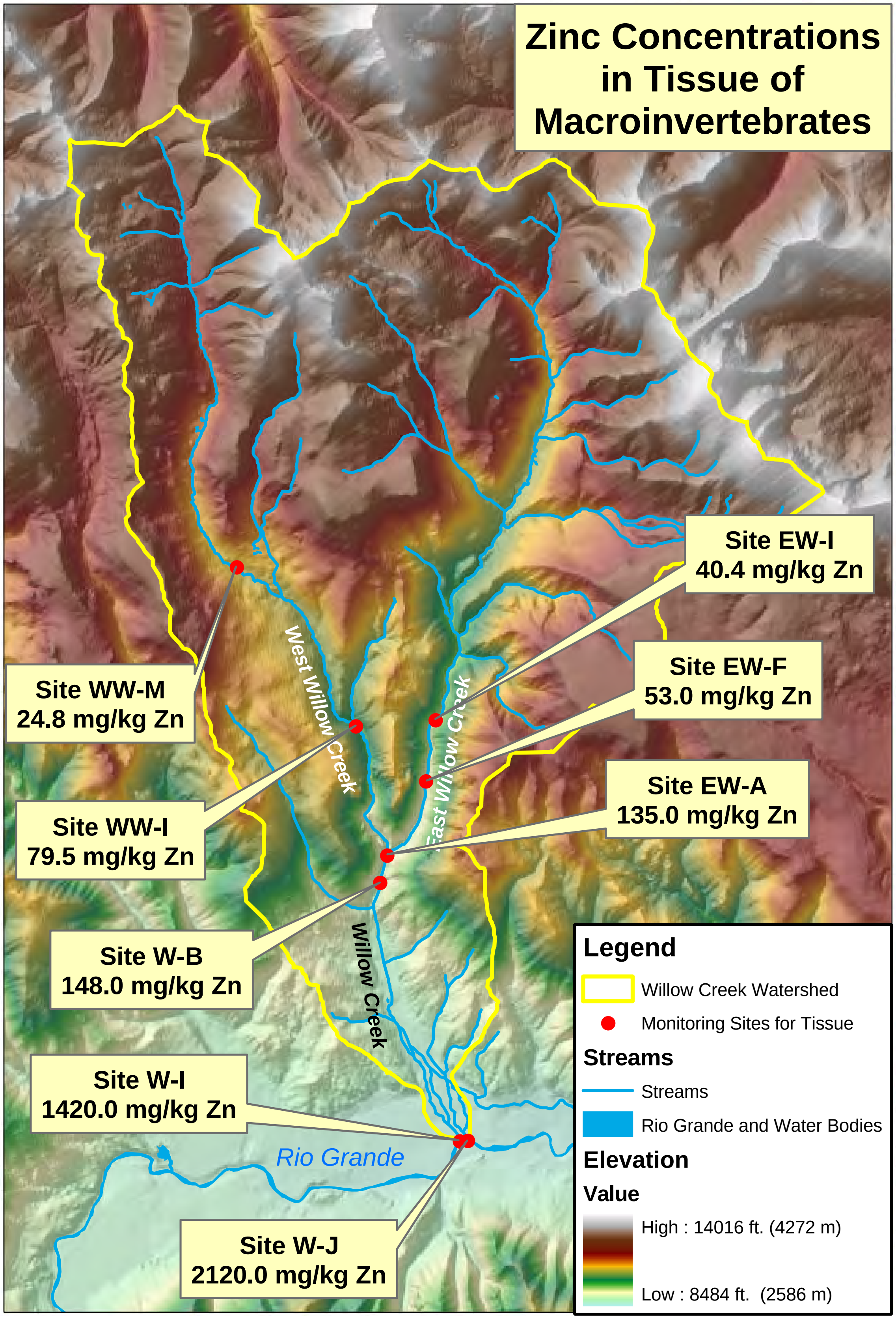
sampling site. In addition, metals concentrations in tissues of aquatic macroinvertebrates were determined. The results of the tissue metals concentrations are presented by site in **Appendix G**.

The USFWS study (Appendix B, WCRC #2) details the total number of species (total abundance), total taxa richness, EPT abundance, and EPT taxa richness for each site sampled (Appendix G). In general, the upstream sites have greater total abundance, total richness, EPT abundance, and EPT richness than the downstream sites. Based on all abundance data considered, East Willow Creek is in markedly better condition than both West Willow Creek and Willow Creek. The data provided for total abundance, EPT abundance, total richness, and EPT richness indicate that the condition of West Willow Creek is similar to that of Willow Creek. However, *Ephemeroptera* and *Plecoptera* were scarce in Willow Creek in comparison to West Willow Creek. The composition of the Willow Creek EPT was dominated by taxa which are more metals-tolerant, while metals-intolerant taxa were not abundant. Thus, given a closer examination of the EPT abundance composition, the two stream reaches are differentiable. The stronger presence of *Ephemeroptera* and *Plecoptera* taxa in West Willow Creek suggests that it is in better condition than Willow Creek and that, at least in the upper reaches of West Willow Creek, metals concentrations are lower than those of Willow Creek. In both East Willow Creek and West Willow Creek, the number of metals-intolerant taxa decreased as metals-tolerant taxa increased from upstream sample sites to downstream sampling sites. In East Willow Creek, at the downstream sample site, *Hydropsychidae*, a metals-tolerant caddis fly, was abundant.

The USFWS study (Appendix B, WCRC #2) included macroinvertebrate tissues for metals concentrations. The analysis found that metal concentrations in macroinvertebrate tissues were elevated in downstream sites, in comparison to upstream sites, considered as reference sites. **Figure 3.4** shows zinc concentrations in macroinvertebrate tissues, illustrating the downstream gradient. The observed concentrations were compared with recommended dietary intake thresholds for birds and fish. The concentrations comparison was made with the lowest observed adverse effects level (LOAEL) and no observed adverse effects level (NOAEL) benchmarks for food (Sample, 1996) and dietary intake values (Eisler, 1998). The concentrations of lead, arsenic, and cadmium were elevated in tissues of invertebrates from various sample locations; however, these concentrations were below recommended dietary intake values that affect birds and fish in East Willow and West Willow Creeks (Appendix G). Site WW-A, the most downstream site on West Willow Creek, was sampled, but no macroinvertebrates were obtained during the May 2001. Based on the known impaired stream chemistry at site WW-A, it is most likely that macroinvertebrates were not present due to elevated metals concentrations in the water (Appendix B, WCRC #2).

In Willow Creek, the concentrations of arsenic, copper, and zinc exceeded the reported dietary exposure concentrations that affect fish, and concentrations of arsenic, cadmium, lead, and zinc exceeded the reported dietary exposure concentrations that affect birds (Appendix G). These organisms therefore present a hazard to other organisms that feed on them due to bioaccumulation and biomagnification. Bioaccumulation is a

Figure 3.4 - Zinc Concentrations in Macroinvertebrate Tissues at Selected Sites



phenomenon by which a toxic substance enters the food chain by building up in the tissues of plants or animals used as food by other creatures. Biomagnification is a phenomenon by which the concentration of a toxic substance increases in organisms from one level in the food chain to higher levels in the food chain. Cadmium, copper, and zinc have the potential to biomagnify and, therefore, may present a far-reaching hazard to other organisms, including fish and fish-eating organisms. **Figure 3.4** presents zinc concentrations in macroinvertebrate tissue for all eight of the sample sites where macroinvertebrates were collected in May 2001. Eisler's dietary intake threshold value for zinc concentration is 178 ppm for birds and between 440 and 1700 ppm for fish (Appendix G) (Appendix B, WCRC #2).

Fish

Following American settlement, the introduction of non-native fish species was a common practice, and species such as the brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) were introduced in the late 19th and early 20th centuries. These and possibly other disturbances, such as fishing pressures and mining impacts from the late 1890s, probably led to the extirpation of native fish species from Willow Creek. The only two fish species now reported to inhabit Willow Creek are brook trout, which is native to eastern North America, and the brown trout, which is native to Europe. Both brook trout and brown trout out-compete cutthroat trout in western streams.

The Continental Divide is a significant geographic barrier for fish species and has caused the native species of the Rio Grande and Colorado River drainages to genetically diverge. This is readily seen in the native fish species, which are restricted to the Rio Grande drainage. Some of those species are the Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*), the Rio Grande sucker (*Catostomus plebeius*), and the Rio Grande chub (*Gila pandora*). According to the USFWS (Appendix B, WCRC #2), no native fish species are known to occur in the Willow Creek Watershed, but it is possible that that they were in the watershed prior to American settlement.

In September of 1999, the USFWS sampled the fish populations of East Willow Creek, West Willow Creek, and Willow Creek (Appendix B, WCRC #2). Willow Creek was devoid of fish except for two brown trout found near the confluence with the Rio Grande (Sites W-I and W-J). These two fish may have moved in from the Rio Grande. Brook trout were abundant throughout the entire studied portion of East Willow Creek, but only one brown trout was captured. The brook trout in West Willow Creek were confined primarily to the Upper Section and the numbers captured in the Middle Section diminished downstream until no fish were captured at the sampling site immediately above the confluence with East Willow Creek (Site WW-A, the only West Willow Creek biological sampling site below the Nelson Tunnel). Brown trout were captured in West Willow Creek in the lower portion of the Upper Section at sites WW-I and WW-K. Overall, the brook trout population was believed to be healthy and self-sustaining, except for in the Middle Section on West Willow Creek and in all of Willow Creek. Brook trout are more tolerant of metals than are brown trout. Fish abundance estimates from the USFWS study are found in **Appendix G**.

Biological Condition Classes

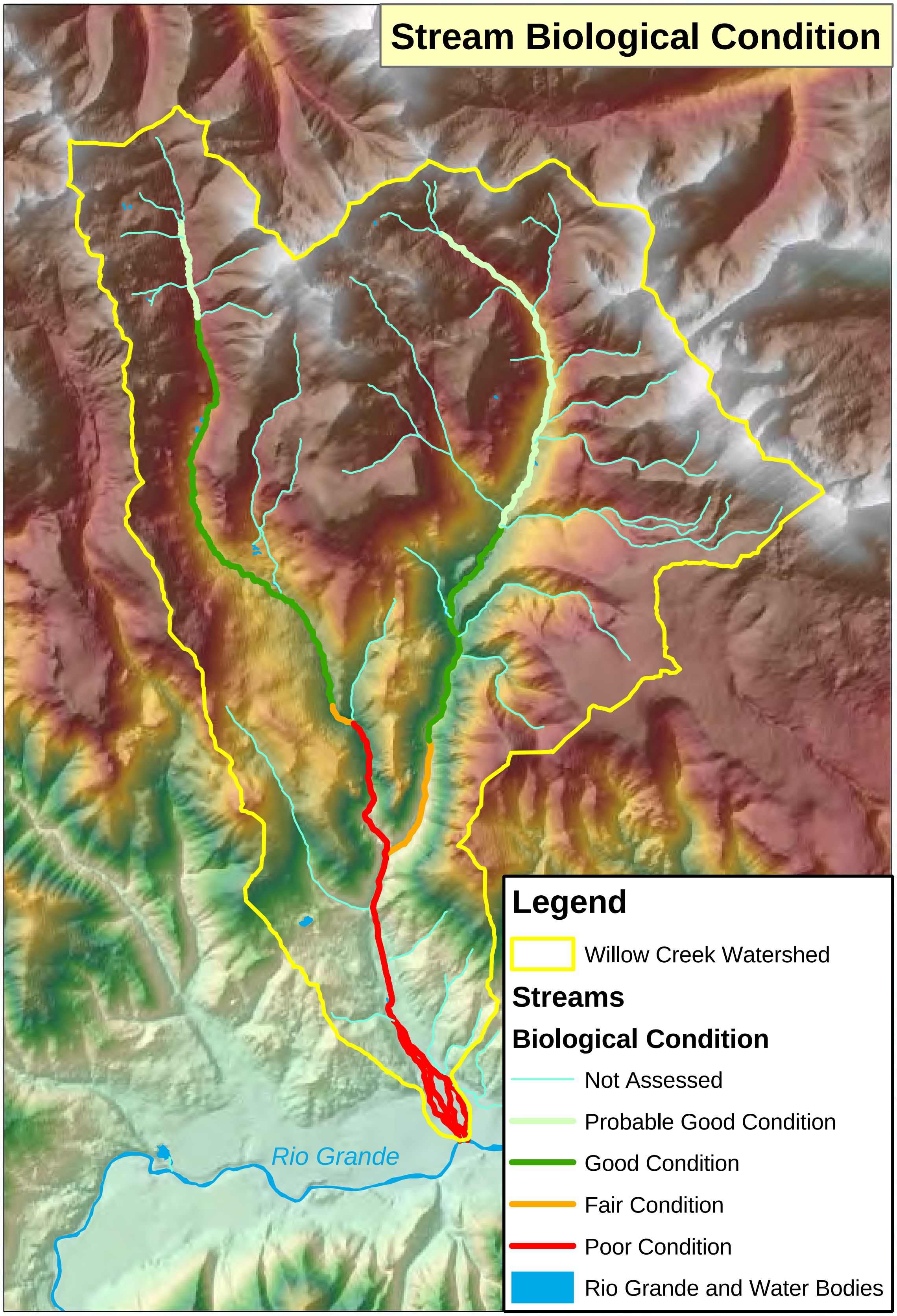
The fish and macroinvertebrate data provide the primary basis for determining the biological condition classes. Stream reaches were assigned to condition classes of *good*, *fair*, and *poor* based on the biological monitoring data at the downstream base of that reach (Figure 3.5). *Poor* condition was easily defined for reaches where no fish, or very small numbers of fish, were captured. In addition, these reaches correlated with sites where metal concentrations in macroinvertebrate tissues exceeded recommended dietary intake values that affect birds and/or fish and had a dominance of metals-tolerant macroinvertebrate species. Reaches classified as *fair* had sites somewhere in between *good* and *poor* condition, where fish numbers and metal concentrations in macroinvertebrate tissues were distinctly different from sites upstream, yet in better shape than those deemed in *poor* condition. These sites also had higher counts of metals-tolerant macroinvertebrate species. The *good* condition reaches were identified upstream from clearly *good* condition sites. The macroinvertebrate assemblages at those sites had good diversity, including metals-tolerant taxa. Biological condition classification for individual reaches with reach monitoring sites identified, are presented in **Appendix G**. An additional condition class, *probably good*, was assigned to perennial reaches upstream from the last monitoring-based condition assignment of *good*, where GIS analysis showed insignificant disturbance. The expectation for those reaches is that they would be in *good* condition; however, monitoring data would be needed to confirm this conclusion.

The interpreted data provide a gradient picture of the biological condition of the watershed. Although monitoring data in the Upper Section of the watershed was limited to the downstream reaches, the upstream reaches are expected to be in *good* condition. The basis for that expectation is from GIS analysis, which shows minimal disturbance upstream from the uppermost monitoring sites and where sampling showed the best biological condition results. **Figure 3.5** shows the stream reach classifications for biological condition.

Beaver

Beaver have been observed in the watershed's Upper Section and some parts of the Middle Section. Once abundant in the mountainous west, the beaver population dramatically decreased as a result of fur trapping in the 1800s. However, the population is reportedly increasing within the Willow Creek Watershed, as well as in many mountain watersheds. Scientists and wildlife managers consider beaver re-colonization in watersheds to be beneficial, providing that populations do not exceed the carrying capacity of the area. Beaver ponds help establish and maintain perennial streams and many wildlife species in the American West, 80 percent by some estimates, depend upon the wetland habitats that beaver create. When beaver abandon a stream, the channel becomes unstable and species diversity declines. The modifications of the landscapes imposed by beaver favors the propagation of aspen and willow, the beaver's

Figure 3.5 - Biological Condition of Perennial Streams in the Watershed



preferred food sources. In addition to benefiting aspen forests and willow thickets along streams, beaver activity favors a myriad of other wetland species, including aquatic and semi-aquatic plants, aquatic macroinvertebrates, fish, amphibians, waterfowl, and semi-aquatic mammals such as the muskrat and even the moose.

The benefits derived from the activities of beaver extend beyond creating habitat and species diversity. The creation of beaver dams and ponds, as well as the channels that beavers dig, tends to improve the hydrologic characteristics within a watershed. These improvements are increased water storage, elevated water table, reduced downstream flooding, and increased stream flow during low-flow periods. Beaver ponds act as a refuge for fish, including trout, during drought and winter ice-over of the stream; they also can be safe havens for wildlife during forest fires. In addition, beaver-occupied streams function more effectively at processing nutrients, neutralizing acids, and removing excess toxins, such as aluminum compounds and sulfates. Finally, values such as aesthetics, wildlife viewing, and recreational opportunities such as fishing and hunting, may be enhanced by the presence of beaver ponds and meadows. These values can be enhanced or maintained by properly managing beaver.

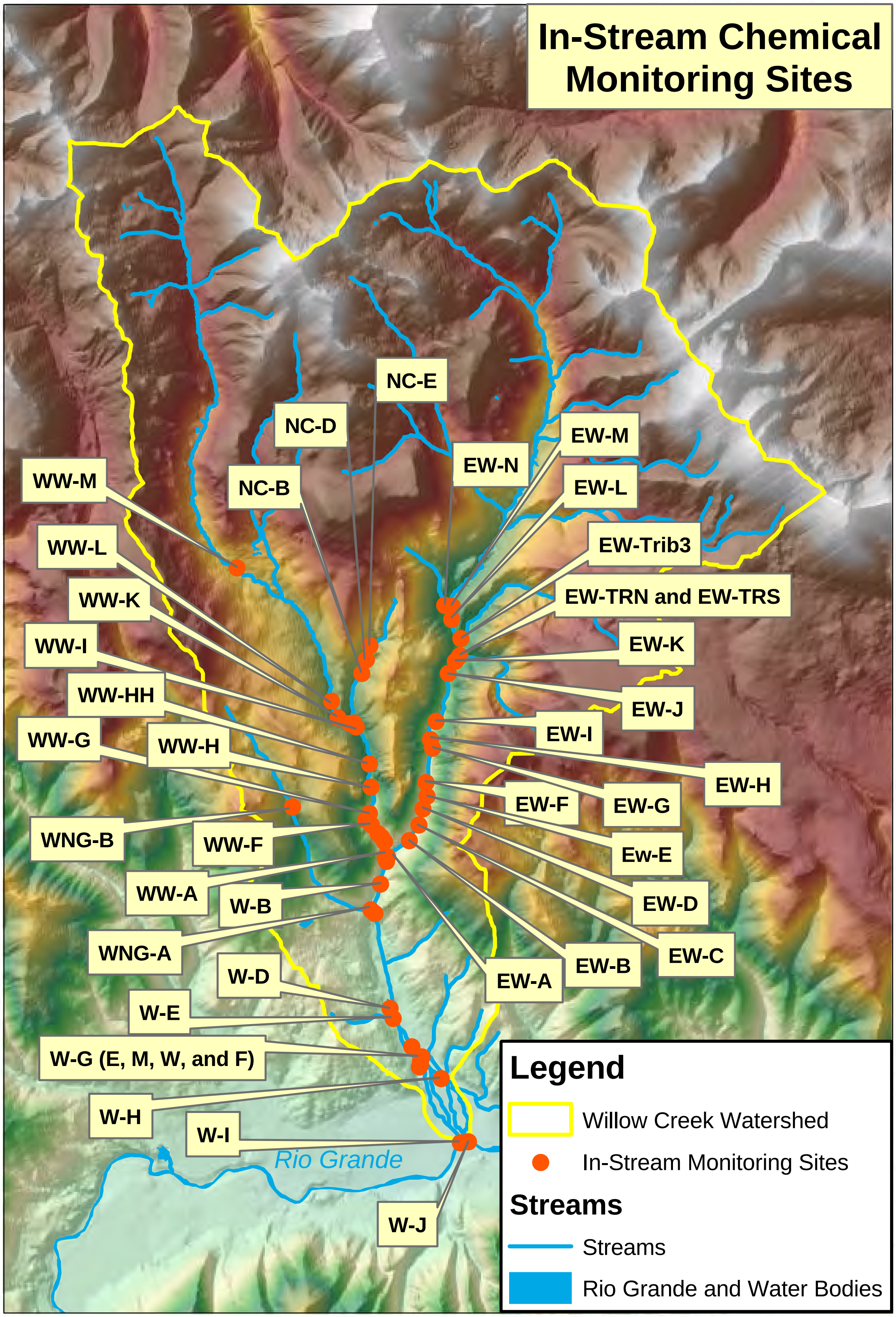
Stressors on Biological Condition

Biological condition stressors are predominately *poor* chemical and physical habitat conditions. Both the chemical and physical habitat conditions are discussed in the following pages. Only two fish species were found in Willow Creek through the USFWS monitoring effort and they were both introduced species. Both of the species, brown and brook trout, are known to out compete other fish species.

Chemical Condition

Chemical condition evaluation of the streams in the Willow Creek Watershed is based on analysis of chemical concentrations from monitoring samples at low-flow. WCRC high-flow monitoring data supports the evaluation. The low-flow concentrations were compared to criteria developed by the State of Colorado for the Rio Grande Basin that include streams in the Willow Creek Watershed (CDPHE – WQCC, Regulation #36: Classifications and Numeric Standards for the Rio Grande Basin, 2003). Metals were the chemical of concern and the subsequently the basis for determination of chemical condition. Standards for metals concentrations, referred to as table value standards, are calculated with a formula for each metal at each sample site. Hardness at each site, at the time of sampling, was used to calculate the table value standards for each metal. These results differ slightly from the WCRC results (Appendix B, WCRC #1), where an average hardness value among multiple sample dates for a site was used. Thus, the table value standards presented in **Appendix H** are not exactly the same as those in the WCRC report. **Figure 3.6** shows the sampling locations where in-stream chemical concentrations were determined. This section discusses the results and compares them to State of Colorado table value standards for the watershed. This section also discusses concentration levels at high-flow and how concentrations are translated into chemical loadings.

Figure 3.6 - In-Stream Chemistry Monitoring Sites in the Willow Creek Watershed



Quality of Chemical Data

WCRC developed a sampling and analysis plan for chemical data. The plan for chemical data is part of the same document mentioned in the biological condition section (Appendix B, WCRC #7). The document details the collection methods and laboratory analyses performed with the chemical data used in this assessment. WCRC's monitoring objectives were to determine the level and severity of stream pollution, how that pollution varies, and to determine the sources of pollution. WCRC met their monitoring objectives through their monitoring efforts. Most sample sites have a single-date low-flow concentration determined for specific metals, while high-flow concentrations were made on multiple dates. Low-flow concentrations drive the chemical condition classification from a State of Colorado standards perspective. In this assessment, the low-flow data are supported by the high-flow concentration results which show the same evaluation story. Low-flow concentrations at multiple sites along a reach, allowed for confident classifications of some reaches based solely on low-flow data.

The WCRC report on sampling and monitoring (Appendix B, WCRC #1) indicates some problems with duplicate analysis of metals and some cases of poor agreement between laboratories. However, for purposes of this assessment, concentrations were compared to table value standards and then classified into condition classes based on the dissolved concentration percentage of the table value standard. This classification process doesn't require extremely accurate concentration values. Therefore, based on an understanding of the methods and the blank and duplicate analysis, the chemical data were deemed an acceptable quality for purposes of this assessment.

Inconsistencies within these data, in terms of "outliers" (values distinctly greater than or less than a majority of otherwise like values) and data omissions, create an undetermined degree of uncertainty in this analysis. Statistical confidence levels have not been determined, but data and methodology have been peer-reviewed and a relatively high degree of confidence can be placed in this analysis.

Chemical Concentrations

The lower portions of East Willow Creek and West Willow Creek in the watershed's Middle Section (below EW-M and WW-M), Nelson Creek, much of Windy Gulch, all of Willow Creek, and the portion of the Rio Grande downstream from the Willow Creek confluence, are contaminated with varying concentrations and combinations of metals. The stream concentration levels for metals that naturally occurred before 1889, when mining began in the watershed, are not known. However, it is clear that mining activity has increased metals loading within the watershed.

Table 3.4 summarizes selected data from the *Report on Surface and Mine Water Sampling and Monitoring in Willow Creek Watershed, Mineral County (1999-2002)*, (Appendix B, WCRC #1), henceforth called the Surface Water Report. The table value standards used in calculating the average table value standard presented in **Table 3.4**

were determined with the site-specific hardness. Detailed, site-by-date data are found in **Appendix H**. Occurrences of low-flow concentrations of a chemical exceeding the table value standards would imply both an impaired site for that chemical and *poor* condition in this assessment. State of Colorado defined impairment should not be confused with the *poor* and *very poor* conditions listed in **Appendix H**. Although the chemical thresholds for *poor* and *very poor* conditions in this assessment are based on the standards, only the State of Colorado can declare impairment for streams in the watershed. That determination requires multiple date low-flow sampling. The chemical condition classification thresholds are described in the next section.

Table 3.4 - Metal Concentrations Shown with Table Value Standards (TVS): Highest and lowest metals concentrations by stream segment. All segments identified in the table exceed State Water Quality Standards.

Stream	Metal	Lowest conc. (µg/l)	highest conc. (µg/l)	average conc. (µg/l)	average chronic TVS (µg/l)	Average acute TVS (µg/l)	Percent highest exceed. chronic TVS	Percent highest exceed. acute TVS	Flow (cfs)	May or Sept. sampling event
WWC	aluminum	32.00	160.00	97.79	87.00	750.00	184	none	12.0	Sept.
W	aluminum	68.00	187.00	107.80	87.00	750.00	215	none	18.7	Sept.
W	aluminum	<15.00	93.00	46.10	87.00	750.00	107	none	39.7	May
EWC	cadmium	<0.15	1.65	0.78	0.61	0.63	274	265	23.0	Sept.
EWC	cadmium	<0.15	0.84	0.32	0.57	0.58	161	166	39.0	May
WWC	cadmium	<0.15	31.26	13.23	1.21	1.80	3,674	3,027	12.0	Sept.
WWC	cadmium	<0.15	14.43	6.00	0.94	1.21	1,527	1,274	33.4	May
W	cadmium	10.40	18.30	13.80	1.42	1.64	1,729	1,484	18.7	Sept.
W	cadmium	5.71	12.97	9.02	0.91	1.16	1,288	980	39.7	May
WWC	copper	<1.00	16.60	7.63	4.46	6.28	567	424	12.0	Sept.
WWC	copper	<1.00	9.90	3.97	3.29	4.47	328	244	33.4	May
W	copper	4.30	9.10	6.13	4.20	5.84	227	171	18.7	Sept.
W	copper	3.30	6.90	4.73	3.19	4.32	230	176	39.7	May
EWC	Lead	<3.00	11.30	6.13	0.36	9.12	3,173	124	23.0	Sept.
EWC	Lead	<3.00	7.50	3.00	0.33	8.37	2,673	104	39.0	May
WWC	Lead	<3.00	92.80	40.88	1.05	26.97	13,443	524	12.0	Sept.
WWC	Lead	<3.00	40.70	15.08	0.07	17.86	4,297	167	33.4	May
W	Lead	9.60	33.40	21.80	0.95	24.41	6,445	251	18.7	Sept.
W	Lead	5.70	16.50	11.20	0.67	17.08	2,685	105	39.7	May
EWC	Zinc	<1.00	207.70	88.96	26.62	26.41	789	795	23.0	Sept.
EWC	Zinc	<1.00	130.50	40.21	24.87	24.67	584	589	39.0	May
WWC	Zinc	<1.00	7,616.80	3,059.00	59.12	58.65	19,210	19,336	12.0	Sept.
WWC	Zinc	<1.00	3,343.60	1,179.28	43.75	43.40	5,672	5,718	33.4	May
W	Zinc	1,425.00	3,196.00	2,672.00	55.81	55.36	8,886	8,958	18.7	Sept.
W	Zinc	709.00	2,513.20	1,760.00	42.47	42.13	5,593	5,639	39.7	May

EWC = East Willow Creek; WWC = West Willow Creek; W = Willow Creek. Sept. refers to low-flow condition and May refers to high-flow condition; cfs = cubic feet per second; < denotes that the concentration was below the limit of detection for the method employed; 'Highest percent of (chronic or acute) TVS' denotes the percentage of the maximum concentration in the stream segment divided by the respective TVS and multiplied by 100.

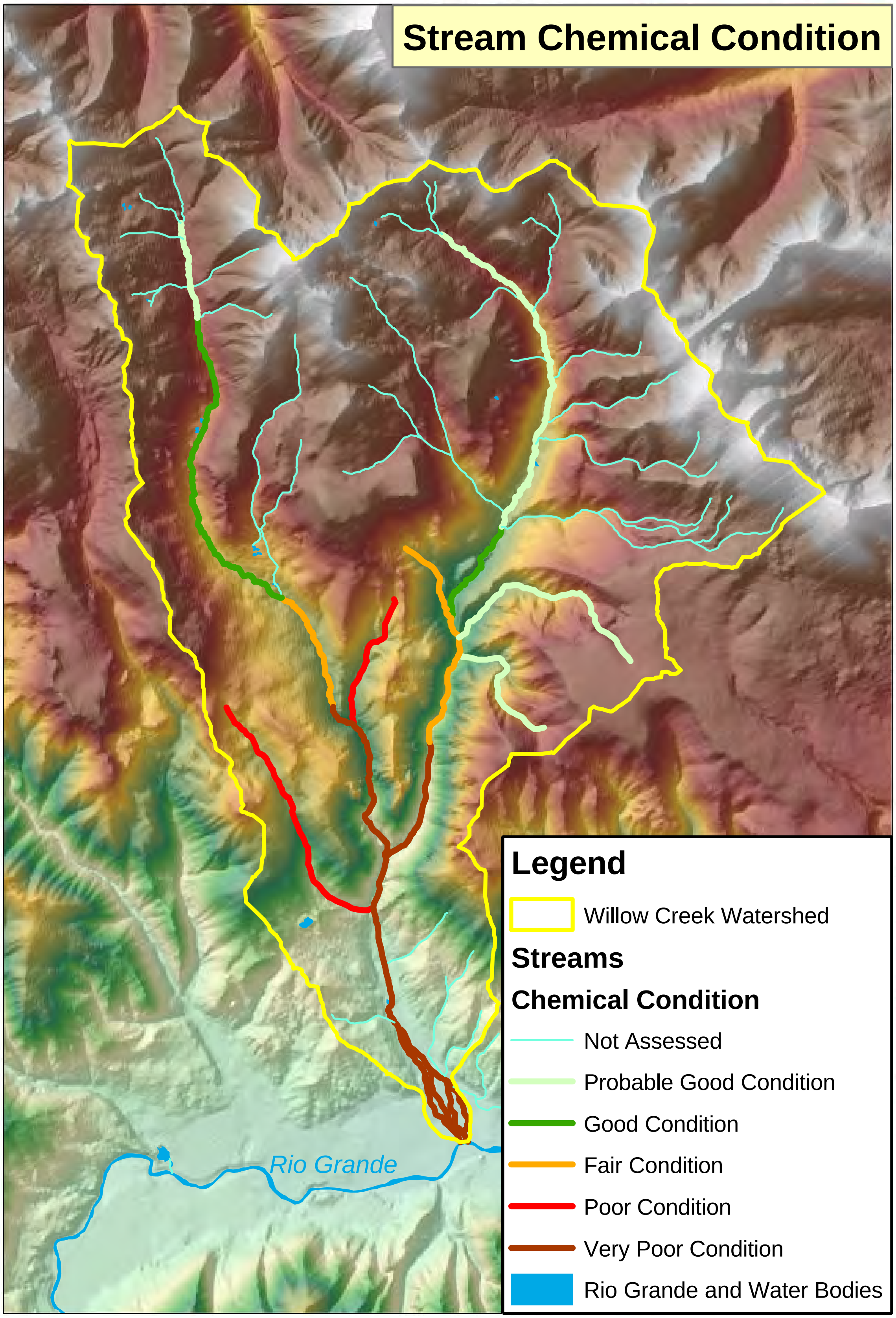
The data in **Table 3.4** show that for both East Willow Creek and West Willow Creek, the lowest concentrations were recorded in the Upper Section of the watershed at, and above, sites WW-L and EW-L (Figure 3.6). The highest concentrations of metals in East Willow and West Willow Creeks were recorded in the lower portion of the Middle Section of the watershed (Appendix H). Of these two streams, concentrations of all metals analyzed were significantly greater in West Willow Creek than in East Willow Creek. West Willow Creek exceeded table value standards for cadmium, zinc, lead, aluminum, and copper. Sample site details of concentrations exceeding acute and/or chronic table value standards are found in **Appendix H**. East Willow Creek exceeded table value standards for cadmium, lead, and zinc. Even so, concentrations of cadmium and zinc were still many times below those of West Willow Creek. In the Creede and Lower Sections of the watershed, Willow Creek samples exceeded table value standards for cadmium, zinc, lead, aluminum, and copper. Except for aluminum, metals tend to increase from very low concentrations in the Upper Section to moderate concentrations for East Willow Creek and very high concentrations for West Willow Creek in the contaminated reaches of the Middle Section. In West Willow Creek, the highest concentrations reported were generally at sample sites immediately downstream of the Nelson Tunnel. In East Willow, the highest concentrations were immediately above the confluence with West Willow Creek, where Willow Creek begins. Zinc, cadmium, and lead are metals of most concern, because they exceed table value standards by the greatest percentages and are the metals that exceed table value standards at the most sites (Table 3.4 and Appendix H).

Results indicate that in-stream concentrations of metals are high for many of the targeted (suspected) sites during both low-flow and high-flow conditions. Site specific analysis confirms in-stream concentration increases due to significant contaminant contributions from both the Nelson Tunnel Adit and the Solomon Adit. This indicates that ground water sources are the major contributors of contaminant load. The data also indicate significant contamination from the Last Chance / Amethyst mine rock waste pile. The assessment does not rule out the potential of other contamination from surface sources, such as other mine rock waste piles and tailings piles, especially, if these piles become disturbed.

Chemical Condition Classification

Figure 3.7 shows the classifications of stream chemical condition. This classification is based on low-flow concentration samples in stream reaches, and on GIS analysis. Condition of a stream reach upstream from a sample site was interpreted from the sample data of that site. When multiple sites occur on a stream reach, the reach chemical condition classification is determined from all the sites along the reach, with attention to the highest concentrations. If no point source inflows (surface) or significant GIS-observed disturbances are present, then a good deal of confidence exists in the reach classification. Several reaches were sub-divided due to observed in-flow occurrences. However, ground water inflows are not taken into account in this process and so the farther upstream from a sampling site, the less confidence in the inference for the

Figure 3.7 - Chemical Condition of Streams in the Willow Creek Watershed



classification. GIS analysis was employed to estimate the probable condition in the upstream portions of the West Willow Creek and East Willow Creek in the Upper Section. The estimates of *probably good* condition are based on the analysis of minimal disturbances and the fact that the closest downstream sample sites showed *good* chemical condition.

Table 3.5 shows the chemical condition classification method. Low-flow concentrations were compared with the calculated table value standards and the dissolved concentration percent of the table value standard for each metal, at each site. If the percentage exceeds 100 percent of the standard, the site is considered in *poor* condition. Percents greater than 1000 are considered *very poor*. Percents between 50 and 100 are classified as *fair* condition. Where percents are less than 50, the site is classified as *good*. **Appendix H** contains tables for low and high-flow dissolved concentrations by individual sites. These tables show the calculated table value standards and the dissolved concentration percent of the table value standards. A summary table in the front of **Appendix H** shows the specific stream reaches associated with each monitoring site and its chemical condition classification. The classes are reported for percents of concentrations that exceed both acute and chronic standards for each site. The overall chemical condition classification is also shown for each reach. Occasionally, a single concentration exceeds the chronic standard. In those cases, a more lenient reach classification of *fair*, is assigned. A professional judgment is made, requiring at least two exceedences for a *poor* classification. In single occurrence cases, additional monitoring data is needed to either confirm or adjust the classification.

Table 3.5 – Chemical Condition Classification

Low-flow Concentration Percent of Table Value Standard	Chemical Condition Class
0 – 50 percent	Good
50 – 99 percent	Fair
100 – 999 percent	Poor
> 1000 percent	Very Poor

Although the lower reaches of both East Willow Creek and West Willow Creek are classified as *very poor*, it should be noted that the lower reach of West Willow Creek is in much worse condition than the lower reach of East Willow Creek. Exceedences greater than 1000 percent of the chronic lead table value standard resulted in the *very poor* classification for East Willow Creek's lower reach. The lower reach of West Willow Creek had greater than 1000 percent exceedences of both acute and chronic table value standards for cadmium, zinc, and lead (Appendix H).

An example of an analysis of stream reach chemical condition is shown in **Figure 3.8**. The example reach, WWC_2, is part of West Willow Creek in the Middle Section of the watershed from the confluence with Nelson Creek upstream to the confluence with

Deer Horn Creek. Three sample sites exist along the reach: sites WW-J, WW-K, and WW-L. WW-J is situated just above the confluence with Nelson Creek, immediately downstream of the Amethyst Mine. WW-K is upstream, but is still in the old mining area. WW-L is upstream of the mining impacted area. The histograms on the right side of **Figure 3.8** show low-flow metals concentrations as a percent of the calculated table value standards for each side. A value of 100 percent means that the observed concentrations are equal to the threshold for impaired condition. The blue bars indicate the percent for acute standards for aquatic life and the green bars indicate the percent for chronic standards for aquatic life. From the figure, one understands that the acute and chronic standards are exceeded at sites WW-J and WW-K for both cadmium and zinc. The chronic standard for lead is exceeded at all three sites. Based on this data, and an examination of individual date samples of low-flow concentrations exceeding standards, the stream reach was classified as *very poor* from the confluence with Nelson Creek upstream to site WW-L. The rest of the reach was classified as *fair*, since only an individual date (9/19/99) had a lead concentration that exceeded the chronic table value standard and none of the metals concentrations exceeded more than 50 percent of the acute table value standards.

Chemical Loads

The WCRC surface water sampling report (Appendix B, WCRC #1) contains considerable chemical loading data, which is a diagnostic method to account for sources of metals. For the purposes of this assessment, these data are used to provide an estimate of the *amount* of metals added to streams and to present a generalized picture of the chemical condition of the sampled waters.

Collection of contaminant concentrations and surface water flow data has allowed the WCRC to estimate the rate of contaminant transport within disparate stream segments within the watershed. The customary environmental term for contaminate transport is "load" which is presented here in pounds per day (lbs/day). Willow Creek carries an estimated 276.3 pounds per day of total aluminum, cadmium, copper, lead, and zinc into the Rio Grande. This means that the estimated loading of metals from Willow Creek to the Rio Grande is approximately 50 tons per year.

Unlike contaminant concentrations in Willow Creek waters, where concentrations decrease by dilution upon entering the Rio Grande, the load contribution from Willow Creek to the Rio Grande essentially remains constant, assuming normal low and high-flow conditions. The data indicate that Willow Creek significantly contributes to water quality exceeding standards for zinc and possibly cadmium in the Rio Grande, and the load contribution from Willow Creek to the Rio Grande significantly increases levels of aluminum, cadmium, copper, lead, and zinc. However, WCRC investigations have also determined other (non Willow Creek) sources of contamination to the Rio Grande.

Figure 3.9 shows the West Willow Creek stream reach upstream of the confluence with East Willow Creek and the zinc loadings for the sample sites along that reach. The impact from the Nelson Tunnel inflow is quite evident in the loading increase.

Figure 3.8 - Stream Reach with Histograms of Selected Metals at Specific Sites

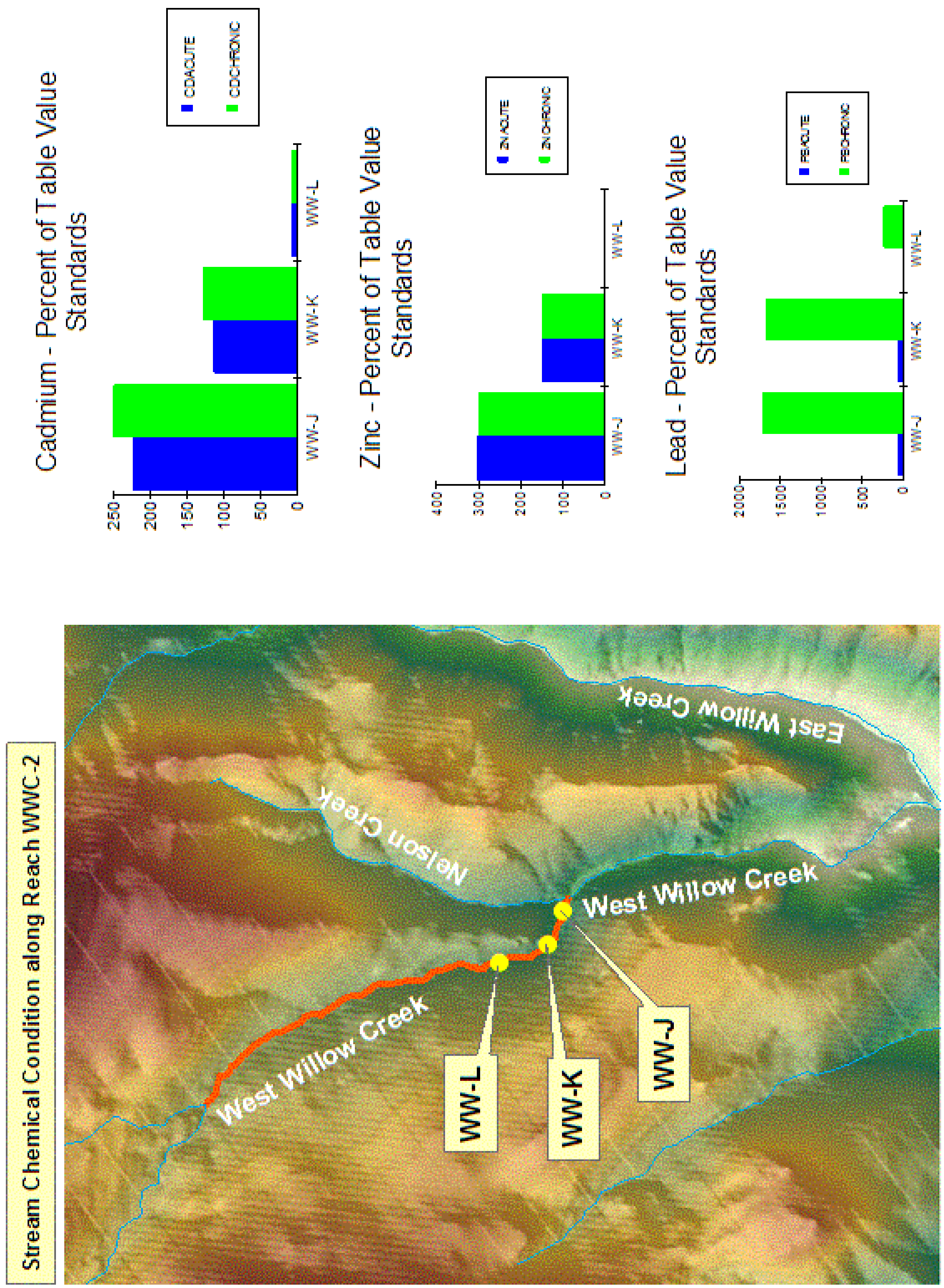
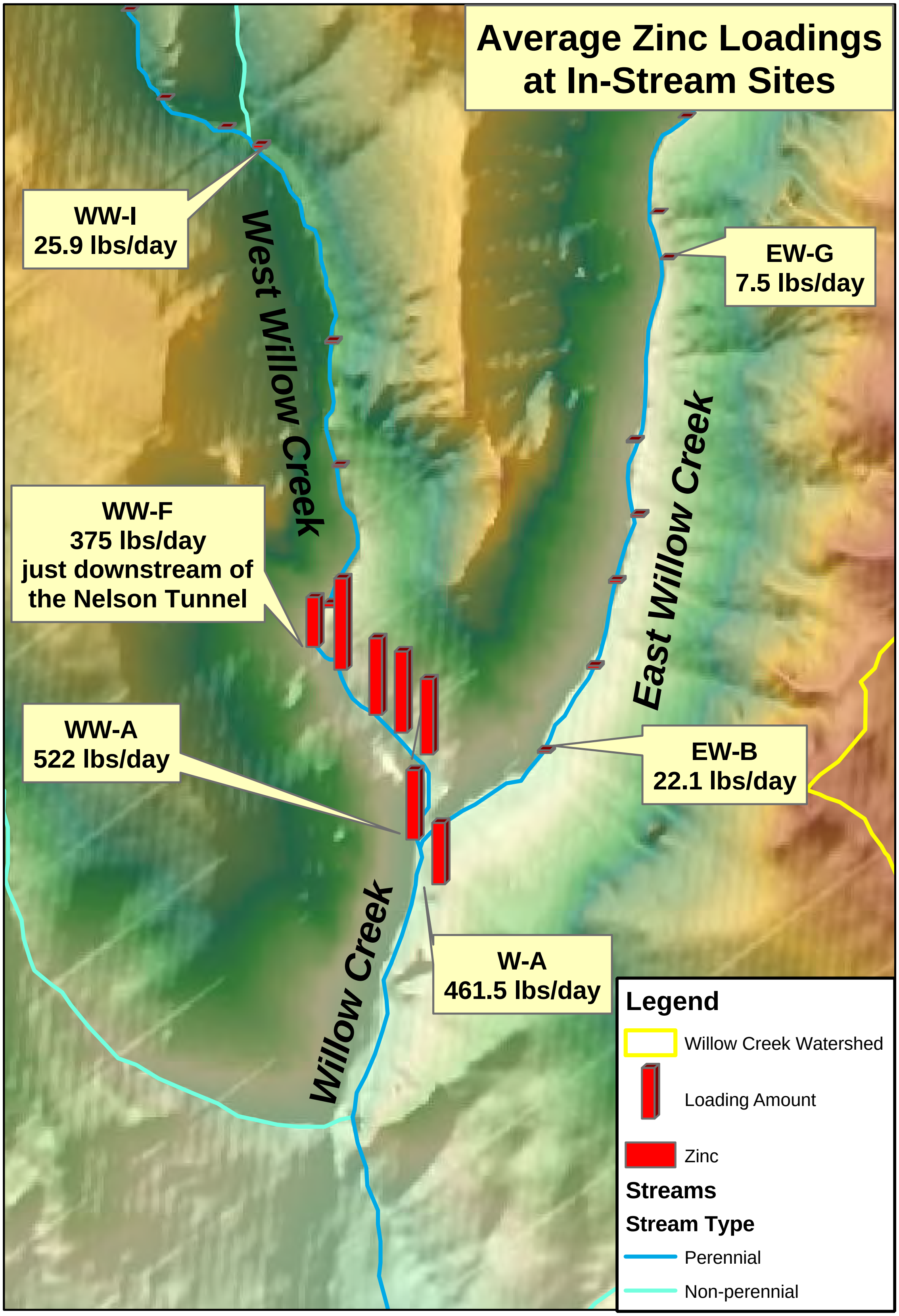


Figure 3.9 – Average Zinc Loadings at In-stream Monitoring Sites



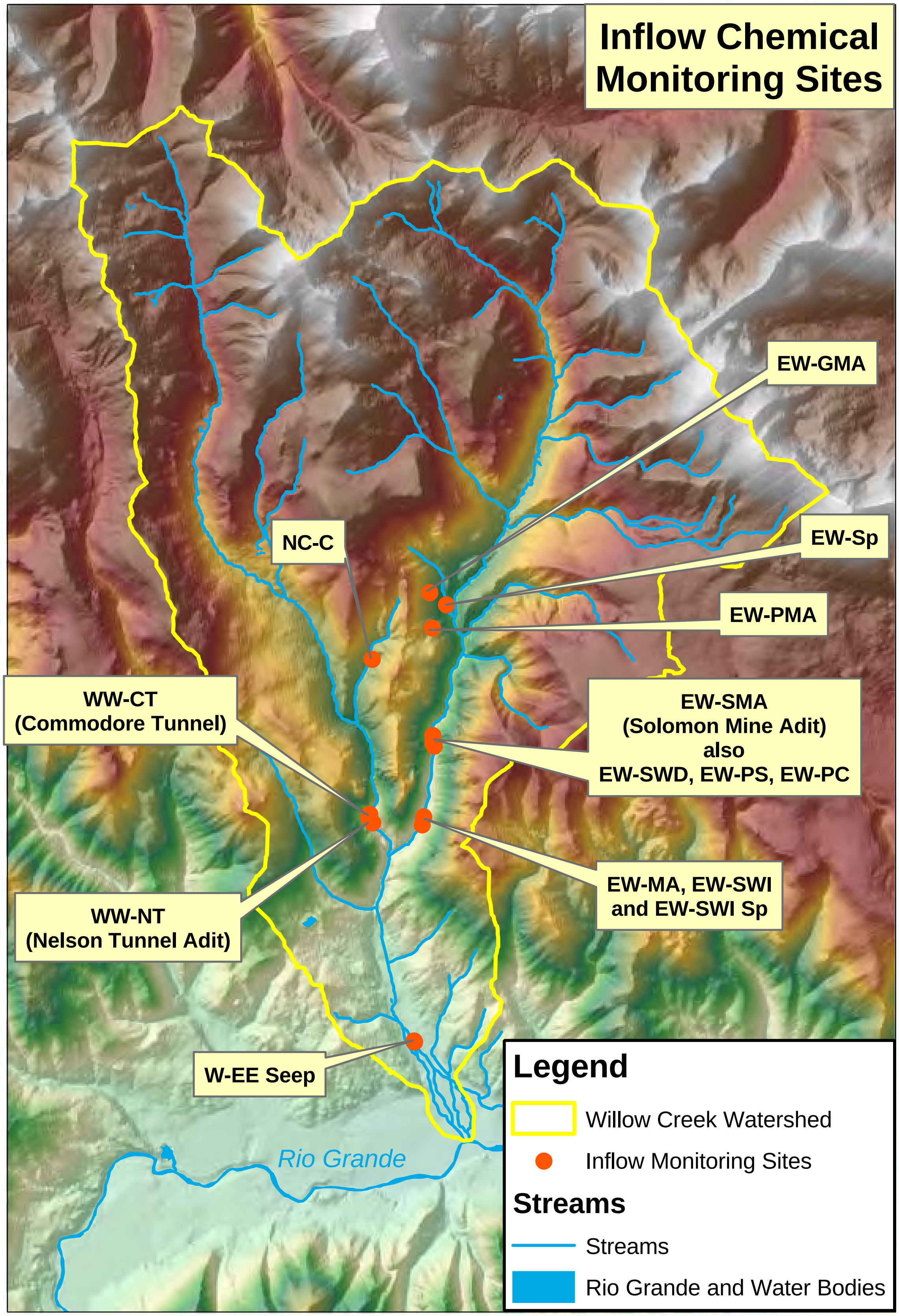
Stressors on Chemical Condition

Mining disturbance impacts are the dominant stressor to stream chemical condition in the Willow Creek Watershed. The inflows and ground water contribution to streams within the heavily-mined area of the Middle Section are the source for chemical condition degradation in the watershed. This degraded condition carries downstream and into the Rio Grande. In addition to in-stream monitoring, monitoring sites for surface inflows, including adits, seeps, and springs, were targeted in the WCRC sampling events at possible point sources of metals (Figure 3.10). Many of these sampling locations proved to be primary sources of metal contamination.

Drainage from the Nelson Tunnel (Figure 3.11) is identified as the greatest single source for metals loadings into a stream in the watershed. The tunnel is the lowest of a vast network of tunnels and associated mine workings throughout the Middle Section of the watershed. The Nelson Tunnel, which is properly called the Nelson / Wooster / Humphries Tunnel, is approximately 11,000 feet long and was constructed in 1899 to facilitate hauling of ore from mines located along the Amethyst Vein complex. The Nelson Tunnel is the lowest tunnel constructed along the Amethyst Vein system and functions as a drain for the underground workings that are connected via winzes and raises. The tunnel portal is located on the west side of West Willow Creek about one mile north of Creede. The elevation of the tunnel portal is about 400 feet above the City and currently discharges about 250 gpm. The adit discharge is the single largest source of dissolved zinc and cadmium to West Willow and Willow Creeks. The pH of the portal discharge ranges from 4 to 5 and the zinc concentrations (based on nine samples) range from 5550 ug/l to 89,800 ug/l. Dissolved cadmium concentrations for the same sampling dates range from 54 to 870 ug/l. Based on concentration and flow data from September 1999, May 2000, and May 2002, the Nelson Tunnel contributes from 169 to 375 pounds of zinc per day to West Willow Creek. It contributes between 45 and 63 percent of the cadmium loading and 34 to 74 percent of the zinc loading to West Willow Creek (Appendix B, WCRC #1). The WCRC, with help from the USEPA and CDMG, is continuing to conduct a hydrogeologic investigation of the Nelson Tunnel. Based on the limited underground investigations that have been conducted to date, it is believed that the ground water, which flows into the tunnel, is derived from deep ground-water flow along the Amethyst Fault. The ground water contribution to the Nelson Tunnel is further discussed in Chapter 5 of this report.

Besides surface point source inflows, ground water recharge and non-point sources are contributors of metals contamination to the streams. Ground water recharge is suspected as an important source and is discussed more in Chapter 5. Mine waste piles, including mill tails, were sampled by WCRC (Appendix B, WCRC #8), and are considered a source, especially, the Last Chance / Amethyst mine rock waste pile. In the Middle Section of the watershed, the topographic slope and the steep stream gradient allow for non-point source from mine waste to descend into the stream and to be carried downstream. In some locations on West Willow Creek in the watershed's Middle Section, the mine waste in the steep 'V'-shaped valley causes the stream bottom to be

Figure 3.10 - Inflow Chemistry Monitoring Sites in the Willow Creek Watershed



made up almost entirely of mine waste rock. The mine waste may act as a source of metals loading to the stream.

Figure 3.11 - Nelson Tunnel Adit

Physical Habitat Condition

Physical habitat in this section refers to an ecological component. Stream physical characteristics related to flooding and other non-ecological interests are discussed in the hydrologic condition section that follows this ecology section.

Assessment of physical habitat condition is determined from monitoring both in-stream and riparian habitat, and from GIS analyses, when monitoring data is not available. The USFWS study mentioned in the biological condition section included an assessment of physical habitat condition for streams (Appendix B, WCRC #2). The monitoring sites at which the physical habitat sampling occurred are a subset of the same sites that were used for biological sampling (Figure 3.3). The methods employed by the USFWS included the Rapid Bioassessment Protocol (RBP) and the Stream Reach Inventory/Channel Stability Index (SRI/CSI). Physical habitat indicators, such as the RBP and SRI/CSI, are tools that score monitored characteristics with respect to ecological health.

Quality of Physical Habitat Data

Both the RBP and the SRI/CSI methods are described in detail in both the USFWS report (Appendix B, WCRC #2) and the WCRC's sampling and analysis plan

(Appendix B, WCRC #7). The data, methods, and indicators are considered suitable for this assessment.

In-Stream Habitat

In-stream habitat includes characteristics of the stream substrate, depth, pools and riffles, gradient, woody debris, and wetted width of the stream. Excess sediment in a stream substrate is an example of poor habitat for aquatic biology.

The SRI/CSI index provides a rating for channel conditions and is the tool for in-stream habitat assessment. Sample data available for in-stream habitat in the watershed begins with the stream channel at sample sites EW-M on East Willow Creek and WW-M on West Willow Creek (Figure 3.3). These sites are at the lower portion of the watershed's Upper Section. Monitoring of physical habitat above those sites has not been done. However, since there is minimal disturbance in the streams and sub-watersheds above these sites, the streams are believed to be in *good* condition with high-quality in-stream and riparian habitat. Non-protocol observations support this estimate. Below these uppermost monitored sites, the stream varies from *good* condition to *poor* condition (Appendix B, WCRC #2). East Willow Creek is considered to be in better condition than West Willow Creek based on the SRI/CSI ratings; however, the two downstream monitoring sites on East Willow Creek have *fair* and *poor* SRI/CSI ratings. The two sites are EW-A (near the confluence with West Willow Creek), which has a *fair* rating, and EW-F (below the Solomon Mine adit), which has a *poor* rating. Along West Willow Creek in the Middle Section, sites WW-K and WW-I are rated *fair*. Both sites are in the vicinity of the Amethyst Mine. The WW-G site, just upstream of the Nelson Tunnel adit is rated *good*. The WW-A site near the confluence with East Willow Creek has a *poor* SRI/CSI rating. The Willow Creek sites W-B and W-D are rated as *fair-poor*. The Willow Creek sites at the confluence with the Rio Grande, sites W-I and W-J, are rated *fair*.

Riparian Habitat

Assessment of riparian habitat considers stream banks, vegetation, and disturbance. Invasive plant species and a lack of stream bank canopy are considered poor riparian habitat characteristics.

The RBP methods provide an assessment tool for overall physical habitat condition. Riparian habitat evaluation is a part of RBP. RBP scores show better physical habitat condition at the most upstream sites (WW-M and EW-M). In fact, these were considered reference sites for the remaining site evaluations. In general, the RBP scores correlate very well with the SRI/CSI ratings for all sites evaluated.

Through analysis of GIS data and aerial photography, a condition gradient of *good* to *poor* is observed from upstream to downstream reaches. In the Middle Section of the watershed for both East and West Willow Creeks, the stream channel occupies a majority of the narrow valleys, with steep banks and a steep stream gradient. The condition of the riparian habitat generally decreases downstream through the Middle Section. In the Creede Section of the watershed, the physical habitat condition is *poor*, primarily because of the alteration of the stream channel into a flume for flood control. Downstream from the flume in the Lower Section of the watershed, the channel divides into two smaller channels and these in turn divide, creating a braided stream in the floodplain. The lack of riparian vegetation in the floodplain is the primary reason for the *poor* classification for physical habitat condition (Figure 3.12).

Figure 3.12 - Willow Creek Floodplain

USGS topographic maps of Creede at the 1:24,000 and 1:125,000, dated 1912 and 1914, respectively, show that the channel of Willow Creek below the City of Creede was not braided (USGS), historically. By 1959, a 1:62,500 USGS topographic map clearly shows braiding in the floodplain.

Two subsequent studies concluded that "man has probably increased sedimentation rates ..." and that "the soils suggest that mine tailing and workings were co-mixed with native material bedload and outwash" (Appendix B, WCRC #10). The evidence suggests that large amounts of sediment entrained during storm events are transported to Willow Creek and deposited. Because it is a floodplain, it could be expected that water would be non-limiting for plant growth. However, the report concludes that water is limiting, because of the "very gravelly and cobbly, stratified loamy sands," which were high above the water table. This, along with additional evidence given in the reports, is likely the reason why Willow Creek is currently braided and barren of vegetation, in stark contrast to the willow-lined single channel prior to 1890. However, high concentrations of metals in ground water, leached from mine tailings deposited in the floodplain, could also partially explain the lack of vegetation.

With the exception of areas disturbed by mining, forests and riparian areas in the Upper Section of the watershed are apparently healthy (GIS analyses). There is no grazing by domestic livestock.

Classification of Physical Habitat Condition

Figure 3.13 shows a classification of estimated overall physical habitat condition. Physical habitat condition classification is based on a composite of monitoring data for both in-stream and riparian habitat, and on the interpretation of aerial photography and GIS data layers covering the stream reaches. The condition classes of *good*, *fair*, and *poor* do not have a direct one-to-one relationship with the SRI/CSI classes in the in-stream section, although the SRI/CSI classes are an important component in determining the composite classification. **Appendix I** shows the USFWS's aquatic habitat assessment scores at monitoring sites for both RBP and SRI/SCI. This assessment's composite condition classification for stream reaches is also presented in the **Appendix I**. The USFWS monitoring sites are identified with the classified reaches.

Stressors on Physical Habitat Condition

Stressors on physical habitat condition include watershed disturbances and hydrologic modifications. The in-stream habitat in the Middle Section is significantly impaired by mine waste rock and mill tailings in steep topographic settings (Figure 3.14). This is especially noticeable on West Willow Creek. The flood control flume through Creede is a serious impairment to physical habitat condition (Figure 3.15), although it is very important for flood mitigation. The flume is a case where the same feature has opposite values depending on the value endpoint of physical habitat or hydrologic conditions. This assessment weights the flood control value of the flume more important than the physical habitat value of removing it. Grazing and forest clear-cutting are not current stressor issues in the watershed.

Gravel and dirt roads are located close to streams and contribute physical habitat stress to some degree (Figure 3.16). The USFS considers the roads in the watershed a high risk for sedimentation delivery to streams. Evaluations were made for Willow Creek, West Willow Creek, and East Willow Creek in the *Rio Grande National Forest Roads Analysis Report* (USFS, 2004). While there are four-wheel drive roads and a low level of off-road use by all-terrain-vehicles outside of hunting season, roads are well maintained. Under these conditions, less erosion is expected. However, dirt and gravel roads, especially in steep terrain, are considered a high threat for sediment delivery to streams, so road maintenance is essential to minimize risks. With proper road maintenance, excess clean sediment delivery to streams can be lessened.

Figure 3.13 - Physical Habitat Condition of Streams in the Willow Creek Watershed

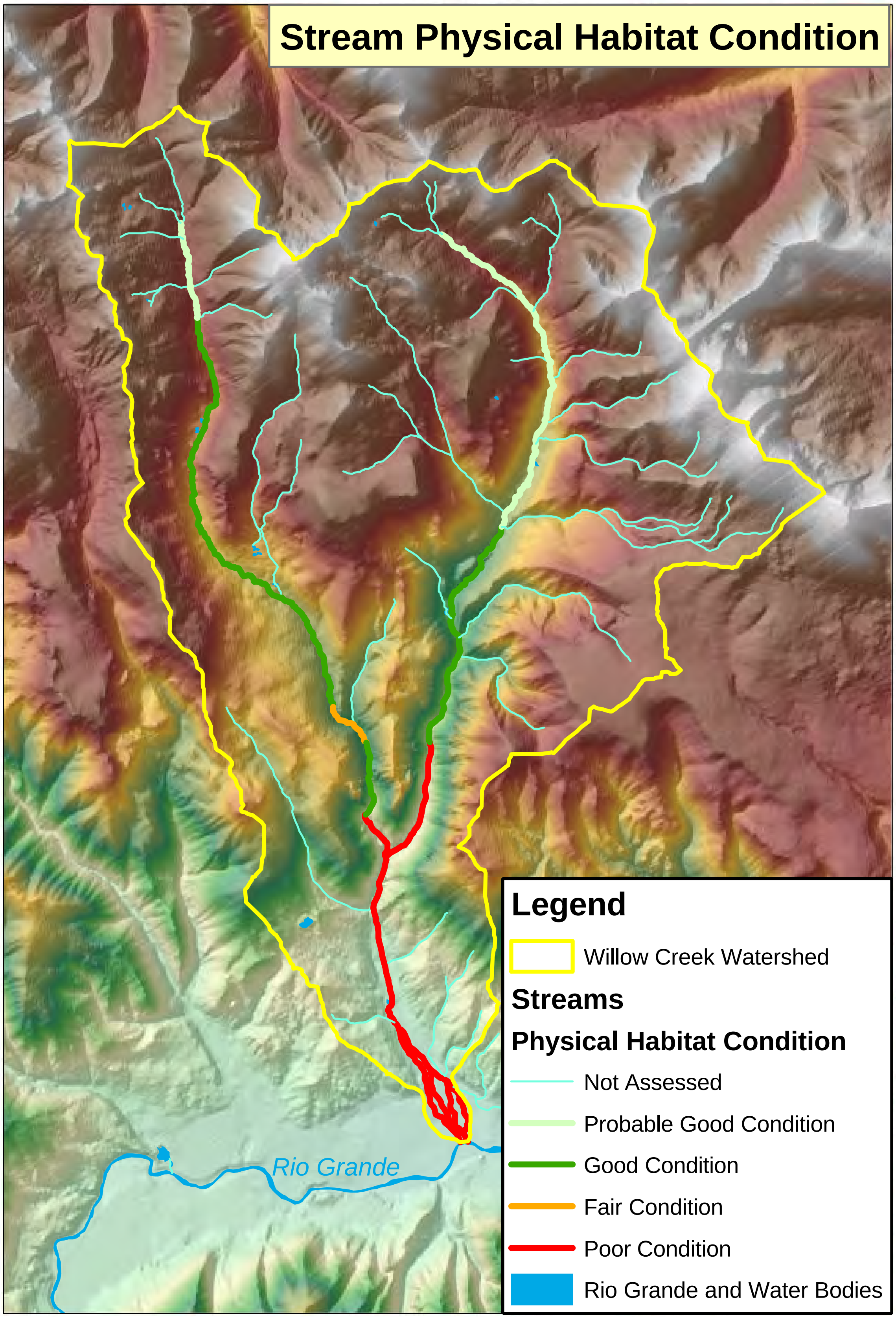
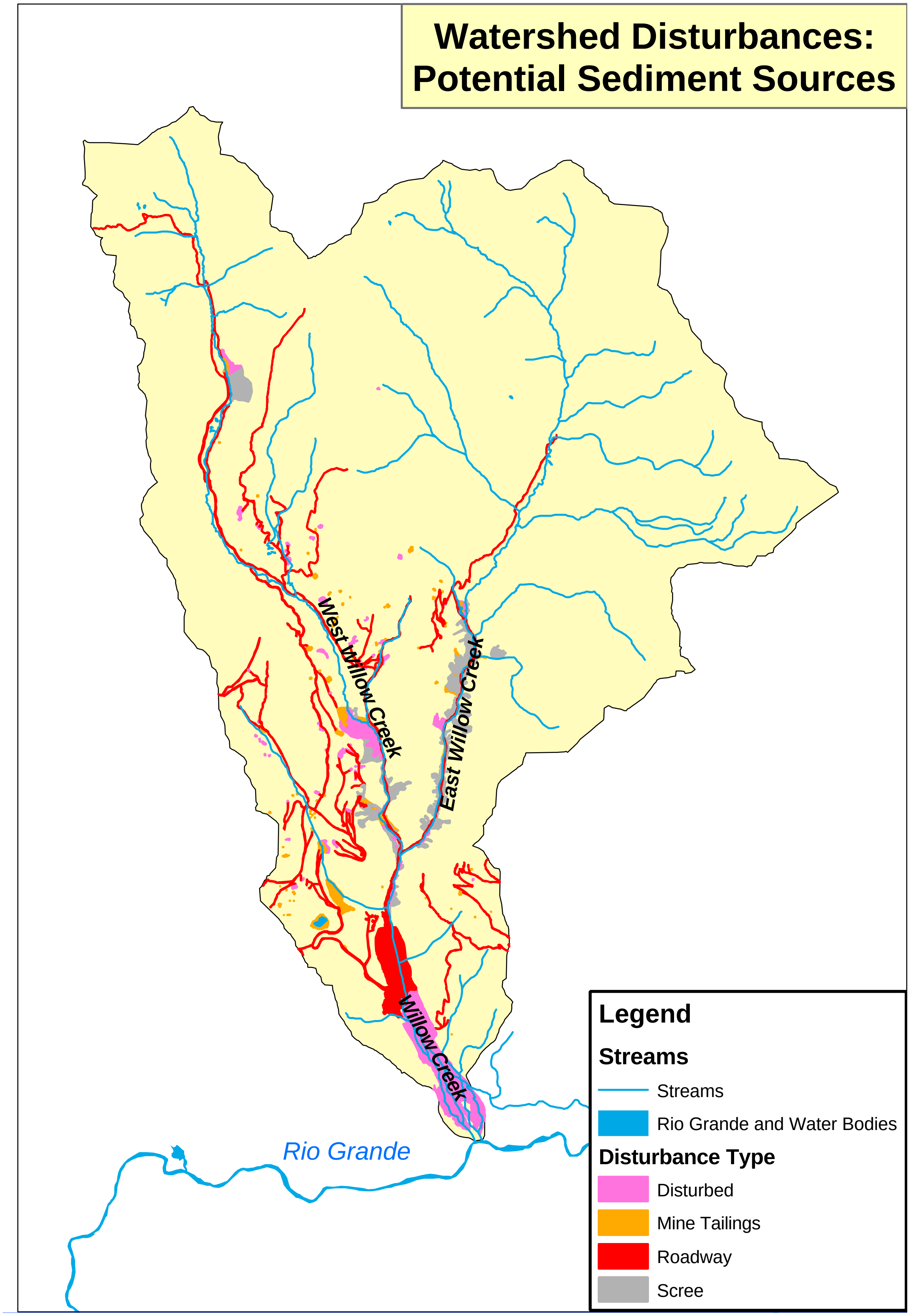


Figure 3.14 - West Willow Creek at the Amethyst Mine

Figure 3.15 - Willow Creek Flume through the City of Creede

Figure 3.16 - Watershed Disturbance: Potential Sediment Sources

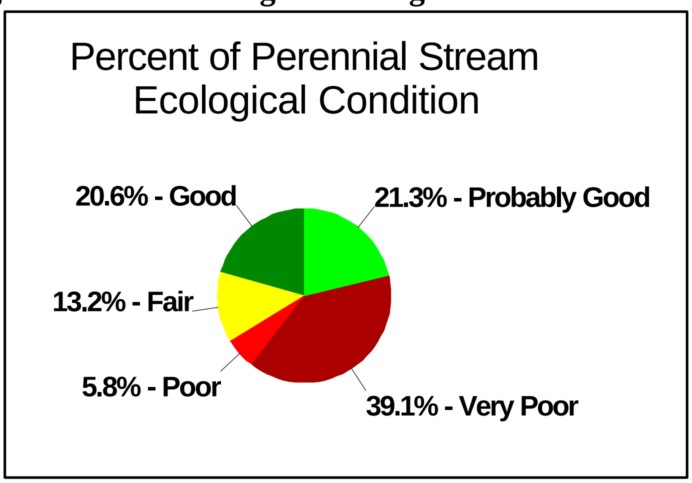


Ecological Condition Classification

The conditions for each of the ecological components (biology, chemistry, and physical habitat) are factored into a composite classification of ecological condition for each individual stream reach (Appendix J). In general, if any one of the factors was in *poor* condition, then the overall ecological condition class was determined as *poor*. **Figures 3.17** through **3.20** present the composite ecological condition of streams for both perennial and non-perennial stream types. Comparing the classification of the stream chemical condition (Figure 3.7) and the overall ecological condition composite, it is clear that the dominant driver for degraded ecological stream condition is stream chemistry. However, consideration of the biology and physical habitat factors made some reach classifications of ecological condition more lenient than the chemical condition classification. This is justified because of the single measurement of chemical concentrations at most of the sites and a heavier weighting of biology in determining the overall ecological classification. Nevertheless, stream chemistry is still the greatest factor determining ecological stream condition. Information gained from additional monitoring can confirm or adjust some of these reach classifications.

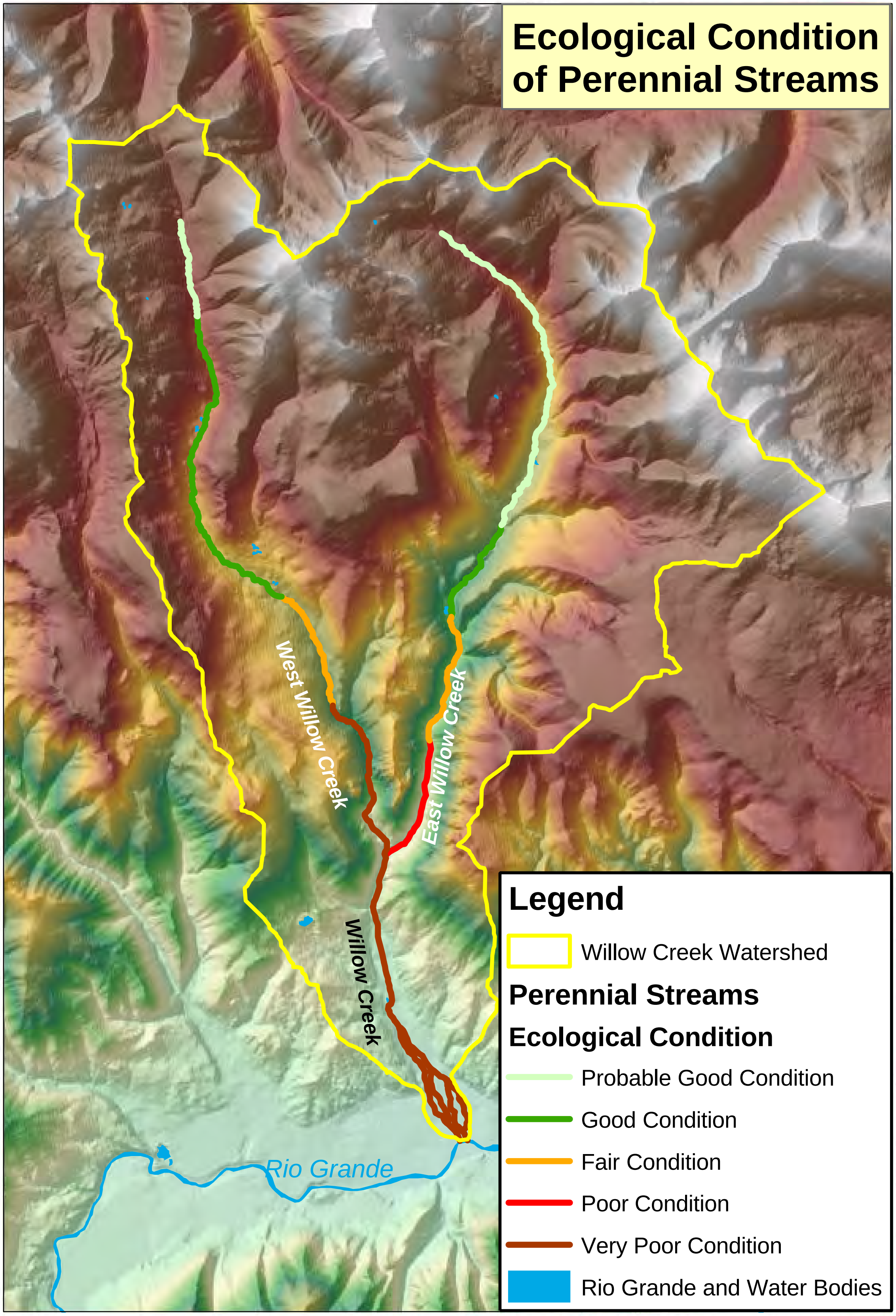
For the perennial streams in the Upper Section of the watershed, 100 percent of the stream length was in either *good* or *probably good* condition. In the Middle Section of the watershed, 81 percent of the perennial stream length was in either *poor* or *very poor* ecological condition, with the remaining 19 percent in *fair* condition. In both the Creede and Lower Sections of the watershed, 100 percent of the perennial streams were in *very poor* condition (Figures 3.17 and 3.18).

Figure 3.17 - Percentage of Ecological Condition Classes for Perennial Streams



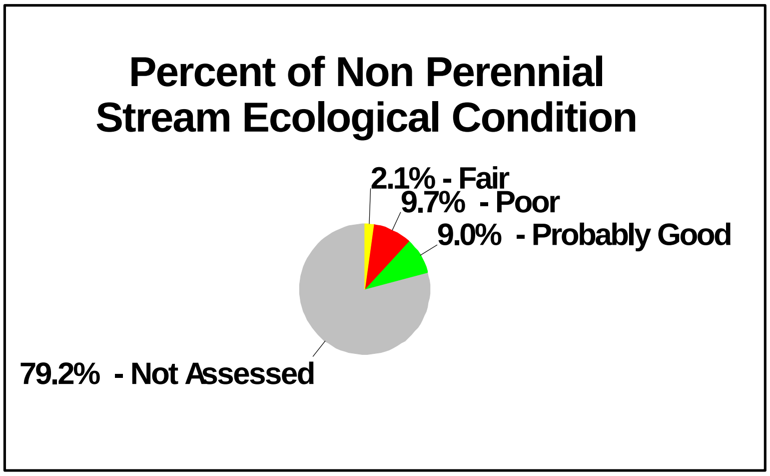
The ecological condition assessment of non-perennial streams in the watershed was based on stream chemistry, where it was monitored. This includes Nelson Creek, Windy Gulch, and the East Willow Creek tributary that enters East Willow Creek at the Phoenix Park Mill Site. Two other tributaries to East Willow Creek, entering from the east between sites EW-L and EW-K, were indirectly evaluated. While some monitoring

Figure 3.18 - Ecological Condition of Perennial Streams in the Watershed



data exists for these tributaries, the data is insufficient to make condition classifications. Instead, a comparison was made for metals of concern between sites EW-L and EW-K on East Willow Creek. Those sites are upstream and downstream of the tributaries. Since the comparison showed no significant differences for those metals, the contribution to East Willow Creek from both of the tributaries is estimated to be *probably good*. GIS analyses support this conclusion. The assessed non-perennial streams represent only 20.9 percent of all non-perennial streams in the watershed. **Figures 3.19** and **3.20** show the results of the non-perennial stream ecological condition classification. Although Figure 3.19 shows 79.2 percent of the non-perennial streams were not assessed, these streams occur in the upper watershed and are most likely in good condition since sources are minimal.

Figure 3.19 - Percentage of Ecological Condition Classes for Non-Perennial Streams



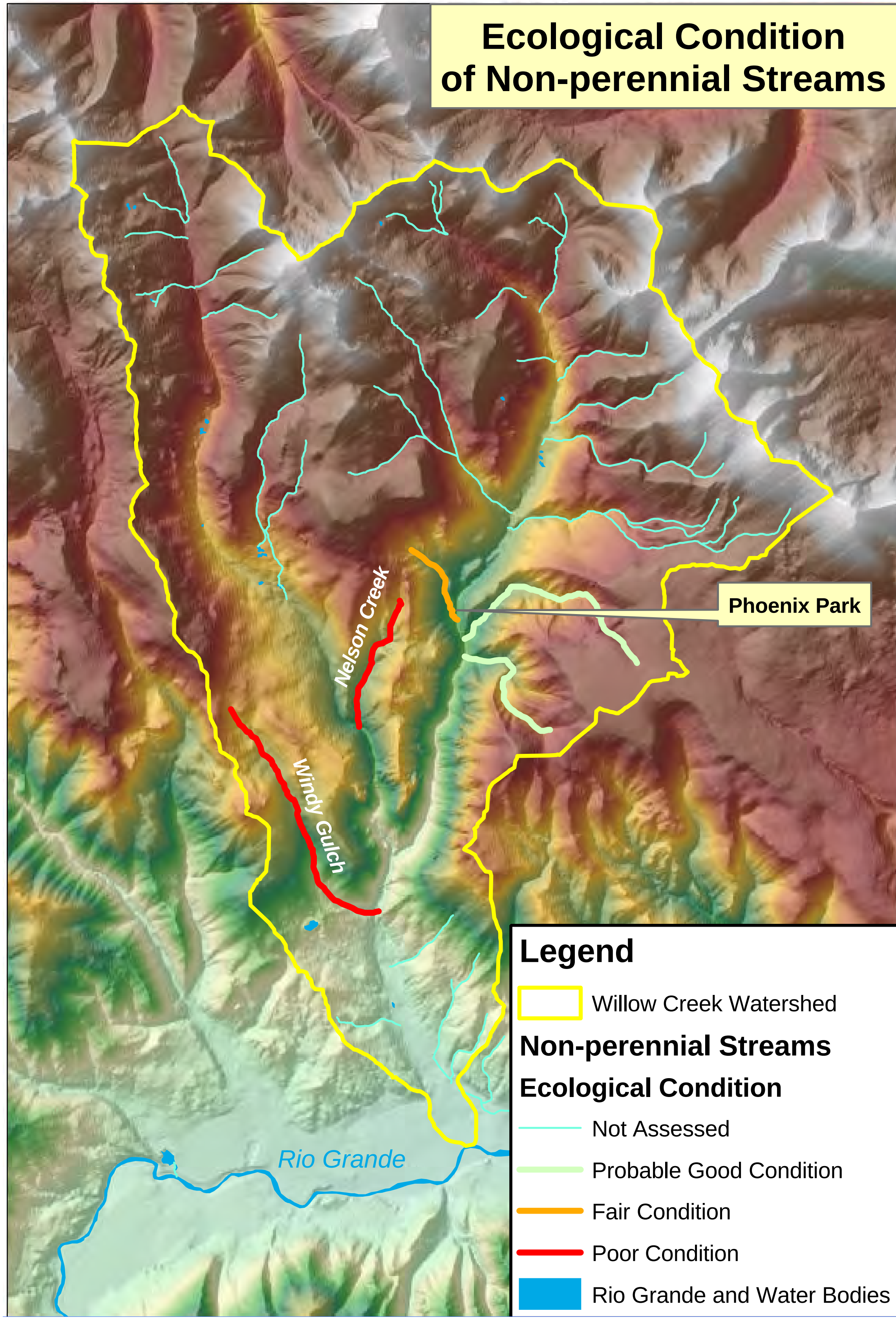
Hydrological Condition

This section addresses the non-ecological, hydrological condition. Hydrologic condition evaluates flooding potential, which is an important stakeholder-stated issue. The water budget and flow are discussed in consideration of flood issues.

A water budget is a significant tool for an aquatic resource assessment and effective management of a watershed. The water budget determines how much water is typically delivered to the system and its fate by calculating, for the watershed, the amount of *Water Flow Out(surface and ground)* + *Evapotranspiration* + *Recharge(surface and ground)* = *Water In*. Flow to shallow and deep ground water is assumed to be small compared to evapotranspiration in most circumstances; however, this may not be the case in the Willow Creek Watershed.

Estimated from the PRISM precipitation model (Figure 2.3), the average annual precipitation in the watershed varies from 35 inches in the headwaters of East and West Willow Creeks, to 14 inches in Creede (Oregon State University Spatial Climate Analysis Service). Annually, it is estimated that the watershed receives approximately 54,000

Figure 3.20 - Ecological Condition of Non-Perennial Streams in the Watershed



acre-feet of precipitation in the form of rain and snow. Monthly mean stream flows at the USGS stream gage on Willow Creek are presented in **Table 3.2**.

Based on the monitoring data, the average surface flow in Willow Creek above Creede is more than the flow from Willow Creek into the Rio Grande. The loss of surface water in Willow Creek between those locations can be attributed to a number of different causes. These include surface water contributions to alluvial or deep ground water, pore-water, loss to the atmosphere by sublimation and evapotranspiration, and diversion to the irrigation ditch in the floodplain. The loss of surface water to ground water within the floodplain was discussed earlier in the hydrographic characterization discussion and could be a major component of the loss. Information on the amount of water diverted to the irrigation ditch is not included in this assessment.

Flooding and Flood Control

Both East and West Willow Creek flow through very narrow, steep canyons immediately upstream of their confluence. Willow Creek also flows through a steep canyon downstream of the confluence of West Willow Creek and East Willow Creek to the upper end of Creede. As a result of the narrow, steep topography, major floods have been an important part of the history of both Creede and North Creede. During the period from 1890 to 1920, when mining activities and the population of Creede were at their peak, major floods destroyed most of the town on more than one occasion. In 1950, the US Army Corps of Engineers (USACOE) designed and constructed a masonry flume to channel Willow Creek through the Creede. The flume was designed to convey a 100-year flood through Creede. However, the Federal Emergency Management Agency's (FEMA) floodplain map shows that portions of Downtown Creede are still within the 100-year floodplain (Appendix B, WCRC #10). In 2002, the Willow Creek Reclamation Committee obtained funds from the Colorado Water Conservation Board to assess flood control and stream stability in the Middle Section of the watershed.

Agro Engineering was contracted to conduct the study. The results of this study are described in an October 2002 report, titled *Upper Willow Creek Watershed –Flood Control and Stream Stability Study* and prepared by Agro Engineering (Appendix B, WCRC #10). Much of the following discussion is taken from this report. As part of the flood control study, Agro Engineering prepared topographic maps with 40 foot contours developed from digital elevation model (DEM) data. These maps were used for general watershed analysis. High resolution topographic maps were prepared for the channel floodplain area of Middle Section of the watershed. These maps were prepared from detailed field measurements from 55 cross sections and 1077 individual points. This data was used, along with aerial color photographs to construct two foot contour maps.

Discharge frequency estimates were developed using a regional watershed methodology. A regression analysis, using data from 17 watersheds, was used to estimate discharge frequency for Willow Creek. Agro Engineering used the USACOE Hydraulic Engineering Center River Analysis System (better known as HEC-RAS) to model channel hydraulics along approximately 15, 900 feet of Willow Creek. The modeling was used to determine areas that would be inundated during various high-flow events. The modeling indicated that during large floods, "supercritical" flow will occur at many locations upstream of Creede. Supercritical flow is highly erosive and can cause significant damage to channel banks, levees and hydraulic structures, especially if debris blockage occurs. Without significant debris blockage or structural failures, the masonry flume and the channel of Willow Creek can contain the 100-year flood.

The modeling indicated that there are numerous locations in the Middle and Creede Sections of the watershed where the risk of flooding is high. The wooden and earthen weir upstream of the mining museum will overtop during a 25-year flood. Floods larger than the 100-year flood would flood the mining museum and fire department tunnels. The culvert at the bottom of Windy Gulch, which is normally a dry channel, cannot handle flows associated with a 10-year flood, which could cause flooding in Downtown Creede. The culvert in North Creede would be overtopped in nearly all flood events. The culvert located just upstream of the concrete bridge below the Commodore Mine on West Willow Creek will be overtopped in a 100-year flood. The flume and metal pipe that carries West Willow Creek through the large mine waste pile below the Commodore Mine could not handle high-flows. Some flooding would occur during a 10-year flood and a 25-year flood would overtop the mine waste pile. At the Amethyst Mine culvert, the 100-year flood will cause overtopping of the culvert.

In steep mountain streams, bedload transport composed of boulders and other large debris derived from broken down stream armour is more of a problem than suspended sediment transport during flooding. This is especially a concern in areas where supercritical flow will occur. Bedload transport rates were estimated for every cross section and potential bedload rates determined to be very high in upper Willow Creek and even extreme in West Willow Creek at the Commodore Mine. In general, Willow Creek has the potential to produce enormous volumes of bedload during floods.

Agro Engineering also developed alternative mitigation strategies to address specific problems and areas. These strategies are discussed in detail for Windy Gulch, the mining museum area, the North Creede culvert, the Commodore Mine area, the Amethyst Mine area, and the West Willow Creek concrete bridge, in the contractor's report. Strategies for dealing with watershed-wide issues such as debris removal, channel improvements and sediment control measures are also included in the Agro Engineering report (Appendix B, WCRC #10). Because wetlands and riparian areas are natural springs, their protection and enhancement (e.g. through beaver activity) in the Upper Section of the watershed would be an important part of any flood mitigation plan.

Water Uses

Water uses of Willow Creek and its tributaries include supporting aquatic life, recreation, and agriculture. In the past, the drinking water source for the Creede was a withdrawal from East Willow Creek. That practice has been discontinued. Presently, the Creede's drinking water source is ground-water obtained from wells just outside of the Willow Creek Watershed in the Rio Grande Valley.

Water Rights

There are no in-stream withdrawals on the Upper, Middle, and Creede portions of the watershed, but there is a water right for the Nelson Tunnel discharge. In the Lower Section, there is a diversion that takes stream flow out of the Willow Creek Watershed through a ditch that parallels the Rio Grande to Wason Ranch for irrigation.

3.5 Stressors

Although ecological stream condition stressors have been discussed within the condition sections, this section identifies and analyzes the natural and anthropogenic factors that negatively affect streams in the Willow Creek Watershed. Stressors to streams fall into several categories:

1. Stressor cause (natural vs. anthropogenic)
2. Time of stress (historical, current, future (potential))
2. Effect of stressors (affect hydrology vs. affect water quality)
3. Source of stressor (point source pollution vs. non-point source pollution)
4. Specific kinds of stressors (kind pollutant, e.g. metals and sediment)

The cause, time, effect, and source of stressors are discussed below by Willow Creek Watershed sections (Figure 2.2).

Pollution Sources

Point source pollution is a discharge to water bodies through a specific entry point such as a pipe and is regulated by the National Pollutant Discharge Elimination System (NPDES) of the Clean Water Act. Point sources need an NPDES permit, issued by the State, in order to be discharges. Industrial wastewater and sewage treatment plants are the main dischargers of this type of pollution. Point source pollutants can include many different organic and inorganic substances, including human waste and toxic metals. An example of point source pollution is the effluent from the Nelson Tunnel into West Willow Creek.

Non-point source (NPS) pollution occurs when rainfall, snowmelt, or irrigation runs over land or through the ground, picks up pollutants, and deposits them into rivers and lakes, or introduces them into ground water. Non-Point sources of pollution are not regulated by NPDES. In general, there are two main kinds of NPS pollutants affecting the streams in the Willow Creek Watershed, metals and sediment.

There are two types of sediment of concern in the watershed, clean sediment and contaminated sediment. Clean sediment carries no contaminants and contaminated sediment carries contaminants adsorbed to particle surfaces. The sources of these types of sediments include mining and roads, and to a lesser extent, urban development, timber harvesting, recreation, and geologic (natural) erosion of barren areas and stream banks. Metals contaminated sediment is of most concern in the Willow Creek Watershed.

While contaminated sediment acts as a source of pollutants, both clean sediment and contaminated sediment can have negative consequences for aquatic life. While some clean sediment is good for aquatic life, excess clean sediment is a major stressor. When transported downstream, excess sediment can cause significant economic losses by clogging water management infrastructure, and increasing the cost of water purification. Additionally, excessive deposition of transported sediment in stream-beds and floodplains, can negatively affect the hydrologic condition and function of the stream. Conversely, a positive benefit might be the creation of fish habit, depending on the ratio of fines to appropriate sediment grain size.

Upper Watershed Section

Historical Stressors

The Upper Section was somewhat impacted by historical mining activities. A couple of low-productive mines, the Equity Mine and the Captive Inca Mine, are located in the Upper Section of the West Willow Creek Watershed (Figures 2.2 and 2.17). Although sheep grazing has had impacts in the past, there has been no grazing in the Willow Creek Watershed for the past 20 years and impacts from the past grazing are no longer evident.

Current and Potential Stressors

The principal natural stressor in the Upper Section is sediment delivered to streams as a result of geologic hill-slope erosion, stream bank erosion caused by natural stream channel migration, or erosion induced by lightening-caused fires. The principal anthropogenic stressor is sediment delivered to streams due to erosion from roads and road banks, hill-slope erosion from off-road recreational vehicles, and disturbances at stream crossings. According to the Rio Grande National Forest Roads Analysis Report (USFS, 2004), roads have a significant impact on aquatic resources in terms of surface hydrology and water quality. The impact of roads on the health of the Willow Creek Watershed is high. This rating is based on a combination of factors, the most important of which for streams are the *Road Crossing Rating*, (low for East Willow Creek Watershed, high for West Willow Creek Watershed, and medium for Willow Creek Watershed) and the *Road Risk Rating on Sensitive Soils* – high hazard of erosion (medium for East Willow Creek Watershed and high for West Willow Creek and Willow Creek Watersheds). The high *Road Crossing Rating* for West Willow Creek is due to the steep road gradient and close stream proximity of the road.

Two other current or potential stressors include sediment produced from off-road use by all-terrain vehicles when these vehicles damage vegetation or leave ruts in wet soil. Another potential stressor is grazing impacts, however, currently there is little or no grazing of domestic livestock within the watershed (Les Dobson, USFS, personal communication, May 24, 2004).

Another stressor is fire suppression by policy and practices that have protected the area for many years. While a forest fuel assessment has not been performed, it is possible that a fuel supply sufficient for a significant fire is present. Due to the steep slopes in the upper part of the watershed and the persistent drought conditions in SW Colorado, a major fire has the potential to cause serious erosion and consequential detrimental sediment loading to the streams and flooding, as has been observed the past few years in the San Juan Mountains near Durango and many other places in Colorado and across the Western U.S. These two potential events, fire and flooding, can cause catastrophic effects, such as the loss of life and property.

Middle Watershed Section

Mining and associated activities are the main historic stressors in the Middle Section. In this Section, the dissolved load of metals from the Nelson Tunnel is the single greatest threat and cause of *poor* chemical stream condition. Contaminated sediment, mainly contaminated by metals, is also a significant threat and a primary source of *poor* stream condition. The sources and potential sources of this kind of sediment are the mine waste piles resulting from historic mining activities. Due to the toxic nature of the metal concentrations in these waste piles, and therefore, lack of protective vegetation, runoff from rainfall and some of the snow melt can easily detach and transport sediment from these waste piles to streams in the watershed, particularly those that are located in or adjacent to streams. However, weathering of minerals creates a hard crust on some of these piles, limiting erosion potential, even where there is no vegetation. "The largest areas of extreme potential are on the tailings piles of the Last Chance / Amethyst and Commodore Mines on West Willow Creek. Additional areas of extreme sediment production potential, include tailings areas on the Ridge Mine, Holy Moses Mine, Outlet Mine, and Carbonate Tunnel on East Willow Creek, the toe of a disturbed talus slope on West Willow Creek, and a debris/sediment pile just downstream of the confluence." (Appendix B, WCRC #10, p. 2-41).

The risk of flooding is another potential source of contaminated sediment. With reference to the Commodore Mine, the report by Agro Engineering states: "The 10-year event will cause flooding of the depressed area at the pipe entrance. A 25-year flood will overtop the tailings pile, causing a high velocity flow down the very steep face of the pile. This event could potentially erode tons of mine tailings and mine debris into Willow Creek. Fine tailing sediments would probably be carried by the flood into the Rio Grande." (p. iii) For further emphasis, "Dump #201 from the Amethyst No. 5 Mine is estimated at 20,000 cubic yards... The dump is barren of vegetation and is cut by gullies that connect directly with West Willow Creek. The toe of the dump extends to and is eroded by West Willow Creek" (Neubert and Wood, p. 22).

Typical rainfall and snowmelt can easily detach and transport contaminated sediments, but less common, high intensity rainfall events and flooding have the potential to trigger mass movements and deposition of such sediment. The subsequent release of metal pollutants could result in extreme water contamination levels in the Middle and Lower Sections of the watershed and the Rio Grande.

Contaminated sediment causes not only the same problems as cited above for clean sediment, but adds significantly to the metal contamination of the water in the stream by dissolution. Also, contaminated sediment deposited in water infrastructure or stream beds adds to the available source of metals over time. Since the waste piles are heterogeneous in terms of metal concentration, particle size, and degree of weathering, it is difficult, if not impossible, to predict the amount of metals that could be released to water due to erosion and deposition of these sediments. However, the potential is extremely high in those sections of the watershed with an intensive mining legacy.

Finally, the close proximity of gravel and dirt roads to streams is a source of clean sediment that places a stress on aquatic resources in this section of the watershed.

Metals

The most significant pollutant in Willow Creek is metals. The concentrations of heavy metals that naturally occurred before 1889, when mineral exploitation began in the watershed is not known. However, given what is known regarding mineral production in the Creede Mining District, there appears to be a correlation between magnitude of historical mineral production and level of water contamination in East and West Willow Creek. East Willow Creek flows parallel and adjacent to the Solomon-Holy Moses Vein, while West Willow Creed flows parallel and adjacent to Amethyst-Last Chance Vein. Prior to 1956, the production in the former vein amounted to approximately 5 percent and the latter to about 93 percent of the total mineral production within the district. The proximity of the streams to the veins clearly is an important determinant of the level of water contamination in the stream. Thus, it is not surprising that West Willow Creek exhibits much greater metals contamination than does East Willow Creek, since much greater quantities of ore were present in Amethyst-Last Chance Vein than in the Solomon-Holy Moses Vein.

Dissolved metals enter water from exposed ore veins and mine waste piles. Some of the metal contamination occurs as surface flow and other portions enter stream when contaminated underground water directly recharges the stream. These can be non-point sources, if the water seeps into the stream across the surface or recharges the stream through the hyporheic zone. They can also be point sources if a tributary runs the contaminated source or if the water enters the stream from an adit discharge, such as the effluent from the Nelson Tunnel.

Creede Watershed Section

Other than the flume, the main stressors in the Creede Section are urban non-point sources of pollution such as sediment, pet wastes, household waste, and yard fertilizers and pesticides.

Lower Watershed Section

The Lower Section is dominated by the Willow Creek floodplain and the main stressor is historic deposition of sediment. A discussion of this phenomenon follows.

Fluvial Processes, Sedimentation, and Stream Braiding

Stream appearance and operations are a product of the relationship of four main physical variables: discharge, slope, sediment size, and sediment load. If one of these variables changes, adjustments in others will occur (Lane, 1955). A stream will be further modified by channel material, basin relief, valley morphology, and local history of erosion and sediment deposition. A stream is stable when it can move its sediment load consistently over time. It becomes unstable when the scouring process erodes a stream channel, *degrading* it, or when excessive sediment deposition causes the stream channel to build up, or *aggrade*. The variables of an unstable stream will change until the relationship among them stabilizes or achieves an *equilibrium*. A stream that retains its width from bank-to-bank (bankfull width) and its depth compared to its width (depth to width ratio) is stable even though it may move back and forth on a valley floor (Rosgen, 1996).

In the past 100 years the physical characteristics of the Willow Creek floodplain have changed due to activities associated with mining as previously described. In particular, sediment load has increased as these materials became available from erosion of tailings, waste rock, and devegetated areas in the middle section of the watershed where the steep slope provides the energy for the stream to move this sediment supply. Through Creede, the natural slope was increased when the flume replaced a stream that once dissipated energy from the upper slopes by meandering and depositing its sediment across the alluvial fan at the bottom of the canyon. The steep slope of the narrow flume abruptly decreases at the end of the flume where the sediment load is finally deposited onto the broad floodplain which has aggraded. Rather than the extensive willow carr (Figure 4.1) that filled the alluvial valley below Creede in the late 1800s, a braided channel now flows through a barren floodplain.

Braided channels like this occur on alluvial fans and valleys consisting of coarse depositional materials formed into moderately steep terrain where there is a high sediment supply and flashy run-off conditions which can frequently vary rapidly from a base flow to a high-flow (Rosgen, 1996). The straight, concrete flume in Creede extends through town the conditions that create a flashy run-off in the steep canyon of the Middle Section. The flume can not dampen flows through absorption and gradual release of water as a meandering stream with a functional riparian area would. The Willow Creek floodplain has become unstable because the kind and amount of the sediment supply and the discharge patterns have changed relatively recently and rapidly. While braided channels can be the natural morphology of some streams, the historical photos suggest that in an undisturbed state, lower Willow Creek was not braided but supported a vegetated floodplain which provided many ecological functions. To restore these functions, the conditions that increased sediment supply and a flashy run-off immediately upstream of the floodplain, as well as any toxicity from metals, need to be addressed (Appendix B, WCRC #23).

Summary

The watershed sections (Figure 2.2) provide a good framework to describe the gradient of stream stressors that correlate with stream condition. The interrelationship between the stream, wetland and riparian, and ground water aquatic resources is apparent in much of the discussion. The metals contaminated loadings, sedimentation, road maintenance, and other discussed stressor concerns are all targets to be addressed in a watershed management plan.

4.0 WETLANDS AND RIPARIAN HABITAT

4.1 Introduction

This chapter describes the wetlands and riparian ecosystems in the Willow Creek Watershed, how they are managed on Federal lands, their desired condition, and adverse impacts on these resources. Additionally, areas are identified where there are restoration opportunities for wetlands and riparian areas.

Wetland and riparian ecosystems are important components of watershed health. In mountain environments, they are usually seasonal, sustained by melting spring snow and high ground water tables. More species of deciduous trees and shrubs live in riparian ecosystems than in any other kind of ecosystem in the Southern Rockies. Regionally important functions provided by montane wetlands in the watershed particularly relevant to the City of Creede are flood attenuation and erosion control. Wetlands are valuable in providing natural channels for flood waters and in attenuating flood peaks by temporarily slowing and storing water. Wetland vegetation found on the banks of streams helps prevent bank erosion and provide cover for aquatic and terrestrial organisms.

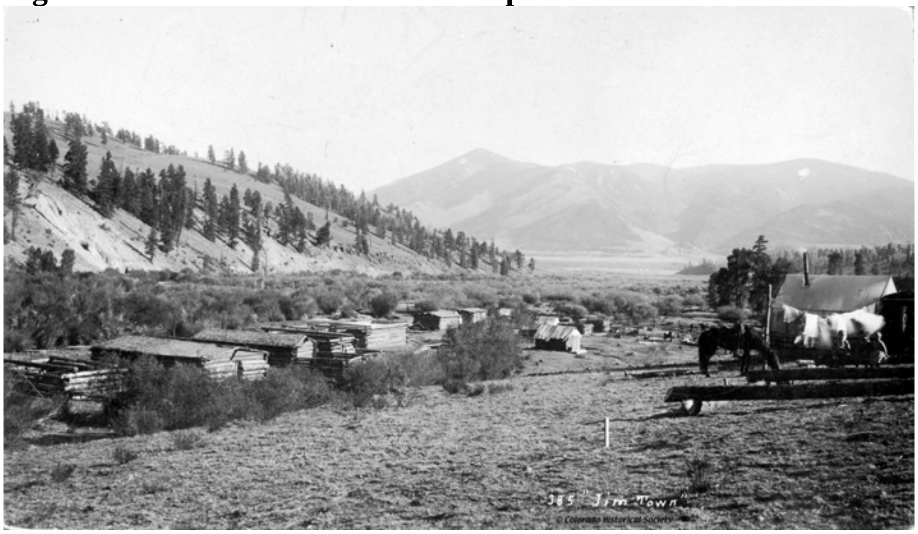
Wetlands in the Willow Creek Watershed also offer a diverse range of functions important for water quality. Most importantly, wetland sediments and organic soils, and some plants, remove metals and other pollutants. Wetlands and riparian areas also provide habitat for a wide range of plants and animals, providing a biological richness beyond what might be expected for their limited extent in the watershed.

4.2 Desired State of the Resource

One of the goals of the WCRC is to restore the floodplain below Creede to help revegetation of the riparian area. To some degree, the historic condition of the floodplain prior to mining disturbances, as shown in old photographs, is a target reference condition (Figure 4.1). Another goal of the committee is to restore degraded sections of the creek within the mining district, including associated riparian areas and adjacent wetlands.

The Clean Water Act (CWA) is an environmental statute with the goal of restoring and maintaining the physical, chemical, and biological integrity of the nation's waters. It provides the regulatory framework for achieving these goals, including the use of permits and enforcement actions, to improve and maintain the environmental quality of surface waters in the United States, including many wetlands, on public and private lands. However, in headwaters streams such as Willow Creek, wetlands important to the ecological health of the watershed, such as isolated seeps, fens, or intermittent wetlands, are often physically removed from streams. Under current regulations, these isolated wetlands are not Federally protected, and so are vulnerable to human disturbance.

Figure 4.1 - The Willow Creek Floodplain in the late 1800s



Creede (Jimtown) / Willow Creek, Circa 1888-90 (Colorado Historical Society)

The desired state of the wetland and riparian resources of the Willow Creek Watershed under the Clean Water Act is healthy ecological and hydrological functioning. This supports the WCRC goals for the watershed because restoration and protection of wetlands and riparian areas maximizes aquatic resource restoration and protection. Thus, understanding the ecological condition and prevalence or scarcity of wetlands and riparian resources and how they are managed by the USFS and other agencies is important to understanding the potential for restoration of degraded or lost aquatic resources in the watershed. Understanding the location and condition of wetlands and riparian areas will help managers target efforts towards more effective aquatic resource management.

The Upper Section of the Willow Creek Watershed is largely National Forest land with some private in-holdings and mining claims. The *Revised Rio Grande National Forest Land and Resource Management Plan* of 1996 includes goals for natural resources, including wetlands and riparian areas, as outlined in Section 4.5. The Forest Management Plan includes specific methods for the management of biodiversity and monitoring activities on the Forest and includes standards and guidelines to protect natural resources.

Several standards apply specifically to the management of wetlands and riparian areas on USFS land. The <u>Water Conservation Practice Handbook</u> is the governing standards and guidelines document developed by the USFS to provide direction for all ground disturbing activities to ensure that wetland/riparian health is protected during project implementation. The Forest Plan's Record of Decision includes forest-wide multiple-use objectives, which include the protection of the, "integrity of soil and water resources by discouraging motorized vehicle use in wetlands, wet meadows and riparian areas" (Forest Object 1.3, Record of Decision, 1996).

4.3 Wetlands and Riparian Characterization

There is limited data and information related to the wetlands and riparian habitat of the Willow Creek Watershed. The extent and location of the watershed's wetland and riparian habitat, mapped by the USFS (Appendix D), is shown in **Figure 4.2**. According to that mapping, the area of wetlands and riparian habitat was estimated to be 852.2 acres (344.9 ha.). However, the estimate does not include most of the approximately 246 acres (100 ha.) of the floodplain. This is probably due to the fact that most of the floodplain is in such poor condition that it isn't recognized as a riparian area. Even if the omission of much of the floodplain is ignored, the USFS mapping should not be considered a comprehensive inventory for all wetlands in the watershed because a detailed evaluation of wetland and riparian area function and value was not done. Additional field reconnaissance is needed to locate wetlands under forest cover and to specifically characterize wetland types in the watershed.

The wetlands in the Willow Creek Watershed are typical of Southern Rockies montane wetland ecosystems. Numerous types of wetlands occur in the watershed (see Table 4.1). East Willow Creek, Willow Creek and the Rio Grande are characterized by extensive riverine and palustrine wetlands (USFWS, Wetland Inventory Maps, page 12; CDPHE, 1995).

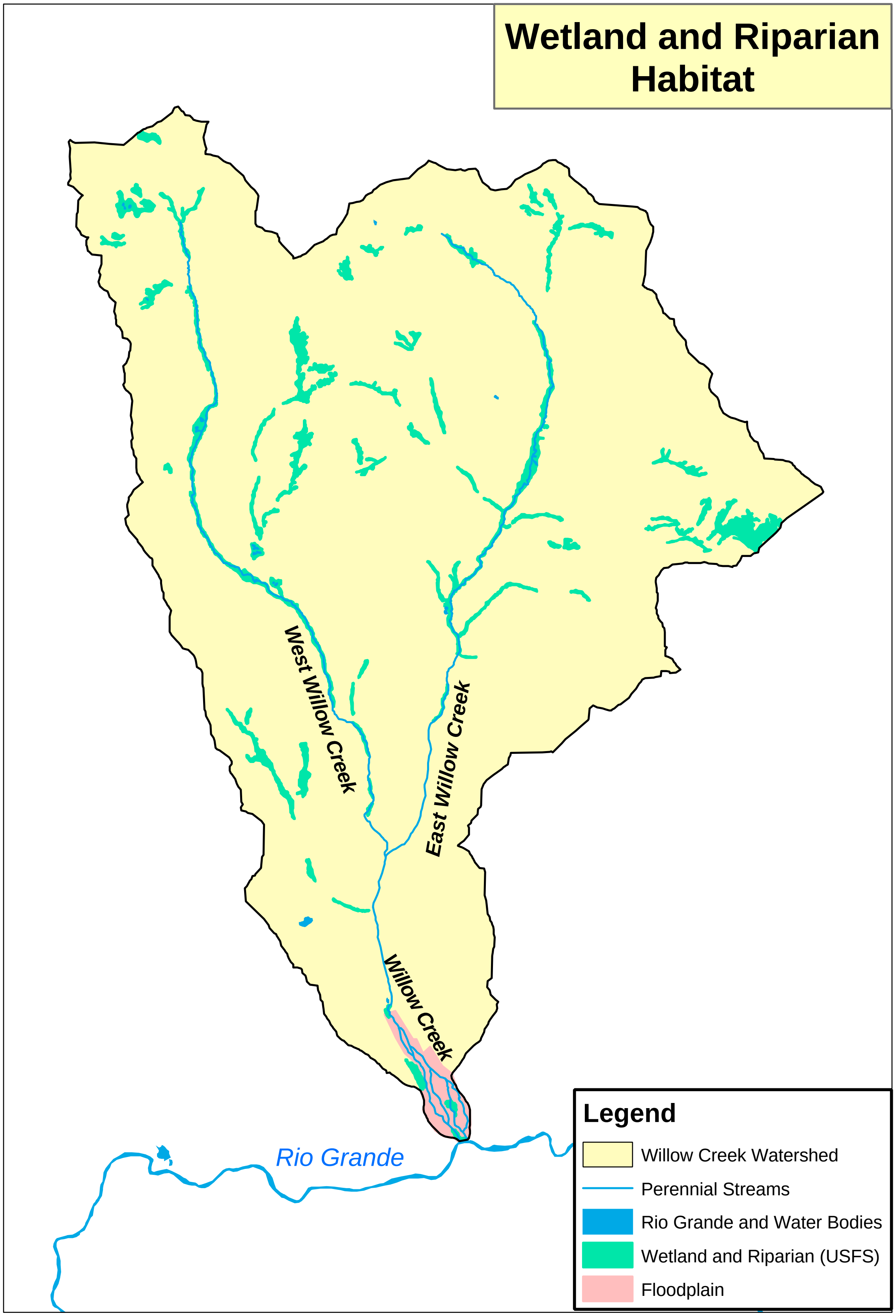
Table 4.1 - Wetlands Types

ROCKY MOUNTAIN WETLANDS TYPES	WILLOW CREEK WATERSHED WETLANDS TYPES
Forested	x
Willow	x
Fens	x
Marshes	x
Bogs	
Alpine Snow Glades	x
Salt Meadows	
Bottomland Shrublands	
Shallow Ponds	x
Playa Lakes	

Source: Rocky Mountain Futures; An Ecological Perspective

East Willow Creek is a relatively confined watershed with steep slopes and narrow riparian areas. It is dominated by a narrow, riparian vegetative community of willow and alder with few wetlands outside of the riparian corridor. Because wetlands

Figure 4.2 - Wetlands and Riparian Habitat



are relatively scarce in the East Willow Creek Watershed and because of limited human land use activities on USFS land, potential impacts to existing wetland and riparian communities are unlikely, but opportunities for restoration are limited.

The Upper Section of West Willow Creek flows through a broad montane valley with abundant, relatively healthy slope-type and riverine-type wetlands adjacent to the active watercourse. Wetlands in this basin include low willow carr, wet meadows (marsh), and fen-type wetlands. Open water beaver ponds are scattered across the valley bottom providing high quality wildlife habitat for resident and migratory birds (Figure 4.3). Remediation of mining waste rock piles and tailings, including the roads built on them, provide excellent restoration opportunities for montane wetland mitigation projects (Figure 4.4).

Figure 4.3 - Beaver Pond

The Middle Sections of both West and East Willow Creek are largely devoid of healthy riparian and wetland ecosystems throughout the mining district. Riparian vegetation could be reestablished in the creek bottoms by using pole plantings of willow and cottonwoods, as well as alder container plantings.

Figure 4.4 - West Willow Creek in the Upper Section

4.4 Current Condition

Biological, Physical, and Chemical Condition

Limited data is available on the biological health of the wetlands and riparian areas of the watershed. The Rio Grande National Forest is currently in the process of mapping aquatic resources for management and planning purposes on USFS land. Only observational and qualitative assessments can be made of the general biological condition of the aquatic resources (as described above).

The physical condition of the wetlands and riparian areas of the watershed has not been documented other than through qualitative observation. The Upper Section of the Willow Creek Watershed has some historic areas of adverse impacts to wetlands related to mining and road building. The most significant physical degradation is in the Middle and Lower Sections of the watershed, where historic and ongoing adverse impacts from mining and associated activities such as housing and road-building have degraded the quality of the aquatic resource.

Portions of the watershed's wetland and riparian communities were severely degraded during the mining era and have also been impacted by the historic development of the City of Creede. These impacts are especially prevalent in the Middle and Lower Sections. Mining in the watershed created large amounts of waste rock, resulting in many years of sediment deposition in the floodplain. The braided condition of the Lower Section of the watershed "is atypical for this region" (Appendix B, WCRC #24) and may indicate impairment by excessive amounts of sediment in this area as previously mentioned in Chapter 3.4. Mining also resulted in the development of the mining boom City of Creede and other mining camps on the floodplain of Willow Creek (Figure 4.5). These adverse impacts occurred over several square miles, with the greatest impacts on the Lower Section directly below present-day Creede. Because of the historic impacts of sediment deposition and housing on the floodplain, there is a permanent lack of riparian vegetation, which severely reduces floodplain function. The floodplain south of Creede presents a stream restoration opportunity currently being developed by the WCRC and the U.S. Department of Agriculture's Natural Resources Conservation Service.

Figure 4.5 - Current View of the Floodplain

The reach of Willow Creek near the confluence with the Rio Grande has abundant wet meadow wetlands and healthy willow communities and could serve as a baseline or reference condition for the restoration reach, as well as a plant source for revegetation efforts (i.e., sod plugs and willow cuttings). This evaluation is based on observations made during a July 2004 site visit by USEPA Region 8 wetlands experts.

It is not known if the wetlands and riparian areas in the watershed are contaminated and, if so, to what degree proper functioning, in particular plant growth, is affected. However, wetlands in mining-impacted sections of Willow Creek presumably contain some level of contaminants and dredging of the sediments should be avoided unless safe disposal methods are identified.

Hydrologic Condition

Hydrology of wetlands and riparian areas in the Willow Creek Watershed are not fully characterized, although the WCRC continues to fill the data gaps. Understanding the basic hydrologic regime, which is the interaction between ground water and surface water, is critical for successful restoration of historic wetlands and riparian areas in the Middle and Lower Sections of the Watershed. While it is also important to understand the basic hydrologic regime for the Upper Section of the Watershed, the good water quality condition, lack of disturbances, and healthy riparian areas keep this off the list of WCRC plans. WCRC has other higher priority issues to address in the Middle and Lower Sections of the Watershed. Techniques to fill this data gap and allow for effective wetland and riparian area restoration may include ground water monitoring wells, gathering hydrologic data, and trenching to determine original soil contours. This information will provide clues and essential data for wetland creation and riparian vegetation planting, including the potential for a restoration of the original contours of specific sites. WCRC is currently trying to better define the shallow ground water conditions in the floodplain below Creede and below the Emperious Mill tailings.

4.5 Stressors, Management Implications, and Restoration Opportunities

Historic mining activities caused disturbances which are still the primary stressors impacting the quality and the quantity of wetlands and riparian habitat throughout the Middle and Lower Sections of the Willow Creek Watershed. Any future projects on forested lands, such as road building and timber harvesting, and potential development on private lands may add to these impacts. However, the USFS is very protective of its lands in the Watershed. No future projects are planned and most likely will not be planned in the future.

The USFS mandate is to protect forest resources while allowing for multiple uses of those resources. The USFS has developed standards and guidelines to minimize project impacts to aquatic ecosystems. The Forest Plan identifies management areas and prescriptions (overlays) where different uses of natural resources are available and where different kinds of management activities can occur. East Willow Creek Watershed in the Upper Section has few roads and only one management area prescription, *Backcountry*, which provides for backcountry experiences for the public. No new road building within the area is allowed and no timber harvest occurs under this prescription. Generally, this tributary and its aquatic resources are protected from activities that would cause any further impairment. Most of the remainder of the sub-watershed is in Management Area Prescription 3.1, *Special Interest Areas, Emphasis on Use or Interpretation* (See Table 2.3).

The Upper Section of the West Willow Creek Watershed is mainly in Management Area Prescription Categories 4 and 5, which allow recreational and other uses. The largest area is in Management Area Prescription 5.11, *General Forest and*

Intermingled Rangelands. Most of the remainder of the Upper Section is in Management Area Prescription 4.3, *Dispersed and Developed Recreation*. The West Willow Creek Watershed has more timber resources and more recreation opportunities and therefore has more prescribed management options. Although these prescriptions allow for undeveloped and developed recreation, timber harvest, livestock grazing, and oil and gas development, projects have not been identified and future proposals would probably be denied because of potential impacts to streams and wetlands and riparian habitat.

In the Middle Section of the Willow Creek Watershed, both tributaries flow through narrow canyons with steep grades that are generally low in vegetative cover both along the stream banks and on the slopes. Private in-holdings and mining areas abut both East and West Willow Creek. Dirt access roads are adjacent to the creeks and may impact the riparian areas. The roads are maintained and may serve as a protective barrier between mine waste piles and the streams. Future studies to remediate the stream corridors through this section of the watershed should include impacts from roads. Options such as hard surfacing the narrowest sections should be considered to minimize impacts and provide opportunities for re-vegetation of the riparian areas.

The Lower Section of the Watershed has more potential threats to wetland and riparian habitats than in the USFS owned lands. Obvious direct impacts to wetlands and riparian areas include filling and draining. The City of Creede and the land downstream of Creede are in private holdings. Significant historic impacts to the floodplain of Willow Creek exist below the current City of Creede. Mine tailings and outwash, including remnants of historic Creede during the mining boom, filled the floodplain in, and destroyed the natural riparian vegetation that existed in pre-mining days. Historic photographs below Creede show a dense willow carr type wetland in the valley bottom (Figure 4.1).

While Federal regulations may protect specific resources within a watershed, proper management of natural resources depends on coordinated actions and attention to cumulative effects of both regulated and unregulated activities. The Federal permit process required under Section 404 of the Clean Water Act is intended to inform the public of proposed development activities and their possible impacts to waters of the U.S. Development activities that fill wetlands and destroy important habitat are often permitted. Mitigation projects that are meant to compensate for these losses are typically removed from the area of habitat loss, so the wetland function is not replaced at the site.

Federal wetlands and riparian area planning authorities under the Clean Water Act are limited to the Army Corps of Engineers' Special Area Management Plans [33 CFR] and EPA's Advanced Identification Authority [40 CFR 230.80]. Both planning processes require extensive interagency coordination and public participation. The intent of these planning exercises is to map and evaluate the functions of the wetlands in the area of concern, facilitate public input, and identify significant wetland resources to minimize development pressure.

Restoration of the Lower Section of Willow Creek may arise through collaborative efforts of the WCRC. However, significant monetary and community time resources spent to revive a degraded reach of the river should not detract from the need to address the potential for continued small, yet cumulatively significant losses of wetland habitat in the basin. To effect lasting improvements to aquatic resources in the area, the community needs to understand their wetland and riparian resources and any development pressure. Development pressures on aquatic resources in the watershed should be evaluated to support efforts to remediate impacted aquatic ecosystems and to protect existing, viable and valuable wetland ecosystems throughout the Willow Creek Watershed.

4.6 Summary

WCRC is currently working on filling the data and information gaps related to the wetlands and riparian habitat of the Lower Section of the Willow Creek Watershed. In that effort, WCRC will develop a more comprehensive assessment of the watershed's wetlands and riparian habitat in the floodplain. With this information, and an understanding of relevant Local, State, and Federal policies, the WCRC could provide information to land use management entities including the City of Creede, Mineral County, and the USFS to allow them to effectively manage the watershed's wetlands and riparian resources.

5.0 GROUND WATER

5.1 Introduction

Within the Willow Creek Watershed, ground water occurs in two types of geologic deposits: (1) unconsolidated surficial deposits including, glacial till, alluvium beneath stream valleys and terraces, and fan deposits and, (2) volcanic rocks, including tuffs, flows, and breccias and associated fluvial deposits (**Figure 2.4**) (Steven and Ratte, 1965 and 1973).

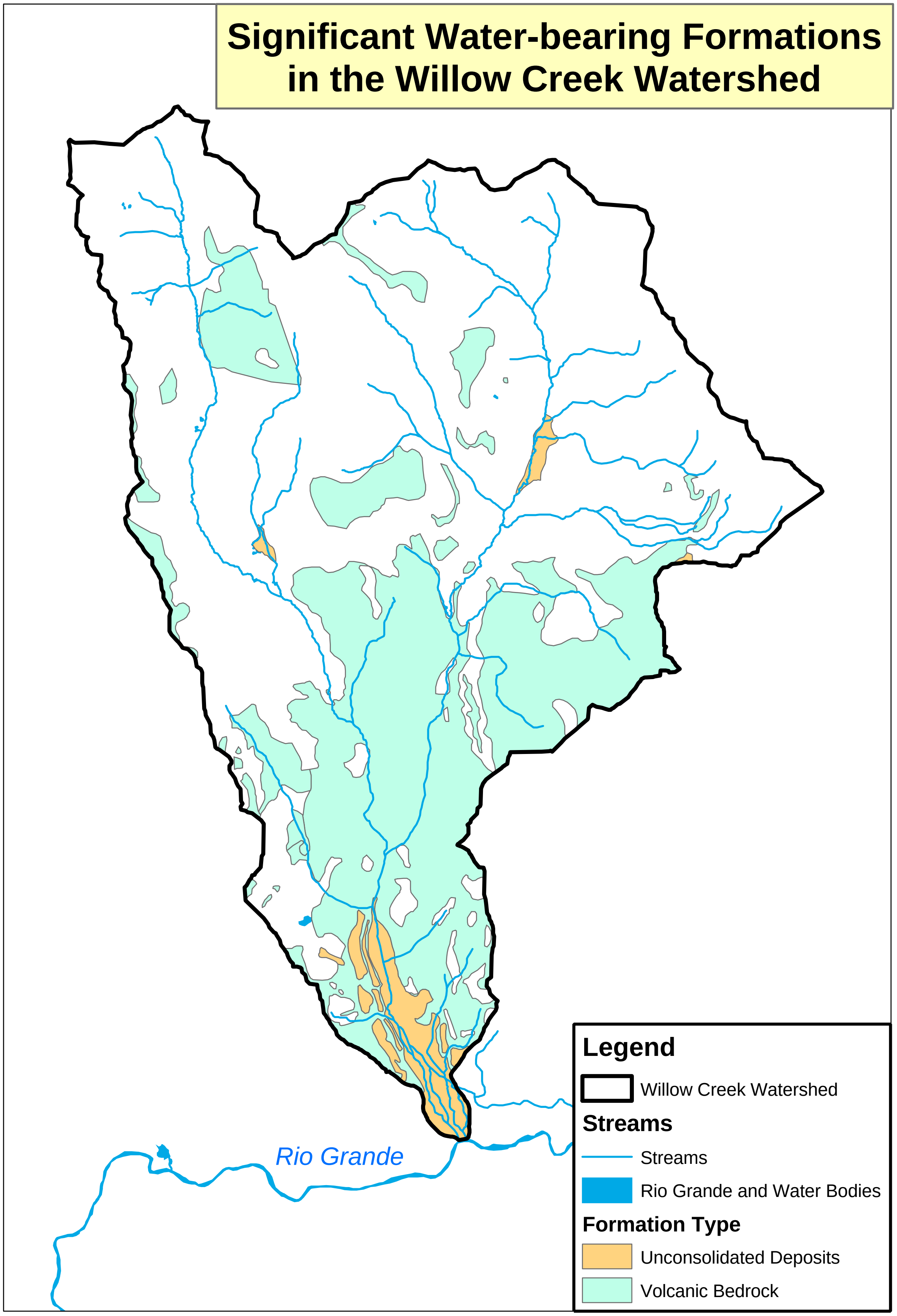
The occurrence and flow of ground water in these two distinct hydrostratigraphic units is very different. In unconsolidated deposits, water flows in pores between the rock grains (primary porosity). How easily the water moves though the material is a function of the grain-size, packing and grain shape. Many types of unconsolidated deposits function as an aquifer where there is sufficient saturated thickness. Except for the valley fill deposits that underlie the Rio Grande Valley, the unconsolidated deposits within the Willow Creek Watershed do not yield significant quantities of water to wells. However, ground water that occurs in these deposits likely plays an important role in maintaining aquatic and riparian ecosystems along Willow Creek.

Volcanic rocks underlying the Willow Creek Watershed have low primary porosity and permeability. The occurrence and flow of ground water within these rocks is controlled by the orientation and distribution of secondary porosity and permeability features, such as fractures or faults. The volcanic rocks that underlie the Willow Creek Watershed are generally poor aquifers; however, significant quantities of ground water can occur locally. **Figure 5.1** shows the significant water-bearing formations within the Willow Creek Watershed.

5.2 Desired State of the Resource

The residents of Creede and the rural parts of the Willow Creek Watershed have expressed a strong desire to restore contaminated ground water and to prevent contamination of un-impacted ground water. The WCRC has also established a goal of restoring a willow-dominated ecosystem along the floodplain of Willow Creek. This type of ecosystem is highly dependent on ground water in the underlying unconsolidated deposits. The depth to ground water in the unconsolidated sediments which underlie the floodplain has probably increased due to deposition of fluvial tailings and other solid mine waste sediments. This constrains the development of a willow community. The desired state is to have high quality ground water that can be used by plants that comprise a willow community.

Figure 5.1 - Significant Water-bearing Formations in the Willow Creek Watershed



5.3 Ground-water Characterization

Significant Water-bearing Unconsolidated Deposits

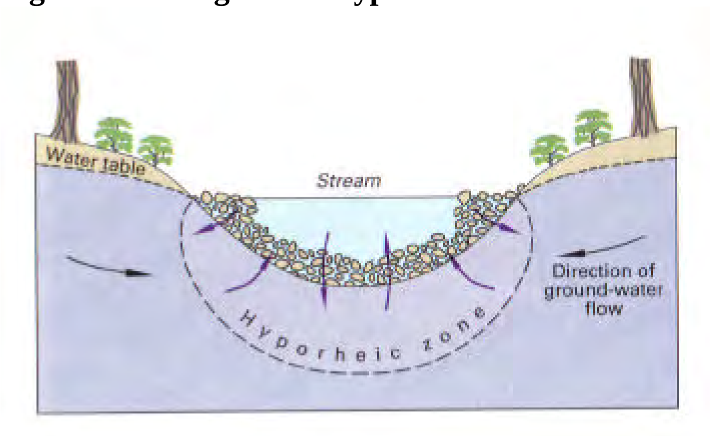
Not all unconsolidated deposits within the Willow Creek Watershed are significant sources ground water. The reader is referred to Steven and Ratte (1973) for a description and distribution of the important water-bearing unconsolidated deposits discussed in this section. Unconsolidated deposits in the Willow Creek valley below the City of Creede and the Rio Grande Valley are comprised of stream alluvium and terrace gravels. Most of this sediment was deposited by glacial melt waters and is very coarse grained, consisting primarily of cobbles and gravel. In the Rio Grande valley and in the lower parts of the Willow Creek valley are two prominent gravel-covered terraces that stand about 50 and 100 feet respectively above the modern-day valley floors. These terrace deposits exceed 125 feet in thickness. It is unknown if there are any water wells developed in the terrace deposits. Because they occur well above the modern day flood plain, it is unlikely that these deposits contain significant saturated thickness. The unconsolidated surficial deposits within the Rio Grande and Willow Creek valleys also include minor amounts of recent deposits of the present streams. These deposits consist primarily of sands and gravels and comprise only a small amount of the valley-fill deposits.

Two significant alluvial fan deposits occur along the northeast side of Willow Creek. The first extends from an area across the road from the Emperious Tailings Pile southeastward to where the Willow Creek valley joins the Rio Grande Valley. A second alluvial fan deposit occurs at the mouth of Dry Creek, a tributary to Willow Creek on the east side (**Figure 5.1**). This deposit extends east to west from the mouth of Dry Creek to Fish Hatchery Road. Alluvial fans consist of poorly sorted sediments that occur where smaller streams deposit sediment loads as they reach the valleys of larger streams. It is likely that ground water in these deposits would discharge into the terrace deposits. This is potentially significant, because the alluvial fan sediments may be mineralized (currently unknown) and ground water that discharges from the upper alluvial fan deposit may influence the chemistry of the ground water downgradient of the Emperious Tailings Pile.

The canyons of East and West Willow creeks above the City of Creede are too steep for sediment deposition. The unconsolidated material that occurs in these canyons is almost all mine waste. Significant morainal deposits flank the upper reaches of East and West Willow Creeks. These deposits include both ground moraines and lateral moraines. Morainal deposits consist of poorly sorted materials ranging from boulders to silt deposited by ice. They can range from tens of feet to more than 100 feet in thickness. Ground water can occur within these types of deposits; however, no published information exists as to the occurrence of ground water in morainal deposits in upper Willow Creek.

Ground water that occurs within the unconsolidated deposits that underlie the floodplain below Creede does not discharge to Willow Creek, but flows southward towards the Rio Grande River and discharges to the valley-fill deposits that underlie the Rio Grande Valley. Ground water that occurs in these deposits may be important for maintaining a healthy riparian ecosystem. Prior to mining activities in the Creede Mining District, a willow-dominated riparian community was well developed in the floodplain, as evidenced in the photograph shown in **Figure 4.1**. This type of riparian community is highly dependent on a seasonally consistent shallow ground-water table and a hyporheic zone undisturbed by human activities. The hyporheic zone is the subsurface zone where stream water flows through short segments of its adjacent bed and banks (**Figure 5.2**). Historic depths to ground water are not known. However, recent water level data from monitoring wells in the floodplain clearly indicate that ground water in the alluvial deposits along Willow Creek does not discharge to Willow Creek.

Figure 5.2 - Diagram of Hyporheic Zone



Scanned from U.S. Geological Survey Circular 1139; Ground Water and Surface Water; A Single Resource

Currently, there is no riparian system along the banks of the Lower Section of Willow Creek. The reason(s) for the disappearance of a historically healthy willow system along lower Willow Creek is not completely understood but is clearly related to historic mining and milling activities. The extent to which a perturbed ground-water flow system or contamination of ground water is responsible for the decline in the riparian system is unknown.

Significant Water-bearing Volcanic Rocks

As discussed in Chapter 2, the bedrock that occurs within the Willow Creek Watershed is primarily moderately to strongly welded ashflow tuffs, and volcanoclastic, stream, lake, and pyroclastic deposits which accumulated in a structural trough around the margin of the Creede Caldera (the Creede Formation). The ashflow tuffs do not store or transmit large quantities of ground water due to low porosity and permeability.

The Creede Formation underlies extensive areas to the east and west of the Lower Section of Willow Creek along the northern side of the Rio Grande Valley. Locally the formation exceeds 2000 feet in thickness. It consists of several distinct rock types that reflect different depositional processes and show significant local variation. In the Creede area, the formation is comprised primarily of thin-bedded lake deposits, mainly shale and sandstone made from reworked volcanic rocks (Steven & Ratte, 1965). Locally, the formation is comprised of conglomerates and travertine deposits. The lithology and the topographic position of the formation indicate that it is not an important water bearing geologic unit. However, the Creede Formation is known to contain some saturated thickness locally. Homestake Mining Company has concluded that minor volumes of ground water from the Creede Formation discharged into mine workings associated with the Bulldog Mine in Windy Gulch.

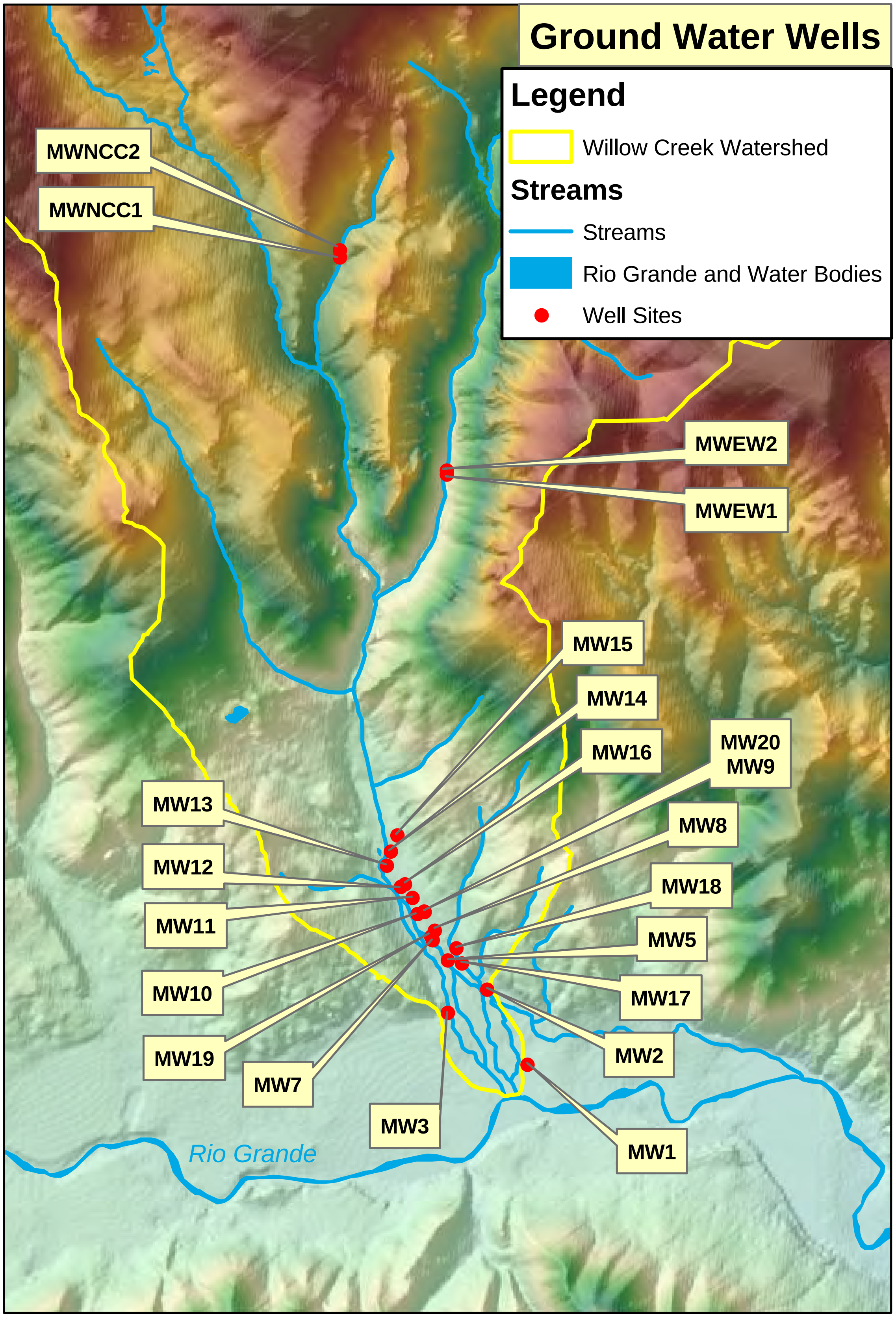
Ground-water flow within the volcanic rocks occurs only along highly preferential pathways - primarily faults. Information and data obtained from hydrogeologic investigations of the underground workings associated with the Amethyst and Homestake mines and the Nelson Tunnel (**Appendix B, WCRC #3**) have shown that there is very little infiltration of rain and snowmelt into the mine workings. Most of the ground water that discharges to the mine workings occurs where the workings intersect the Amethyst fault, which is a deep graben fault (**Figure 2.6**). Recent underground investigations suggest that this discharge occurs where the Amethyst fault intersects cross faults.

Investigations in the Willow Creek Watershed have noted the absence of springs discharging from the tuffs. This is another indication of poor ground water flow within these rocks. Within the watershed there are a number of domestic water supply wells constructed in the tuffs. Most of these are very deep (more than 200 feet) and yield small quantities of water.

Ground-water Use

The City of Creede obtains its public water supply from three municipal wells that pump ground water from the terrace and alluvial deposits of the Rio Grande Valley. These wells are located on the north side of the Rio Grande in Section 6 of Township 41 N, Range 1 E. Geologic and well completion information are available for only one of the three wells. Well # 046925-F is 122 feet deep and screened from 62 to 115 feet below the ground surface. The terrace and alluvial deposits of the Rio Grande Valley comprise a highly productive aquifer. It is likely that there are numerous domestic wells that utilize this aquifer to the west of the confluence with Willow Creek. There are few, if any, domestic wells that produce ground water from the unconsolidated deposits that occur in the Willow Creek Watershed. There are a number of low-yielding domestic wells within the Willow Creek Watershed that are constructed in the volcanic rocks.
In addition to the Creede public supply wells, records from the Colorado State Engineer's Office indicate that there are two domestic wells located in North Creede. These wells (permit numbers 158584 and 166748 are 43 and 42 feet deep.

Figure 5.3 – Ground Water Monitoring Well Locations



5.4 Current Condition

As discussed above, the WCRC recognizes the importance of restoring and maintaining high quality ground water in the unconsolidated floodplain deposits below the City of Creede. To better characterize and monitor this critical ground-water resource the WCRC has completed the drilling and installation of 18 ground-water monitoring wells located on the floodplain below the City (**Figure 5.3**). These wells were installed in 1999, 2001 and 2002. Well location data and well depths for these 18 wells are included in **Table 5.1**. Three synoptic sampling events were completed in November 2001, April 2002 and November 2002.

Table 5.1 - Ground Water Monitoring Wells in the Willow Creek Floodplain

Well name	Well depth (ft)	Northing UTM coordinate	Easting UTM coordinate	Elevation of toc (ft above msl)
MW1	25.50	4187917.06	332109.41	8616.265
MW2	23.50	4188628.13	331728.65	8657.605
MW3	13.50	4188406.38	331361.16	8652.747
MW5	14.40	4188904.00	331361.00	8681.643
MW7	15.94	4189091.23	331217.08	8692.163
MW8	13.85	4189180.53	331233.35	8698.722
MW9	17.12	4189358.13	331138.08	8697.023
MW10	12.18	4189339.54	331076.00	8718.465
MW11	14.83	4189490.09	331026.53	8714.224
MW12	11.44	4189594.66	330916.99	8728.557
MW13	13.78	4189796.99	330784.86	8733.356
MW14	13.70	4189928.28	330820.71	8748.614
MW15	14.93	4190082.82	330884.78	8758.389
MW16	17.30	4189620.22	330953.83	8768.682
MW17	22.65	4188874.45	331493.94	n/a
MW18	15.25	4189016.70	331441.16	n/a
MW19	14.40	4189127.41	331201.48	n/a
MW20	16.58	4189362.45	331136.42	n/a

From *Report on Characterization of Ground Water in the Alluvial Deposits Beneath the Floodplain of Willow Creek Below Creede* (Appendix B, WCRC #3)

Table 5.2 – Ground Water Monitoring Wells: East Willow and West Willow Creeks

Well name	Well depth (ft)	Northing (UTM)	Easting (UTM)	Elevation of toc (ft above msl)
MWNCC1	8.5	~ 4195540	~330340	~10240
MWNCC2	13.8	~ 4195610	~330340	~10240
MWEW1	13.58	~ 4193490	~331350	~9200
MWEW2	9.07	~ 4193530	~331350	~9200

From *Report on Characterization of Ground Water in the Alluvial Deposits Beneath the Floodplain of Willow Creek Below Creede* (Appendix B, WCRC #3)

Data from ground-water samples collected from these wells indicate that ground water in the unconsolidated deposits on the east side of Willow Creek below the Emperious tailings pile has been contaminated by a plume of primarily zinc and cadmium which extends southward from the south end of the tailings pile (**Figure 5.4**). In the center of the plume, dissolved zinc concentrations exceeded 300,000 ug/l in each of the sampling events. Also in the center of the plume, values for dissolved cadmium exceeded 800 ug/l and pH ranged from 3.0 to 5.1. There were significant seasonal differences in metals concentrations. Water chemistry data from 18 ground-water monitoring wells and Willow Creek indicate that this plume is not discharging to Willow Creek and is not known to have reached the north boundary of Wason Ranch. There is also a possibility that ground water discharges to the Willow Creek valley fill sediments from the fan and debris deposits to the east of the road. This ground water may contain significant concentrations of heavy metals. At this time the importance of this inflow is unknown. All of the sampling data associated with these wells and more complete construction data are included in a report entitled *Report on Characterization of Ground Water in the Alluvial Deposits Beneath the Floodplain of Willow Creek Below Creede* (Appendix B, WCRC #3).

In 2001, the WCRC installed two ground-water monitoring wells in the alluvial deposits below the Solomon Mine waste piles along East Willow Creek and two ground-water monitoring wells in the alluvial deposits below the Midwest Mine on upper West Willow Creek (Figure 5.3). Well location and depth data for these wells is included in Table 5.2. Dissolved zinc concentrations for the two wells below the Solomon Mine waste piles ranged from 1433 to 2030 ug/l. Dissolved cadmium concentrations for these two wells ranged from 4.0 to 8.3 ug/l.

5.5 Stressors

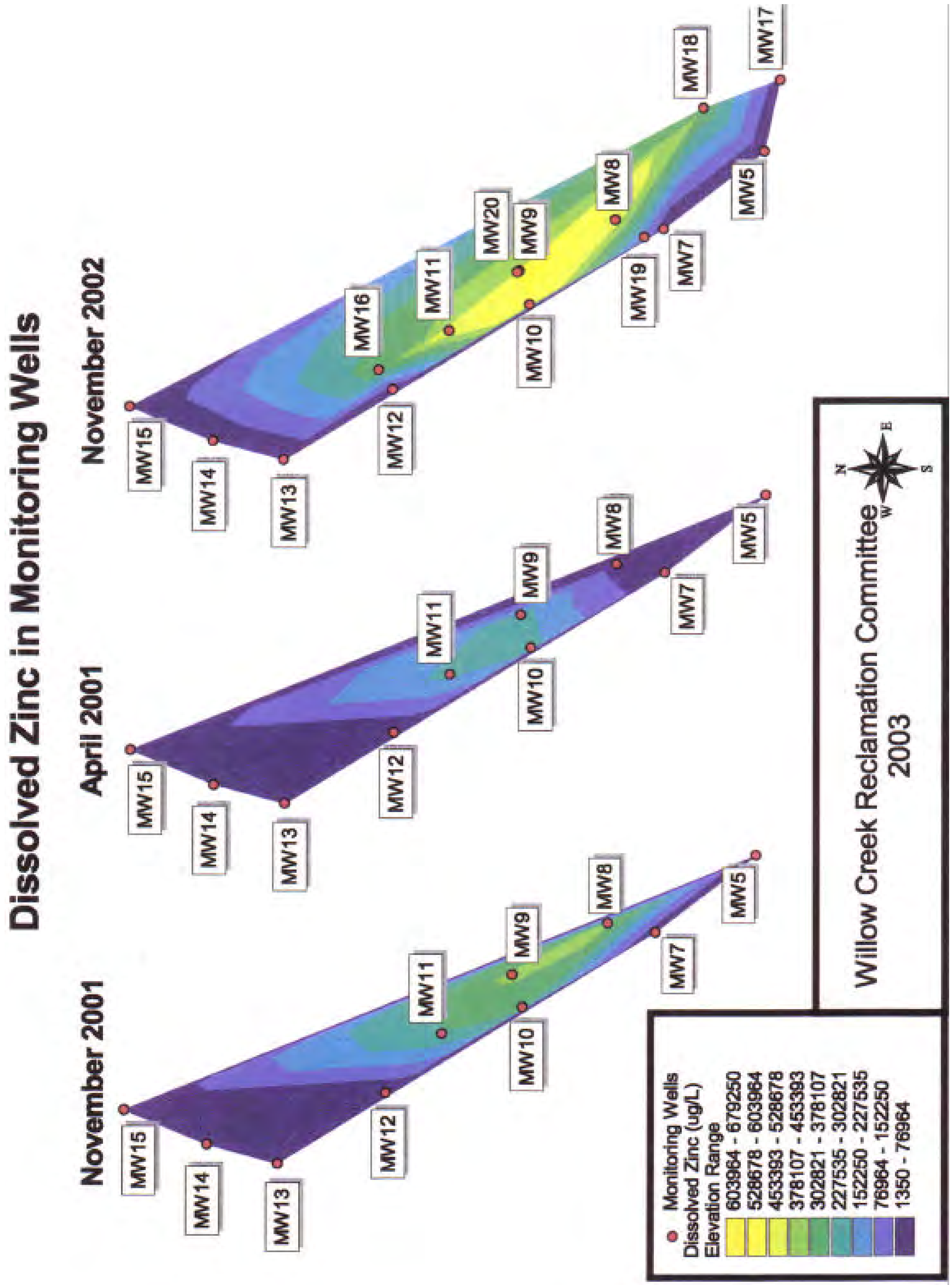
The most significant stressors of ground-water resources in the watershed include: 1) the continuing impacts from leachate contaminated primarily with zinc and cadmium generated from the Emperious Tailings Pile, 2) the potential for metals contamination of alluvial ground water via stream discharge, and (3) the highly disturbed nature of the floodplain sediments along lower Willow Creek.

5.6 Summary

With respect to water supply, the only major aquifer within the Willow Creek Watershed is comprised of the terrace and alluvial deposits of the Rio Grande Valley. The volcanic bedrock formations are used for domestic water supply for a small number of homes and cabins within the watershed.

There is a small, but significant ground-water contamination plume (zinc and cadmium) from the Emperious tailings pile in the floodplain. This plume extends southward from the south end of the tailings pile. It is a plume that does not discharge to

Figure 5.4 – Dissolved Zinc Plume from the Emperious Tailings



Willow Creek. Based on data from monitoring well MW-1 the plume does not appear to extend past the Wason Ranch boundary.

It is likely that the ground water that occurs within the floodplain sediments underlying lower Willow Creek plays some role in the ability to maintain a healthy riparian ecosystem along lower Willow Creek. It is unknown to what extent contamination of this ground water and /or modification of the ground-water flow system within these sediments has impacted the willow-dominated ecosystem that once existed along lower Willow Creek.

6.0 CONCLUSIONS

6.1 Overview

This chapter presents the major findings and conclusions derived from the discussions presented in Chapters 2 through 5 of this report. The conclusions are grouped by themes: the watershed and aquatic resource, watershed management issues, watershed protection and management, ecological condition, and stressors on ecological condition. Many of these conclusions are already well understood by members of the WCRC and others who have been involved in the environmental characterization and cleanup efforts during the past six years. The conclusions presented are a concise summary of important information related to the condition of the aquatic resource in the Willow Creek watershed. The information contained in this report could be useful to those who develop and implement a watershed management plan.

6.2 The Watershed and its Aquatic Resources

This assessment has taken a watershed approach to characterizing aquatic resources, including their condition and the factors that affect that condition. The entire watershed was examined, which extends the WCRC's investigations that focused on areas affected by mining. Biological, chemical, physical, climatic, and anthropogenic factors shape and influence the aquatic resources of the watershed, so all of these factors were evaluated in determining condition. Once the condition of the resource was evaluated, it was compared to the desired state of the resource as expressed by the stakeholders. From a watershed perspective, improving water quality requires attention to all parts of the watershed. Remediation efforts in one portion may be diminished by neglect in another, therefore, those efforts should consider the balance of stressors to ensure the health of the remainder of the watershed. Effectiveness of remediation depends on a comprehensive, rather than localized, knowledge of stressors and their sources.

An assessment of aquatic resources in a mountain watershed should consider surface water and ground water to be a single, inter-related resource. In mountain watersheds, it is common for ground water to discharge to streams in the upper reaches of a watershed and for streams to discharge to ground water in the lower reaches. Along the reach of Willow Creek below the City of Creede, the stream water commonly flows through short segments of its adjacent bed and banks (the hyporheic zone). Hydrogeochemical and biological processes operating within the hyporheic zone are important for maintaining water quality conditions that are suitable for aquatic life and healthy riparian communities in the floodplain of Lower Section of the Willow Creek Watershed. Wetlands that occur in the watershed are mostly ground-water discharge areas and stream-fed riparian-type wetlands. This hydrologic "connectedness" is an important concept with regard to sustainable management of aquatic resources in the watershed.

6.3 Watershed Management Issues

Remediation and Challenges

A portion of the Willow Creek Watershed contains part of a historically significant mining district. The Middle Section of the watershed was intensely mined from the 1890s to the 1920s. That historic mining activity is largely responsible for current water quality problems in the Middle, Creede, and Lower Sections of the watershed. Any attempts to improve water quality within the watershed must begin in the Middle Section where the Nelson Tunnel is the largest single contributor of metals contamination to Willow Creek. The steep stream gradients, steep terrain slopes, and narrow canyons present significant challenges to remediation of these sources of contamination. Capital and long-term costs of treatment or hydraulic control measures pose obstacles for remediation of the Nelson Tunnel discharge.

Flooding Potential

In the past, the threat of significant impacts to Creede from flooding has forced the community to choose flood control measures that have contributed to a deterioration of the aquatic resource. Current and future flood control actions should be considered as remediation and restoration plans are developed. The outcome would be plans that can meet both protection and ecological restoration goals. Actions that provide flood protection without precluding floodplain restoration would be more desirable.

WCRC Priorities

The WCRC has already accomplished numerous cleanup efforts and has plans to address problem sites that this assessment confirms are high priorities for water quality improvement (WCRC web site). Through WCRC's extensive characterization efforts, the top priority restoration and remediation projects have already been identified: the Nelson Tunnel and the floodplain downstream of Creede. The Solomon Adit and the Last Chance / Amethyst Mine Waste Pile are also important restoration projects recognized by the WCRC.

6.4 Watershed Protection and Management

Wetland Restoration and Protection

Wetlands are critical to ecosystem health and watershed function despite their relatively small percentage of land in the Willow Creek Watershed (3.3 percent, which does not include most of the floodplain). Wetlands are especially important in the Upper Section of the watershed because of their role in flood attenuation. Although preserving and protecting wetland and riparian areas are addressed in resource management prescriptions in the revised Rio Grande National Forest Land and Resource Management

Plan (USFS, 1996), Federal regulations play a minimal role in wetland protection in this watershed. Consequently, community regulatory and voluntary actions are essential for wetlands protection. Wetland and riparian restoration efforts would benefit both tributaries of Willow Creek as well as lower Willow Creek. Because beaver create and maintain vital wetlands, they are considered a keystone species. Their watershed population should be maintained at a level that helps improve and sustain wetland and riparian functions.

Sediment and Erosion Risk from Disturbance

In the Middle Section, current and potential excess sediment delivery from mining activities is partly being addressed through actions to stabilize waste rock and tailings piles. There are also risks of erosion from roads and road maintenance near streams in the Middle Section, and roads in the West Willow Creek portion of the Upper Section. The risk of damaging erosion from a hot forest fire, as has occurred in other parts of Colorado, is unknown and should be evaluated.

U.S. Forest Service Management

Because eighty-five percent of the watershed is managed by the USFS, its land management is a critical component to any watershed-wide planning effort. Currently, the East Willow Creek watershed is mostly protected by a USFS backcountry management prescription. However, the West Willow Creek watershed could be more vulnerable to disturbance due to USFS management prescriptions that allow for potential disturbance from resource development activities in the future. Given the poor ecological condition of streams in the West Willow Creek Watershed, any additional disturbances could worsen current condition. Currently, there is very little activity taking place on the National Forest land. Under the Forest Plan provisions, any acceptable new activities proposed in the future would require full implementation of comphrensive conservation practices.

6.5 Ecological Condition

Looking at the watershed as a whole, the aquatic resources in the Upper Section of the watershed, 69 percent of the watershed, are apparently in good ecological condition with respect to the desired condition. However, much of the estimated ecological stream condition in the Upper Section is based on GIS analyses and observational information, not on field monitoring data, and most of the non-perennial streams have not been assessed at all. Monitoring information is needed to validate these coarse estimates. The aquatic resources in the Middle to Lower Sections of the watershed are in generally poor ecological health. This is due primarily to the loading of metals and sediment from past hard-rock mining activities within the Middle Section of the watershed and associated development on the floodplain.

Streams

Assessment of ecological condition for perennial streams in the watershed shows 49 percent in *poor* or *very poor* condition and 42 percent in *good* or *probably good* condition. The *poor* and *very poor* conditions exist in the lower half of the watershed. In the Middle Section of the watershed, West Willow Creek is in much worse ecological condition than East Willow Creek. On West Willow Creek, the USFWS found there are no fish from the Nelson Tunnel to the confluence with East Willow Creek. From the Amethyst Mine (upstream of the Nelson Tunnel) to the confluence with East Willow Creek, only small numbers of metals-tolerant macroinvertebrates are present. Although brook trout are found in the Middle Section of East Willow Creek, the chemical and physical habitat condition of the lower portion of the stream indicates an undesirable environment for aquatic life (Appendix B, WCRC #2). The *poor* condition of aquatic resources in the Middle Section of the watershed is due to metals loading into West Willow Creek and East Willow Creek and to physical perturbations of the stream morphology due to historic disposal of mine waste into the streambeds.

The condition for aquatic life from the Nelson Tunnel on West Willow Creek to the Rio Grande is *very poor*. Willow Creek, in the Creede and Lower Sections of the watershed, not only has a *very poor* chemical condition from the metals loadings in the Middle Section, but the stream's physical habitat condition is also *poor* as a result of past sediment deposition and anthropogenic disturbances, including deforestation. These disturbances resulted from the construction of Creede and related mining camps, road construction, the milling of ore, and flood control efforts. Efforts to remedy water quality should be complemented with efforts to improve physical habitat through stream and riparian area restoration efforts.

Wetlands and Riparian

There is very little specific information or data on the function and value of wetlands within the watershed. Although there is a riparian delineation from the USFS, there is no comprehensive wetlands inventory. Given the importance of wetlands and riparian systems to watershed health, an inventory and assessment are needed to provide information on the types and location of wetlands and their relative functions and values. This information can be useful in determining future management objectives since some wetland types may be providing functions more critical to overall watershed health than others. Adverse impacts are occurring in areas where ongoing road grading is diminishing riparian/wetland vegetation in the mining area.

Based on old photographs and maps, the lack of riparian area and the braided condition of Willow Creek in the floodplain in the Lower Section is not natural. The current condition is most likely caused by transport of sediment made available from mining activities, from mining town development during the mining boom, and flood control measures. Furthermore, surface water is reduced in the floodplain reach as it flows into the permeable alluvial deposits. Designs to restore the floodplain must consider both the surface and ground water hydrology and the fluvial geomorphologic setting to be successful.

Ground Water

Ground water in the Middle Section of the watershed, notably discharging from the Nelson Tunnel, is a significant impact on water quality in West Willow Creek and Willow Creek.

Deposition of mine waste material on the floodplain below Creede has lowered the water table and seriously perturbed the hyphoreic zone. There is also a shallow, narrow contamination plume moving southward from the Emperious Tailings in the floodplain.

The Rio Grande valley-fill aquifer is the most productive high-quality ground water. The City of Creede's municipal wells, located upstream of, but close to, where Willow Creek joins the Rio Grande, produce water from this aquifer. The City of Creede, with assistance from CDPHE, is in the process of developing a source protection program.

6.6 Stressors on Condition

Metals

The primary stressor on aquatic resource ecological condition is the load of metals in streams in the Middle Section of the watershed. Both point and non-point sources of metals loadings are responsible for the degraded condition of streams and wetlands and riparian areas. Past mining disturbance is the cause for the ongoing release of metals. Cadmium, lead, and zinc are the primary metals of concern. To a lesser degree, copper, aluminum, and arsenic are also problems.

The Nelson Tunnel and Other Inflows

The most significant point source inflow to West Willow Creek is the Nelson Tunnel Adit. This adit represents a very high percentage, between 40 to 70 percent, of all metals loading to streams within the watershed. The loadings from the Nelson Tunnel portal represent between 34 and 74 percent of zinc and between 45 and 63 percent of cadmium loadings from Willow Creek into the Rio Grande. Dissolved concentration levels entering West Willow Creek from the Nelson Tunnel Adit range from 5,550 ug/l to 89,800 ug/l of zinc and 54 ug/l to 870 ug/l of cadmium, based on nine samples. Based on underground investigations to date, the source of the water that discharges from the portal of the Nelson Tunnel is ground water moving upwards along the deep-seated Amethyst Fault. It is this deep ground water entering the Nelson Tunnel that must be addressed to remediate the problem. Simply plugging the above ground workings to resolve contaminated surface inflow is not necessarily a viable solution or treatment.

Remediation of the Nelson Tunnel is critical for purposes of meeting the total maximum daily load (TMDL) requirements for zinc and cadmium on the 303(d) listed segment of the Rio Grande below Willow Creek.

The Solomon Mine Adit is the most significant point source for metals loadings to East Willow Creek. While the source is minor compared to the Nelson Tunnel Adit, improvements to East Willow Creek require improved restoration efforts at the Solomon discharge.

Roads and Mine Waste

Roads and mining-related disturbances are a sedimentation threat to water quality and ecosystem function in the watershed. These are primarily concerns within the Middle, Creede, and Lower Sections of the watershed. Roads along West Willow Creek in the Upper Section are also a potential problem, and rated as a high risk as a source for excess stream sedimentation in the Rio Grande Forest Management Plan (USFS, 1996). Some sediments in the Middle, Creede, and Lower Sections are mine waste-related and are contaminated with lead, arsenic, cadmium, and zinc. Contaminated sediment is a continuing source of metals from waste in or adjacent to streambeds. These sediments are also a human health problem where they occur in yards, where ingestion of lead is a concern. In addition, excessive sediment has altered channel morphology, floodplain, riparian and wetland areas severely compromising ecosystem functions.

7.0 RECOMMENDATIONS

The results of this assessment indicate that there are some significant issues which should be addressed in order to complete and implement a comprehensive watershed management plan. The following recommendations for the Willow Creek Reclamation Committee, are focused on improving the aquatic and riparian conditions within the watershed and providing a long term watershed management and monitoring strategy.

7.1 Watershed Management

The WCRC should be designated as a formal, permanent committee in order to develop and implement a watershed management plan, as well as advise and recommend management measures to the City of Creede, Mineral County, and the USFS.

Protection strategies are already in place to maintain the 50 percent of the watershed in the Upper Section that is currently in good condition. These strategies are included recommendations in the USFS Rio Grande National Forest Land and Resource Management Plan. The USFS management prescriptions in the Willow Creek Watershed are very limiting in what they allow. The USFS has no plans or intent to increase watershed disturbances in the Willow Creek Watershed and even if they did occur in the future, they would be controlled by an exhaustive set of conservation measures that are designated to prevent any impact to stream channels.

The four defined watershed sections, Upper, Middle, Creede, and Lower Sections, would form an effective basis for watershed management. In the Middle Section, where the canyons are well defined, there should be a focus on implementing erosion control measures and completing ongoing remedial measures. This includes management of roads to minimize erosion.

Water Resources Monitoring Program

A long-term water quality monitoring program should be implemented by the WCRC. A subset of the current monitoring sites have already been identified by WCRC as fixed sites in this program. A list of indicator parameters should be developed and used to guide sampling activities. These will provide confirmation, or adjustments, on the current condition estimated in this assessment and provide data to monitor the ecological health of the watershed into the future. The program should include regular chemical monitoring and periodic biological and physical habitat monitoring. Post-project monitoring should be included in the overall monitoring design in order to evaluate the effectiveness of remediation efforts, such as those funded by CWA 319 projects.

7.2 Remediation of Point and Non-Point Sources of Heavy Metals

Remediation of the Nelson Tunnel is highest priority for stakeholders' desire for stream water quality improvement. However, the underground characterization needs to be completed so that the most effective remediation project for the Nelson Tunnel discharge can be identified. The magnitude of annual and seasonal zinc and cadmium loads from the Nelson Tunnel, is not known accurately enough to calculate the actual loads and to develop Total Maximum Daily Loads (TMDL). Once-a-month monitoring of discharge from the Nelson Tunnel portal and once-a-month sampling for zinc and cadmium is suggested in order to get data necessary to make the detailed load calculation.

Restoration of the dysfunctional passive wetland treatment system at the Solomon Mine Adit seems to be the most promising approach to reduce metals loadings to East Willow Creek.

WCRC needs to remediate the Amethyst and Last Chance mine waste piles. In addition to identifying an effective remedy for the waste piles, WCRC will need to obtain adequate funding through sources such as 319 grants, USFS money, and the community.

Other mine waste piles identified in the WCRC waste rock report (Appendix B, WCRC # 8) were ranked. WCRC should consider the rankings identified in the report in determining projects after the Nelson, Solomon, Amethyst and Last Chance projects.

7.3 Flood Control

Implementation of flood control measures, that were recommended in the Agro Engineering Report (Appendix B, WCRC #10), by WCRC would significantly minimize flooding risk. Funding and implementation of the recommendations through USDA, USFS, CO Water Conservation Board, and USEPA authorities, expertise, and funding opportunities should be explored. WCRC would be a good coordinating entity for this effort.

7.4 Future Studies

Wetland and Riparian Resources

The first step in restoring the riverine ecosystem below Creede, including its channel, floodplain, and riparian area, is to have a qualified consultant develop a conceptual design. This design would inform the WCRC of the type, extent, and cost of work necessary to meet specific restoration goals.

An inventory and assessment of all types of wetland and riparian resources in the watershed needs to be undertaken. This inventory should include identification of wetland type and the quality of functions these resources provide to the overall watershed.

Glossary

Abiotic - Not biotic. Something that is not lifelike, or has no specific lifelike conditions. A term often referred to in context of abiotic resources, which are considered not renewable. Zinc ore and crude oil are examples of abiotic resources.

Active Hyporheic Zone - The area below the streambed where water percolates through spaces between the rocks and cobbles. An important site for decomposition and nutrient turnover in many river ecosystems. (see Hyporeic Zone below).

Acute - In the context of toxicological or ecological stress, acute is short-term stress with immediate effect. In the context of water quality criteria that are developed to protect aquatic life, acute refers to short term exposure.

Adit - An opening driven horizontally, or nearly horizontally into the side of a mountain or hill for providing access to a mineral deposit and drainage from it.

Alluvial aquifer - A water-bearing deposit of unconsolidated material (sand and gravel) left behind by a river or other flowing water.

Alluvium - Loose material, clay, silt, sand, gravel, and larger rocks, washed down from mountains and hills and deposited in lower areas.

All Terrain Vehicle (ATV) – Four Wheel Drive individual and multi-participant motorized recreational vehicle.

Anthropogenic - Occurring because of, or influenced by, human activity.

Aquatic - Of water. Referring or pertaining to the act of living or growing in or on water.

Aquifer - A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to a well.

Assessment – The act or process of fact finding, evaluation and study of a resource, see Ecological Assessment below.

Bioaccumulation - The biological sequestering of a substance at a higher concentration than that at which it occurs in the surrounding environment or medium. Also, the process, whereby, a substance enters organisms through the gills, epithelial tissues, dietary, or other sources.

Biomagnification - A phenomenon by which the concentration of a toxic substance increases in organisms from one level in the food chain to higher levels in the food chain.

Bioavailability - The capacity of a chemical constituent to be taken up by living organisms either through physical contact or by ingestion.

Biodegradation - Transformation of a substance into new compounds through biochemical reactions or the actions of microorganisms such as bacteria.

Biotic - Lifelike, renewable resources.

Caldera - A geologic structure formed during a massive, explosive volcanic eruption after which the volcano collapses inward, forming a large crater, generally with a resurgent dome in its center.

Carr - Woodland growing on soils with permanently high water levels ad dominated usually by alder or willow.

Channel Morphology – A science and classification system that defines describes and characterizes the physical characteristic of a stream channel.

Chronic – In the context of toxicological or ecological stress chronic is long-term stress with prolonged effect. In the context of water quality criteria that are developed to protect aquatic life, chronic refers to long term exposure.

Climatology - The science of climate and its causes, an important analysis in understanding regional issues in watershed science. Though sometimes used synonymously with weather, climate is actually a distinct term with important ecological ramifications. Climate refers to an aggregate of average and extreme conditions of temperature, humidity, and precipitation (including type and amount), winds, and cloud cover, measured over an extended period of time. Weather refers to present-day environmental conditions; current temperatures and meteorological events. Long-term weather trends establish averages which become climatic regimes.

Concentration - The amount or mass of a substance present in a given volume or mass of sample. Usually, expressed as microgram per liter (water sample), or micrograms per kilogram (sediment or tissue sample).

Conglomerates - Sedimentary rock composed largely of pebbles or other rounded particles whose diameter is larger than 2 mm (.08 in.). Essentially a cemented gravel, conglomerates are formed along beaches, as glacial drift, and in river deposits. Conglomerates formed of angular shaped pebbles are called breccias.

Constituent - A chemical or biological substance in water, sediment, or biota that can be measured by an analytical method.

Contaminant Transport – a.k.a. "load" the rate, at a specific concentration, of contamination transported by a stream (e.g. 276.3 pounds per day of total aluminum, cadmium, copper, lead, and zinc flows into the Rio Grande from Willow Creek).

Contamination - Degradation of water quality compared to original or natural conditions, due to human activity.

Detection limit - The concentration below which a particular analytical method cannot determine, with a high degree of certainty, a concentration.

Digital Elevation Model (DEM) – The digital cartographic representation of the surface of the earth or a subsurface feature through a series of three-dimensional coordinate values. A visual presentation of electronically digitized geophysical and geospatial data layers that consist of a sampled array of elevations for a number of ground positions at regularly spaced intervals. Data file(s) consist of a set of regularly spaced x, y, z coordinates where z usually represents elevation. These data files facilitate the use of large amounts of information overlays, or layers, for complex cognitive work that can be used for assessment, making conclusions and decisions.

Dissolved solids - Amount of minerals, such as salt, that are dissolved in water; amount of dissolved solids is an indicator of salinity or hardness.

Drainage Basin - The topographic region from which a stream receives runoff, through surface and groundwater flow. Drainage basins are divided from each other by topographic barriers called a watershed and are arbitrarily defined based on the topographic information available on a map.

Droughtiness - A state of dryness of the weather; want of rain.

Ecological Assessment – The process or effort to collect and consolidate new and existing environmental, biological, physical, and socioeconomic information in a given ecological area. The process of Ecological Assessment is envisioned as one part of an overall program of adaptive planning, management, monitoring, and research supporting ecosystem management.

Ecoregion - An area of similar climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.

Ecosystem – "The interacting system of a biological community and its non-living environmental surroundings" (EPA 1993, 10)

EPT – Common term for Ephemeroptera, Plecoptera, and Tricoptera, which are groupings of organisms, and are also the three most commonly used taxa in stream macroinvertebrate analysis. Indicators of good water quality.

Evapo-transpiration - A collective term that includes water lost through evaporation from the soil and surface-water bodies and by plant transpiration.

Fauna - Animal species

Fens - Rare, ecologically important and biologically diverse wetlands.

Floodplain - The relatively level area of land bordering a stream channel and inundated during moderate to severe floods.

Flora - Plant species

Flume – An artificial channel or chute for a stream of water.

Geographic Information System (GIS) – "A collection of computer hardware, software, and geographic data designed to capture, store, update, manipulate, analyze and display geographically referenced data" (EPA/620/R-94/016 February 1964).

Groundwater - In general, any water that exists beneath the land surface, but more commonly applied to water in fully saturated soils and geologic formations.

Habitat - The part of the physical environment where plants and animals live.

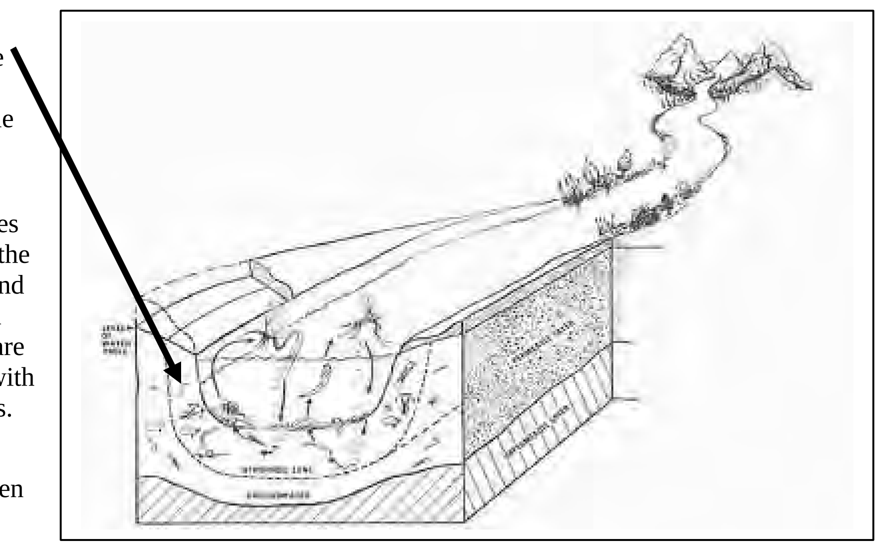
Hydrography - the art and science of compiling and producing charts, or maps, of water-covered areas of the Earth's surface.

Hydrologic function – The purpose, condition or interaction of an aquatic system (stream, river, lake, reservoir) in the environment (see Hydrology below).

Hydrology - The science of water, as it relates to the hydrologic cycle. More specifically, it is the science of water in all its forms (liquid, gas, and solid) on, in and over the land areas of the earth, including its distribution, circulation and behavior, its chemical and physical properties, together with the reaction of the environment (including all living things) on water itself.

Hydrostratigraphic - Types, layers or areas of subsurface soil and groundwater zones that make up the subsurface soils and groundwater profiles of a given study area, often graphically portrayed by cross sections.

Hyporheic Zone: The area below a streambed's surface water, within the saturated soils zone, where water percolates through spaces between the rocks and cobbles.



Histogram - A graphical display showing the distribution of data values in a sample by dividing the range of the data into non-overlapping intervals and counting the number of values which fall into each interval. These counts are called frequencies. Bars are plotted with height proportional to the frequencies.

Igneous - Rock or mineral that solidified from molten or partly molten material.

Invertebrate – An animal having no backbone or spinal column.

Leachate - A liquid that results from water collecting contaminants as it trickles through wastes, agricultural pesticides, or fertilizers and may result in hazardous substances entering surface water, groundwater, or soil.

Lithology – The description of rocks, esp. in hand specimen and in outcrop, on the basis of such characteristics as color, mineral composition, and grain size. The physical character of a rock.

LOAEL - Lowest Observed Adverse Effects Level **-** The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects on people or animals.

Management Area Prescription – A designation of use, and/or management, with associated rules and regulations for a specifically delineated area within a forest of the United States under management and responsibility of the U.S. Forest Service.

Macro-Invertebrates - Larger-than-microscopic invertebrate animals. Freshwater macroinvertebrates include aquatic insects, worms, clams, snails, and crustaceans.

Mainstem - The principal course of a river or a stream.

Micrograms per liter (μg/L) **-** A unit expressing the concentration of constituents in solution as weight (micrograms) of solute per unit volume (liter) of water; equivalent to one part per billion in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.

Milligrams per liter (mg/L) - A unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water; equivalent to one part per million in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.

Mine Tailings/Tailings/Tailings Piles - Refuse or worthless material remaining after ore has been processed that mining operations have determined should be removed (a.ka. dross).

Montane Wetland – wetlands that only occur in the mountains and high plateau areas in Utah

Monitoring well - A well designed for measuring water levels and testing ground-water quality.

Moraine - Material transported by a glacier and then deposited

NOAEL - No Observed Adverse Effects Level **-** The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

Nonpoint source - A pollution source that cannot be defined as originating, from discrete points such as a pipe discharge. Areas of fertilizer and pesticide applications, atmospheric deposition, manure, and natural inputs from plants and trees are types of nonpoint source pollution.

Palustrine - All nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and all such tidal wetlands where ocean-derived salinities are below .5 ppt. This category also includes wetlands lacking such h vegetation but with all of the following characteristics: (1) area less than 8 ha; (2) lacking an active wave-formed or bedrock boundary; (3) water depth in the deepest part of the basin less than 2 m (6.6 ft) at low water; and (4) ocean-derived salinities less than .5 ppt. (Cowardin, et al, 1979, www. water.NCSU.edu/watersheds)

Perennial Stream – A stream that carries flowing water continuously throughout the year, regardless of weather conditions. The streambed of these systems lies below the groundwater table and is fed by groundwater sources. The systems also receive input from precipitation events and runoff. Only infrequent periods of hydrologic drought, where the water table recedes below the streambed, will cause the channel to be dry. The biology of these systems includes organisms whose life cycles require a fully aquatic environment for a year or more.

Point-source contaminant - Any substance that degrades water quality and originates, from a discrete locations such as discharge pipes, drainage ditches, wells, concentrated livestock operations, or floating craft.

Pollutant - Any substance that, when present in a hydrologic system at sufficient concentration, degrades water quality in ways that are or could become harmful to human and/or ecological health or that impair the use of water for recreation, agriculture, industry, commerce, or domestic purposes.

Pore-water - The water filling the spaces between grains of sediment.

Rapid Bioassessment Protocol – An efficient and cost effective method of biological assessment in streams based on comparing habitat, water quality, and biological measures of a given stream with an expected state, or stream reference condition, that would exist in the same type of stream.

Regression Analysis - A statistical method, applied to data to determine, for predictive purposes, any trend that might exist among important factors. It's the process of determining the degree of correlation of a dependent variable with one or more independent variables. An example in fisheries management is the link between catch and other factors like fishing effort and natural mortality.

Riparian - Areas adjacent to rivers and streams with a high density, diversity and productivity of plant and animal species relative to nearby uplands.

Riverine - All wetlands and deepwater habitats contained within a channel except those wetlands (1) dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2)which have habitats with ocean-derived salinities in excess of .5 ppt. (Cowardin, et al, 1979, ww.water.NCSU.edu/watersheds)

Sedge – A grasslike plant with a triangular stem often growing in wet areas.

Stream Equilibrium – A classification that describes and/or defines the status of a stream system between aggradations (steepening gradient due to sediment deposition) and degradation (lessoning of a stream's gradient due to erosion of stream bed sediment). Stream equilibrium refers to conditions that extend beyond the standard range of erosion and deposition of sediment.

Stream Reach - Section of stream between two specified points. A length of stream, usually more or less uniform with respect to discharge, depth, area, and slope

Stream Reach Inventory/Channel Stability Index (SRI/CSI) – Stream characterization data that provides a rating for channel conditions and is used as a tool for in-stream habitat assessment.

Sub-Watershed - A micro-basin, where all water entering the micro-basin and remaining as surface water, i.e., not contributing to ground water supply or exiting via evaporation, evapo-transpiration, etc., will exit via essentially one point called the pour point.

Supercritical Flow - The flow in open channels and closed conduits can be classified according to the level of energy contained in the flow itself as represented by the nondimensional ratio of the inertial force to the force of gravity for a given fluid flow (Froude number). The *subcritical* flow range has Froude numbers less than 1.0 and is characterised by low velocities and high depths found typically on hydraulically mild slopes. *Supercritical flow* has a Froude number greater than 1.0 and is characterised by high velocities and low depths developed in a hydraulically steep channel or pipe.

Table Value Standard - The numeric representation or value of water quality, for various parameters in water, which are assigned by the Colorado Water Quality Control Commission. Table Value Standards are criteria set forth in the Basic Standards and Methodologies for Surface Water for which actual stream conditions and on actual and potential water uses are not known or not considered necessary.

Taxa (plural of Taxon) - Any identifiable group of taxonomically related organisms.

Total Maximum Daily Load (TMDL) - A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources.

Travertine Deposits - A light-colored porous calcite, $CaCO_3$, deposited from solution in ground or surface waters and forming, among other deposits, stalactites and stalagmites.

Unconsolidated Floodplain – the area of the Willlow Creek Floodplain that is made up mostly of alluvial fan or loose bed and soils materials.

Vegetation Zonation - Variations in vegetation based on spatial distribution (as the result of influences like climate, elevation, soils, etc.).

Vegetative Community - All plants not limited to, but for example including, grasses, forbs, bushes and trees within a specific area.

Volcanic Breccia – Rock formed by the action of a volcano composed of sharp-angled fragments embedded in a fine-grained matrix

Water Budget – A calculation of how much water is typically delivered to the stream system or watershed, and the fate of the water. Water budgets are done by calculating the amount of Water Flow Out + Evapotranspiration = Water In

Water quality criteria - Specific levels of water quality which, if reached, are expected to render a body of water unsuitable for its designated use. Commonly refers to water-quality criteria established by the U.S. Environmental Protection Agency. Water-quality criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes. Water quality criteria for the protection of aquatic life are of two types: (1) **acute** cover short-term exposures and **chronic** cover long-term or permanent exposures. Water quality criteria to preserve biologic integrity are developed as **biological** criteria and **sediment** criteria. The antidegradation policy is designed to conserve, maintain, and protect existing uses and the water quality necessary to protect these uses. (EPA, September, 1994)

Water-quality guidelines - Specific levels of water quality which, if reached, may adversely affect human health or aquatic life. These are nonenforceable guidelines issued by a governmental agency or other institution.

Water quality standards - State-adopted and U.S. Environmental Protection Agency-approved ambient standards for waterbodies. Standards include the use of the water body and the water-quality criteria that must be met to protect the designated use or uses. A water quality standard consists of three elements: (1) the designated beneficial use or uses of a waterbody or segment of a waterbody; (2) the water quality criteria necessary to protect the use or uses of that particular waterbody; and (3) an antidegradation policy.

Watershed - "The terrestrial area of the landscape contributing to flow at a given stream location. The land area that drains into a stream (EPA 1992, 31)."

Watershed Approach - A coordinating framework for environmental management that focuses public and private sector efforts to address the highest priority problems within hydrologically-defined geographic areas, taking into consideration both ground and surface water flow (U.S. EPA).

Watershed Ecology: The study of watersheds as ecosystems, primarily the analysis of interacting biotic and abiotic components within a watershed's boundaries.

Water table - The point below the land surface where ground water is first encountered and below which the earth is saturated. Depth to the water table varies widely across the country.

Wetlands - "Lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or where shallow water covers the land and where at least one of the following attributes holds: (1) at least periodically, the land supports aquatic plants predominately; (2) undrained hydric soils are the predominant substrate; and (3) at some time during the growing season, the substrate is saturated with water (Cowardin et al. 1997). An area that is saturated by surface or groundwater with vegetation adapted for life under those soil conditions, as swamps, bogs, fens, marshes, and estuaries (EPA 1992, 31)."

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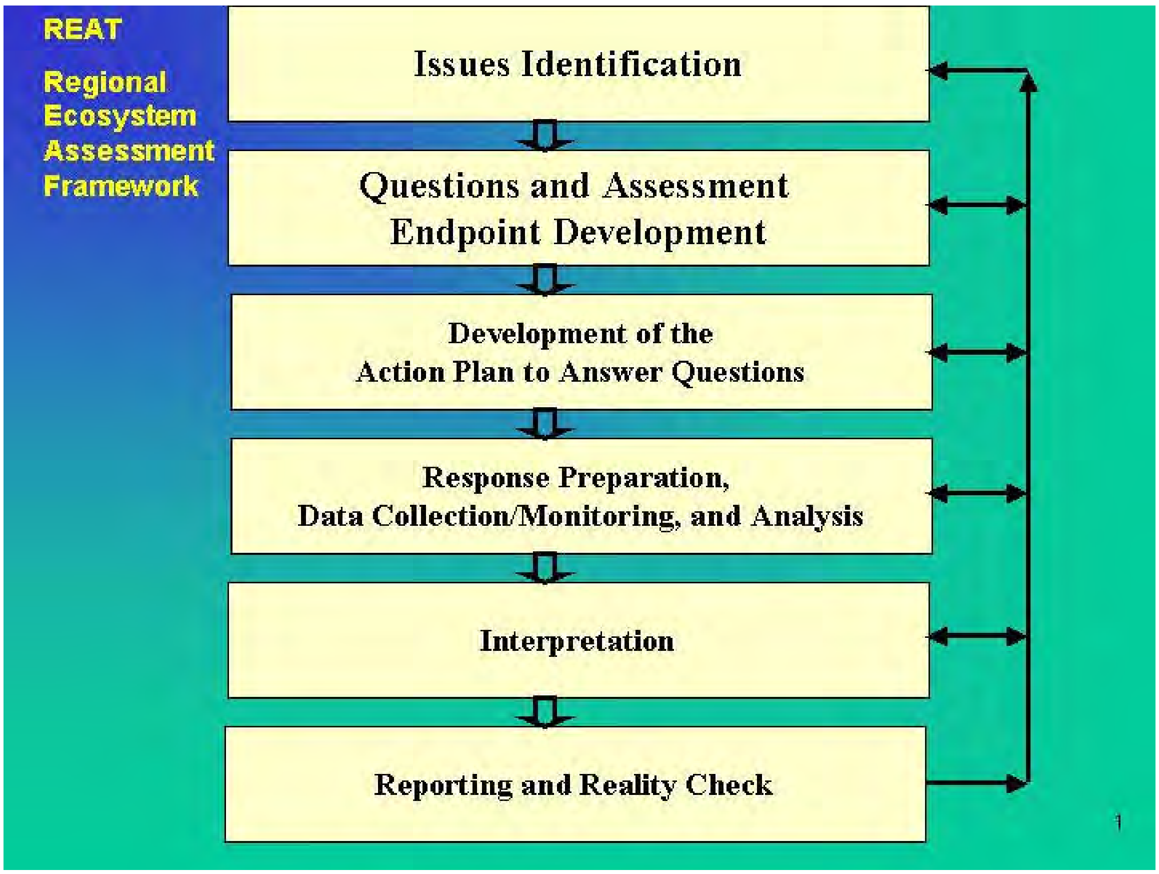
Appendix A

USEPA Region 8 Ecological Assessment Methodology

Background

USEPA Region 8 has developed an ecological assessment framework for employment in a number of projects. The framework is based on a number of a review of literature and experience of staff in ecological assessment projects. An assessment framework is built around assessment endpoints, which are what you want to understand related to the issues at hand. There are many potential assessment endpoints for the Willow Creek Watershed, such as the ecological integrity of streams in the watershed. Assessment questions are identified around the endpoints. These are questions that address a particular aspect of an endpoint. For example, 'what is the current biological condition of Willow Creek watershed streams' is a question that addresses a piece of the ecological integrity endpoint. The figure below shows the flow of an assessment process. It is not necessary to follow the process from top to bottom. In fact, many assessments begin with data that has already been collected and then revisit the issues around why it might have been collected.



The Ecosystem Approach

An ecosystem approach (or watershed approach) utilizes an ecosystem assessment to provide information in guiding ecosystem management activities and investments. Therefore, an assessment for the Willow Creek watershed would be an ideal tool (or source of information) for the watershed management plan.

The Willow Creek Watershed Assessment

A great deal of time and money has gone into collecting data and generating reports about the aquatic resources in the Willow Creek Watershed. The Willow Creek Reclamation Committee has previously identified the desire/need to produce a summary report. The proposed assessment is more than just a summary of the existing reports; it provides the context for the other reports. It is a comprehensive understanding of the watershed issues. It provides the necessary interpretation of data resulting in answers and a priority ranking of issues. Foremost, it provides key findings in clear, straightforward language that are directly related to carefully constructed assessment questions.

The proposed assessment would utilize the data that has been collected and the reports that have been produced and take the additional steps of interpretation and prioritization. The term 'key findings', would be used in the assessment product to clearly identify the most important information from all the data in answering the assessment questions. Thus, it becomes clear that one must carefully develop the set of assessment questions. I expect that a number of questions and answers will easily be documented from all the good work that has already been done. In this sense, some of the effort will only be 'packaging' information into a clear, concise, document.

The primary assessment endpoint would be the ecological condition of the aquatic resources in the Willow Creek Watershed. This covers streams, (lakes?), wetlands, and groundwater. The assessment units would include individual stream reaches, as well as, the entire watershed.

Ecological Assessment

What is Ecological Assessment

Ecological assessment is the process of determining and reporting ecological status, condition, and trends, as well as, the factors that influence that condition. It is the first of two components in the ecosystem approach, the second being ecosystem management opportunities. Focused on ensuring a sustainable economy and sustainable environment, the ecosystem approach attempts to gain a comprehensive understanding of ecosystems, how we use them, what factors effect them, and finally, optimal management and stewardship. A successful ecological assessment process provides relevant information to a variety of stakeholders that empowers them with an understanding of the existing condition of the environment and the abilities to make effective resource management decisions.

White River, Colorado

There is an interrelationship between ecological systems and sustainable economies. An appropriate ecological assessment process employs the best available information and sound science to gain an understanding of the multidimensional aspects of natural systems and anthropogenic stresses on those systems.

There are a couple of key elements for successful assessments.

- First, a necessary holistic style approach requires expertise from a number of disciplines. Therefore partnerships with other agencies and organizations are highly desirable and perhaps critical for success.
- Secondly, no matter how good the analysis and interpretation in the assessment process, without effective communication of relevant information to the stakeholders for the practice of ecosystem management, the value is lost.

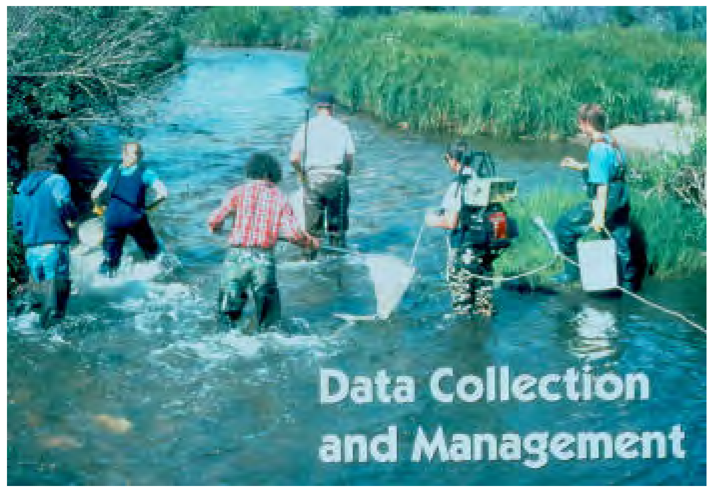
Ecological Indicators

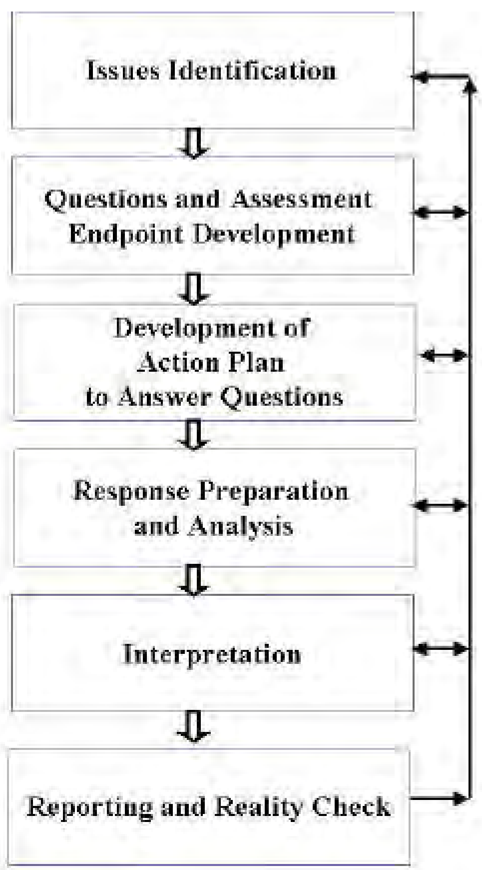
Ideally, the ecological assessment process is iterative. In this way, trends can be monitored and *adaptive* management can be effectively practiced.

In order to accomplish this, a primary assessment tool set is the employment of *ecological indicators*. Designed properly, indicators can be associated with assessment and/or measurement endpoints and can provide status information with respect to that issue(s).

The amount or percent of resource in a given area is an example of an indicator. A direct measure is a measurement endpoint and an indirect measurement is an assessment endpoint.

Monitored over time, the indicator may show loss or gain of the resource. Understanding the ecosystem dynamics, the loss of a particular resource may imply loss of a habitat, etc. Likewise, stressor indicators can show increase or decrease of a particular ecological stress over time (e.g., impact of anthropogenic nitrogen releases over time).





Employing Ecological Assessment in EPA Region 8

EPA Region 8 is promoting an ecological assessment framework to employ as 'the way it does business'. The framework provides a logical approach to identify issues, develop assessment goals and questions to be answered, analyze and interpret information, and to effectively report the findings to relevant stakeholders. Currently, several Region 8 projects incorporate the framework. Future plans for broader use include the upcoming Regional State of the Environment.

Karl A. Hermann 303-312-6628

Ecosystem Protection Program, EPA Region 8

Appendix B

Willow Creek Reclamation Committee Technical Reports

Referenced in Text as (WCRC #)

1. Report on Surface and Mine Water Sampling and Monitoring in Willow Creek Watershed, Mineral County, CO (1999-2002). Willow Creek Reclamation Committee, June 2003.

2. Final Report on Characterization of Fish and Aquatic Macroinvertebrates in Willow Creek. U.S. Fish and Wildlife Service, Willow Creek Reclamation Committee February 12, 2004.

3. Report on Characterization of Groundwater in the Alluvial Deposits Beneath the Floodplain of Willow Creek Below Creede. Willow Creek Reclamation Committee, May 1, 2003.

4. Comparison of Electromagnetic and Natural Potential Geophysical Investigations Near the Emperious Tailings Pile, Creede, Colorado. Agro Engineering, Inc. and the Willow Creek Reclamation Committee. January 26, 2004.

5. Water Wells In and Near the Creede Graben, North of Creede, Colorado. Robert M. Kirkham, Consulting Geologist. Revised May 29, 2003

6. Results of Ground-Water Tracing Experiments in the Nelson-Wooster-Humphrey Tunnel. Cambrian Ground Water Co.

7. Sampling and Analysis Plan for Site Reclamation and Surface Water, Groundwater, Biological, and Waste Rock Sampling, Willow Creek Watershed. Willow Creek Reclamation Committee, December 1999, April 2001, and May 2003.

8. Report on Characterization of Waste Rock and Tailings Piles Above Creede, Colorado. Willow Creek Reclamation Committee, May 2003.

9. Interim underground Report, December 2002 to December 2003. Colorado Division of Minerals and Geology, Willow Creek Reclamation Committee, December 31, 2003.

10. Upper Willow Crek Watershed Flood Control and Stream Stability Study. Prepared for the Willow Creek Reclamation Committee by Agro Engineering. October 2002.

11. Restoration of Abandoned Mines Program, Willow Creek Monitoring Well Installation Project. Creede, Colorado. US Army Corps of Engineers. April 2003.

12. Re-Vegetation Trials, Willow Creek Floodplain, 1999-2003. Willow Creek Reclamation Committee, USDA Natural Resources Conservation Service, US Forest Service, and Colorado State University.

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15. Historical Context For The Creede Mining District. Twitty, Eric R., 1999. Mountain States Historical

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17. Mining The Holy Moses Vein. Eric R. Twitty. Mountain States Historical. 2001.

18. Mining and Prospecting the Alpha Corsair and Other Veins. Eric R. Twitty. Mountain States Historical. May 2003

19. Emperious Tailing, Midwest Mine, and Solomon Mine Well Installation and Sampling. URS. Feb. 6, 2002

20. Natural Potential Survey Along Willow Creek in Creede, Colorado. Karst Geophysics. June 24, 2002

21. Geophysical Investigation Near the Emperious Tailing Pile, Creede, Colorado. URS. August 20, 2002

22. Underground Investigations of the Amethyst Vein, Interim Report. Willow Creek Reclamation Committee. June 21, 2001

23. Hydraulic Analysis Report. Natural Resources Conservation Service. June 14, 2002

24. Regional Bankfull Characteristics for the Lower Willow Creek Stream Restoration. Natural Resources Conservation Service. October 31, 2003

25. Channel Replacement Feasibility Report. Natural Resources Conservation Service. August 13, 2003

In order to obtain many of the reports listed above and for information on the Willow Creek Reclamation Committee and its activities, go to: http://www.willowcreede.org

Appendix C

Assessment Questions
for the
Aquatic Resources Assessment
of the Willow Creek Watershed

Aquatic Resource Characterization

What are the extent and location of the surface water resources of the Willow Creek Watershed?

What are the extent and location of the ground water resources of the Willow Creek Watershed?

What are the extent and location of the wetland resources of the Willow Creek Watershed?

Which aquatic resources are perennial and non-perennial in the Willow Creek Watershed?

What is the seasonal stream flow within the Willow Creek Watershed?

What management factors affect the flow within the Willow Creek Watershed?

What are the land cover and land use classes of the sub-watersheds of the Willow Creek Watershed?

What is the land ownership within the Willow Creek Watershed?

Aquatic Resource Values

What are the State of Colorado designated beneficial uses of the streams of the Willow Creek Watershed?

What are the community and other stakeholders' desires for the condition and uses of the streams of the Willow Creek Watershed?

What laws, policies, local ordinances, and programs are important for the Willow Creek Watershed?

What are the status and apparent trends in water usage and supplies within the watershed, including water rights?

Aquatic Resource Condition (good, fair, and poor)

What is the biological condition of streams in the Willow Creek Watershed?
(determined from fish and macroinvertebrates assemblages)

What is the biological condition of wetlands in the Willow Creek Watershed?

What is the chemical condition of streams in the Willow Creek Watershed?

What is the chemical condition of ground water in the Willow Creek Watershed?

What is the chemical condition of wetlands in the Willow Creek Watershed?

What is the physical condition of streams in the Willow Creek Watershed?

What is the physical condition of wetlands in the Willow Creek Watershed?

Stressors Impacting Aquatic Resources

How, and to what extent, are the Willow Creek Watershed aquatic resources being affected by anthropogenic activities?

Which chemicals have an impact on the stream biological condition and where does that occur?

What are the sources for the chemicals that affect the condition of the aquatic resources?

What is the distribution of human population of the Willow Creek Watershed?

What is the estimated population growth for the next 10 – 20 years and where is that growth expected to occur?

What affect do altered hydrological conditions have on the biological and physical condition of the watershed?

Appendix D

GIS Data and Analysis Methodologies

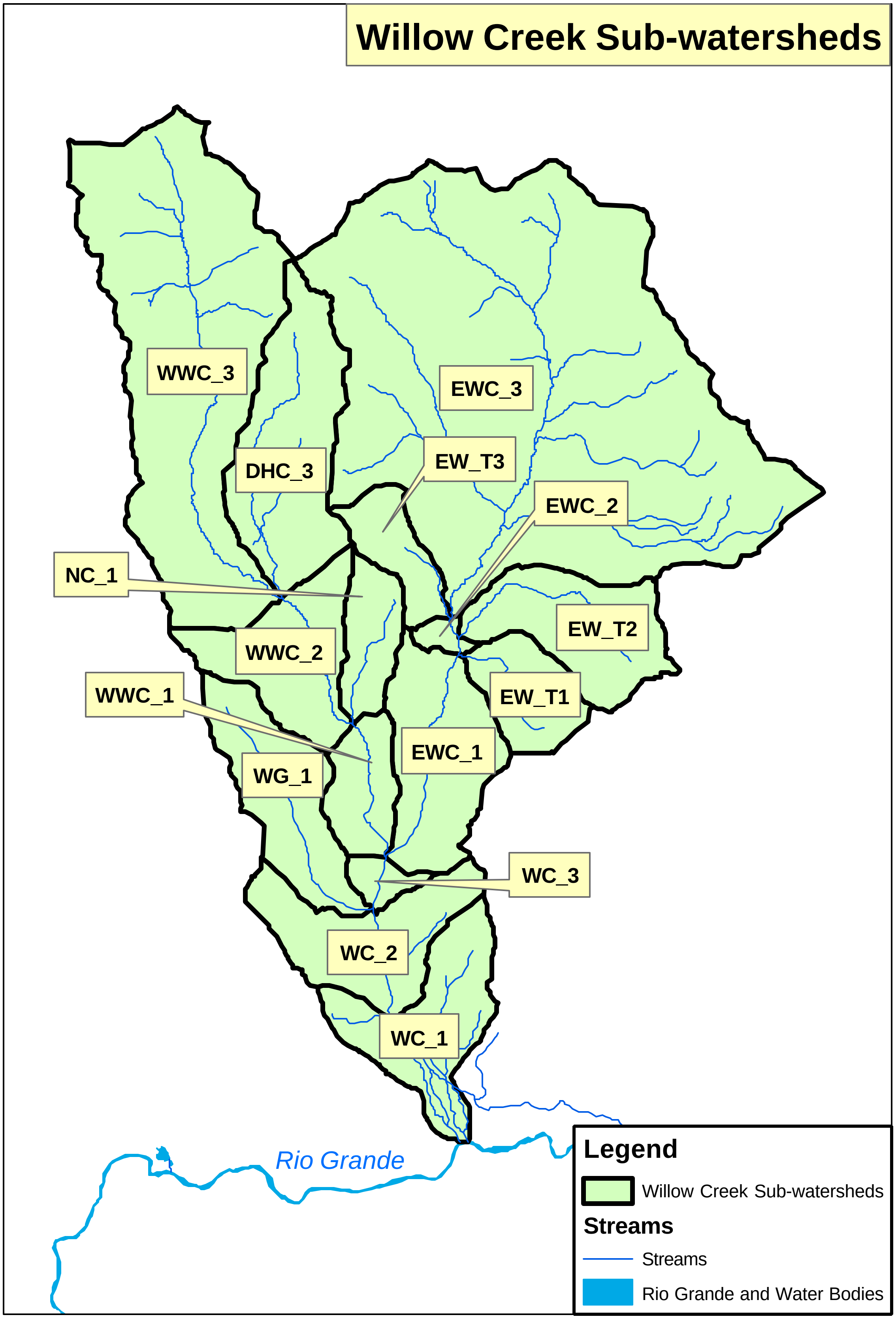
GIS Data Layers

All data layers are in UTM Zone 13, meters, NAD27

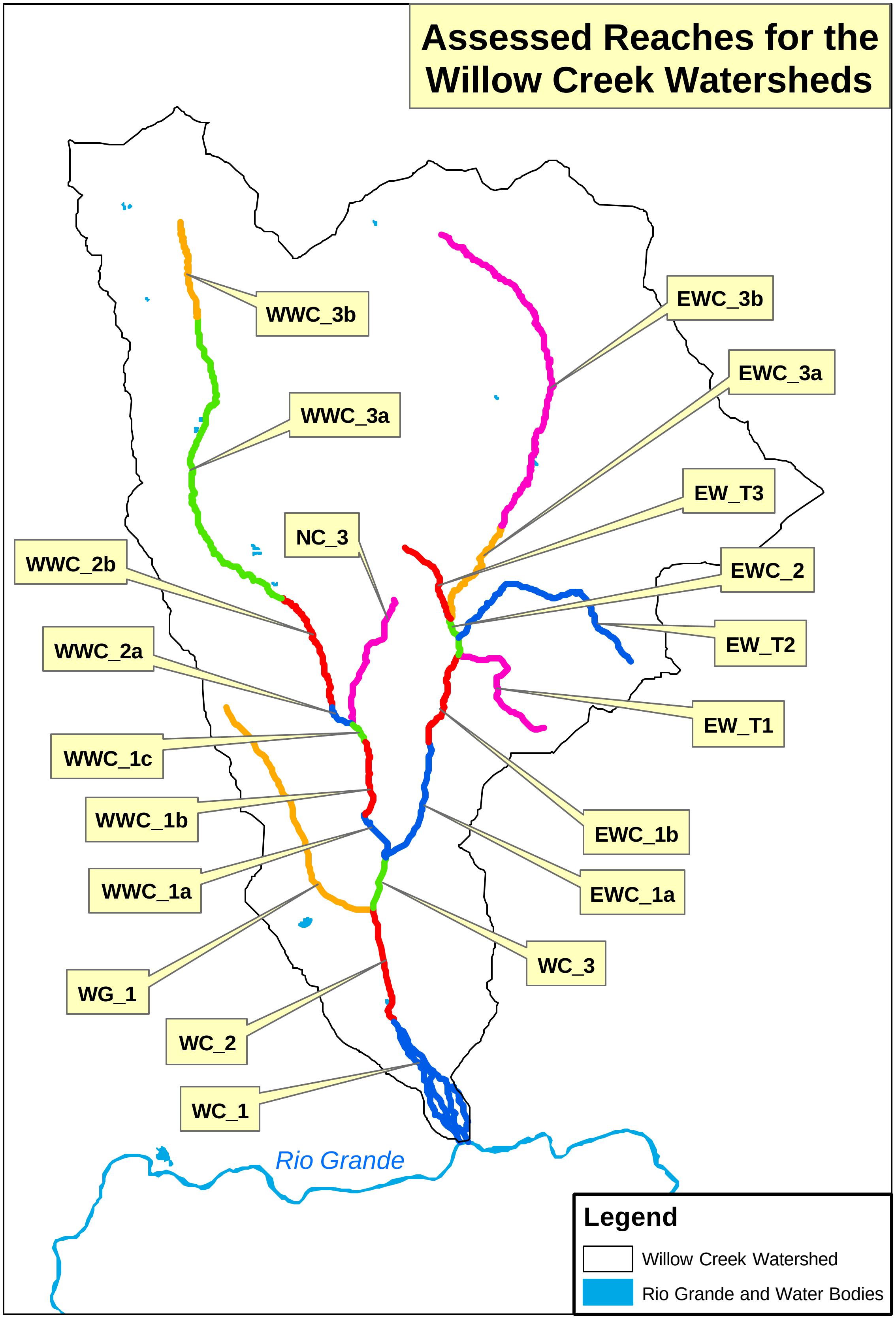
Elevation – 10 meter digital elevation model from USFS National Elevation Dataset (NED)
Topography – hill-shaded relief model derived from elevation
USGS Topographic map – compilation of USGS topographic maps in digital raster graphic format at the 1:24000 scale
Streams – digitized from USGS 1:24000 topographic map in digital raster graphic format
Water Bodies - digitized from USGS 1:24000 topographic map in digital raster graphic format
Monitoring Sites (surface water and ground water wells) – created from WCRC data files
Vegetation – acquired from USFS
Soils - acquired from USFS
USFS Management Prescription Areas - acquired from USFS
Roads - acquired from USFS
Willow Creek Watershed – derived from Elevation model and edited in floodplain with WCRC version
Sub-watersheds - derived from Elevation model and edited in floodplain with WCRC version
Geology – scanned 1:62500 USGS (T.A. Steven and J.C. Ratte, 1973) map and georeferenced to UTM Zone 13, NAD27
PRISM Annual Precipitation Estimates – Oregon State University
Wetland and Riparian Resources - acquired from USFS
Suitable Beaver Habitat – modeled from Elevation, Streams, and Vegetation
Mine Sites – digitized from USGS 1:24000 topographic map in digital raster graphic format
Mining Areas - acquired from USFS
Geologic Veins – interpreted from reference reports
USFS Land Status - acquired from USFS
Slope - derived from Elevation model
Significant Water-bearing Formations – digitized from Geology layer
Watershed Disturbance - acquired from WCRC (USFS)
Digital Orthophotoquads - acquired from WCRC
High Resolution Imagery - acquired from WCRC

NOTE: The wetlands in the ***Soils*** layer and the ***Wetlands and Riparian Resources*** are slightly different. This is due to different methodologies used in mapping.

Sub-watersheds



Assessed Reaches



GIS Analysis Methodologies

Sub-watersheds were determined from 10-meter DEM for appropriate analysis of stream reaches. Larger basins in the Upper Section were used, since a lack of monitoring data existed there. Percent disturbances, vegetation, and other layers were calculated for each sub-watershed. Those indicator percentages and image interpretation were utilized in estimating condition or supporting estimated condition.

Appendix E

Creede Area Geologic Map Rock Units

(showing relative stratigraphic position and age)

Quaternary Age

Qa, alluvium and terrace gravels

Qf, alluvial-fan deposits

Qls, landslide debris

Qd, glacial drift

Tertiary Age

Miscellaneous Rock Types

Creede Formation

Tc, stream, lake, and deposits from explosive volcanism

Tct, travertine

Tlb, Landslide and avalanche debris interlayered with ash-flow tuff units

Ash-Flow Sequence

Nelson Mountain Tuff

Tn, Biotite-pyroxene, quartz latitic ash-flow tuff containing about 30% mineral crystals

Rat Creek Tuff

Trc, Ranges from densely welded biotite-pyroxene quartz latitic ash-flow tuff in the upper part to cyrstal-poor, non-welded rhyolitic ash-flow tuff in the lower part

Quartz Latitic to Rhyolitic lavas and related intrusive rocks

Fisher Quartz Latite

Tf, lava flows containing large mineral crystals, and breccias

Tfl, related intrusive rocks

Miscellaneous Rock Types

Ash-Flow Sequence

Wason Park Tuff

Tw, Red rhyoltic ash-flow tuff containing about 30% mineral crystals of feldspar, platy biotite, and sparse pyroxene. White collapsed pumice fragments are characteristic

Mammoth Mountain Tuff
Tm, Younger Mammoth Mountain rocks are biotite-pyroxene quartz-latitic ash-flow tuffs containing 30-50% mineral crystals. Older Mammoth Mountain and Farmer's Creek rocks are crystal-poor rhyolitic ash-flow tuffs.

Bachelor Mountion Tuff
Tbi, flow-layered rhyolitic intrusive rocks
Tbwg, Windy Gulch Member: poorly welded pumiceous ash-flow tuff

Phoenix Member of the La Garita Tuff
Tgp, Three local flows of biotitie-hornblende quartz latitic ash-flow tuff containing about 50% mineral crystals

Tbc, Campbell Mountain Member: densely welded crystal-poor rhyolitic ash-flow tuff. Abundant rock fragments.

Tbw, Willow Creek Member: densely welded crystal-poor rhyolitic ash-flow tuff. Streaked and layered by secondary viscous flow

Quartz Latitic to Rhyolitic lavas and related intrusive rocks

Quartz Latitic to Rhyoltic lavas and related rocks
Interlayered with ash-flow sequence extending from above Rat Creek Tuff to below Mammoth Moutain Tuff
Tqf, lava flows containing mineral crystals, and breccias
Tqi, related intrusive rocks

Shallow Creek Quartz Latite
Tsc, biotite-horneblende quartz latitic flows and breccias with abundant mineral crystals

Miscellaneous Rock Types	Ash-Flow Sequence	Quartz Latitic to Rhyolitic lavas and related intrusive rocks
		Rhyolite of Miner's Creek
	Outlet Member of the La Garita Tuff **Tgo**, Biotite-hornblende quartz latitic ash-flow containing aobut 50% phenocrysts	**Tmc**, rhyolitic flows and breccias with many large mineral crystals.

Contact _____ __ __ …… dashed where gradational, dotted where concealed

Fault _____ _ _ …... dashed where approximate, dotted where concealed. Bar a ball on downthrown side

after Steven and Ratee,1973

Appendix F

Wetland/Riparian Soil Descriptions

Map Unit Symbol	Soil Map Unit Name	Soil Description
105	Aquic Cryofluvents, 0 to 5 percent slopes	This map unit occurs on the heavily disturbed floodplain of the braided Willow Creek between Creede and the confluence with the Rio Grande. (Figure 2.7) These soils are deep and poorly drained and consist of very gravelly and very cobbly stratified sands and loamy sands formed in native bedload and outwash material mixed with mine waste. The permeability is rapid and the available water capacity is very low. Depth to a seasonal high water table is 0.5 to 3.0 feet (15 to 90 cm.). It is unknown if this soil is hydric. The soil has a pH of 5.4 to 5.6. Some areas have surface salinity at a level that, together with droughtiness in the surface layers, decreases the chance of plant survival. Some of the area has an overburden, from a few inches to several feet thick, of acid overwash material from mine waste. Depth to the water table is significantly greater in areas with an overburden. Vegetated areas have grasses, sedges, rushes, willow, cinquefoil, and other species. Approximately 65 to 75 percent of the area is devoid of vegetation. This is an "unhealthy" riparian corridor. (Information for this soil description is extracted from both the Forest Service Soil Resource and Ecological Inventory of the Rio Grande National Forest as cited above and the "Re-Vegetation Trials, Willow Creek Floodplain, 1999-2003," (WCRC, USDA/Natural Resources Conservation Service, US Forest Service, Colorado State University)).
123	Cryaquepts, 0 to 6 percent slopes, stony	These deep, poorly drained soils are on flood plains above 11,600 feet (3536 m.). Depth to a water table is 0.5 to 2.0 feet (15 to 60 cm.). It is unknown if this soil is hydric. The potential natural vegetation is planeleaf willow/cliff sedge. These riparian areas are in good condition.
124	Cryaquolls-Cryoborolls association, 0 to 20 percent slopes	This unit, at elevations above 9,000 feet (2740 m.), is comprised of about 55 percent deep, very poorly drained Cryaquolls on flood plains and in swales and 30 percent deep, well drained to moderately well drained Cryoborolls with on toeslopes and alluvial fans. Depth to a seasonal high water table is 0.5 to 4.0 feet (15 to 120 cm.). The Cryaquolls are probably hydric soils. The remainder consists of inclusions of other kinds of soils. The potential natural vegetation is willow/sedge on the Cryaquolls and Thurber fescue/Arizona fescue on the Cryoborolls. These areas are in good condition.
128	Cryohemists-Cryaquolls association, 0 to 12 percent slopes	This unit, above 9,500 feet (2900 m.), is comprised of deep, poorly and very poorly drained soils on flood plains and fans and in closed basins. Depth to a seasonal high water table is 0.5 to 1.5 feet (15 to 45 cm.) for the Cryohemists and 0.5 to 4 feet (15 to 120 cm.) for the Cryaquolls. Both soils are probably hydric soils. The potential natural vegetation is sedge/elephant-head on the Cryohemists and willow/sedge on the Cryaquolls. These areas are in good condition.

Extracted from "Soil Resource and Ecological Inventory of the Rio Grande National Forest – west Part, Colorado, U.S. Forest Service, 1996 Draft" and WCRC, USDA/Natural Resources Conservation Service, US Forest Service, Colorado State University.

Upland Soil Descriptions

Map Unit Symbol	Soil Map Unit Name	Soil Description
106	Bachelor-Lymanson complex, 8 to 50 percent slopes	This unit, at elevations of 8,700 to10,000 feet (2650 to 3050 m.), consists of about 55 percent Bachelor soils and 30 percent Lymanson soils on moderate to steep mountain slopes. The remaining 15 percent consists of inclusions of other soils. The Bachelor soil is deep and well drained. The Lymanson soil is moderately deep and well drained. Runoff is rapid and the erosion hazard is moderate for both soils. The potential natural vegetation is Arizona fescue/mountain muhly.
125	Cryoboralfs-Rock outcrop complex, 35 to 75 percent slopes, very stony	The unit, at elevations of 8,600 to 11,600 feet (2620 to 3535 m.), consists of about 55 percent Cryoboralfs and 30 percent rock outcrop on rugged mountain slopes. The remaining 15 percent consists of inclusions of other soils. The Cryoboralfs are shallow to deep, well drained soils. Runoff is rapid and the erosion hazard is high. The potential natural vegetation is subalpine fir-Engelmann spruce/common juniper.
129	Cryumbrepts-Rock outcrop-Rubble land complex, 20 to 80 percent slopes, extremely stony	Cryumbrepts-Rock outcrop-Rubble land complex, 20 to 80 percent slopes, extremely stony This unit, at elevations of 8,600 to 11,600 feet (2620 to 3535 m.), comprises about 40 percent Cryumbrepts, 25 percent rock outcrop, and 25 percent rubble land. The remaining 10 percent consists of inclusions of other soils. The Cryumbrepts are shallow to deep, well drained soils. Runoff is rapid and the erosion hazard is high. The potential natural vegetation is kobresia/forbs.
140	Frisco-Agneston association, 5 to 50 slopes, stony	This unit, at elevations of 9,400 to 11,800 feet (2865 to 3600 m.), consists of about 50 percent Frisco soils and 35 percent Agneston soils on moderate to steep mountain slopes. The remaining 15 percent consists of inclusions of other soils. The Frisco soils are deep and well drained. Runoff is medium and the erosion hazard is moderate. The Agneston soils are moderately deep and well drained. Runoff is medium to rapid as this soil occurs on the steeper portion of the landscape and the erosion hazard is high. The potential natural vegetation is subalpine fir-Englemann spruce/Rocky mountain whortleberry.
154	Mirror-Teewinot association, 8 to 45 percent slopes, very stony	Mirror-Teewinot association, 8 to 45 percent slopes, very stony This unit, at elevations of 11,600 to 13,700 feet (3535 to 4175 m.), consists of about 55 percent Mirror soils on gentle and moderate alpine backslopes and 30 percent Teewinot soils on moderate alpine backslopes. The remaining 15 percent consists of inclusions of other soils. The Mirror soils are moderately deep and well drained and runoff is medium. The Teewinot soils are shallow and well drained and runoff is rapid. The erosion hazard is moderate for both soils. The potential natural vegetation is kobresia/golden avens.
162	Rock outcrop and Rubble land	This unit, at elevations above 7,800 feet (2375 m.), is mostly non-vegetated rock outcrop and rubble land covered with stones and boulders. Less than 15 percent of the unit has soil.
165	Seitz cobbly loam, 15 to 60 slopes	This unit, at elevations of 9,800 to 11,500 feet (2990 to 3500 m.) consists of deep, well drained soils on moderate and steep mountain slopes. Runoff is rapid and the erosion hazard is high. This soil has been selected as the state soil for Colorado. The potential natural vegetation is subalpine fir-Englemann spruce/Rocky mountain whortleberry.

Extracted from "Soil Resource and Ecological Inventory of the Rio Grande National Forest – west Part, Colorado, U.S. Forest Service, 1996 Draft"

Appendix G

Stream Biological Condition

Biological condition is determined for each perennial reach through best professional judgment of macroinvertebrate and fish indicators. These indicators are grouped into the classes of macroivertebrate tissue, macroinvertebrate assemblages, and fish assemblages. Each of those groups is given a best professional judgment score (good, fair, or poor), and then a composite best professional judgment score is compiled from the three group scores.

Indicators for groups are:
Macroivertebrate tissue: tissue metals concentrations (USFWS Table 9)
Macroinvertebrate assemblages: total abundance, total taxa richness, EPT abundance, EPT taxa richness, and metals-tolerant species (USFWS Tables 6, 7, and 8)
Fish assemblages: total abundance and biomass (USFWS Table 5)

Biological Condition Classification

Stream Reach	Sampling Site	Macro. Tissue. (Classifications)	Macro. Assem. (Classifications)	Fish Assem. (Classifications)	=>	Biological Condition
East Willow Creek						
EWC_1a						*fair*
	EW-A	*poor*	*fair*	*good*		
	EW-F	*fair*	*good*	*good*		
EWC_1b						*good*
	EW-I	*fair*	*good*	*good*		
	EW-J	n/a	*good*	*fair*		
	EW-K	n/a	*good*	*good*		
EWC_2						*good*
	none	*(inferred and GIS supported)*				
EWC_3a						*good*
	EW-M	n/a	*good*	*good*		

Stream Reach	Sampling Site	Classifications: Macro. Tissue.	Macro. Assem.	Fish Assem.	=>	Biological Condition
West Willow Creek						
WWC_1a						*poor*
	WW-A	*none found*	*poor*	*poor*		
WWC_1b						*poor*
	WW-G	n/a	*poor*	*poor*		
WWC_1c						*poor*
	WW-I	*poor*	*poor*	*fair*		
WWC_2a						*fair*
	WW-K	n/a	*fair*	*fair*		
WWC_2b						*good*
	none	*(inferred and GIS supported)*				
WWC_3a						*good*
	WW-M	*fair*	*good*	*good*		
Willow Creek						
WC_1						*poor*
	W-I	*poor*	*poor*	*poor*		
	W-J	*poor*	*poor*	*poor*		
WC_2						*poor*
	W-D	n/a	*poor*	*poor*		
WC_3						*poor*
	W-B	*poor*	*poor*	*poor*		

USFWS Study Data

Invertebrate Tissue Metals Concentrations

(Appendix B, WCRC # 2, Table 9)

Table 9. Invertebrate tissue metals concentrations (mg/kg wet weight) collected 22 May 2001.

	EWI	EWF	EWA	WWM	WWI	WB	WI	WJ
Al	60	31	17	166	139	97	1010	747
As	3.6	5.2	1.4	0.2	**4**[1]	1.2	**14**[1]	22.0
Cd	2.43	2.98	1.40	0.07	2.15	2.06	14.60	12.00
Ca	470	1080	408	220	290	440	**600**[1]	260
Cu	7.7	6.2	3.5	2.7	11.5	6.7	69.0	62.9
Fe	112.0	76.3	47.5	170.0	276.0	77.2	1050.0	807.0
Pb	15.9	39.6	21.1	0.1	99.1	31.0	391.0	556.0
Mg	240	250	201	150	180	170	**600**[1]	260
Mn	15.4	13.7	16.2	30.2	21.0	18.9	539.0	253.0
Zn	40.4	53.0	135.0	24.8	79.5	148.0	1420.0	2120.0

[1]Bold type indicates values below the Practical Quantiative Limit as determined by ACZ Labs for that given sample and dilution.

USFWS Study Data

Dietary Exposure Benchmarks for Fish Compared to Potential Exposures on East, West, and Mainstem Willow
(Appendix B, WCRC # 2, Table 10)

Dietary Exposure Benchmarks for Birds Compared to Potential Exposures on East, West, and Mainstem Willow
(Appendix B, WCRC # 2, Table 11)

Table 10. Dietary Exposure Benchmarks for fish compared to potential exposures on East, West, and Mainstem Willow (ppm, dw)

Analyte	Dietary Intake Values (ppm)	East Willow Invertebrate Data Range	West Willow Invertebrate Data Range	Mainstem Willow Invertebrate Data Range
As	10 fish – no effect[1] 90 fish[1]	7.58 – 28.18	1.084 – 21.68	6.5 – 119.24
Cd	Waterborne concentration most important for fish[2]	7.58 – 16.15	0.38 – 11.65	11.17 – 79.13
Cu	<178 fish[2]	18.97 – 41.73	14.63 – 62.33	36.31 – 373.98
Pb	Waterborne concentration most important for fish[2]	86.18 – 214.63	0.54 – 537.12	168.02 – 3013.52
Zn	440 – 1700 fish – no effect[1]	218.97 – 731.7	134.42 – 430.89	802.16 – 11490.4

[1] U.S. DOI 1998
[2] Eisler 2000

Table 11. Dietary Exposure Benchmarks for birds compared to potential exposures on East, West, and Mainstem Willow (ppm, dw)

Analyte	NOAEL-Based Benchmark – Food (ppm)[1]	LOAEL-Based Benchmark – Food (ppm)[1]	Dietary Intake Values (ppm)	East Willow Invertebrate Data Range	West Willow Invertebrate Data Range	Mainstem Willow Invertebrate Data Range
As	4.3 – 29.2[2]	10.6 – 73.1[2]	<30 mallards[3]	7.58 – 28.18	1.084 – 21.68	6.5 – 119.24
Cd	1.2 – 14.98[4]	16.56 – 206.61[4]	<2 birds[3]	7.58 – 16.15	0.38 – 11.65	11.17 – 79.13
Cu	38.9 – 485.5[4]	51.1 – 637.4[4]	<200 poultry[3]	18.97 – 41.73	14.63 – 62.33	36.31 – 373.98
Pb	0.94 – 11.67[5] 3.19 – 39.77[6]	9.36 – 116.73[5]	<5 birds[3]	86.18 – 214.63	0.54 – 537.12	168.02 – 3013.52
Zn	12.0 – 149.8[4]	108.5 – 1353.3[4]	<178 birds[3], 150-200 recommended[3]	218.97 – 731.7	134.42 – 430.89	802.16 – 11490.4

[1] Sample et al. 1996
[2] Low value for sodium arsenite in American Robin. High value for sodium arsenite in Great Blue Heron.
[3] Eisler 2000
[4] Low value for American Robin. High value for Red-tailed Hawk.
[5] Lead acetate. Low value for American Robin. High value for Red-tailed Hawk.
[6] Metallic Lead. Low value for American Robin. High value for Red-tailed Hawk.

USFWS Study Data

Invertebrates Sampled from East Willow Creek, West Willow Creek, and Willow Creek
(Appendix B, WCRC # 2, Tables 6, 7, and 8)

NOTE: Some of the macroinvertebrate assemblage indicator terminology differs between that used by the USFWS in their Report (including the following USFWS tables) and that used in this assessment report. The following crosswalk shows how the indicator names equate.

USFWS Terminology	=	**Assessment Terminology**
Total Abundance	=	*same* (Total Abundance)
Species Abundance	=	Total Taxa Richness
EPT Abundance	=	*same* (EPT Abundance)
Number EPT Species	=	EPT Taxa Richness

Table 6. Invertebrates sampled from East Willow 22 September 1999 (white background) and 16-18 May 2000 (yellow background).

			EWM		EWK		EWJ		EWI		EWF		EWA	
Order Ephemeroptera	Ameletidae	Ameletus sp.						4						
	Baetidae	Baetis bicaudatus	13	884	9	178	27	704	11	108	9	48	28	28
	Ephemerellidae	Drunella coloradensis		20		8		32		2	1	1		
		Drunella doddsi			2			4			1	1		
		Ephemerella infrequens				6		8						
	Heptageniidae	Cinygmula sp.	1	56	2	10	3	136	2	3	2	6		4
		Epeorus sp.	4		1		1	8	2		4		2	4
		Rhithrogena robusta		4						1				
Order Plecoptera	Capniidae	Paraleuctra sp.		4		2		8						
	Chloroperlidae	Chloroperlidae	1	8	2		7			3		2		8
		Plumiperla diversa		8		4		8		14		15		20
		Sweltsa sp.		4		2		12	1	1	4	1	3	
	Nemouridae	Podmosta sp.		60		8		64		2		2		124
		Prostoia besametsa		16		12		16		1		3		140
		Zapada sp.	1	8			1	56			3	2	1	40
	Perlodidae	Kogotus modestus												4
		Megarcys signata	11	4	13	8	23	12	35	4	42	21	7	4
	Perlodinae	Cultus aestivalis						12				3		
		Diura knowltoni												
	Taeniopterygidae	Doddsia occidentalis												
		Taenionema sp.		8		2								
Order Trichoptera	Brachycentridae	Brachycentrus sp.							1					
		Micrasema sp.												
	Hydropsychidae	Arctopsyche grandis			1						7		104	48
	Limnephilidae	Chyrandra centralis						4						
		Hesperophylax sp.							1				1	
	Rhyacophilidae	Rhyacophila brunnea		4		16		36		3		3		4
		Rhyacophila coloradensis												
		Rhyacophila hyalinata						8				13		52
		Rhyacophila pellisa		64		22		56		12		10		
		Rhyacophila sp.	9	4	20		17	8	10		13			
	Uenoidae	Neothremma alicia	57	196	41	62	48	180	41	2	31	55	4	32
		Oligophlebodes sp.		8		4		4		1		7		32
Order Coleoptera	Elmidae	Heterlimnius corpulentus	1	56	13	48	19	92	8	1	16	5	19	312
		Optioservus sp.												
Order Diptera	Athericidae	Atherix pachypus												
	Blephariceridae	Bibiocephala grandis				6								
	Ceratopogonidae	Ceratopogonidae	2	8	4	10	3						1	12
	Chironomidae	Brillia sp.						4						
		Chaetocladius sp.		36		18		4						
		Corynoneura sp.				2								4
		Cricotopus/Nostocociadius sp.												
		Cricotopus/Orthocladius sp.			3	4	7	12				1	6	60
		Diamesa sp.		16										8
		Eukiefferiella sp.		8		6		28		1		2		84
		Heleniella sp.				2								
		Heterotrissocladius sp.						4						
		Limnophyes sp.		4										
		Macropelopia	1		1		3							
		Micropsectra sp.		12		52		32				3		52
		Pagastia sp.		4										12
		Parachaetocladius sp.												
		Parametriocnemus sp.												4
		Parorthocladius sp.												
		Polypedilum sp.				2								
		Rheocricotopus sp.				2		4						16
		Stempellina sp.												
		Tvetenia sp.		12		6		4		1		1		48
	Empididae	Chelifera sp.		12	1		1	4			3	1	4	24
		Clinocera sp.			2		6				1		1	
		Oreogeton sp.												
	Muscidae	Limnophora aequifrons									3			
	Psychodidae	Pericoma sp.	3	36	7	26	2	32		3	3	1		
	Simulidae	Prosimulium sp.		108		46		160		5				56
		Simulium sp.	1	12			2	12			4			68
	Tipulidae	Dicranota sp.		4	1	6		8				1		
		Hexatoma sp.	1		1	2	1							
		Tipula sp.	1		1				1		1			
Class Arachnida	Subcohort Hydracarina	Lebertia sp.		4		4		12		1				8
		Sperchon sp.												4
Phylum Mollusca	Class Bivalvia	Pelecypoda pisium			2									
	Class Gastropoda	Family Limnaedae												
Phylum Platyhelminthes	Class Turbellaria	Polycelis coronata												
Phylum Nematomorpha		Gordius sp.			2		3							
		Total Abundance	107	1692	129	586	174	1792	113	169	148	208	181	1316
		Species Abundance	15	33	21	32	18	37	11	20	18	25	13	31
		Number EPT Species	8	18	9	15	8	22	9	14	11	17	8	15
		EPT Abundance	97	1360	91	344	127	1380	104	157	117	193	150	544

Table 7. Invertebrates sampled from West Willow 22 September 1999 (white background) and 16-18 May 2000 (yellow background).

			WWM		WWK		WWI		WWG		WWA	
Order Ephemeroptera	Ameletidae	Ameletus sp.										
	Baetidae	Baetis bicaudatus	14	103		38	6	54	23	6		
	Ephemerellidae	Drunella coloradensis		3								
		Drunella doddsi								1		
		Ephemerella infrequens		1				1				
	Heptageniidae	Cinygmula sp.		37	1		3	1				
		Epeorus sp.		1		1			2		2	
		Rhithrogena robusta	11			3				2		
Order Plecoptera	Capniidae	Paraleuctra sp.		5		1						
	Chloroperlidae	Chloroperlidae		26		2		1				
		Plumiperla diversa		13		1						1
		Sweltsa sp.	6	9	6	6	9	1		4		
	Nemouridae	Podmosta sp.		14		2		4		20		2
		Prostoia besametsa		11		4		6		23		27
		Zapada sp.	11	1						1		
	Perlodidae	Kogotus modestus										
		Megarcys signata	29	1	3	1	18	3	17	7		
	Perlodinae	Cultus aestivalis		2						6		
		Diura knowltoni										1
	Taeniopterygidae	Doddsia occidentalis										
		Taenionema sp.				1		1		1		
Order Trichoptera	Brachycentridae	Brachycentrus sp.										
		Micrasema sp.	1		1		3			1		
	Hydropsychidae	Arctopsyche grandis							1	1	1	
	Limnephilidae	Chyrandra centralis										
		Hesperophylax sp.										
	Rhyacophilidae	Rhyacophila brunnea		3		1		1		5		1
		Rhyacophila coloradensis										
		Rhyacophila hyalinata				1		1		13		
		Rhyacophila pellisa		23		1		4		1		
		Rhyacophila sp.	16		4		12					
	Uenoidae	Neothremma alicia										
		Oligophlebodes sp.		1								
Order Coleoptera	Elmidae	Heterlimnius corpulentus	89	40	15	5	42	2	25	11	6	3
		Optioservus sp.										
Order Diptera	Athericidae	Atherix pachypus										
	Blephariceridae	Bibiocephala grandis		4		3		2				
	Ceratopogonidae	Ceratopogonidae		4				1				
	Chironomidae	Brillia sp.										
		Chaetocladius sp.										
		Corynoneura sp.										
		Cricotopus/Nostococladius sp.				1						
		Cricotopus/Orthocladius sp.						2		1		1
		Diamesa sp.										1
		Eukiefferiella sp.				1				10		
		Heleniella sp.		1								
		Heterotrissocladius sp.										
		Limnophyes sp.										
		Macropelopia										
		Micropsectra sp.		3								
		Pagastia sp.										
		Parachaetocladius sp.		2								
		Parametriocnemus sp.										
		Parorthocladius sp.										
		Polypedilum sp.										
		Rheocricotopus sp.								2		
		Stempellina sp.				3		1				
		Tvetenia sp.				2				1		
	Empididae	Chelifera sp.				1			1	17	1	1
		Clinocera sp.	2				9		2			
		Oreogeton sp.								2		
	Muscidae	Limnophora aequifrons										
	Psychodidae	Pericoma sp.	3							1		
	Simulidae	Prosimulium sp.		20		6		3				2
		Simulium sp.								1		
	Tipulidae	Dicranota sp.		1								
		Hexatoma sp.	3					1				
		Tipula sp.					2					
Class Arachnida	Subcohort Hydracarina	Lebertia sp.										
		Sperchon sp.										
Phylum Mollusca	Class Bivalvia	Pelecypoda pisium										
	Class Gastropoda	Family Limnaedae										
Phylum Platyhelminthes	Class Turbellaria	Polycelis coronata										
Phylum Nematomorpha		Gordius sp.										
		Total Abundance	185	329	30	85	104	90	71	138	10	40
		Species Abundance	11	25	6	22	9	19	7	24	4	10
		Number EPT Species	7	17	5	14	6	12	4	15	2	5
		EPT Abundance	88	254	15	63	51	78	43	92	3	32

Table 8. Invertebrates sampled from Mainstem Willow 22 September 1999 (white background) and 16-18 May 2000 (yellow background).

			WB		WD		WI		WJ	
Order Ephemeroptera	Ameletidae	Ameletus sp.				1				
	Baetidae	Baetis bicaudatus	3	1	1					
	Ephemerellidae	Drunella coloradensis								
		Drunella doddsi		1						
		Ephemerella infrequens		1						
	Heptageniidae	Cinygmula sp.								
		Epeorus sp.				1		1		
		Rhithrogena robusta								
Order Plecoptera	Capniidae	Paraleuctra sp.								
	Chloroperlidae	Chloroperlidae	1					1		
		Plumiperla diversa								
		Sweltsa sp.				1				
	Nemouridae	Podmosta sp.		5		45				
		Prostoia besametsa		20		11				
		Zapada sp.								
	Perlodidae	Kogotus modestus								
		Megarcys signata	2		5					
	Perlodinae	Cultus aestivalis		1						
		Diura knowltoni								
	Taeniopterygidae	Doddsia occidentalis		1						
		Taenionema sp.								
Order Trichoptera	Brachycentridae	Brachycentrus sp.	1		1		2		1	
		Micrasema sp.								
	Hydropsychidae	Arctopsyche grandis	26	4	16	5				
	Limnephilidae	Chyrandra centralis								
		Hesperophylax sp.			1	2	32	7	14	131
	Rhyacophilidae	Rhyacophila brunnea								
		Rhyacophila coloradensis				2				
		Rhyacophila hyalinata		2		1				
		Rhyacophila pellisa				3				
		Rhyacophila sp.	3		1	1				
	Uenoidae	Neothremma alicia	2	1	1					
		Oligophlebodes sp.		1						
Order Coleoptera	Elmidae	Heterlimnius corpulentus	3	5	1	4				
		Optioservus sp.		1						
Order Diptera	Athericidae	Atherix pachypus				4		2		
	Blephariceridae	Bibiocephala grandis								
	Ceratopogonidae	Ceratopogonidae				1				
	Chironomidae	Brillia sp.				1				
		Chaetocladius sp.								
		Corynoneura sp.								
		Cricotopus/Nostococladius sp.								
		Cricotopus/Orthocladius sp.		3	7	22				1
		Diamesa sp.				18				
		Eukiefferiella sp.		17		19		2		3
		Heleniella sp.				3				
		Heterotrissocladius sp.								
		Limnophyes sp.								
		Macropelopia								
		Micropsectra sp.		1		42				
		Pagastia sp.				7				
		Parachaetocladius sp.								
		Parametriocnemus sp.								
		Parorthocladius sp.				1				
		Polypedilum sp.				1				
		Rheocricotopus sp.		1		66		3		5
		Stempellina sp.								
		Tvetenia sp.		1		32				
	Empididae	Chelifera sp.	2	6	15	39				
		Clinocera sp.				5				
		Oreogeton sp.								
	Muscidae	Limnophora aequifrons								
	Psychodidae	Pericoma sp.								
	Simulidae	Prosimulium sp.		3		12				
		Simulium sp.		2		1				
	Tipulidae	Dicranota sp.								
		Hexatoma sp.								
		Tipula sp.							1	1
Class Arachnida	Subcohort Hydracarina	Lebertia sp.				1				
		Sperchon sp.				2				
Phylum Mollusca	Class Bivalvia	Pelecypoda pisium								
	Class Gastropoda	Family Limnaedae					1			
Phylum Platyhelminthes	Class Turbellaria	Polycelis coronata				1				
Phylum Nematomorpha		Gordius sp.								
		Total Abundance	43	78	49	355	35	16	16	141
		Species Abundance	9	21	10	32	3	6	3	5
		Number EPT Species	7	11	7	11	2	3	2	1
		EPT Abundance	38	38	26	73	34	9	15	131

USFWS Study Data

Sampling Site Variables and Fish Abundance Estimates
(Appendix B, WCRC # 2, Table 5)

NOTE: Fish assemblage indicator terminology differs between that used by the USFWS in their Report (including the following USFWS tables) and that used in this assessment report. The following crosswalk shows how the indicator names equate.

USFWS Terminology	=	**Assessment Terminology**
Abundance	=	Total Abundance

Table 5. Sampling site variables and fish abundance estimates from 22-24 September 1999.

Site	Reach Length (ft)	Reach Width (ft)	Reach Size (acres)	Trout Species	Abundance	Weight (lbs)	Species Percent of Total Abundance	Species Percent of Total Weight	Biomass (lbs/acre)	Abundance per mile	Abundance per acre	Length in inches Mean (Range)	Weight in lbs Mean (Range)
EWM	330	11	0.09	Brook	36	3.34	100	100	38.98	576.0	420.5	5.3 (2.0-9.8)	0.09 (0.002-0.41)
EWK	420	12	0.11	Brook	58	13.25	100	100	117.42	729.1	514.1	7.6 (2.0-10.4)	0.23 (0.002-0.55)
EWJ	262	20	0.12	Brook	15	1.45	100	100	12.05	302.3	124.7	5.4 (2.0-10.0)	0.10 (0.004-0.38)
EWI	390	15	0.13	Brook	41	4.21	98	97	31.33	555.1	305.3	5.6 (1.7-9.3)	0.10 (0.002-0.34)
				Brown	1	0.12	2	3	0.89	13.5	7.4	6.7	0.12
EWF	500	17	0.20	Brook	52	5.08	100	100	26.05	549.1	266.5	5.0 (1.9-9.8)	0.10 (0.002-0.42)
EWA	420	14	0.14	Brook	34	5.72	100	100	41.75	427.4	248.3	6.9 (2.5-10.0)	0.17 (0.004-0.46)
WWM	300	9	0.06	Brook	68	8.18	100	100	129.11	1179.2	1057.4	6.1 (1.9-9.9)	0.12 (0.002-0.34)
WWK	420	11	0.10	Brook	5	0.91	20	17	8.94	62.9	49.4	7.8 (6.2-9.8)	0.18 (0.08-0.35)
				Brown	20	4.53	80	83	44.73	251.4	197.6	8.3 (1.9-11.2)	0.23 (0.002-0.49)
WWI	330	11	0.08	Brook	11	1.79	79	72	21.52	176.0	132.0	7.4 (5.7-9.2)	0.16 (0.08-0.27)
				Brown	3	0.70	21	28	8.46	48.0	36.0	7.8 (4.0-10.9)	0.23 (0.02-0.48)
WWG	330	19	0.14	Brook	4	0.47	100	100	3.24	64.0	27.8	5.8 (3.0-8.5)	0.12 (0.02-0.26)
WWA	420	13	0.12	NONE									
WB	500	12	0.14	NONE									
WD	480	15	0.17	NONE									
WI	820	20	0.38	Brown	1	0.08	100	100	0.20	6.4	2.7	5.9	0.08
WJ	800	12	0.22	Brown	1	0.41	100	100	1.84	6.6	4.5	10.4	0.41

Appendix H

Stream Chemical Condition

In the tables below, the number of metal concentrations exceeding their table value standards for each site is listed by acute and chronic occurrences. In addition, the chemical condition is noted for the reach involving each set of sites. If no exceedences are noted for a reach and the chemical condition is listed as *fair*, then at least two metals had their concentration percent of table value standards greater than 50. If the chemical condition is listed as *poor*, then there at least two exceedences are listed in the reach. Chemical conditions listed as *very poor* have some metal concentration percent of its table value standard exceeding 1000.

Stream Chemical Condition Classification

Stream Reach	**Sampling Site**	**Classifications: Acute TVS Exceedences**	**Classifications: Chronic TVS Exceedences**	**=>**	**Chemical Condition**
East Willow Creek					
EWC_1a					*very poor*
	EW-A	3	3		
	EW-B	3	3		
	EW-C	3	3		
	EW-D	3	3		
	EW-E	2	3		
	EW-F	3	3		
	EW-G	3	3		
EWC_1b					*fair*
	EW-H	0	0		
	EW-I	0	0		
	EW-J	0	0		
	EW-K	0	0		
EWC_2					*fair*
	EW-L	0	0		
EWC_3					*good*
	EW-M	0	0		

Stream Reach	Sampling Site	Classifications: Acute Exceedences	Chronic Exceedences	=>	Chemical Condition
East Willow Creek Tributaries					
EW_T1	*(based on analysis of EW-K and EW-L)*				*prob. good*
	EW-TRN	n/a	n/a		
	EW-TRS	n/a	n/a		
EW_T2	*(based on analysis of EW-K and EW-L)*				*prob. good*
	EW_Trib3	n/a	n/a		
EW_T3					*fair*
	EW-N	0	1		
West Willow Creek					
WWC_1a					*very poor*
	WW-A	4	5		
	WW-B	4	5		
	WW-C	4	5		
	WW-D	4	5		
	WW-E	3	5		
	WW-F	3	5		
WWC_1b					*very poor*
	WW-G	2	5		
	WW-H	3	5		
	WW-HH	2	4		
WWC_1c					*very poor*
	WW-I	2	4		
WWC_2a					*very poor*
	WW-J	2	3		
	WW-K	1	4		
WWC_2b					*fair*
	WW-L	0	0		
WWC_3					*good*
	WW-M	0	0		

Stream Reach	Sampling Site	Classifications: Acute Exceedences	Chronic Exceedences	=>	Chemical Condition
Nelson Creek					
NC_1					*poor*
	NC-A	0	2		
	NC-B	3	4		
	NC-D *(dry)*				
	NC-E	1	1		
Willow Creek					
WC_1					*very poor*
	W-I	2	5		
	W-J	2	5		
	W-G-E	3	5		
	W-G-M	4	5		
	W-G-W	3	5		
	W-G-FW	2	4		
	W-H	3	5		
	W-F *(dry)*				
WC_2					*very poor*
	W-E	3	4		
	W-D	3	4		
	W-C	4	5		
WC_3					*very poor*
	W-B	4	4		
	W-A	3	5		
Windy Gulch					
WG_1					*poor*
	WNG-A	2	2		
	WNG-B	0	1		

East Willow Creek

Chemical Monitoring Data by Sample Site

Low-Flow Concentrations, Table Value Standards for Acute and Chronic, and Low-Flow Concentration Percent of Table Value Standards for Acute and Chronic

East Willow Creek, From Table 8 of Surface and Mine Water Report											
Fall - "Low Flow"					**Cadmium**						
					WCRC reported Cd TVS = 0.61 ug/l						
Date	**Site**	**Flow (CFS)**	**Alk (mg/L)**	**Hard (mg/L)**	**TVS - Cd acute (ug/l)**	**TVS - Cd acute (trout) (ug/l)**	**TVS - Cd chronic (ug/l)**	**dCd (ug/L)**	**% dCd relative to acute TVS**	**% dCd relative to acute (trout) TVS**	**% dCd relative to chronic TVS**
EW-A	9/18/99	22	20	17	0.62	0.54	0.60	**1.65**	**265**	**305**	**274**
EW-B	9/18/99	23.5	22	18	0.66	0.58	0.63	**1.54**	**232**	**267**	**245**
EW-C	9/18/99	24.5	21	18	0.66	0.58	0.63	**1.47**	**222**	**255**	**234**
EW-D	9/18/99	27.6	21	18	0.66	0.58	0.63	**1.33**	**201**	**231**	**212**
EW-E	9/19/99	18.4	22	18	0.66	0.58	0.63	**1.17**	**176**	**203**	**186**
EW-F	9/19/99	26.4	22	18	0.66	0.58	0.63	**0.97**	**146**	**168**	**154**
EW-G	9/19/99	24.2	21	17	0.62	0.54	0.60	**0.93**	**149**	**172**	**154**
EW-H	9/19/99	24.5	22	17	0.62	0.54	0.60	0.31	50	57	51
EW-I	9/18/99	28.9	22	16	0.58	0.51	0.58	0.27	46	53	47
EW-J	9/18/99	25.8	21	16	0.58	0.51	0.58	0.29	50	57	50
EW-K	9/20/99	18.3	21	17	0.62	0.54	0.60	<0.15			
EW-L	9/20/99	16.6	22	17	0.62	0.54	0.60	<0.15			
EW-M	9/20/99	18.8	20	17	0.62	0.54	0.60	<0.15			

East Willow Creek, From Table 8 of Surface and Mine Water Report											
Fall - "Low Flow"					**Zinc**						
					WCRC reported Zn TVS = 26.7 ug/l						
Date	**Site**	**Flow (CFS)**	**Alk (mg/L)**	**Hard (mg/L)**	**TVS - Zn acute (ug/l)**	**TVS - Zn chronic (ug/l)**	**dZn (ug/L)**	**% dZn relative to acute TVS**	**% dZn relative to chronic TVS**		
EW-A	9/18/99	22	20	17	26.11	26.32	**207.7**	**795**	**789**		
EW-B	9/18/99	23.5	22	18	27.41	27.63	**191.3**	**698**	**692**		
EW-C	9/18/99	24.5	21	18	27.41	27.63	**187.3**	**683**	**678**		
EW-D	9/18/99	27.6	21	18	27.41	27.63	**167.0**	**609**	**604**		
EW-E	9/19/99	18.4	22	18	27.41	27.63	**153.4**	**560**	**555**		
EW-F	9/19/99	26.4	22	18	27.41	27.63	**112.8**	**412**	**408**		
EW-G	9/19/99	24.2	21	17	26.11	26.32	**115.8**	**443**	**440**		
EW-H	9/19/99	24.5	22	17	26.11	26.32	18.7	72	71		
EW-I	9/18/99	28.9	22	16	24.80	25.01	<1				
EW-J	9/18/99	25.8	21	16	24.80	25.01	<1				
EW-K	9/20/99	18.3	21	17	26.11	26.32	<1				
EW-L	9/20/99	16.6	22	17	26.11	26.32	<1				
EW-M	9/20/99	18.8	20	17	26.11	26.32	<1				

East Willow Creek, From Table 8 of Surface and Mine Water Report

Fall - "Low Flow"

					Lead				
					WCRC reported Pb TVS = 0.36 ug/l				
Site	**Date**	**Flow (CFS)**	**Alk (mg/L)**	**Hard (mg/L)**	**TVS - Pb acute (ug/l)**	**TVS - Pb chronic (ug/l)**	**dPb (ug/L)**	**% dPb relative to acute TVS**	**% dPb relative to chronic TVS**
EW-A	9/18/99	22	20	17	8.98	0.35	**11.1**	**124**	**3173**
EW-B	9/18/99	23.5	22	18	9.58	0.37	**9.6**	**100**	**2572**
EW-C	9/18/99	24.5	21	18	9.58	0.37	**10.7**	**112**	**2867**
EW-D	9/18/99	27.6	21	18	9.58	0.37	**9.7**	**101**	**2599**
EW-E	9/19/99	18.4	22	18	9.58	0.37	**8.3**	87	**2224**
EW-F	9/19/99	26.4	22	18	9.58	0.37	**11.3**	**118**	**3027**
EW-G	9/19/99	24.2	21	17	8.98	0.35	**10**	**111**	**2858**
EW-H	9/19/99	24.5	22	17	8.98	0.35	<3		
EW-I	9/18/99	28.9	22	16	8.38	0.33	<3		
EW-J	9/18/99	25.8	21	16	8.38	0.33	<3		
EW-K	9/20/99	18.3	21	17	8.98	0.35	<3		
EW-L	9/20/99	16.6	22	17	8.98	0.35	<3		
EW-M	9/20/99	18.8	20	17	8.98	0.35	<3		

East Willow Creek, From Table 8 of Surface and Mine Water Report											
Fall - "Low Flow"					**Aluminum**						
Site	**Date**	**Flow (CFS)**	**Alk (mg/L)**	**Hard (mg/L)**	**TVS - Al acute (ug/l)**	**TVS - Al chronic (ug/l)**	**dAl (ug/L)**	**% dAl relative to acute TVS**	**% dAl relative to chronic TVS**		
EW-A	9/18/99	22	20	17	750	87	71	9	82		
EW-B	9/18/99	23.5	22	18	750	87	53	7	61		
EW-C	9/18/99	24.5	21	18	750	87	53	7	61		
EW-D	9/18/99	27.6	21	18	750	87	49	7	56		
EW-E	9/19/99	18.4	22	18	750	87	54	7	62		
EW-F	9/19/99	26.4	22	18	750	87	67	9	77		
EW-G	9/19/99	24.2	21	17	750	87	68	9	78		
EW-H	9/19/99	24.5	22	17	750	87	69	9	79		
EW-I	9/18/99	28.9	22	16	750	87	85	11	98		
EW-J	9/18/99	25.8	21	16	750	87	53	7	61		
EW-K	9/20/99	18.3	21	17	750	87	52	7	60		
EW-L	9/20/99	16.6	22	17	750	87	51	7	59		
EW-M	9/20/99	18.8	20	17	750	87	37	5	43		

Nelson Creek

Chemical Monitoring Data by Sample Site

Low-Flow Concentrations, Table Value Standards for Acute and Chronic, and Low-Flow Concentration Percent of Table Value Standards for Acute and Chronic

Nelson Creek, From Table 15 of Surface and Mine Water Report										
Fall - "Low Flow"				**Aluminum**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Al acute (ug/l)**	**TVS - Al chronic (ug/l)**	**dAl (ug/L)**	**% dAl relative to acute TVS**	**% dAl relative to chronic TVS**		
NC-A	9/20/99	0.038	23	750	87	**258**	34	**297**		
NC-B	9/20/99	0.0009	19	750	87	**325**	43	**374**		
NC-C	9/20/99	0.023	22	750	87	**708**	94	**814**		
NC-D	9/20/99	dry	dry	750	87	dry				
NC-E	9/20/99	0.0066	19	750	87	**1003**	**134**	**1153**		

Nelson Creek, From Table 15 of Surface and Mine Water Report										
Fall - "Low Flow"				**Cadmium**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Cd acute (ug/l)**	**TVS - Cd chronic (ug/l)**	**TVS - Cd chronic(trout) (ug/l)**	**dCd (ug/L)**	**% dCd relative to acute TVS**	**% dCd relative to acute (trout) TVS**	**% dCd relative to chronic TVS**
NC-A	9/20/99	0.038	23	0.866	0.751	0.754	0.3	35	40	40
NC-B	9/20/99	0.0009	19	0.703	0.611	0.654	**0.83**	**118**	**136**	**127**
NC-C	9/20/99	0.023	22	0.825	0.716	0.729	**1.16**	**141**	**162**	**159**
NC-D	9/20/99	dry	dry				dry			
NC-E	9/20/99	0.0066	19	0.703	0.611	0.654	<0.15			

Nelson Creek, From Table 15 of Surface and Mine Water Report										
Fall - "Low Flow"				**Copper**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Cu acute (ug/l)**	**TVS - Cu chronic (ug/l)**	**dCu (ug/L)**	**% dCu relative to acute TVS**	**% dCu relative to chronic TVS**		
NC-A	9/20/99	0.038	23	3.4	2.6	**2.8**	83	**110**		
NC-B	9/20/99	0.0009	19	2.8	2.2	**13.4**	**477**	**618**		
NC-C	9/20/99	0.023	22	3.2	2.5	**27.8**	**861**	**1132**		
NC-D	9/20/99	dry	dry			dry				
NC-E	9/20/99	0.0066	19	2.8	2.2	<1				

Nelson Creek, From Table 15 of Surface and Mine Water Report										
Fall - "Low Flow"				**Manganese**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Mn acute (ug/l)**	**TVS - Mn chronic (ug/l)**	**dMn (ug/L)**	**% dMn relative to acute TVS**	**% dMn relative to chronic TVS**		
NC-A	9/20/99	0.038	23	1829.9	1011.0	47.8	3	5		
NC-B	9/20/99	0.0009	19	1717.1	948.7	375.2	22	40		
NC-C	9/20/99	0.023	22	1803.0	996.2	75.3	4	8		
NC-D	9/20/99	dry	dry			dry				
NC-E	9/20/99	0.0066	19	1717.1	948.7	<10				

Nelson Creek, From Table 15 of Surface and Mine Water Report										
Fall - "Low Flow"				**Lead**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Pb acute (ug/l)**	**TVS - Pb chronic (ug/l)**	**dPb (ug/L)**	**% dPb relative to acute TVS**	**% dPb relative to chronic TVS**		
NC-A	9/20/99	0.038	23	12.63691	0.492442	<3				
NC-B	9/20/99	0.0009	19	10.18309	0.39682	<3				
NC-C	9/20/99	0.023	22	12.01863	0.468349	<3				
NC-D	9/20/99	dry	dry			dry				
NC-E	9/20/99	0.0066	19	10.18309	0.39682	<3				
Nelson Creek, From Table 15 of Surface and Mine Water Report										
Fall - "Low Flow"				**Zinc**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Zn acute (ug/l)**	**TVS - Zn chronic (ug/l)**	**dZn (ug/L)**	**% dZn relative to acute TVS**	**% dZn relative to chronic TVS**		
NC-A	9/20/99	0.038	23	33.7	34.0	29.3	87	86		
NC-B	9/20/99	0.0009	19	28.7	28.9	**60.4**	**211**	**209**		
NC-C	9/20/99	0.023	22	32.5	32.8	**96.4**	**297**	**294**		
NC-D	9/20/99	dry	dry			dry				
NC-E	9/20/99	0.0066	19	28.7	28.9	<1				

West Willow Creek

Chemical Monitoring Data by Sample Site

Low-Flow Concentrations, Table Value Standards for Acute and Chronic, and Low-Flow Concentration Percent of Table Value Standards for Acute and Chronic

West Willow Creek, From Table 11 of Surface and Mine Water Report										
Fall - "Low Flow"				**Cadmium**						
				WCRC reported Cd TVS = 1.84 ug/l						
Date	**Site**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Cd acute (ug/l)**	**TVS - Cd acute(trout) (ug/l)**	**TVS - Cd chronic (ug/l)**	**dCd (ug/L)**	**% dCd relative to acute TVS**	**% dCd relative to acute (trout) TVS**	**% dCd relative to chronic TVS**
WW-A	9/18/99	13.9	27	1.03	0.89	0.85	**31.18**	**3027**	**3486**	**3674**
WW-B	9/18/99	13.9	36	1.41	1.22	1.05	**30.4**	**2159**	**2487**	**2894**
WW-C	9/18/99	13.1	79	3.30	2.87	1.88	**31.26**	**946**	**1090**	**1663**
WW-D	9/18/99	14.9	76	3.17	2.75	1.83	**30.67**	**968**	**1115**	**1679**
WW-E	9/18/99	11	76	3.17	2.75	1.83	**22.74**	**718**	**827**	**1245**
WW-F	9/18/99	10.1	81	3.39	2.95	1.92	**19.23**	**567**	**653**	**1004**
WW-G	9/19/99	10.9	35	1.37	1.19	1.03	**3.98**	**291**	**336**	**387**
WW-H	9/19/99	11	29	1.11	0.97	0.89	**4.09**	**367**	**423**	**457**
WW-HH	9/19/99	13.5	32	1.24	1.08	0.96	**4.21**	**340**	**391**	**437**
WW-I	9/19/99	12.4	30	1.16	1.00	0.92	**3.63**	**314**	**362**	**396**
WW-J	9/19/99	12.1	32	1.24	1.08	0.96	**2.41**	**195**	**224**	**250**
WW-K	9/19/99	13.2	32	1.24	1.08	0.96	**1.23**	99	**114**	**128**
WW-L	9/19/99	11.5	29	1.11	0.97	0.89	<0.15			
WW-M	9/19/99	6.3	34	1.32	1.15	1.01	<0.15			

West Willow Creek, From Table 11 of Surface and Mine Water Report

Fall - "Low Flow"				**Zinc**						
				WCRC reported Zn TVS = 93.9 ug/l						
Date	**Site**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Zn acute (ug/l)**	**TVS - Zn chronic (ug/l)**	**dZn (ug/L)**	**% dZn relative to acute TVS**	**% dZn relative to chronic TVS**		
WW-A	9/18/99	13.9	27	38.64	38.96	**7483.6**	**19366**	**19210**		
WW-B	9/18/99	13.9	36	49.31	49.71	**7449.4**	**15107**	**14986**		
WW-C	9/18/99	13.1	79	95.97	96.75	**7616.8**	**7937**	**7873**		
WW-D	9/18/99	14.9	76	92.87	93.63	**7594.5**	**8177**	**8111**		
WW-E	9/18/99	11.0	76	92.87	93.63	**6317.3**	**6802**	**6747**		
WW-F	9/18/99	10.1	81	98.02	98.82	**5289.2**	**5396**	**5352**		
WW-G	9/19/99	10.9	35	48.15	48.54	**225.7**	**469**	**465**		
WW-H	9/19/99	11.0	29	41.05	41.39	**229.3**	**559**	**554**		
WW-HH	9/19/99	13.5	32	44.63	44.99	**234.6**	**526**	**521**		
WW-I	9/19/99	12.4	30	42.25	42.59	**183.9**	**435**	**432**		
WW-J	9/19/99	12.1	32	44.63	44.99	**134.5**	**301**	**299**		
WW-K	9/19/99	13.2	32	44.63	44.99	**66.7**	**149**	**148**		
WW-L	9/19/99	11.5	29	41.05	41.39	<1				
WW-M	9/19/99	6.3	34	46.98	47.36	<1				

West Willow Creek, From Table 11 of Surface and Mine Water Report										
Fall - "Low Flow"				**Lead**						
				WCRC reported Pb TVS = 1.88 ug/l						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Pb acute (ug/l)**	**TVS - Pb chronic (ug/l)**	**dPb (ug/L)**	**% dPb relative to acute TVS**	**% dPb relative to chronic TVS**		
WW-A	9/18/99	13.9	27	15.14	0.59	**79.3**	**523.8**	**13442.7**		
WW-B	9/18/99	13.9	36	20.90	0.81	**83.0**	**397.1**	**10190.5**		
WW-C	9/18/99	13.1	79	49.92	1.95	**82.2**	**164.7**	**4225.8**		
WW-D	9/18/99	14.9	76	47.84	1.86	**92.8**	**194.0**	**4977.7**		
WW-E	9/18/99	11.0	76	47.84	1.86	**72.1**	**150.7**	**3867.4**		
WW-F	9/18/99	10.1	81	51.30	2.00	**79.4**	**154.8**	**3971.5**		
WW-G	9/19/99	10.9	35	20.25	0.79	**17.5**	86.4	**2217.4**		
WW-H	9/19/99	11.0	29	16.40	0.64	**17.0**	**103.6**	**2659.4**		
WW-HH	9/19/99	13.5	32	18.32	0.71	**11.0**	60.0	**1540.9**		
WW-I	9/19/99	12.4	30	17.04	0.66	**10.9**	64.0	**1641.5**		
WW-J	9/19/99	12.1	32	18.32	0.71	**12.2**	66.6	**1709.0**		
WW-K	9/19/99	13.2	32	18.32	0.71	**11.9**	65.0	**1666.9**		
WW-L	9/19/99	11.5	29	16.40	0.64	<3				
WW-M	9/19/99	6.3	34	19.61	0.76	<3				

West Willow Creek, From Table 11 of Surface and Mine Water Report

Fall - "Low Flow" — **Aluminum**

WCRC reported Al TVS = 87 ug/l

Site	Date	Flow (CFS)	Hard (mg/L)	TVS - Al acute (ug/l)	TVS - Al chronic (ug/l)	dAl (ug/L)	% dAl relative to acute TVS	% dAl relative to chronic TVS
WW-A	9/18/99	13.9	27	750	87	**124**	17	**143**
WW-B	9/18/99	13.9	36	750	87	**141**	19	**162**
WW-C	9/18/99	13.1	79	750	87	**138**	18	**159**
WW-D	9/18/99	14.9	76	750	87	**160**	21	**184**
WW-E	9/18/99	11.0	76	750	87	**100**	13	**115**
WW-F	9/18/99	10.1	81	750	87	**131**	17	**151**
WW-G	9/19/99	10.9	35	750	87	**98**	13	**113**
WW-H	9/19/99	11.0	29	750	87	**112**	15	**129**
WW-HH	9/19/99	13.5	32	750	87	60	8	69
WW-I	9/19/99	12.4	30	750	87	54	7	62
WW-J	9/19/99	12.1	32	750	87	70	9	80
WW-K	9/19/99	13.2	32	750	87	**100**	13	**115**
WW-L	9/19/99	11.5	29	750	87	49	7	56
WW-M	9/19/99	6.3	34	750	87	32	4	37

West Willow Creek, From Table 11 of Surface and Mine Water Report										
Fall - "Low Flow"				**Copper**						
				WCRC reported Cu TVS = 7.12 ug/l						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Cu acute (ug/l)**	**TVS - Cu chronic (ug/l)**	**dCu (ug/L)**	**% dCu relative to acute TVS**	**% dCu relative to chronic TVS**		
WW-A	9/18/99	13.9	27	3.91	2.93	16.6	**424**	**567**		
WW-B	9/18/99	13.9	36	5.13	3.74	15.7	**306**	**420**		
WW-C	9/18/99	13.1	79	10.76	7.32	16.2	**151**	**221**		
WW-D	9/18/99	14.9	76	10.38	7.08	16.5	**159**	**233**		
WW-E	9/18/99	11.0	76	10.38	7.08	10.2	98	**144**		
WW-F	9/18/99	10.1	81	11.02	7.48	9.7	88	**130**		
WW-G	9/19/99	10.9	35	5.00	3.65	4.3	86	**118**		
WW-H	9/19/99	11.0	29	4.19	3.11	4	96	**129**		
WW-HH	9/19/99	13.5	32	4.59	3.38	3.9	85	**115**		
WW-I	9/19/99	12.4	30	4.32	3.20	3.6	83	**112**		
WW-J	9/19/99	12.1	32	4.59	3.38	2.9	63	86		
WW-K	9/19/99	13.2	32	4.59	3.38	2.2	48	65		
WW-L	9/19/99	11.5	29	4.19	3.11	<1				
WW-M	9/19/99	6.3	34	4.86	3.56	<1				

Willow Creek

Chemical Monitoring Data by Sample Site

Low-Flow Concentrations, Table Value Standards for Acute and Chronic, and Low-Flow Concentration Percent of Table Value Standards for Acute and Chronic

Mainstem Willow Creek, From Table 17 of Surface and Mine Water Report										
Fall - "Low Flow"				**Aluminum**						
				WCRC reported Al TVS = 87 ug/l						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Al acute (ug/l)**	**TVS - Al chronic (ug/l)**	**dAl (ug/L)**	**% dAl relative to acute TVS**	**% dAl relative to chronic TVS**		
W-A	9/18/99	29.6	45	750	87	**92**	12	**106**		
W-B	9/22/99	31.4	24	750	87	74	10	85		
W-C	9/20/99	37.7	42	750	87	**91**	12	**105**		
W-D	9/21/99	31.3	42	750	87	68	9	78		
W-E	9/21/99	30.5	44	750	87	68	9	78		
W-F	9/21/99	dry	dry	750	87	dry				
W-G-E	9/21/99	4.75	44	750	87	**168**	22	**193**		
W-G-M	9/21/99	27.4	42	750	87	**158**	21	**182**		
W-G-W	9/21/99	0.26	44	750	87	**111**	15	**128**		
W-G-FW	9/21/99	1.56	43	750	87	79	11	91		
W-H	9/21/99	4.12	44	750	87	**187**	25	**215**		
W-I	9/21/99	22.6	43	750	87	**107**	14	**123**		
W-J	9/21/99	3.4	39	750	87	**90**	12	**103**		

Mainstem Willow Creek, From Table 17 of Surface and Mine Water Report										
Fall - "Low Flow"				**Cadmium**						
				WCRC reported s TVS = 1.31 ug/l						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Cd acute (ug/l)**	**TVS - Cd chronic (ug/l)**	**TVS - Cd chronic(trout) (ug/l)**	**dCd (ug/L)**	**% dCd relative to acute TVS**	**% dCd relative to acute (trout) TVS**	**% dCd relative to chronic TVS**
W-A	9/18/99	29.6	45	1.794	1.557	1.239	**13.03**	**726**	**837**	**1051**
W-B	9/22/99	31.4	24	0.907	0.787	0.778	**13.45**	**1484**	**1709**	**1729**
W-C	9/20/99	37.7	42	1.664	1.445	1.178	**12.57**	**755**	**870**	**1067**
W-D	9/21/99	31.3	42	1.664	1.445	1.178	**14.07**	**845**	**974**	**1195**
W-E	9/21/99	30.5	44	1.751	1.520	1.219	**13.5**	**771**	**888**	**1107**
W-F	9/21/99	dry	dry				dry			
W-G-E	9/21/99	4.75	44	1.751	1.520	1.219	**16.85**	**963**	**1109**	**1382**
W-G-M	9/21/99	27.4	42	1.664	1.445	1.178	**12.87**	**773**	**891**	**1093**
W-G-W	9/21/99	0.26	44	1.751	1.520	1.219	**11.52**	**658**	**758**	**945**
W-G-FW	9/21/99	1.56	43	1.707	1.482	1.198	**18.33**	**1074**	**1236**	**1530**
W-H	9/21/99	4.12	44	1.751	1.520	1.219	**15.44**	**882**	**1016**	**1267**
W-I	9/21/99	22.6	43	1.707	1.482	1.198	**13.98**	**819**	**943**	**1167**
W-J	9/21/99	3.4	39	1.536	1.333	1.115	**10.38**	**676**	**778**	**931**

Mainstem Willow Creek, From Table 17 of Surface and Mine Water Report										
Fall - "Low Flow"				**Copper**						
				WCRC reported Al TVS = 4.84 ug/l						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Cu acute (ug/l)**	**TVS - Cu chronic (ug/l)**	**dCu (ug/L)**	**% dCu relative to acute TVS**	**% dCu relative to chronic TVS**		
W-A	9/18/99	29.6	45	6.3	4.5	**5.5**	87	**122**		
W-B	9/22/99	31.4	24	3.5	2.6	**6**	**171**	**227**		
W-C	9/20/99	37.7	42	5.9	4.3	**6.4**	**108**	**150**		
W-D	9/21/99	31.3	42	5.9	4.3	**5.2**	88	**122**		
W-E	9/21/99	30.5	44	6.2	4.4	**5.1**	82	**115**		
W-F	9/21/99	dry	dry			dry				
W-G-E	9/21/99	4.75	44	6.2	4.4	**7.1**	**115**	**160**		
W-G-M	9/21/99	27.4	42	5.9	4.3	**9.1**	**153**	**213**		
W-G-W	9/21/99	0.26	44	6.2	4.4	**6.8**	**110**	**153**		
W-G-FW	9/21/99	1.56	43	6.1	4.4	**5.5**	91	**126**		
W-H	9/21/99	4.12	44	6.2	4.4	**6.9**	**111**	**155**		
W-I	9/21/99	22.6	43	6.1	4.4	**5.7**	94	**131**		
W-J	9/21/99	3.4	39	5.5	4.0	**4.3**	78	**107**		

Mainstem Willow Creek, From Table 17 of Surface and Mine Water Report								
Fall - "Low Flow"				**Manganese**				
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Mn acute (ug/l)**	**TVS - Mn chronic (ug/l)**	**dMn (ug/L)**	**% dMn relative to acute TVS**	**% dMn relative to chronic TVS**
W-A	9/18/99	29.6	45	2288.4	1264.3	525	23	42
W-B	9/22/99	31.4	24	1856.1	1025.5	525.8	28	51
W-C	9/20/99	37.7	42	2236.4	1235.6	462.5	21	37
W-D	9/21/99	31.3	42	2236.4	1235.6	506.1	23	41
W-E	9/21/99	30.5	44	2271.3	1254.9	496.5	22	40
W-F	9/21/99	dry	dry			dry		
W-G-E	9/21/99	4.75	44	2271.3	1254.9	697.9	31	56
W-G-M	9/21/99	27.4	42	2236.4	1235.6	512.3	23	41
W-G-W	9/21/99	0.26	44	2271.3	1254.9	474.1	21	38
W-G-FW	9/21/99	1.56	43	2254.0	1245.3	355.9	16	29
W-H	9/21/99	4.12	44	2271.3	1254.9	656.3	29	52
W-I	9/21/99	22.6	43	2254.0	1245.3	451	20	36
W-J	9/21/99	3.4	39	2181.9	1205.5	398.4	18	33

Mainstem Willow Creek, From Table 17 of Surface and Mine Water Report										
Fall - "Low Flow"				**Lead**						
				WCRC reported Al TVS = 1.14 ug/l						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Pb acute (ug/l)**	**TVS - Pb chronic (ug/l)**	**dPb (ug/L)**	**% dPb relative to acute TVS**	**% dPb relative to chronic TVS**		
W-A	9/18/99	29.6	45	26.81	1.04	**30.3**	**113**	**2901**		
W-B	9/22/99	31.4	24	13.26	0.52	**33.3**	**251**	**6445**		
W-C	9/20/99	37.7	42	24.82	0.97	**33.4**	**135**	**3453**		
W-D	9/21/99	31.3	42	24.82	0.97	**26.7**	**108**	**2760**		
W-E	9/21/99	30.5	44	26.14	1.02	**26.3**	**101**	**2581**		
W-F	9/21/99	dry	dry			dry				
W-G-E	9/21/99	4.75	44	26.14	1.02	**16.9**	65	**1659**		
W-G-M	9/21/99	27.4	42	24.82	0.97	**25.7**	**104**	**2657**		
W-G-W	9/21/99	0.26	44	26.14	1.02	**16.9**	65	**1659**		
W-G-FW	9/21/99	1.56	43	25.48	0.99	**15.1**	59	**1521**		
W-H	9/21/99	4.12	44	26.14	1.02	**16.8**	64	**1649**		
W-I	9/21/99	22.6	43	25.48	0.99	**10.9**	43	**1098**		
W-J	9/21/99	3.4	39	22.86	0.89	**9.6**	42	**1078**		

Mainstem Willow Creek, From Table 17 of Surface and Mine Water Report										
Fall - "Low Flow"				**Zinc**						
				WCRC reported Al TVS = 64.02 ug/l						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Zn acute (ug/l)**	**TVS - Zn chronic (ug/l)**	**dZn (ug/L)**	**% dZn relative to acute TVS**	**% dZn relative to chronic TVS**		
W-A	9/18/99	29.6	45	59.6	60.1	**2950.3**	**4952**	**4913**		
W-B	9/22/99	31.4	24	35.0	35.3	**3133**	**8958**	**8886**		
W-C	9/20/99	37.7	42	56.2	56.6	**2831.4**	**5039**	**4998**		
W-D	9/21/99	31.3	42	56.2	56.6	**2918.4**	**5194**	**5152**		
W-E	9/21/99	30.5	44	58.4	58.9	**2744.1**	**4695**	**4657**		
W-F	9/21/99	dry	dry			dry				
W-G-E	9/21/99	4.75	44	58.4	58.9	**3196**	**5468**	**5424**		
W-G-M	9/21/99	27.4	42	56.2	56.6	**2310.8**	**4113**	**4079**		
W-G-W	9/21/99	0.26	44	58.4	58.9	**1799.8**	**3079**	**3054**		
W-G-FW	9/21/99	1.56	43	57.3	57.8	**2891.9**	**5045**	**5004**		
W-H	9/21/99	4.12	44	58.4	58.9	**2792.5**	**4778**	**4739**		
W-I	9/21/99	22.6	43	57.3	57.8	**2533.3**	**4420**	**4384**		
W-J	9/21/99	3.4	39	52.8	53.2	**1425.1**	**2701**	**2679**		

Windy Gulch

Chemical Monitoring Data by Sample Site

Low-Flow Concentrations, Table Value Standards for Acute and Chronic, and Low-Flow Concentration Percent of Table Value Standards for Acute and Chronic

Windy Gulch, From Table 20 of Surface and Mine Water Report								
Fall - "Low Flow"				**Aluminum**				
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Al acute (ug/l)**	**TVS - Al chronic (ug/l)**	**dAl (ug/L)**	**% dAl relative to acute TVS**	**% dAl relative to chronic TVS**
WNG-A	9/20/99	0.038	140	750	87	**38**	5	**44**
WNG-B	9/20/99	0.0009	42	750	87	**482**	64	**554**

Windy Gulch, From Table 20 of Surface and Mine Water Report										
Fall - "Low Flow"				**Cadmium**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Cd acute (ug/l)**	**TVS - Cd chronic (ug/l)**	**TVS - Cd chronic(trout) (ug/l)**	**dCd (ug/L)**	**% dCd relative to Acute TVS**	**% dCd relative to Chronic TVS**	**% Cd relative to chronic(trout)**
WNG-A	9/20/99	0.038	140	6.140	5.331	2.870	**23.51**	**383**	**441**	**819**
WNG-B	9/20/99	0.0009	42	1.664	1.445	1.178	<0.15			

Windy Gulch, From Table 20 of Surface and Mine Water Report								
Fall - "Low Flow"				Copper				
Site	Date	Flow (CFS)	Hard (mg/L)	TVS - Cu acute (ug/l)	TVS - Cu chronic (ug/l)	dCu (ug/L)	% dCu relative to acute TVS	% dCu relative to chronic TVS
WNG-A	9/20/99	0.038	140	18.5	11.9	10.9	59	91
WNG-B	9/20/99	0.0009	42	5.9	4.3	<1		

Windy Gulch, From Table 20 of Surface and Mine Water Report								
Fall - "Low Flow"				Manganese				
Site	Date	Flow (CFS)	Hard (mg/L)	TVS - Mn acute (ug/l)	TVS - Mn chronic (ug/l)	dMn (ug/L)	% dMn relative to acute TVS	% dMn relative to chronic TVS
WNG-A	9/20/99	0.038	140	3339.8	1845.2	233.4	7	13
WNG-B	9/20/99	0.0009	42	2236.4	1235.6	35.6	2	3

Windy Gulch, From Table 20 of Surface and Mine Water Report										
Fall - "Low Flow"				**Lead**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Pb acute (ug/l)**	**TVS - Pb chronic (ug/l)**	**dPb (ug/L)**	**% dPb relative to acute TVS**	**% dPb relative to chronic TVS**		
WNG-A	9/20/99	0.038	140	92.96929	3.622879	<3				
WNG-B	9/20/99	0.0009	42	24.82495	0.967392	<3				
Windy Gulch, From Table 20 of Surface and Mine Water Report										
Fall - "Low Flow"				**Zinc**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Zn acute (ug/l)**	**TVS - Zn chronic (ug/l)**	**dZn (ug/L)**	**% dZn relative to acute TVS**	**% dZn relative to chronic TVS**		
WNG-A	9/20/99	0.038	140	155.8	157.1	**4146.5**	**2661**	**2639**		
WNG-B	9/20/99	0.0009	42	56.2	56.6	<1				

Commodore Tunnel and Nelson Tunnel

Chemical Monitoring Data by Sample Site

Low-Flow Concentrations, Table Value Standards for Acute and Chronic, and Low-Flow Concentration Percent of Table Value Standards for Acute and Chronic

West Willow Drainage, From Table 12 of Surface and Mine Water Report

Fall - "Low Flow" — **Aluminum**

Site	Date	Flow (CFS)	Hard (mg/L)	TVS - Al acute (ug/l)	TVS - Al chronic (ug/l)	dAl (ug/L)	% dAl relative to acute TVS	% dAl relative to chronic TVS
WW-CT	9/19/99	0.041	88	750	87	524	70	**602**
WW-NT	9/18/99	0.77	708	750	87	**1028**	**137**	**1182**
WW-NT	9/5/02	0.47	854	750	87	**349.8**	47	**402**

West Willow Drainage, From Table 12 of Surface and Mine Water Report

Fall - "Low Flow" — **Cadmium**

Site	Date	Flow (CFS)	Hard (mg/L)	TVS - Cd acute (ug/l)	TVS - Cd chronic (ug/l)	TVS - Cd chronic(trout) (ug/l)	dCd (ug/L)	% dCd relative to acute TVS	% dCd relative to acute (trout) TVS	% dCd relative to chronic TVS
WW-CT	9/19/99	0.041	88	3.713	3.223	2.036	**103.9**	**2799**	**3223**	**5103**
WW-NT	9/18/99	0.77	708	35.423	30.755	9.469	**241.8**	**683**	**786**	**2554**
WW-NT	9/5/02	0.47	854	43.367	37.652	10.866	**80.6**	**186**	**214**	**742**

West Willow Drainage, From Table 12 of Surface and Mine Water Report										
Fall - "Low Flow"				**Copper**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Cu acute (ug/l)**	**TVS - Cu chronic (ug/l)**	**dCu (ug/L)**	**% dCu relative to acute TVS**	**% dCu relative to chronic TVS**		
WW-CT	9/19/99	0.041	88	11.9	8.0	**37.4**	**314**	**466**		
WW-NT	9/18/99	0.77	708	85.0	47.7	**106.7**	**126**	**224**		
WW-NT	9/5/02	0.47	854	101.4	56.0	**99.2**	98	**177**		

West Willow Drainage, From Table 12 of Surface and Mine Water Report										
Fall - "Low Flow"				**Manganese**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Mn acute (ug/l)**	**TVS - Mn chronic (ug/l)**	**dMn (ug/L)**	**% dMn relative to acute TVS**	**% dMn relative to chronic TVS**		
WW-CT	9/19/99	0.041	88	2861.2	1580.8	**3853.4**	**135**	**244**		
WW-NT	9/18/99	0.77	708	5730.5	3166.1	**19290**	**337**	**609**		
WW-NT	9/5/02	0.47	854	6099.7	3370.1	**11690**	**192**	**347**		

West Willow Drainage, From Table 12 of Surface and Mine Water Report										
Fall - "Low Flow"				**Lead**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Pb acute (ug/l)**	**TVS - Pb chronic (ug/l)**	**dPb (ug/L)**	**% dPb relative to acute TVS**	**% dPb relative to chronic TVS**		
WW-CT	9/19/99	0.041	88	56.1749	2.189055	**46**	82	**2101**		
WW-NT	9/18/99	0.77	708	498.8892	19.44099	**1440**	**289**	**7407**		
WW-NT	9/5/02	0.47	854	599.161	23.34844	**412**	69	**1765**		
West Willow Drainage, From Table 12 of Surface and Mine Water Report										
Fall - "Low Flow"				**Zinc**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Zn acute (ug/l)**	**TVS - Zn chronic (ug/l)**	**dZn (ug/L)**	**% dZn relative to acute TVS**	**% dZn relative to chronic TVS**		
WW-CT	9/19/99	0.041	88	105.2	106.0	**9770.7**	**9292**	**9217**		
WW-NT	9/18/99	0.77	708	615.3	620.3	**89800**	**14594**	**14476**		
WW-NT	9/5/02	0.47	854	721.3	727.1	**11500**	**1594**	**1582**		

East Willow Creek Inflows and Tributary (based on EW-N)

Chemical Monitoring Data by Sample Site

Low-Flow Concentrations, Table Value Standards for Acute and Chronic, and Low-Flow Concentration Percent of Table Value Standards for Acute and Chronic

East Willow Drainage, From Table 9 of Surface and Mine Water Report								
Fall - "Low Flow"				**Aluminum**				
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Al acute (ug/l)**	**TVS - Al chronic (ug/l)**	**dAl (ug/L)**	**% dAl relative to acute TVS**	**% dAl relative to chronic TVS**
EW-MA	9/18/99	0.16	16	750	87	<15		
EW-SWI	9/18/99	0.13	22	750	87	**121**	16	**139**
EW-SMA	9/18/99		296	750	87	**1522**	**203**	**1749**
EW-SWD	9/19/99	0.035	292	750	87	**1418**	**189**	**1630**
EW-PC	9/18/99	0.035	27	750	87	68	9	78
EW-Sp	9/20/99	0.002	20	750	87	**379**	51	**436**
EW-N	9/20/99	0.58	21	750	87	**129**	17	**148**
EW-GMA	9/20/99	0.0037	29	750	87	117	16	134

East Willow Drainage, From Table 9 of Surface and Mine Water Report										
Fall - "Low Flow"				**Cadmium**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Cd acute (ug/l)**	**TVS - Cd chronic (ug/l)**	**TVS - Cd chronic(trout) (ug/l)**	**dCd (ug/L)**	**% dCd relative to acute TVS**	**% dCd relative to acute (trout) TVS**	**% dCd relative to chronic TVS**
EW-MA	9/18/99	0.16	16	0.58	0.51	0.58	0.42	72	83	73
EW-SWI	9/18/99	0.13	22	0.82	0.72	0.73	**7.35**	**891**	**1026**	**1008**
EW-SMA	9/18/99		296	13.81	11.99	4.98	**192.9**	**1397**	**1609**	**3870**
EW-SWD	9/19/99	0.035	292	13.60	11.81	4.94	**180.4**	**1326**	**1527**	**3655**
EW-PC	9/18/99	0.035	27	1.03	0.89	0.85	**5.44**	**528**	**608**	**641**
EW-Sp	9/20/99	0.002	20	0.74	0.65	0.68	<0.15			
EW-N	9/20/99	0.58	21	0.78	0.68	0.70	<0.15			
EW-GMA	9/20/99	0.0037	29	1.11	0.97	0.89	<0.15			

East Willow Drainage, From Table 9 of Surface and Mine Water Report										
Fall - "Low Flow"				**Copper**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Cu acute (ug/l)**	**TVS - Cu chronic (ug/l)**	**dCu (ug/L)**	**% dCu relative to acute TVS**	**% dCu relative to chronic TVS**		
EW-MA	9/18/99	0.16	16	2.39	1.87	<1				
EW-SWI	9/18/99	0.13	22	3.23	2.46	1.5	46	61		
EW-SMA	9/18/99		296	37.36	22.64	**58.6**	**157**	**259**		
EW-SWD	9/19/99	0.035	292	36.89	22.38	**48.3**	**131**	**216**		
EW-PC	9/18/99	0.035	27	3.91	2.93	1.6	41	55		
EW-Sp	9/20/99	0.002	20	2.95	2.26	<1				
EW-N	9/20/99	0.58	21	3.09	2.36	<1				
EW-GMA	9/20/99	0.0037	29	4.19	3.11	<1				

East Willow Drainage, From Table 9 of Surface and Mine Water Report								
Fall - "Low Flow"				**Manganese**				
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Mn acute (ug/l)**	**TVS - Mn chronic (ug/l)**	**dMn (ug/L)**	**% dMn relative to acute TVS**	**% dMn relative to chronic TVS**
EW-MA	9/18/99	0.16	16	1621.6	895.9	<10		
EW-SWI	9/18/99	0.13	22	1803.0	996.2	<10		
EW-SMA	9/18/99		296	4285.8	2367.9	**6482.9**	**151**	**274**
EW-SWD	9/19/99	0.035	292	4266.4	2357.2	**6336.9**	**149**	**269**
EW-PC	9/18/99	0.035	27	1930.3	1066.5	<10		
EW-Sp	9/20/99	0.002	20	1746.7	965.0	<10		
EW-N	9/20/99	0.58	21	1775.3	980.9	<10		
EW-GMA	9/20/99	0.0037	29	1976.8	1092.2	<10		

East Willow Drainage, From Table 9 of Surface and Mine Water Report										
Fall - "Low Flow"				**Lead**						
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Pb acute (ug/l)**	**TVS - Pb chronic (ug/l)**	**dPb (ug/L)**	**% dPb relative to acute TVS**	**% dPb relative to chronic TVS**		
EW-MA	9/18/99	0.16	16	8.38056	0.326578	<3				
EW-SWI	9/18/99	0.13	22	12.01863	0.468349	**41.4**	**344**	**8840**		
EW-SMA	9/18/99		296	205.6854	8.015262	**1434**	**697**	**17891**		
EW-SWD	9/19/99	0.035	292	202.7868	7.90231	**1395**	**688**	**17653**		
EW-PC	9/18/99	0.035	27	15.13817	0.589913	**112.2**	**741**	**19020**		
EW-Sp	9/20/99	0.002	20	10.79155	0.420531	<3				
EW-N	9/20/99	0.58	21	11.40346	0.444376	<3				
EW-GMA	9/20/99	0.0037	29	16.40399	0.63924	<3				

East Willow Drainage, From Table 9 of Surface and Mine Water Report

Fall - "Low Flow"				**Zinc**				
Site	**Date**	**Flow (CFS)**	**Hard (mg/L)**	**TVS - Zn acute (ug/l)**	**TVS - Zn chronic (ug/l)**	**dZn (ug/L)**	**% dZn relative to acute TVS**	**% dZn relative to chronic TVS**
EW-MA	9/18/99	0.16	16	24.8	25.0	<1		
EW-SWI	9/18/99	0.13	22	32.5	32.8	**1160.3**	**3572**	**3543**
EW-SMA	9/18/99		296	293.9	296.3	**36900**	**12555**	**12454**
EW-SWD	9/19/99	0.035	292	290.5	292.9	**36300**	**12494**	**12394**
EW-PC	9/18/99	0.035	27	38.6	39.0	**945.9**	**2448**	**2428**
EW-Sp	9/20/99	0.002	20	30.0	30.2	<1		
EW-N	9/20/99	0.58	21	31.2	31.5	<1		
EW-GMA	9/20/99	0.0037	29	41.1	41.4	<1		

Appendix I

Stream Physical Habitat Condition

Physical Habitat Condition is determined from a professional judgement interpretation of the RBP and SRI/CSI indicators produced by the USFWS.

Under RBP % of Ref. (reference), a '*' indicates a site used as a reference site (EW-M and WW-M).

Stream Physical Habitat Condition Classification

Stream Reach	**Sampling Site**	**RBP Score**	**RBP % of Ref.**	**SRI/CSI Rating**	**=>**	**Physical Habitat Condition**
		Classifications				
East Willow Creek						
EWC_1a						*poor*
	EW-A	122	70	fair		
	EW-F	91	52	poor		
EWC_1b						*good*
	EW-I	134	77	good		
	EW-J	138	79	good		
	EW-K	211	121	good		
EWC_2	*(inferred and GIS supported)*					*good*
	none					
EWC_3a						*good*
	EW-M	174	100 *	good		

Stream Reach	Sampling Site	Classifications RBP Score	RBP % of Ref.	SRI/CSI Rating	=>	Physical Habitat Condition
West Willow Creek						
WWC_1a						*poor*
	WW-A	85	50	*poor*		
WWC_1b						*good*
	WW-G	131	77	*good*		
WWC_1c						*fair*
	WW-I	115	68	*fair*		
WWC_2a						*fair*
	WW-K	85	50	*fair*		
WWC_2b	*(inferred and GIS supported)*					*good*
	none					
WWC_3a						*good*
	WW-M	170	100 *	*good*		
Willow Creek						
WC_1						*poor*
	W-I	69	*(no ref.)*	*fair*		
	W-J	69	*(no ref.)*	*fair*		
WC_2						*poor*
	W-D	49	*(no ref.)*	*fair-poor*		
WC_3						*poor*
	W-B	64	*(no ref.)*	*fair-poor*		

USFWS Study Data

Aquatic Habitat Assessment Scores
(Appendix B, WCRC #2, Table 12)

Table 12. Aquatic habitat assessment scores evaluated September 1999.

SITE	Total Reach Length (ft)	RBP Habitat Score	RBP % reference	SRI/CSI Score	SRI/CSI Rating
East Willow Creek					
EWM	330	174	100	43	good
EWK	420	211	121	56	good
EWJ	262	138	79	72	good
EWI	390	134	77	61	good
EWF	500	91	52	115	poor
EWA	420	122	70	81	fair
West Willow Creek					
WWM	420	170	100	54	good
WWK	300	85	50	104	fair
WWI	330	115	68	91	fair
WWG	330	131	77	72	good
WWA	420	85	50	114	poor
Willow Creek					
WB	500	64		111	fair-poor
WD	480	49		107	fair-poor
WI	820	69		93	fair
WJ	800	69		93	fair

Appendix J

Stream Ecological Condition Classification

The ecological condition classification is a composite interpretation of each of the component condition classifications: biological, chemical, and physical habitat.

Stream Reach / Sampling Site	Biological Condition	Chemical Condition	Physical Habitat Condition	=>	Ecological Condition
	Classifications				
East Willow Creek					
EWC_1a	*fair*	*very poor*	*poor*		*poor*
EW-A					
EW-B					
EW-C					
EW-D					
EW-E					
EW-F					
EW-G					
EWC_1b	*good*	*fair*	*good*		*fair*
EW-H					
EW-I					
EW-J					
EW-K					
EWC_2	*good*	*fair*	*fair*		*fair*
EW-L					
EWC_3a	*good*	*good*	*good*		*good*
EW-M					
EWC_3b	*prob. good*	*prob. good*	*prob. good*		*prob. good*
GIS-based					

Stream Reach	Sampling Site	Biological Condition	Chemical Condition	Physical Habitat Condition	=>	Ecological Condition
		Classifications				
East Willow Creek Tributaries						
EW_T1		n/a	*prob. good*	n/a		*prob. good*
	EW-TRN					
	EW-TRS *(based on analysis of EW-K and EW-L)*					
EW_T2		n/a	*prob. good*	n/a		*prob. good*
	EW_Trib3 *(based on analysis of EW-K and EW-L)*					
EW_T3		n/a	*fair*	n/a		*fair*
	EW-N					
West Willow Creek						
WWC_1a		*poor*	*very poor*	*poor*		*very poor*
	WW-A					
	WW-B					
	WW-C					
	WW-D					
	WW-E					
	WW-F *(dry)*					
WWC_1b		*poor*	*very poor*	*good*		*very poor*
	WW-G					
	WW-H					
	WW-HH					
WWC_1c		*poor*	*very poor*	*fair*		*very poor*
	WW-I					
WWC_2a		*fair*	*very poor*	*fair*		*very poor*
	WW-J					
	WW-K					
WWC_2b		*good*	*fair*	*good*		*fair*
	WW-L					
WWC_3a		*good*	*good*	*good*		*good*
	WW-M					

Stream **Reach**	**Sampling Site**	**Biological Condition**	**Chemical Condition**	**Physical Habitat Condition**	=>	**Ecological Condition**
		Classifications				
WWC_3b	*GIS-based*	*prob. good*	*prob. good*	*prob. good*		*prob. good*
Nelson Creek						
NC_1		n/a	*poor*	n/a		*poor*
	NC-A					
	NC-B					
	NC-D					
	NC-E					
Willow Creek						
WC_1		*poor*	*very poor*	*poor*		*very poor*
	W-I					
	W-J					
	W-G-E					
	W-G-M					
	W-G-W					
	W-G-FW					
	W-H					
	W-F					
WC_2		*poor*	*very poor*	*poor*		*very poor*
	W-E					
	W-D					
	W-C					
WC_3		*poor*	*very poor*	*poor*		*very poor*
	W-B					
	W-A					

		Classifications				
Stream Reach	**Sampling Site**	**Biological Condition**	**Chemical Condition**	**Physical Habitat Condition**	**=>**	**Ecological Condition**
Windy Gulch						
WG_1		n/a	*poor*	n/a		*poor*
	WNG-A					
	WNG-B					